Galloper Wind Farm Project

Environmental Statement - Chapter 14: Marine Mammals

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14 MARINE MAMMALS

14.1 Introduction

14.1.1 This Chapter of the Environmental Statement (ES) describes the existing environment with regard to marine mammals, which includes pinnipeds (seals) and cetaceans (whales, dolphins and porpoises), within the proposed Galloper Wind Farm (GWF) site and wider study area, as well as the Outer Thames Estuary and southern North Sea.

14.1.2 This Chapter serves to characterise the distribution and abundance of marine mammal species which have been recorded within the study area and wider region through site specific or regional surveys. Subsequently, it presents the findings of an assessment of potential impacts arising from the construction, operation and decommissioning phases of the GWF project on regional marine mammal populations and provides detail on potential mitigation and monitoring measures for these impacts.

14.1.3 For the purposes of the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009, **Figures 14.7** to **14.9** taken together with this Chapter, fulfil the requirements of Regulation 5(2)(l) in relation to the effects of the proposed development on marine mammals.

14.2 Guidance and Consultation

Legislation, policy and guidance

14.2.1 The assessment of potential impacts upon marine mammals has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIP). Those relevant to GWF are:

- Overarching NPS for Energy (EN-1); and
- NPS for Renewable Energy Infrastructure (EN-3).

14.2.2 The following paragraphs provide detail from the National Policy Statement for Renewable Energy Infrastructure (EN-3) (July 2011), which contains specific requirements for the assessment of impacts on marine mammals. The assessment requirements suggested within the NPSs have been applied to this assessment and where appropriate the specific sections of this Chapter that address the EN-3 issues are highlighted. Where any part of the NPS has not been followed within this assessment, it is stated within in the ES why the requirement was not deemed relevant or has been met in another manner.

14.2.3 Paragraphs 2.6.90-2.6.99 of the National Policy Statement (NPS) are relevant to marine mammals, with Paragraph 2.6.92 maintaining that:

"*Where necessary, assessment of the effects on marine mammals should include details of*:

- *Likely feeding areas* (see **Section 14.4**);
- *Known birthing areas / haul out sites* (see **Section 14.4**);
- *Nursery grounds* (see **Section 14.4**);
- *Known migration or commuting routes* (see **Section 14.4**);
- *Duration of the potentially disturbing activity including cumulative/in-combination effects with other plans or projects* (see **Section 14.6** to **14.10**);
- *Baseline noise levels* (see **Section 14.4, 14.6** and **Chapter 5 Project Details**);
- *Predicted noise levels in relation to mortality, permanent threshold shift (PTS) and temporary threshold shift (TTS*) (see **Section 14.6**);
- *Soft-start noise levels according to proposed hammer and pile design* (see **Section 14.6**); and
- *Operational noise* (see **Section 14.7**)".

14.2.1 In addition, in Section 2.6.93 of the NPS, it is outlined that:

"*The applicant should discuss any proposed piling activities with the relevant body. Where assessment of noise from offshore pile driving may reach noise levels likely to lead to an offence as described in Section 2.6.91 above, the applicant should to look at possible alternatives or appropriate mitigation before applying for a licence*." (see **Section 14.6**).

14.2.2 The following guidance documents have also been used to inform the assessment of potential impacts on marine mammals:

- Guidance on the Assessment of Effects on the Environment and Cultural Heritage from Marine Renewable Developments. Produced by: the Marine Management Organisation (MMO), the Joint Nature Conservation Council (JNCC), Natural England, the Countryside Council for Wales (CCW) and the Centre for Environment, Fisheries & Aquaculture Science (Cefas) (In draft, December, 2010);
- The protection of marine European Protected Species (EPS) from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area, draft (JNCC, CCW and Natural England, 2010);

- Guidelines for Ecological Impact Assessment in Britain and Ireland, Marine and Coastal (Institute for Ecology and Environmental Management (IEEM) (2010);
- Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments Final Report. Report by The Sea Mammal Research Unit on behalf of The Crown Estate. August 2010;
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Draft for consultation. Cefas. Report reference: ME5403 – Module 15. Issue date: 10th March 2011; and
- Statutory Nature Conservation Agency Protocol for Minimising the Risk of Injury to Marine Mammals from Piling Noise (JNCC, 2010).

Legislation

14.2.3 Cetaceans and pinnipeds are protected under an assortment of national and international legislation, as summarised in **Table 14.1**.

Table 14.1 National and international legislation in relation to marine mammals

Legislation	Protection	Details
Convention on International Trade in Endangered Species (CITES)	All cetaceans	Appendix I lists species that are the most endangered and, therefore, prohibits commercial trade, while Appendix II lists species that are not necessarily now threatened with extinction, but may become so unless trade is closely controlled.
Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS)	Odontocetes	Formulated in 1992, this agreement has been signed by eight European countries bordering the Baltic and North Seas (including the English Channel) and includes the United Kingdom (UK). Under the Agreement, provision is made for the protection of specific areas, monitoring, research, information exchange, pollution control and increasing public awareness of small cetaceans.
The Berne Convention 1979	All cetaceans, grey and harbour seal	The Convention conveys special protection to those species that are vulnerable or endangered. Appendix II (strictly protected fauna): 19 species of cetacean. Appendix III (protected fauna): all remaining cetaceans, grey and harbour seal. Although an international convention, it is

Legislation	Protection	Details
		implemented within the UK through the Wildlife and Countryside Act 1981 (with any aspects not implemented via that route brought in by the Habitats Directive)
The Bonn Convention 1979	All cetaceans	Protects migratory wild animals across all, or part of their natural range, through international co-operation, and relates particularly to those species in danger of extinction. One of the measures identified is the adoption of legally binding agreements, including ASCOBANS.
The Wildlife and Countryside Act 1981 (as amended)	All cetaceans	Schedule five: all cetaceans are fully protected within UK territorial waters. This protects them from killing or injury, sale, destruction of a particular habitat (which they use for protection or shelter) and disturbance. Schedule six: common dolphin, bottlenose dolphin and harbour porpoise; prevents these species being used as a decoy to attract other animals. This schedule also prohibits the use of vehicles to take or drive them, prevents nets, traps or electrical devices from being set in such a way that would injure them and prevents the use of nets or sounds to trap or snare them.
The Countryside and Rights of Way Act 2000	All cetaceans	It is an offence to deliberately or recklessly damage, or disturb any cetacean in English and Welsh protected waters under this Act.
OSPAR	Bowhead whale *Balaena mysticetus*, Northern Right Whale *Eubalaena glacialis*, Blue whale	OSPAR has established a list of threatened and/or declining species in the north-east Atlantic. These species have been targeted as part of further work on the conservation and protection of marine biodiversity under Annex V of the OSPAR Convention. The list seeks to complement, but not duplicate, the work under the EC Habitats and Birds directives and measures under the Berne Convention, the Bonn Convention.

Legislation	Protection	Details
	Balaenoptera musculus, and Harbour Porpoise *Phocoena phocoena*	
The Conservation of Habitats and Species Regulations 2010	All cetaceans, grey and harbour seal	In England and Wales, The Conservation of Habitats and Species Regulations 2007 (as amended) consolidate all the various amendments made to the Conservation (Natural Habitats, &c.) Regulations 1994, implementing the requirements of the Habitats Directive into UK law. All cetacean species are listed under Schedule 2 (European Protected Species (EPS)) and all seals are listed under Schedule 4 (animals which may not be captured or killed in certain ways). Provisions of The Habitats Regulations are described further in Section 14.2.4349.
Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended)	All cetaceans, grey and harbour seal	The Offshore Marine Conservation Regulations 2007 (as amended) apply the Habitats Directive to marine areas within UK jurisdiction, beyond 12 nautical miles, and provide further clarity on the interpretation of "disturbance" in relation to species protected under the Habitats Directive. Thus, enabling energy developers to better qualify and, where possible, quantify, the impacts on marine mammals and determine whether the potential disturbance is permissible as part of a consented development. Provisions of The Offshore Marine Regulations are described further in Section 14.2.4349
Conservation of Seals Act 1970	Grey and harbour seal	Provides closed seasons, during which it is an offence to take or kill any seal except under licence or in certain particular circumstances (Grey seal: 1 September to 31 December; Harbour seal: 1 June to

Legislation	Protection	Details
		31 August). Following the halving of the harbour seal population as a result of the Phocine Distemper Virus (PDV) in 1988, an Order was issued under the Act which provided year round protection of both grey and harbour seal on the east coast of England. The Order was last renewed in 1999.
UK Biodiversity Action Plan (BAP)	Harbour porpoise	Harbour porpoise are a feature of the Norfolk, Suffolk and Essex Local Biodiversity Action Plans (LBAPs). These LBAPs are a process rather than a plan which seek to ensure that nationally and locally important species and habitats are conserved and enhanced in a given area through focused local action.

The Habitats Directive

14.2.43 Probably the most important wildlife legislation in relation to marine renewable energy and marine mammals is the European Union (EU) Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive).

14.2.44 All cetaceans are protected under Annex IV of the Habitats Directive because they are classified as being endangered, vulnerable or rare. Both grey seal and harbour seal are protected under Annex II of the Habitats Directive. Grey seal and harbour seal are also listed on Annex V of the Habitats Directive, which requires their exploitation or removal from the wild to be subject to management measures. Both these measures are provided for within national legislation, as for cetaceans.

14.2.45 Harbour porpoise *Phocoena phocoena* and bottlenose dolphin *Tursiops truncatus* are also listed under Annex II of the Habitats Directive, which requires Member States to designate areas essential to their life and reproduction as Special Areas of Conservation (SAC). There are currently no areas considered essential to life and reproduction for these species within or adjacent to the GWF wind farm boundary (see **Chapter 8 Nature Conservation Designations**).

14.2.46 Under Article 12 of the Directive, Member States are required to take the requisite measures to establish a system of strict protection for species in their natural range prohibiting (a) all forms of deliberate capture or killing of specimens of these species in the wild, (b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration and (c) deterioration or destruction of breeding sites or resting places.

Habitats Regulations and Offshore Marine Regulations Guidance

14.2.47 Subject to Regulation 39(1) of the Habitats Regulations ('HR' as amended) and Offshore Marine Regulations 2009 ('OMR' as amended), a person is guilty of an offence if a person:

(a) Deliberately captures, injures or kills any wild animal of an EPS; and

(b) deliberately disturbs wild animals of any such species.

14.2.48 The nature of 'disturbance' is further detailed, with an offence arising if the disturbance of any such species is likely:

(a) to impair their ability:

(i) to survive, to breed or reproduce, or to rear or nurture their young; or

(ii) in the case of animals of a hibernating or migratory species, to hibernate or migrate; or

(b) to affect significantly the local distribution or abundance of the species to which they belong; or

(c) deliberately take or destroy the eggs of such an animal; or

(d) damage or destroy, or does anything to cause the deterioration of, a breeding site or resting place of such an animal.

14.2.49 Following the amendments made to the HR and OMR in January 2009, the Regulations now more clearly transpose the requirement contained in the Habitats Directive to prohibit deliberate disturbance, and better reflect the circumstances in which disturbance may be particularly damaging to the animals concerned (as envisaged by Article 12). In addition, the HR and OMR provide for the offence of deliberate injuries.

Favourable Conservation Status

14.2.50 In order to assess whether a disturbance could be considered non-trivial in relation to the objectives of the Habitats Directive, consideration should be given to the definition of the Favourable Conservation Status (FCS) of a species given in Article 1(i) of the Habitats Directive. There are three parameters that determine when the FCS of a species can be taken as favourable:

- Population(s) of the species is maintained on a long-term basis;
- The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future; and

- The habitat on which the species depends (for feeding, breeding, rearing etc) is maintained in sufficient size to maintain the population(s) over a period of years/decades.

14.2.51 Member states report back to the European Commission (EC) every six years on the conservation status of marine EPS. **Table 14.2** highlights that the UK assessed six out of eleven cetacean species as having an 'unknown' FCS, mainly as a result of the fact that either there were no recent population[1] estimates that encompassed their natural range in UK and adjacent waters and / or there was no evidence to assess long-term trends in population abundance. Another 17 species were considered to be uncommon, rare or very rare in occurrence, so it was not possible to ascertain their conservation status. The five species outlined in **Table 14.2** as having a favourable FCS, are underpinned by an assessment of moderate to low reliability. It can be interpreted that:

- A greater understanding of the species / population(s), or the factors affecting it, is required before a confident concluding judgment can be made by experts; and
- The current estimate of population and/or trend are based on recent, but incomplete or limited survey data, or based predominately on expert opinion.

14.2.52 At the time of writing, no conservation status criteria were available to inform a quantitative assessment of potential disturbance effects arising from the proposed GWF development on the FCS of cetacean populations within the North Sea.

14.2.53 **Table 14.2** presents the conservation status of commonly occurring cetacean species within UK waters and their best available abundance estimates generated from the Small Cetaceans in the European Atlantic and North Sea (SCANS) surveys (SMRU, 2006) and Cetacean Offshore Distribution and Abundance (CODA) surveys (JNCC *et al.* 2010).

Table 14.2 Common cetacean species in Annex IV of the Habitats Directive occurring in UK and adjacent waters

Species	FCS Assessment	Southern North Sea Population	North Sea Population	European Population
Harbour porpoise *Phocoena phocoena*	Favourable	SCANS II: 134,434	SCANS II: 335,000	SCANS II: 385,617 [95% CI = 261,266-569,153]

[1] Population' is defined in the EC guidance on the strict protection of animal species as a group of individuals of the same species living in a geographic area at the same time that are (potentially) interbreeding (i.e. sharing a common gene pool).

Species	FCS Assessment	Southern North Sea Population	North Sea Population	European Population
Minke whale *Balaenoptera acutorostrata*	Favourable	Unknown	SCANS II: 10,541	SCANS II: 18,614 [95% CI = 10,445-33,171] CODA: 6,765 [95% CI = 1,239-36,925]
Fin whale *Balaenoptera physalus*	Favourable	Unknown	Unknown	CODA: 7,523 [95% CI = 4,945-11,444]
Common dolphin *Delphinus delphis*	Unknown	Unknown	Unknown	SCANS II: 63,366 [95% CI = 26,973-148,865] CODA: 162,266 [95% CI = 65,990-399,001]
Long-finned pilot whale *Globicephala melas*	Unknown	Unknown	Unknown	CODA+: 83,441 [95% CI = 33,875-205,528]
Risso's dolphin *Grampus griseus*	Unknown	Unknown	Unknown	JNCC *et al* (2010): Estimated at 100s, 1000s
Atlantic white-sided dolphin *Lagenorhynchus acutus*	Unknown	Unknown	Unknown	Unknown
Killer whale *Orcinus orca*	Unknown	Unknown	Unknown	JNCC *et al.*, (2010): Estimated at 1000s
White-beaked	Favourable	Unknown	SCANS II:	SCANS II: 22,664

Species	FCS Assessment	Southern North Sea Population	North Sea Population	European Population
dolphin *Lagenorhynchus albirostris*			10,562	[95% CI = 10,341-49,670]
Sperm whale *Physeter macrocephalus*	Unknown	Unknown	Unknown	CODA: 2,424 [95% CI = 1,250 – 4,700]
Bottlenose dolphin *Tursiops truncatus*	Favourable	Unknown (the only known resident populations within the UK are found within the Moray Firth (n = 129 individuals) and Cardigan Bay (n=213 individuals)	Unknown	SCANS II: 12,645 [95% CI = 7,504-21,307] CODA: 19,295 [95% CI = 11,842-31,440]

Source: JNCC *et al*., (2010). It should be noted that the CODA results presented in this table are preliminary.

European Protected Species Guidance

14.2.99 The JNCC, Natural England and CCW (October 2010) have produced draft guidance concerning the new Regulations on the deliberate disturbance of marine EPS (cetaceans, turtles and Atlantic sturgeon), which provides an interpretation of the regulations in greater detail. It has been indicated that the guidance will be finalised and published through Defra towards the end of 2011[2].

14.2.100 The guidance details all activities at sea that could potentially cause a deliberate injury or disturbance offence and summarises information and sensitivities of species to which the regulations apply. The guidance refers to the Habitats Directive Article 12 Guidance (European Commission (EC), 2007) stating that, in their view, significant disturbance must have some ecological impact.

14.2.101 The guidance provides the following interpretations of deliberate injury and disturbance offences under Regulation 39(1) of the HR and OMR, as detailed in the paragraphs below.

[2] Confirmed on 10.08.11 by Karen Hall, JNCC Offshore Industries Advisor

Interpretation of "deliberate"

14.2.102 "*Deliberate actions are to be understood as actions by a person who knows, in light of the relevant legislation that applies to the species involved, and the general information delivered to the public, that his action will most likely lead to an offence against a species, but intends this offence or, if not, consciously accepts the foreseeable results of his action*."

Interpretation of an "injury offence"

14.2.103 Certain activities that produce loud sounds in areas where EPS could be present have the potential to result in an injury offence, unless appropriate mitigation measures are implemented to prevent the exposure of animals to sound levels capable of causing injury (JNCC *et al*., 2010). Further details of how best practice mitigation measures (JNCC *et al*., 2010) can be used and adapted to reduce the risk of an injury offence occurring at the GWF are presented in **Section 14.6**.

Interpretation of a "disturbance offence"

14.2.104 The term "disturbance" is not defined in Article 1 or Article 12 of the Habitats Directive or in the HR or OMR. Although not legally binding, The Habitats Directive Article 12 Guidance (European Commission, 2007) states that:

"In order to assess a disturbance, consideration must be given to its effect on the conservation status of the species at population level and biogeographic level in a Member State. For instance, any disturbing activity that affects the survival chances, the breeding success or the reproductive ability of a protected species or leads to a reduction in the occupied area should be regarded as a "disturbance" in terms of Article 12."

14.2.105 Following amendments, the HR and the OMR better define the level of disturbance which constitutes an offence. Regulation 39(1)(b)(1A) makes it clear that any disturbance which is likely to have any of the negative effects, which are potentially significant contributors with regard to impact on the conservation status of EPS, will amount to disturbance under regulation 39(1)(b).

14.2.106 The EC Guidance also highlights that sporadic, *"trivial disturbance*" should not be considered as a disturbance offence under Article 12.

14.2.107 For the purposes of marine users, the draft EPS guidance (JNCC *et al.,* 2010) states that non-trivial disturbance should be interpreted as:

"Any action that would impair the ability of animals to survive, breed or reproduce, or rear or nurture their young, or to migrate could increase the risk of detriment to population viability on a long-term basis. Any action that would cause a significant deviation from a population's natural variability in distribution or abundance could increase the risk of reduction of the natural range or size of the habitat of a species and also the risk of detriment to population viability".

14.2.108 It should be noted that on Page 76, the EPS Guidance (JNCC *et al*. 2010) states: "*for most populations of marine EPS in UK waters, the removal of tens, hundreds, and even thousands of animals for the most abundant species (e.g. harbour porpoise), would not result in detriment to the population at FCS*".

FCS in relation to a fraction of the population affected by injury or disturbance effects arising from the GWF

14.2.109 In order to assess the number of individuals from a species that could be removed from the regional population through injury or disturbance without compromising the FCS in its natural range, this ES considers:

- The numbers affected in relation to the best and most recent estimate of population size;
- The threshold for potential impact on the FCS, which will depend on:
    - The species'/populations' life-history;
    - The species' FCS assessment in UK waters; and
    - Other pressures encountered by the population (cumulative effects).

14.2.110 One of the key parameters for consideration within this assessment is the population size. The EPS Guidance advises that the best available abundance estimates could be used as a baseline population size, taking account of any evidence of regional population structuring (JNCC *et al.* 2010). In the case of the proposed GWF project, **Table 14.2** suggests that the European population estimates derived from the SCANS II and CODA surveys offer the best reference population for all commonly occurring cetacean species in the UK. In the case of harbour porpoise, the SCANS II data also offer the opportunity for assessing potential impacts of the GWF in the context of the North Sea population.

The requirement of an EPS licence for GWF

14.2.111 An EPS license is required if the risk of injury or disturbance to cetacean species is assessed as likely under regulations 41(1)(a) and (b) in The Conservation of Habitats and Species Regulations and 39(1)(a) and (b) in The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (amended in 2009 and 2010). Consultation with the JNCC highlighted that it is important to note that disturbance which impacts on species at a population level (i.e. is likely to affect FCS) cannot be licensed, whereas disturbance that does not have an impact on the species at population level but is sufficient to constitute an offence can potentially be licensed.

14.2.112 Advice from the JNCC in the Scoping Opinion (August 2010) and Section 42 consultation response (July 2011) indicates that an EPS licence is likely to be required for the proposed GWF project where piling of foundations is proposed (see **Table 14.3**).

14.2.113 Given the potential implications of the EPS Guidance, this EIA has focused on cetaceans which have been recorded as either common, regular or uncommon, seasonal visitors to the GWF study area. It follows that if an EPS licence is required, the risk assessment would also focus on these species.

14.2.114 As part of the risk assessment for potential injury and disturbance offences, GWFL will undertake an assessment of any injury and / or disturbance offences likely to occur from construction, operation and decommissioning activities at the GWF.

14.2.115 Additionally, it is noted that that many activities at sea will not require a licence, since their potential for injury and / or disturbance can be effectively mitigated or because the characteristics of the disturbance will fall below the threshold of an offence.

14.2.116 If a licence is required an application must be submitted, the assessment of which comprises three tests to ascertain:

1. whether the activity fits one of the purposes specified in the Regulations;
2. whether there are no satisfactory alternatives to the activity proposed (that would not incur the risk of offence); and
3. that the licensing of the activity will not result in a negative impact on the species'/population's FCS.

14.2.117 Under the revised definitions of 'deliberate disturbance' in the HR and OMR, chronic exposure and/or displacement of animals could be regarded as a disturbance offence. If these risks cannot be avoided, then GWFL is likely to be required to apply for a marine wildlife licence from the Marine Management Organisation (MMO) in order to exempt GWFL from the offence.

14.2.118 An EPS licence, if granted, will be valid for a limited time period, therefore an application will be submitted after the Development Consent Order (DCO) application is made prior to the onset of construction, and in consultation with the relevant Statutory Nature Conservation Agencies (SNCAs).

14.2.119 As confirmed in recent correspondence with the JNCC (Mendes, 2011) GWFL is proposing that the EPS licence application would draw on the information captured in this Chapter. It is also expected that, if further information were available at the time of application (notably the JCP density estimates which are likely to be published in April 2012 (Mendes, 2011)), this would be used to augment the baseline captured during the GWF EIA to ensure GWFL draw on the latest and most accurate site characterisation data.

Consultation

14.2.120 As part of ongoing consultation, key stakeholders were invited by the IPC to respond to a scoping document produced as part of the EIA process (GWFL, 2010). **Table 14.3** summarises issues that were highlighted by the consultees in the IPC Scoping Opinion (IPC, 2010) and indicates which sections of the this assessment address each of the issues raised. Further consultation was undertaken through formal section 42 consultation under the Planning Act 2008 (see Chapter **7 Consultation**) via the submission of a Preliminary Environmental Report (PER). Detailed responses pertaining to marine mammals were received from the JNCC and Natural England; a brief summary of the main points raised is included in **Table 14.3**. Full details of responses received are presented in the IPC Scoping Opinion report (IPC, 2010) and the Consultation Report that accompanies the DCO application.

Table 14.3 Summary of consultation and issues

Date	Consultee	Summary of issue	Section where addressed
August 2010	JNCC / Natural England (Scoping Opinion)	Concerns raised over site surveys and EPS considerations. EPS licence under regulations 53/56 (Habitats Regulations/Offshore Marine Regulations respectively) is likely and also potentially a Wildlife and Countryside Act licence if using acoustic deterrents. Cumulative Impact Assessment (CIA) will need to consider geophysical and seismic surveys. It noted that this may be of particular importance for harbour porpoise.	Section 14.6 and 14.7
August 2010	JNCC / Natural England (Scoping Opinion)	It is important to understand the distribution and abundance of marine mammals for a particular area and to estimate under different scenarios of construction, the numbers of animals (per species/population) likely to be affected.	Section 14.4
August 2010	IPC (Scoping Opinion)	The commission recommends that disturbance as a result of noise and vibration should be assessed.	Section 14.6 and 14.7
August 2010	JNCC/ Natural England (Scoping Opinion)	Potential impacts on marine mammals during decommissioning requires further discussion and should also contain discussion as to the potential impacts associated with repowering.	Repowering is not considered within the ES as discussed in **Chapter 5** and decommissioning is discussed in Section 14.8
August 2010	JNCC/ Natural England (Scoping Opinion)	Impacts on marine mammals due to pre-construction seabed monitoring should be assessed.	Section 14.6
August 2010	Norfolk County Council	Cumulative impacts with respect to marine mammals. Projects to be Incorporated within the CIA should include not only other potential wind farms but also other types of project taking place in the marine	Section 14.10

Date	Consultee	Summary of issue	Section where addressed
	(Scoping Opinion)	environment or onshore.	
July 2011	JNCC / Natural England (Section 42)	Chapter presents a good summary of the best available data to inform a baseline for the GWF area, however the site specific incidental sightings are presented without an indication of survey effort do not further inform this or validate this baseline. It may be worth considering the applicability of the JCP to further inform the baseline for marine mammals, outputs from the JCP will be available from February 2012. The use of this baseline will be particularly important in informing any survey effort to quantify the cumulative effect of offshore renewables development.	Section 14.4 The JCP will not be available prior to the submission of the DCO application and ES, however if possible GWFL intend to use this within the EPS licence application
July 2011	JNCC / Natural England (Section 42)	Further clarification is required to support the cumulative assessment; in addition further details may be available with respect to the likely construction period of the East Anglia ONE Project. Should the timeline of the construction of GWF or any of the projects within the area of impacts with respect to construction noise change then the projects included in the cumulative assessment may be required to be altered. We would recommend that a worst case scenario is adopted and those where construction is likely to occur at roughly the same time should be considered to be occurring concurrently.	Section 14.10
July 2011	JNCC / Natural England (Section 42)	JNCC recommend that information pertaining to the effects of underwater noise during operation fully considers the potential effect of increased operational noise associated with the use of larger wind turbine generators.	Section 14.7
July 2011	JNCC / Natural England	Seal carcasses exhibiting corkscrew injuries have also been found stranded on the Scottish coast. The investigation is not restricted to vessels using Dynamic Positioning (DP) but all vessels using ducted	Section 14.4, 14.6 and 14.7

Date	Consultee	Summary of issue	Section where addressed
	(Section 42)	propellers for slow manoeuvring. Mitigation measures may be required to be included in the MMMP for the inshore components of this development. However, the SNCAs are currently in discussion relating to this issue and will be able to provide more specific advice on review of the MMMP.	
July 2011	JNCC / Natural England (Section 42)	An EPS licence will be required to cover the risk of disturbance to cetacean species identified as likely to be in the area under Regulations 41(1)(a) and (b) of The Conservation Habitats and Species Regulations and 39(1) (a) and (b) of The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (amended in 2009 and 2010).	Section 14.2 and 14.6
July 2011	JNCC / Natural England (Section 42)	It would be useful to explore the findings at the Horns Rev and Nysted wind farms in Denmark.	Section 14.6
July 2011	JNCC / Natural England (Section 42)	JNCC welcome GWFL's intention to develop their Marine Mammal Mitigation Plan in close consultation with the SNCAs and endorse any measures that have been shown to reduce the sound at source.	Section 14.11
July 2011	JNCC / Natural England (Section 42)	The ES must include recommendations for post consent monitoring of the identified potential impacts of the wind farm. Data should be collected before, during and possibly after construction, to determine the associated impacts and/or recovery of populations. Developers will need to undertake some form of power analysis to inform how many samples are required so that it can be ensured that the data collected can identify any differences in abundance. This is also important from a regulatory perspective to enable assessment of FCS in the future.	Section 14.11

Date	Consultee	Summary of issue	Section where addressed
July 2011	JNCC / Natural England (Section 42)	It would be useful for assessment in relation to this to be undertaken across the range of potential pile diameter size, particularly if a middle range diameter is the most likely to end up being used and given the large range in impact distances estimated.	Both 3m and 7m pile sizes are assessed within the Chapter, the rationale for this is presented in Sections 14.5 and 14.6.
August 2011	JNCC (Mendes, 2011)	Provision of further advice on the marine mammal impact assessment.	
		GWFL should seek to find an appropriate method to predict the likely number of animals potentially affected from underwater noise during construction. The use of site specific density estimates (as well as density estimates from other sources) should be used alongside noise modelling outputs to estimate the likely number of animals affected. JNCC agreed that the confidence in the site specific data, when used in this way, is very low.	Section 14.6
		The cumulative assessment should consider other wind farms in the area, as well as timeframes and the subsequent potential for cumulative displacement of marine mammals.	Section 14.10
		The JCP, although not finalised in time for the DCO submission should be used for the EPS licence application. The final draft of the JNCC EPS guidance will be available by the end of September 2011	This is noted and the JCP, if finalised, will be used in the EPS licence application

14.3 Methodology

The study area

14.3.1 As highly mobile marine predators, the status and activity of marine mammals known to occur within or adjacent to the GWF site and export cable corridor will be considered in the context of regional dynamics across the Outer Thames Estuary and southern North Sea.

Characterisation of the existing environment

14.3.2 In order to provide spatial and temporal information on marine mammals within the proposed development area and regional waters, several sources have been used to inform the site characterisation within this ES (see **Table 14.4**).

Table 14.4 Broad-scale data sources to inform the marine mammal site characterisation at the GWF

Title	Nature of the data	Spatial coverage	Data holder	Publication
Atlas of Cetacean Distribution in North-west European Waters "Joint Cetacean Database".	Provides an account of the distribution of all 28 cetacean species that are known to have occurred in the waters off north-west Europe in the last 25 years, Data sources: SCANS data, European Seabirds at Sea and the Sea Watch Foundation.	North-west European waters, including North Sea, Irish Sea and English Channel.	The JNCC	Reid *et al.*, 2003
Small Cetacean Abundance in the North Sea and Adjacent Waters (SCANS).	Shipboard (890 000 km^2) and aerial line (150 000 km^2) transect surveys conducted to provide accurate and precise estimates of abundance as a basis for conservation strategy in European waters.	North Sea, English Channel, Celtic Sea, western Baltic Sea, waters around north-east Scotland and the west coast of Norway/Sweden.	The Sea Mammal Research Unit (SMRU).	Surveys conducted in summer 1994. Report by Hammond *et al*., 2002, published in Journal of Applied Ecology.
Small Cetacean Abundance in the Atlantic and North Sea (SCANS II).	SCANS-II provides the most precise broad-scale estimates of cetacean abundance in UK waters,	SCANS extended west and south into Irish, French and Spanish waters.	SMRU	Surveys carried out in 2005, report published 2006 (SMRU, 2006).

Title	Nature of the data	Spatial coverage	Data holder	Publication
	covering over 1,350,000 km^2 and over 35,000 km of survey track line (boat and aerial surveys combined).			
The Coastal Directive Project - JNCC Coasts and Seas of the United Kingdom.	The Coastal Directories Project, coordinated by the JNCC, was developed to produce a wide-ranging baseline of environmental information for each part of the UK coastal and near shore marine zone. Each section provides a summary of the regions environment, including protected sites, wildlife habitats and species, human uses, archaeology etc.	Region 6 Eastern England: Flamborough Head to Great Yarmouth	JNCC	Evans, 1995; Duck, 1995.
Distributions of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008. Wildfowl and Wetlands	Data on the distributions and abundances of cetaceans, seals, turtles, sharks and Ocean Sunfish were collected opportunistically	Majority of English and Welsh coastline, some areas of Scotland and Northern Ireland	The Wildfowl & Wetlands Trust (Consulting) Ltd (WWT Consulting)	WWT, 2009

Title	Nature of the data	Spatial coverage	Data holder	Publication
Trust (WWT)	during aerial surveys for waterbirds conducted by Wildfowl and Wetlands Trust Consulting. The report details the distributions of all records of these species collected in areas of waterbird surveys around the UK coast between 2001 and August 2008 using distance-sampling methodology developed in Denmark by National Environment Research Institute (NERI)			
Harbour seal telemetry data	Pinniped tagging programmes are included as part of regular population monitoring programmes (e.g. SCOS 2008). The telemetry data allow usage of coastal and marine areas to be examined.	UK wide	SMRU	Sharples *et al.*, 2008
Special Committee on Seals	Scientific advice to	UK wide	SMRU	SCOS, 2009, SCOS 2008,

Title	Nature of the data	Spatial coverage	Data holder	Publication
(SCOS).	government on matters related to the management of seal populations, the Special Committee on Seals (SCOS) formulates this advice.			SCOS 2007
Round 2 Offshore Wind Farm Development Strategic Environmental Assessment (SEA).	Section 8.4.2.1 provides information on marine mammal distribution and abundance with the Wash and Greater Thames Estuary	UK wide	Department of Energy and Climate Change (DECC)	DECC, 2003
Strategic Environmental Assessment (SEA) 3.	Information on the abundance and distribution of marine mammals within the SEA 3 Block. In particular, important seal breeding colonies in the Humber Estuary, The Wash and the Farne Islands.	Southern North Sea, from Dover to Berwick-Upon-Tweed.	DECC	DECC, 2002

Site specific marine mammal surveys at GWF

14.3.3 Information from the data sources detailed in **Table 14.4** has been supplemented by site specific boat-based surveys within the GWF site and adjacent waters between June 2008 and May 2011. **Table 14.5** summarises the site specific data used in this assessment.

Table 14.5 Summary of site specific surveys used to inform the marine mammal site characterisation and impact assessment presented in this Chapter

Survey	Year	Details
GWF Baseline	2008 – ongoing	Completed alongside the Greater Gabbard Offshore Wind Farm pre-construction monitoring required under the project's Food and Environment Protection Act (FEPA) licence (see **Chapter 11 Offshore Ornithology** for further details on survey methodology).
Greater Gabbard Offshore Wind Farm (GGOWF) Baseline	2004-2006	Baseline surveys carried out to inform the GGOWF EIA.
GGOWF Ornithological Monitoring Programme	2008 – ongoing	Required under the FEPA licence and scheduled for completion in 2013/2014. Pre-construction to second year during-construction.
Subacoustech Underwater Noise Report in relation to the GWF (Subacoustech, 2011. **Technical Appendix 13.B**)	2011	Technical study of the potential impacts of underwater noise during impact pile driving operations to install foundation pieces at the GWF site, including review of GGOWF construction data.

14.3.4 The GWF sightings data were collected alongside the pre- and during-construction monitoring programme of ornithological features at the adjacent GGOWF project.

14.3.5 The GGOWF was formally awarded consent in February 2007. Conditions contained in the project's FEPA licence 33097/07/0 (dated 24th July, 2007), set the requirement for additional ornithological monitoring of the site, which includes the wind farm area, 1km buffers, 4km buffers and a control area, with surveys during pre-construction, construction and operation. During the same year, the GWF was proposed and in anticipation of an application to

The Crown Estate, the monthly pre-construction surveys were adapted to include the GWF area.

14.3.6 Pre-construction boat-based transect surveys were conducted between June 2008 and May 2009 (construction at the GGOWF actually started in August 2009), with during-construction surveys underway between June 2009 to May 2010 (phase 1) and June 2010 to May 2011 (phase 2).

14.3.7 The surveys were undertaken following the standard methods recommended by COWRIE (Camphuysen *et al*., 2004). As part of the GWF ornithological site characterisation surveys (for further details see **Section 11.4** of **Chapter 11**) incidental sightings of marine mammals were also recorded, with numbers recorded along transects. Where individuals were exhibiting feeding activity, this was also recorded. **Figure 14.1** illustrates the survey transect routes taken by the boat based surveys across GGOWF and GWF.

14.3.8 It should be recognised that the value of incidental sightings to infer relative abundance or distribution of marine mammals is fairly limited outside of a targeted observation protocol. Generally, such datasets cannot be analysed in a quantitative manner because they contain no record of effort or detection probability (SMRU, 2010). The GWF marine mammal dataset, presented herein, provides a general picture of the range of species encountered within the study area, presence / absence and distribution over different times of year.

Encounter rates

14.3.9 The encounter rate (animals / km surveyed) of harbour porpoise has been calculated using the raw sightings data and the length of transect surveyed in order to incorporate survey effort into the findings and further validate the baseline description. Using encounter rates to interpret apparent fine-scale trends in relative abundance and/or distribution should note the following limitations:

- Untargeted sampling design leading to unknown biases;
- Data are also not corrected for responsive movement away from the boat or availability biases (proportion of animals will be below the surface and therefore 'unavailable');
- Low sample size;
- Surveying in sea states suboptimal for sighting marine mammals; and
- Not exploring the effect of distance band on detection and including sightings from all distance bands in derivation of encounter rates.

14.3.1 The transects undertaken within the GWF survey areas (Area A and B; Area A and B 1km buffers; Area A and B 1-4km buffers), the lengths of which were recorded during each individual survey, are illustrated on **Figure 14.1** (further details on survey methodology and transect lengths is provided in **Section 11.4** of **Chapter 11** and associated appendices).

14.3.2 Encounter rate (animals / km) was defined as:

***n* / L**

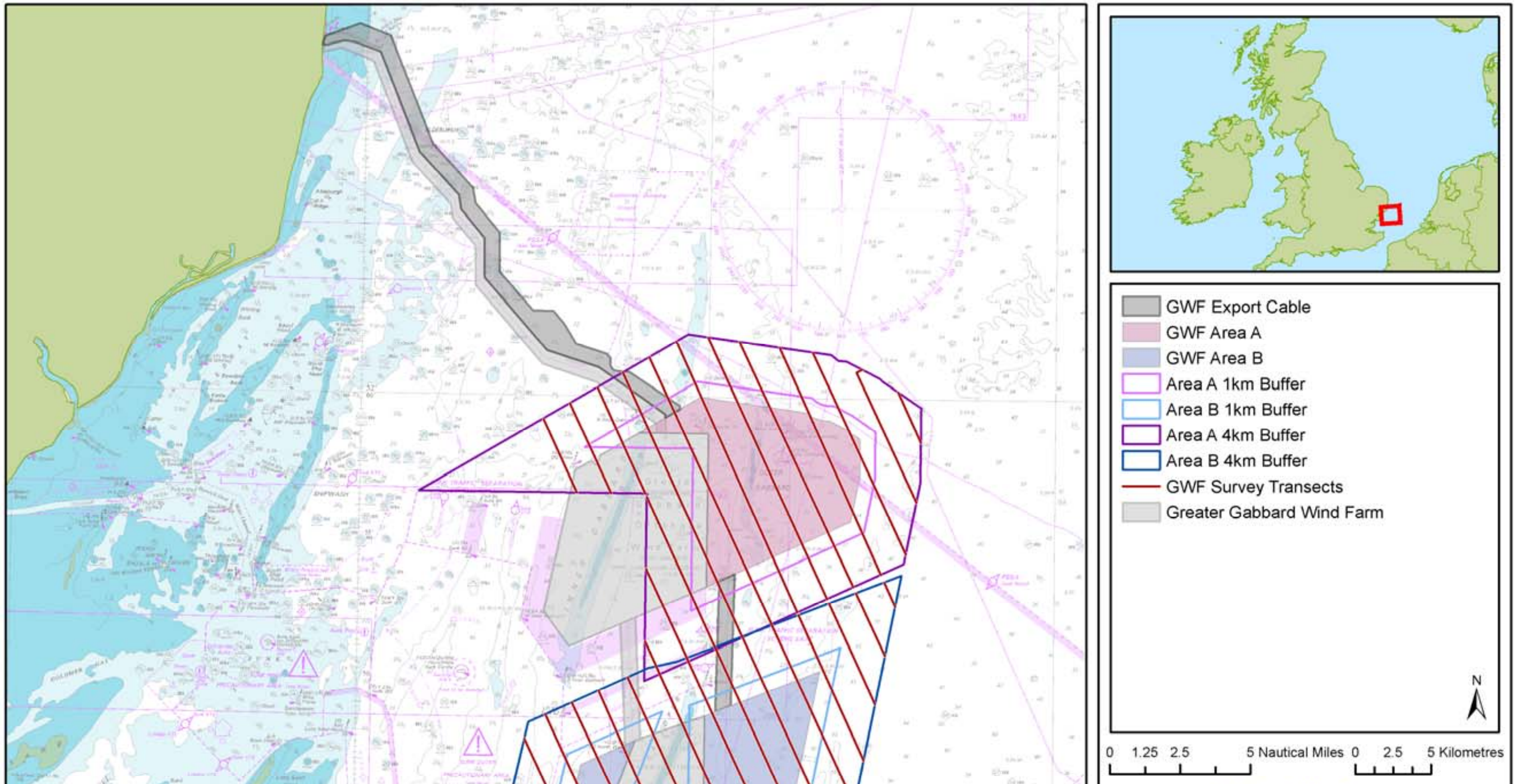
Where n is the number of animals encountered and L is the transect length (in km) undertaken for each survey month. Similar methodology was used by Boisseau et al. (2010) where encounter rates were weighted for length of trackline.

14.3.3 Species density estimate (animals / km²) was defined as:

***n* / A**

Where n is the number of animals encountered and A is the survey area (in km²). Survey area was calculated by multiplying the transect length by 0.6 (300m was surveyed either side of the transect).

14.3.4 Transect lengths varied by small amounts during the monthly boat based surveys as a result of weather conditions and other variables. The transect lengths were recorded for the majority of survey months, however where an exact transect length could not be obtained, a nominal length was used from the first survey undertaken. This was considered to be the most accurate.



Galloper Wind Farm

Figure 14.1

GWF Survey Areas and Transect Routes

Drawing Number: GWF_585_R4	Rev: 4
Date: 01/11/11	Created: LW / Checked: SS
Scale: 1:400,000	Page: A4
Datum: WGS1984	Projection: UTM Zone 31N

Greater Gabbard Offshore Wind Farm surveys

14.3.5 Information about marine mammals in the vicinity of the proposed GWF site has also been supplemented by marine mammal surveys commissioned by Greater Gabbard Offshore Winds Limited (GGOWL) to inform the GGOWF Environmental Statement (GGOWL, 2005). The studies, undertaken by the British Trust for Ornithology (BTO) and Environmentally Sustainable Systems Limited (ESS Ecology), comprised offshore boat-based surveys carried out between February 2004 and April 2006, to ascertain the abundance and distribution of birds and marine mammals in the wind farm area, associated buffer zones and control site (Banks *et al*., 2006).

14.3.6 Throughout all surveys incidental sightings of marine mammals have also been recorded in both the GGOWF and GWF footprints. **Figure 11.2 in Chapter 11** shows the layout and coverage of the surveys undertaken between 2004 and 2011.

14.3.7 **Table 14.6** provides an overview of GGOWF ornithological and marine mammal monitoring to date over the six year monitoring period.

Table 14.6 GGOWF pre- and post-consent marine mammal monitoring timeline

Monitoring Period	Phase	Indicative Timing	Status
Baseline Surveys (ES)	Pre-consent	February 2004- April 2006	Complete
Year 1	Pre-construction	June 2008-May 2009	Complete
Year 2	Construction (Phase 1)	June 2009 – May 2010	Complete
Year 3	Construction (Phase 2)	June 2010- May 2011	Complete
Year 4	Post construction*	June 2011 – May 2012	Surveys underway
Year 5	Post construction	June 2012 – May 2013	-
Year 6	Post construction	June 2013 – June 2014	-

*construction at GGOWF is still ongoing. At the time of writing all 140 monopile foundations are in place and 108 turbines have been installed. In the meantime, other works at the site have continued and over half the turbines are now energised. Construction at GGOWF is due to be completed in 2012.

Impact assessment

14.3.8 Impacts associated with the construction, operation and decommissioning of the GWF are assessed in accordance with the methodology detailed in **Chapter 4**. The details provided in **Chapter 5** have been used to establish a realistic worst case development scenario for the assessment of impact on marine mammals, see **Section 14.5**.

Underwater noise impact assessment

14.3.9 Subacoustech Environmental Limited (Subacoustech) has undertaken a study of the potential impacts of underwater noise during impact pile driving operations to install foundation pieces at the GWF site (Subacoustech, 2011). The results of the modelling have been interpreted in terms of the potential impact that this noise may have on various marine species present in the area, including marine mammals and important prey species (Subacoustech, 2011). This report is also contains modelling results for fish species, and as such is presented in **Technical Appendix 13.B** that supports **Chapter 13**.

14.3.10 Since construction of the GGOWF commenced in August 2009, caution must be taken when interpreting the data to characterise the existing environment for marine mammals in the GWF study area. Construction at the GGOWF, and in particular, monopile installation activities, is likely to have temporarily affected marine mammal distribution and behaviour within the GWF study area. The 2008-2009 incidental sightings records represent the only un-impacted characterisation of marine mammal activity within the GWF.

14.3.11 The EPS risk assessment framework for injury and disturbance offences has also been considered within this assessment to help inform a future EPS licence application, if required. The impact assessment focuses mainly on the potential effects of the development on harbour porpoise, as these are the most commonly occurring species within the study area.

14.3.12 Other Chapters within this ES (such as **Chapter 5** and **Chapter 13 Fish and Shellfish Resources**) have been used to inform the assessment where inter-relationships may exist. For example, impacts on the intensity and distribution of commercial fishing activity within important marine mammal foraging areas may lead to a reduction in prey resource and/or increase bycatch interactions.

14.3.13 In response to comments from the SNCAs during the Section 42 consultation period, an impact assessment methodology for estimating the number of animals potentially effected by development activities at GWF was developed in close consultation with the JNCC (see **Table 14.3**). .

14.3.14 Density estimates derived from the regional datasets have then been compared to the impact ranges produced during the noise impact modelling carried out by Subacoustech (2011) (**Technical Appendix 13.B**) to estimate the likely number of animals affected by the GWF development.

14.3.15 In order to present a quantitative assessment using site specific incidental sightings data (from the boat based surveys described above), assumptions have been made and the resultant conclusions drawn are associated with high levels of uncertainty. These concerns were highlighted by GWFL through recent consultation with the JNCC (Mendes, 2011). Through this additional consultation it was agreed that as marine mammal sightings were recorded outside a targeted sampling programme (which was previously agreed with the JNCC and Natural England), the methodology represents an unknown level of bias or record of survey effort. The surveys were designed to inform a primarily qualitative assessment in relation to presence / absence of marine mammals within the GWF study area over space and time. The JNCC agreed that confidence in the incidental sightings data to provide an accurate measure of relative abundance or fine-scale distribution patterns for any marine mammal species was very low (Mendes, 2011).

14.3.16 The JNCC have suggested that a range of density estimates, from a number of sources where larger scale surveys have been undertaken at greater effort, could be presented alongside those presented from the boat-based counts (such as SCANS and WWT, 2009: **Table 14.4**). It is important to note that these surveys were undertaken within a targeted marine mammal sampling protocol, the SCANS survey also provides an index of the 'confidence' surrounding the dataset in relation to survey effort (coefficient of variation).

14.3.17 As a result of the uncertainties associated with incidental sightings, conclusions drawn regarding the relative abundance of marine mammals (as a function of extrapolated densities) at the GWF site will be highly inaccurate. Based on the limitations discussed above, it was agreed with the JNCC that by extrapolating a density estimate from the site specific incidental sightings, a number of assumptions in distance-based analysis would be compromised, particularly:

- Assuming complete homogeneity in sightings distribution within the footprint of the predicted sound impact areas (the sound impact areas are themselves are an estimate); and

- Assuming that the incidental sightings collected within the surveyed area are representative of the number of animals in the unsurveyed area.

14.3.18 Therefore, it is considered that despite limitations in the temporal and fine-scale resolution of the SCANS and WWT (2009) density estimate, they offer a more accurate, effort-limited range of metrics to inform the GWF impact assessment.

14.3.19 It is noted that as part of any future EPS licence application, GWFL will augment the assessment presented in this ES with the cetacean density estimates that will come out of the forthcoming JCP (*In Prep*, April 2012).

14.4 Existing Environment

The study area

14.4.1 Cetacean populations occurring in UK waters are generally wide-ranging, their distribution and abundance vary considerably over time and space influenced by both natural and anthropogenic factors (Reid *et al.,* 2003).

There may be some areas of regular high density for some species, but how important these areas are in comparison to others in their natural range, is still in general unknown (Reid *et al.,* 2003). For cetaceans in UK waters, and in contrast with some other parts of the world's oceans, there is also currently no evidence to show that any particular areas are consistently more important than others within their range for specific purposes / behaviours with the possible exception of the SACs for bottlenose dolphin *Tursiops truncatus* and some tidal narrows sites (JNCC comment, as cited in IPC, 2010).

14.4.2 Compared to other areas of the UK, the level of pinniped interest within the outer Thames is relatively low. When considering the foraging and haul-out patterns of harbour *Phoca vitulina* and grey seal *Halichoerus grypus* presented, the potential effects of the GWF can be assessed in relation to a small number of breeding colonies scattered along the Essex and Suffolk coast.

The North Sea

14.4.3 The study area for marine mammal interest with regard to the GWF is relatively wide, covering a large portion of the southern North Sea, the Essex and Suffolk coast and the outer Thames Estuary.

14.4.4 The species diversity and abundance of marine mammals within the southern North Sea is relatively low and reduces progressively southwards (Sea Watch Foundation, 2008). The most common and regularly occurring cetaceans are those species associated with relatively shallow continental seas, such as the harbour porpoise *Phocoena phocoena* and white beaked dolphin *Lagenorhynchus albirostris*.

14.4.5 The data presented by Reid *et al.,* (2003), SCANS I and SCANS II (**Table 14.3**) reveal that eight marine mammal species occur regularly over large parts of the southern North Sea. These include:

- Pinnipeds; grey seal and harbour seal;
- Odontocetes; harbour porpoise, bottlenose dolphin, white-beaked dolphin, Atlantic white-sided dolphin *Lagenorhynchus acutus*, and killer whale *Orcinus orca*; and
- Mysticetes; minke whale *Balaenoptera acuturostrata*.

14.4.6 Other species, including sperm whale *Physeter macrocephalus*, long-finned pilot whale *Globicephala melas* and short-beaked common dolphin *Delphinus delphis* are occasional visitors to the southern North Sea. The FCS and best available population estimates for these species is presented in **Table 14.2**.

Cetaceans

14.4.7 Based on the information presented above, harbour porpoise is likely to be the only cetacean species that is regularly encountered within the shallow coastal waters within and immediately adjacent to the GWF site, with the others present as occasional visitors.

Harbour porpoise

Broad-scale survey data

14.4.8 The harbour porpoise is the most commonly sighted cetacean in the North Sea and is the only cetacean likely to be found in any significant numbers around the proposed GWF development area.

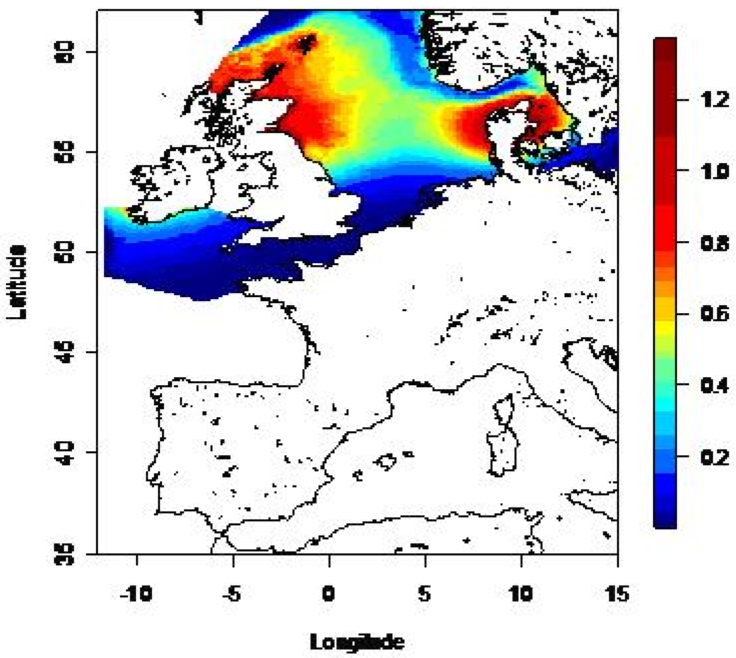
14.4.9 The Small Cetacean Abundance in the North Sea (SCANS) was a major international collaborative survey program carried out to provide baseline data on cetacean abundance in the North Sea, Baltic and Celtic Seas. The first SCANS project took place in the early 1990's and estimated the harbour porpoise population of the North Sea at between 210,000 to 340,000 individuals in the summer of 1994.

14.4.10 The SCANS II project, which aimed to update these estimates, took place in 2005. SCANS II estimated the North Sea harbour porpoise population to be 335,000, indicating that the population did not change significantly between 1994 and 2005 (SMRU, 2006).

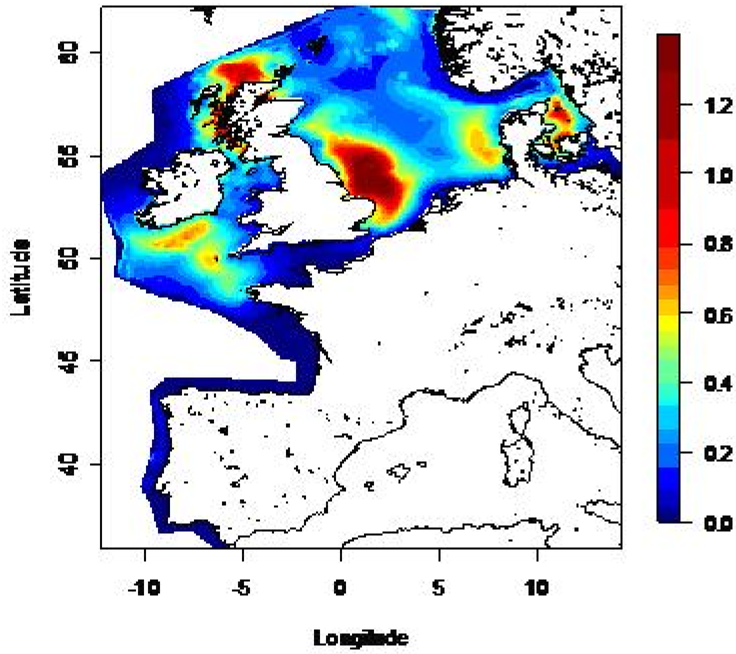
14.4.11 However, large scale changes in the distribution of porpoise were observed between 1994 and 2005, with the main concentration shifting from north-eastern UK and Denmark to the southern North Sea (**Figure 14.2**). This trend is likely the result of changes to the availability of principle prey, notably within the northern North Sea (SMRU, 2006).

Figure 14.2 Harbour porpoise estimated density surface (animals per km²) in (a) 1994 and (b) 2005

1994



2005

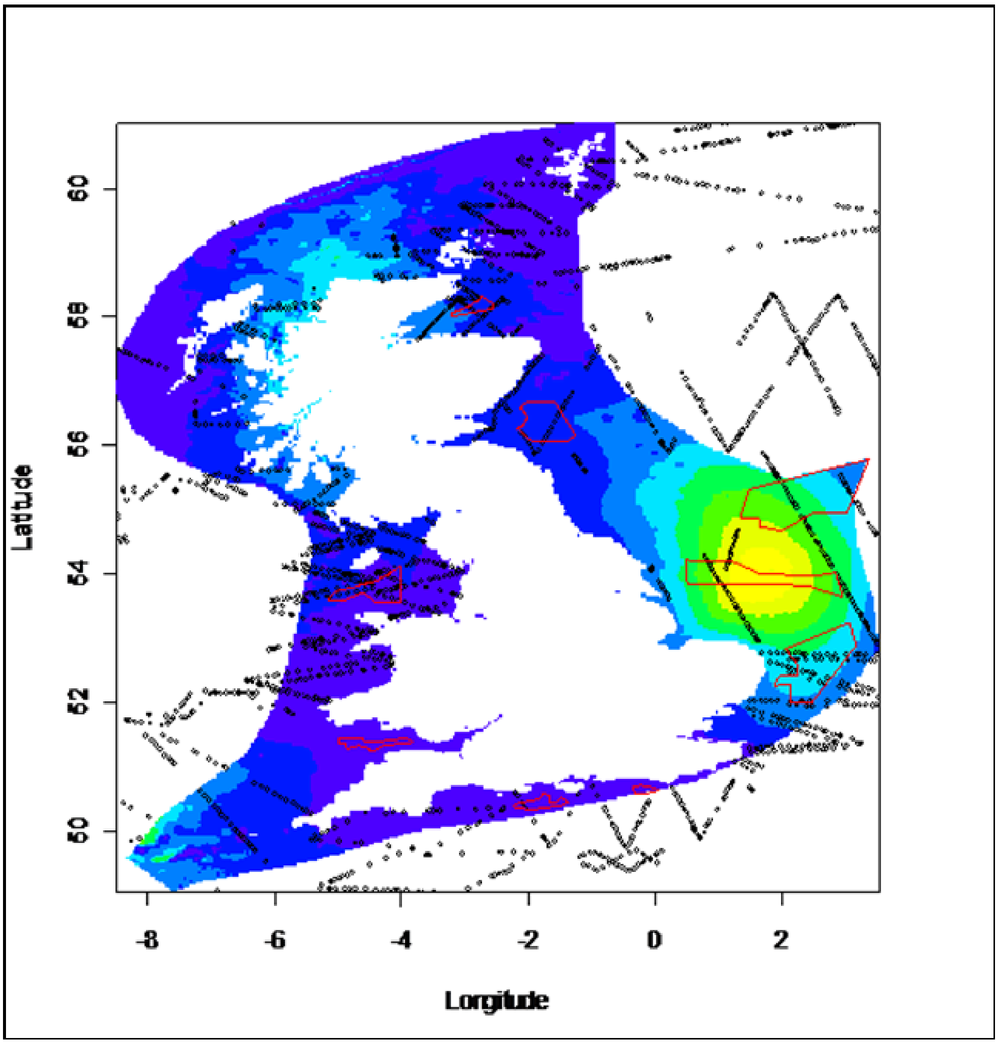


14.4.12 As part of the SCANS II survey analysis, model-based estimates of harbour porpoise abundance were obtained by fitting a GAM-based density surface model to the survey data that included longitude, latitude, depth and distance to coast. The predictions from these models were used to obtain local density estimates (animals/km²) on a two minute grid (i.e. ~8.15km²). **Figure 14.3** shows the latest North Sea harbour porpoise surface densities derived from the SCANS II dataset (SMRU, 2010). The data indicate that this species is likely to be present within the GWF study area.

14.4.13 These data confirm that, relative to the offshore areas of the southern North Sea, the waters within and adjacent to the GWF study area have consistently lower encounter rates for harbour porpoise.

14.4.14 Throughout the species' range in UK waters no areas have been identified as being of particular importance that would justify designation as a Marine Protected Area (MPA).

Figure 14.3 Estimates of local harbour porpoise density (animals/km²) from SCANS-II at 2 min² grid resolution.



Source: SMRU (2010). Key: Intervals: 0 – 0.2 violet, 0.2 – 0.4 deep blue, 0.4 – 0.6 medium blue, 0.6 - 0.8 pale blue, 0.8 – 1 blue-green, 1 – 1.2 green, 1.2 – 1.4 yellow. R3 zones are shown in red. Dots indicate survey effort.

14.4.15 In general, abundance estimates from surveys with a lot of effort and sightings tend to be more precise i.e. have a low coefficient of variation (CV). CVs for each grid cell were estimated from 200 bootstrap replicates made by re-sampling on transects (SMRU, 2010). **Figure 14.4** shows the levels of uncertainty in relation to harbour porpoise density estimates over the UK continental shelf

14.4.16 Highest modeled harbour porpoise densities occurred off the east coast of the UK, particularly in the region of the Dogger Bank site. The uncertainty associated with the estimates for porpoise in the Dogger Bank region is high. The CVs in the regions of interest will be related to the error in the model which in turn will be locally affected by the amount of survey effort. Thus the CVs represent the uncertainty associated with each cell as a function of the underlying intrinsic uncertainty in the population size, mitigated by local effort if any. **Figure 14.4** suggests that the SCANS II survey effort within the Outer Thames Estuary reduces the uncertainty associated with the harbour porpoise density surfaces estimated for the GWF study area.

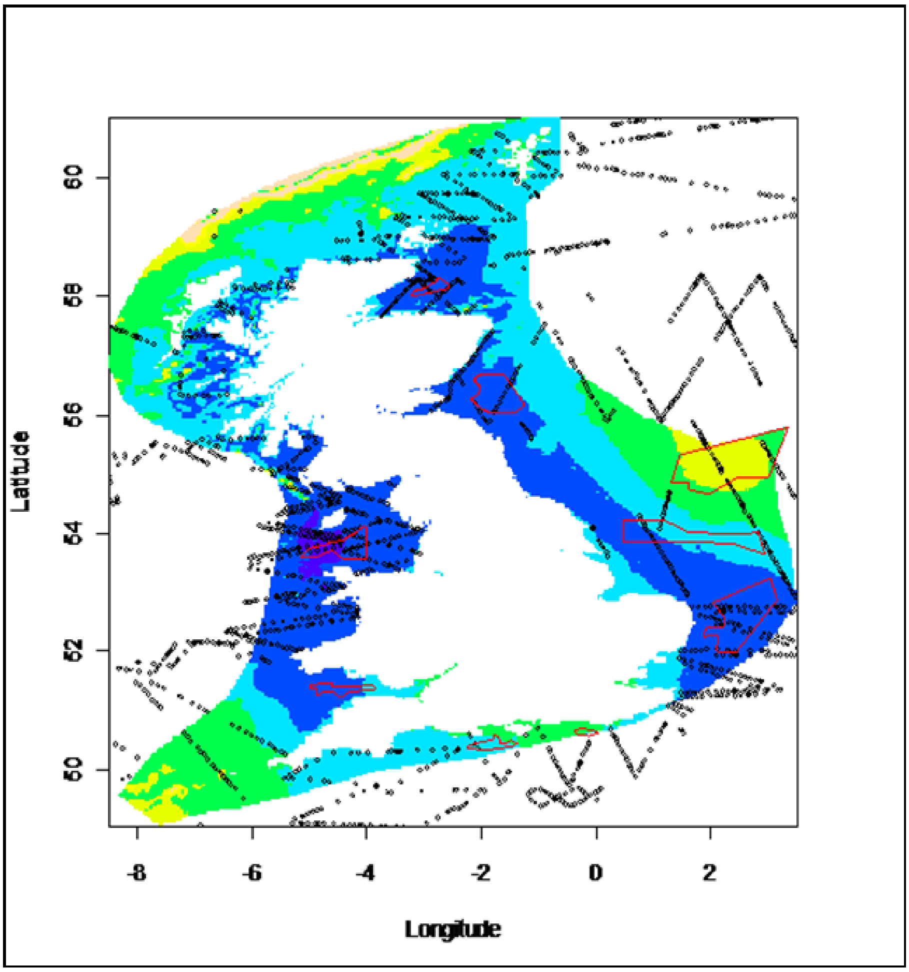
14.4.17 Looking at another historical dataset, **Figure 14.5** summarises the annual harbour porpoise distribution around the UK from the Atlas of Cetacean Distribution in North-west European Waters (Reid et al., 2003). Harbour porpoise have been reported as being widely distributed across the north and central North Sea, with important concentrations off the west coast of Scotland in the southern Irish Sea, and off south-western Ireland. It was generally believed that the shallow, more silt laden, waters of the southern North Sea have fewer sightings, and authors have suggested that numbers of harbour porpoise in the southern North Sea and English Channel declined during the 20th century (Reid *et al*., 2003). However, as highlighted by SCANS I and SCANS II, there is potential for changes in distribution to occur, the most likely cause being changes in availability and distribution of their prey species.

14.4.18 Harbour porpoise feed mainly on small shoaling fishes from both demersal and pelagic habitats, such as whiting *Merlangius merlangus* and sandeels *Ammodytidae*, Santos and Pierce (2003).

14.4.19 The SCANS II density surfaces presented in **Figure 14.3** suggest that the Outer Thames Estuary has a density of between 0.2-0.6 harbour porpoise /km^2. Comparatively, historical surveys carried out by the Joint Nature Conservation Committee (JNCC) Seabirds at Sea Team within the outer Thames Estuary in 1998 recorded encounter rates for harbour porpoise up to 0.09 animals/km during November to April and May to October.

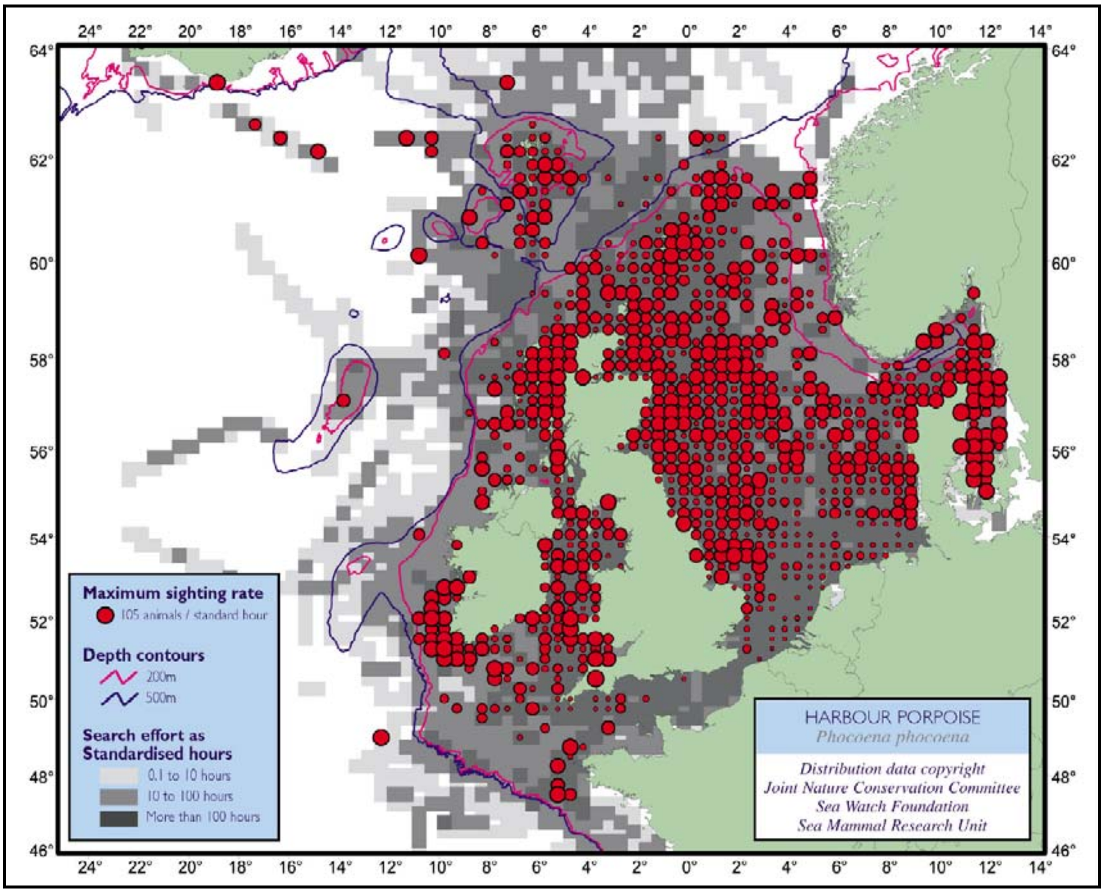
14.4.20 More recently, the Environmental Statement for the London Array Offshore Wind Farm (London Array Limited ‘LAL’, 2005), situated 16km to the south-west of the proposed GWF site, reported an encounter rate of 0.042 harbour porpoise/km (boat surveys carried out from 2002-2004). It should be noted that the density estimates calculated for the London Array ES were derived from incidental sightings collected during the targeted ornithological surveys. With no dedicated sightings effort for marine mammals or record of detection probability it is highly likely that these incidental sightings underestimate harbour porpoise activity within the London Array study area, hence the disparity between the SCANS II estimates, which have a higher precision.

Figure 14.4 Estimates of coefficients of variation of SCANS-II harbour porpoise density estimates at 2 minute² resolution.



Source: SMRU (2010). Key: Intervals: 0 – 0.16, violet, 0.16 – 0.30, medium blue, 0.3 – 0.5, pale blue, 0.5 – 1 green, 1- 2 green-yellow, 2 -3 yellow, 3+ beige. R3 zones are shown in red. Dots indicate survey effort.

Figure 14.5 Annual harbour porpoise distribution around the UK



Source: Reid *et al.*, 2003

14.4.21 A study of the distribution of cetaceans and pinnipeds (as well as sharks, turtles and ocean sunfish) has also been carried out by the WWT (2009) (see **Table 14.4**) Data on distribution and abundance were collected opportunistically during aerial surveys for waterbirds conducted by WWT Consulting from 2001-2008. The survey method was comparable to that used for the collection of previous cetacean data including the SCANS project (Hammond *et al*. 2002).

14.4.22 A total of 4,588 sightings, comprising 5,439 individual animals, were made of harbour porpoise. The results show similar a distribution to those presented in Reid *et al.* (2003), with higher frequencies close to shore around the west coast and off the Lincolnshire and Yorkshire coasts, but with much higher frequencies recorded off the coast between Norfolk and Kent.

14.4.23 Results are also similar to those recorded in the SCANSII project (2006), in which much larger numbers of harbour porpoise were recorded in the southern North Sea than in the 1994 SCANS surveys.

14.4.24 Density estimates for harbour porpoise are illustrated in **Figure 14.6**.

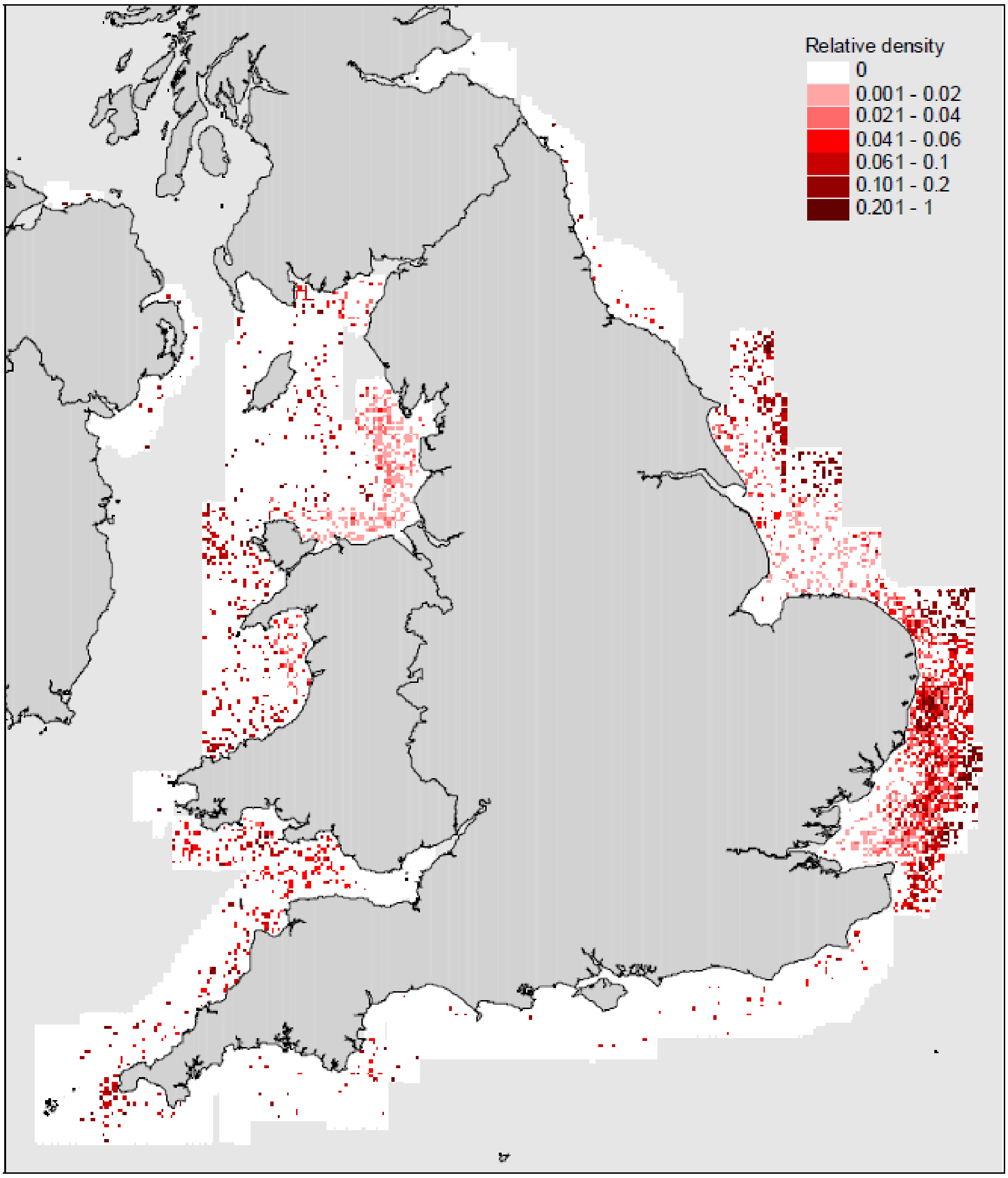
14.4.25 The precise location of each observation was calculated by linking the time at which they were recorded to the interpolated GPS position at that time. The location of most observations was consequently considered to be accurate to within 200-300m.

14.4.26 Relative densities for species and species groups were calculated by splitting observations into 2km x 2km (Ordnance Survey Great Britain) cells then summing these and normalising by coverage. This provided the number of observations per kilometre of survey effort. Relative density maps were then produced showing values for each species or species group in 2km x 2km grid cells.

14.4.27 The survey areas north of Dover to the north Norfolk coast contained a high number of records with a dense cluster offshore of Southwold (**Figure 14.6**). Records were limited closer inshore towards the Thames Estuary.

14.4.28 The results from the waters near GWF indicate that harbour porpoise were present in densities ranging from 0 to 0.2 animals/km². Further north at Southwold, and in areas further offshore, densities from 0 to 1 animal/km² were recorded during the WWT aerial surveys.

Figure 14.6 Harbour porpoise densities from WWT (2009)



Source: WWT (2009)

Site specific boat-based sightings data June 2008 to May 2011

14.4.29 Site–specific marine mammal data is also available from the monthly boat-based surveys that cover the GWF survey areas (Area A and Area B; Area A and B 1km buffer; Area A and Area B 1-4km buffer) (see **Figure 14.1**). As described in **Section 14.3**, these surveys commenced in June 2008 and are ongoing. The ES draws upon on a larger pool of data than the PER (submitted for consultation in July 2011) which assessed survey data collected from June 2008 to August 2010. The ES captures sightings data from June 2008 to May 2011 and therefore assesses 36 months of (semicontinuous) survey effort giving further insight into the presence / absence and general activity of marine mammal species within GWF study area.

14.4.30 As detailed in **Section 14.3**, further work has been undertaken on the site specific incidental sightings data, however a high level of uncertainty is associated with the results presented. Where this is the case it has been highlighted and explained. The data collected in the six survey areas at GWF is presented as raw counts and encounter rate (animals / km). Estimated density (animals / km^2) of animals is presented from the results of other studies covering wider areas and involving greater survey effort (i.e. SCANS).

Raw counts

14.4.31 Sightings of harbour porpoise within the GWF study area between June 2008 and May 2011 are presented in **Table 14.7. Figure 14.7** illustrates the sightings across the GWF and GGOWF study areas. Harbour porpoise were recorded in low numbers across the GWF study area throughout the majority of the year, with a peak in sightings during the spring (March-May). Numbers in the spring of 2011 are down on previous years, this might be as a result of construction activities at GGOWF. Harbour porpoise were largely absent from surveys during the summer months.

14.4.32 These results also correspond with data for the south-east North Sea, which recorded a peak in sightings throughout January to May (Reid *et al.,* 2003).

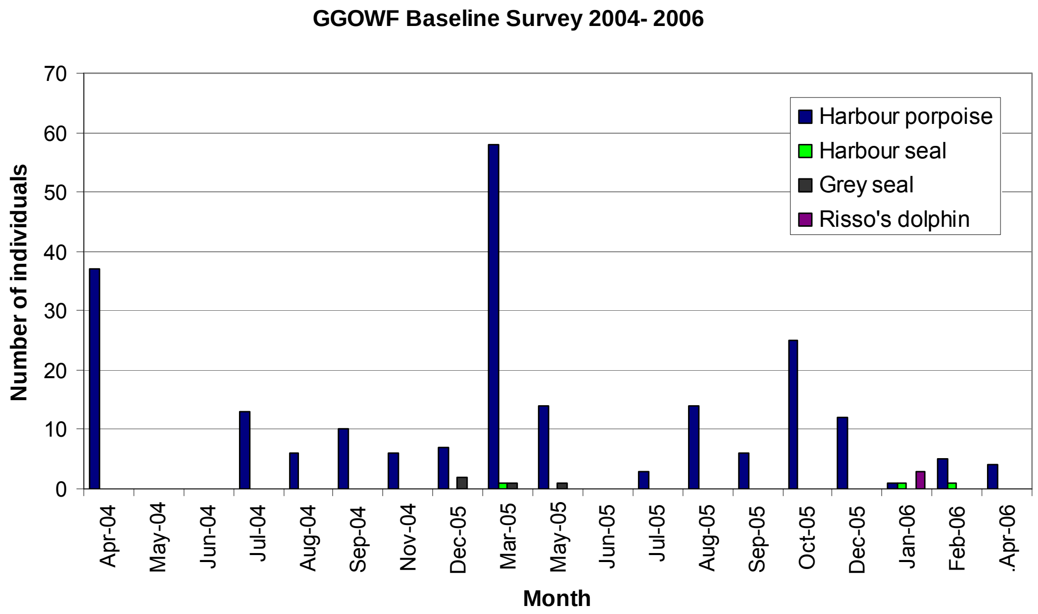
Table 14.7 Raw count data for harbour porpoise sightings during the GWF surveys

Month	Survey Area						Total
	Area A	Area A 1km buffer	Area A 1-4km buffer	Area B	Area B 1km buffer	Area B 1-4km buffer	
Jun-08	0	0	0	0	0	1	**1**
Jul-08	0	0	0	0	0	1	**1**
Aug-08	0	2	0	0	0	9	**11**
Sep-08	4	0	0	1	0	0	**5**
Oct-08	0	0	2	0	0	1	**3**
Nov-08	0	0	2	0	0	0	**2**
Dec-08	0	0	2	0	1	10	**13**
Jan-09	0	0	0	0	0	0	**0**
Feb-09	0	7	11	19	8	11	**56**
Mar-09	8	4	7	1	1	0	**21**
Apr-09	11	0	12	2	0	1	**26**
Jun-09	0	0	1	4	1	7	**13**
Aug-09	2	0	1	0	0	2	**5**

Month	Survey Area						Total
	Area A	Area A 1km buffer	Area A 1-4km buffer	Area B	Area B 1km buffer	Area B 1-4km buffer	
Sep-09	0	0	1	1	4	1	**7**
Oct-09	0	0	1	0	0	2	**3**
Jan-10	0	0	1	0	0	5	**6**
Feb-10	3	2	3	2	1	0	**11**
Mar-10	2	0	2	1	0	0	**5**
Apr-10	9	14	70	2	13	48	**156**
May-10	40	7	43	15	3	32	**140**
Jun-10	2	0	4	0	0	2	**8**
Jul-10	4	2	20	1	0	0	**27**
Aug-10	0	0	0	0	0	0	**0**
Sep-10	0	0	2	0	1	0	**3**
Oct-10	0	0	0	0	0	0	**0**
Nov-10	0	1	0	0	0	2	**3**
Dec-10	1	0	4	2	0	3	**10**
Jan-11	0	0	0	0	0	1	**1**
Feb-11	4	1	12	4	0	3	**24**
Mar-11	0	0	0	0	0	0	**0**
Apr-11	3	2	0	0	0	2	**7**
May-11	1	0	1	0	0	0	**2**
Total	**94**	**42**	**202**	**55**	**33**	**144**	

14.4.33 The seasonal trend identified in the raw data also follows the peak sightings in April (n=37) and May (n=54) observed in the pre-consent baseline at the GGOWF (2004-2006), as shown in **Plot 14.1**.

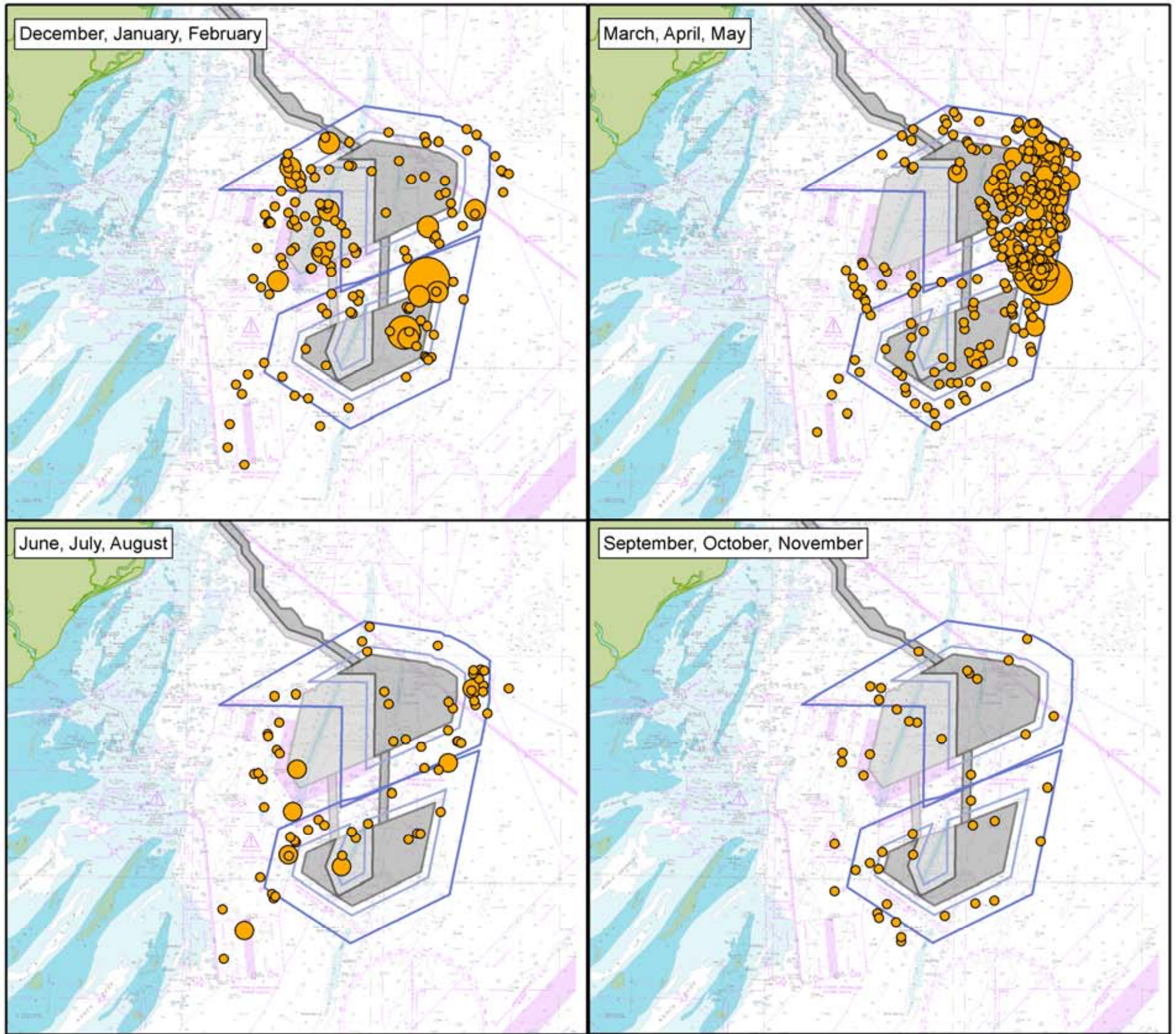
Plot 14.1 Number of harbour porpoise recorded during the GGOWF baseline surveys (2004-2006)

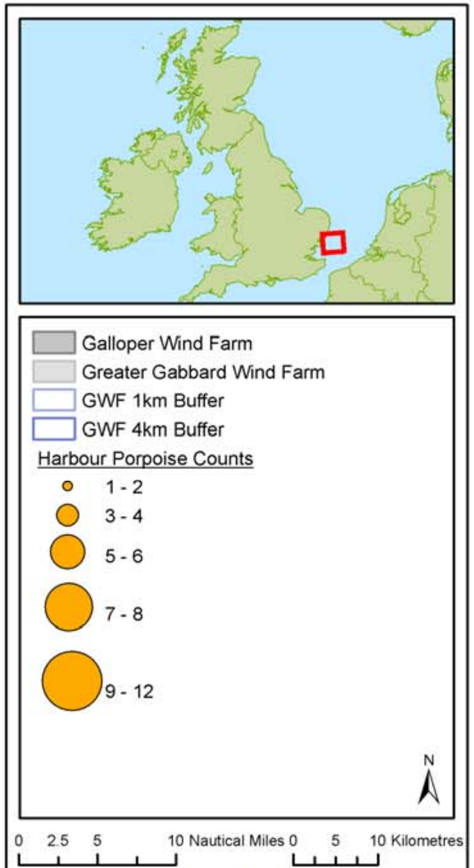


Source: GGOWF Summary Progress Report April 2006, BTO and ESS Ltd

14.4.34 Drawing on more information from the GGOWF, the vast majority of harbour porpoise sightings were of individual adults; although, on occasion up to six individuals were seen. Occasionally, the surveyors noted size differences between individuals travelling with the pod, suggesting the presence of mother and calf assemblages within the study area, particularly during the spring months.

14.4.35 **Figure 14.7** illustrates harbour porpoise sightings across the wider GWF and GGOWF survey area. The species appears to be wide-spread across the study areas. Data from February-May suggests that there may have been an eastern bias for sightings during this period.





Galloper Wind Farm		
Figure 14.7		
Boat Surveys June 2008 - May 2011: Harbour Porpoise		
Draw ing Number: GWF_584_R3		Rev: 3
Date: 01/11/11	Created: LW	Checked: SS
Scale: 1:800,000	Page: A4	
Datum: WGS1984	Projection: UTM Zone 31N	

Encounter rate

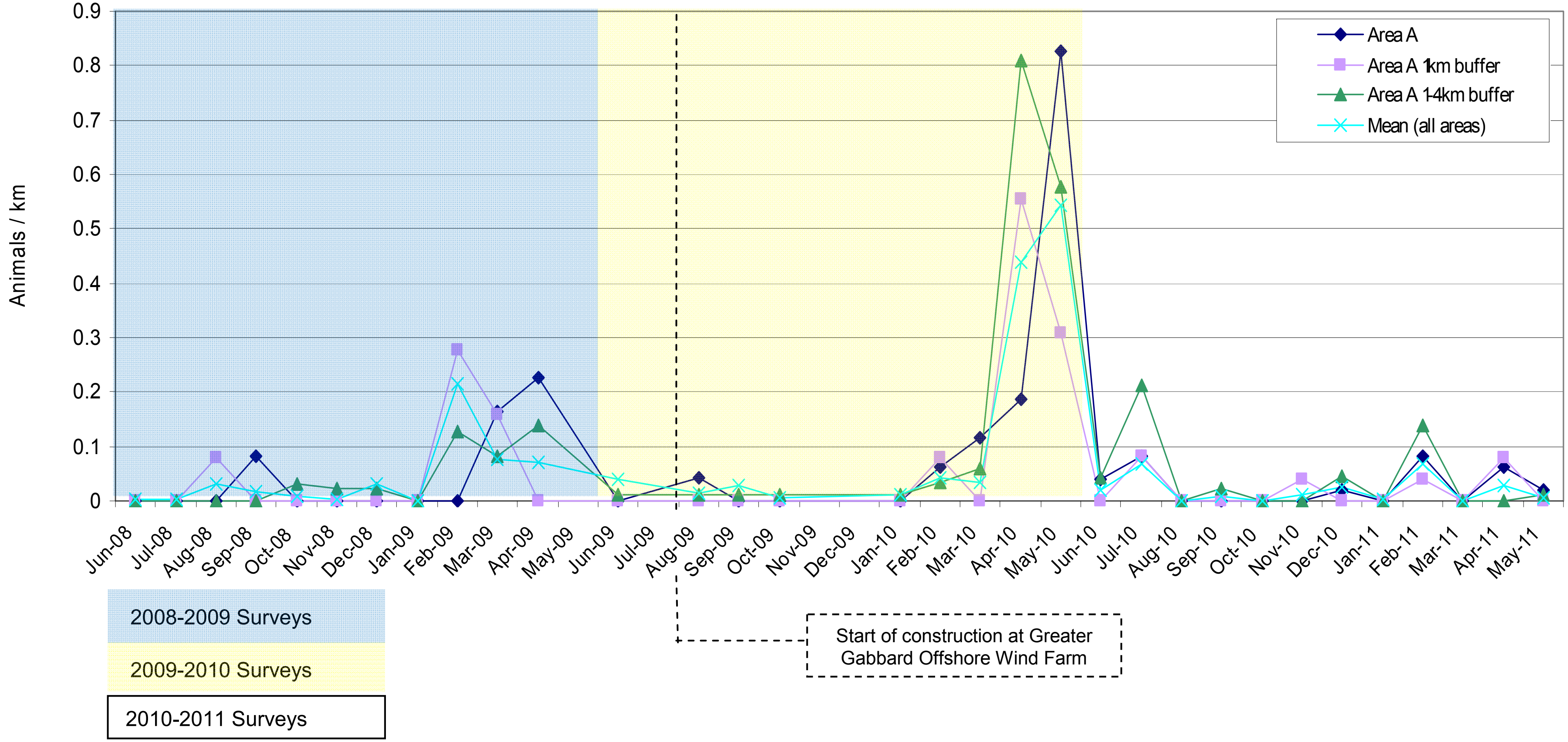
14.4.36 **Plot 14.2** and **14.3** illustrate the encounter rate within Area A and the associated buffers, and Area B and associated buffers, respectively, over the 36 month survey period. The mean of all six study areas is also included in both plots for comparison.

14.4.37 Encounter rates do not exceed 0.9 animals / km in any of the study areas, with the mean maximum encounter rate being significantly lower at approximately 0.55 animals / km. Both plots again indicate the seasonal variances in harbour porpoise encounter rates at the GWF site, with sightings above 0.1 animals / km only occurring in the months of February to April 2009 and March to May 2010, although encounter rates were higher in the latter survey year. In 2011 a small peak is seen in February, however encounter rates have not reached the peak levels as seen in previous years, this may be as a result of construction activities at GGOWF.

14.4.38 As detailed in SMRU (2010) the power to detect changes in population trends that could be significant is usually very low and there tends to be a direct relationship between statistical power and the amount of data collected. Even very significant changes in abundance are difficult to detect reliably without considerable effort, and it is considered that the amount of data collected at GWF is limited in its ability to show population trends.

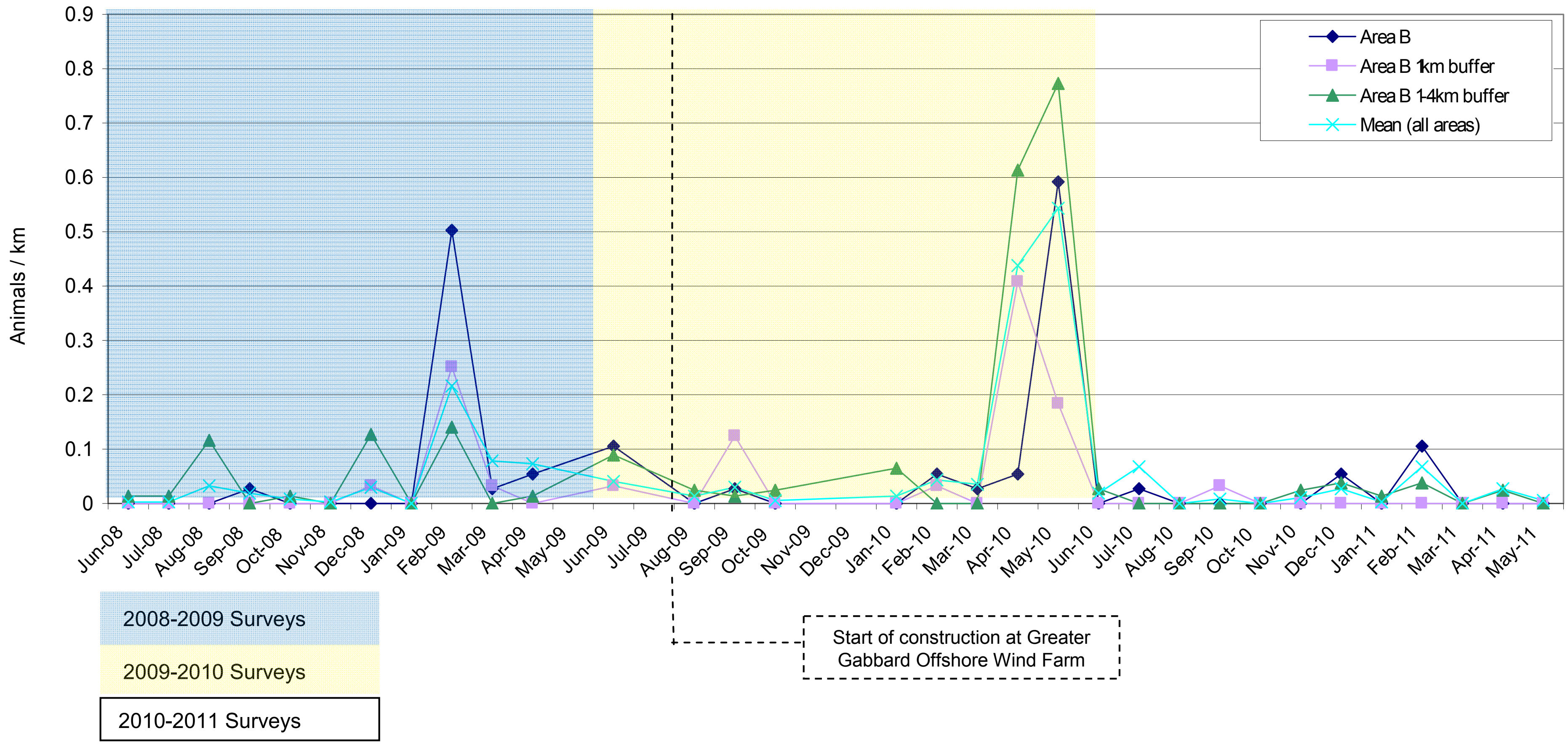
14.4.39 The limitations of the data collected (done so in accordance with best practice techniques with scope of works agreed in advance with the JNCC) have been highlighted by JNCC and are recognised by GWFL (see GWFL, 2011; Mendes, 2011 and **Section 14.3**).

Plot 14.2 Encounter rate of harbour porpoise in Area A and associated buffers*



*No surveys undertaken in May and July 2009, November and December 2009

Plot 14.3 Encounter rate of harbour porpoise in Area B and associated buffers*



*No surveys undertaken in May and July 2009, November and December 2009

Regional density estimates for marine mammals

14.4.40 The SCANS II study estimated the density of harbour porpoise in the GWF area to be between 0.4-0.6 animals / km² (see **Figure 14.3**). Estimates from the WWT (2009) surveys range between 0 and 1 animal / km² in the GWF site and the surrounding waters (although densities above 0.2 animals / km² are associated with areas further offshore and north of GWF).

14.4.41 Compared to the GWF-specific encounter rates presented in **Table 14.8**, broad scale survey data suggests that, relative to the offshore areas of the southern North Sea, the waters within and adjacent to the GWF study area have relatively lower encounter rates and densities for harbour porpoise.

Harbour porpoise ecology

14.4.42 In the British Isles and adjacent seas, calves have been observed between February and September, particularly during May to August with a peak in June, coinciding with the findings of reproductive studies conducted on stranded or by-caught animals. The gestation period of the harbour porpoise is ten months, with peak mating activity likely to occur in August. Evidence for social and sexual activity in late summer has been widely reported. Females are believed to nurse their calves for between eight and twelve months. Weaning is a gradual process with young starting to take solid food after a month or two (Seawatch Foundation Fact Sheet, accessed 2011).

14.4.43 Studies using skeletal material, along with studies of tooth structure and genetics together suggest that sub-populations of harbour porpoise may exist in the North Sea and adjacent waters, with possible separate populations occurring in the Irish Sea, northern North Sea, and southern North Sea (Netherlands). Genetic evidence from the UK and elsewhere also indicates that males disperse more widely than females (Reid *et al.,* 2003).

14.4.44 Harbour porpoise in the North Sea feed mainly on demersal fish, notably small gadoids, clupeids and sandeels (Seawatch Foundation Fact Sheet, accessed 2011). It is believed that the balance of their diet has changed over the past 40 years from herring to whiting dominated, reflecting the change in composition of available food resources (Reid *et al.,* 2003).

Other cetaceans

Broad-scale survey data

14.4.45 When compared to offshore areas of the southern North Sea, the Suffolk coast and Outer Thames Estuary is widely reported as having relatively low levels of cetaceans; both in terms of numbers and diversity.

14.4.46 The WWT report (WWT, 2009) shows that records of other cetaceans (including Harbour Porpoise, Bottlenose Dolphin, Common Dolphin, White-beaked Dolphin, Atlantic White-sided Dolphin, Risso's Dolphin, Long-finned Pilot Whale, Killer Whale, Sperm Whale, Fin Whale and Minke Whale) in the outer Thames Estuary were limited and around the GWF site densities recorded were very low (0 to 0.05 animals / km²). North of Margate, records increased dramatically until reaching the north Norfolk coast. Again, the higher densities were associated with areas further offshore (WWT, 2009).

14.4.47 No dolphin species (Bottlenose Dolphin, Common Dolphin, White-beaked Dolphin, Atlantic White-sided Dolphin and Risso's Dolphin) were recorded around the GWF site during the 2001-2008 WWT (2009) surveys, in this part of the North Sea records were confined to deeper offshore waters.

14.4.48 White-beaked dolphin are wide-spread across the northern European continental shelf. The species is the most numerous cetacean after the harbour porpoise in the North Sea (Jansen *et al.,* 2010), with a distribution centered around Scotland and north-east England. Sightings are common throughout the year, with peaks between June and October (Reid *et al.* 2003). The latest SCANS II data confirms that the GWF study area is not an area of importance for white-beaked dolphin. The waters of the outer Thames Estuary have an estimated density of zero animals (WDCS, 2010).

14.4.49 SCANS and SCANS II surveys have established that Atlantic white-sided dolphin is one of the most frequently encountered cetaceans in the southern North Sea, though it is relatively scarce in the English Channel and has never been recorded as part of incidental sightings within the GWF study area. Population estimates for the North Sea, excluding the Channel (within which the GWF study area lies), were updated to 10,600 animals after the 2005 survey (SCANS II; GGOWL, 2005; LAL 2005).

14.4.50 Few sightings of Risso's dolphin *Grampus griseus* are made on the east coast of the UK or in the eastern extent of the Channel (Clark *et al*, 2010) as this species tends to associated with the deeper waters of the continental slope (Baumgartner, 1997).

Site specific boat-based sightings data June 2008 to May 2011

14.4.51 Other than harbour porpoise, white beaked dolphin were the only other cetacean species encountered within the GWF study area during the 2008-2011 study period (**Table 14.8)**. Four white-beaked dolphin were recorded in the GWF study area in June 2009. Some / all of the nine unidentified cetaceans (all recorded as odontocetes) and three unidentified dolphins recorded between April-June 2010 are likely to be white-beaked dolphin. Encounter rates of other cetaceans were also low (**Table 14.8**), the highest being 0.19 animals / km during April 2010 and the lowest 0.02 animals / km in June 2010.

14.4.52 It is worth noting that four Risso's dolphin were also recorded within the adjacent GGOWF study area in January 2006.

Table 14.8 Number of other cetacean species sighted at GWF, and associated encounter rates (no other cetacean species were recorded during the remainder of the survey period).

Cetacean species	Area	Month	Number of individuals	Encounter rate
Unidentified cetacean	Area A 1-4km buffer	Apr-2010	2	0.03
Unidentified cetacean	Area B 1km buffer	Apr-2010	6	0.19
Unidentified cetacean	Area B 1-4km buffer	Jun-2010	1	0.02
Unidentified dolphin	Area B 1km buffer	Apr-2010	3	0.09
Unidentified dolphin	Area A	Apr-2011	1	0.02
White beaked dolphin	Area A	Jun-2009	4	0.08

14.4.53 Estimated densities of other cetaceans identified during the surveys was also very low, as shown in **Plot 14.5**, the highest of which was 0.07 animals / km² during April 2010. Smaller peaks in density of less than 0.025 animals / km² were seen during 2008 and 2011

14.4.54 Broad scale and site specific data indicate that the Suffolk coast (and GWF) is of low importance for other cetacean species.

Cetacean ecology

14.4.55 The diet of white-beaked dolphins within the North Sea is dominated by Gadidae, notably whiting and cod (Jansen *et al.* 2010).

14.4.56 The status of Risso's dolphins in the UK is currently unknown, and there is no population estimates available (SCANS II, 2006; *Clark et al.*, 2010). The typical diet of this species is largely thought to comprise of neritic and oceanic squid, they may also feed on crustaceans and octopus (Culik 2004).

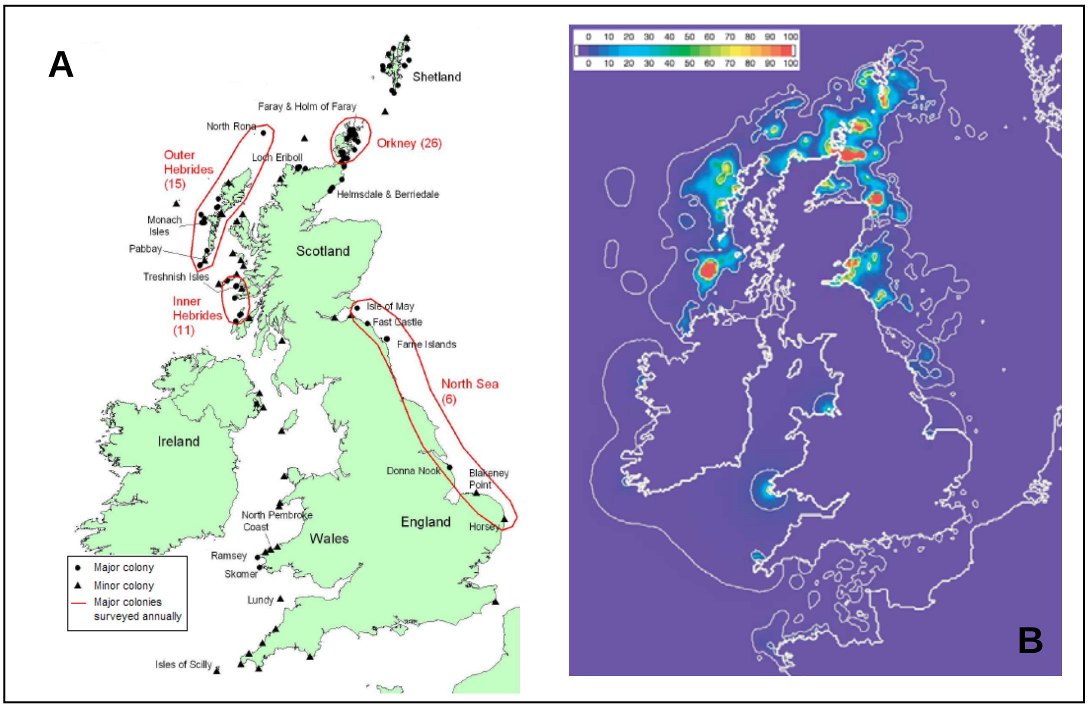
Pinnipeds

Grey seal

14.4.57 Grey seal is the more abundant of the two species of pinniped found around the UK (the other species being the harbour seal). Approximately 45% of the world's grey seal breed in the UK and 90% of these breed at colonies in Scotland, with the main concentrations in the Outer Hebrides and in Orkney. There are also breeding colonies in Shetland, on the north and east coasts of mainland Britain and in the south-west of England and Wales (SCOS, 2009), **Figure 14.8**. Although the number of pups throughout Britain has grown steadily since the 1960s when records began, there is evidence that this growth is levelling off (SCOS, 2009). In 2009, SCOS estimated the grey seal population associated with annually monitored breeding sites in the UK to be 183,000 animals.

14.4.58 There appears to be a relatively low level of grey seal activity within the outer Thames Estuary (see **Figure 14.8**). The nearest known grey seal haul-out is at Scroby Sands, approximately 70km north of the site. It should be noted that grey seal are known to forage within 145km of their haul out sites (Thompson *et al.,* 1996) although based on the number of incidental sightings of this species within the GWF study area between 2008-2011, this area is unlikely to offer a unique or productive foraging habitat when compared to other sandbank systems in the wider Thames Estuary.

Figure 14.8 UK grey seal breeding colonies (A) and marine usage (B)



Source: (A) SCOS (2007) Major and minor breeding colonies, those circled in red are surveyed annually; (B) Matthiopoulos *et al*., (2004), warmer colours represent areas of higher usage. Contours show log-transformed usage to reveal some detail in areas used less frequently.

14.4.59 There were six individual grey seals recorded within the GWF study area over the entire survey period (**Table 14.9**). As so few seals were recorded encounter rates were very low ranging between approximately 0.01 and 0.03 seals / km (**Plot 14.4**). Similarly estimated densities of seals throughout the GWF survey area were also very low the maximum being 0.016 animals / km² during April 2010. Results during all other months fell between 0 (the majority) and approximately 0.008 animals / km².

Table 14.9 Raw count data for harbour porpoise sightings during the GWF surveys

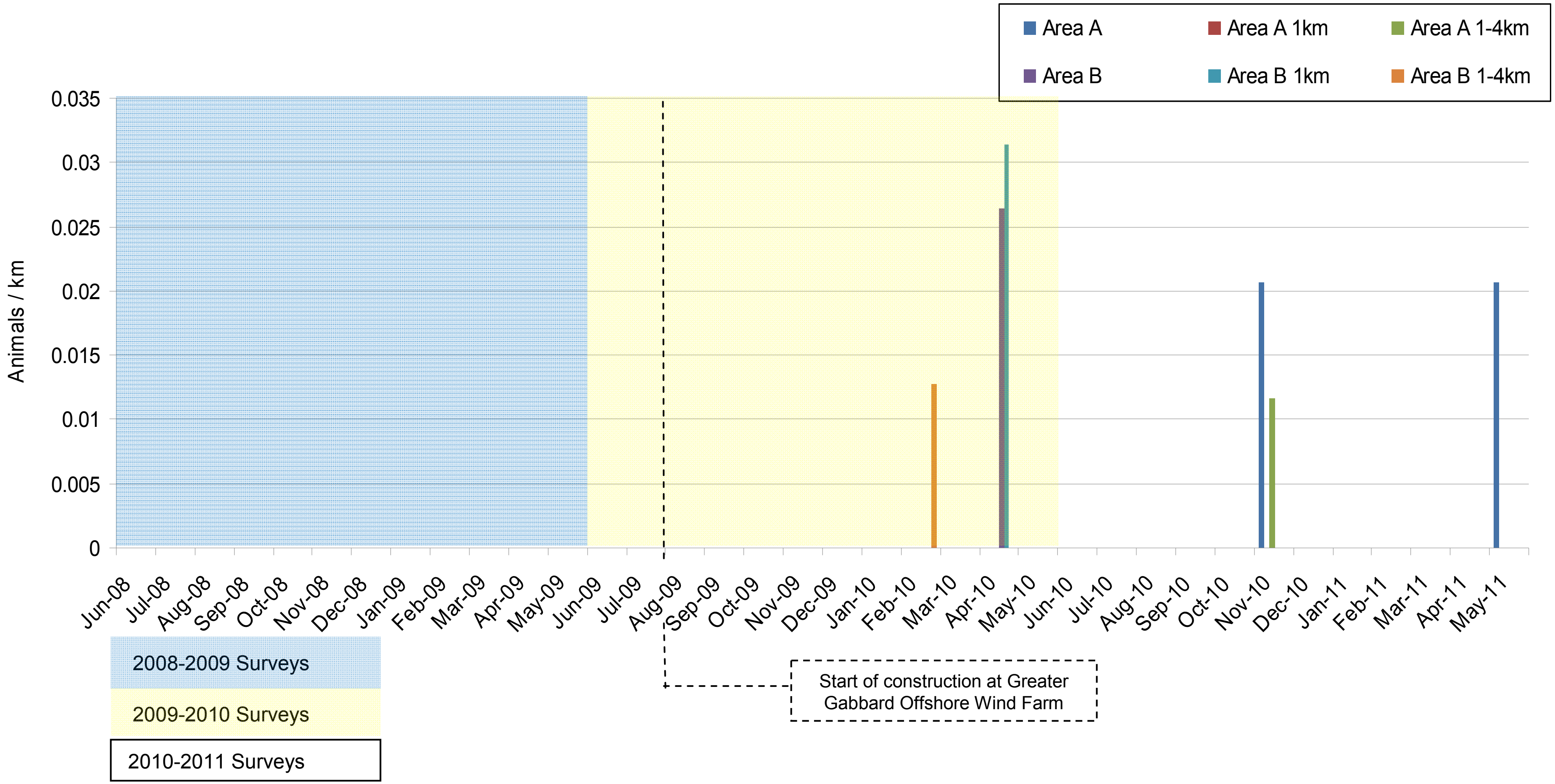
Month	Number of seal species recorded at the GWF site	
	Grey seal	Harbour seal
Jun-08	0	0
Jul-08	0	0
Aug-08	0	0

Month	Number of seal species recorded at the GWF site	
	Grey seal	Harbour seal
Sep-08	0	2
Oct-08	0	0
Nov-08	0	0
Dec-08	0	0
Jan-09	0	0
Feb-09	0	0
Mar-09	0	0
Apr-09	0	0
Jun-09	0	0
Aug-09	0	0
Sep-09	0	0
Oct-09	0	0
Jan-10	0	0
Feb-10	1	0
Mar-10	0	0
Apr-10	2	0
May-10	0	0
Jun-10	0	0
Jul-10	0	0
Aug-10	0	0
Sep-10	0	0
Oct-10	0	0
Nov-10	2	1
Dec-10	0	0
Jan-11	0	0
Feb-11	0	0
Mar-11	0	0
Apr-11	0	0
May-11	1	0
Total	**6**	**3**

14.4.60 Grey seals in the North Sea pup in winter (October to January) with southern animals pupping later than their northern counterparts. Moulting takes place in February and March (SCOS, 2009). An investigation into the movements and foraging behaviour of grey seal in the general area of the proposed Rødsand Wind Farm, Denmark, established average home range (the area in which a seal regularly forages for food) of 3,980km² (Dietz *et al,* 2003). A similar investigation in the Baltic Sea revealed home ranges from 1,088 to 6,400 km² (Dietz *et al.,* 2003). Thus, grey seal may be expected to forage over a very wide area and individuals associated with widely dispersed haul outs around the UK and European mainland coasts could theoretically forage over the proposed GWF development area.

14.4.61 The grey seal is an opportunistic hunter that feeds on a variety of fish and invertebrates. In the UK, prey items are dominated by sandeel, whitefish, (cod, haddock, whiting, ling), and flatfish (plaice, sole, flounder, dab) (SCOS, 2009).

Plot 14.4 Grey seal encounter rate across GWF study areas*



*(All sightings of individual seals)

Harbour seal

14.4.62 The level of harbour seal activity within the outer Thames is low in comparison to other areas of the UK (see **Figure 14.9**). Harbour seal along the Essex and Kent coastlines account for only 0.3% of the British population and harbour seal are not known to breed in Suffolk (SCOS, 2009). SCOS (2009) estimate the total British population to be approximately 40,000 to 46,000 individuals (most recent surveys 2006 to 2008) and over 80% of these occur in Scotland.

14.4.63 Approximately 3,200 harbour seal are believed to be present around the coast of England. The majority (approximately 2,800) are associated with colonies around The Wash and Blakeney Point, the remaining east coast sites represent a small percentage of the UK population, with an approximate population of 400 (SCOS, 2009). Smaller groups of common seal are widely distributed within the Thames Estuary including groups on sandbanks off Herne Bay and Margate in Kent, as well as other locations off the Essex coast.

14.4.64 Only 3 harbour seals were recorded within the GWF study area over the entire survey period (shown in **Table 14.9**). As so few seals were recorded encounter rates were very low with a maximum of 0.02 seals / km during September 2008 and during the majority of survey months the encounter rate was 0. Similarly, estimated densities of seals throughout the GWF survey area (**Plot 14.5**) were also 0 for the majority of months during 2009-2011 survey period.

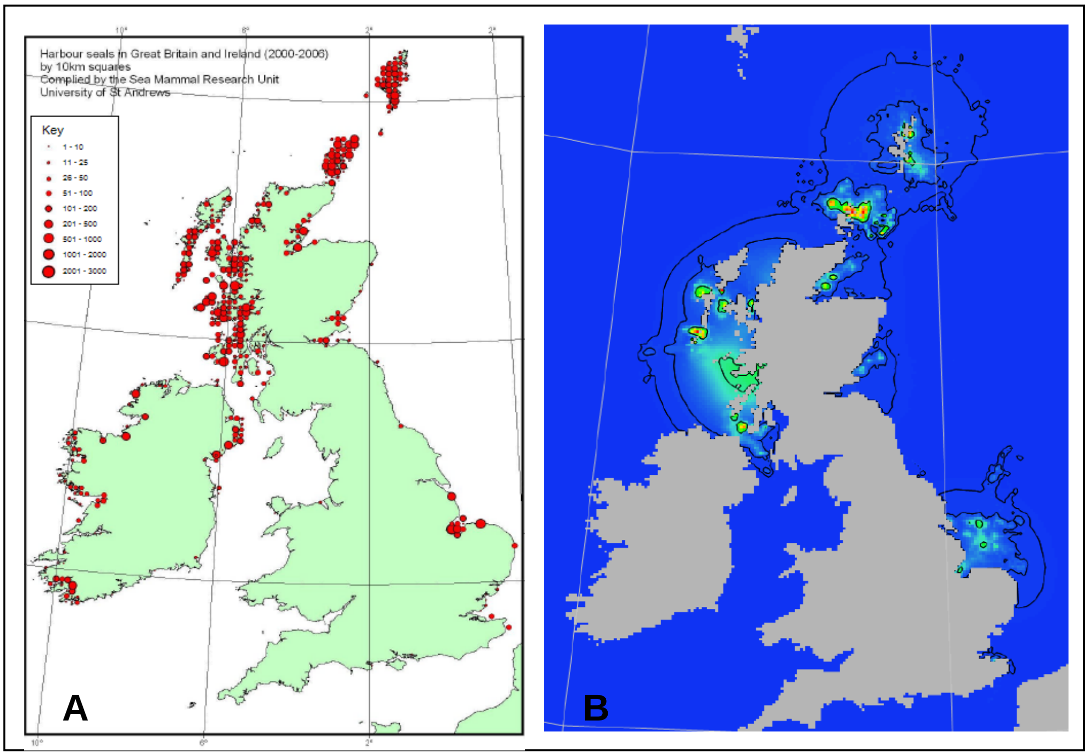
14.4.65 Harbour seal have a circumpolar distribution and are widespread throughout the Northern Hemisphere. The UK population is understood to be recovering following a severe decline in numbers associated following a significant outbreak of the phocine distemper virus (PDV) in 1988 (SCOS, 2009), with smaller outbreaks since. The nearest location where harbour seals occur regularly is understood to be Hamford Water (GGWOL, 2005), nearly 40km west of the proposed GWF site.

14.4.66 Pupping occurs in summer (June to August) for harbour seal. Moulting at haul outs generally occurs in August. Harbour seal have generally been considered to range less widely than grey seal; foraging within 60km or so of their haul out sites. However, recent evidence from Denmark suggests that harbour seal may range much more widely than this (Dietz *et al.*, 2003).

14.4.67 Harbour seal eat a wide range of prey, including sandeel, gadoids, herring, sprat, flatfish, octopus and squid (SCOS, 2009).

14.4.68 No pinniped species were reported in proximity of the GGOWF site by the JNCC Seabirds at Sea Team (GGOWL, 2005). Records of pinniped sightings are kept at Landguard Bird Observatory (Felixstowe). Here, only occasional grey and harbour seal are seen and these tend to be of individual animals.

Figure 14.9 UK harbour seal numbers at haul-out sites (A) and marine usage (B)



Sources: (A) SCOS (2007), numbers derived from aerial surveys over the period 2000-2006 by 10km squares. (B) Sharples *et al*., (2008), warmer colours represent areas of higher usage. Contours show log-transformed usage to reveal some detail in areas used less frequently.

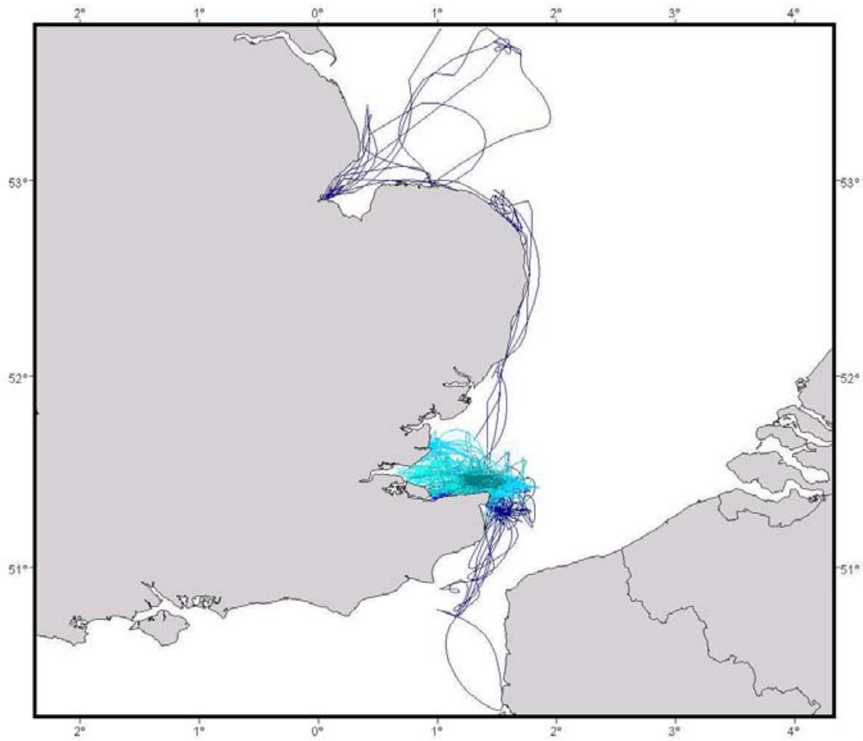
14.4.69 There is some February 2006 data from tag deployments on harbour seal from the Margate and Long Sands cSAC in the outer Thames. Nine harbour seal (all males) were tagged. The majority of animals made very short duration, short range foraging trips within 40km of haul-out sites, diving to a maximum depth of 35m. However, one of the animals also travelled into the English Channel, hauling-out near Saint-Valery-sur-Somme in France and foraged and hauled out in The Wash (see **Figure 14.10**), more than 660km between the southern and northern extent of its movements (Sharples *et al.,* 2008).

14.4.70 The at-sea usage presented in **Figure 14.11** does not appear to show any overlap in important foraging, breeding or migratory areas of harbour seal within the Outer Thames and the GWF development area.

14.4.71 There have also been a larger number of tagging deployments in The Wash on harbour seal (24 seals between October 2003 and March 2005). It is worth noting that none of the seals tagged in The Wash travelled down the coast to Suffolk.

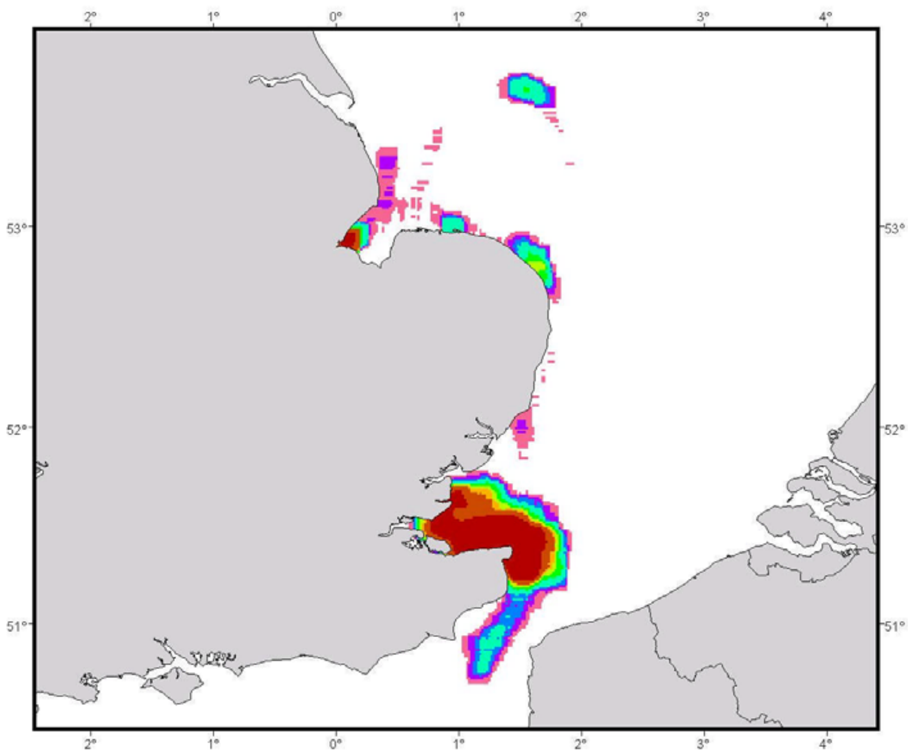
14.4.72 As part of the WWT (2009) aerial surveys, the majority of seals were not recorded to species level given the risk of confusion between common and grey seals with sub-optimal views. Very few seals were recorded in the waters surrounding the GWF site, with most records from the east coast coming from the inner Thames Estuary and the Wash.

Figure 14.10 Individual filtered tracks of all harbour seals captured in the Outer Thames.



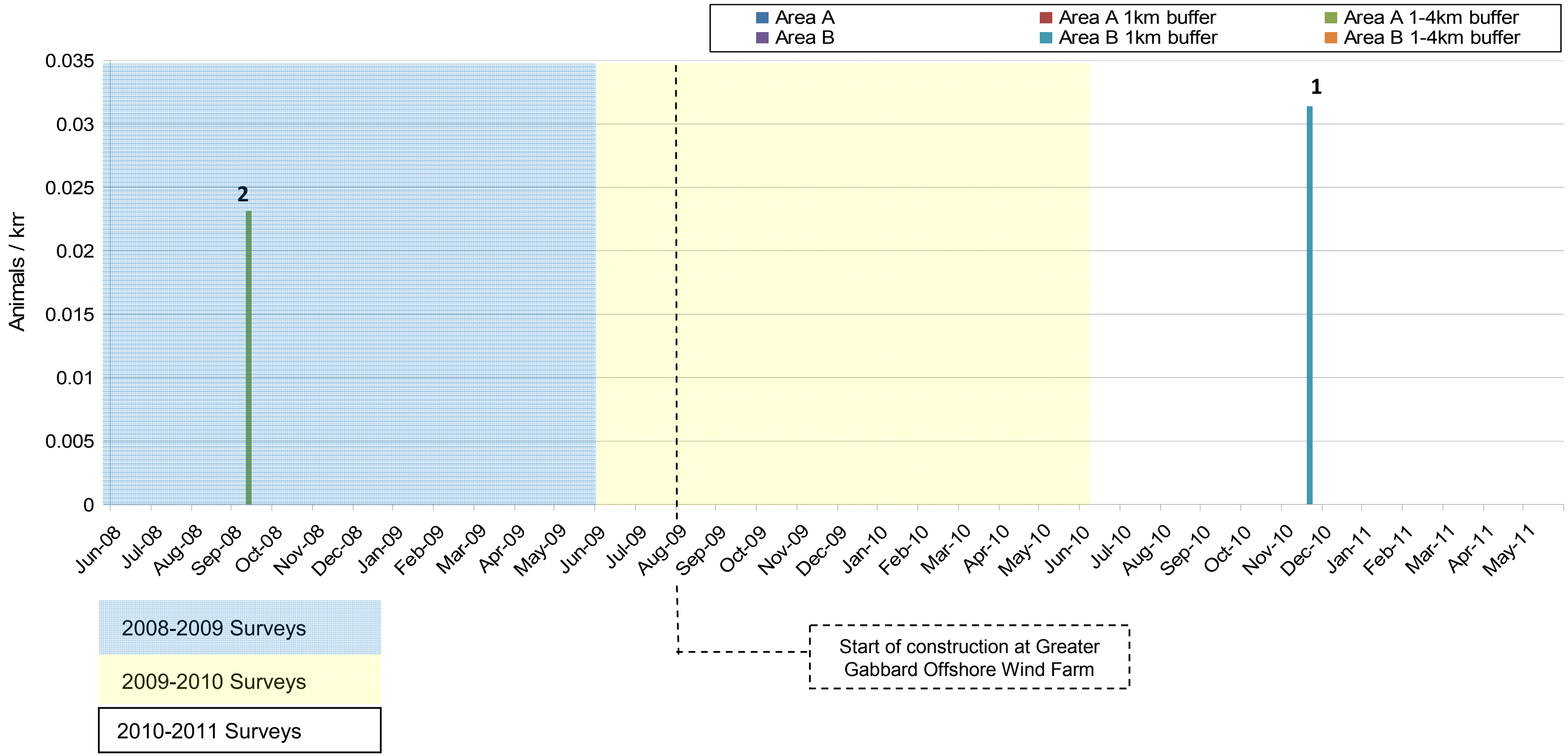
Source: Sharples *et al.,* 2008.

Figure 14.11 Density of 'at sea' surface densities per 100 m^2 from nine seals tagged in the Outer Thames Estuary.



Source: Sharples *et al.,* 2008.

Plot 14.5 Harbour seal encounter rate*



*Number of individuals indicated above bar

Marine mammal distribution summary

14.4.73 The existing marine mammal distribution on or near the GWF site has been assessed using desk-based methods and incidental sightings data derived from original survey.

14.4.74 In the context of the wider UK, the Outer Thames Estuary is not noted for the diversity or abundance of its marine mammal interest.

Cetaceans

Harbour porpoise

14.4.75 Harbour porpoise were the most frequently encountered marine mammal within the GWF study area. Peaks in harbour porpoise activity across the site appear to occur between January and May. Given the low number of sightings, the value of interpreting quantitative or semi-quantitative trends in inter- and intra-annual variation is limited. Most marine mammal sightings were brief encounters with individual animals. For such low numbers of sightings it is difficult to reveal patterns in behavioural activity (for example, foraging, socialising or travelling) or to identify areas of differing relative importance within the GWF study area.

Other cetaceans

14.4.76 No other cetacean species are likely to occur within the GWF study area on a regular basis or in significant numbers. Species such as white-beaked dolphin were occasional visitors to the sight in low numbers, with apparent pea sightings in June.

14.4.77 No baleen whales were recorded within the GWF study area over the entire 2008-2010 survey period.

14.4.78 Despite the infrequent and transient sightings of marine mammals within the GWF development area throughout the year, small groups of animals, in particular harbour porpoise, could be present in the vicinity of the wind farm during construction, operation and decommissioning. This presents a potential risk for the occurrence of an injury and/or disturbance offence under Regulation 39 1(A) of the HR and OMR. The sensitivities of harbour porpoise to disturbance effects during construction and operation are considered in more detail within **Section 14.6** and **Section 14.7**.

The sensitivity of marine mammals to underwater noise

14.4.79 Many species of marine mammal use sound for prey detection, communication and navigation. Anthropogenic noise which falls within the audible range of a marine mammal and exceeds natural background levels has the potential to disturb, and in extreme cases, severely injure such individuals within the local area.

14.4.80 The behavioural and physiological effects of noise on a particular species depend on its intensity, frequency bandwidth, duration and the heterogeneity of ambient physical and environmental parameters such as water depth, salinity and substrate (see Parvin *et al.*, 2006, for a review), as well as the particular species' sensitivity to sound. Background underwater noise is generally higher than in air.

14.4.81 The potential harmful effects of high-level underwater noise for cetaceans, which depends on variables such as the source noise (frequency and decibels (dB)), species, distance from source and factors such as noise attenuation, can be categorised as follows (Parvin *et al*., 2006);

- **Lethal:** at very close range from the source the peak pressure levels have the potential to cause death, or severe injury leading to death;
- **Physical injury:** at greater range the construction noise may cause physical injury to organs such as the lungs, liver, intestines, ears and other soft tissues surrounding gas containing structures of the body;
- **Hearing impairment:** at high enough sound levels, (generally taken to be 180 dB re. 1µPa for all species of marine mammals) the underwater sound has the potential to cause permanent hearing impairment in marine species (Nehls *et al*., 2007); and
- **Behavioural response:** Behavioural responses are influenced by a variety of factors including food motivation, learning processes (e.g. habituation), psycho-physiological features of a sound, and sensation levels (Götz & Janik, 2010). This complexity of animal behaviour is also the most likely reason for the marked variation in responses found across studies.

14.4.82 Hearing damage may initially manifest itself as a temporary, recoverable change of the hearing threshold (TTS). Exposure to higher intensity or longer stimuli may eventually lead to chronic hearing damage (PTS). The risk of hearing damage is therefore considered to be a function of both sound pressure level and exposure time (Eldred *et al*., 1955). These effects are classed as:

- **TTS:** symptoms may include temporary loss of hearing, pain vertigo, but no permanent injury to the ear; and
- **PTS:** the point at which the level and duration of noise exposure results in permanent injuries which may include destruction of receptor hair cells, rupture of the round and oval window leading to fluid leaking into the middle ear. Other effects can lead to neurodegenerative disorders and head trauma.

14.4.83 Non lethal and behavioural responses such as avoidance of an area may be significant where the man-made noise source is in the vicinity of important areas such as breeding grounds, migratory routes or key feeding grounds for marine mammal populations (Subacoustech, 2011*)* (**Technical Appendix 13.B** that supports **Chapter 13**). More subtle behavioural effects, such as masking of marine mammal vocalisations may result in the temporary loss of communication (Subacoustech, 2011*)* (**Appendix 13.B**).

14.4.84 The marine environment is noisy with ambient noise arising from sources such as wave action, bubble formation, action of wind and rain on the sea surface. This ambient noise combines with man made noise produced from sources such as shipping, offshore installations and fishing sonar to produce background noise which varies between locations due to the influences of the existing sea bed; geology, bathymetry and temperature (Subacoustech, 2011*)* (**Technical Appendix 13.B**).

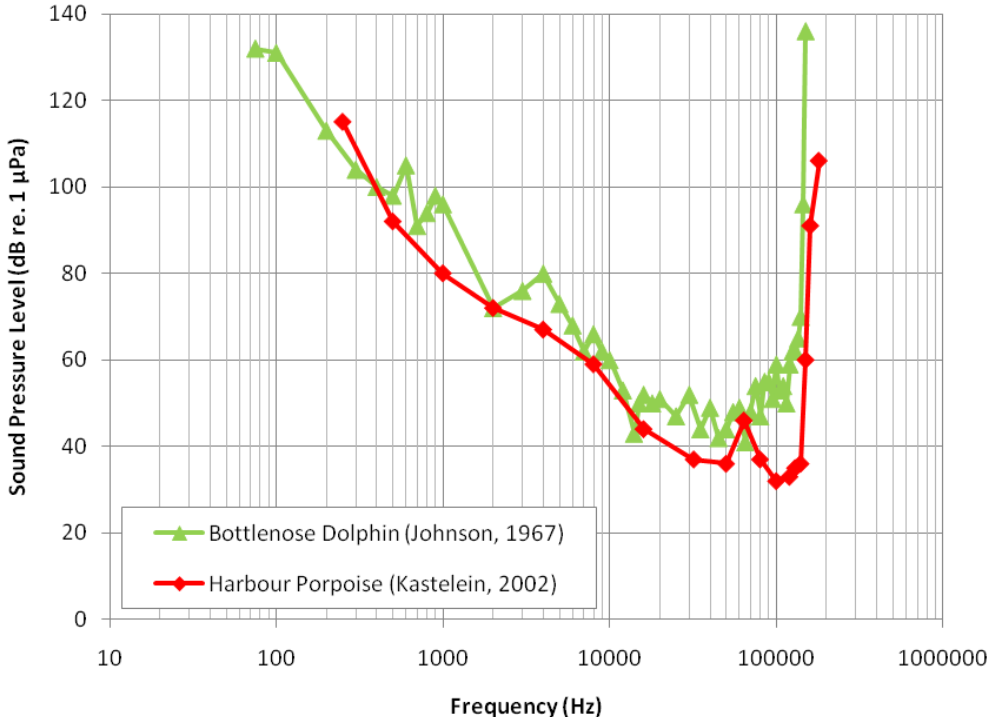
14.4.85 Background underwater noise measurements were undertaken in the area prior to the installation of GGOWF. These measurements indicated that in general the background noise levels range from 110 to 150 dB re 1 µPa, levels which are typical of coastal noise (GGOWL, 2005). In 2009 broadly similar overall levels were observed although unsurprisingly levels were slightly higher as a result of increased shipping traffic due to GGOWF construction activity (Gardline, 2010). Increased shipping results in an increase in noise at lower frequencies (<100 Hz) while also introducing high frequency (kHz) sounds from equipment such as echosounders and sonar (Gardline, 2010).

14.4.86 In recent years, the potential ecological impacts of underwater noise associated with the construction of offshore wind farms has been a key topic of research (Subacoustech, 2011*)* (**Technical Appendix 13.B**). It is widely accepted that impact piling operations are likely to be the principal source of noise that has the potential to impact upon marine life within and adjacent to the development area (Subacoustech, 2011*)* (**Technical Appendix 13.B**). Less significant sources of noise are also associated with other activities such as increased local vessel movement (many of which have loud bow thrusters to maintain station), seismic surveys, ground preparation and cable laying (Subacoustech, 2011*)* (**Technical Appendix 13.B**).

14.4.87 A review of literature pertaining to the impact of underwater sound and vibration on marine mammals can be found within Subacoustech, 2011. The fundamental measure of the sensitivity of sound is called an audiogram; this depicts a species threshold of hearing with increasing frequency. It should be noted that for marine mammals the audiogram data has often been compiled using very few individuals which are often old, captive animals, subsequently their levels of hearing may be poorer than those in the wild (Subacoustech, 2011*)*.

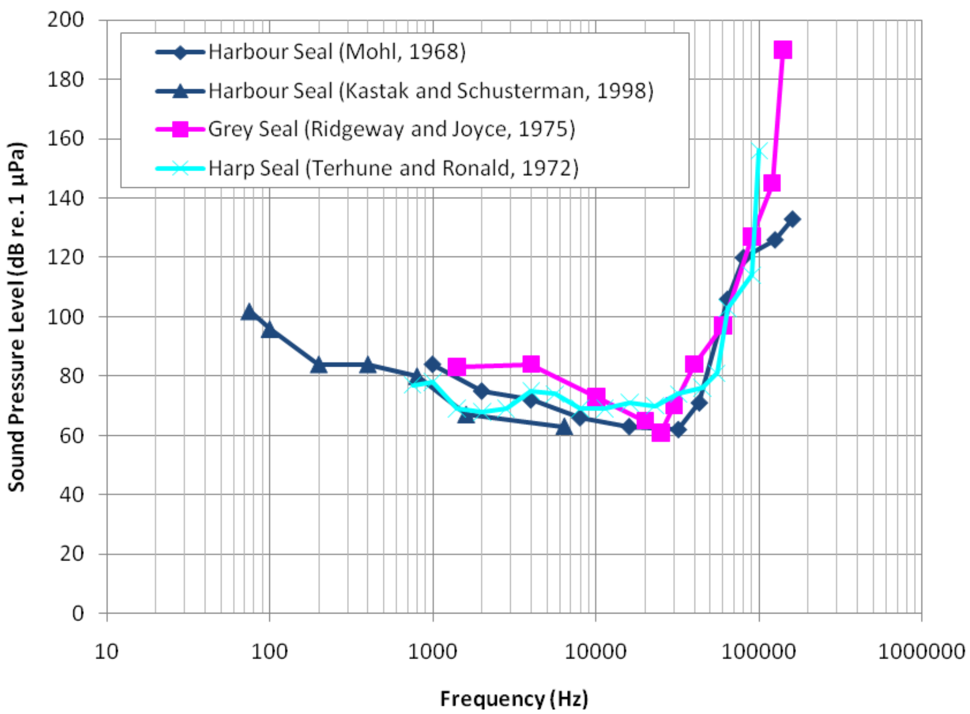
14.4.88 Audiograms for a number of species of cetacean and pinniped are provided in **Plots 14.6** and **Plot 14.7** respectively.

Plot 14.6 Comparison of hearing threshold levels for bottlenose dolphin and harbour porpoise



Source: Subacoustech, 2011

Plot 14.7 Comparison of hearing threshold levels for harp, grey and harbour seal



Source: Subacoustech, 2011

14.4.89 The cetacean audiogram (**Plot 14.6**) highlights that the harbour porpoise is sensitive to a very broad bandwidth of sound from approximately 200Hz to 170kHz.

14.4.90 **Plot 14.7** indicates that harbour seal has better low and mid frequency hearing (frequency range from 100Hz to 5kHz) than the harbour porpoise, and has an audible range that does not extend to such high frequencies. The grey seal audiogram data indicates a similar sensitivity to noise at the harbour seal, albeit starting from around 1kHz.

14.4.91 This assessment applies two sound metrics, the M-weighted Sound Exposure Level (SEL) metric (Southall *et al.,* 2007) and the dB_{ht} (species) metric (Subacoustech, 2011) (**Technical Appendix 13.B**).

The M-weighting metric

14.4.92 In order to represent the levels of underwater noise perceived by marine mammals, Southall *et al.,* (2007) proposes filtering underwater noise data using a generalised frequency weighting function, designed to match the frequency response of different groups of marine mammals. The authors group marine mammals into five groups, four of which are relevant to underwater noise (the fifth is for pinnipeds in air). For each group an approximate frequency range of hearing is proposed based on known audiogram data, where available, or inferred from other information such as auditory morphology (**Table 14.10**).

Table 14.10 Functional marine mammal groups, their assumed auditory bandwidth of hearing and genera presented in each group (after Southall et al., (2007))

Functional hearing group	Estimated auditory bandwidth	Genera represented	Example species
Low frequency cetaceans	7Hz to 22kHz	*Balaena, Caperea, Eschrichtius, Megaptera, Balaenoptera (13 species/subspecies)*	Gray whale, Right whale, Humpback whale, Minke whale
Mid frequency cetaceans	150Hz to 160kHz	*Steno, Sousa, Sotalia, Tursiops, Stenella, Delphinus, Lagenodelphis, Lagenorhynchus, Lissodelphis, Grampus, Peponocephala, Feresa, Pseudorca, Orcinus, Globicephala, Orcaella, Physeter, Delphinapterus, Monodon, Ziphius,*	Bottlenose dolphin, Striped dolphin, Killer whale, Sperm whale

Functional hearing group	Estimated auditory bandwidth	Genera represented	Example species
		Berardius, Tasmacetus, Hyperoodon, Mesoplodon (57 species/subspecies)	
High frequency cetaceans	200Hz to 180kHz	*Phocoena, Neophocaena, Phocoenoides, Platanista, Inia, Kogia, Lipotes, Pontoporia, Cephalorhynchus (20 species/subspecies)*	Harbour Porpoise, River dolphin, Hector"s dolphin
Pinnipeds (in water)	75Hz to 75kHz	*Arctocephalus, Callorhinus, Zalophus, Eumetopias, Neophoca, Phocarctos, Otaria, Erignathus, Phoca, Pusa, Halichoerus, Histriophoca, Pagophilus, Cystophora, Monachus, Mirounga, Leptonychotes, Ommatophoca, Lobodon, Hydrurga, and Odobenus (41 species/subspecies)*	Fur seal, Harbour (common) seal, Grey seal

Source: Subacoustech, 2011

14.4.93 By filtering impact piling noise data for these frequency ranges and analysing the result to obtain SELs, estimates of the impact ranges from the GWF can be provided based on the M-weighted metric. The criteria for injury outlined by Southall *et al.*, (2007) considers PTS-onset to constitute injury as noise induced PTS represents irreversible damage, as opposed to TTS which represents temporary effects. Southall *et al*., consider pile driving activities to be a Multiple Pulsed Source (MPS), the relevant injury criteria for which are as follows:

For Low, Mid and High frequency cetaceans:

- *Pressure Level injury criteria: 230 dB re 1 µPa (peak) (flat)*; and
- *SEL injury criteria: 198 dB re 1 µPa2 –s (M-weighted) for multiple pulses.*

For pinnipeds in water:

- *Pressure Level injury criteria: 218 dB re 1 µPa (peak) (flat)*; and
- *SEL injury criteria: 186 dB re 1 µPa2 –s (M-weighted) for multiple pulses.*

14.4.94 The M-weighting metric has been adopted by the JNCC in its EPS Guidance (JNCC *et al.,* 2010) for addressing impacts on marine mammals.

The dBht (species) metric

14.4.95 The dB_{ht}(*species*) metric (level of noise above the hearing threshold level of a species) has also been developed as a means for quantifying the potential for a behavioural impact on a species in the underwater environment (Nedwell *et al.,* 2007b). As any given sound will be perceived differently by different species (since they have differing hearing abilities) the species name must be appended when specifying a level.

14.4.96 The perceived noise levels of sources measured in dB_{ht}(species) are usually much lower than the un-weighted (linear) levels, both because the sound will contain frequency components that the species cannot detect, and also because most species that live in the underwater environment have high thresholds of perception to sound.

14.4.97 If the level of sound is sufficiently high on the dB_{ht}(species) scale, it is likely that an avoidance reaction will occur. The response from a species will be probabilistic in nature (e.g. at 75 dB_{ht}(species) one individual from a species may react, whereas another individual may not; the metric indicates the probability of an individual reacting), and may also vary depending upon the type of signal. A level of $0dB_{ht}$(species) represents a sound that is at the hearing threshold for that species and is, therefore, at a level at which sound will start to be heard. At this and lower perceived sound levels, no response occurs as the receptor cannot hear the sound.

14.5 Assessment of Impacts – Worst Case Definition

14.5.1 The assessment of potential impacts are based on the worst case scenarios for each receptor and establish the maximum potential adverse impact as a result. Therefore no impacts of greater adverse significance would arise should any other development scenario (as described in **Chapter 5**) to that assessed within this Chapter be taken forward in the final scheme design. Full details on the range of options being considered by GWFL are provided throughout **Chapter 5**. For the purpose of the marine mammal assessment, the worst case scenario, taking into consideration these options, is detailed in **Table 14.11**.

14.5.2 The JNCC have indicated that it would be useful to assess impacts across the range of potential pile diameter size (see **Table 14.3**). As detailed in the response letter to the JNCC and Natural England (GWFL, 2011) all options considered where any range exists (such as pile diameter) are considered realistic and therefore, assessing the worst case option is considered most practicable and conservative. It is considered that if residual impacts on the worst case scenario are acceptable then this will apply to all options within the range.

14.5.3 It is noted that only those design parameters detailed under each specific impact have the potential to influence the level of impact experienced by the relevant receptor. Therefore, if the design parameter is not discussed then it is considered not to have a material bearing on the outcome of the assessment.

14.5.4 The worst case scenarios identified in **Table 14.11** are also applied to the assessment of cumulative impacts. In the event that the worst case scenarios for the project in isolation do not result in the worst case for cumulative impacts, this is addressed within the cumulative assessment section of the Chapter (see **Section 14.10**).

Table 14.11 Realistic worst case scenarios for construction and operational impacts on marine mammals

Impact	Realistic worst case scenario	Justification
Construction		
Underwater noise arising from pre-construction geophysical surveys	Use of sidescan, multibeam and sub-bottom profiling across all three Development Areas and export cable corridor.	The worst case is established by the maximum potential survey duration, which will be reflective of the extent of the surveyed area. Development of a scenario with a smaller geographical footprint (such as use of only Area A and B, or just Area A alone) would reduce the level of survey effort required, and therefore, duration of potential impact. It should be noted that the JNCC EPS Guidance (2010) suggests that there is a negligible risk of an injury or disturbance offence from equipment used during pre-construction geophysical surveys.
Construction noise (injury, disturbance, displacement and barrier effects to marine mammals and important prey species)	*Lethal effect and physical injury* Maximum number of structures (140 WTGs, three met masts, and four ancillary infrastructures) on 7m diameter monopiles. The predicted noise level associated with a hammer blow for a 7m pile is 254dB re 1 µPa @ 1m (see **Chapter 5** and **Technical Appendix 13.B**) Up to two piles installed at any one time (each taking an indicative 4	7m piles represent the largest foundation options which require piling and will be associated with the loudest noise and therefore considered the worst case for lethal effect and physical injury. Criteria used in this assessment comprise the 130dbht metric which represents the level at which hearing damage may occur, and M-weighted metric which considers PTS (onset to constitute injury as noise induced PTS represents irreversible damage). Piling occurring intermittently over 39 months (the longest time period over which piling can occur – see **Chapter 5**) is considered the worst case as it represents the greatest potential for lethal effect and auditory injury to occur as a result of the timescale and the evidence from other wind farms which suggest marine mammals return to an area upon cessation of a piling event (see Section 14.4). This scenario therefore gives marine mammals that may have left the area as a result of a piling operation the opportunity to return and be at risk of physical or lethal injury.

Impact	Realistic worst case scenario	Justification
	hours to install). Based on the assumption of one vessel being able to install one pile a day (therefore two vessels would install a total of two piles per day) 70 days of piling will be required, taking place intermittently over a 39 month period (approximately two per week). Structures located across all three Development Areas within 45m below Chart Datum (CD) water depths, so that two piles could be installed simultaneously at the furthest distance from each other within the site boundary (as shown in the modelled positions from (Subacoustech, 2011) (**Technical Appendix 13.B**).	Monopiles will only be installed out to a depth of 45m below CD. Modelling undertaken by Subacoustech (2011) of 3m pin piles (used for space frame foundations) was also undertaken to investigate if the installation of smaller piles in deeper parts of the site (over 45m where monopiles would not be used) might produce a greater noise impact range than 7m monopiles in shallower water (as noise travels further in deeper water). As detailed in Subacoustech (2011), the worse case scenario for noise associated with piling is represented by the 7m pile as the noise associated with its installation extends the furthest even though it's use in the site is more constrained than space frame options. Modeling carried out by Subacoustech (2011) for 7m piles was carried out at six locations (the seventh was only modeled for 3m pile due to the water depth) (see **Figure 14.12**). The worse case predicted noise impact range for 7m piles is from positions B, D and G for pinnipeds (in water) (186 dB re 1 μPa^2/s (M_{lf})) (19km) and for high frequency cetaceans which represent harbour porpoise (198 dB re 1 μPa^2/s (M_{hf}) (1.2km). The maximum impact range for the 130 dB_{ht} level is represented by positions A, B, D, F, and G (all 1400m) and B, D, F and G for harbour seal are the same (200m). For harbour porpoise the greatest impact area is represented by position D (130 dB_{ht}) (5.7 km^2) and for harbour seal the impact area for all positions is 0.1km^2. For the 198 dB re 1 μPa^2/s (M_{lf}) the worst case impact range is represented by position G (4.48 km^2). Noise from simultaneous piling installation could represent a larger area for lethal effect and auditory injury for marine mammals. As there is no overlap in the impact areas for physical injury, it has been assumed that the worst case would be that two piles are installed under

Impact	Realistic worst case scenario	Justification
		similar conditions as those described in the worst case for an individual piling event. Therefore it has been assumed that the effect of a multiple piling event is double that of an individual piling event and the worst case impact areas described above have simply been doubled. Although multiple piling remains a possibility, it is unlikely that more than one foundation will be piled at any one time as a result of engineering constraints. In order to ensure a thorough assessment, piling of one foundation has been assessed alongside multiple piling. The options stated will result in the maximum potential for noise disturbance and marine mammal displacement.
	Behavioural effects Maximum number of structures on space frame foundations (140 WTGs (4 legs), three met masts (4 legs), and four ancillary infrastructures (6 legs). Each space frame foundation leg using a maximum of two pin piles. The predicted noise level associated with a hammer blow for a 3m pin pile used in space frame foundations is 239dB re 1 µPa @ 1m (see **Chapter 5** and **Technical**	Piling is considered to create the greatest potential for noise impacts upon marine mammals during construction. 3m piles used for space frame foundations represent the foundation option which, as a result of the number required, will result in the maximum number of piling events over the installation period of construction at GWF. This provides the greatest potential for disturbance and behavioural effects. It is considered that if the maximum number of piling operations take place throughout the maximum period during which piling might take place this represents the worst case scenario due to the continuous noise and subsequent disturbance (see **Chapter 5** for further details on construction timescales). Criteria used in this assessment comprise the 75 dB_{ht} and 90 dB_{ht} levels which represent strong and significant behavioural responses by marine mammals. Modeling carried out by Subacoustech (2011) for 3m piles was carried out at seven locations

Impact	Realistic worst case scenario	Justification
	Appendix 13.B) 1,192 piles installed over a 39 month period (assuming one pile is installed at any one time) which equates to approximately 1 pile per day (assuming construction 7 days per week). Structures located across all three Development Areas	(see **Figure 14.12**). The worse case predicted noise impact range (in km's) for the 90dBht level is from Position D and G for harbour porpoise (18km for 90dBht and 37km for 75dBht) and Position G and E (8.4km for 90dBht and 24km for 75dBht level) for harbour seal. The worst case impact areas are represented by Position E for harbour porpoise (802.74km² for the 90dBht level and 2967.04km² for the 75dBht) and also Position E for harbour seal (197.34km² for the 90dBht level and 1357.32km² for the 75dBht level). Only individual piling is considered in this assessment as it represents more frequent piling events over the construction phase. As a worst case, a total of 1,192 3m piles will be required at the GWF if space frame foundations are used. This is based on 1,120 3m piles for 140 WTG foundations (based on 4 legs and 2 piles per leg), 48 3m piles for ancillary structures (based on 6 legs and 2 piles per leg) and 24 3m piles for met masts (based on 4 legs and 2 piles per leg).
Collision risk	Maximum number of structures and subsea cabling (140 WTGs, three met masts, four ancillary structures, 300km of inter / intra-array cables, 190 export cable kilometres) spread over all three Development Areas. Construction taking place all year over a 56 month construction window	The worst case scenario for collision risk is established through providing a scenario that will result in the maximum level of construction activity over the largest geographical extent and longest duration, thereby providing for the maximum potential for collision risk. Any alternative scenario would result in either less activity or activity over a smaller extent which would reduce the probability of encounter with marine mammals (and therefore, serve to lower collision risk).

Impact	Realistic worst case scenario	Justification
	using vessels comprising foundation installation via HLV / jack-up barge, possible grouting vessel, possible foundation transportation vessel, substation installation vessel and possible support vessels.	
Loss of important habitat and/or prey source	**Habitat loss:** 101 * 45m Gravity base structure (GBS) foundations with scour protection applied to 100% of all foundations (160,590m^2 + 174,730m^2 = 335,320m^2 (0.335km^2)) Three met mast foundations on 45m GBS foundations including 100% scour protection (4,770m^2 + 5,190m^2 = 9,960m^2 (0.01km^2)) Up to four ancillary structures (this may comprise a combination of offshore substation platforms (OSPs), collection platforms and / or accommodation platforms) on space	The worst case scenario for habitat loss is justified in detail in **Table 12.3** in **Chapter 12 Marine and Intertidal Ecology**, but summarised as follows: The loss of subtidal habitat will result from the placement of built structures (and associated scour protection material) on the seabed. The worst case scenario is therefore, represented by the largest footprint from the foundation structures (and associated scour protection) under consideration. The GBS foundations have a larger footprint than any of the foundations under consideration. Of the GBS options for the WTGs, there could be up to 101 45m base diameter structures or 140 35m base diameter structures. Scour protection for 45m base diameter structures is 10m in radius around all structures and 9m around all structures for the 35m base diameter option. Therefore, the total footprint for the 45m base diameter option is 335,320m^2, whilst for the 35m option it is 308,856m^2. The 101 45m base diameter option therefore, has the largest overall footprint. For the met masts GBS options are considered and therefore, the 45m base diameter option presents the worst case.

Impact	Realistic worst case scenario	Justification
	frame (self-jacking suction can) foundations (four leg jackets) assuming 100% scour protection = 18,748m^2 (0.019km^2)) Rock placement for cable protection at a total of 9 export cable crossings (3,240m^2) ***Total area = 0.335 + 0.01 + 0.019 + 0.003 = 0.37km^2*** **Disturbance of prey species from underwater noise:** *Behavioural effects – general fish assemblages* Maximum number of structures on space frame foundations (140 WTGs (4 legs), three met masts (4 legs), and four ancillary infrastructures (6 legs). Each space frame foundation leg using a maximum of two pin piles.	For the ancillary structures, only space frame (piled, suction can and self-jacking) and monopile foundations are considered. The area for a single self-jacking (suction can) space frame foundation (based on up to four legs) with 100% scour protection is 4,687m^2. For the four foundations this equates to a total area of 18,748m^2. The area for a single (piled) space frame foundation (based on up to six legs (3m diameter) each with up to two (3m diameter) pin piles) is 85m^2. The piled space frame requires 100% scour protection (with an additional 5m radius around each structure) the area of scour protection for four space frame structures is therefore 9,388m^2. A 7m monopile has a footprint of 38.5m^2 with a scour protection footprint of 1,700m^2 and therefore an overall footprint of 1,739m^2 (total area of 6,956 m^2 for four foundations). All other foundation types considered (**Chapter 5**) would result in a smaller loss of habitat. The worst case scenario justification for disturbance to prey species is detailed in **Table 13.9** of **Chapter 13,** The worst case scenario provides for the greatest potential to disturbance of fish assemblages and therefore, potential loss of prey source from the proposed development area.

Impact	Realistic worst case scenario	Justification
	The predicted noise level associated with a hammer blow (470 kJ) for a 3m pin pile used in space frame foundations is 239dB re 1 μPa @ 1m (see **Chapter 5** and **Technical Appendix 13.B**) 1,192 piles installed over a 39 month period (assuming one pile is installed at any one time) which equates to approximately 1 pile per day (assuming construction 7 days per week). Structures located across all three Development Areas.	
Operation		
EMF	Cabling with 300km of 66kV inter / intra-array cabling and up to 190 cable kilometres of 132kV export cable. Representative average minimum burial depth for inter / intra-	EMF impacts are governed by depth of (cable) burial and not the number of turbines or their layout or location within the GWF area. Therefore, the worst case scenario is represented by the shallowest burial depth for all cables. Because the burial depth achieved varies greatly an average minimum burial depth is applied.

Impact	Realistic worst case scenario	Justification
	array, and export cables will be 0.6m.	
Collision risk	Bi-annual maintenance and inspection visits Requirement for retrofitting and upgrading works using jack up rigs. 5 maintenance craft per day travelling to/from the wind farm site Unscheduled repair activities equal to one visit per turbine per month serviced with a wind-cat style boat. Development across all three array Areas.	The scenario provides for the highest level of vessel activity over greatest geographical extent and therefore, represents the greatest likelihood of interactions with marine mammals occurring
Disturbance from underwater noise arising from operational turbines and maintenance vessels	Monopile or GBS foundations for 140 WTG's WTG's concentrated in the deeper regions of the site. The worst case for noise associated with maintenance traffic is	Based on published measurements for operational wind turbines in Sweden (Lidell 2003), even though a larger capacity turbine might have a louder source noise level during operation, more, smaller are considered likely to result in a greater overall noise footprint. A study by Hammar *et al.* (2010) suggests that monopile and GWS structures will both radiate sound more than a space frame foundation, although it should be noted that the scientific knowledge in this area is limited. Therefore, the chosen layout represents the greatest number of turbines over the maximum geographical extent.

Impact	Realistic worst case scenario	Justification
	considered the same as the scenarios presented for collision risk above	Underwater noise generally propagates more efficiently in deeper water conditions (Subacoustech, 2011) and will transmit better from a large steel structure (as opposed to a steel lattice or concrete base).
Decommissioning		
Underwater noise Collision risk Loss of important habitat and/or prey source	Removal of all structures associated with the wind farm in line with the detail provided for the construction phase above.	Arrangements associated with decommissioning will be determined prior to construction and a full Decommissioning Plan for the project will be drawn up and agreed with DECC. Until the arrangements have been clarified, the worst case scenario is that all structures will be removed.

14.6 Assessment of Impacts during the Construction Phase

14.6.1 This section provides an assessment of the potential impacts from the construction phase of the GWF project on marine mammals. Potential construction impacts identified during the scoping process are associated with:

- Underwater noise arising from pre-construction geophysical surveys and construction activities (in particular, monopile installation);
- Collision risk from increased vessel activity; and
- Loss of important prey species.

14.6.2 The effects of noise on marine mammals can be assessed in two ways, firstly by assuming that the animal is static and secondly that the animal is fleeing. The static animal noise dose model assumes that a marine animal makes no effort to move away from the source of the noise, leading to apparently high levels of Noise Dose. In practice, it is reasonable to assume that piling noise at high loudness levels will be aversive to marine animals, and that they will attempt to swim away from the noise source. This assessment has therefore concentrated on the fleeing animal model as this is based on more realistic assumptions of animal behaviour. The Fleeing Animal Noise Dose Model combines the species perceived loudness (dB_{ht} L_{eq}) as it varies with range, with cumulative Noise Dose ($L_{EP,D}$) as the animal moves away from the source.

Disturbance during pre-construction geophysical surveys

14.6.3 Prior to the start of construction it will be necessary to carry out geophysical surveys (as detailed in **Chapter 5**). Consultation responses received from the JNCC and Natural England (**Table 14.3**) have indicated concerns related to potential noise disturbance from geophysical surveys.

14.6.4 The equipment used for these surveys will include sub-bottom profilers, side scan sonar and single or multibeam echosounders, all of which were used during the GWF baseline and GGOWF pre- construction seabed site characterisation. Each of these types of equipment work by emitting a particular sound source vertically downwards into the water column, a receiver then monitors the return signal that has been reflected off the seafloor and builds up a picture of the properties of the seabed. It is noteworthy that these equipment have a directed sound source (which will be focused down towards the seabed), rather than a general noise emission and so the noise footprint will be somewhat restricted.

14.6.5 The noise produced by side scan sonar surveys is of an intermittent nature with lower noise doses than would occur for continuous signals. Page 43-44 of the EPS Guidance (JNCC *et al.,* 2010) advises of side scan sonar that "*this type of survey is of a short-term nature and results in a negligible risk of an injury or disturbance offence (under the Regulations).*"

14.6.6 In respect to sub-bottom profiling, the lower frequencies generated are within the hearing range of all marine mammals. Therefore, in a few cases, this could cause localised short-term overt-behavioural responses such as avoidance. The JNCC EPS Guidance (2010) concludes that it is "*unlikely that this would be considered as disturbance in the terms of the Regulations*". In addition, it is unlikely that injury would occur as an animal would need to locate in the very small zone of ensonification and stay in that zone associated with the vessel for a prolonged period of time, which is also unlikely (JNCC *et al.*, 2010).

14.6.7 These statements in the JNCC guidance are taken to suggest that an injury or disturbance offence to the harbour porpoise (as defined by Regulation 391(a) and (b) of the HR and OMR) is unlikely to occur from the pre-construction geophysical profiling at GWF.

14.6.8 Given their protected status, all cetaceans and pinnipeds have a high conservation value and therefore a moderate sensitivity to low-energy geophysical surveys. Any short-term overt behavioural responses (such as avoidance) will however be tolerable and reversible.

14.6.9 In the context of the FCS of the regional (i.e. North Sea) population of harbour porpoise, the impact magnitude would be negligible as a result of the short duration, small extent of effect against a background low marine mammal encounter rate) and no change for other cetaceans and pinnipeds given their extremely low and irregular sightings within the GWF study area.

14.6.10 Consequently, the impact would have a **negligible** significance on harbour porpoise and a **no impact** on other marine mammal species.

Injury and/or disturbance due to construction noise

Physiological injury and disturbance

14.6.11 Intense underwater noise can have a severe effect on marine mammals which are encountered in the immediate vicinity of the noise source (Nedwell *et al.*, 2003). As the distance from the source increases, noise will naturally attenuate and the potential effects will diminish.

14.6.12 For the purpose of the impact assessment Subacoustech (2011) have used un-weighted (in relation to the frequency response) sound level metrics to define the potential for gross damage to marine species. These are:

- **Lethal Effect**: where peak to peak levels exceed 240dB re 1uPa or an impulse of 100 Pa.s; and

- **Physical Injury**: where peak-to-peak levels exceed 220dB re 1uPa, or an impulse of 35 Pa.s.

14.6.13 For the M-weighted sound exposure levels, the criteria are:

- For Low, Mid and High frequency cetaceans:
  - Pressure Level injury criteria: 230 dB re 1 μPa (peak) (flat); and
  - SEL injury criteria: 198 dB re 1 μPa2 –s (M-weighted) for multiple pulses.
- For pinnipeds in water:
  - Pressure Level injury criteria: 218 dB re 1 μPa (peak) (flat); and
  - SEL injury criteria: 186 dB re 1 μPa2 –s (M-weighted) for multiple pulses.

14.6.14 In addition, the 130 dBht (species) level has been used to assess the possibility of traumatic hearing damage from a single event.

14.6.15 Behavioural response ranges have been estimated using frequency weighting based on hearing thresholds and the perceived loudness of noise for representative marine species (**Table 14.12**).

Table 14.12 Behavioural response thresholds

Level in dB_{ht} (species)	Effect
75	Significant avoidance – at this level 85% of individuals will react to the noise. Effect likely to be limited by habituation
>90	Strong avoidance reaction by virtually all individuals
>110	Tolerance limit of sound; unbearably loud

Source: Subacoustech, 2011

14.6.16 A detailed review of the use of, and sensitivity to, sound in cetaceans has been provided by the Thames Estuary Developers Group in support of applications for the Thanet, London Array and GGOWF (Parvin *et al.*, 2006 and Sheppard *et al.,* 2007). A number of sources of noise and vibration were identified during the construction phase of these wind farms as having the potential to impact on marine mammal populations. They include pile driving, gravity base structure installation, drilling, trenching and the increased activity from jack-up / heavy lift vessels and other support vessels.

14.6.17 Monopile installation activities are of particular concern during the construction phase because they generate very high broadband sound pressure levels. It is considered that the most significant factors that affect the noise level produced during pile driving operations include pile diameter, local geology (and hence energy required to install the pile) and bathymetry.

14.6.18 The audible range (i.e. the range over which marine species can hear the construction activity) will extend to the distance where the construction noise either falls below the ambient perceived sea noise level or the auditory threshold of the animal. Therefore, a sound level of 0 – 10dB_{ht}(*species*) is only just audible, whereas 75dB_{ht}(*species*) will probably cause mild behavioural effects and noise at levels of over 90dB_{ht}(*species*) are likely to elicit an overt behavioural response (see **Table 14.12**). Recent studies funded by COWRIE (Nedwell *et al.,* 2007; Nedwell *et al.,* 2003) suggest that the noise generated during pile driving operations may result in the injury of marine species at distances of the order of 100m from the noise source.

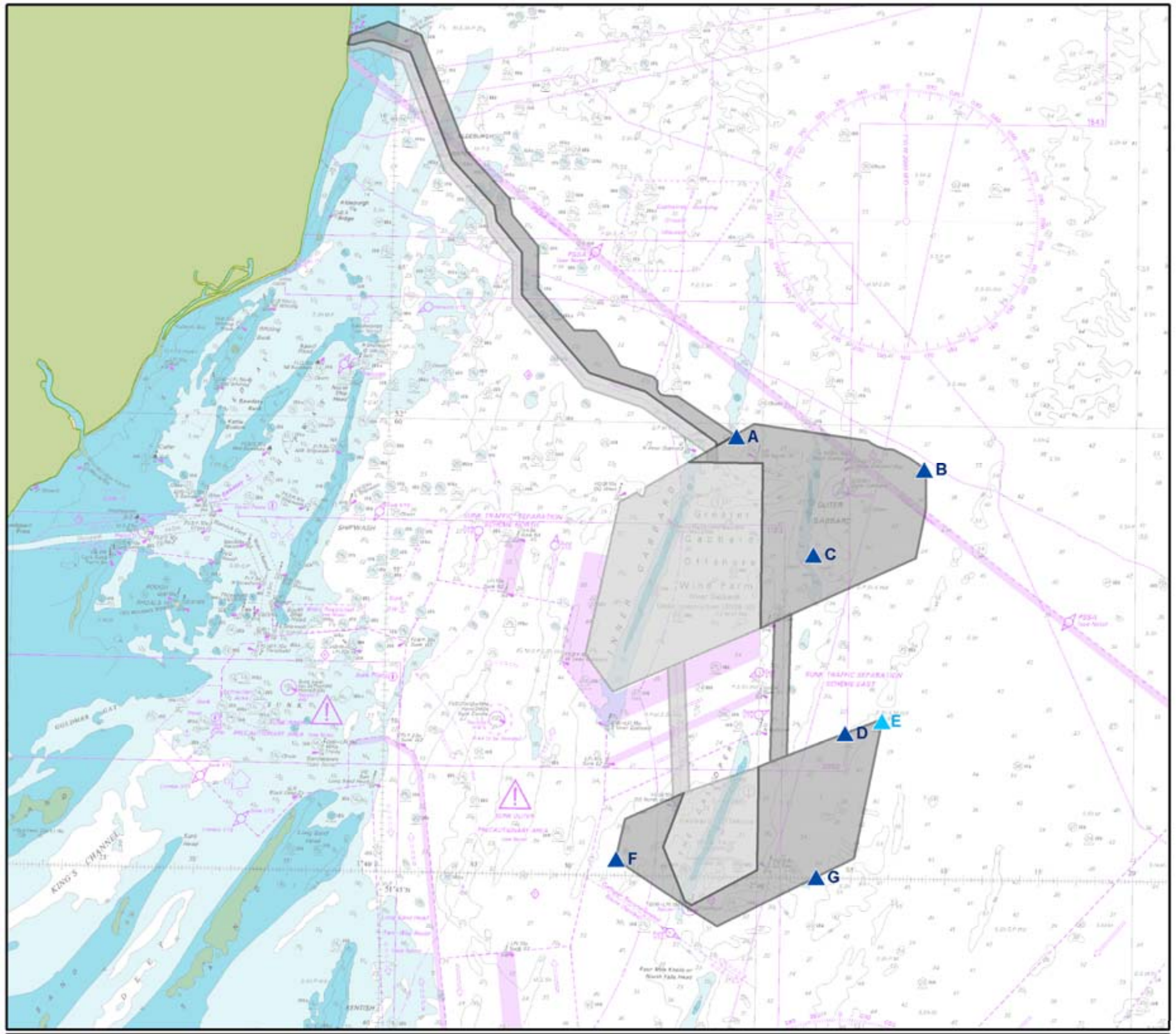
14.6.19 The estimated spatial effects of pile driving activities will vary between marine mammal species. Recent analysis within the Offshore Energy SEA (DECC, 2009) concluded that pile driving sources are generally unlikely to have a significant effect on marine mammal populations. This conclusion was based mainly on the fact that the spatial scales over which either observable or biologically meaningful effects will be felt are unlikely to support significant populations of animals.

The dBht (species) metric: estimates of lethal, physical and auditory injury in marine mammals at GWF

14.6.20 In order to establish the worst case levels of underwater noise from impact piling operations for 7m diameter monopiles out to 45m below Chart Datum (CD) as well as smaller pin piles (proposed for space frame foundations that could be used in water depths beyond 45m CD), site specific modelling was carried out at seven representative locations (shown in **Figure 14.12**) using a three dimensional underwater sound propagation model (INSPIRE v18) (Subacoustech, 2011, see **Technical Appendix 13.B** that supports **Chapter 13**). The INSPIRE model enables the level of noise at various ranges from the piling operation to be estimated for varying tidal conditions, water depths and piling locations. The model is validated against a large existing database of measurements of piling noise.

14.6.21 For the smaller pin piles, the initial modelling that was carried out and presented in the PER was based on a 2.5m diameter pile, as that represented the largest size being considered at that time. Subsequently, the maximum pin pile size was increased to 3m. Therefore for the purpose of this EIA, modelling for 3m pin piles has been carried out and presented here.

14.6.22 As detailed in **Chapter 4** and **Table 14.11**, the worse case scenario, as defined by the Rochdale Principle, for piling related noise impacts on marine mammals is represented by the largest (7m) diameter monopiles for lethal and physical injury. Due to the number required, 3m piles installed over a longer time period represent the greatest potential for behavioural impacts. However, the additional modelling carried out for 3m pin piles allows an assessment of the potential impacts related to much smaller piles which are also being considered. Full details of the noise modelling are presented in Subacoustech (2011), see **Technical Appendix 13.B**.



Galloper Wind Farm

Figure 14.12

Noise Modelling Positions

Drawing Number: GWF_594_R3		Rev: 3
Date: 01/11/11	Created: LW	Checked: SS
Scale: 1:400,000	Page: A4	
Datum: WGS1984	Projection: UTM Zone 31N	

14.6.23 A summary of the effects of piling operations on harbour porpoise and harbour seal is provided in **Table 14.13** (full details provided in Subacoustech, 2011, see **Technical Appendix 13.B**). Species were chosen which had the most GWF specific sensitivity, which is largely as a function of their presence and general activity levels within the study area. Harbour porpoise was chosen because it represents the only commonly occurring cetacean within the GWF study area and also represents high frequency cetaceans (see **Table 14.10**). Compared to grey seal, harbour seal have more breeding sites in proximity to the GWF. It should be noted that harbour and grey seal have broadly similar hearing abilities and can act as a viable proxy for each other (see **Plot 14.7**).

Table 14.13 Maximum range of effects on harbour porpoise and harbour seal from piling operations (using dB_{ht} metric)

Effect	Measure of noise		Maximum range of impact (m) Harbour porpoise		Maximum range of impact (m) Harbour seal	
	Un-weighted peak to peak level (dB re 1µPa)	Perceived noise level (dB dBht)	7m pile	3m pile	7m pile	3m pile
Lethal Injury	240	-	7	<1	7	<1
Physical Injury	220	-	130	16	130	16
			7m pile	3m pile	7m pile	3m pile
Possibility of traumatic hearing damage from single event	-	130	1,400	590	200	80
Strong behavioural avoidance response by virtually all individuals	-	90	28,000	18,000	15,000	8400
Significant avoidance - 85% of individuals will react (effect likely to be limited by habituation).		75	49 000	37 000	34 000	24 000

Source: Subacoustech, 2011 (**Technical Appendix 13.B**).

14.6.24 For both harbour porpoise and harbour seal, the predicted peak to peak un-weighted levels of underwater noise indicate that during piling of a 7m diameter monopile, lethality may be possible out to ranges up to 7m from the monopile and physical injury out to ranges up to 130m. Beyond these ranges severe physical effects are not expected to occur based on the assessment criteria used in this study. An assessment of the potential for traumatic hearing damage occurring in marine mammals has been based on the $130dB_{ht}$ perceived level criteria. The data indicate that harbour porpoise may suffer traumatic hearing damage out to the 1.4km, assuming piling at full blow force of a 7m diameter monopile.

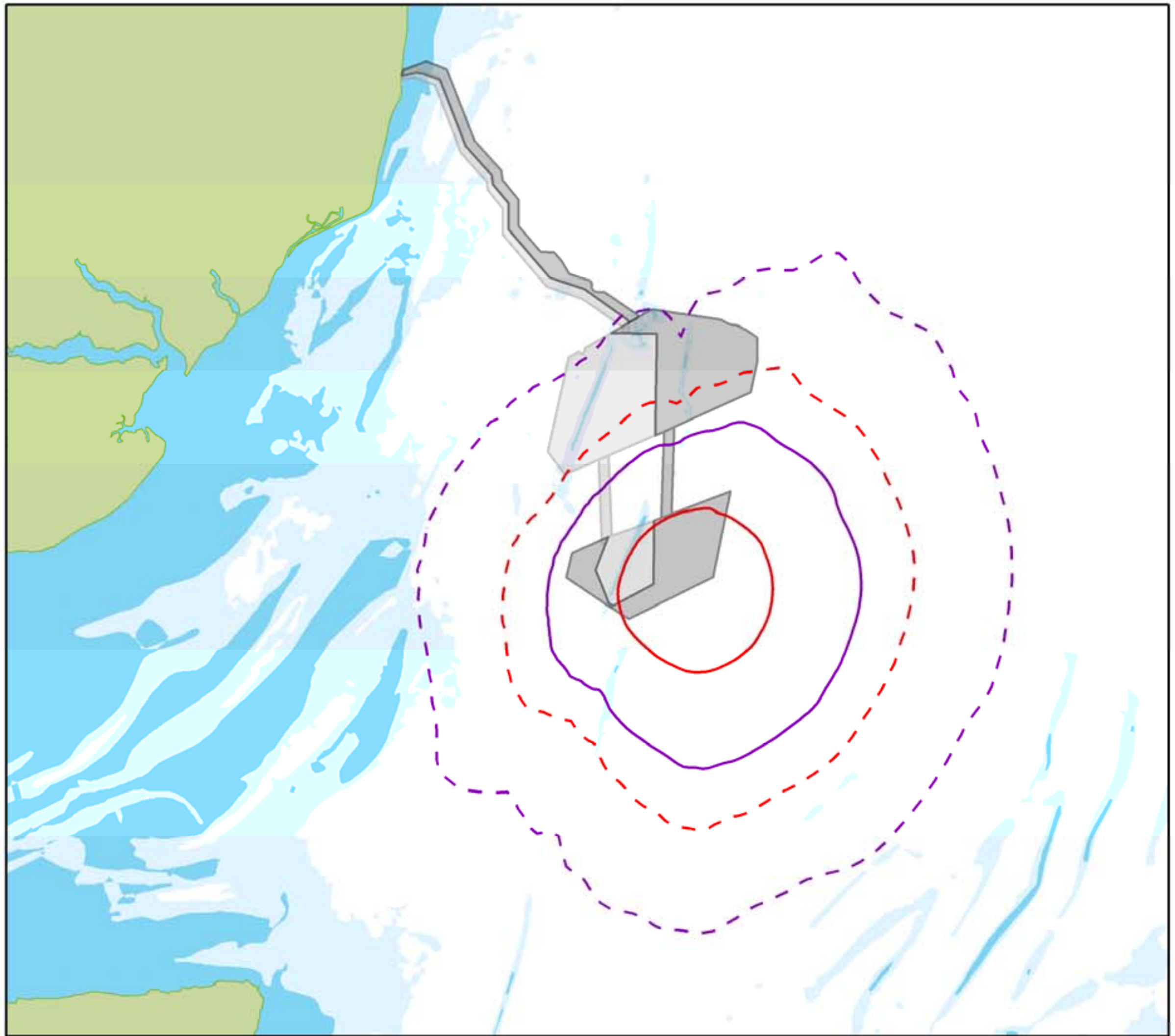
14.6.25 For a 3m diameter pin pile the levels of noise produced would not be of sufficient level to cause lethality (range <1m), however physical injury might occur out to a maximum range of only about 16m.

14.6.26 In regard to behavioural effects, significant avoidance of 85% of harbour porpoise individuals could occur up to 49km from the source of a 7m pile and 37km for a 3m pin pile. For harbour seal avoidance could occur 34km and 24km from the source of a 7m and 3m pile, respectively.

14.6.27 This assessment also considers the different design and layout scenarios that will be captured by the Rochdale envelope. Modelling plots of the likely impact zone for harbour porpoise (**Figure 14.13**) and harbour seal (**Figure 14.14**) are presented for deployment in Development Area B (position D on **Figure 14.12**), on the eastern side of the GWF site at a depth of 32m. Full details, including figures of all modeled locations, are provided in Subacoustech (2011).

14.6.28 It is noted that as a general principal noise propagation increases with water depth (Subacoustech, 2011). Whilst it is acknowledged that the figures (**Figures 14.13** and **14.14**) presented do not represent maximum water depth at the GWF site, they do however represent one of the positions where the maximum range of effect is anticipated.

14.6.29 **Figure 14.13** shows behavioural effects (75 and 90dBht) for 3m piles at position G for harbour porpoise (37km maximum range) and harbour seal (24km maximum range). For the 130dBht level for 7m monopiles, which represents potential for injury, there is very little variation in the results. For harbour seal the maximum range falls between 200m (positions B, D, F, G) and 190m (positions A, C) and for harbour porpoise the maximum range is 1400 for all positions except C which is 1300m. **Figure 14.14** shows the impact ranges for position B.



Bathymetry received from TCarta Marine Ltd 2010. Noise modelling conducted by Subsacoustech 2011

Galloper Wind Farm	
Figure 14.13	
90 and 75 dBht contours for 3.0m pile for Harbour Porpoise and Harbour Seal (Position G)	
Draw ing Number: GWF_642_R2	Rev: 2
Date: 01/11/11	Created: LW / Checked: SS
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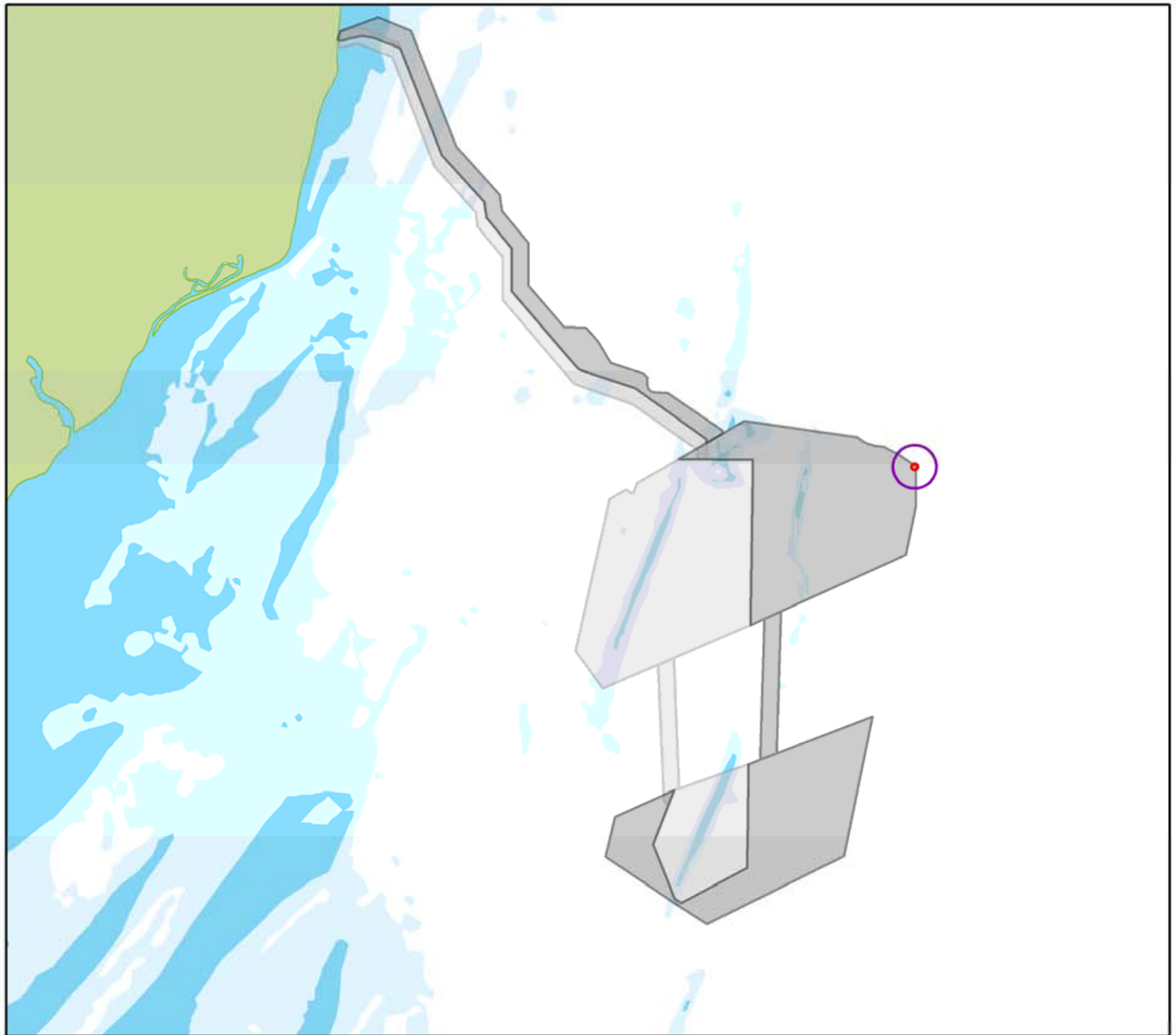
Datum: WGS1984	Projection: UTM Zone 31N



Galloper Wind Farm
Greater Gabbard Wind Farm
Noise Modelling - Harbour Seal
130 dBht
Noise Modelling - Harbour Porpoise
130 dBht

Bathymetry received from TCarta Marine Ltd 2010. Noise modelling conducted by Subsacoustech 2011

Galloper Wind Farm		
Figure 14.14		
130 dBht contours for 7.0m pile for Harbour Porpoise and Harbour Seal (Position B)		
Draw ing Number: GWF_643_R2		Rev: 2
Date: 01/11/11	Created: LW	Checked: SS
Scale: 1:400,000	Page: A4	
Datum: WGS1984	Projection: UTM Zone 31N	

M-weighted Sound Exposure Levels: estimates of auditory injury in marine mammals at GWF

14.6.30 Modeling has been carried out in order to provide the estimated impact ranges for marine mammals in terms of the M-weighted SELs metric. To assess the potential for auditory injury using M-weighted SELs, existing measured data for impact piling at a variety of sites using a range of pile sizes and water depths were analysed for SELs. The data were then filtered using the M-weighting criteria for low, mid and high frequency cetacean groups as well as for pinnipeds using the frequency ranges described by Southall *et al*. (2007). Harbour porpoise are classed as a high frequency cetacean.

14.6.31 The analysed data were then used as input to validate the INSPIRE propagation model in order to accurately estimate the propagation losses and the resulting standoff ranges for each marine mammal group. The standoff range is defined here as the closest a receptor can be to the piling operation at the onset of piling without receiving a cumulative exposure to noise that is likely to cause auditory injury. For the assessment 7m monopiles have been modeled for a period of 4 hours with an average maximum blow energy of 1100kJ (estimated by INSPIRE from a database of previously measured data, see Subacoustech, 2011 (**Technical Appendix 13.B**)). 3m monopiles have been modeled over a period of 2 hours at an average maximum blow energy of 470kJ. A strike rate of 1 strike per second and an animal flee speed of 1m/s has been used throughout. The results are presented in **Table 14.14** to **14.17**.

Table 14.14 Summary of estimated standoff ranges for the Low Frequency Cetaceans hearing group using the Southall *et al*., (2007) criteria

Low Frequency Cetaceans	Range to Auditory Injury (198 dB re 1µPa^2/s (M_{lf}))	
	7m diameter pile	3m diameter pin pile
Position A	5.3 km	720 m
Position B	6.7 km	820 m
Position C	5.5 km	660 m
Position D	6.7 km	840 m
Position E	-	880 m
Position F	5.8 km	760 m
Position G	6.8 km	840 m

Table 14.15 Summary of estimated standoff ranges for the Mid Frequency Cetaceans hearing group using the Southall *et al*., (2007) criteria

Mid Frequency Cetaceans	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{mf}))	
	7m diameter pile	3m diameter pin pile
Position A	2.3 km	220 m
Position B	2.8 km	240 m
Position C	2.2 km	190 m
Position D	2.9 km	250 m
Position E	-	250 m
Position F	2.5 km	230 m
Position G	2.9 km	250 m

Table 14.16 Summary of estimated standoff ranges for the High Frequency Cetaceans hearing group using the Southall *et al*., (2007) criteria

High Frequency Cetaceans	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{hf}))	
	7m diameter pile	3m diameter pin pile
Position A	1.0 km	70 m
Position B	1.2 km	80 m
Position C	990 m	70 m
Position D	1.2 km	80 m
Position E	-	80 m
Position F	1.1 km	70 m
Position G	1.2 km	80 m

Table 14.17 Summary of estimated standoff ranges for the Pinnipeds (in water) hearing group using the Southall *et al*., (2007) criteria

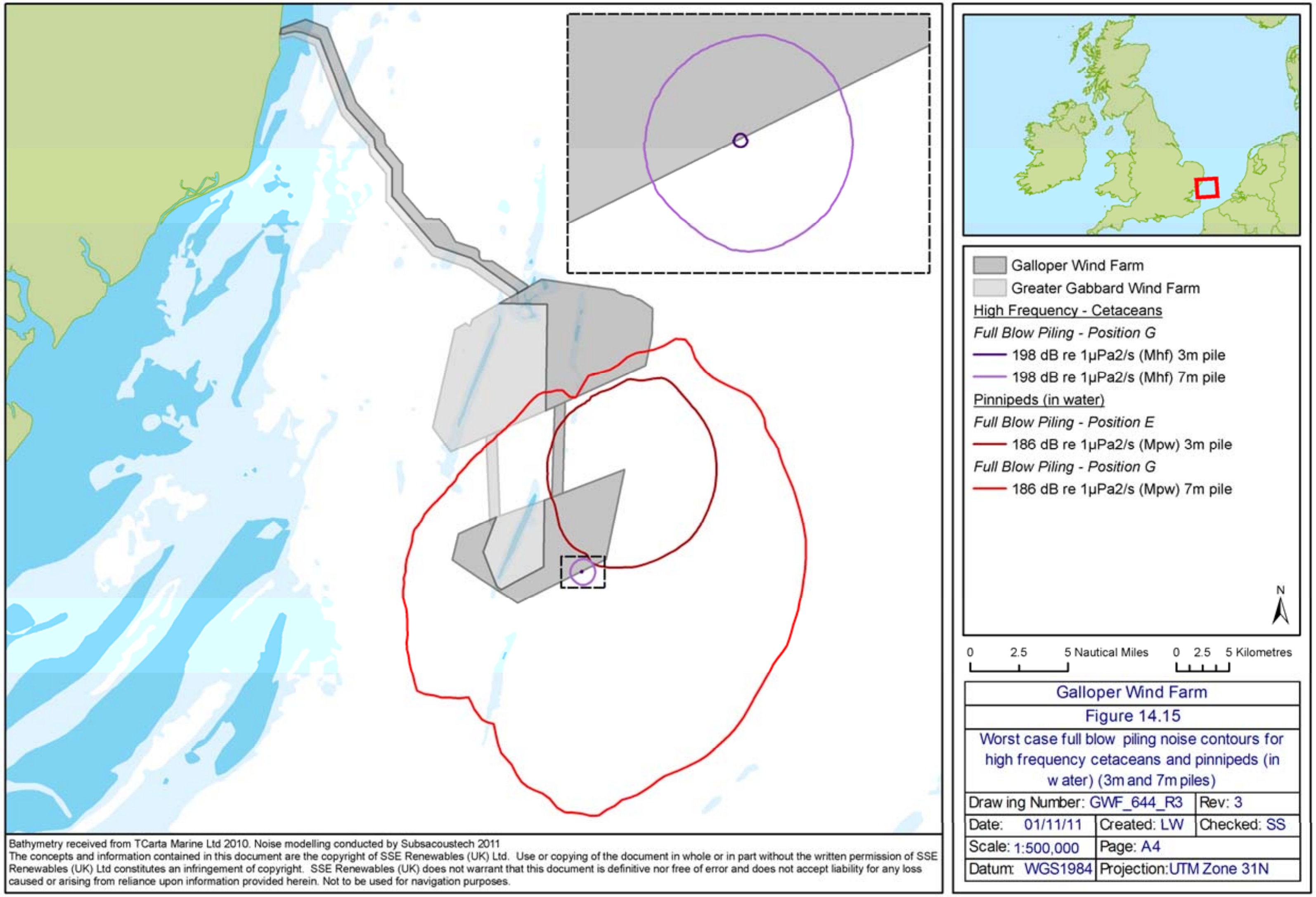
Pinnipeds (in water)	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{pw}))	
	7m diameter pile	3m diameter pin pile
Position A	16 km	6.7 km
Position B	19 km	8.1 km
Position C	17 km	6.9 km
Position D	19 km	8.1 km

Pinnipeds (in water)	Range to Auditory Injury (198 dB re 1µPa^2/s (M_{pw}))	
	7m diameter pile	3m diameter pin pile
Position E	-	8.4 km
Position F	17 km	7.2 km
Position G	19 km	8.2 km

14.6.32 The largest auditory injury standoff ranges are estimated for the pinnipeds (in water) hearing group with a maximum range of 19km predicted during piling of a 7m diameter pile and 8.4km during piling of a 3m diameter pile (**Table 14.17**). Smaller ranges are predicted for the three cetacean groups, with the largest impact ranges predicted for the low frequency cetaceans group (**Table 14.14**: 6.8km for a 7m diameter pile, 880mm for 3m diameter pile), followed by mid frequency cetaceans (**Table 14.15**: 2.9km for a 7m diameter pile, 250m for 3m diameter pile) and with high frequency cetaceans (**Table 14.16**: 1.2km for a 7m diameter pile, 80m for a 3m diameter pile) having the lowest predicted impact ranges.

14.6.33 It should be noted that the results presented in **Table 14.14** to **Table 14.17** do not take into account the mitigating effects of a soft start procedure and assume a high blow force at the onset of piling (soft start piling is discussed in the mitigation and residual impact section presented after the impact assessment).

14.6.34 **Figure 14.15** shows the impact range contours for position G which represents one of the worst case positions for the noise impact range upon harbour porpoise (high frequency cetacean) for 3 and 7m piles and also shows position G and E for harbour seal which represent the worst case scenario for a pinniped (in water) for 7m and 3m piles respectively.


Galloper Wind Farm
Greater Gabbard Wind Farm
High Frequency - Cetaceans
Full Blow Piling - Position G
198 dB re 1μPa2/s (Mhf) 3m pile
198 dB re 1μPa2/s (Mhf) 7m pile
Pinnipeds (in water)
Full Blow Piling - Position E
186 dB re 1μPa2/s (Mpw) 3m pile
Full Blow Piling - Position G
186 dB re 1μPa2/s (Mpw) 7m pile
N
0 2.5 5 Nautical Miles
0 2.5 5 Kilometres
Galloper Wind Farm
Figure 14.15
Worst case full blow piling noise contours for high frequency cetaceans and pinnipeds (in water) (3m and 7m piles)
Drawing Number: GWF_644_R3 | Rev: 3
Date: 01/11/11 | Created: LW | Checked: SS
Scale: 1:500,000 | Page: A4
Datum: WGS1984 | Projection: UTM Zone 31N
Bathymetry received from TCarta Marine Ltd 2010. Noise modelling conducted by Subsacoustech 2011
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Evidence from monitoring at other wind farms

GGOWF

14.6.35 During-construction underwater noise monitoring has been undertaken during monopile installation activities at the neighbouring GGOWF. Sound levels were measured during the installation of a 6.3m diameter monopile. Based on the results of the noise modelling, GGOWL were able to estimate the ranges at which the received level is equal to the hearing thresholds for harbour porpoise. These distances are shown in **Table 14.18.**

14.6.36 It follows that the results from the GGOWF are comparable with the sound propagation outputs presented in this assessment. The worst case predictions presented by Subacoustech (2011) for installation of the 7m pile at GWF are highly conservative. The sound propagation outputs do not account for the application of mechanical soft starts or the fact that pile driving will rarely, if ever, be carried out at full power.

Table 14.18 Estimated threshold ranges for harbour porpoise during monopiling activity at GGOWF

Effect	Range for a 6.3m diameter monopile (m)
Lethal effect	2
Physical Injury	40
Traumatic auditory Injury	820 ± 95
Strong behavioural avoidance response	14,360 ± 800
Perceived background noise	35,500 ± 5,000

Source: Gardline (2010)

14.6.37 The method proposed by Southall *et al*., (2007) was applied to the measured GGOWF piling driving data to calculate the cumulative exposure in terms of the SEL metric. Firstly, the measured pulses were weighted using the M-weighting approach (Gardline, 2010). The results show that for a fleeing cetacean, so long as the start range is greater than 10m from source, the threshold injury criteria of 198 dB re 1μPa2s (multiple pulse source) can be avoided (**Table 14.19**). However, for a static cetacean, this range increases to 1.5km (**Table 14.19**). For pinnipeds in water, the lower threshold criteria of 186 dB re 1μPa2s leads to a required range of 4km to avoid injury assuming the pinniped flees (**Table 14.19**). Assuming the pinniped remains at a fixed range and below water during the entire piling sequence the range at which injury is avoided has been estimated at 7.5km (**Table 14.19**). It should be noted that the flee speed used during the GGOWF modeling was assumed to be 1.5m, however in the GWF modeling descried in the previous section, a precautionary flee speed of 1m/s has been used.

Table 14.19 Start range to avoid injury criteria for a fleeing and a static animal of various animal group

Animal group	Static (km)	Fleeing (at 1.5 ms^{-1}) (km)
High freq. cetacean (198 dB re 1μPa^2s)	1.5	0.1
Mid freq. cetacean (198 dB re 1μPa^2s)	1.5	0.1
Low freq. cetacean (198 dB re 1μPa^2s)	1.5	0.1
Pinniped in water (186 dB re 1μPa^2s)	7.5	4

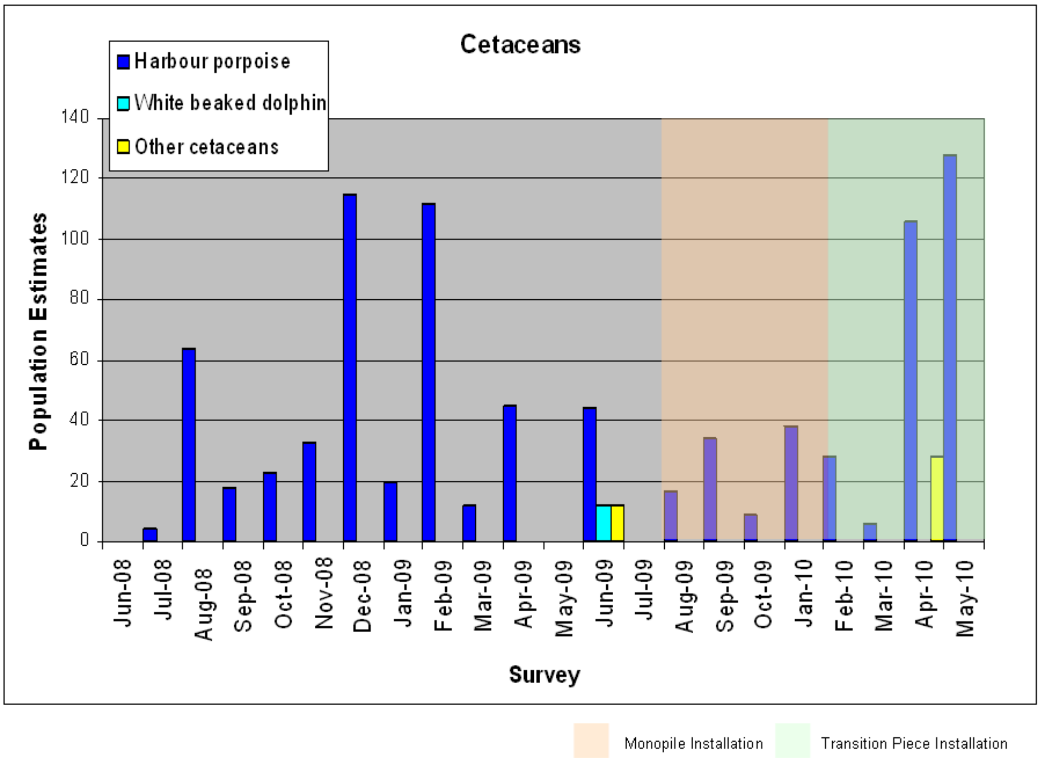
Source: Gardline (2010)

14.6.38 Seals are more sensitive to lower frequency noise than small dolphins and porpoises, which are generally more sensitive to mid-high frequencies. Subsequently, if a seal is underwater at less than 4km when the piling starts and proceeds to swim away there will be a risk of PTS, however, it should be noted that seals can come to the surface where the exposure levels will be significantly reduced. In addition,, evidence appears to suggest that seals are able to habituate to anthropogenic noise and are even known to haul out near to military firing ranges (Thompson *et al.,* 2010).

14.6.39 Sightings records within the GGOWF and GWF baseline surveys, and the GGOWF ongoing monitoring programme, suggest that pinnipeds are infrequent visitors to the development area (see **Section 14.4**). However, the fact that both grey and harbour seals are present from time to time within the study area dictates that the potential for short-term disturbance and injuries in the immediate vicinity of piling activities cannot be ruled out.

14.6.40 The results from the GGOWF monitoring surveys (2008 to 2010) provide a qualitative assessment of the presence/absence of marine mammals, notably harbour porpoise, in the adjacent study area throughout periods of piling activity at GGOWF. **Plot 14.6** presents incidental sightings of cetacean species within the GGOWF study area over the two year period.

Plot 14.6 Sightings data for cetaceans observed within the GGOWF study area between 2008-2010



(Source GGOWL: 2nd Annual Monitoring Report October 2010)

14.6.41 The GGOWF monitoring results suggest that after the period of monopile installation, which started in August 2009 and ran up until February 2010, numbers of porpoise increased to previous peak sightings levels within four weeks of piling finishing. This observation is consistent with studies at the Horns Rev and Nysted wind farms in Denmark (Tougaard *et al.,* 2006a, 2006b) (discussed in subsequent sections of this Chapter). This increase in porpoise activity within the GGOWF study area occurred during a period of significant vessel traffic within the wind farm site, associated with transition piece installation. In addition the results show that during construction, although animals may be avoiding the immediate wind farm footprint, they are still regularly recorded within the study area throughout periods of pile-driving activity.

14.6.42 Harbour and grey seal were rarely sighted within the GGOWF study area during either the pre-construction baseline or first year construction period and therefore drawing any conclusions with regard to the potential impact of the GGOWF piling activity on pinnipeds in the area is not possible.

14.6.43 Given the lack of available evidence from the adjacent GGOWF project, the following paragraphs draw on knowledge gained from other offshore wind farm developments.

Nysted Offshore Wind Farm

14.6.44 The Nysted Offshore Wind Farm (NOWF), which became operational in 2003, is situated at the entrance to the Baltic Sea. The wind farm consists of seventy two 2 - 3MW capacity wind turbine generators. A study by Tougaard *et al*; (2006a) describes the result of a four year investigation of the response of harbour porpoise to the construction and subsequent operation of NOWF.

14.6.45 The investigation was conducted with acoustic dataloggers: T-PODs that record and store the time and length of echolocation sounds of harbour porpoises. Four indicators were calculated on basis of the click recordings and used for the analysis:

- Porpoise positive minutes (minutes with porpoise clicks recorded), which is an indication of porpoise echolocation activity;
- Waiting time (time between groups of echolocation clicks) indicates how often porpoises enters the area;
- Encounter duration indicates how long the porpoises remain in detectable range of the T-POD; and
- Number of clicks per porpoise positive minute is an indicator of how intensive the porpoise uses its echolocation when within detectable range.

14.6.46 During construction and the first two years of operation, waiting time between enounters increased and porpoise positive minutes decreased considerably in the wind farm area. This suggests that fewer porpoise were present (Tougaard *et al*; 2006a). A smaller, yet still significant increase in waiting time and decrease in porpoise positive minutes was also observed in the reference area, which may signify a general effect of wind farm construction on porpoise abundance in the wider area (Tougaard *et al*., 2006a).

14.6.47 Encounter duration and number of clicks per porpoise positive minute decreased significantly from baseline to construction period in the wind farm area indicating that not only were there fewer porpoises in the area during construction, but their echolocation behaviour may also have been affected (Tougaard et al; 2006a). By the second year of operation, this effect had disappeared, suggesting that porpoise abundance and behaviour had returned to baseline levels (Tougaard et al; 2006a).

14.6.48 The results suggest that porpoises left the general area during construction, although there are few indications as to why they did so and whether particular activities during construction played a larger role than others. For example, the effects could have been as a result of shipping activities or changes in prey species. In addition, some of the data collected during the piling activity demonstrated that porpoises left the area during piling and returned again after a period of up to several days. This suggests that, in isolation, piling noise may have had a temporary impact on the relative abundance/ distribution of harbour porpoise within the study area.

Horns Rev

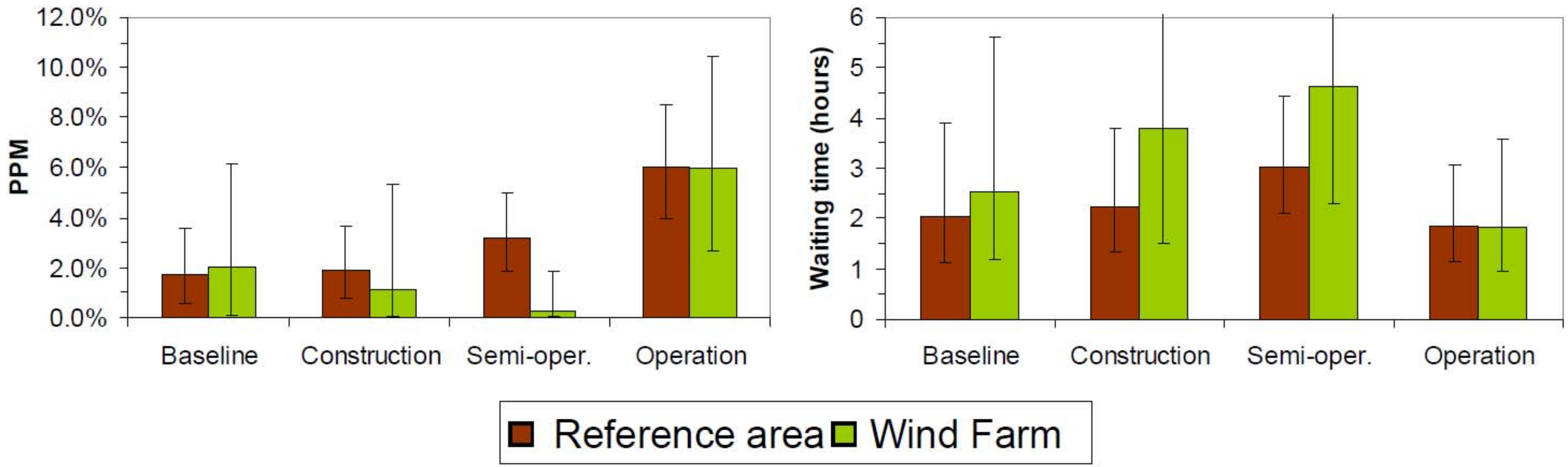
14.6.49 Horns Rev Offshore Wind Farm, which was constructed by Elsam A/S on the Horns Reef in the Danish North Sea in 2002, consists of 80 2MW wind turbines. The 2006 (b) report by Tougaard *et al.* describes results of the monitoring program on harbour porpoises on Horns Reef, conducted in the period from 1999 to 2005. The seven years of boat based surveys and five years of acoustic recordings of harbour porpoises on Horns Reef have resulted in a set of data documenting effects of the construction and operation of one of the world's largest offshore wind farms.

14.6.50 Baseline observations on Horns Reef showed that harbour porpoise are abundant in the Horns Reef area, including the area now occupied by the wind farm (Tougaard *et al*; 2006b). The monitoring results indicate that during construction and semi-operation (the period following construction, where intensive maintenance and service operations occurred and the turbines thus were not operating at full capacity) there was a small negative impact on porpoises, with more specific effects linked to pile driving activities (Tougaard *et al*; 2006b). No effects were observed from the operating wind farm. Acoustic recordings did not show any significant change in abundance in the wind farm area as a whole during construction (see **Plot 14.7**) (Tougaard *et al*; 2006b). Harbour porpoise acoustic activity was higher in the operation phase than during baseline, but this was the case both in the wind farm and in the surrounding reference areas (Tougaard *et al*; 2006b).

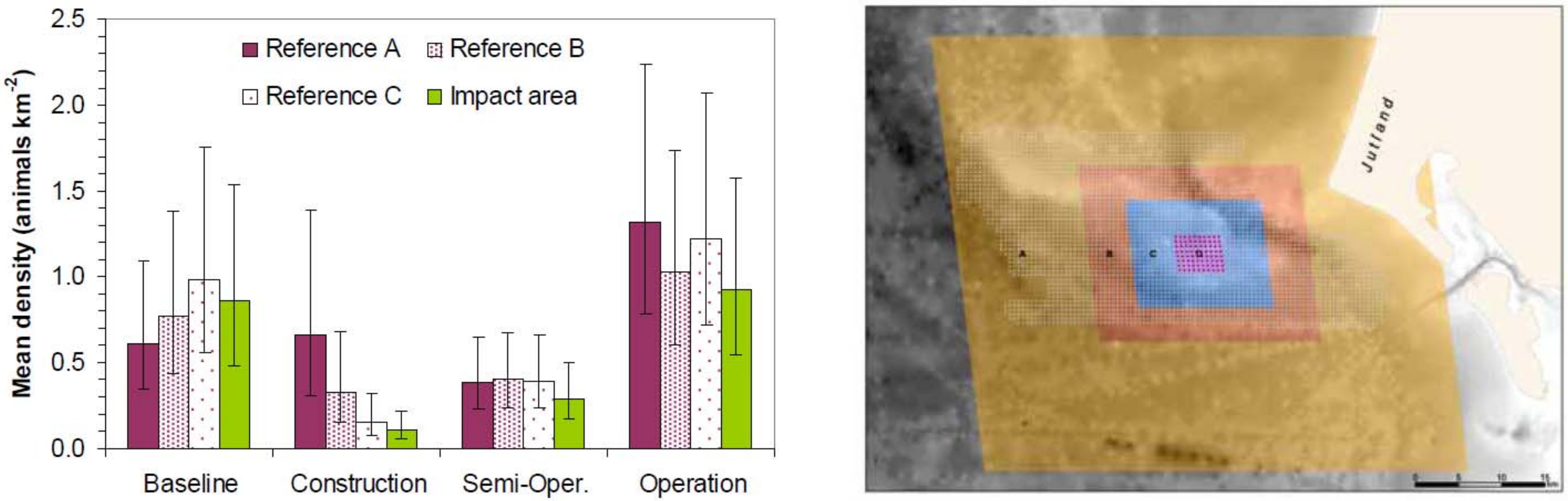
14.6.51 Conclusions from the ship surveys showed similar results to the acoustic data (see **Plot 14.8)**, although the ship survey data indicated more porpoises in the area as a whole during the operational period than for any other of the periods, baseline included (Tougaard *et al*; 2006b).

14.6.52 Specific effects resulting from the construction monitoring indicated that porpoises left the entire Horns Reef area in response to the loud impulse sound generated by the pile driving operation (Tougaard *et al*; 2006b). After a period of 6-8 hours, porpoise activity returned to levels normal for the construction period as a whole (Tougaard *et al*; 2006b).

Plot 14.7 Mean values for porpoise positive minutes (PPM, equal to the fraction of a day where porpoises could be detected), recorded by acoustic dataloggers (TPODs) placed inside Horns Rev Offshore Wind Farm and in nearby reference areas. Values are separated into four periods: baseline, construction, semi-operation, and operation. Error bars indicate 95% confidence limits for the mean values (Tougaard *et al*; 2006b).



Plot 14.8 Estimated mean densities of porpoises for combinations of the four areas shown on the map and the four time periods, based on observations from ship surveys conducted throughout the entire period from 1999 to 2005. Error bars show the 95% confidence intervals for the estimated mean densities. Note the gradient in density towards wind farm during construction (Tougaard *et al*; 2006b).



Impact assessment

14.6.53 The assessment of potential behavioural and injurious effects of the GWF on marine mammals is separated into those associated with lethality, physical trauma and behavioural disturbance. This is to ensure that the worst case scenario for each effect is captured by the complexities presented for modelling the underwater sound field from a range of foundation types and blow energies, **Table 14.11**.

14.6.54 The consideration of impacts related to injury and lethal effects use a worst case scenario of 7m monopiles, which is shown to create the greatest potential for noise levels which might result in injury / death. The assessment related to behavioral effects uses the worst case scenario of 3m pin piles associated with space frame jacket foundations. These represent the maximum level of disturbance (as a result of the greater number of piles required and therefore piling duration) over the likely installation period. **Table 14.11** should be referred to for justification on the worst case scenario used in the assessment.

14.6.55 In terms of establishing noise impacts from GWF, the site's species encounter rates can be compared against each species' intrinsic conservation value and sensitivity to disturbance from underwater noise.

14.6.56 In addition, the number of animals potentially disturbed by piling operations can be estimated using the densities derived from regional scale surveys (as detailed in **Section 14.4**) and the worse case predicted noise impact ranges (see **Table 14.11**). However, it should be noted that these calculations are based on assumptions which result in high levels of uncertainty in relation to the numbers of animals affected.

14.6.57 When compared to sightings records from other areas in the North Sea, the GWF study area does not appear to be an important area for marine mammals. However, the occurrence of relatively low numbers of harbour porpoise at the site throughout the year and occasional sightings of white-beaked dolphin, grey seal and harbour seal, signify they could occur within the wind farm site while piling is underway.

Lethal effect and physical injury

14.6.58 **Table 14.20** summarises the estimated maximum number of harbour porpoise which could be subject to physical injury as a result of individual, and multiple 7m piling events at the GWF. The table uses densities derived for the area surrounding GWF, from the literature described in **Section 14.4** and estimates the maximum numbers of animals that might be disturbed as a result of piling operations at GWF in relation to the North Sea population (from SCANS population estimates – see **Table 14.12**).

14.6.59 Within **Table 14.20**, the number of animals disturbed is defined as (this equation is also relevant to **Table 14.25** and **14.26**):

de **x NF**

*Where **de** is the density estimate (animals/km²) and **NF** is the worst case noise footprint area (in km²)*

14.20 Estimated number of harbour porpoise suffering injurious effects as a result of 7m pile installation, estimated percentage of the North Sea population is also stated.

Study	**Density estimate** animals/km²		**M-weighted Auditory Injury** **High frequency cetacean** 198 dB re 1µPa²s		**Possibility of traumatic hearing damage** 130dBht	
			Single pile	Multiple pile	Single pile	Multiple pile
	Worst case impact area (km²)		4.48	8.96	5.7	11.4
SCANS	**Lower**	0.4 (cv = 0.3-0.5*)	1.7	3.6	2.3	4.6
		% of N Sea population	0.0005	0.001	0.0007	0.001
	Upper	0.6 (cv = 0.3-0.5*)	2.7	5.4	3.4	6.8
		% of N Sea population	0.0008	0.0002	0.001	0.002
WWT (2009)	**Lower**	0	0	0	0	0
		% of N Sea population	0	0	0	0
	Upper	0.2	0.9	1.8	1.1	2.3
		% of N Sea population	0.0003	0.0005	0.0003	0.0007

* cv's are provided from Figure 14.4 which is linked to densities shown in Figure 14.3 (the use of which was suggested by the JNCC (Mendes, 2011). Due to the resolution of national scale surveys it is not possible to provide more accurate cv's to be used in this data set. The cv is likely to be higher than that stated (with the maximum value being above 0.6), however there was a high survey effort in the area surrounding GWF so confidence in the data is relatively high.

14.6.60 For an individual or multiple piling event very small numbers of harbour porpoise (between 1 and 6 using SCANS estimates, and between 0 and 2 using WWT (2009) estimates) might exhibit auditory injury using the M-weighted level for a high frequency cetacean and slightly more using the 130dBht level (between 2 and 7 using SCANS estimates, and between 0 and 3 using WWT (2009) estimates). All of these values represent a very small percentage of the regional population, which is less than 0.002% in all instances (**Table 14.20**).

14.6.61 For lethal injury (un-weighted peak to peak level of 240 dB re 1μPa – see **Table 14.11**) the impact range for harbour porpoise is anticipated to be only 7m from the pile installation. Even when using the most conservative density estimate (SCANS upper density of 0.6 animals/km²) and assuming a multiple piling event, the number of animals potentially impacted at this level is not considered to be significant (0.00004 animals).

14.6.62 It is considered that the proposed GWF site is not important for seal species and encounter rates across the site were relatively low, as detailed in **Section 14.4**. Seals are not an EPS and given the low level of seal activity within the GWF study area (which has not been raised in the context of HRA), it is not felt that attempts to quantify potential effects of underwater noise on the sporadic sightings of seals at the GWF would add any genuine value to this impact assessment.

14.6.63 Given the intermittent nature of pile driving operations and the low probability that significant numbers (in the context of the FCS of regional populations presented in **Table 14.2**) of marine mammal would occur within range of lethal effect an auditory injury, the magnitude of the impact on harbour porpoise is considered to be low, with a negligible magnitude on all other regional populations of pinniped and cetacean.

14.6.64 Given their protected status, all cetaceans and pinnipeds have a high conservation value and a high sensitivity to piling noise. Consequently, the overall unmitigated impact would have **minor adverse** significance for all cetaceans and pinnipeds.

Mitigation and residual impact

14.6.65 As discussed in **Section 14.2**, the FCS factors that have the potential to be adversely affected by disturbance and displacement from underwater noise include: the maintenance of the population on a long-term basis, the natural range of the species and the maintenance of habitat on which the species depends over a period of years / decades.

14.6.66 The following paragraphs outline how best practice mitigation and monitoring will serve to reduce this risk to EPS and seals found within the study area.

14.6.67 The modelled ranges and discussion presented above are based on the assumption of piling at full blow force, which was carried out in order to assess the worst case scenario. ‘Soft start’ piling is generally considered industry best practice and would be applied at the GWF site alongside the establishment of a Marine Mammal Mitigation Protocol (MMMP) that will entail making best efforts to ensure that no marine mammals are present within 500m of a pile driving activity prior to soft starts commencing.

14.6.68 It should be noted that the modeled underwater noise impact ranges for the majority of offshore wind farms consented to date have been shown to be precautionary (Subacoustech, 2011, see **Technical Appendix 13.B**). In the field, it is rare for pile driving to reach full force on the hammer. This is contrary to the modeling which has formed the basis of the worst case impact assessment, which assumes that the installation is occurring at full power for the whole duration.

14.6.69 A soft start procedure (an incremental increase in power (blow force) over a set time period until full operational power is achieved) is often used in piling operations where there is a potential to impact sensitive receptors (such as marine mammals). When a soft start procedure is used at the onset of piling, the levels of underwater noise from the piling work are lower than during piling at maximum blow force, but above the $90dB_{ht}$ strong behavioural avoidance perceived level for many marine species at close range (Subacoustech, 2011). Provided the soft start procedure gradually increases the blow force over time, marine mammals should have a sufficient opportunity to flee the area out to a safe distance to avoid injury.

14.6.70 Measurements of soft start procedures indicate that the perceived levels of noise for the harbour porpoise at the start of the soft start procedure may be reduced by up to 18dB when compared to pile driving at high blow forces (Subacoustech, 2011) (see **Technical Appendix 13.B**).

14.6.71 Modeling has been carried out in order to provide the estimated impact ranges for marine mammals in terms of the M-weighted SEL metric using a soft start piling procedure. The assessment has been undertaken using the same methodology as outlined for a full blow piling installation (see **Technical Appendix 13.B**). However in order to assess the potential for auditory injury using soft start methodology the modeling was carried using the assumption that 20% of the maximum blow force was used for the first 20 minutes and then 100% thereon (7m monopiles: 220kJ for the first 20mins and then 1100kJ for the remaining 3h40mins, 3m monopiles: 95kJ for the first 20mins and then 470kJ for the remaining 1h40mins). In line with the full blow modeling a strike rate of 1 strike per second and an animal flee speed of 1m/s has been used throughout.

14.6.72 The standoff ranges using this methodology are presented in **Tables 14.21** to **14.24** and can be compared to the full blow impact ranges in **Tables 14.14 - 14.17**. **Figure 14.16** shows the worst case impact ranges using the soft start procedure, compared to the worst case impact ranges for full blow pile installation (shown by: position G for harbour porpoise (high frequency cetacean) for 3 and 7m piles and position G and E for harbour seal (pinniped (in water)) for 7m and 3m piles respectively).

14.6.73 For pinnipeds (in water) the soft start measures have reduced the standoff range by up to 1km for 7m piles and by over 1km for 3m pin piles. For high frequency cetaceans (harbour porpoise) the impact range has been reduced by over 500m for 7m piles and up to 60m for 3m pin piles.

Table 14.21 Summary of estimated standoff ranges for the Low Frequency Cetaceans hearing group using the Southall *et al*., (2007) criteria

Low Frequency Cetaceans	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{lf}))	
	7m diameter pile	3m diameter pin pile
Position A	4.4 km	140 m
Position B	5.7 km	180 m
Position C	4.6 km	120 m
Position D	5.7 km	200 m
Position E	-	210 m
Position F	4.9 km	160 m
Position G	5.8 km	200 m

Table 14.22 Summary of estimated standoff ranges for the Mid Frequency Cetaceans hearing group using the Southall *et al*., (2007) criteria

Mid Frequency Cetaceans	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{mf}))	
	7m diameter pile	3m diameter pin pile
Position A	1.5 km	30 m
Position B	1.9 km	30 m
Position C	1.4 km	30 m
Position D	2.0 km	30 m
Position E	-	30 m
Position F	1.7 km	30 m
Position G	2.0 km	30 m

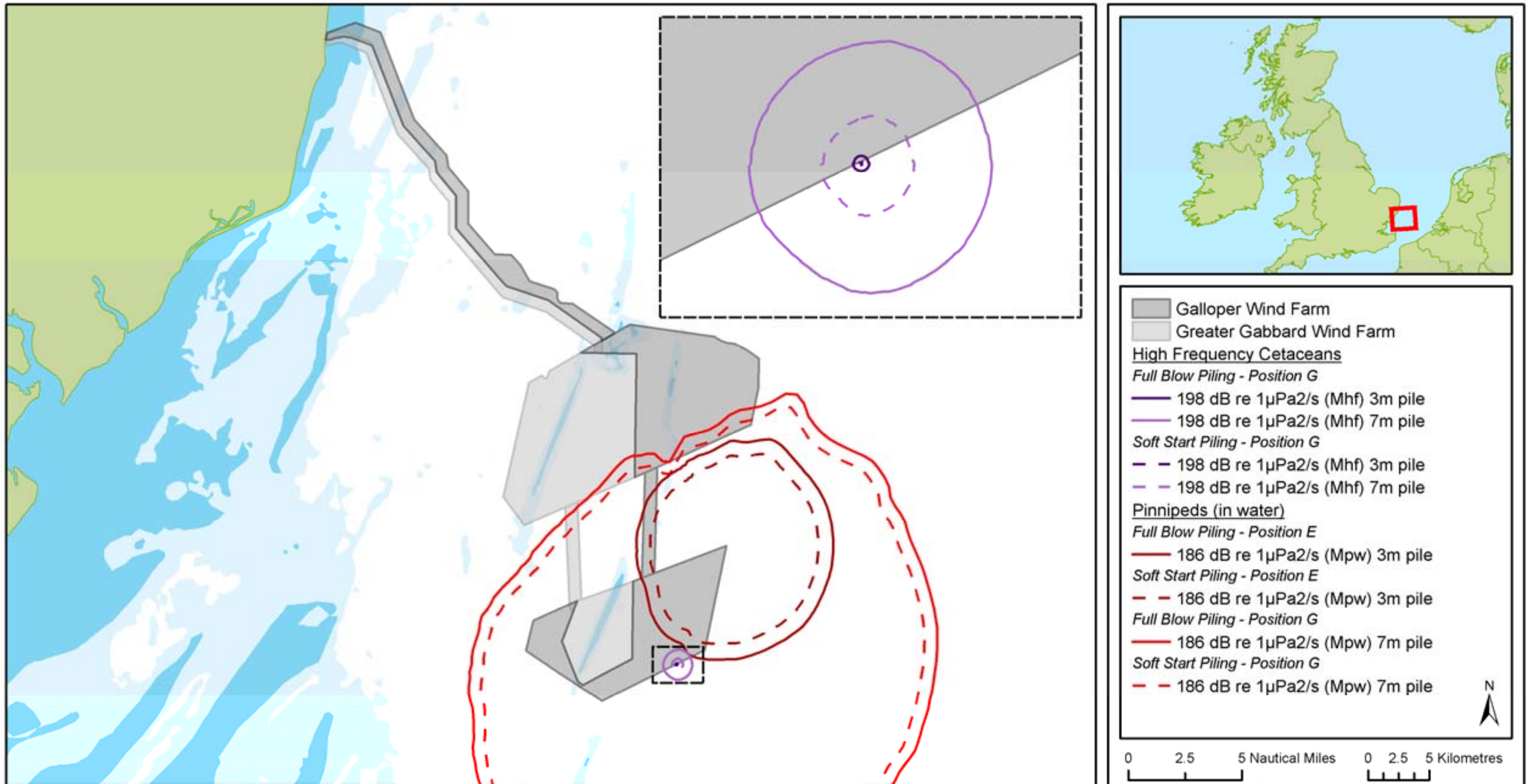
Table 14.23 Summary of estimated standoff ranges for the High Frequency Cetaceans hearing group using the Southall *et al*., (2007) criteria

High Frequency Cetaceans	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{hf}))	
	7m diameter pile	3m diameter pin pile
Position A	340 m	20 m

Position B	430 m	20 m
Position C	320 m	20 m
Position D	450 m	20 m
Position E	-	20 m
Position F	380 m	20 m
Position G	450 m	20 m

Table 14.24 Summary of estimated standoff ranges for the Pinnipeds (in water) hearing group using the Southall *et al*., (2007) criteria

Pinnipeds (in water)	Range to Auditory Injury (198 dB re 1μPa^2/s (M_{pw}))	
	7m diameter pile	3m diameter pin pile
Position A	15 km	5.6 km
Position B	18 km	6.9 km
Position C	16 km	5.8 km
Position D	18 km	6.9 km
Position E	-	7.2 km
Position F	16 km	6.1 km
Position G	18 km	7.0 km



Galloper Wind Farm		
Figure 14.16		
Worst case soft start and full blow piling noise contours for high frequency cetaceans and pinnipeds (in w ater) (3m and 7m piles)		
Draw ing Number: GWF_645_R3		Rev: 3
Date: 01/11/11	Created: LW	Checked: SS
Scale: 1:500,000	Page: A4	
Datum: WGS1984	Projection: UTM Zone 31N	

Bathymetry received from TCarta Marine Ltd 2010. Noise modelling conducted by Subsacoustech 2011

14.6.74 The results of soft start pile installation in regard to the number of harbour porpoise which might be subject to auditory injury are presented in **Table 14.25** (for a description of the methods used to calculate the values see **Table 14.20** and associated text).

14.25 Estimated number of harbour porpoise disturbed as a result of 7m pile installation using soft start measures, estimated percentage of the North Sea population is also stated.

Study	**Density estimate** animals/km²		**M-weighted Auditory Injury** **High frequency cetacean** 198 dB re $1\mu Pa^2s$	
			Single pile	Multiple pile
	Worst case impact area (km²)		0.66	1.32
SCANS II	**Lower**	0.4 (cv = 0.3-0.5*)	0.3	0.5
		% of N Sea population	0.00008	0.0002
	Upper	0.6 (cv = 0.3-0.5*)	0.4	0.8
		% of N Sea population	0.0001	0.0002
WWT (2009)	**Lower**	0	0	0
		% of N Sea population	0	0
	Upper	0.2	0.1	0.3
		% of N Sea population	0.00004	0.00008

14.6.75 The modeling data (Subacoustech, 2011 see **Technical Appendix 13.B**) indicate that the use of the soft start procedure would be likely to reduce the possibility of lethal effect and physical injury in marine mammal species (Subacoustech, 2011). For an individual or multiple piling event the soft start methodology has reduced the numbers of harbour porpoise which might be susceptible to auditory injury to less than 0.5 animals for an individual piling event and less than 1 animal for a multiple piling event. These values represent a percentage of the regional population which is an order of magnitude lower than that presented for full blow piling (a maximum percentage of 0.002% for full blow and 0.0002% for soft start).

14.6.76 For lethal effects (un-weighted peak to peak level of 240 dB re 1μPa – see **Table 14.11**) soft start modeling is not applicable to this method of measuring sound levels, as a result the worst case impact range will remain at 7m. Using the most conservative density estimate (SCANS upper density of 0.6 animals/km^2) and assuming a multiple piling event, the number of animals potentially impacted at this level is not considered to be significant (0.00004 animals).

14.6.77 Combined with the intermittent nature of monopile installation and the fact that pile installation very rarely requires pile driving at full blow force, soft start procedures are considered to provide an effective form of mitigation for physical effects on marine mammal species.

14.6.78 It has been acknowledged that there is potential for disturbance to marine mammals (individuals or groups) during the construction, operation and decommissioning of GWF. Therefore, in addition to the soft start procedures described above, a MMMP will be developed, in close consultation with the MMO and statutory stakeholders (including the JNCC and Natural England), at least four months prior to the commencement of offshore construction.

14.6.79 The key objective of the MMMP will be to ensure, as far is reasonably practicable, that there is no recorded marine mammal activity within a defined monitoring zone around a pile driving operation for a defined period of time prior to commencement of the soft start pile driving.

14.6.80 The MMMP will be developed in accordance with the guidance detailed in the latest version of the "*Statutory nature conservation agency protocol for minimising the risk of disturbance and injury to marine mammals from piling noise*" (JNCC, 2009; JNCC and Natural England, 2010). The guidelines detail the use of a Marine Mammal Observer (MMO) and Passive Acoustic Monitoring (PAM) during piling activities and recommend the following protocol:

- The establishment of a mitigation zone around the piling site in which the MMO / PAM operative will monitor marine mammals before piling commences. The extent of this zone is likely to be 500m (in accordance with JNCC guidance noted above) and will be confirmed through discussions with JNCC during the consultations undertaken to inform the MMMP;
- That piling should not commence during periods of darkness or poor visibility (such as fog), or during periods when the sea state is not conducive to visual mitigation. The use of acoustic deterrents and PAM may negate this requirement, as has been the case on other offshore wind farm projects. This will be confirmed through discussions with JNCC during the consultations undertaken to inform the MMMP;
- That the pre-piling search should be a minimum of 30 minutes;
- That piling should not commence if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection;

- Soft start to piling activities. The soft-start is the incremental increase in pile power over a not less than 20 minutes until full operational power is achieved; and
- If there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences. The suitability of the 10 minute period will be discussed with JNCC during the consultations undertaken to inform the MMMP.

14.6.81 Measures such as the use of acoustic deterrent devices (Northridge *et al.* 2010, Diaz and Marino, 2011) and noise attenuating piling sleeves (Nehls *et al.,* 2007) are currently being considered at an industry level; however the commercial availability and industry / Regulatory Authority acceptance of these approaches are not yet confirmed. Therefore the MMMP will draw together the best available information on current developments in mitigation techniques to ensure that a robust and defensible protocol is developed to minimise disturbance and monitor effects on marine mammals at an appropriate scale and in line with the anticipated impacts at GWF.

14.6.82 Use of industry-standard and best practice mitigation measures (soft and slow mechanical starts to impact piling operations) are considered likely to provide sufficient mitigation of the possibility of traumatic hearing damage in marine mammals at GWF and to significantly reduce the impact range of pile driving activities (Subacoustech, 2011).

14.6.83 As a result of the soft start measures and the MMMP, the reduction in potential for lethal or traumatic injury through allowing the marine mammals to move away from the main impact zone would serve to reduce the magnitude of the impact to negligible levels for harbour porpoise from the North Sea population which regularly visit the site in low numbers. It is likely that there will be no change to the regional populations of other cetaceans from the wider North Sea and pinnipeds that occasionally visit the site in low numbers.

14.6.84 It is therefore considered that the residual impacts in respect to lethal effect and physical injury for harbour porpoise will be of **minor adverse** significance, and for other cetaceans and pinnipeds there will be **no impact**.

14.6.85 Given the assessment provided above, it is anticipated that the duration and intensity of disturbance caused by pile driving activities at GWF, in isolation, is unlikely to have the potential to cause an offence on EPS under Regulation 39 1(a) and (b) of the HR and OMR at population level for either lethal effects and/or auditory injury. As highlighted through consultation with the SNCBs (**Table 14.3**) an EPS licence will be required to cover the risk of disturbance to cetacean species identified as a result of activities associated with construction (only disturbance that does not have an impact on the species at population level, but is sufficient to constitute an offence, can potentially be licensed).

Behavioural responses

14.6.86 **Table 14.26** summarises the estimated maximum number of harbour porpoise disturbed as a result of individual 3m piling events which in the context of the project are considered to be the worst case scenario for behavioural responses of marine mammals (see **Table 14.11**). The table uses densities derived for the area surrounding GWF from the literature described in **Section 14.4** and estimates the maximum numbers of animals that might be disturbed as a result of piling operations at GWF in relation to the North Sea population (from SCANS population estimates – see **Table 14.2**) (for a description of the methods used to calculate the values see **Table 14.20** and associated text). The assessment uses the behavioural response thresholds outlined in **Table 14.12**

Table 14.26 Estimated number of harbour porpoise disturbed as a result of 3m pile installation, estimated percentage of the North Sea population is also stated.

Study	Density estimate animals/km²		Single pile 75dBht	Single pile 90dBht
	Worst case impact area (km²)		2967	802.4
SCANS II	**Lower**	0.4 (cv = 0.3-0.5*)	1,187	321
		% of N Sea population	0.35	0.10
	Upper	0.6 (cv = 0.3-0.5*)	1,780	482
		% of N Sea population	0.53	0.14
WWT (2009)	**Lower**	0	0	0
		% of N Sea population	0	0
	Upper	0.2	593	161
		% of N Sea population	0.18	0.05

* cv's are provided from Figure 14.4 which is linked to densities shown in Figure 14.3 (the use of which was suggested by the JNCC (Mendes, 2011). Due to the resolution of national scale surveys it is not possible to provide more accurate cv's to be used in this data set. The cv is likely to be higher than that stated (with the maximum value being above 0.6), however there was a high survey effort in the area surrounding GWF so confidence in the data is relatively high.

14.6.87 Using the SCANS II estimate for density for single piling events (considered to be the worst case as detailed in **Table 14.11**), the number of animals which might exhibit significant avoidance behaviour (75dBht) is estimated to be between 0.1% to 0.53% of the North Sea population. Using the WWT

(2009) estimates, between 0% and 0.18% of the North Sea population might exhibit significant avoidance behaviour.

14.6.88 Numbers disturbed during an individual piling event are lower for the 90dBht avoidance level and fall between 0.1% and 0.14% of the SCANS II North Sea population estimates (SCANS, 2005).

14.6.89 As detailed in **Table 14.11** the worst case for piling operations in relation to behavioural effects for marine mammals is approximately one pile per day over a 39 month period. It is important to note that this represents a time period within which disturbance effects might occur, the 90dBht and 75dBht represent avoidance rather than injury. Furthermore, this would not be 39 consecutive months of piling activity (see **Section 13.6** of **Chapter 13)**, with the possibility of breaks over more than two herring (November to February) or sole (February to May, inclusive) spawning periods.

14.6.90 However, implications associated with disturbance and significant behavioural responses over a prolonged timescale could result in a barrier effect, whereby an animal alters its normal route to avoid an area 'ensonified' by the disturbing sound field. This may result in increased energy expenditure if the individual was required to travel further as a result of avoiding the disturbance source. Barrier effects can also result in the loss of valuable feeding, breeding and socialising areas, or displacing animals from important transit routes to such areas.

14.6.91 It has been suggested that effects at 75dBht are likely to be limited by habituation (Subacoustech, 2011) (**Technical Appendix 13.B**). **Table 14.24** indicates that at the 90dBht level, relatively low numbers of animals will be subject to disturbance during this period. In addition, evidence from **Section 14.4** strongly suggests that, when compared to sightings records from other areas in the southern North Sea, the GWF study area does not appear to be important for marine mammals. In should also be noted that the worst case scenario assumes that one 3m pin pile will be installed each day and each 3m pile installation will take a maximum of two hours to install, at any other time of day (or night) marine mammals will be able to use the area undisturbed by piling noise.

14.6.92 Using the upper SCANS II density estimate for harbour porpoise, a maximum of 1,780 animals might be disturbed at the 75dBht level and 482 at the 90dBht level. As discussed in Section 14.2, the EPS Guidance (JNCC *et al.* 2010) states: "*for most populations of marine EPS in UK waters, the removal of tens, hundreds, and even thousands of animals for the most abundant species (e.g. harbour porpoise), would not result in detriment to the population at FCS*".

14.6.93 Given the intermittent nature of pile driving operations and the low probability that significant numbers of marine mammal (**Table 14.2**) would occur within the GWF construction site at the point of installation, the magnitude of the impact on harbour porpoise is considered to be low, with a negligible magnitude on all other regional populations of pinniped and cetacean.

14.6.94 Based on the very low encounter rates within the offshore waters of the GWF (6 individual grey seals and 3 individual harbour seals sited within GWF between 2008-2010), **Section 14.4,** it is unlikely that this area is important for harbour or grey seals. Seals are not an EPS and given the low level of seal activity within the GWF study area (which has not been raised in the context of HRA), it is not felt that attempts to quantify potential effects of underwater noise on the sporadic sightings of seals at the GWF would add any genuine value to this impact assessment.

14.6.95 Given their protected status, all cetaceans and pinnipeds have a high conservation value and a high sensitivity to piling noise. Consequently, the overall unmitigated impact would have **minor adverse** significant impact for regional cetacean and pinniped populations.

14.6.96 It should be noted that the JNCC guidance (2010) advises that;

"Although no direct evidence exists for a causal link between pile driving sound and physical injury to cetaceans, data on auditory sensitivities and comparison with human and other terrestrial mammal data suggests that pile driving in the marine environment without mitigation is likely to produce noise levels capable of inducing avoidance reactions that could constitute disturbance under the Regulations, and injuries (e.g. physical damage or hearing impairment) or even death in marine mammals that are in very close proximity. In addition to these effects, exposure to sound may also result in non-auditory physiological effects such as stress and tissue injury. Given the risk for injury and disturbance offences under the regulation 39(1)(a) and (b), appropriate mitigation should be sought and employed where possible in order to reduce the risk to negligible levels."

Mitigation and residual impact

14.6.97 As detailed in the impact assessment associated with lethal effect and physical injury, the use of soft start procedures and the MMMP will reduce physical effects for marine mammals in close proximity to the piling installation. However, these measures will not reduce the impacts associated with far-field behavioural effects for marine mammals. Therefore, the residual impact remains a **minor adverse** significant impact for cetaceans and pinnipeds.

14.6.98 Given the assessment provided above, it is anticipated that the duration and intensity of disturbance caused by pile driving activities at the GWF is unlikely to have the potential to cause an offence on EPS under Regulation 39 1(a) and (b) of the HR and OMR at population level for behavioural effects. As highlighted through consultation with the SNCBs (**Table 14.3**) an EPS licence will be required. This covers the risk of disturbance to cetacean species as a result of activities associated with construction, it should be noted that only disturbance that does not have an impact on the species at population level, but is sufficient to constitute an offence, can be licensed.

Collision Risk

14.6.99 The greatest collision risk to marine mammals is likely to occur during the construction phase of the project due to the number and types of vessels operating in the area. Ship strikes are known to cause mortality to marine mammals world-wide. Strikes are far from infrequent, with the majority going unnoticed (Wilson *et al*., 2007).

14.6.100 Injuries tend to fall into two categories:

- Lacerations from propellers; and
- Blunt traumas from impact with the hull.

14.6.101 It is probable that, if these injuries do not cause the immediate death of the animal, they will leave it vulnerable to death from secondary infections, complications or predation (Wilson *et al*., 2007).

14.6.102 The main drivers that are thought to influence the number and severity of ship strikes are reviewed in Wilson *et al.,* (2007) as:

- Vessel type and navigation speed;
- Underwater noise – high levels of ambient noise can result in difficulty in detection of approaching vessels;
- Weather conditions and time of navigation – this can both affect the ability of crew to locate whales and add to ambient noise; and
- Whale behaviour – which is species specific; juvenile and sick individuals appear to be more vulnerable.

14.6.103 Laist *et al.,* (2001) concluded that vessels over 80m in length cause the most severe or lethal injuries and that serious injury rarely occurs if animals are struck by vessels travelling at speeds below 10 knots. The types of HLVs expected to be involved in the construction of GWF may be in excess of 80m in length and velocities typically in the region of 10 knots. Other vessels such as guard vessels and crew transfer boats are likely to travel at speeds in excess of 10 knots.

14.6.104 During the summer of 2008 to the summer of 2010, more than 50 seal carcasses (both grey and harbour) with unusual 'corkscrew-like' injuries have washed up close to important breeding colonies on the east coast of England and Northern Ireland as well as Scotland. The injuries are consistent with the animal having encountered a single, rotating right-angled blade, resulting in a severe smooth-edged cut starting from the head and spiraling around the body (Thompson, 2010).

14.6.105 The Sea Mammal Research Unit (SMRU) has examined a number of corpses and in all cases the wound inflicted on the individual caused the fatality. A number of possible causes of these injuries have been considered by the SMRU, including deliberate killing, predation and military activities, all of which are considered unlikely. The injuries were found to be consistent with the animals being drawn through some form of ducted propeller system, common to a wide range of azimuth drives on the dynamic positioning systems of various types of offshore support vessels and research boats, such as tugs, self propelled barges and rigs (Thompson, 2010).

14.6.106 At the time of writing, a link between this wide-spread phenomena and the use of ducted propellers for slow maneuvering not been proven (Thompson, 2010). Anecdotal evidence from SMRU suggests that the noise signatures from some bow thrusters may attract seals (particularly female harbour seals during the breeding season and juvenile grey seals) into proximity with the ducted propeller. With investigations ongoing, GWFL will work closely with the statutory nature conservation bodies (SNCBs) and SMRU to ensure that the latest information and guidance on this issue is captured within the MMMP.

14.6.107 Given the level of protection afforded to pinnipeds and the risk of collision impacts associated with the 'corkscrew-like' injuries reported by Thompson (2010) the sensitivity of seals to collision risk is considered to be high. The risk based approach has not been taken for cetaceans and they are likely to have a medium sensitivity to the relatively small-scale, temporary and localised nature of the construction traffic associated with the GWF.

14.6.108 In the context of the level of marine mammal interest within the GWF study area, the potential and likelihood of collision risks is low, especially when considered in context with the volume of existing vessels in the Outer Thames Estuary. The local magnitude of collision risk from direct strikes with construction vessels is considered to be low in the context of all regional marine mammal populations (**Table 14.2**). Therefore, the potential impact of direct vessel collisions would be of **minor adverse** for seals and **negligible** significance for harbour porpoise and other cetaceans.

Mitigation and residual impact

14.6.109 The mitigation measures that will be considered to reduce the likelihood of collisions comprise:

- All vessels being used during the operational phase of GWF will be made aware of the risk of potential collision so that the risk can be minimised through awareness; and
- A protocol for collision events will be considered as part of the Marine Mammal Mitigation Programme (MMMP); should such a protocol be developed, this would include the requirement for any such collisions to be reported to JNCC and Natural England immediately.

14.6.110 The implementation of these mitigation measures in the context of the cryptic nature of some marine mammals and their nocturnal movements mean that, on balance, the impact magnitude is likely to remain **minor adverse** for seals and **negligible** significance for harbour porpoise and other cetaceans.

14.6.111 Given the assessment provided above, it is anticipated that the collision risk caused by activities at GWF, in isolation, is unlikely to have the potential to cause an offence on EPS under Regulation 39 1(a) and (b) of the HR and OMR at population level any marine mammal species.

Indirect impacts due to loss of prey source

14.6.112 The key prey species for marine mammals include a number of flatfish, gadoids, clupeid and sandeel species. As discussed in **Chapter 13** the construction process, particularly in the case of large diameter pile driving, has the potential to impact on certain fish species. The indirect loss of fish prey resource is assessed in **Chapter 13** and while it is anticipated that significant mortality impacts can be reduced through the use of appropriate mitigation (detailed within **Chapter 13**), the underwater noise generated from impact piling operations could result in hearing sensitive fish such as herring and sprat temporarily moving away from the construction area for the duration of piling operations. Piling operations are intermittent and any displacement of prey species would therefore only occur for a short duration, a response that may be mirrored by predators such as marine mammals. **Chapter 13** concludes that the overall effects as a result of loss of fish prey resource would be **negligible**.

14.6.113 The high mobility and large foraging ranges of most species of marine mammal means that they are likely to be able to accommodate such localised changes in prey source. However, the value and sensitivity is considered to be medium given their protected status. **Figure 14.10** suggests the seabed and waters within and immediately adjacent to the GWF are unlikely to represent a unique or productive foraging resource for common seal with breeding colonies within the Thames Estuary. Therefore, the magnitude of the subsequent impact on the regional population is likely to be negligible. The impact magnitude on harbour porpoise, which occur within the GWF study area in relatively low numbers throughout the year, and have a very wide foraging range is also considered to be negligible in the context of the wider North Sea population (**Table 14.2**). It follows that the localised and temporary loss in prey source would be of **negligible** significance to all marine mammal regional populations.

14.6.114 In relation to predicted impacts on EPS, given the relative low usage of the site for marine mammals and the lack of significant residual impact on prey source it is not anticipated that these activities would result in an offence under Regulation 39 1(a) and (b) of the HR and OMR at a population level for any species of marine mammal.

14.7 Assessment of Impacts during the Operation Phase

14.7.1 This section provides an assessment of the impacts from the operation phase of the GWF project on marine mammals. Aspects associated with the operation phase (as identified during the Scoping process) include:

- Operational noise;
- Collision risk;
- Barrier effects; and
- Electromagnetic fields (EMF).

Disturbance through underwater noise and vibration

14.7.2 Details of the expected operational noise levels are provided in **Chapter 5**. In summary, the levels of the noise generated by a working WTG is at very low levels when compared to the noise created during construction (Nedwell *et al.,* 2007). The overall operational noise from a wind farm may only be expected to be above background levels in a few limited frequency bands in the immediate vicinity of the turbines (Subacoustech, 2011, see **Technical Appendix 13.B**).

14.7.3 Comprehensive environmental monitoring has been carried out at Horns Rev and Nysted wind farms in Denmark during the operational phase (1999 to 2006, Diederichs *et al.,* 2008). Numbers of porpoise within Horns Rev were thought to be slightly reduced compared to the wider area during the first two years of operation, however it was not possible to conclude that the wind farm was solely responsible for this change in abundance without analysing other dynamic environmental variables (Tougaard *et al.,* 2005). Later studies (Diederichs *et al.*, 2008) recorded no significant effect on the abundances of harbour porpoise at varying wind velocities and operational studies at both of the Dutch offshore wind farms following two years of operation. Monitoring studies at Horns Rev have suggested that operational activities have had no impact on regional seal populations.

14.7.4 A recent study by Lindeboom *et al.*, (2011) summarises the results of a monitoring programme undertaken at the operational Egmond aan Zee in the Netherlands, as well as other Dutch and Danish projects. For porpoises, the acoustic recordings at Egmond aan Zee show that significantly more porpoise activity was recorded in the operational wind farm as compared to the reference areas outside the farm and it has been indicated that this may be linked to increased food availability or that wind parks could provide areas of relative quiet in comparison to the surrounding waters with high vessel activity (Lindeboom *et al.,* 2011). Both Dutch and Danish research studies indicate that operational wind farms are frequently visited by harbour porpoises and most likely used for foraging. It appears that these relatively small wind farms do not induce aversive responses from harbour porpoise and in fact may provide suitable habitat for feeding and shelter (Lindeboom *et al.,* 2011 and references therein).

14.7.5 The studies discussed above relate to smaller WTGs (2MW to 3MW) than those anticipated for GWF, which is considering WTGs of between 3.6MW and 7MW capacity. However if a larger turbine was selected for use at GWF, fewer WTGs would be required to meet the maximum installed capacity. Based on published measurements of the 1/3-octave band source levels for the operational wind turbines in Sweden (Lidell, 2003), it is concluded that even though an individual larger capacity turbine could be louder, the layout with the greatest number of turbines would still produce a larger noise footprint than a layout with fewer but larger capacity turbines. Therefore the assessment of smaller capacity turbine generators as part of a larger array has been used as the worst case scenario in the marine mammal assessment (see **Table 14.11**).

14.7.6 The main contribution to the underwater noise emitted from the wind turbines is expected to be from acoustic coupling of the vibrations of the substructure into the water rather than from transmission of in-air noise from the turbines into the water (Lidell 2003). At the Naikun Wind Farm in British Columbia, JASCO (2009) predicted sound pressure levels for 3.6MW WTGs greater than 120 dB re 1 µPa rms SPL would occur at ranges less than 8.5km. It should be noted that this estimate is from the distance to the centre of the wind farm grid and not to a single turbine. This study concluded that noise levels of the operating wind farm would be too low to cause injury to marine mammals.

14.7.7 Any increases in noise associated with frequent (up to one transit a day) of small maintenance craft at the site are likely to be short term, localised in nature and set against a background on high levels of commercial shipping activity in surrounding waters (see **Chapter 16 Shipping and Navigation**).

14.7.8 The value and sensitivity of the receptor is considered to be medium, given the protected nature of marine mammals but their likely ability to tolerate such relatively low levels of noise. The magnitude would be at worst negligible given the low level and localised nature of noise anticipated. Therefore, based on the available evidence, it is considered that the operational noise impact of GWF on regional populations of marine mammals would be **negligible** significance. Furthermore, any impact arising would be highly unlikely to elicit an adverse behavioural response from marine mammals that could compromise the FCS of regional populations, both in terms of maintaining their population size and their natural range (**Section 14.2**).

14.7.9 As a result of the predicted negligible impacts on EPS, it is not anticipated that these activities will result in an offence under the Regulations.

Collision risk

14.7.10 Other than routine maintenance and survey activity it is likely that there will be a low density of shipping associated with the wind farm site during the operational phase. Additionally vessels will be smaller in size, and whilst working within the wind farm site are unlikely to exceed speeds of 10 knots.

14.7.11 With regard to the WTGs themselves, due to their static nature it is highly unlikely that marine mammals will collide with the foundation structures.

14.7.12 As discussed in **Section 14.4** the waters within and adjacent to the GWF do not appear to be an important area for marine mammals (low incidental sightings throughout the year, with limited records of animals observed actively foraging within the area).

14.7.13 Those species which are likely to be encountered are very agile and the type of vessels used during operation (typified by the wind-cat style of vessel) will be of a small size and very shallow draft. Therefore, it is anticipated that the risk of a collision with marine mammals is unlikely, with the magnitude considered to be negligible.

14.7.14 Marine mammals are likely to have a medium sensitivity to the relatively small crafts and localised nature of the maintenance traffic associated with the GWF. Therefore, collision risk of an individual would be considered of **negligible** significance.

Mitigation and residual impact

14.7.15 The mitigation measures that will be considered to reduce the likelihood of collisions comprise:

- All vessels being used during the operational phase of GWF will be made aware of the risk of potential collision and all practicable measures will be taken to minimise this risk.
- A protocol for collision events will be considered as part of the Marine Mammal Mitigation Programme (MMMP); should such a protocol be developed, this would include the requirement for any such collisions to be reported to JNCC and Natural England immediately.

14.7.16 The implementation of these mitigation measures in the context of the cryptic nature of some marine mammals and their nocturnal movements mean that, on balance, the impact magnitude is likely to remain as **negligible** for all species of marine mammal.

14.7.17 Given the assessment provided above, it is anticipated that the collision risk caused by activities at GWF, in isolation, is unlikely to have the potential to cause an offence on EPS under Regulation 39 1(a) and (b) of the HR and OMR at population level any marine mammal species.

Barrier effects

14.7.18 A barrier effect is caused when an animal alters its normal route to avoid a wind farm and is a form of displacement. Defra guidance on nature conservation for offshore wind farm development (Defra, 2005) notes that barrier effects may be a potential issue for marine mammals during offshore wind farm operation.

14.7.19 Studies at Nysted and Horns Rev have found no significant influence on harbour porpoise numbers following two years of operation (Diederichs *et al.,* 2008). At Nysted, during the first year of operation, significantly fewer porpoise were recorded within the wind farm area in comparison to the baseline period. During the following two years, the numbers increased up to the original baseline, indicating that harbour porpoise were once again foraging within the wind farm at a level similar to the pre-construction phase.

14.7.20 Studies of operational wind farms suggest a highly temporary reduction in the abundance and foraging activity of marine mammals, when compared to reference sites, the significance of which appears to be highly variable dependant on location and species involved. It is anticipated that, as for other operational sites, marine mammals around GWF will readily habituate to the wind farm within one to two years of operation, particularly if the wind farm becomes an important refuge for prey species.

14.7.21 Given the tolerance of marine mammals to such potential effects their sensitivity is considered to be medium. The magnitude of such an effect would be negligible in that animal densities are relatively low and the impact it is not certain to occur and would only likely be temporary in nature. Therefore, the barrier effect impact of the operational phase of the GWF would be anticipated to be of **negligible** significance.

14.7.22 In relation to predicted impacts on EPS, it is not anticipated that these activities would result in an offence under the Regulations.

Electromagnetic fields

14.7.23 There is a potential for electromagnetic fields (EMF), produced from the GWF export cables, to affect marine mammals present in the area.

14.7.24 Detail on EMF are provided in **Chapter 5** and explained further in **Chapter 13**. No evidence has been found to suggest that pinnipeds are magnetoreceptive (Gill *et al.*, 2005) and, therefore, the impacts referred to in this section refer primarily to cetaceans.

14.7.25 A review on the potential effects of EMF generated by sub-sea power cables associated with offshore wind farms by Gill *et al.,* (2005) indicated that cable burial was ineffective in 'dampening' the B field (and resultant iE field). However, cable burial to a depth of least 1m is likely to provide some mitigation for the possible impacts of the strongest B field and iE fields (that exist within millimeters of the cable) on sensitive species, including cetaceans. Ten cetacean species in UK coastal waters are known to be magnetoreceptive (i.e. have shown evidence of response to B fields) including harbour porpoise and bottlenose dolphin (Gill *et al.*, 2005). For these species, sensitivity to the magnetic fields is associated with a direction finding ability e.g. migration. As migration generally occurs in open water and away from the seabed, wind farms are reported to be unlikely to have a detrimental effect on migration (Gill *et al.*, 2005).

14.7.26 Although it is assumed that harbour porpoise (and other cetacean species) are capable of determining small differences in relative magnetic field strength, this is unproven and is based on circumstantial information (Marine Scotland, 2011). There is also at present, no evidence to suggest that existing cables have influenced migration of cetaceans. Migration of the harbour porpoise in and out of the Baltic Sea requires several crossings over operating subsea high voltage direct current cables in the Skagerrak and western Baltic Sea without any apparent effect on their migration pattern (Marine Scotland, 2011).

14.7.27 The conservation value of all marine mammals recorded within the wind farm footprint and in proximity to the cable route is high, however, their sensitivity to the EMF of a buried cable is considered to be low. Cetaceans are not present in high numbers in the area around the proposed cable route and are unlikely to use this area on a regular basis. Based on the available evidence the impact magnitude is likely to be low. Consequently, overall impacts from EMF on marine mammals would be considered to be of **negligible** significance to regional populations.

14.8 Potential Impacts during Decommissioning

14.8.1 Impacts to marine mammals associated with decommissioning of the GWF project are anticipated to be broadly similar to those outlined during the construction phase (**Section 14.6**). However, as no piling activities are associated with decommissioning, and noise from piling is identified as the key impact of concern, the impacts as a result of underwater noise will be significantly less.

14.9 Inter-relationships

14.9.1 The inter-relationships between the marine mammals and other physical, environmental and human parameters are inherently considered throughout the assessment of impacts (**Sections 14.5** to **14.7**) as a result of the receptor lead approach to the assessment. For example, marine mammals have the potential to be influenced by changes in availability of prey resource (namely fish) as a result of the proposed development. The potential impacts as a result of this indirect effect have been discussed within this Chapter based on the findings of the assessments made in **Chapter 13 Fish and Shellfish Resource**.

14.9.2 **Table 14.27** summarises those inter-relationships that are considered of relevance to marine mammals and identifies where within this assessment these relationships have been considered.

Table 14.27 Marine mammal inter-relationships

Inter-relationship	Section where addressed	Linked Chapter
Construction and decommissioning		
Influence of loss of prey resource on marine mammals during construction	Section 14.6	Influencing parameter: Chapter 12 Marine and Intertidal Ecology, Chapter 13 Fish and Shellfish Resource and Chapter 9 Physical Environment
Cumulative		
Cumulative collision risk	Section 14.10	Influencing parameter: Chapter 15 Commercial Fisheries Influencing parameter: Chapter 16 Shipping and Navigation Influencing parameter: Chapter 18 Other Human Activities
Cumulative impacts associated with commercial fisheries (reduction in prey resource and / or increases in interaction with vessels)	Section 14.10	Influencing parameter: Chapter 15 Commercial Fisheries

14.9.3 **Chapter 29 Inter-relationships** provides a holistic overview of all of the inter-related impacts associated within the project.

14.10 Cumulative Impacts

14.10.1 A cumulative impact can only occur where a project aspect is identified as having an impact on a receptor in isolation.

14.10.2 The unmitigated significant impacts identified during the construction (**Section 14.6**), operation (**Section 14.7**) and decommissioning phases (**Section 14.8**) of the GWF project that therefore have the potential to result in cumulative effects comprise:

- Underwater noise from pre-construction geophysical surveys (as detailed in **Chapter 5**);

- Construction noise; and
- Collision risk.

14.10.1 The cumulative impacts associated with the GWF development may occur on a number of levels:

- Interactions between different aspects of the GWF project with other wind farms; and
- Interactions with other regulated activities occurring in the region.

GWF and other wind farm projects

14.10.2 The existing and planned wind farms in the Outer Thames Estuary area which could contribute to cumulative effects when considered alongside the GWF are shown in **Table 14.28** along with the planned construction period for these projects.

Table 14.28 Distances (km) of Outer Thames wind farm sites from GWF

Project Details	Status	Distance From Galloper Site (km)	Predicted Construction Period[3]
Galloper	EIA Stage	N/A	Total maximum piling duration of 39 months, notionally assuming an earliest Q2 or Q3 2015 commencement within the 56 month offshore construction window
Greater Gabbard	In construction	0	2009 - 2012
East Anglia ONE	Zonal Assessment and Scoping for Project ONE	25.2	Project ONE to commence at earliest in 2015
London Array I	In construction	24.3	2011 - 2012

[3] Construction times supplied via *www.4coffshore.com* and associated web links to site pages

Project Details	Status	Distance From Galloper Site (km)	Predicted Construction Period[3]
London Array II	Consented	15.1	2014 - 2015
Thanet	Operational	37	Operational
Gunfleet Sands I	Operational	42.6	Operational
Gunfleet Sands II	Operational	40	Operational
Gunfleet Sands Extension	In planning	46.4	2011 - 2012
Kentish Flats	Operational	61.6	Operational
Kentish Flats Extension	EIA Stage	61.5	2013 -2014

Source: *www.4coffshore.com*

14.10.3 It is considered that the offshore wind farms listed in **Table 14.28** are of most relevance to potential cumulative impacts on marine mammals, due to their location within the Outer Thames Estuary.

14.10.4 In relation to the FCS of the North Sea harbour porpoise population, it is important to consider the potential effects of concurrent, or even subsequent, noisy works at all East coast wind farms. The following list provides an overview of all offshore wind farms which may have overlapping construction phases with GWF[4]:

- Dudgeon;
- Docking Shoal;
- Race Bank;
- Hornsea (R3);
- Westermost Rough;
- Dogger (R3);
- Neart na Gaoithe;

[4] Estimated construction timetables have been informed from the global wind resource website www.4coffshore.com, and relate to the entire construction period not specifically the offshore components of construction

- Inch Cape; and
- Firth of Forth (R3)

14.10.5 It is important to note that the foundation type and installation methodology for the majority of these projects has yet to be decided. London Array (Phase II) is the only wind farm, in relative proximity, which is likely to undertake simultaneous construction. The extent and potential consequences of the overlapping sound fields in regard to potential adverse behavioural response and displacement are discussed in more detail in the remainder of this Section. It is not technically feasible to undertake a quantitative assessment of the long-term effects of noise generating works at all of the projects listed above within the GWF EIA. On a regional scale, one of the key parameters that will need investigating as part of this form of assessment will likely involve habitat association modelling for apparent areas of importance across the southern North Sea. In line with recent consultation with the JNCC (Mendes, 2011), GWFL would welcome the opportunity to engage with The Regulators in taking this assessment forward at a strategic level.

Potential cumulative impacts during construction and decommissioning

14.10.6 The potential significance of cumulative construction impacts arising from the construction of the GWF site would occur if:

- The construction of the site coincided with construction timetables for other projects; and
- The activities of the displaced receptors (foraging, migrating or breeding marine mammals) were impacted by the cumulative construction activities of those wind farms which occurred concurrently with the GWF site.

14.10.7 From **Table 14.28** it can be seen that the GWF construction period has the potential to coincide with construction of East Anglia ONE, London Array (Phase II) and the Kentish Flats Extension project.

14.10.8 Marine mammal populations are wide-ranging across the Outer Thames Estuary. It is not possible to provide abundance estimates for each wind farm site in order to quantify the full range of potential impacts. Consultation with the JNCC (Mendes, 2011) confirmed that an assessment of potential impacts to wide-ranging populations at a strategic scale is a more appropriate remit for The Regulators. However, it follows that disturbance effects arising from multiple wind farm sites could act in-combination to adversely effect the FCS of a regional population and/or displace animals from important foraging or breeding areas into smaller patches of habitat within surrounding areas. These potential cumulative impacts are assessed in more detail below.

Underwater noise

14.10.9 The evidence presented in **Chapter 5** and **Section 14.6** would suggest that the most pervasive noise source from offshore wind farms that has the potential to overlap with that of another wind farm and/or act additively with the displacement effects of another wind farm to increase the ecological pressure in smaller pockets of sub-prime habitat, is associated with pile-driving activity associated with the construction phase. Potential for cumulative underwater noise impacts to affect marine mammals is, therefore, dependent on two or more projects undertaking pile driving concurrently.

14.10.10 There is also potential for geophysical surveys occurring concurrently within a region to increase the 'noise footprint' across sensitive habitat.

14.10.11 While several offshore wind farms are planned for future construction in the region (see **Table 14.28**), following a review of the anticipated construction schedules for these projects, only three projects are identified as potentially coinciding with the GWF project. These are the Kentish Flats Extension, London Array Phase II and East Anglia ONE (although there is a significant degree of uncertainty associated with this project timescale). Based on the significant distance to the Kentish Flat Extension site there is not anticipated to be an interaction between the sites.

14.10.12 East Anglia ONE is located 25km from the proposed GWF site, this distance is approximately equal to the maximum impact range for the 90dBht level modeled for the proposed GWF wind farm, it is therefore considered that there is limited potential for two simultaneous pile driving operations at these sites to have overlapping spatial impact footprints. Insufficient data for East Anglia ONE offshore wind farm is available (i.e. foundation types, sizes and installation techniques) to undertake noise propagation modelling therefore it is not possible to quantify the two potential impact footprints. It is however, recognised that should East Anglia ONE progress at on a similar development timeframe to GWF, and adopt use of piled foundation options, then there is potential for cumulative disturbance to occur.

14.10.13 The noise impact ranges from the London Array Phase II project have been modeled as the information is available and at 16km from the proposed GWF site, represents a worst case for cumulative impacts, it is also likely to coincide (in time) with the GWF project.

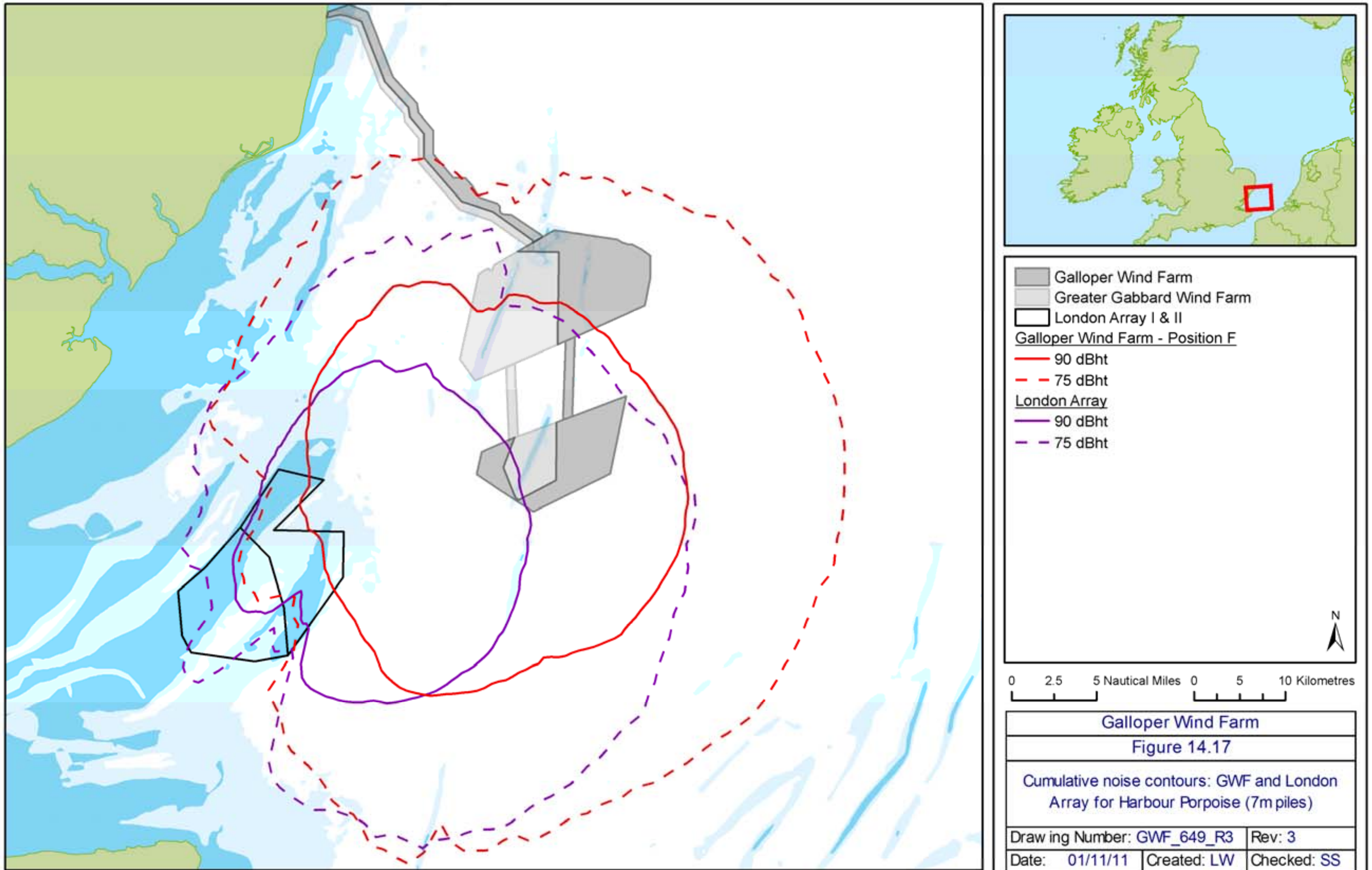
14.10.14 The assessment of cumulative impact between GWF and London Array Phase II has been carried out in two ways to give a broader picture of the impacts that may occur; a behavioural impact assessment for pile driving at two locations, analysing where the $90dB_{ht}$ contours overlap, and an assessment based on perceived noise dose criteria.

14.10.15 The cumulative contour plots for harbour porpoise and harbour seal between pile driving operations at the closest boundary points of GWF and London Array Phase II are presented in Figures **14.17 to 14.18** respectively.

SSE Renewables

RWE npower renewables

ROYAL HASKONING Enhancing Society



Bathymetry received from TCarta Marine Ltd 2010. Noise modelling conducted by Subsacoustech 2011

Galloper Wind Farm		
Figure 14.17		
Cumulative noise contours: GWF and London Array for Harbour Porpoise (7m piles)		
Drawing Number: GWF_649_R3		Rev: 3
Date: 01/11/11	Created: LW	Checked: SS
Scale: 1:600,000	Page: A4	
Datum: WGS1984	Projection: UTM Zone 31N	

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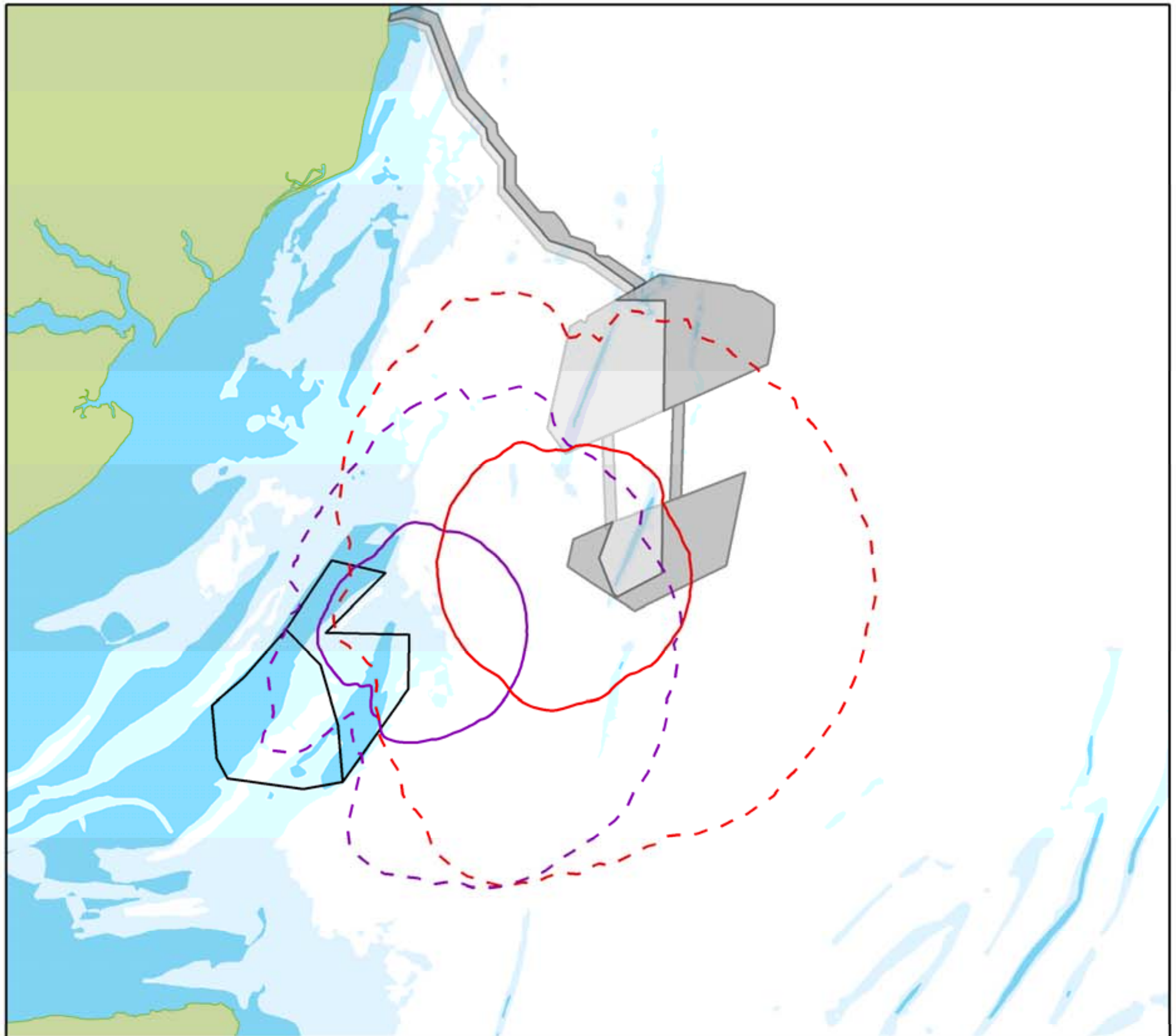

Galloper Wind Farm
Greater Gabbard Wind Farm
London Array I & II
Galloper Wind Farm - Position F
90 dBht
75 dBht
London Array
90 dBht
75 dBht

N

0 2.5 5 Nautical Miles 0 5 10 Kilometres

Galloper Wind Farm		
Figure 14.18		
Cumulative noise contours: GWF and London Array for Harbour Seal (7m piles)		
Draw ing Number: GWF_650_R2		Rev: 2
Date: 01/11/11	Created: LW	Checked: SS
Scale: 1:600,000	Page: A4	
Datum: WGS1984	Projection: UTM Zone 31N	

Bathymetry received from TCarta Marine Ltd 2010. Noise modelling conducted by Subsacoustech 2011

14.10.16 With regard to the cumulative noise assessment for the GWF and London Array Phase II wind farm, under some circumstances the areas around two simultaneous pile driving operations at different sites may converge. However, typically pile driving will only occur for an hour or two each day, therefore, the possibility of such an overlap occurring is small.

14.10.17 The cumulative noise assessment (Subacoustech, 2011) has also used received Noise Dose and SEL methodologies (these methodologies are outlined in more detail within **Chapter 5**) to assess the auditory injury zone for marine mammals in the vicinity of an impact piling operation. This study used the approach that the degree of hearing damage depends upon both the received level of noise, and the time of exposure to it.

14.10.18 The predicted impact ranges for the assessment were similar to those predicted for the 130dB_{ht} perceived level at which traumatic hearing damage from a single pile driving event would be expected, therefore, indicating that any possibility of hearing damage would most likely be as a result of underwater noise from the nearest pile to the animal rather than a cumulative effect. These data, therefore suggest that the cumulative noise dose from impact pile driving operations at the London Array Phase II and Galloper site is unlikely to increase the likelihood of auditory injury.

14.10.19 There is however the potential for multiple discrete disturbance / displacement effects to occur simultaneously or in rapid succession. This may lead to a short-term restriction on habitat range and/or barrier effects (notably where sound fields overlap, with regard to London Array Phase II in particular).

14.10.20 As highlighted in **Section 14.2.50**, the FCS of marine mammals can be assessed against three parameters. The value / sensitivity of cetaceans and pinnipeds to cumulative injury and/or disturbance effects in relation to maintaining their regional populations (**Table 14.2** and **Section 14.4.44**) over the long-term is considered medium. The impact magnitude of cumulative piling on the population status of harbour porpoise is considered to be low, and as a result of the low numbers present in the area is considered to be negligible for all other cetaceans and pinnipeds As a consequence, the overall cumulative impact on long-term regional population levels for all harbour porpoise is considered to be of **minor adverse** significance and **negligible** significance for other marine mammals and pinnipeds.

14.10.21 With respect to maintaining the natural range and suitable habitat for regional populations, the value / sensitivity of cetaceans and pinnipeds known to occur within the GWF study area is considered medium. The impact magnitude of cumulative piling on the range and habitat resource for regional populations of marine mammals is considered to be medium. As a consequence, the overall cumulative impact on the natural range and habitat of regional marine mammals is considered to be of short-term **minor adverse** significance.

Mitigation and residual impact

14.10.22 As discussed under construction phase noise mitigation, there are two principal measures that will be adopted to reduce the level of impact on marine mammals at project specific level (soft and slow mechanical start to impact piling and the development of a MMMP), and these measures would also serve to similarly reduce cumulative impact levels for lethal and injurious effects.

14.10.23 The JNCC have suggested that due to the potential cumulative impacts between GWF and London Array (Phase II), GWFL should consider mitigation measures that could be developed through agreements with the developers at London Array. Consequently, GWFL will work with London Array (and East Anglia ONE if further information is available at that juncture that indicates cumulative impacts are likely) and SNCAs in developing the MMMP.

Interaction with other activities

14.10.24 The interactions which will take place in association with GWF and have the potential to result in cumulative impacts on marine mammals comprise collision risk associated with increased vessel activity.

14.10.25 During the construction phase there would be a localised increase in vessel traffic. When considered with existing commercial traffic within the region (**Chapter 15 Commercial Fisheries**, **Chapter 16 Shipping and Navigation** and **Chapter 18 Other Human Activities**), such as commercial shipping, aggregate vessels and fishing vessels, the increase in vessel movements associated with the construction and operation of GWF could cumulatively increase collision risk for marine mammals in the region.

Commercial fisheries

14.10.26 Impacts on the intensity and distribution of commercial fishing activity within areas frequented by marine mammals in the outer Thames Estuary may lead to a reduction in prey resource and/or an increase in interactions between fishing nets and vessels and marine mammals.

14.10.27 The GWF site is considered to be of low importance for marine mammals in respect to foraging habitat, therefore there is the possibility that fishing boats displaced from the site may move into an area that has greater foraging potential and therefore has a higher usage by marine mammal species. As a result this could increase the possibility of interactions between commercial fisheries and marine mammals in these areas.

14.10.28 The value / sensitivity of all marine mammal species in relation to collision risk and bycatch from interactions with commercial fisheries is considered medium. However, given the low level of marine mammal activity within the wider study area, and the fact that fisheries will not be excluded from the wind farm site during operation (with the exception of 50m safety zones around the turbines which will be applied for post consent – see **Chapter 15**) these interactions are unlikely to occur, with any impacts having a negligible magnitude. As a consequence, the overall impact of interactions with commercial fisheries is considered to be of **negligible** significance.

Shipping

14.10.29 The magnitude of the cumulative effect of collision risk from increased numbers of vessels in the GWF development area is considered to be negligible as the number of vessels associated with GWF is small in comparison to the existing level of commercial shipping activity within the region. The value / sensitivity of all marine mammal species in relation to collision risk from a localised increase in shipping is considered low. In addition, the numbers of marine mammals present in the region are generally low. Therefore, given the short-term nature of the works and the limited number of marine mammals, the magnitude of the cumulative impact of noise and collision risk from vessels is assessed as being negligible, and the impact assessed as being of **negligible** significance.

Marine aggregate extraction

14.10.30 The GWF site is located close to a number of known marine aggregate extraction areas (**Chapter 18**). A ten year review' (1998 to 2007) (Crown Estate, 2008) provides some detailed assessment of dredging activity within the region. Over this period, 230.19km² of licensed area was surrendered, in comparison only 9.05km² of new area was licensed. During 2010, in the Thames Estuary, the total area licensed equaled 9.17km^2 and the total area dredged was only 4.18km^2 having decreased year on year from 2008 (The Crown Estate, 2011). During the period 1998 to 2007 the average area of new seabed dredged was 3.38km² per year (The Crown Estate, 2008).

14.10.31 The value / sensitivity of all marine mammal species in relation to displacement and habitat loss associated with dredging activity in the Thames estuary is considered negligible. Given the limited spatial extent of aggregate activity and the temporary duration of the displacement by construction activity on GWF the combined impact magnitude of displacement on marine mammals is likely to be negligible. It is, therefore, considered that interactions with dredging activities associated with marine aggregate extraction would have a **negligible** impact on marine mammals.

14.11 Transboundary Effects

14.11.1 This Chapter has considered the potential for transboundary effects to occur on marine mammals as a result of the construction, operation or decommissioning of the proposed GWF project. In all cases it is concluded that the potential impacts arising, by virtue of the predicted spatial and temporal magnitude of the effects, would not give rise to significant transboundary effects on the environment of another European Economic Area (EEA) member state. A summary of the likely transboundary effects of the proposed GWF are summarised in **Chapter 31 Transboundary Effects**.

14.12 Monitoring

14.12.1 As discussed throughout Section 14.7, as a result of potential impacts, largely associated with construction noise, GWFL will produce a MMMP in conjunction with the SNCAs once the project design has been finalised and at least four months prior to the need for any pre-construction monitoring work to commence.

14.12.2 Monitoring of marine mammal interest within the GWF site will be carried out in order to validate some of the predicted impacts on the receiving environment and populations. Based on the best practice guidance (SMRU, 2010; MMO *et al.*, 2010; Cefas, 2011) and the findings of ongoing monitoring carried out at the adjacent GGOWF, monitoring at GWF will be informed by a combination of:

- During-construction noise measurement, at sea, to verify the modelling work undertaken by Subacoustech (2011), presented herein; and
- The MMMP will seek to develop a programme of targeted surveys (either through PAM and/or boat-based, aerial visual/digital surveys) to be carried out over an appropriate spatial (i.e. wide enough to capture far-field behavioural effects) and temporal scale. This sampling strategy and reporting schedule will be developed in close consultation with the SNCAs' marine mammal specialists at least four months prior to the commencement of any construction works or the need to commence monitoring surveys if it precedes construction activity.

14.13 Summary

14.13.1 This Chapter of the ES has provided a characterisation of the existing marine mammal populations based on both existing and site specific survey data, which has established that communities present are indicative of the region and occur over broad extents throughout the Outer Thames Estuary and southern North Sea.

14.13.2 In general, few species were found at the site in any notable or significant densities. Harbour porpoise were the most frequently encountered marine mammal species within the GWF study area. Other species infrequently recorded included white-beaked dolphin, harbour seal and grey seal.

14.13.3 **Table 14.29** provides a summary of the predicted impact on marine mammals arising from the worst case scenarios set out in **Table 14.11**.

Table 14.29 Summary of predicted impacts of the GWF

Description of Impact	Impact	Possible Mitigation Measures	Residual impact
Construction Phase			
Geophysical surveys	Harbour porpoise: negligible All other cetaceans and pinnipeds: no impact	N/A	N/A
Construction related	All marine	Outlined in the MMMP,	Harbour

Description of Impact	Impact	Possible Mitigation Measures	Residual impact
noise – *lethal effect and physical injury*	mammals: Minor adverse	include the use of a MMO/PAM Operator and mechanical soft starts	porpoise: minor adverse All other cetaceans and pinnipeds: negligible
Construction related noise – *behavioural response*	All marine mammals: Minor adverse	N/A	N/A
Collision risk	Pinnipeds: minor adverse All other cetaceans: negligible	Vessels made aware of the risk of potential collision. Protocol developed as part of the MMMP	Pinnipeds: minor adverse All other cetaceans: negligible
Loss of prey species	All marine mammals: negligible	See Chapter 13	All marine mammals: negligible
Operational Phase			
Noise and vibration	All marine mammals: negligible	N/A	N/A
Collision risk	All marine mammals: negligible	Vessels made aware of the risk of potential collision. Protocol developed as part of the MMMP	All marine mammals: negligible
Barrier effect	All marine mammals: negligible	N/A	N/A
Electromagnetic fields	All marine mammals: negligible	N/A	N/A
Decommissioning Phase			
Impacts during decommissioning are anticipated to be broadly similar to those outlined during construction, however without piling activities impacts the are likely to be less significant			

14.13.4 No significant residual impacts are anticipated from the construction, operation or decommissioning phases of the GWF project, however as detailed in **Section 14.13** an EPS licence will be required to cover the risk of disturbance to cetacean species.

14.13.5 In terms of cumulative impacts, if construction timescales overlapped or were successive with the closest offshore wind farm developments (principally Phase II of London Array and also, potentially, East Anglia ONE), there is potential for multiple discrete disturbance/displacement effects to occur simultaneously or in rapid succession. This may lead to a short-term restriction on habitat range and/or barrier effects (notably where sound fields overlap).

14.13.6 Given the relatively low numbers of marine mammals encountered within and adjacent to the GWF site throughout the year and the application of best-practice mitigation, the FCS of regional, national and international marine mammal populations is unlikely to be adversely affected by the GWF development.

14.14 EPS Licence

14.14.1 Consultation with SNCAs has confirmed that an EPS license will be required to cover the risk of disturbance to cetacean species identified as likely to be in the area under regulations 41(1)(a) and (b) in The Conservation of Habitats and Species Regulations and 39(1)(a) and (b) in The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (amended in 2009 and 2010).

14.14.2 As such, GWFL, in their application for an EPS license, will give consideration to less noisy alternatives to piling, the total area of impact, the duration of impact and the number of animals to be affected.

14.15 References

Banks, A.N., Maclean, I.M.D., Burton, N.H.K., Austin, G.E., Caretr, N., Chamberlain, D.E., Holt, C., Rehfisch, M.M., Pinder, S., Batty, A., Wakefield, E. Gill, P. (2006). The Potential Effects on Birds of the Greater Gabbard Offshore Wind Farm Report for February 2004 to April 2006. BTO Research Report 440. ISBN 978-1-906204-05-1.

Boisseau, O., Lacey, C., Lewis, T., Moscrop, A., Danbolt, M., and McLanaghan, R. (2010) Encounter rates of cetaceans in the Mediterranean Sea and contiguous Atlantic area. *Journal of the Marine Biological Association of the United Kingdom* 90: 1589-1599

Camphuysen, K., Fox, T., Leopold, M., & Petersen, K. (2004). Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. A Comparison of Ship and Aerial Sampling Methods for Marine Birds, and Their Applicability to Offshore Wind Farm Assessments. Koninklijk Nederlands Instituut voor Onderzoek der Zee Report commissioned for COWRIE.

Clark, J., Dolman, S.J. and Hoyt, E. (2010). Towards Marine Protected Areas for Cetaceans in Scotland, England and Wales: A scientific review identifying critical habitat with key recommendations. Whale and Dolphin Conservation Society. Chippenham, UK, 178pp.

Culik, B.M. (2004). Review of Small Cetaceans: Distribution, Migration and Threats. CMS Report, UNEP/CMS Secretariat, Bonn, Germany. 343pp.

DECC (2009). Offshore Energy SEA. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/wind_leasing/wind_leasing.aspx

DECC (2002). Strategic Environmental Assessment (SEA) 3. Available at http://www.offshore-sea.org.uk/site/index.php

DECC (2003). Round 2 Offshore Wind Farm Development Strategic Environmental Assessment (SEA). Available at http://www.offshore-sea.org.uk/site/index.php

Diaz. B., Marino. F. A trial of acoustic harassment device efficacy on free-ranging bottlenose dolphins in Sardinia, Italy. Marine and Freshwater Behaviour and Physiology. Published 26th September 2011. DOI: 10.1080/10236244.2011.618216

Dietz, R., Teilmann, J., Henrisksen, O.D. Laidre. K. (2003). Movements of seals from Rodsand sanctuary monitored by satellite telemetry. Relative importance of the Nysted Offshore Wind Farm are to seals. NERI, Denmark. Report No. 429: Page 44

Eldred, K. M., Gannon, W. J. & Von Gierke, H. E. (1955). Criteria for short time exposure of personnel to high intensity jet aircraft noise. In: *OH: U.S. Air Force; WADC Technical Note*: Wright-Patterson Air Force Base.

European Commission (2007). Guidance document on the strict protection of animal species of community interest under the Habitats Directive 92/43/EEC.

Evans (1995). Chapter 5.15 Whales, dolphins and porpoises. In: Coasts and seas of the United Kingdom. Region 6 Eastern England: Flamborough Head to Great Yarmouth. Ed. By Barne, J.H., Robson, C.F., Kaznowska, S.S., Doody, J.P. and Davidson, N.C. 129-133. Peterborough, Joint Nature Conservation Committee.

Evans (1995). Chapter 5.14 Seals. In: Coasts and seas of the United Kingdom. Region 6 Eastern England: Flamborough Head to Great Yarmouth. Ed. By Barne, J.H., Robson, C.F., Kaznowska, S.S., Doody, J.P. and Davidson, N.C. 129-133. Peterborough, Joint Nature Conservation Committee.

Diederichs, A., G. Nehls, M. Dähne, S. Adler, S. Koschinski, U. Verfus. (2008). Methodologies for measuring and assessing potential changes in marine mammal behaviour, abundance or distribution arising from the construction, operation and decommissioning of offshore windfarms. BioConsult SH report to COWRIE Ltd.

Gardline (2010). Greater Gabbard Offshore Wind Farm Underwater Noise Monitoring During Marine Piling, Flour Ltd. Project Ref. 8503 September 2010

Gill, A.B., Gloyne-Phillips, I., Neal, K.J. and Kimber, J.A. (2005). COWRIE 1.5 Electromagnetic Fields Review. The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. Commissioned by COWRIE. Available at URL: http://www.offshorewindfarms.co.uk/Assets/COWRIE_Final_compiled.pdf. Accessed 08/04/2010

Götz, T. & Janik, M. M. (2010). Aversiveness of sound in phocid seals: psycho-physiological factors, learning processes and motivation. Journal of Experimental Biology, 213, 1536-1548.

Greater Gabbard Offshore Winds Ltd (GGOWL) (2005). Greater Gabbard Offshore Wind Farm Environmental Statement, 2005. Prepared by Project Management Support Services Ltd (672 pp).

GGOWF Summary Progress Report (2006). British Trust for Ornithology and Environmentally Sustainable Systems Ltd

Hammar, L., Andersson, S. and Rosenberg, R. (2010) Adapting offshore wind power foundations to local environment. Translation: Anna Dimming. Swedish Environmental Protection Agency.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Joergensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F., Oeien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. J Appl Ecol 39: 361-376.

IEEM (2010). Guidelines for Ecological Impact Assessment in Britain and Ireland. Final Version 5 August 2010

IPC (2010). Scoping opinion proposed Galloper Wind Farm Project, August 2010. Available at http://infrastructure.independent.gov.uk/wp-content/uploads/2010/09/Galloper-scoping-opinion_web.pdf

JASCO (JASCO Applied Sciences) (2009) Naikun offshore wind energy project. Volume 4 – noise and vibration. JASCO Applied Sciences March 2009. Available at http://a100.gov.bc.ca/appsdata/epic/documents/p230/d29852/1242851925970_65f01eb6ca8c72dd6b6b913184fc3f67b13510f066a1689fbf7098ea323ed76c.pdf

JNCC, CCW and Natural England (October 2010). The protection of marine European Protected Species from injury and disturbance: Guidance for the marine area in England and Wales and the UK offshore marine area, draft guidance

JNCC (2010). Statutory Nature Conservation Agency Protocol for Minimising the Risk of Injury to Marine Mammals from Piling Noise.

Laist. D.W., Knowlton. A.R. Mead. J.G. Collet. A.S. Podesta (2001). Collisions between ships and whales. Marine Mammal Science 17: 35-75

Lidell, H. 2003. Utgrunden off-shore wind farm: Measurements of underwater noise. Technical report prepared for Airicole, GE Wind Energy and SEAS/Energi/E2 by Ingemansson Technology AB, Goteborg, Sweden.

Lindeboom, H. J., Kouwenhoven, H. J., Bergman, M. J. N., Bouma, S., Brasseur, S., Daan, R., Fijn, R. C., de Haan, Dirksen S.D., van Hal, R., Hille Ris Lambers, R., ter Hofstede, R., Krijgsveld, K.L., Leopold, M., and Scheidat. M Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. *Environ. Res. Lett.* **6** 035101

London Array Limited (LAL) (2005). London Array Offshore Wind Farm Environmental Statement. RPS plc.

Marine Scotland (2011) Habitats Regulations Appraisal of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Appropriate Assessment Information Review. Available at http://www.scotland.gov.uk/Publications/2011/03/04165857/17 Accessed 08.04.2011

Matthiopoulos, J., McConnell, B., Duck, C. & Fedak, M. (2004). Using satellite telemetry and aerial counts to estimate space use by grey seals around the British isles. J. Appl. Ecol. 41, 476-491.

Mendes, S. (2011) (JNCC) Sonia.Mendes@jncc.gov.uk. Galloper Offshore Wind Farm - advice on approach to marine mammal impact assessment. Correspondence via e mail - 18.08.11

Nedwell J R, Turnpenny A W H, Lovell J, Parvin S J, Workman R, Spinks J A L, Howell D (2007). *A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise*. Subacoustech Report Reference: 34R1231, Published by Department for Business, Enterprise and Regulatory Reform.

Nedwell, J.R, LAngworthy, J. and Howell, D (2003). Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impacts on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise. Report No.. 544 R 0424, A report to COWRIE. May 2003.

Nehls, G., Betke, K., Eckelmann, S. & Ros. M. (2007). Assessment and costs of potential engineering solutions for the mitigation of the impacts of underwater noise arising from the construction of offshore windfarms. BioConsult SH report, Husum, Germany. On behalf of COWRIE Ltd.

Northridge, S.P., Gordon, J.G., Booth, C., Calderan, S., Cargill, A., Coram, A., Gillespie, D., Lonergan, M. and Webb, A. 2010. Assessment of the impacts and utility of acoustic deterrent devices. Final Report to the Scottish Aquaculture Research Forum, Project Code SARF044. 34pp.

Parvin, S.J., Nedwell, J.R., Workman, R. (2006). Underwater noise impact modelling in support of the London Array, Greater Gabbard and Thanet offshore wind farm developments. Subacoustech Report No. 710R0515

Reid, J.B, Evans, P.G.H and Northridge, S.P. (2003). Atlas of cetacean Distribution in North-west European waters. JNCC, Peterborough

Royal Haskoning (2010). Galloper Wind Farm Project, Scoping Study. June 2010. Available at http://infrastructure.independent.gov.uk/wp-content/uploads/2010/07/Galloper-Scoping-report.pdf

SCOS (2009). (SCOS Report) Scientific Advice on Matters Related to the Management of Seal Populations: 2009. Available at www.smru.st-and.ac.uk SCOS, 2008

SCOS (2008). (SCOS Report) Scientific Advice on Matters Related to the Management of Seal Populations: 2008. Available at www.smru.st-and.ac.uk

SCOS (2007). (SCOS Report) Scientific Advice on Matters Related to the Management of Seal Populations: 2007. Available at www.smru.st-and.ac.uk

Seawatch Foundation, (2008). Cetaceans of eastern and south-east England. Regional fact sheets. Available at http://www.seawatchfoundation.org.uk./fact-sheets.php

Seawatch Foundation Fact Sheet (accessed 2011). Harbour porpoise. Available at http://www.seawatchfoundation.org.uk/fact-sheets.php

Sharples RJ, Matthiopoulos J, Hammond PS (2008). Distribution and movements of Harbour seals around the coast of Britain. Report to the Department of Energy and Climate Change (DECC). Sea Mammal Research Unit, St Andrews, UK, 65pp.

SMRU (2010). Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments Final Report. Report by The Sea Mammal Research Unit on behalf of The Crown Estate. August 2010

Subacoustech (2011). Nedwell, J. R., Brooker, A.G., Barham, R., Lovell, J. J., and Lambert, D. Galloper Offshore Wind Farm Project: Underwater Noise Impact Assessment Subacoustech Environmental Report No. E218R0119

Shepherd, B., Weir, C., Golightly, C., Holt, T. and Gricks, N. (2006). Underwater noise impact assessment on marine mammals and fish during pile driving of proposed round 2 offshore wind farms in the Thames Estuary. RPS report No. EOR0524 prepared for CORE Ltd.

SMRU (2006). SCANS II Small Cetaceans in the European Atlantic and North Sea. Available at http://biology.st-andrews.ac.uk/scans2/index.html

The Crown Esate (2008) The Area Involved. 10th Annual Report Published by The Crown Estate and the British Marine Aggregate Producers Association ISBN 978-1-906410-03-2

The Crown Esate (2010) The Area Involved. 13th Annual Report Published by The Crown Estate and the British Marine Aggregate Producers Association ISBN: 978-1-906410-25-4

Tougaard, J., Carstensen, J., Henriksen, O.D., Skov, H., and Teilmann, J. (2003). Short-term effects of the construction of wind turbines on harbour porpoises at Horns Reef. - Hedeselskabet, Roskilde, Denmark, 72 pp.

Tougaard, J., Carstensen, J., Wisz, M.S., Teilmann, J., and Bech, N.I. (2005). Harbour Porpoises on Horns Reef - Effects of the Horns Reef Wind Farm. Annual Status Report 2004 to Elsam Engineering A/S.

Tougaard, J., Carstensen, J., M. S. Wiesz, M. Jespersen, J. Teilmann & N. I. Bech. (2006a). Harbour porpoises on Horns Reef, effects of the Horns Reef wind farm. Final report to Vattenfall A/S. Roskilde, Denmark, NERI.

Tougaard, J.; Carstensen, J.; Bech, N. I. & Teilmann, J. (2006b). Final report on the effect of Nysted offshore wind farm on harbour porpoises - Annual Report 2005. Technical report to Energi E2 A/S. Ministry of the Environment, Roskilde, Denmark. NERI.

Thompson, P.M, McConnell, B.J., Tollit, D.J., Mackay, A., Hunter, C., Racey, P.A. (1996). Comparative distribution, moements and diet of harbour and grey seals from the Moray Firth, N.E. Scotland. Journal of Applied Ecology. 33: 1572-1584.

Thompson, C., Bexton, S., Brownlow, A., Wood, S., Patterson, T. Pye, K., Lonergan, M. and Milne, R. (2010). Report on recent seal mortalities in UK waters caused by extensive lacerations October 2010. Sea Mammal Research Unit.

Wildfowl and Wetland Trust (WWT) (2009). Distributions of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008. WWT Consulting. Report to Department of Energy and Climate Change.

Wilson. B., Battty. R.S., Daunt. F., Carter. C. (2007). Collision risks between marine renewable energy devices and mammals, fish and diving birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland, PA37 1QA.