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Anholt Offshore Wind Farm

Marine Mammals

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Table of contents

1. Summaries

1.1 Dansk resume

Baseline for de tre regelmæssigt forekommende havpattedyr i Projektområdet; Marsvin, Spættet Sæl og Gråsæl er beskrevet på basis af habitatmodeller udviklet på grundlag af historiske satellitsporingsdata (Spættet Sæl og Marsvin) og akustiske data (Marsvin) indsamlet i sommeren 2009. Påvirkninger på Marsvin og Spættet Sæl er vurderet ved at koble de identificerede habitater til støj-relateret forstyrrelse ved anvendelse af *in situ* målinger sammen med en frekvensrelateret effektvurdering af worst-case med anlæg af monopælfundamenter.

Mængden af data der var til rådighed omkring forekomsten af Marsvin og Spættet Sæl i Projektområdet før baseline var begrænset, men inkluderede satellitsporingsdata på begge arter, som blev indsamlet af Danmarks Miljøundersøgelser i perioden 2000-2008. I løbet af perioden 16 juni til 16 august blev disse data suppleret med akustiske data på marsvin indenfor og udenfor Projektområdet samt af malinger af baggrundsstøj. Derudover blev flytællingsdata på antallet af sæler på Anholt, Bosserne, Møllegrund, Hesselø og Læsø og observationer af Marsvin fra området mellem Djursland, Læsø og Anholt udført i.f.m. flybaserede vandfugletællinger mellem1999 and 2006 anvendt til vurderingen.

De dominerende gradienter i habitatkvaliteten for Marsvin og Spættet Sæl i de forskellige dele af den undersøgte region blev estimeret på basis af observationerne fra fly og satellitsporingsdata. Eftersom de to datasæt repræsenterer data med meget forskellige karakteristika blev der anvendt en robust statistisk metode til modellering af den gennemsnitlige habitatkvalitet i regionen. Korrelationer mellem miljøparametre og havpattedyrobservationer blev beregnet ved rumlig modellering (Ecological Niche Factor Analyse).

Målinger af undervandstøj viste kun små forskelle under de samme forhold, medens der blev registreret signifikante forskelle i forbindelse med passerende færger i regionen.

Observationerne af marsvin fra de flybaserede surveys reflekterede en bias mod de dybere og mere pelagiske dele af regionen, en situation som tydeligt påvirkede de modellerede habitatkvalitet for Marsvin. Den modellerede habitatkvalitet på basis af satellitsporingsdata indikerede, at den sydlige og centrale del af regionen og området nord for Anholt anvendes mere intensivt end de mere lavvandede områder med lavere saltholdighed og fladt havbundsrelief. Selvom enkelte observationer af Marsvin blev gjort i den sidste type af områder, faldt satellitsporingerne generelt indenfor de estimerede områder med høj habitatkvalitet. Habitatkvaliteten i Projektområdet blev klassificeret som medium til høj indenfor den undersøgte region i det nordvestlige Kattegat.

Klik-togsindeks (DPM per time) viste, at Marsvin forekom in Projektområdet gennem hele sommerperioden 2009. Maximum- og middel-DPM var generelt højest for station 2 og 4, og mindst for station 5 og 6. Maximum DPM-værdierne for station 2 og 4 var ca. 50 %. Middel-DPM for stationerne 2 og 4 var 1-2 pr. time, medens de var mindre end 1 DPM pr. time for de andre stationer. DPM-værdierne indikerede en forekomst af Marsvin, som kan karakteriseres som intermediær mellem den kystnære del af Nordsøen (højerere tætheder) og den vestlige Østersø (lavere tætheder).

Den modellerede habitatkvalitet på baggrund af alle tilgængelige satellitsporingsdata på Spættet Sæl fra kolonien på Anholt gav et relativt klart billede af tendenserne i arten's habitat i det nordvestlige Kattegat. De modellerede habitatkvalitetværdier indikerer forekomsten af et sammenhængende område med høj habitatkvalitet, som strækker sig i nord-sydlig retning fra kolonien og et mindre men veldefineret område lokaliseret 5 km østfor Projektområdet. Selve Projektområdet og hovedparten af regionen blev estimeret til at være uegnet som habitat for Spættet Sæl.

Påvirkningerne på alle tre havpattedyrarter som følge af emmissioner af undervandsstøj under anlægget af Anholt Havmøllepark vurderes at være moderate. Vurderingerne konkluderer, at hørezonen vil strække sig fra 20 til 80 km. Ved Projektområdet er baggrundsstøjen på 100 dB rms at 2 kHz (1/3 oktav bånd). Frekvenserne over 2 kHz vil ligge under niveauet for baggrundsstøj og Marsvin og sæler vil sandsynligvis ikke registrere dem over større afstande (> 50 km). En større zone med adfærdsreaktioner forventes for bade Marsvin og sæler; et realistisk estimat vil være en radius på mindst 20 km fra rammestedet for reaktioner fra de to arter. Denne radius fra Projektområdet vil inkludere områder med intermediær habitatkvalitet for Marsvin og høj habitatkvalitet for Spættet Sæl. Det forventes, at disse effekter vil have kort varighed, og at dyrene vil være i stand til at returnere til deres oprindelige habitat efter pæleramningsaktiviteterne. Maskering af kommunikationen mellem Marsvin og sæler under ramning kan forekomme over afstande på mere end 20 km fra kilden, men effekten forventes at være begrænset. Temporært tab af hørelsen (TTS) vurderes at kunne forekomme på en afstand af indtil 1,000 m hos Marsvin og 250 m hos sæler.

Andre påvirkninger under anlæg af havmølleparken forventes at være minimale. Under driften af mølleparken forventes ligeledes kun minimale påvirkninger af havpattedyr. Resultaterne indikerer således en mindre hørezone, og støjniveauer der er for lave til at kunne afstedkomme adfærdsreaktioner, maskering eller TTS hos Marsvin. Hos Spættet Sæl kan maskering forekomme indenfor en afstand på 1 km.

Afværgeforanstaltninger kan iværksættes for at reducere de potentielle TTS-effekter under pæleramning.

1.2 Summary

The baseline situation for the three regularly occurring species of marine mammals at the Project Area, Harbour porpoise, Harbour and Grey seal, has been described on the basis of habitat models applied to the available telemetry data and acoustic data recorded during summer 2009. Impacts on the regional populations of the two spe-

cies have been assessed by linking the identified habitats to noise-related disturbance using *in situ* measurements together with a frequency-related impact assessment.

Existing data on the abundance and distribution of Harbour porpoises and Harbour seals in the Project Area included Satellite telemetry data on both species, which have been collected during the period 2000-2008 by National Environmental Reseach Institute (NERI). These data was supplemented by acoustic data on Harbour porpoises recorded inside ad outside the project area and measurements of background subsea noise performed in the period 16 June to 16 August. In addition, data from aerial counts (total numbers) of seals on the haul-out sites Bosserne, Møllegrund, Hesselø and Læsø and Encounter rates (n/km) of Harbour porpoise in the area between Djursland, Læsø and Anholt obtained by 16 aerial waterbird line transect surveys between 1999 and 2006 were used to the assessment.

The major gradients in the suitability of habitats for Harbour porpoises and Harbour seals in various parts of the region were estimated on the basis of the aerial survey data and the telemetry data. As the two data sets represent data with strikingly different characteristics (telemetry=presence data, aerial surveys=presence/absence data) a robust statistical method was applied to model the mean habitat suitability of the region. To correlate the environmental variables of the area to the presence data of marine mammals a spatial modelling technique called Ecological Niche Factor Analysis (ENFA) was applied.

While differences between measurements with similar conditions were small, a big difference in background noise could be observed for varying maritime traffic. In other words, it can be expected that the ambient noise is influenced by ship traffic, especially the ferry traffic.

The observations of Harbour porpoises from the aerial surveys were biased towards the deeper and more pelagic south-easterly part of the region, a situation which clearly affected the modelled habitat suitability for Harbour porpoise. The modelled habitat suitability on the telemetry data indicates that the southern-central part of the region and the area north of Anholt is used more intensively than the shallower areas with lower salinity and more flat terrain. Although single records of porpoises were located in the latter type of areas, the satellite fixes generally fall within the predicted areas of high suitability. Accordingly, the habitat suitability of the Project Area classifies as medium to high within the range of habitat quality to porpoises found in the north-western Kattegat.

The click train indices (hourly DPM) show that Harbour porpoises were present in the Project Area throughout the summer period. Maximum and mean DPM-values were generally largest for stations 2 and 4, and smallest for stations 5 and 6. Maximum DPM levels for stations 2 and 4 were close to 50 %. Mean DPM values for stations 2 and 4 were 1-2 per hour, while they were less than 1 DPM per hour for the other stations, Table 3-3. The DPM values indicate an abundance of porpoises which may be considered as intermediate between the coastal North Sea (higher abundance) and the western Baltic (lower abundance).

The modelled habitat suitability of all records of Harbour seal satellite telemetry activities in the north-western Kattegat resulted in relatively clear estimates of the trends in habitat use of the species. The modelled habitat suitability values indicate clearly that a coherent area of high suitability is aligned north-south off the Totten colony and a smaller but well-defined is located just east of the Project Area. The Project Area itself seems to be unsuitable for Harbour seals coming from the Totten colony.

The impacts due to subsea noise emissions during the construction phase are assessed as moderate for all three species of marine mammals. Taking all possible uncertainties into account the assessment of impacts due to underwater noise emission during construction concluded that a zone of audibility will extend between 20 and 80 km from the source for the species. At the Project Area, background noise is 100 dB rms at 2 kHz (1/3 octave band). Frequencies higher than app. 2 kHz will be below background noise and porpoises and seals will most likely not detect them at large distances (> 50 km). A wide zone of responsiveness in Harbour porpoises and Harbour seals is estimated. As a realistic estimate, the responsive radius can be defined as at least 20 km from the construction site. For the entire Project Area of the Anholt OWF the range of 20 km will cover areas of intermediate habitat suitability to Harbour porpoises and high habitat suitability to Harbour seals in the Kattegat. However, these effects should be of short duration, allowing the animals to return to the areas of origin following pile driving activities. Masking of communication may occur in Harbour porpoises and seals over distances of more than 20 km from the source, yet the effect is assessed to be small. Temporal hearing loss (TTS) might occur at 1,000 m in Harbour porpoises and 250 m in seals.

Other impacts during construction are considered as minor. Noise from ships associated with the construction activity could lead to responsive reactions in Harbour porpoises and at close range (2-300 m).

During operation only minor impacts are envisaged. The results indicate a rather small zone of audibility and noise levels, at ranges smaller than 1,000 m are too low to induce responsiveness, masking or TTS in porpoises. There might be masking of Harbour seal sounds but this will happen at close ranges well below 1 km.

The potential major impacts related to the potential TTS zone during pile-driving operations can be mitigated, while the overall moderate impacts due to short- term responsive movements may be impossible to mitigate. A range of mitigation measures are recommended.

Regarding operational noise from the planned Universal Wind OWF and suspension of sediments, traffic and electromagnetic fields, no cumulative effects on marine mammals is expected.

2. Introduction

2.1 Background

In 1998 the Ministry of Environment and Energy empowered the Danish energy companies to build offshore wind farms of a total capacity of 750 MW, as part of fulfilling the national action plan for energy, Energy 21. One aim of the action plan, which was elaborated in the wake of Denmark's commitment to the Kyoto agreement, is to increase the production of energy from wind power to 5.500 MW in the year 2030. Hereof 4.000 MW has to be produced in offshore wind farms.

In the years 2002-2003 the two first wind farms was established at Horns Rev west of Esbjerg and Rødsand south of Lolland, consisting of 80 and 72 wind turbines, respectively, producing a total of 325,6 MW. In 2004 it was furthermore decided to construct two new wind farms in proximity of the two existing parks at Horns rev and Rødsand. The two new parks, Horns rev 2 and Rødsand 2, are going to produce 215 MW each and are expected to be fully operational by the end 2010.

The 400 MW Anholt Offshore Wind Farm constitutes the next step of the fulfilment of aim of the action plan. The wind farm will be constructed in 2012, and the expected production of electricity will cover the yearly consumption of approximately 400.000 households. Energinet.dk on behalf of the Ministry of Climate and Energy is responsible for the construction of the electrical connection to the shore and for development of the wind farm site, including the organization of the impact assessment which will result in the identification of the best suitable site for constructing the wind farm. Rambøll with DHI and other sub consultants are undertaking the site development including a full-scale Environmental Impact Assessment for the wind farm.

The present report is a part of a number of technical reports forming the base for the Environmental Impact Assessment for Anholt Offshore Wind Farm.

The Environmental Impact Assessment of the Anholt Offshore Wind Farm is based on the following technical reports:

- Technical Description
- Geotechnical Investigations
- Geophysical Investigations
- Metocean data for design and operational conditions
- Hydrography including sediment spill, water quality, geomorphology and coastal morphology]
- Benthic Fauna
- Birds
- Marine mammals
- Fish
- Substrates and benthic communities

- Benthic habitat
- Maritime archaeology
- Visualization
- Commercial fishery
- Tourism and Recreational Activities
- Risk to ship traffic
- Noise calculations
- Air emissions

2.2 Content of memo

This memo describes the results of the baseline investigations and the impact assessment on marine mammals. Three species of marine mammals occur regularly within the region; Harbour porpoise (Phocoena phocoena), Harbour seal (Phoca vitulina) and Grey seal (Halichoerus grypus). Thus, baseline investigations and impact assessment on marine mammals focus on these three species. The memo is divided into chapters describing methods and results for the baseline study and environmental impact assessment. Separate chapters are covering mitigation measures, cumulative impacts and decommissioning, as well the assessment of impacts due to the sub-station and offshore cable.

Factors which may affect marine mammal species includes generation of underwater noise, physical disturbances and secondary effects such as disturbance of navigation patterns due to the presence of the wind farm. The impact assessment be based on existing knowledge of the sensitivity of marine mammals to underwater noise and other disturbances largely following the methods developed and applied during the assessments of the impact of the Horns Rev1, Horns Rev 2, Nysted and Rødsand 2 offshore wind farms /1/, /2/, /3/, /4/,/5/,/6/,/7/,/8/, /23/.

In addition, the assessment will draw upon the experiences from the monitoring activities related to the construction and operation of the above mentioned wind farms. Compared to the environment of the planned Anholt OWF, the OWFs at Horns Rev and Nysted have slightly shallower depth, and roughly the same dimensions as Anholt. The wave conditions at Anholt are intermediate to those found at Horns Rev and Nysted. The most striking difference between the three locations in terms of marine mammals is the larger population of Harbour porpoise found at Horns Rev (500-1000 animals,

/9/).

The scope includes impact assessments for two different foundation designs. In addition, the cumulative effects of all ongoing and planned activities in the region on marine mammal populations in the Kattegat will be assessed.

3. Offshore wind farm

3.1 Project description

This chapter describes the technical aspects of the Anholt Offshore Wind Farm. For a full project description reference is made to /66/. The following description is based on expected conditions for the technical project; however, the detailed design will not be done until a developer of the Anholt Offshore Wind Farm has been awarded.

3.1.1 Site location

The designated investigation area for the Anholt Offshore Wind Farm is located in Kattegat between the headland Djursland of Jutland and the island Anholt – see Figure 3-1. The investigation area is 144 km2, but the planned wind turbines must not cover an area of more than 88 km2. The distance from Djursland and Anholt to the project area is 15 and 20 km, respectively. The area is characterised by fairly uniform seabed conditions and water depths between 15 and 20 m.

3.1.2 Offshore components

3.1.2.1 Foundations

The wind turbines will be supported on foundations fixed to the seabed. The foundations will be one of two types; either driven steel monopiles or concrete gravity based structures. Both concepts have successfully been used for operating offshore wind farms in Denmark /77/, /78/.

The monopile solution comprises driving a hollow steel pile into the seabed. A steel transition piece is attached to the pile head using grout to make the connection with the wind turbine tower.

The gravity based solution comprises a concrete base that stands on the seabed and thus relies on its mass including ballast to withstand the loads generated by the offshore environment and the wind turbine.

3.1.2.2 Wind turbines

The maximum rated capacity of the wind farm is by the authorities limited to 400 MW

/79/. The farm will feature from 80 to 174 turbines depending on the rated energy of the selected turbines corresponding to the range of 2.3 to 5.0 MW.

Preliminary dimensions of the turbines are not expected to exceed a maximum tip height of 160 m above mean sea level for the largest turbine size (5.0 MW) and a minimum air gap of approximately 23 m above mean sea level. An operational sound power level is expected in the order of 110 dB(A), but will depend on the selected type of turbine.

The wind turbines will exhibit distinguishing markings visible for vessels and aircrafts in accordance with recommendations by the Danish Maritime Safety Administration and the Danish Civil Aviation Administration. Safety zones will be applied for the wind farm area or parts hereof.

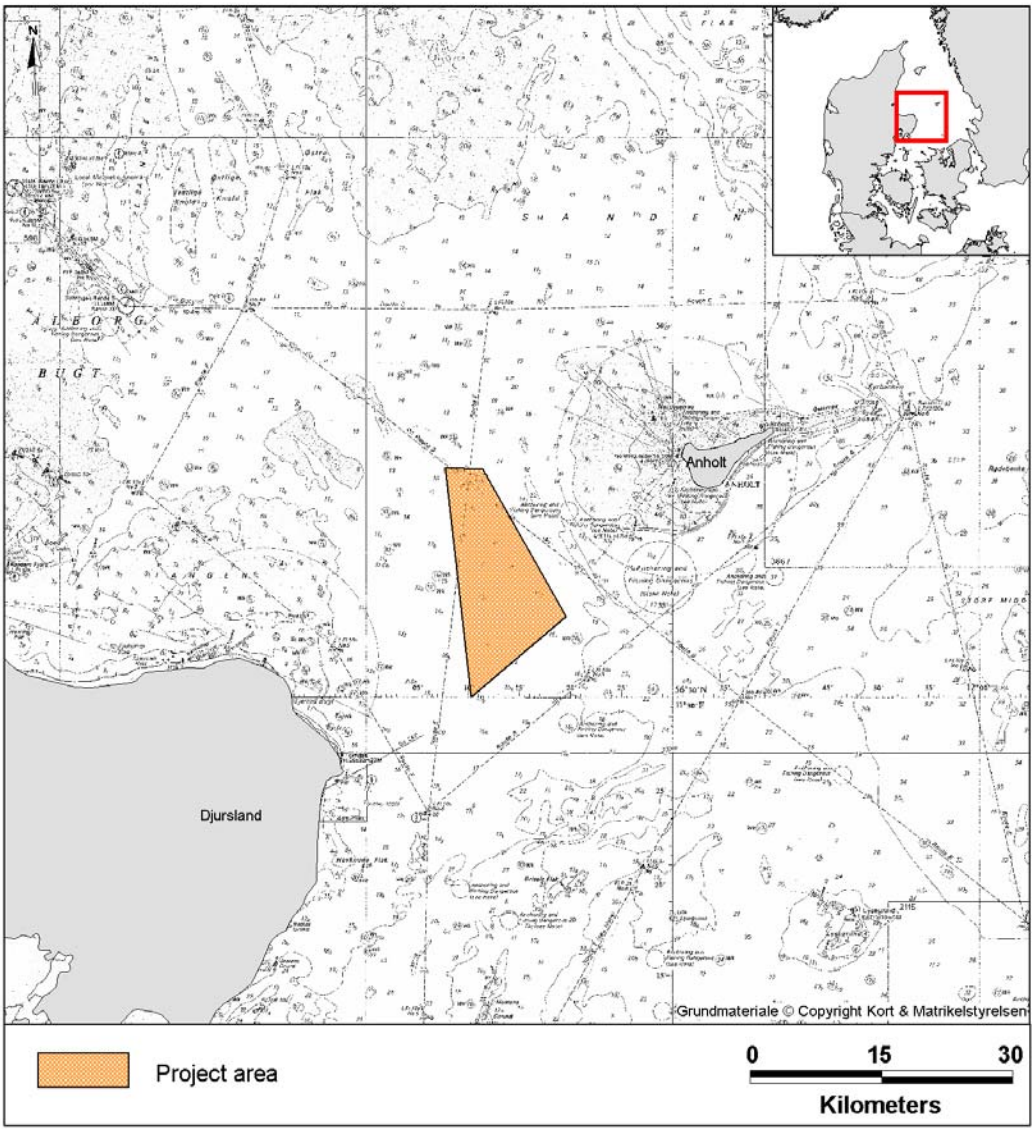


Figure 3-1 Location of the Anholt Offshore Wind Farm project area.

3.1.3 Installation

The foundations and the wind turbine components will either be stored at an adjacent port and transported to site by support barge or the installation vessel itself, or transported directly from the manufacturer to the wind farm site by barge or by the installation vessel.

The installation will be performed by jack-up barges or floating crane barges depending on the foundation design. A number of support barges, tugs, safety vessels and personnel transfer vessels will also be required.

Construction activity is expected for 24 hours per day until construction is complete. Following installation and grid connection, the wind turbines are commissioned and are available to generate electricity.

A safety zone of 500 m will be established to protect the project plant and personnel, and the safety of third parties during the construction and commissioning phases of the wind farm. The extent of the safety zone at any one time will be dependent on the locations of construction activity. However the safety zone may include the entire construction area or a rolling safety zone may be selected.

3.1.3.1 **Wind turbines**

The installation of the wind turbines will typically require one or more jack-up barges. These vessels stand on the seabed and create a stable lifting platform by lifting themselves out of the water. The area of seabed taken by a vessels feet is approximately 350 m2 (in total), with leg penetrations of up to 2 to 15 m (depending on seabed properties). These holes will be left to in-fill naturally.

3.1.3.2 **Foundations**

The monopile concept is not expected to require any seabed preparation.

The installation of the driven monopiles will take place from either a jack-up platform or an anchored vessel. In addition, a small drilling spread may be adopted if driving difficulties are experienced. After transportation to the site the pile is transferred from the barge to the jack-up and then lifted into a vertical position. The pile is then driven until target penetration is achieved, the hammer is removed and the transition piece is installed.

For the gravity based foundations the seabed needs most often to be prepared prior to installation, i.e. the top layer of material is removed and replaced by a stone bed. The material excavated during the seabed preparation works will be loaded onto split-hopper barges for disposal. There is likely to be some discharge to water from the material excavation process. A conservative estimate is 5% material spill, i.e. up to 200 m3 for each base, over a period of 3 days per excavation.

The installation of the concrete gravity base will likely take place using a floating crane barge, with attendant tugs and support craft. The bases will either be floated and towed to site or transported to site on a flat-top barge. The bases will then be lowered from the barge onto the prepared stone bed and filled with ballast.

After the structure is placed on the seabed, the base is filled with a suitable ballast material, usually sand. A steel 'skirt' may be installed around the base to penetrate into the seabed and to constrain the seabed underneath the base.

3.1.4 **Protection systems**

3.1.4.1 **Corrosion**

Corrosion protection on the steel structure will be achieved by a combination of a protective paint coating and installation of sacrificial anodes on the subsea structure. The anodes are standard products for offshore structures and are welded onto the steel structures.

3.1.4.2 **Scour**

If the seabed is erodible and the water flow is sufficient high a scour hole will form around the structure. The protection system normally adopted for scour consists of rock placement in a ring around the in-situ structure. The rock will be deployed from the host vessel either directly onto the seabed from the barge, via a bucket grab or via a telescopic tube.

For the monopile solution the total diameter of the scour protection is assumed to be 5 times the pile diameter. The total volume of cover stones will be around 850-1,000 m^3 per foundation. For the gravity based solution the quantities are assessed to be 800–1100 m^3 per foundation.

3.2 Protection of marine mammals

A number of international treaties, agreements and regulations have been enacted in order to protect marine mammals. All three species is preserved according to Danish law and listed in Annex II of the Habitats Directive (92/43/EEC), which concerns species that require the establishment of designated Special Areas of Protection (NATURA 2000 areas). Accordantly all species are included in the basis of designation for a number of NATURA 2000 areas in the Kattegat (Figure 3-2).

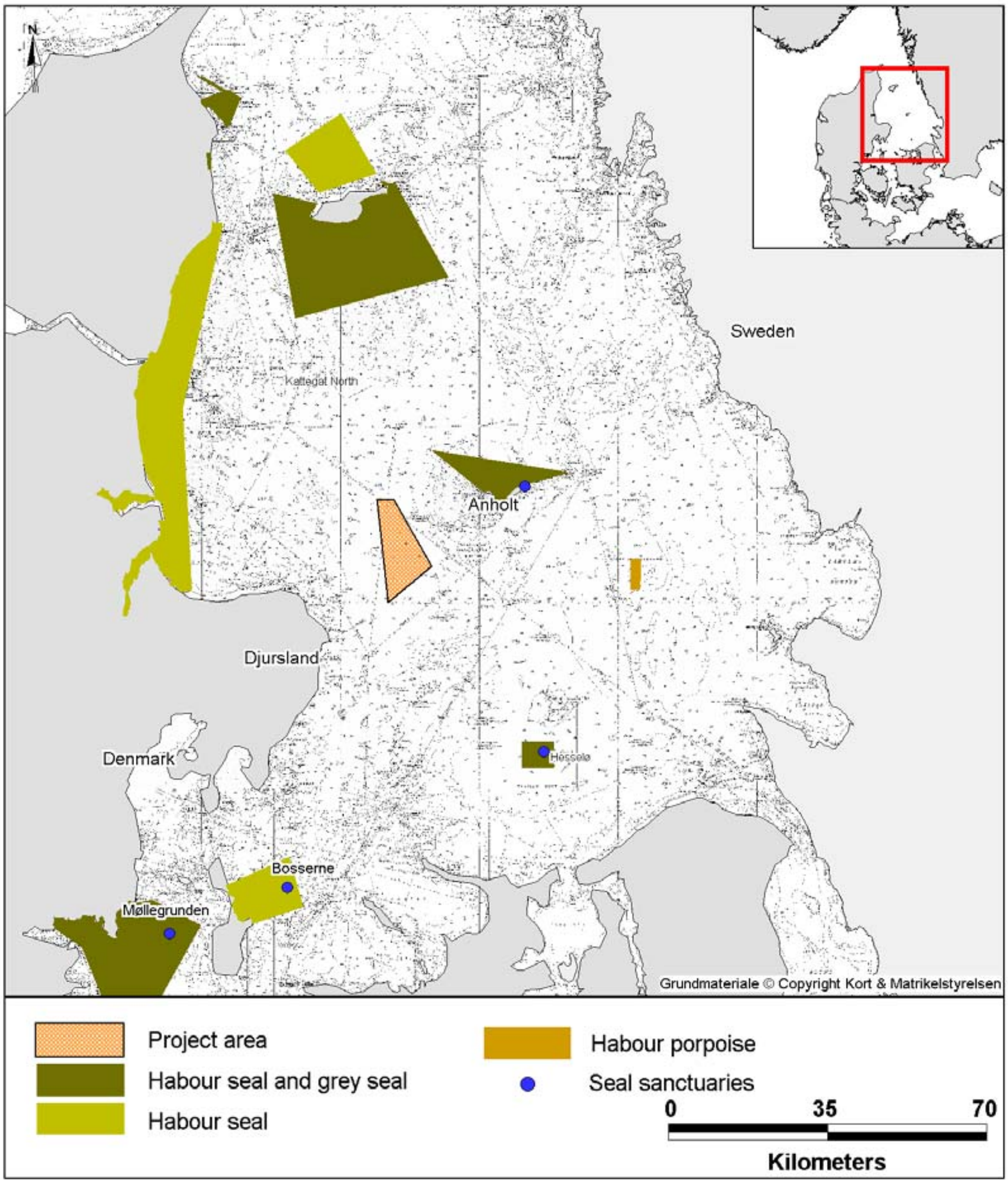


Figure 3-2 NATURA 2000 areas in Kattegat where Harbour seal, Grey seal and Harbour porpoise are part of the designation. The figure furthermore shows seal sanctuaries.

Harbour porpoise is furthermore listed in Annex IV in the Habitats directive, which contains a more general protection. The wording of the consolidation act, regarding Annex IV is basically very restrictive and declares that it is prohibited to authorizes or approve plans and the like that can damage or destroy breeding places or resting places for special designated species no matter a project takes place inside or outside the Special Areas of Conservation as well as inside /63/. The commission though has elaborated guidelines concerning the protection of Annex IV species in the Habitats Directive and in this connection a more flexible protection is introduced. This protection is based on a broader ecological comprehension that addresses maintenance of a continued ecological functionality /64/.

Both Harbour porpoise and seals are protected by Danish law and must not be an object for hunting activities. Consequently, a number of important breeding locations in Danish waters have been appointed as seal sanctuaries, including Totten on Anholt, Hesselø and Bosserne and Møllegrunden (Figure 3-2). Furthermore the Danish Nature and Forest Agency have elaborated action plans establishing guidelines for the management of both Harbour porpoises and seals in Denmark /70/,/75 /. The primary goal of the action plan is to ensure the marine mammals optimal conditions and robust populations and thereby ensuring their general survival.

Finally, all three species is included in the Convention on the Conservation of European Wildlife and Habitats (Bern Convention). In addition, Denmark is a signatory to the agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) and has applied its provisions, including Resolution No. 4 on Disturbance. These include the requirement that the signatories work towards the prevention of disturbance, e.g. from acoustic noise. Harbour and Grey seals are included in the recommendations from Helsinki Commission (HELCOM) regarding the seal populations in the Baltic area (Baltic Sea, the Belts and the Kattegat) and furthermore mentioned in the Bonn convention.

3.3 Baseline study

The baseline study charts the distribution of marine mammals in the Kattegat with particular interest on the marine mammal's affiliation to the project area. This includes an extensive field program charting occurrences of Harbour porpoise in the vicinity of the project area and measurements of background noise. In addition, the baseline study analyses the spatial gradients and suitability of habitats for Harbour porpoise and Harbour seal based on satellite telemetry data.

3.3.1 Methods

Data concerning marine mammals comes from two sources; historic data made available specifically for this assessment by National Environmental Research Institute (NERI) and time series of acoustic click detections of Harbour porpoises collected during June-August 2009. In addition, measurements of background subsea noise levels were obtained in June 2009. The data collected by NERI cover:

- Aerial counts (total numbers) of seals on the haul-out sites Bosserne, Møllegrund, Hesselø and Læsø;

- Satellite tracking data (presence) 2000-2008 on Harbour seal and Harbour porpoise in the entire Kattegat, location class 1-3;

- Encounter rates (n/km) of Harbour porpoise in the area between Djursland, Læsø and Anholt obtained by 16 aerial line transect surveys between 1999 and 2006. The line transect surveys were designed to count waterbirds.

Description of methods used by NERI for satellite telemetry of seals and porpoises are described in /71/ and /10/, while the methods used for the line transect counts of porpoises are described in /11/.

3.3.1.1 Determination of spatial gradients in habitat suitability

The major gradients in the suitability of various parts of the region as habitats to Harbour porpoises and Harbour seals were estimated on the basis of the aerial survey data and the telemetry data made available by NERI. As the two data sets represent data with strikingly different characteristics (telemetry=presence data, aerial surveys=presence/absence data) a robust statistical method was applied to model the mean habitat suitability of the region. To correlate the environmental variables of the area to the presence data of marine mammals a spatial modelling technique called Ecological Niche Factor Analysis (ENFA) was applied. ENFA has been successfully applied to presence-only data in terrestrial /14/ and marine ecology /15/ and basically estimates the environmental gradients in presence data. The method is highly applicable to telemetry and lines transect survey data as the method is indifferent to the high level of spatial and serial autocorrelation which lies within these types of information. The outputs of ENFA show two key aspects of the investigated species' habitat: marginality and specialization. Habitat marginality can be defined as the direction on which the species habitat differ the most from the available conditions in the north-western Kattegat. Habitat specialization is defined as the ratio of the standard deviation of the global distribution to that of the species distribution.

ENFA tests were made using the aggregated telemetry and survey data for the whole period between 1999 and 2008 and presence data were aggregated into grids of 667 m resolution. To fully understand the foraging ecology of predators also the information about the conditions under which predators forage is needed. Prey availability is often correlated with physical and biological properties of the ocean. Accordingly, the following physical oceanographically variables were included in the statistical analyses:

1. V = Long-shore current vector at the surface (m/s);
2. S = Salinity at the surface (psu);
3. Gradient in V, measured as the slope of each grid cell based on the cell resolution and the values of the immediate neighbouring cells to the top, bottom, left and right of the cell in question using the following formula:

$$Tangent = \sqrt{\left(\left(\left(right - left\right)/\left(res \bullet 2\right)\right)^2 + \left(\left(top - bottom\right)\left(res \bullet 2\right)\right)^2\right)}$$

which measures the tangent of the angle that has the maximum downhill slope; left, right, top, bottom are the attributes of the neighbouring cells and res is the cell resolution;

4. Gradient in S, same GIS method as 3;
5. Bathymetry: negative values;
6. Bottom relief: slope same GIS method as 3;
7. Bottom complexity (F) calculated for 5x5 kernel: F = (n-1)/(c-1) Where n = number of different classes present in the kernel, c = number of cells;
8. Distance to shallow areas (< 6 m water depth): Euclidean distance in m from each cell.

3.3.1.2 Analysis of spatial variation in the indicators

DPM indicator values were assumed to be affected by the following factors: Station, C-POD-number, year, season and month. In addition DPM (Detection-positive minutes per hour)was assumed affected by diurnal phase. The influence of the different factors was tested with a linear model using a factorial design by the equation:

μ = station + year + season (year) month (season, year) + day/night + C-POD-number

The analysis of environmental factors as predictors for indicators of acoustic activity was carried out using a combined factorial and polynomial model design in PLS regression analysis. PLS regression is an extension of the multiple linear regression model and is used to predict responses of species to different environmental factors. The dynamic environmental parameters listed in chapter 7.1.1 were extracted as hourly and daily means from the DHI NOVANA hydrodynamic model data and added to the existing synoptic DPM and EPD (Encounters per day) data.

3.3.1.3 C-Pod investigations

The C-POD is a self-contained and fully automated system for the detection of echolocation clicks from Harbour porpoises and other cetaceans. It is programmable via specialized software. The C-POD consists of a hydrophone, a digital click detector, a digital timer and a duration logger.


Figure 3-3. The C-POD used in the project.

3.3.1.3.1 **Statistical analysis**

A classic BACI design (ANOVA area-time factorial design) was applied the acoustic measurements testing the effects of a number of variables such as year and treatment (pre-construction and post-construction). The main hypothesis being tested is that acoustic activity of Harbour porpoises at the Anholt OWF will be reduced during the construction phase, but will return to 'background levels' during the post-construction phase. Once the OWF site has been determined it is likely that the design needs modification to increase the power of the statistical model used to describe the acoustic activity.

3.3.1.3.2 **Deployment and data processing**

Three impact stations, each equipped with 2 C-PODs, were placed inside the Project Area, and three reference stations were placed outside the Project Area. The location of the six acoustic stations was determined by the expected main environmental gradient in the area from north to south /1/.

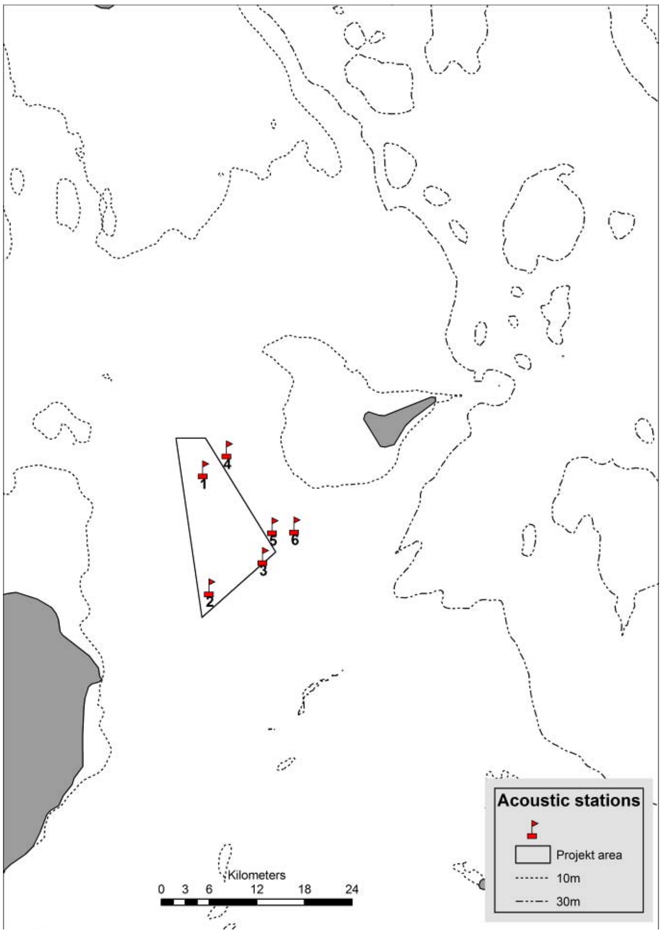


Figure 3-4. Map showing the location of the six acoustic stations.

The C-PODs were deployed 17 June 2009 using the mooring system depicted in Figure 3-5. Two C-PODs are attached to a rope 5 and 8 m above the sea floor. A small anchor attaches the C-POD rope to the sea floor, and is attached by a 60 m wire to a large anchor block.

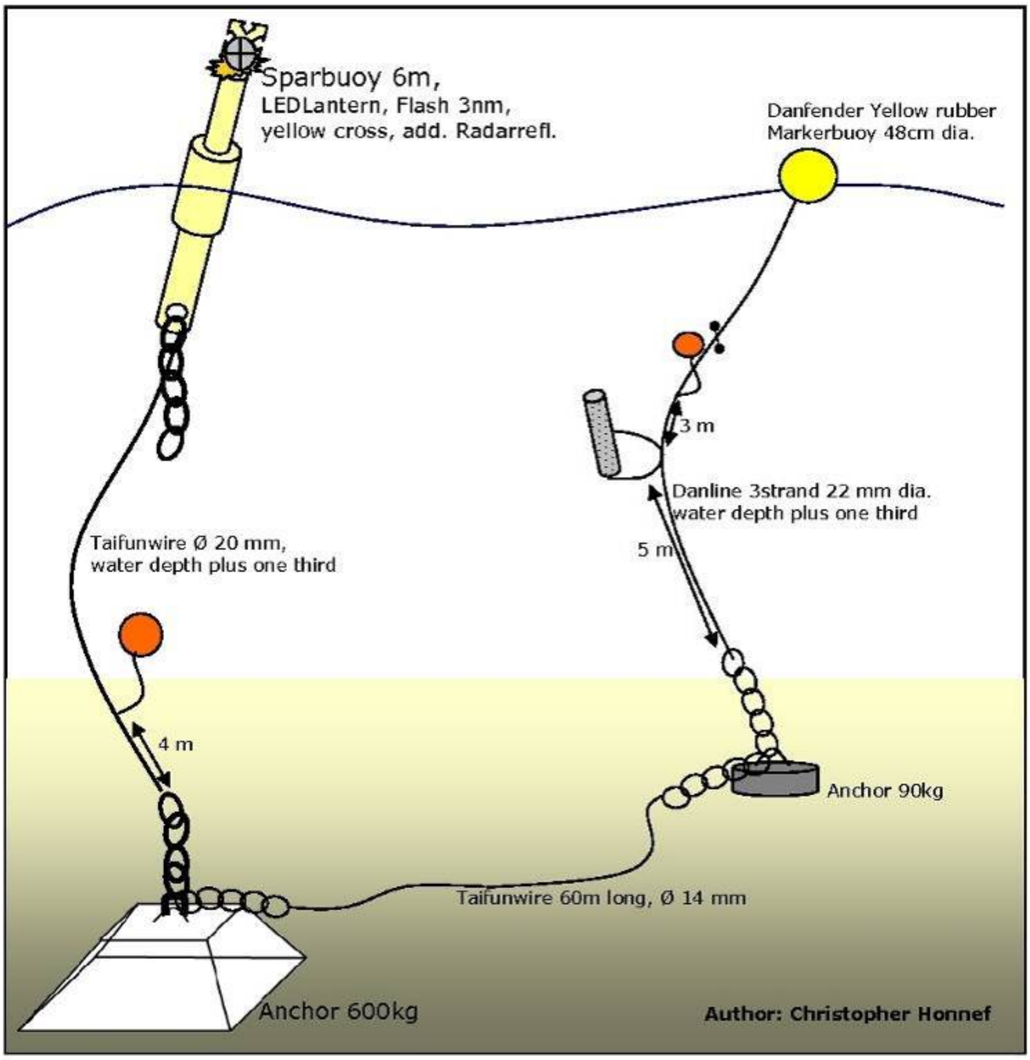


Figure 3-5. Mooring system applied for the acoustic baseline program at Anholt OWF.

All acoustic recordings were processed with the C-Pod software, provided by Chelonia Ltd. (http://www.chelonia.co.uk/html/pod.html). An overview of the C-PODs and the C-POD-software, including a manual for data-acquisition and analysis, can be found at http://www.chelonia.co.uk/html/pod.html and in /13/.

Detection-positive minutes per hour (DPM): number of minutes with positive clicks train detections, were used as an index of acoustic activity, indicating a higher presence of porpoises.

3.3.1.4 **Underwater noise measurements**

The measurements were performed from the vessel "Blue Vega" at the C-POD position 2 and 4 (Figure 3-4) using the same spot-measurement methodology used for the Horns Rev 1, Nysted, Horns Rev 2 and EIA for the Rødsand 2 OWFs /82/. Measurements were performed on June 8th-9th 2009 at wind speeds ranging from 3 to 9 m/s. The background noise in this position was measured without and with ferries passing by closely to the position and underwater noise was measured when both machinery and generator were switched off and therefore did not influence the measurement results.

The frequency range used in the investigation (10 Hz to 100 kHz) includes frequencies that are audible for seals and Harbour porpoise. All measurements of underwater noise were converted to 1/3 octave bands levels (dB re. 1 µPa).

The following measurement equipment has been used:
- B&K 8101 hydrophone which included 10 Hz high pass filter
- B&K 2804 power supply (with outside power supply)
- B&K 2693 Nexus DeltaTron amplifier (10 Hz high pass filter)
- Roga plug.n DAQ (data acquisition)
- PicoScope PC Oscillopscope 3224
- Highpass filter 500 Hz
- Laptop with data acquisition PTAanalyzer, PicoScope and PicoLog Recorder
- B&K 4223 calibrator

The measurements were performed with the use of hydrophones. Prior to the measurements the acoustic system was calibrated against noise coming from the system itself. The hydrophone was positioned 7 to 8 meters below the water surface, which was approximately halfway between the surface and the seabed (Figure 3-6). The signals were recorded by the in-house data acquisition programme PT-Analyzer (in conjunction with a Roga plug.n.DAQ) in the frequency range up to 20 kHz. Signals in 20-100 kHz frequency range were recorded through a PicoScope Oscilloscope with a high-pass filter using the data acquisition programmes PicoScope and PicoLog Recorder.

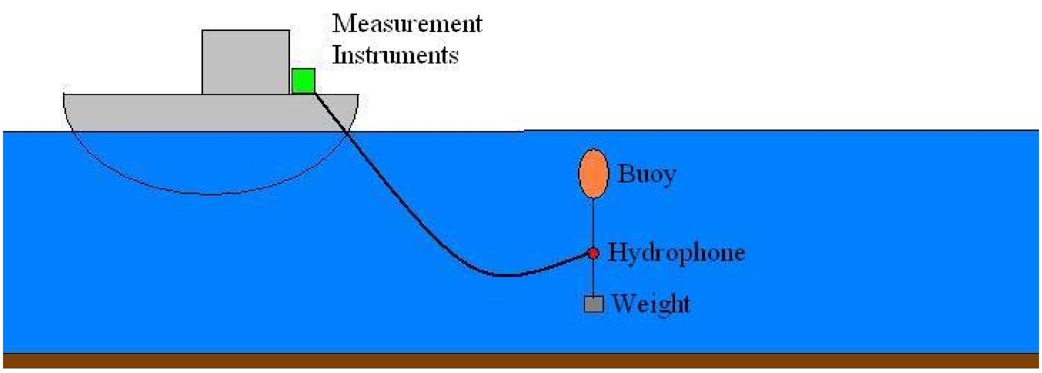


Figure 3-6. The field-test set-up for underwater noise measurements.

3.3.2 Transmission loss calculations

Transmission loss calculations are used to estimate the spreading of the underwater noise. As wind turbines are currently planned in relatively shallow waters below 50 m transmission loss might be described by cylindrical spreading, 10 log R /17/. However, several field studies indicate a higher transmission loss in shallow waters, depending on local conditions /18/, /19/. The following formula is developed for coastal North Sea waters with a sandy bottom and wind-speeds up to 20 knots/22/:

$$TL = (16.07 + 0.185\ FL)\ (\log (r/1.000\ m) + 3) + (0.174 + 0.046\ FL + 0.005\ FL^2)\ r$$

(FL = 10 log (f / 1 kHz; 1 m - 80 km, Frequencies f in kHz (100 Hz - > 10 kHz))

The advantage of this particular formula is that the frequency dependent attenuation is taken into account. Control measurements in the field have showed that this transmission loss model is quite feasible for waters with a similar bathymetry as north-western Kattegat /22/. The assessment of noise influences based on this formula can therefore be viewed as quite realistic and hence reliable.

The formula predicts sound levels at different distances from the source. As distance from the source increases, sound levels decrease to a point where the animal cannot detect the noise.

3.3.3 Background subsea noise

The primary source of the underwater noise in the project area is caused by ferries, which crosses in vicinity of the area (Figure 3-7 and Figure 3-8). The frequency range up to 20 kHz and is increased by up-to 20 dB when a ferry is passing by.

No significant difference is observed between the noise levels at the two different measurement positions (Figure 3-9, Figure 3-10). As the small differences observed are within the measurement uncertainty, it can be concluded that the ambient noise level for the measured positions can be regarded as equal.

The underwater ambient noise level was determined by the bubbles and waves, which are dependent on wind speed. While differences in measurements under similar conditions are small, there are big differences when maritime traffic passes. Each passing contributes to the background noise in the planned offshore wind farm, which concurs with experiences from other offshore wind farms /3//16/.

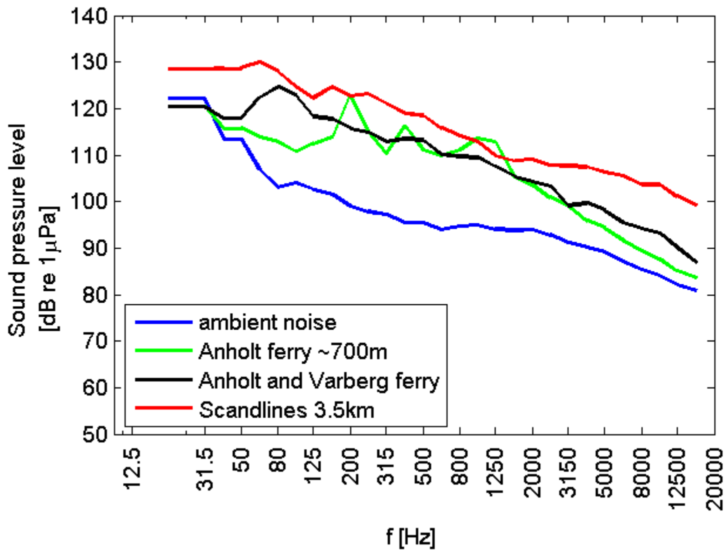


Figure 3-7. Underwater noise measured at position 2, with different ship traffic. The frequency range from 10 Hz to 20 kHz is shown as sound pressures given in 1/3-octave bands.

Figure 3-8. Ferries passing by Position 2 while measuring. Figure (A) shows the Anholt ferry, Figure (B) shows the ferry going from Grenå to Varberg and Figure (C) shows a Scandlines ferry. This ferry is not passing by regularly.

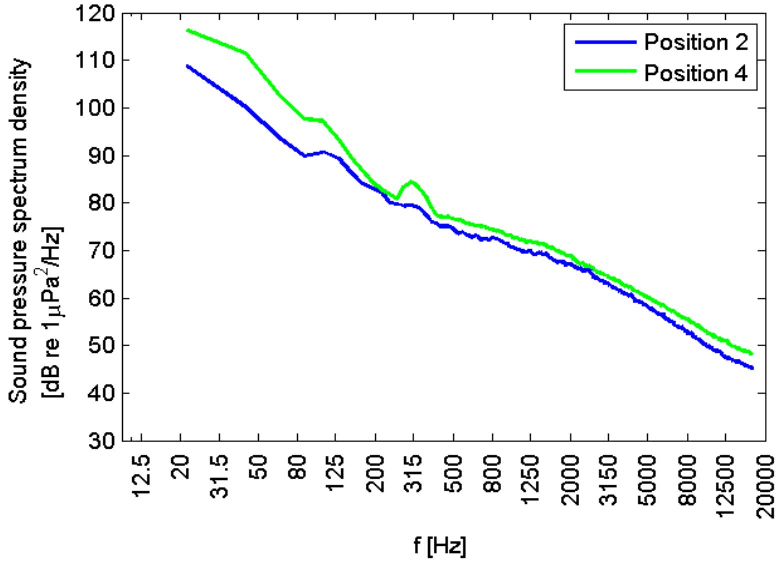


Figure 3-9. Averaged power spectral density level for Position 2 and Position 4 in the frequency range of 10 to 20000 Hz, which is shown as sound pressures given in Power Spectral Density (PSD).

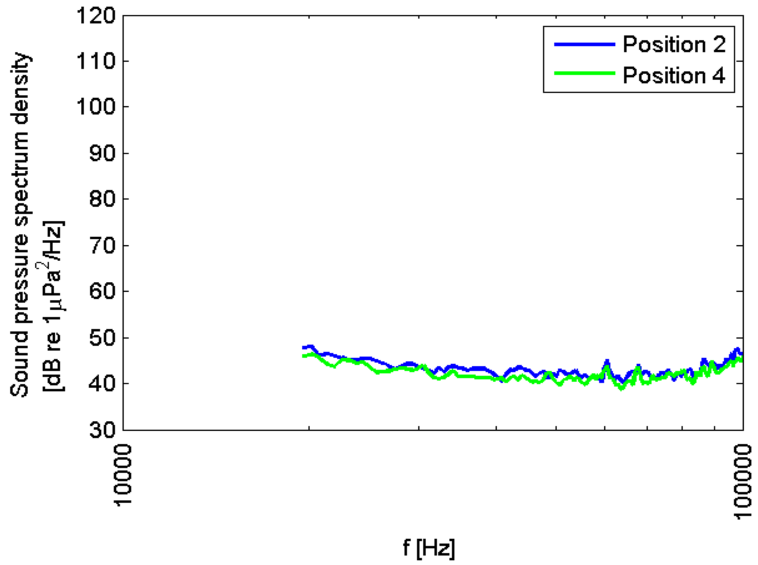


Figure 3-10. Averaged power spectral density level for Position 2 and Position 4 in the frequency range of 20 to 100 kHz, which is shown as sound pressures given in Power Spectral Density (PSD).

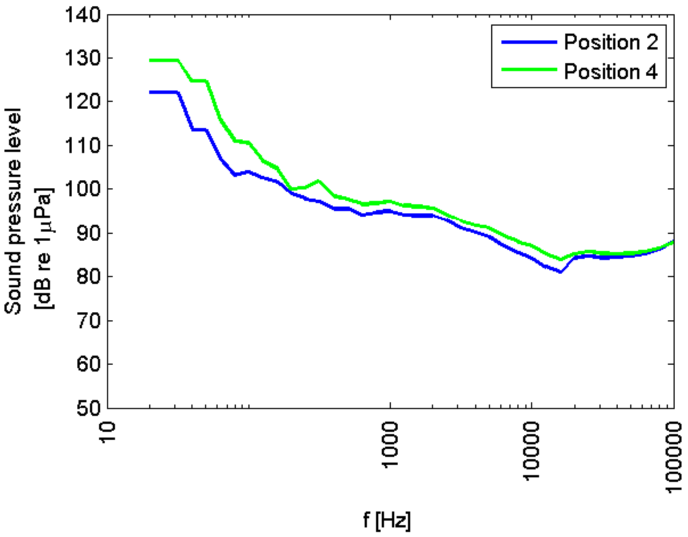


Figure 3-11. Sound pressure level in 1/3-octave-bands for Position 2 and Position 4 in the frequency range of 20 to 100000 Hz.

3.3.4 Harbour porpoise

Harbour porpoise is the only cetacean, which live on a regularly basis in the inner Danish waters. Full-grown individuals measures only 1.5-1.8 meter and weighs about 55-65 kg and accordantly the Harbour porpoise is among the smallest whales in the world. The colouration is grey-blue with a light grey or white abdomen.

Figure 3-12. Harbour porpoise female with calf.

The Harbour porpoise males reaches maturity at age 2-3, at a length of approximately 1,3-1,4 meter, whereas the female matures at age 3-4 measuring about 1,4-1,5 meters. The mating finds place in late summer and the female is pregnant for a period of 11 months. The newborn calf is about 0,7-0,8 meters long weighing about 10 kg and suckle almost a year. Normally females give birth to a calf every year.

The Harbour porpoise is very versatile when it comes to the choice of food, which depends of the availability of prey in the specific areas. The diet comprises of all kinds of fish such as gadoids, herrings, flat fish, which the Harbour porpoise catches either in the water column or by disturbing the bottom sediment to lure out the prey. Squids often constitute another important part of the diet.

3.3.4.1 Distribution and habitat suitability

The Harbour porpoise normally travels in groups of 2-5 individuals, but are often found in larger groupings. The population of Harbour porpoise in Danish waters can be divided into 3 subpopulations. The first includes the North Sea, and the northern part of Kattegat (north of Læsø). The second constitutes the inner Danish waters and the third a small population in the Baltic. The inner Danish waters, which contains the Anholt OWF Project Area is a high-density area for porpoises housing approximately 37.000 individuals/11/. The data however also suggest that abundance inside the region is highly variable and that high-density areas within the region is confined to the Little Belt and Great Belt region, whereas the north-western Kattegat is a low-density area. The locations closets to the Anholt OWF, which is of importance for porpoises, is the area north of Samsø and Middelgrunden east of Anholt, which used frequently in summertime /11/.

The modelled habitat suitability of all sightings of Harbour porpoises from aerial waterbird surveys and records from satellite telemetry activities in the north-western Kattegat evaluated with a combination of topographic and hydrodynamic variables partly resulted in contradicting and partly in analogous estimates of the trends in habitat use of the species. The overall marginality of the habitat use indicated by the telemetry data was higher (0.47) than for the aerial survey data, while the overall specialisation score was higher for the aerial survey data (1.48 vs. 1.03), showing that porpoise habitat differs from the mean conditions found in the north-western Kattegat, and that they are quite restrictive on the range of conditions. According to both the telemetry and survey data gradients in surface salinity are a major habitat characteristic. The marginality coefficients for telemetry data further indicated sea-bed's with high complexity and relief as well as high surface salinity as key drivers separating porpoise habitats from the general conditions in the region. The survey data on the other hand indicated deeper areas with lower salinity as key drivers of habitat marginality.

Both telemetry and survey data gave high habitat specialisation scores for the deeper parts of the regions, while the surveys also gave high scores for higher surface salinity, showing that within the identified marginal habitats Harbour porpoises seem to make more use of the pelagic than benthic (shallower, less saline) environments.

The computed habitat suitability illustrate how the observations of Harbour porpoises from the aerial surveys are biased towards the deeper and more pelagic south-easterly part of the region, a situation which clearly affected both the marginality and specialisations coefficients and the modelled trends in habitat suitability (Figure 3-13). The modelled habitat suitability on the telemetry data indicates that the southern-central part of the region and the area north of Anholt is used more intensively than the shallower areas with lower salinity and more flat terrain. Although single records of porpoises were located in the latter type of areas, the satellite fixes generally fall within the predicted areas of high suitability. The modelled suitability according to the survey data, on the other hand, indicated less use of the deeper and more saline area to the southeast, and the shallows at Anholt. Due to the obvious bias in the coverage of the survey data the results of the telemetry data are retained for the assessment of impacts. Accordingly, the habitat suitability of the Project Area is classified as medium to high within the range of habitat quality found in the north-western Kattegat. Tests of model robustness (Receiver Operating Characteristics) are included in Appendix 1.

Table 3-1. Results of the ecological niche factor analysis for the aerial survey observations of Harbour porpoises. Coefficient values for the marginality factor are given. Positive/negative values mean that porpoises prefer location with higher/lower values than average for the modelled area.

Variable	Marginality
Water depth	0.593
Seabed complexity	-0.180
Distance to shallows (6 m)	-0.230
Gradient in surface salinity	0.391
Gradient in surface current velocity	0.334
Surface salinity	-0.545
Seabed terrain	0.006
Surface current velocity	-0.036

Table 3-2. Results of the ecological niche factor analysis for the satellite telemetry records of Harbour porpoises. Coefficient values for the marginality factor are given. Positive/negative values mean that porpoises prefer location with higher/lower values than average for the modelled area.

Variable	Marginality
Water depth	-0.244
Seabed complexity	0.465
Distance to shallows (6 m)	-0.102
Gradient in surface salinity	0.359
Gradient in surface current velocity	-0.025
Surface salinity	0.485
Seabed terrain	0.571
Surface current velocity	-0.149

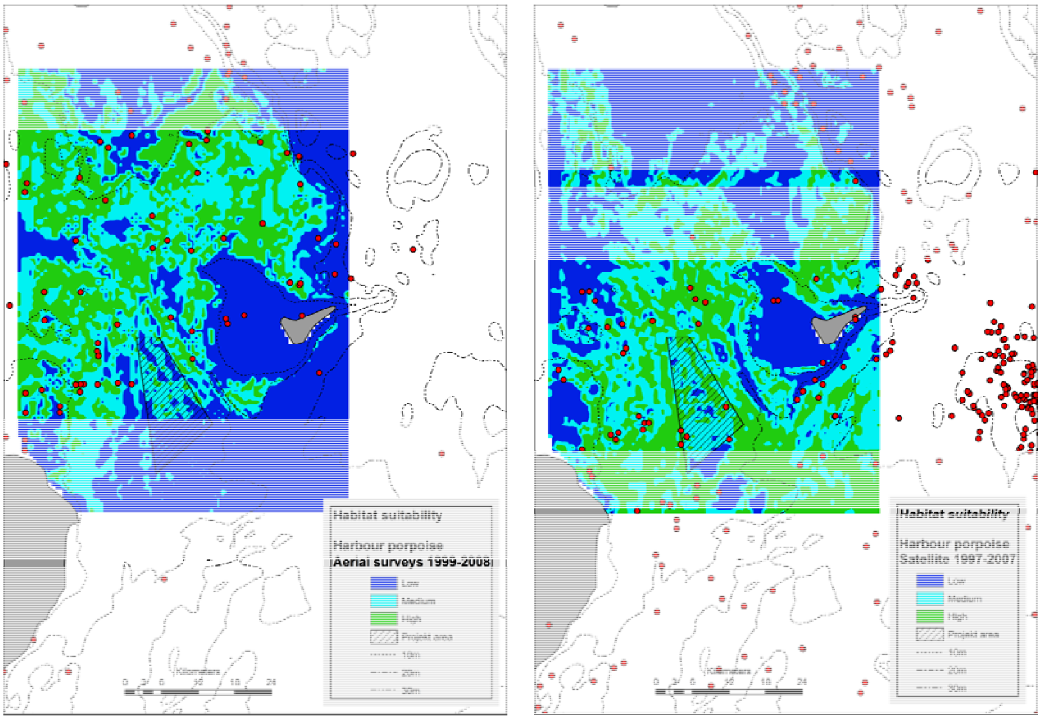


Figure 3-13. Modelled habitat suitability for Harbour porpoise in the north-western part of the Kattegat using available recent aerial survey (left panel) and satellite telemetry data (right panel) /10/ and /11/. The observations and satellite receiver recordings (location class 1-3) are shown as red dots. The project area is indicated by the black box.

3.3.4.2 **Acoustic activity**

The click train indices (hourly DPM) calculated for the period 16 June to 16 August 2009 shows that Harbour porpoises were present in the Project Area throughout the summer period. Maximum and mean DPM-values are generally largest for stations 2 and 4, and smallest for stations 5 and 6. Maximum DPM levels for stations 2 and 4 are close to 50 %. Mean DPM values for stations 2 and 4 are 1-2 per hour, while they are less than 1 DPM per hour for the other stations, Table 3-3 .

Although not directly comparable to DPM values obtained from T-PODs in earlier studies the recorded DPM values indicate an abundance of porpoises which may be considered as intermediate between the coastal North Sea (higher abundance) and the western Baltic (lower abundance) /8/,

/9/.

Table 3-3. Mean and standard variation of the index of acoustic activity (DPM) recorded at the six C-POD stations (Figure 3-4) between 16 June and 16 August 2009. Values are shown for each station numbered 1-6 and C-POD (T=Top mooring, B=Bottom mooring).

Station	**1-T**	**1-B**	**2-T**	**2-B**	**3-T**	**3-B**	**4-T**	**4-B**	**5-T**	**5-B**	**6-T**	**6-B**
Mean	0.46	0.48	1.35	1.20	0.78	0.56	1.39	1.32	0.52	0.38	0.56	0.38
STD	1.57	1.30	2.33	2.45	1.68	1.23	3.02	2.80	1.18	0.95	1.34	0.98

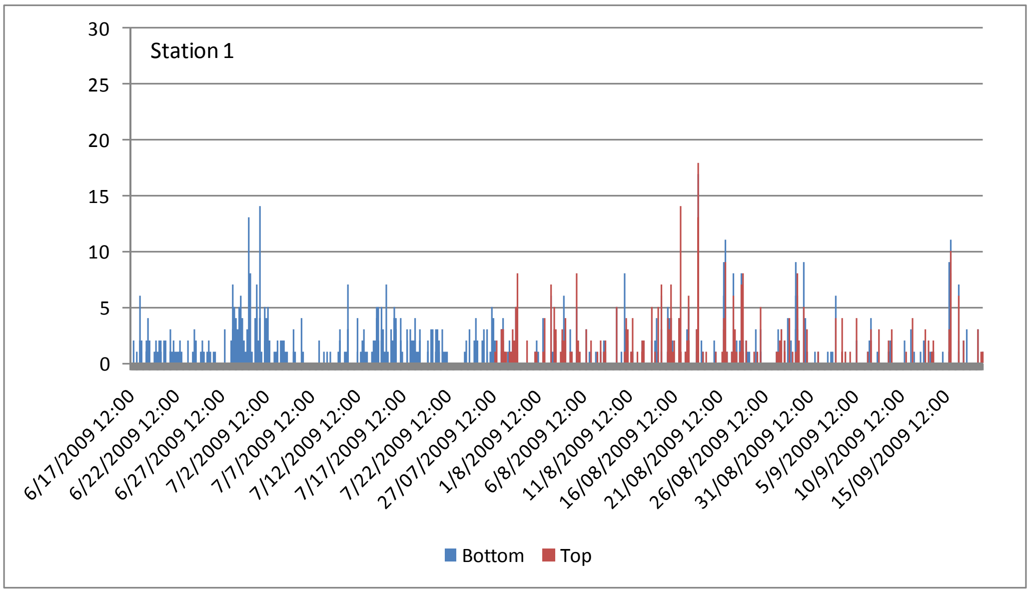
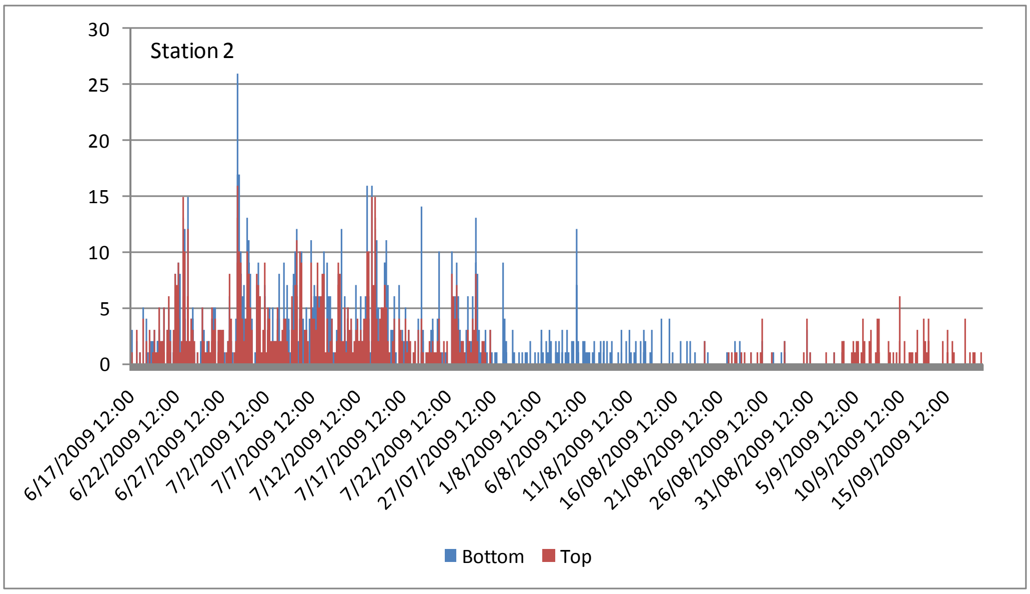


Figure 3-14. Daily DPM measured at each C-POD station (Figure 3-4) between 16 June and 16 August 2009. Bottom/Top indicates the position of the C-POD on each mooring. No data were recorded by the C-POD positioned at the top of the mooring in the first half of the period at station 1 and in the second half of the period at Station 2.



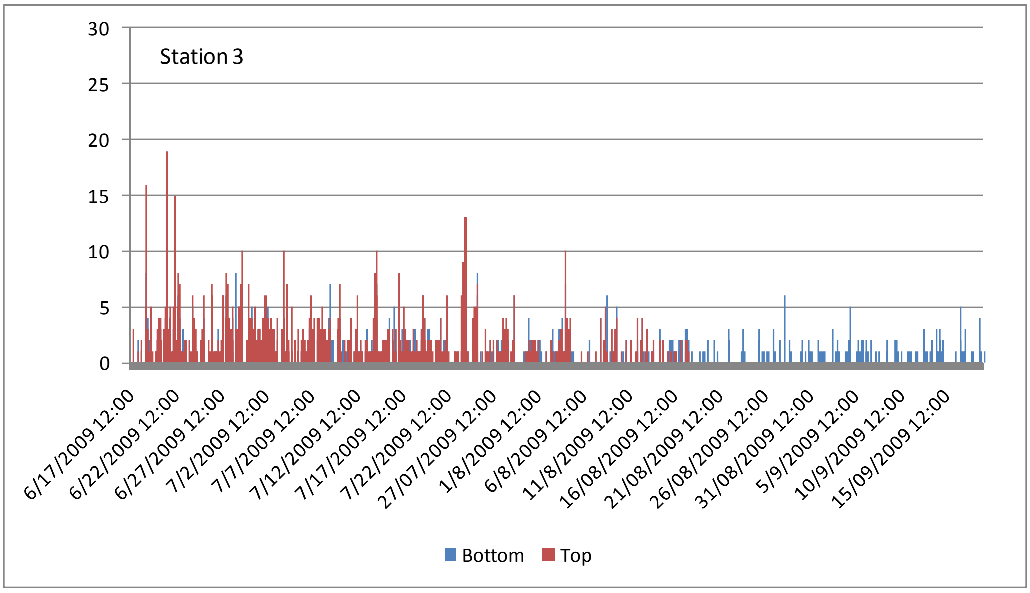
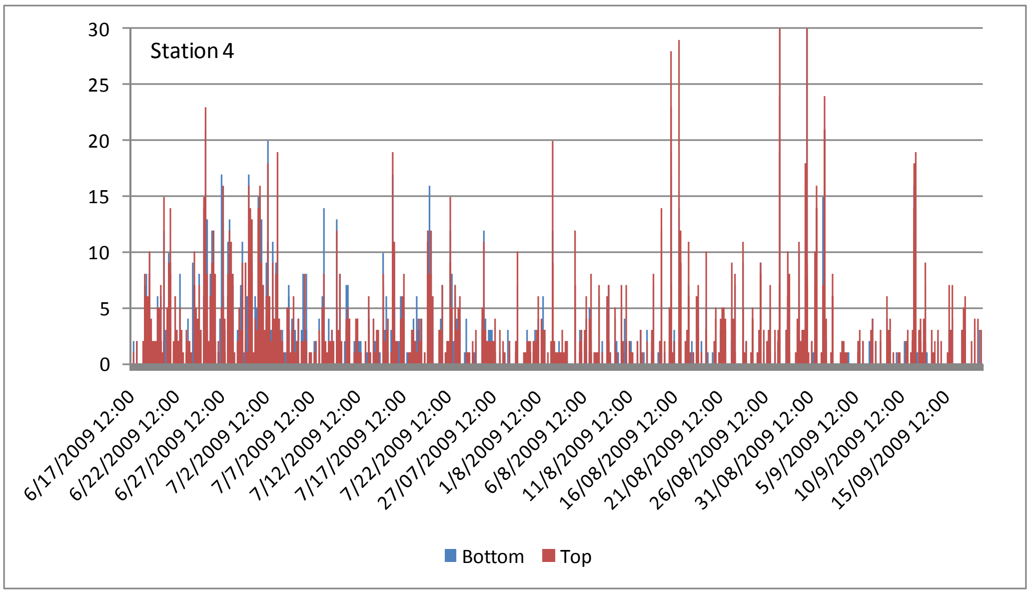


Figure 3-14 continued.



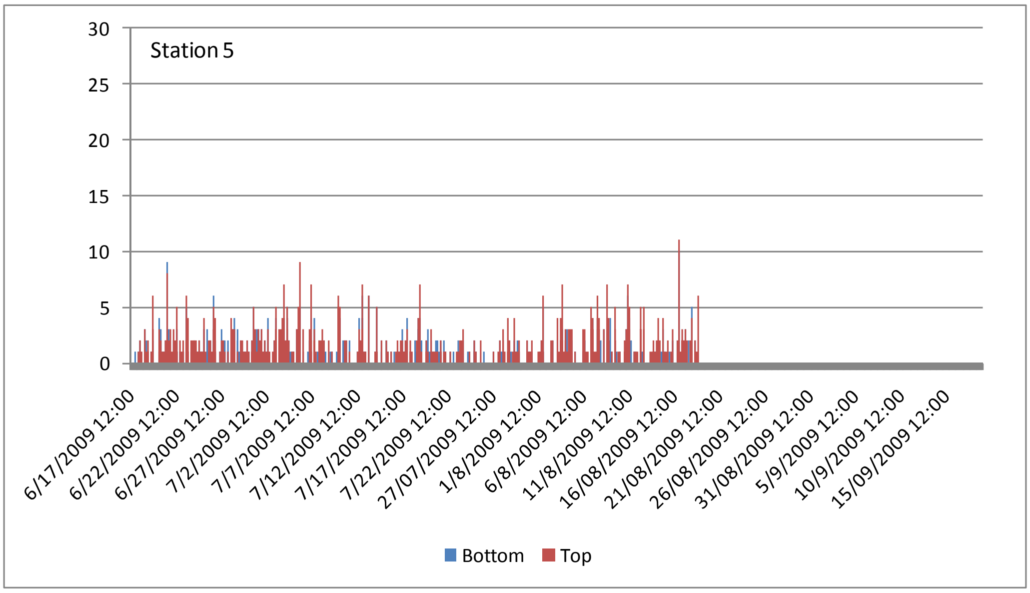


Figure 3-14 continued.

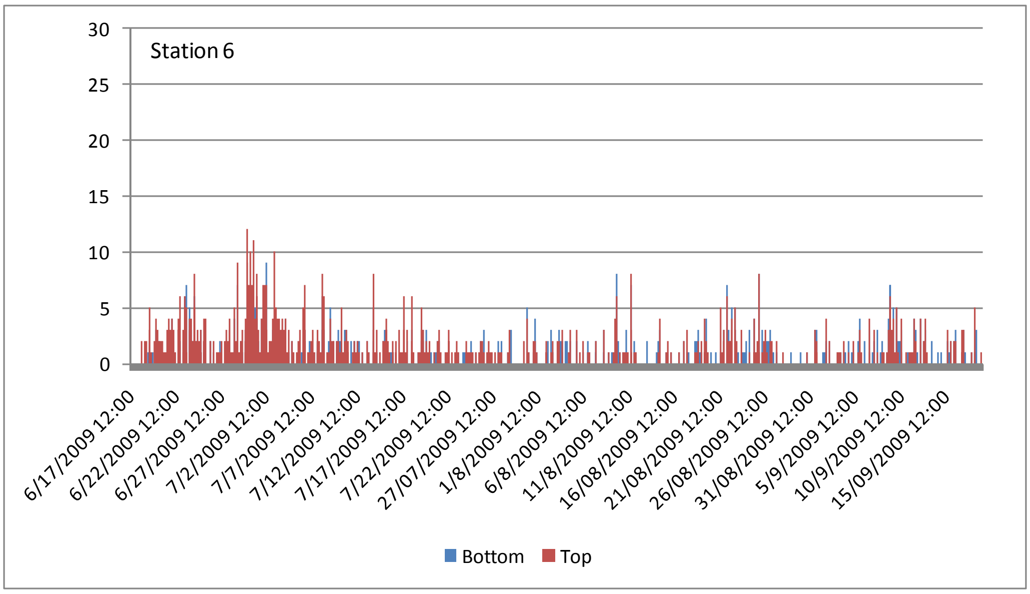


Figure 3-14 continued.

3.3.5 Harbour and Grey seal

The Harbour seal is easy recognizable with a doglike appearance and a snout which arches downward and its light grey to grey-brown coloration. Harbour seal is the only seal species, which with certainty breed regularly in Denmark. Grey seal can be relatively easily distinguishing from Harbour seal from it larger size, male's weighing up to 300 kg. In addition Grey seal has a cone-shaped snout, which in old males coves markedly upwards.

Both Harbour seal and Grey seal primarily feed on fish, but the seals also devour other prey such as squids and crustaceans. The Harbour seals affiliated to Kattegat is versatile in their choice of diet, which consist of fish as common sole, lemon sole, lesser sandeel, dab, flounder, plaice and gadoids like cod, Norwegian pout, haddock and whiting/67//68//69/.

Harbour seal males and females both get fertile at age 3-5 and mating takes place in July to August. The females are pregnant about 10 -11 months and normally deliver one pup each year, which at birth measures about 80 cm and weighs a little below 10 kilos. In Grey seals the time of sexually maturing differs between males and females. Females mature at age 4 or 5, whereas the males are about 8 years before they mate, as they are not able to compete with the full-grown males before this time. Normally the female delivers one pup each year in September – October.

The population of Harbour seal in Denmark constitutes a genetically distinct population and can be subdivided into seven areas, where Kattegat and the area around Samsø comprises a more or less isolated area, meaning that exchange of individuals with other subpopulations are limited/60/. The number of Harbour seals in Kattegat and area around Samsø has increased more or less steadily since 1979, only interrupted by two large declines in 1988 and 2002 caused by two epidemic outbreaks of Phocine Distember Virus (PDV) /59//60/. Today the population in the two regions is about 9.500, whereof 5000 live in Kattegat alone/69/.

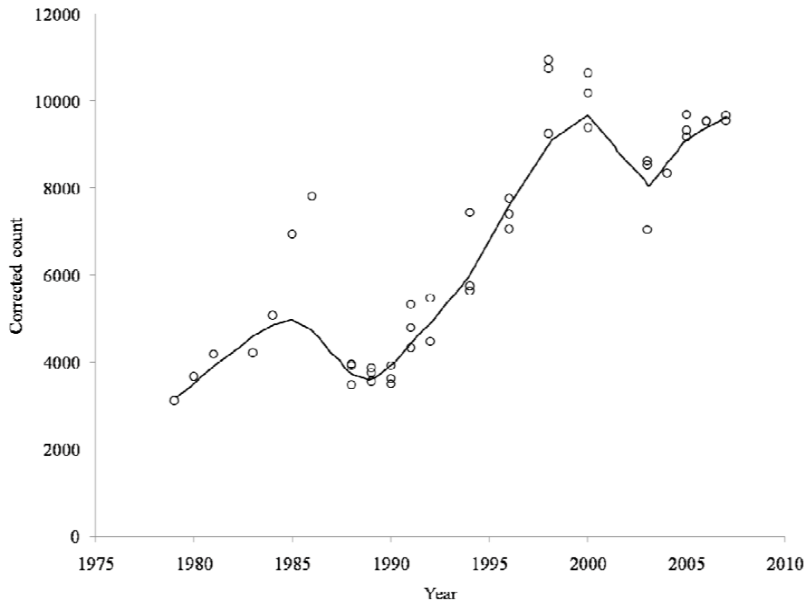


Figure 3-15. Estimated population development of Harbour seals in haul-out location in Kattegat and Belt region from 1979-2008 based on aerial counts of seals on land in August and corrected with seals in the water (from /60/)

The most important haul-out site and breeding ground for Harbour seal in Kattegat, and Northern Europe is Anholt, which is located approximately 30 kilometres from the wind farm area. The eastern tip of Anholt, called Totten, is appointed as a seal sanctuary and about 1.000 Harbour seal haul-out on the location (data NERI). Besides Anholt there a number of other haul-out and breeding locations in Kattegat and Belt region comprising Hesselø (Approximately distance to Project Area: 55 km) Læsø (65 km), Sjællands Odde (70 km), the area around Samsø (75 km) and the Swedish West coast (90 km)/72//73//74/. Of these is Hesselø is the most important, with up to 1.000 breeding individuals in late summer.

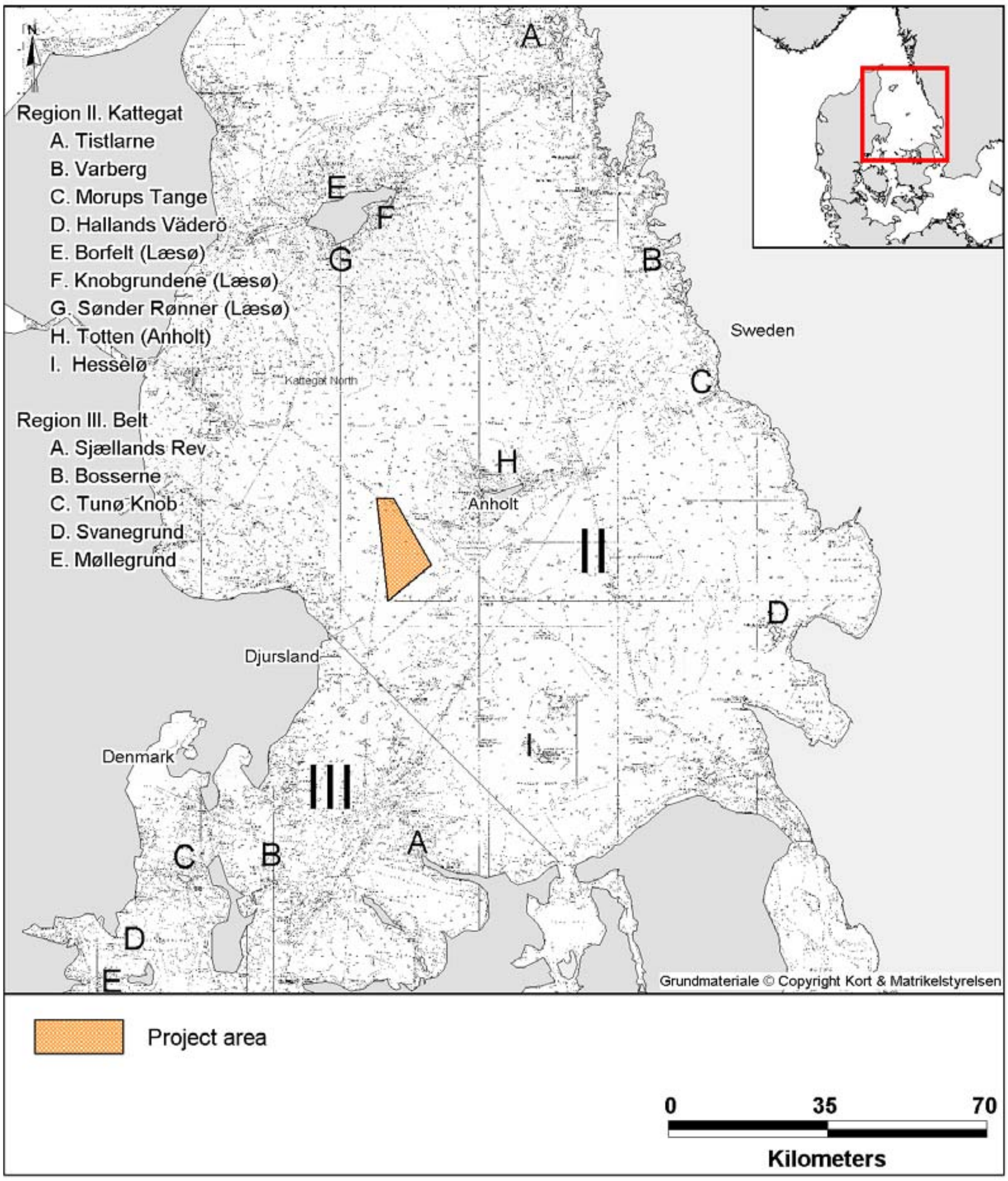


Figure 3-16. Management regions II and III and haul-out sites for Harbour seal in Kattegat and Belt region. Regions have been defined on the basis of geographical features, behavioural and telemetry studies and genetic analyse/62/.

Grey seal was formerly common in Denmark and breed regularly, but intensive hunting resulted in that the Grey seal became extinct in Danish waters. In the recent years, the Grey seal, however, have returned to Denmark, and a few animals have been observed breeding at Rødsand south of Lolland and in the Wadden Sea. In the Kattegat area the Grey seal are not breeding, but there are frequently observed either as single individuals or small groups at the shores at Anholt. It is estimated that the population in the Kattegat area have been constant of approximately 25 individuals since the 1970's/61/.

3.3.5.1 Distribution and habitat suitability

The modelled habitat suitability of all records of satellite telemetry activities in the north-western Kattegat resulted in relatively clear estimates of the trends in habitat use of the species. The overall marginality of the habitat use was 1.65 and specialisation 1.74, showing that Harbour seal habitat differs to a great extent from the mean conditions found in the north-western Kattegat, and that they are very restrictive on the range of conditions. The marginality coefficients outlined in Table 3-4 show that the primary drivers of habitat marginality of the seals are the distance to Totten and the gradient in surface salinity. Specialisation is primarily controlled by the distance to Totten, high surface salinity and shallow water depth.

The modelled habitat suitability values for Harbour seals (Figure 3-17) clearly indicate that a coherent area of high suitability is aligned north-south off the Totten colony and a smaller but well-defined is located just east of the Project Area. Analyses by M. Chudzinska indicate that the Project Area may be used regularly for feeding /69/. However, more than 80% of the modelled region, incl. the Project Area, has low suitability values. The satellite telemetry records fall well within the predicted areas of high suitability. In conclusion, the Project Area for the Anholt OWF seems to be unsuitable for Harbour seals coming from the Totten colony. However, an area of estimated higher habitat suitability is found 5-10 km east of Project Area.

Table 3-4. Results of the ecological niche factor analysis for the satellite telemetry records of Harbour seals. Coefficient values for the marginality factor are given. Positive/negative values mean that porpoises prefer location with higher/lower values than average for the modelled area.

Variable	Marginality
Water depth	-0.044
Seabed complexity	0.360
Distance to shallows (6 m)	-0.395
Distance to Totten	-0.597
Gradient in surface salinity	0.517
Gradient in surface current velocity	0.033
Surface salinity	0.014
Seabed terrain	0.181
Surface current velocity	-0.234

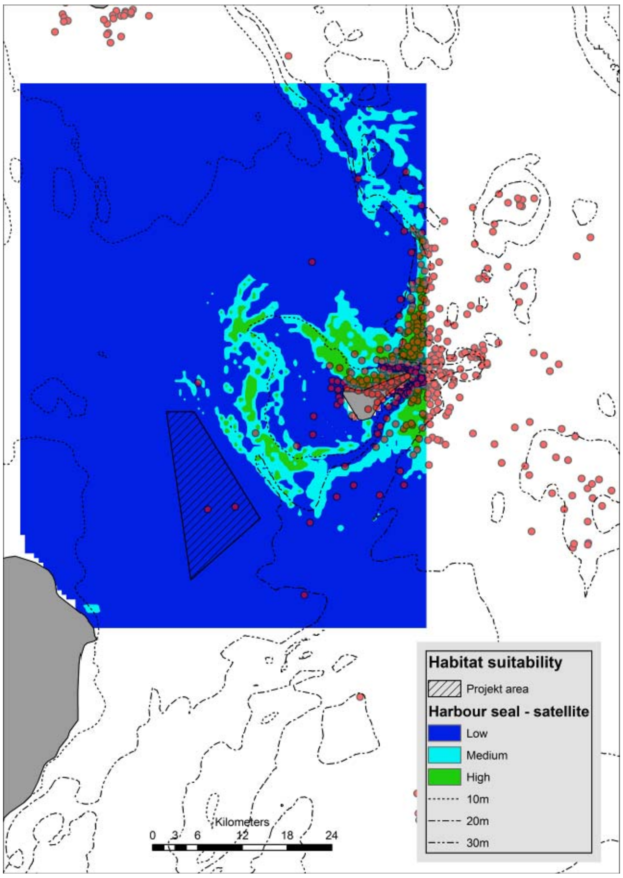


Figure 3-17. Modelled habitat suitability for Harbour seal in the northwestern part of the Kattegat using available recent satellite telemetry data /71/. The satellite receiver recordings (location class 1-3) are shown as red dots. The project area is indicated by the black box.

3.4 Environmental impacts

3.4.1 Method for Environmental impact assessment

In order to generate an overview of the effects of the Anholt OWF on marine mammals all effects are rated using criteria outlined in Table 3-5.

Table 3-5. Criteria used in the environmental impact assessment for the off-shore wind farm.

Intensity of effect	Scale of effect	Duration of effect	Overall significance of impact[1]
No	Local	Short-term	No impact
Minor	Regional	Medium-term	Minor impact
Medium	National	Long-term	Moderate impact
Large	Transboundary		Significant impact

[1]: Evaluation of overall significance of impact includes an evaluation of the variables shown and an evaluation of the sensitivity of the resource/receptor that is assessed.

Concerning noise-related impacts existing knowledge of noise-related disturbance in Harbour porpoises and seals will be reviewed with the aim to identify the most reliable methodology for estimating noise influence radii for the Anholt OWF. The noise influence radii will be combined with the results of the spatial modelling of survey and telemetry data and time series analyses of C-POD data to estimate impacts on the two species and assess their importance. As there are no present studies of the audible properties of Grey seal, the impact assessment of Grey seal will be based on analysis of Harbour seals assuming the senses of the two species to be comparable, due to the close taxonomic relationship and comparable anatomy /7/.

3.4.2 Impacts during the construction phase

Establishment of a marine wind farm is associated with a number of construction activities primarily including: traffic (vessels), pile driving, preparation of the seabed, sediment removal and deposition and cable laying. These activities result in a number of different impacts on the biological communities:

- Noise and vibrations
- Suspension of sediments
- Traffic
- Habitat loss

3.4.2.1 Noise and vibration

3.4.2.1.1 Noise influence zones

Richardson /17/ defined four zones of noise influence on marine mammals. The zone of audibility is defined as the area within which the animal is able to detect the sound. The zone of responsiveness is the region with which the animal reacts behaviourally or physiologically. This zone is usually smaller than the zone of audibility.

The zone of masking is highly variable, usually somewhere between audibility and responsiveness and defines the region within which noise is strong enough to interfere with detection of other sounds, such as communication signals or echolocation clicks. The zone of hearing loss is the area near the noise source where the received sound level is high enough to cause tissue damage resulting in either temporary threshold shift (TTS), permanent threshold shift (PTS) or even more severe damage as acoustic trauma. The different zones are illustrated in Figure 3-18.

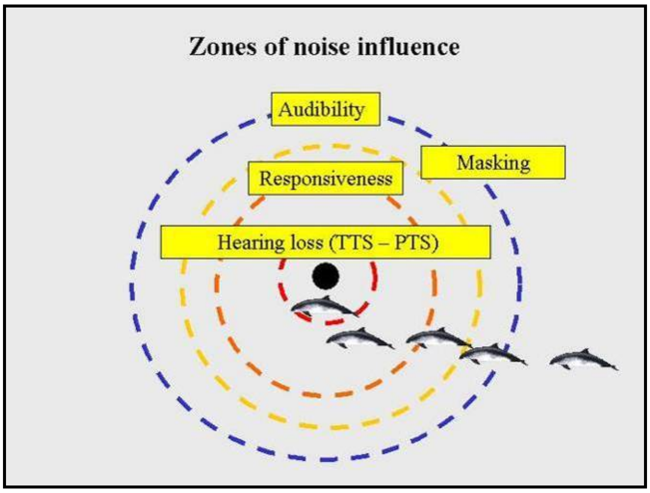


Figure 3-18. Zones of noise influence (after /17/).

As sound usually spreads omni-directionally from the source, the zones of noise influences are given as the distance from the source indicating a radius rather than a straight line from the source. For example, a radius (r) of 10 km results in a zone of audibility of A = π * r2 ; 3.1416 * 10 km2 = 314.16 km2 .

3.4.2.1.2 **Hearing in Harbour porpoises**

Investigations of hearing in Harbour porpoises have deployed different methods (Table 3-6). Hearing thresholds have been derived either through auditory-brainstem-responses (ABR) or behaviourally experiments.

Table 3-6. Overview of the results of hearing studies in Harbour porpoises.

Reference	/24/	/25/	/26/	/27/
Method	**ABR's**		**Behavioural audiogram**	
Stimulus	**Sinus-tone 10 – 25 ms**	**Clicks broadband 5µs**	**Sinus-tone 1.5 s**	**Sinus-tone 2 s**
Stimulus frequency (kHz)	**Sound pressure (dB_{rms} re 1µPa)**			
0.25				115
0.3	117			
0.5	119			92
0.7	109			
1	105		82	80
1.4	97			
2	90-95		65	72
2.8	78			
4	91		53	57
5.6	71			
8	85		49	59
10	59	87		
11.2	90			
16	53		52	44
20		81		
30		62		
32			47	37
50		78		36
70		74		
100		71	60	32
125		55		
160		102		91

Harbour porpoises exhibit a very wide hearing range with relatively high hearing thresholds of 92 – 115 dBrms re 1 µPa below 1 kHz, good hearing with thresholds of 60 – 80 dBrms re 1 µPa between 1 and 8 kHz, and excellent hearing abilities (threshold = 32 – 46 dBrms re 1 µPa) from 16 – 140 kHz, (Figure 3-19). The reported hearing abilities closely match the sounds emitted by the porpoises, which can be divided after into four classes /29/:

- Low frequency sounds at 1.4 – 2.5 kHz for communication
- Sonar-clicks (echolocation) at 110 – 140 kHz
- Low-energy sounds at 30 – 60 kHz
- Broadband signals at 13 – 100 kHz

Most of the energy of acoustic emissions is exhibited in sonar clicks probably due to high absorption of ultrasounds underwater /29//30/. Accordingly, the hearing system in Harbour porpoises is well adapted for detecting these essentially short-range sonar-clicks.

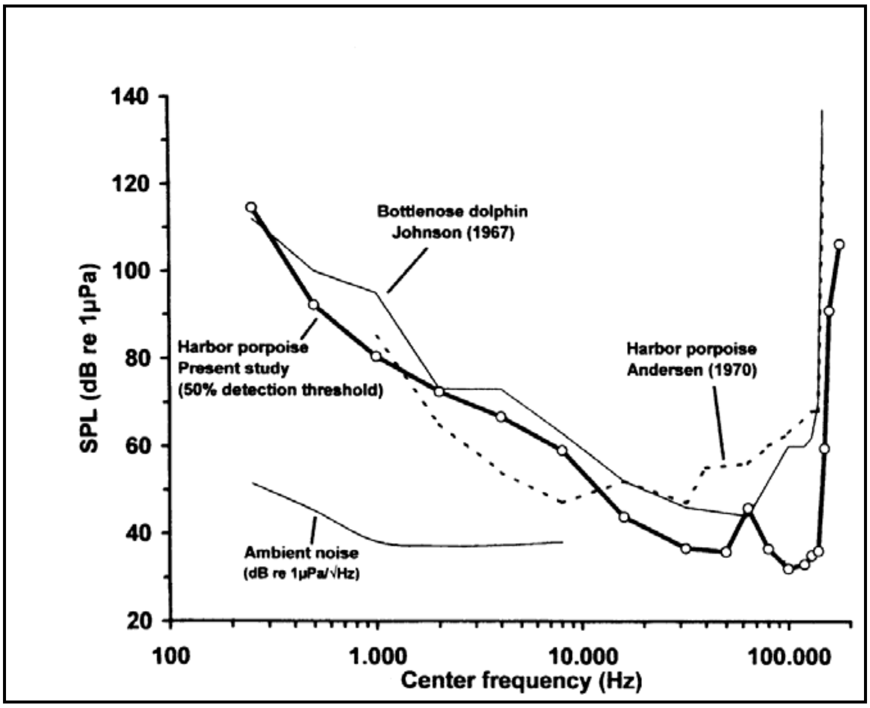


Figure 3-19. Audiograms of Harbour porpoise and bottlenose dolphin (from /27/)

The results between the different types of studies are quite different probably due to inter-individual differences in sensitivity and the variable methods used (ABR/central-nervous-processing). The following calculations will be based on the behavioural studies /26/,/27.

3.4.2.1.3 Hearing in Harbour seals

Harbour seals have an underwater hearing range of 0.07 – 60 kHz and are most sensitive between 8 – 30 kHz (threshold = 60 – 70 dB re 1 µPa) /31/. Hearing thresholds in lower frequencies at and below 1 kHz are reported to range between 70 and 80 dB dB re 1 µPa /31/, /32. /33/ measured underwater hearing in one individual to frequencies of 6 kHz and derived thresholds between 63-102 dBrms re 1 µPa (22 mins).

The relatively good sensitivity in lower frequencies matches closely the frequencies of sounds used in underwater communication that range between 0.5 - 3.5 kHz /17/. Very similar to Harbour porpoises, Harbour seals are most sensitive in those frequencies were biologically relevant signals are emitted.

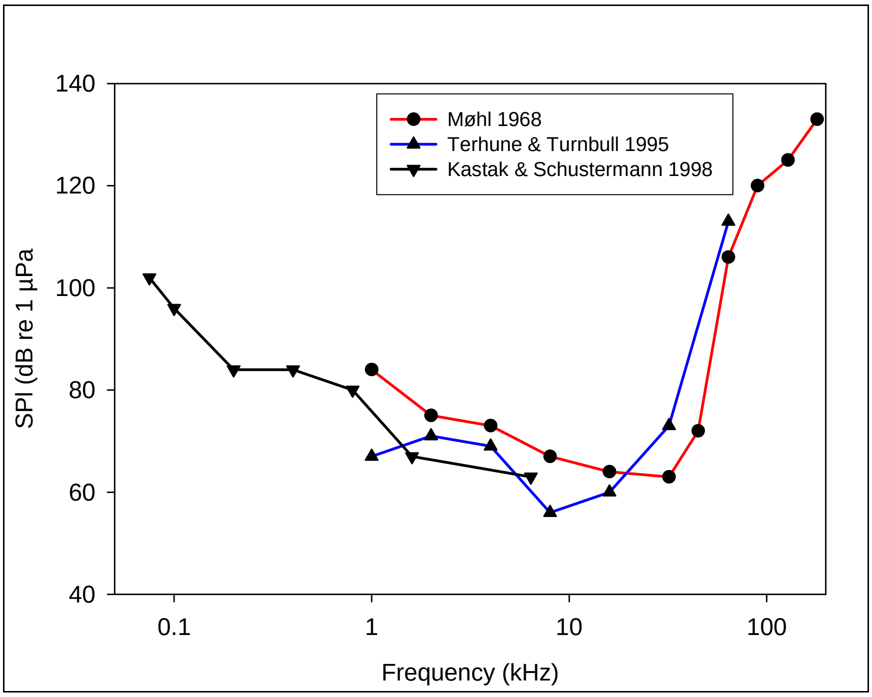


Figure 3-20. Underwater audiograms of Harbour seals.

Table 3-7. Underwater hearing threshold of a Harbour seal (after /33/).

Frequency [kHz]	Hearing threshold (dB_{rms} re 1μPa)
0.075	102
0.1	96
0.2	84
0.4	84
0.8	80
1.6	67
3.2	-
6.3	-
6.4	63

3.4.2.1.4 **Pile-driving**

Pile-driving activities are of special concern as they generate very high sound pressure levels and are relatively broad-banded /18/, /19/. Thus, the assessment of impacts of construction noise on seals and porpoises has been based on the worst-case scenario using monopole foundations. Noise will be emitted both above and below the water, but due to the different physical properties of air and water the transmission of noise in the two media differs. Low frequency noise dies out more quickly in air than in water, whereas the transmission distances from the sources will be highest in the air.

Degn /20/ measured 205 dB re 1 µPa at 30 m distances from the source during pile-driving at Utgrunden, Sweden. Nedwell et al. /18/ estimated a peak source level of 262 dBp-p re 1 µPa @ 1 m during the construction of the North-Hoyle offshore wind farm. However, the transmission loss used to calculate the source level was relatively high with the substrate being rocky. Therefore the results might not be applicable for the relatively sandy substrate at the Anholt OWF. The most detailed measurements to date were obtained by ITAP /21/ during the construction of the FINO-1 research platform off Eastern Frisia (Jacket-pile construction, diameter = 1.5 m per pile, sandy bottom, water depth ~ 30 m). They estimated a broadband peak source level of 228 dB0-p re 1 µPa @ 1 m. More importantly, ITAP measured third-octave-sound pressure levels as peak and sound exposure levels directly at 400 m from the source. These values were back-calculated using a formula by Thiele /22/ resulting in the spectrum shown in Figure 3-21. It can be seen that the sound pressure level was highest at the 315 centre frequency (Lpeak = 2180-p dB re 1 µPa @ 1 m) with additional peaks at 125 Hz and 1 kHz with considerable pressures above 2 kHz.

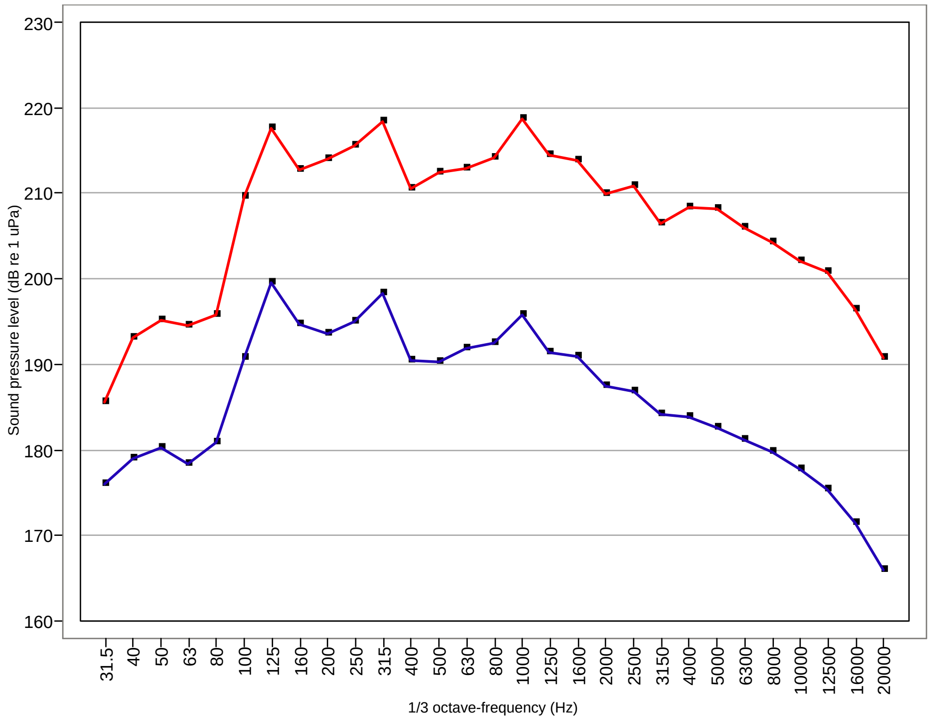


Figure 3-21. Frequency spectrum (Third octave band sound pressure level) of ramming pulses (FINO 1-platform) back-calculated to 1 m (red = dB0-p re 1 µPa, blue = dBE re 1 µPa from /21/).

Sound pressure levels in impact pile-driving are dependent on the length and diameter of the pile and the impact energy. ITAP /21/ measured 1/3 octave-band sound pressure levels during impact pile-driving in an adjacent region to FINO-1 (Amrumbank-West). The pile had a diameter of 3.5 m and the impact-energy therefore was considerably higher than at FINO-1. The increase in sound pressure levels was approximately 10 dB for every 1/3 octave-band. Since the Anholt OWF may use monopiles of a comparable diameter, 10 dB have to be added to every 1/3 octave band to derive a meaningful model of sound pressure levels during construction.

3.4.2.1.5 Audibility

The pile driving of monopiles into the seabed will transmit substantial noise to the surrounding environment. The attenuation of pile-driving noise at different distances from the source is shown in Figure 3-22. Values are calculated with the transmission loss formula by Thiele (2002) and background noise levels as measured in the area. Pile driving noise decreases with distance and higher frequencies are more rapidly attenuated than lower ones. At a distance of 80 km the sound pressure levels at frequencies <4 kHz are below background noise. Maximum sound pressure levels at 80 km distance are 144 dB0-p re 1 µPa (125 Hz), 146 dB0-p re 1 µPa (250 Hz) and 148 dB0-p re 1 µPa (315 Hz). These levels are approximately 70 dB above background noise. However, since background noise levels are given in a different dB unit than pile driving noise levels, this has to be considered as a rough estimate. For the Horns Rev 2 OWF /5/ estimated that pile-driving noise levels at frequencies below 4 kHz would be 60 – 70 dB above background noise levels under moderate conditions at an 80 km distance. At the Anholt OWF, equivalent noise levels would be 30-40 dB above background noise levels.

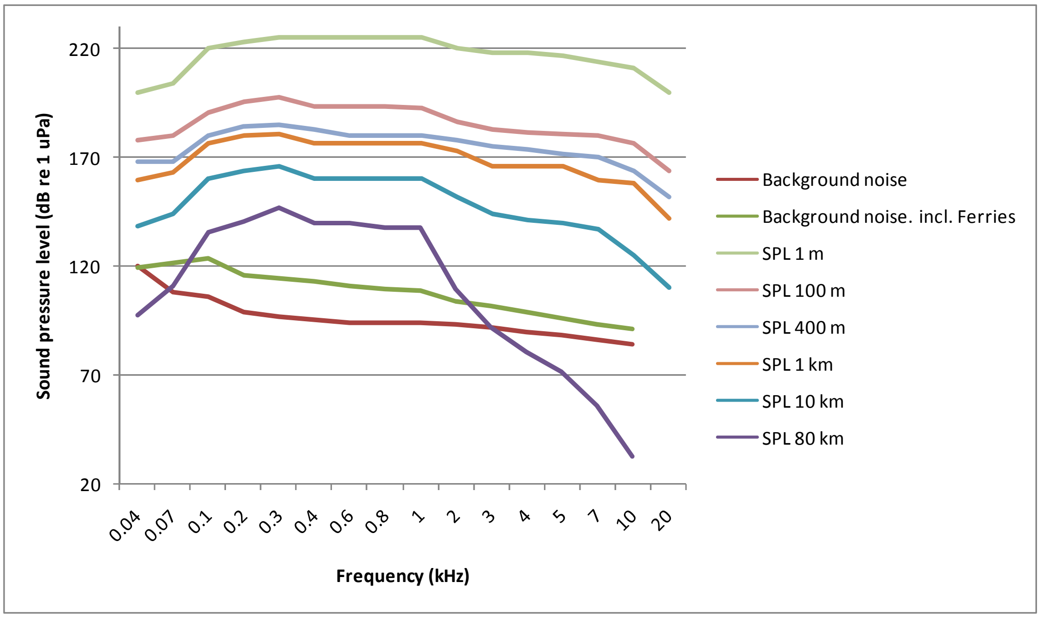


Figure 3-22. Attenuation of pile-driving noise at different distances from the source and background noise levels at moderate wind-speeds. Pile-driving noise after /21/ ; values as dB_{0-p} re 1 µPa in 1/3 octave-bands; TL-calculations after /22/; Background noise levels as 1/3 octave-bands in dB_{Leq} re 1 µPa after Betke et al., 2004).

A comparison of pile driving noise levels at different distances and audiograms of Harbour porpoises and Harbour seals (Figure 3-23) shows that the sound pressure levels are up to 56 - 59 dB above the hearing threshold of porpoises and seals. The results should be interpreted with some caution, since the audiogram values are given as RMS, dB-values and therefore not be compared 1:1, and consequently the figure serves as an illustration rather than a quantitative measure /5/.

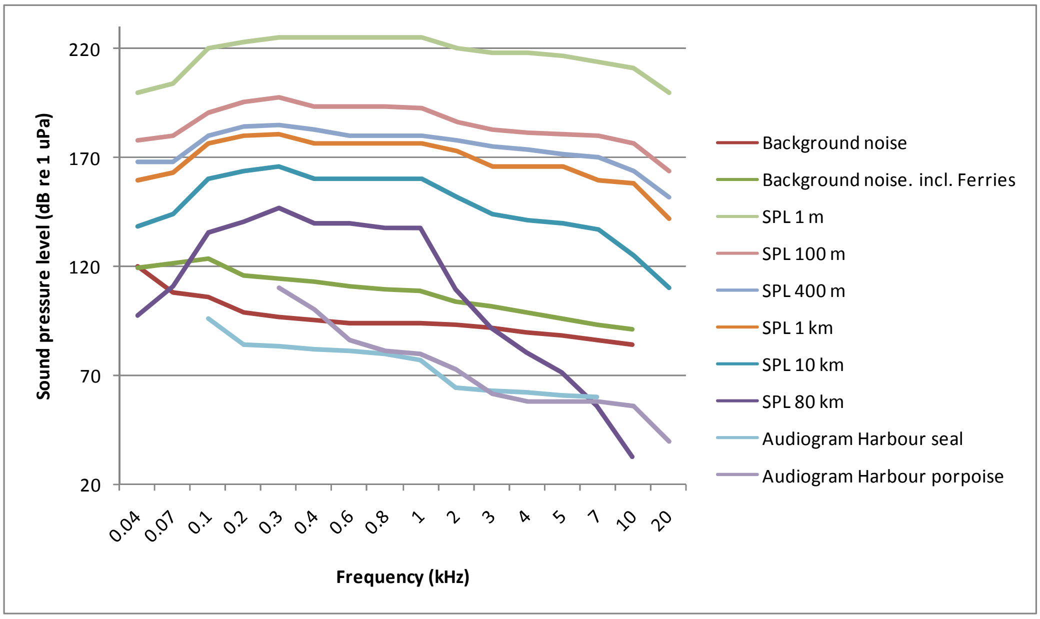


Figure 3-23. Pile-driving noise and background noise (see Figure 3-22) compared to the audiogram of Harbour porpoises and Harbour seals (audiogram values as dB_{rms} re 1 μPa; after /27/, /33/) (from /5/).

Taking all possible uncertainties into account, it can however be concluded that the zone of audibility will extend between 20 and 80 km from the source for both Harbour porpoise and seals, as the background noise levels at the OWF site are above the noise levels estimated for the piling activities. At the Project Area, background noise is 100 dB rms at 2 kHz (1/3 octave band see Figure 3-23). It can be seen that the pile-driving noise at this frequency is at the same level or below the level of the background noise and therefore not audible. However, due to frequency dependent absorption, the range of detection will be smaller than for the lower frequency part of the ramming pulse. Thus, frequencies higher than app. 2 kHz will be below background noise and porpoises and seals will most likely not detect them at large distances (> 50 km, Figure 3-23).

3.4.2.1.6 **Responsiveness**

The behavioural response of marine mammals is affected by different factors and some of them are shown in Figure 3-24. Subsequently, the zone of behavioural response is particularly difficult to assess /17/, /19/.

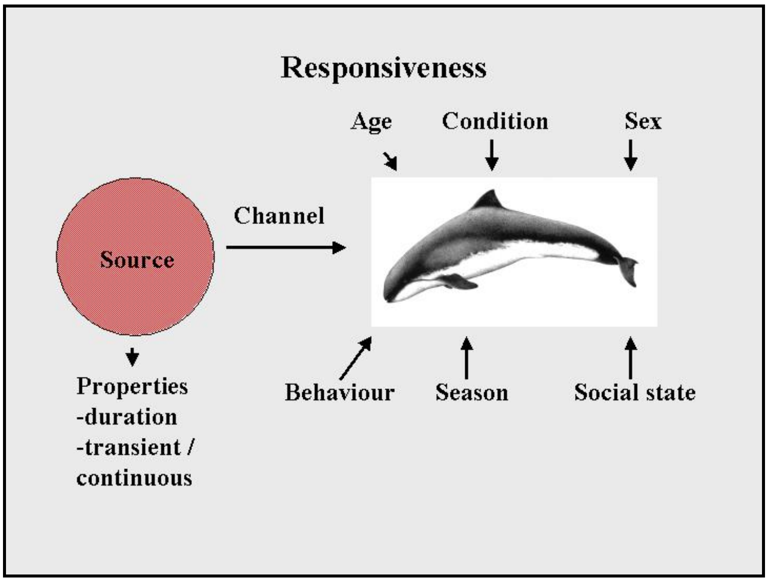


Figure 3-24. Factors affecting responsiveness in marine mammals (Harbour porpoise drawing by D. Bürkel, Hamburg).

It is important to note that pile driving pulses are transient stimuli and that at certain frequencies (see above) impact-pulses are probably the only signals the animals hear. Therefore, Harbour porpoises should react strongly to them /35/. On the other hand, pulses are of short duration, probably well below the time where full detection of signals is possible to porpoises /5/. It is therefore possible that there is a trade-off between transition and duration that will lead to an intermediate behavioural reaction.

Theoretical assumptions and some empirical data suggest a wide zone of responsiveness for pile-driving noise, and /5/ estimates that if the model pile driving noise is assumed to be broadband with 238 dB0-p and the calculated transmission loss is assumed to be 16 log (r) – the lowest transmission loss reported so far for pile-driving noise /19/. It would lead to a 25 km radius for behavioural reaction.

Nedwell et al. /36/ defined a dBht (ht = hearing threshold) value at which behavioural reactions should occur in cetaceans. They postulate that sound pressure levels between 75 and 90 dB above hearing threshold should lead to mild and strong behavioural reactions in cetaceans. The way this value is calculated is not exactly explained and the authors also admit that the dBht values are derived from studies on other taxa, mostly fish, and need further evaluation. The advantage of this method is that impacts are calibrated against the hearing abilities of any species. Skov & Thomsen /5/ added a 75 dB value to the audiogram by Kastelein et al. /27/, and calculated different reaction-thresholds, including a zone of 20 km for peak noise values (Table 3-8). Here, the 1 kHz frequency Peak-SPL is above the threshold. The RMS value is well below threshold.

Table 3-8. Behavioural reaction thresholds for Harbour porpoises after /5/ and /36/ and received sound pressure levels at 20 km distance from an impact pile-driver (Transmission loss calculated after /22/).

Frequency (kHz)	Reaction Threshold (dB_{rms} re 1µPa)	Received SPL at 20 km (dB_{0-p} re 1µPa)	Received SPL at 20 km (dB_{rms} re 1µPa)
0.25	190	160	152
0.5	167	154	145
1	155	156	146
2	147	141	132
4	142	131	120
8	134	118	107
16	119	98	87
20	115	89	77

In a recently published experiment, Kastelein et al. /35/ tested the reaction of Harbour porpoises in a pool to different signals with main frequencies around 12 kHz. They found aversive responses at received levels of 97 – 111 dBLeq re 1 µPa, including one signal resembling pile-driving noise (1.0 s pulse duration; 0.7 interval between pulses), which induced aversive responses at a received level of 103 dBLeq re 1µPa. Using the transmission loss model /5/ calculated the threshold for behavioural reaction would be reached at an approximately 7.5 km distance from the source. Empirical studies at the Horns Rev 1 Offshore Wind Farm /37/, /38/, /83/ have shown that Harbour porpoises reacted to impact pile driving sounds at ranges of at least 20 km. However, the effects were of short duration (6-24 hours). It should also be noted that both pingers and seal-scarers were used before ramming. The seal scarers might have caused avoidance response since the source levels used were high (189 dBp-p re 1 µPa) with frequencies of 13 – 15 kHz, where Harbour porpoises have very acute hearing /5/. Therefore it cannot be ruled out that some of the observed effects were caused by the mitigation measures employed rather than by the construction activity.

For Harbour seals, the zone of responsiveness of impact-pile-driving is even more difficult to assess than for porpoises. After /17/ and /39/, impulsive sounds have less negative impact on seals than on cetaceans. Using satellite telemetry, Tougaard et. al.,

/9/ could show that Harbour seals transited Horns Rev during pile driving. On the other hand, Edren et al. /40/ found a 10 – 60% decrease in the number of hauled out Harbour seals on a sandbank 10 km away from the construction during days of ramming activity compared to days were no pile-driving took place. However, this effect was of short duration since the overall number of seals remained the same during the whole construction phase. As a conservative measure, the behavioural reaction radius of seals should be viewed as a similar dimension as in porpoises. The results of the different studies are summarised in Table 3-9.

Table 3-9. Summary of recent studies looking at behavioural response in cetaceans.

Reference	Method	Species studied	Stimulus	Reaction threshold	Estimated radius of response for Harbour porpoises
McCauley et al. (2004)	empirical	Humpback whales	Airgun-pulse (60 ms; 0.1 – 2kHz)	172 dB_{p-p} re 1µPa	25 km
Nedwell et al. (2003)	theoretical	various	-	75 dB above hearing threshold	10 – 20 km
Kastelein et al. (2005)	empirical	Harbour porpoise	Pulsed tone (12 kHz; 1.0 s)	103 dB_{Leq}	7.5 km
Tougaard et al. (2004)	empirical	Harbour porpoises	Impact-pile-driving (> 220 dB_{p-p})	-	15 km

To summarise, the reported assumptions and empirical studies lead to a wide zone of responsiveness in Harbour porpoises and Harbour seals. As a conservative measure, the responsive radius can be defined as at least 20 km from the construction site. For the entire Project Area of the Anholt OWF the range of 20 km will cover areas of intermediate habitat suitability to Harbour porpoises and high habitat suitability to Harbour seals in the Kattegat. The level of impact will depend on the length of the pile-driving activities. In worst-cases, both seals and porpoises may be impacted during prolonged periods of pile-driving. However, measured over the entire construction period of several months these effects are most likely to be moderate, allowing the animals to return to the areas of origin in between pile-driving activities.

3.4.2.1.7 Masking

The zone of masking, defined as the range at which sounds levels from the noise source are received above threshold within the critical band centered on the signal /41/. In other words, masking starts when the sound level of the masking sound equals the ambient noise.

Due to the short signal duration and pulsation of the ramming signal (minimum of 1.0 s interval between pulses, and a puls duration of 0.1 s) masking by impact pile-driving sounds is considered as minimal. However, sound pressure levels are rather high and might cause stress, which might in turn also affect communication among Harbour porpoises and Harbour seals to some degree /19/.

Since the sonar of Harbour porpoises operates in a frequency range of 120 – 150 kHz, where ramming pulses have probably very low intensities, masking of echo location is not an issue. Amundin /42/ and Verboom & Kastelein /29/ described low-frequency sounds from porpoises around 2 kHz emitted either as by-product of high-frequency clicks or independently and speculated about their possible function in communication, for example between mother and calf. However, to date, no investigation has dealt directly with those signals and essential data to predict the zone of masking for them (e.g. source levels) are unknown. It should be emphasised that studies on the communicative significance of Harbour porpoise sounds are urgently needed to derive meaningful conclusions considering masking.

Harbour seals use signals between 0.2 - 3.5 kHz for communication between mother and pup and as territorial signals among males /17/. According to calculations in /5/ the received 1/3 octave sound pressure level would be well above the hearing threshold so masking would occur at least at a radius of more than 20 km and probably farther.

3.4.2.1.8 **Hearing loss (TTS – PTS)**

Both TTS (=temporary threshold shift) and PTS (=permanent threshold shift) represent changes in the ability of an animal to hear, usually at a particular frequency, with the difference that TTS is recoverable after hours or days and PTS is not. Impairment through TTS or PTS of a marine animal's ability to hear can potentially have quite adverse effects on its ability to communicate, to hear predators and to engage in other important activities. Both TTS and PTS are triggered by the level and duration of the received signal. Sound can potentially have a range of non-auditory effects such as damaging non-auditory tissues, including traumatic brain injury/neurotraumaTTS has been measured in white whales (Delphinapterars leucas) and bottlenose dolphins (Tursiops truncatus). Noise stimuli varied greatly in the experiments and the results indicate a linear relationship between sound exposure level and duration of exposure; the longer an animal is exposed, the lower the level of TTS. For short signals, however, sound pressure levels had to be 90 – 120 dB above hearing threshold to induce TTS /43/, /44/, /45/, /46/ and /47/.

From a regulatory perspective, injury is a concern when the received broadband sound pressure level exceeds 180 dBrms re 1 µPa for cetaceans and 190 dBrms re 1 µPa for pinnipeds /48/. Recently, Southall et al. proposed sound exposure criteria for cetaceans and pinnipeds composed both of peak pressures and sound exposure levels which are an expression for the total energy of a sound wave /84/. These values are currently discussed within the scientific community as they are based on very limited data sets with respect to noise induced injury and behavioural response in marine mammals. Using a model impact pile-driving broadband sound pressure level of 229 dBrms re 1 µPa at 1 m and calculating a TL of 16 log (r) TTS-zones were estimated by /5/ at 1,000 m for Harbour porpoises and 250 m for pinnipeds.

Frequency-dependent TTS has not been studied in cetaceans to date but it might become an important issue for further impact assessment since TTS-thresholds might vary considerably with hearing sensitivity. In humans, exposure to continuous airborne noise, 90 – 100 dB above hearing threshold, will cause TTS. Permanent hearing impairment is induced if noise exposure is 80 dB above hearing threshold (8 h per day exposure for 10 years; /17/). It is uncertain to what degree these 'dB-above threshold criteria' are applicable to cetaceans /17/. However, looking at the

TTS-studies so far, it is likely that the ‘theoretical threshold shift zone’ in cetaceans is of similar dimensions. After /49/, broadband noise exposure between 4 - 11 kHz for 30 min causes TTS in a bottlenose dolphin at a received level of 160 dBrms re 1 µPa. Looking at the hearing threshold at these frequencies (4 kHz = 70 dBrms re 1 µPa; 11 kHz = 50 dBrms re 1 µPa), the received levels would be between 90 - 110 dB above threshold. As worst case scenario, a 90 dB above threshold criterion might be feasible to work with.

Figure 3-25 shows the result if frequency dependent TTS is taken into account. Again, the model sound is the impact pile-driving pulse in 1/3 octave sound pressure levels calculated at different distances from the source. The audiogram by Kastelein et al. /27/ and a theoretical threshold shift zone of 90 dB above it are plotted for comparison. Again, the model has to be interpreted with caution since peak values and RMS values differ at about 6- 12 dB (see above) and RMS values can not readily be derived for transient signals /19/.

The radius of TTS in this example lies somewhere between 1 - 10 km and at 1 km, frequencies above 1 kHz are higher above TTS-threshold than those below 1 kHz. It should be emphasised that this is only an example that should show two things that might be important for future assessments. First, if frequency dependent TTS is taken into account, the radius for TTS might be wider as suggested by a regulatory approach. Of course, this depends solely on the thresholds used, but even elevating the threshold to 100 dB above audiogram would still result in an impact zone of more than 1,000 m as frequencies around 4-6 kHz would still be considerably above the TTS-zone at that distance. Second, the model implies that the higher frequency component of the signal would be more harmful than the lower one. If unmitigated, TTS impacts may be important, as both seals and porpoises may use the wind farm site regularly.

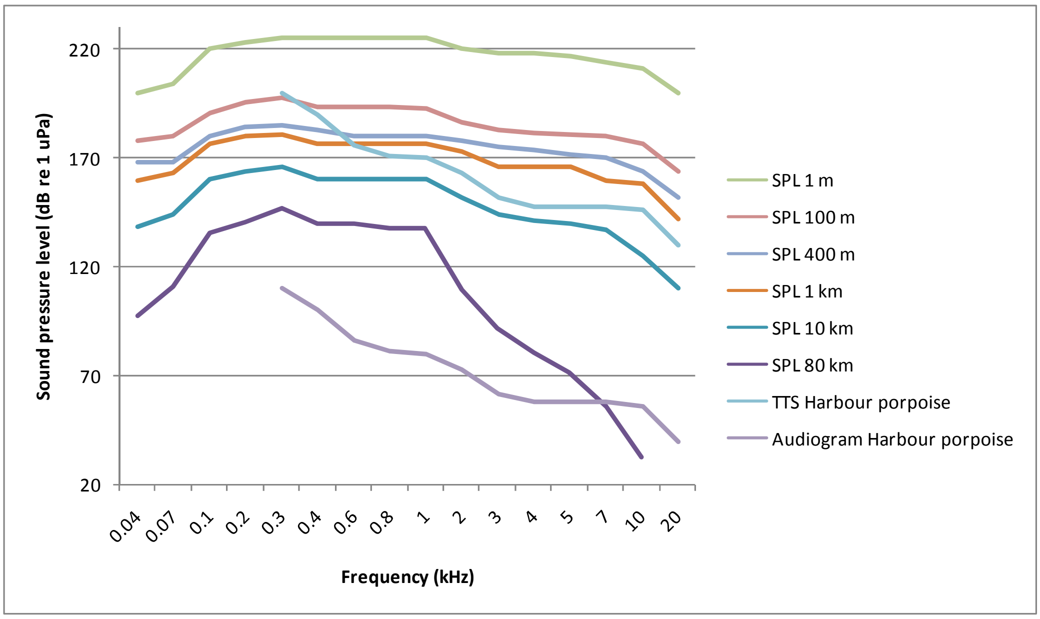


Figure 3-25 Attenuation of impact pile-driving noise at different distances from the source compared with the audiogram and a theoretical threshold shift zone of 90 dB above audiogram.

3.4.2.1.9 **Airborne noise**

Studies concerning sound emission from pile drivings have concentrated on underwater noise, due to the large impact zone of low frequencies noise. Airborne noise, however are of importance for the seals, which haul-out and breeds on land. The Harbour seals give birth to their pups in July and August and the pups suckle subsequently for about three to four weeks. Suckling always takes place on land, but if mothers and pups are disturbed on land they will flee together into the water. Accordantly disturbances in the breeding season can severely affect reproduction.

The investigations made during construction of Rødsand 1 Wind Farm placed only 5 km from the nearest haul-out site, showed an increased frequency of seal fleeing into the water during pile drivings/7/. The experiences from Horns rev 1 which is placed approximately 15 kilometres from the nearest haul-out site, however showed no alterations in the time on land as a result of pile drivings /4/, /76/. Consequently it is unlikely that airborne sound emission from pile diving at Anholt OWF will alter the haul-out behaviour of the seals on the Totten colony (approximately 30 km from the Anholt OWF).

3.4.2.1.10 **Summary of impacts from pile driving**

To summarize masking of communication might occur in seals and Harbour porpoises over distances of more than 20 km from the source, while masking of echo location is not an issue. Responsive reactions in both Harbour porpoises and Harbour seals might occur to at least a distance of 20 km from the source. For the seals, the latter will included suitable habitat to the animals from the colony of Totten. Temporal hearing loss might occur at 1,000 m in Harbour porpoises and 250 m in Harbour seals from a regulatory perspective. If frequency dependent hearing loss is taken into account, temporal hearing loss might occur at greater distances as predicted by a regulatory approach.

Table 3-10. Extension of the noise impact from the construction of Anholt OWF.

	Harbour seal and Grey seal	Harbour porpoise
Zone of Audibility (km)	>20	20
Zone of responsiveness (km)	20	20
Zone of masking (km)	>20	None
Zone of hearing loss (km)	0.25	1

3.4.2.1.11 **Ship Noise and vibrations**

Most construction of offshore wind farms involve a relatively high amount of ship-traffic for carrying parts of the pile and rotor, maintenance of construction platforms, etc /19/. Sound levels and frequency characteristics are broadly depending on ship size and speed with variation among vessels of similar classes. Medium sized support and supply ships generate frequencies mainly between 20 Hz and 10 kHz with source levels between 130 and 160 dB re 1 µPa at 1m /17/. In the following which is based on calculations made by Skov & Thomsen /5/ a broadband source level of 160 dBrms @ 1m was used.

3.4.2.1.12 **Audibility**

Audibility Table 3-11 shows sound pressure levels of ship noise at 0.25 kHz and 2 kHz at various distances from the source. Both frequencies were picked because most noise from construction / maintenance ships is exhibited in lower frequencies /17/. They are also applicable for Harbour porpoises and Harbour seals, since both species are suspected or known to communicate at low frequencies with acute hearing abilities around 2 kHz.

If detection thresholds for Harbour porpoises are considered (115 dBrms re 1 µPa at 0.25 kHz; 83 dBrms re 1 µPa at 2 kHz) then it can be concluded that ship noise around 0.25 kHz will be detected by the species at distances of 1 km. Ship noise around 2 kHz will be detected at a distance of approximately 17 km. For Harbour seals (detection thresholds = 84 and 83 dBrms re 1µPa at 0.25 and 2 kHz respectively), the zone of audibility will be app. 15 km for the 0.25 content of ship noise and identical to the 2 kHz content (Table 6.5).

Table 3-11. Sound pressure levels of ship noise at different distances from the source calculated after /5/ and /22/.

	Ship noise (dB_{rms} re 1 µPa)	
Distance to source	**0.25 kHz**	**2 kHz**
1 m	160	160
10 m	145	143
50 m	135	132
100 m	130	127

	Ship noise (dB$_{rms}$ re 1 µPa)	
Distance to source	**0.25 kHz**	**2 kHz**
1 km	115	110
10 km	99	90
80 km	80	50

3.4.2.1.13 **Responsiveness**

As sound pressure levels from ships are considerably lower than those during pile driving, the zone of responsiveness to ship noise will be much smaller than for pile-driving noise. For porpoises, the lower frequency component of the ship noise will be audible only at distances of 1 km. The 2 kHz component will be detected at ranges of 15 km. Richardson et al. /17/ defined a received level of 120 dB for continuous noise as a criterion for responsiveness in cetaceans. Looking at the results shown in Table 3-11, the zone of responsiveness should be limited to approximately 200 – 300 m.

3.4.2.1.14 **Masking**

As stated above, no information on the communicate significance of low-frequency sounds in Harbour porpoises exist. Therefore, the zone of masking can't be determined. For seals, masking might occur up to the range of audibility (~ 17 km), depending on the exact characteristics of the boat-noise.

3.4.2.1.15 **Hearing loss**

Due to the much lower noise levels from construction ships compared to pile-driving, TTS would occur in both species only at very close distances to ships.

3.4.2.2 **Suspension of sediments**

Various disturbances to the sediment in the wind farm area will invariably take place in the construction phase. These include the digging operations needed for construction of foundations and scour protection and for sluicing down the cables. The affected area amounts to 0.2-0.3% of the total wind farm area depending on the foundation type. Typical disturbances are the formation of plumes of suspended sediment and the subsequent sedimentation of suspended sediments. The magnitude of these plumes is dependent on the type of foundation chosen (monopile or gravitation foundations) Table 3-12.

Table 3-12. Example of the magnitude and duration of important work elements related to the construction of one foundation for gravitation and mono-pile foundations (from Engell-Sørensen & Skyt, 2001).

	Gravitation	Mono-pile
Material removed (m^3) Total	106,000	16,000
Foundation material (concrete) (m^3) Total	102,000	15,000
Sediment spill (m^3) Total	4,000	1,000
Duration per turbine of - Preparation - Installation - Scour protection	 7 days 6 hours 4 days	 2 days 4 hours 2 days
Stones and rocks used per turbine (m^3)	500	100

Table 3-12 indicates that the sediment works are much more comprehensive for the gravitation foundation than for the monopile foundation. This is due to the amounts of foundation material to be laid out and the volumes of sediments to be removed from the sea floor.

The extension/propagation of the plumes are strongly dependent on the local current conditions at the time of construction, but the sediment plumes generated from the gravitation foundation are expected to be greater than sediment plumes generated from the monopile foundations /34/.

The modelled sediment plumes (gravity foundations) are not expected to cause any direct impact on seals and porpoises, and concentrations of suspended material are not expected to reduce the availability of prey, especially juvenile fish. Hence, no significant negative effects are expected.

3.4.2.3 **Traffic**

The construction phase is associated with intense vessel traffic. Collisions involving small cetaceans and seals are normally limited to fast sailing boats like transport boats with service personnel. Collisions with Harbour porpoises and seals are most likely to happen in the high-use zones. In general, knowledge of the migratory routes of porpoises and seals in the central Kattegat is inadequate to evaluate to what degree the wind farm construction will potentially act as barriers to those routes. It is judged as most likely that the barrier effect will be small due to the width of the area between Anholt and Djursland.

3.4.2.4 **Habitat changes**

The establishment of the Anholt OWF implies destruction of existing habitats as well as generation of new habitats. The effected area is however very small, 0.2-0.3% of the total wind farm area (88 km2).

3.4.2.4.1 Loss of existing habitats

Establishing turbine foundations and scour protections amounting to a total of 0.2-0.3% of the total wind farm area invariably implies permanent (= the life time of the wind farm) destruction of a minor part of the total sandy habitat. This loss is considered insignificant in terms of total habitat availability to Harbour porpoises and Harbour seals in north-western Kattegat.

The baseline for fish and fisheries indicates that the main habitats for fish are found in the southern part, which may house high densities of key prey fish like herring and sprat /65/. The fish will though aggregate in suitable foraging sites from a larger area of the north-western Kattegat. The digging and excavation operations performed during the construction phase will invariably, but only temporarily, affect the existing spawning areas for demersal spawners, but have no significant effect on the total population of the fish species. Likewise, the excavation operations are not expected to have any significant effect to the adult demersal fish species.

3.4.2.4.2 Reef effect

The dominant substrate type at the wind farm area is sand. The erection of wind turbines with foundations and scour protections made from stones and rocks will introduce hard bottom substrate to the area, thus resulting in completely new habitats in the area. A colonisation similar to the one observed at the turbine foundations and scour protections in Horns Rev 1 Offshore Wind Farm is also likely to occur at the Anholt OWF. Although colonisation is fast, only the initial phases of the colonisation are expected to take place during the relatively short construction phase.

3.4.2.5 Conclusions of impacts during construction

Impacts during construction is foremost an issue during pile drivings, where sound emission are audible for marine mammals > 20 km from the Project Area. Other impacts such as ship noise, suspension of sediment, traffic and loss of existing habitats is assessed to only have minor impact on the marine mammals affiliated to the area. The zone of behavioural response during pile drivings is expected to be a 20 km radius from the site of ramming. Considering the modelled habitat suitability (Figure 3-13 and Figure 3-17) inside the zone of responsiveness it is clear that a number of areas with high suitability for both Harbour porpoise and seals are included. On the other hand nothing suggests that the modelled area is of greater importance to seals or Harbour porpoise than the rest of Kattegat. Previous investigations of the distribution of 63 Harbour porpoises in Danish waters indicate that the deeper parts of Kattegat, south-east of Anholt, are used much more frequently than the sound-western part of Kattegat /11/.

To summarize there can be anticipated a temporary disturbance of both seals and Harbour porpoise in a 20 km radius of the Anholt OWF during the period of pile drivings. However, due to the short duration of the period, it is unlikely that the disturbance will result in any permanent changes in the behaviour of animals affiliated to the area. Consequently, it can be expected that the population dynamic of the three species will be unaffected by the project and hence the ecological functionality is sustained for both seal and Harbour porpoise.

Table 3-13. Overview of impacts on marine mammals during the construction phase at Anholt OWF.

Impact	Intensity of effect	Scale/geographical extent of effect	Duration of effect	Overall significance of impact
Noise and vibrations	Medium	Regional	Medium-term	Moderate
Suspension of sediment	Minor	Local	Medium-term	Minor
Traffic	Minor	Local	Long-term	Minor
Habitat changes	Minor	Local	Long-term	Minor

3.4.3 Impacts during the operation phase

Impacts during operation comprises following parameters:

- Noise and vibrations
- Traffic
- Electromagnetic field
- Reef effect

3.4.3.1 Noise and vibrations

Noise during operation has been measured from single piles (maximum power 2 MW) in Sweden, Denmark and Germany and has been found to be of much lower intensity than the noise during construction (review in /19/). Again, the most detailed measurements have been obtained by ITAP /21/ during the operation of an offshore turbine in Sweden (1.5 MW) at moderate-strong wind speeds of 12 m/s. 1/3 octave sound pressure levels ranged between 120 and 145 dBLeq re 1 µPa @ 1 m with most energy at 50, 160 and 200 Hz. Since the measurements of ITAP are the most detailed to date, they will be used as inputs in assessments of influence of operational noise.

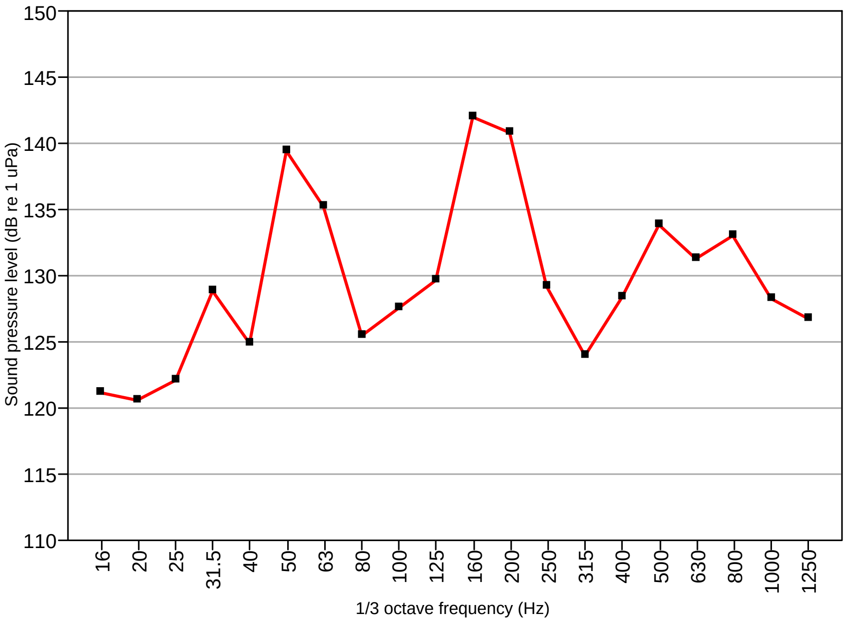


Figure 3-26. Operational source level noise in dBLeq of an offshore wind turbine measured at a 110 m distance and back-calculated to 1 m (from /21/).

Figure 3-27 shows sound pressure levels of a 1.5 MW turbine in operation at wind-speeds of 12 m/s (bft = 6). At 100 m, - turbine noise would be audible to both Harbour porpoises and Harbour seals. At 1,000 m, the signal to noise ratio is too low for detection in both Harbour porpoises, and in Harbour seals.

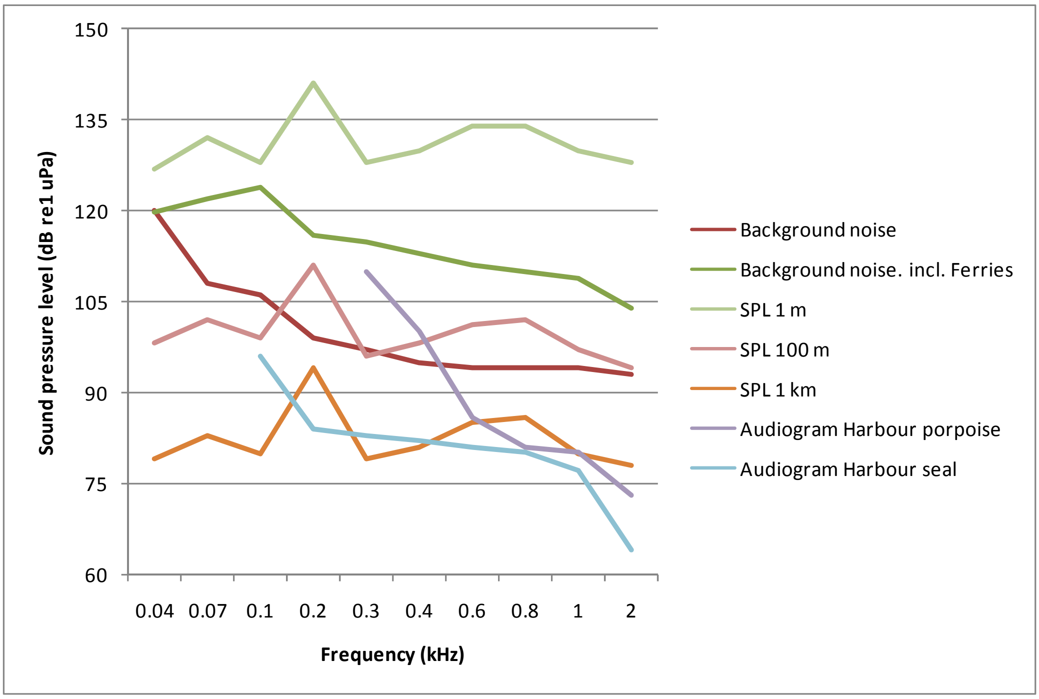


Figure 3-27. Sound pressure levels at an offshore wind farm in operation at different distances from the source compared to the audiogram of Harbour porpoises and Harbour seals and background noise (SPL = Leq in 1/3 octave sound pressure levels; 110 m = measurement; 1 m = back-calculated after /5/ and /22/; 1,000 m calculated with 16 log (r); background noise after /19/; audiogram Harbour porpoise by /27/; Harbour seal by /33/.

The calculations above depend on the signal to noise ratio of turbine and background noise. In calmer conditions, the detection range of the signal will probably increase. However, since turbine noise decreases in calmer conditions, the overall ranges should remain constant. The results indicate a rather small zone of audibility and noise levels, at ranges smaller than 1,000 m are too low to induce responsiveness, masking or TTS in porpoises. There might be masking of Harbour seal sounds but this will happen at close ranges well below 1 km. Experiences from the Horns Rev 1 Offshore Wind Farm indicate no negative behavioural response to the production noise. Both species are seen regularly within the wind farm. Koschinski et al. /50/ reported behavioural responses in both species to playback of simulated offshore turbine sounds. However, as Madsen et al. /19/ point out, Koschinski et al. might have introduced artefacts at higher frequencies that were responsible for the reactions. It is unknown if and to what degree higher-powered turbines, as planned at the Anholt OWF are noisier. However, it might be reasonable to conclude that elevation of noise levels will happen predominately in lower frequencies below 100 Hz /5/. Since all species are probably not very sensitive in this range, it is questionable if larger turbines would have a greater effect than smaller ones.

Noise levels of more powerful and hence larger (~ 4-5 MW) turbines are probably greater /19/. However, it is currently unknown to what extent noise levels will be elevated and if this would account for frequencies relevant to the hearing of Harbour porpoises and seals.

3.4.3.2 **Traffic**

Running maintenance of the turbines involves some vessel activities in the wind farm area. The traffic during the operational phase is restricted to smaller vessels participating in the maintenance operations. The possibility of collisions between marine mammals and maintenance vessels much be considered as marginal and restricted to fast sailing vessels such as speed boats.

3.4.3.3 **Electromagnetic fields**

During operation, the power cables connecting the wind farm to shore will generate a narrow zone of electromagnetism along the cables. Marine mammals are generally not regarded as sensitive to electromagnetic fields generated close to the cable, although the range of electromagnetism is detectable by electro-sensitive fish species /51/, /52/. Modelling, measurements and monitoring results show that the field of impact is narrow (< 1 m) and impacts on local fish stocks are non-significant /52/, /53/. Accordantly impacts on marine mammals are deemed negligible.

3.4.3.4 **Reef effect**

Colonising of foundations and scour protections will continue during the operation phase. New species will inhabit the hard structure habitats as the biomasses of sessile organisms and flora increase. Additionally, the artificial reefs are potential spawning and nursery areas for a number of fish species and potentially result in an increase in diversity during the operation phase. The increased availability of potential prey for porpoises and seals like cod (Gadus morhua) and whiting (Merlangius merlangus) within the wind farm may have a positive effect attracting the animals to the wind farm site.

In addition to the reef effect, it deserves mentioning that construction of the Anholt OWF will exclude commercial fishery from taking place within the wind farm area for a period of at least 25 years (expected minimum life time of the wind farm). During this period (mainly the operation period) incidental catches and disturbance of Harbour porpoises will be reduced in the area of the wind farm.

3.4.3.5 **Conclusions of impacts during operation**

Impacts during construction are assessed to only have minor impact on the marine mammals.

Table 3-28 Summary of impact on marine mammals during operation

Impact	Intensity of effect	Scale/geographical extent of effect	Duration of effect	Overall significance of impact
Noise and vibrations	Minor	Local	Medium-term	Minor
Traffic	Minor	Local	Medium-term	Minor
Electromagnetic fields	Minor	Local	Long-term	Minor
Reef effects	Minor	Local	Long-term	Minor

3.5 Mitigation measures

Listed below are some proposals for mitigative measures in the four different phases of the life cycle of the wind farm related to the perceived moderate and major impacts.

3.5.1 Construction phase

The construction phase contains the most intensive impacts regarding emission of noise and vibration. The potential major impacts related to the potential TTS zone during pile-driving operations can be mitigated, while the overall moderate impacts due to short- term responsive movements may be impossible to mitigate. Mitigation measures during construction can focus on the source of noise as well as the receiver, in this case Harbour porpoises and seals. Looking at the source, there are several mitigation options:

- Extending the duration of the impact during pile-driving (decrease of 10-15dB in SL; mostly at higher frequencies > 2 kHz)
- Mantling of the ramming pile with acoustically-isolated material (plastic etc.; decrease of 5 –25 dB in SL; higher frequencies better than lower ones)
- Air bubble curtain around the pile (decrease of ~ 10 dB /58/)
- Soft-start / ramp-up procedure (slowly increasing the energy of the emitted sound /17/)

The methods mentioned above have benefits and costs; extending the duration of the impact reduces source levels very efficiently but has biological implications since signals of longer duration would mask Harbour seal and possibly Harbour porpoise communication signals to a greater extent than shorter signals. The method is also limited technically, since shorter pulses are more effective in driving the pile into the bottom than longer ones. Mantling seems to be very promising but has so far only been tested in a relatively short pile. Air bubble curtains are very expensive and might only be effective in relatively shallow water /54/. Soft-start procedures are theoretically promising but their effect has not been tested to a large degree. Ramping-up might also make it more difficult for cetaceans and seals localizing the sound source /17/.

Looking at the receiver, acoustic harassment devices have been used both for seals and Harbour porpoises and have proven to be effective in scaring the animals away from the source /55/, /56/. /56/ reported a mean avoidance zone of 500 m around a 'pinger' for porpoises. /57/ reported a smaller avoidance response of approximately 208 m. At Horns Rev 1 Offshore Wind Farm, a seal scarer with an effective range of 300 m was used. Therefore, both systems seem to work at relatively short ranges, well below the potential TTS zone (see above). It might therefore be necessary to deploy several pingers at different distances from the construction site.

To sum up, the recommended mitigation measures are the application of seal scarers and pingers in combination with ramp-up procedures during pile driving. The seal scarers are judged essential, as they have the most potential for effective mitigation against TTS impacts.

3.5.2 **Operation phase**

As there are no significant impacts expected for seals and porpoises during operation of wind farms, no mitigation measures are needed.

3.5.3 **Decommissioning phase**

As impacts of decommissioning are mainly the reverse of construction the use of seal-scarers and pingers might be an effective mitigation measure.

3.6 Cumulative effects

Although the impacts from Anholt OWF are primarily assessed on its individual merits, it is also clear that due to the presence of other human activities in the region, impacts from the latter cannot be disregarded, but must be taken into consideration as cumulative impacts. Similarly, cumulative impacts and effects can be generated by the joint impacts from various activities in the lifetime of the Anholt OWF.

The greatest impact from construction of the Anholt OWF is noise emitted from pile drivings. The noise levels during ramming are expected to lead to behavioural response of marine mammals in a 20 km radius from the site of ramming. If ramming of monopiles are chosen as foundation type it is expected to take place during 2012-2013. According to the Swedish authorities this will most likely not overlap with the planned construction period for Store Middelgrund Offshore Wind Farm approximately 60 kilometres from Anholt OWF /81/. Thus, cumulative impacts, i.e during a situation where pile drivings are performed simultaneously in the two wind farms will be moderate, and no large-scale cumulative barrier effect is foreseen impeding the migration of marine mammals back and forth between the northern and southern part of Kattegat.

Concerning the operation phase, no measurements of noise so far have been published from larger wind turbines or larger wind farms, such as Horns Rev 1 Offshore Wind Farm. Accordantly no reliable estimate can be made on the effects of operational noise from other offshore wind farms on the construction phase of the Anholt OWF. However, it is not very likely that operational noise from the planned Universal Wind OWF on Store Middelgrund 20 km away is audible to porpoises or seals under moderate conditions. The cumulative effects are therefore assessed to be minimal. It has to be noted here that during the construction phase, noise will probably lead to a behavioural reaction of Harbour porpoises and seals in a radius of 20 km from the construction site. The zone of behavioural response can therefore be expected to be approximately 1,250 km^2. Any possible effects of operation from a wind farm 20 km away will be negligible compared to the effects during the construction phase of the Anholt OWF itself. Regarding suspension of sediments, traffic and electromagnetic fields, no cumulative effects is expected.

3.7 Decommissioning

Impacts on seals and Harbour porpoises envisaged during decommissioning are similar to some of the disturbance impacts expected during construction, depending on the activities of pile removal and service boats. The potential disturbance effects will be smallest for decommissioning of gravity foundations. As decommissioning involves activities similar to construction, the cumulative effects will be the same as those mentioned in section 3.5.

3.8 Technical deficiencies or lack of knowledge

Baseline data on acoustic activity of Harbour porpoise in the planned construction area of the Anholt OWF has only been collected during a 2 month period in summer 2009. Hence, the available data can not establish to what degree the recorded levels of acoustic activity are typical for the site.

3.9 Conclusion of impacts related to the Anholt Offshore Wind Farm

In this chapter the EIA evaluation of potential impacts are concluded for the Anholt OWF. Table 4-3 an example of the EIA evaluation of potential impact, significance rating of the assessed impact and the quality of data/documentation is given based on the principles from the memo describing "Method for Impact Assessment (May 2009)". These principles are resumed below as Table 4-4 .

Table 3-29. Impacts on marine mammals during construction and operation of the Anholt Offshore Wind Farm.

Effect	**Overall significance of impact**	**Significance rating for the assessment**
IMPACTS ON MARINE MAMMALS		
Construction phase		
Noise and vibrations	Moderate	3
Suspension of sediment	Minor	2
Traffic	Minor	3
Habitat changes	Minor	3
Operational phase		
Noise and vibrations	Minor	3
Traffic	Minor	3
Electromagnetic fields	Minor	3
Reef effect	Minor	3

Table 3-30. Principles for the EIA evaluation of potential impact, the significance rating of the assessed impact and the quality of data/documentation (from the memo describing "Method for Impact Assessment (May 2009)".

Quality of availably data

In order to evaluate the quality and significance of data and documentation for the impact assessment a significance rating of data and documentation should be evaluated within the specific technical subject topics using the following categories:

- 1 – Limited (scattered data, some knowledge)
- 2 – Sufficient (scattered data, field studies, documented)
- 3 – Good (time series, field studies, well documented)

For the EIA-document an impact arising from a planned activity will, depending on its magnitude and the environmental sensitivity, be given a significance rating as follows:

: No impact	*No impact*: There will be no impact on structure or function in the affected area;
: Minor impact	*Minor impact*: The structure or functions in the area will be partially affected, but there will be no impacts outside the affected area;
: Moderate Impact	*Moderate Impact*: The structure or function in the area will change, but there will be no significant impacts outside the affected area;
: Significant impact	*Significant impact*: The structure or function in the area will change, and the impact will have effects outside the area as well;

4. Transformer platform and offshore cable

4.1 Project description

An offshore transformer platform will be established to bundle the electricity produced at the wind farm and to convert the voltage from 33 kilovolts to a transmission voltage of 220 kilovolts, so that the electric power generated at the wind farm can be supplied to the Danish national grid.

4.1.1 Transformer platform

Energinet.dk will build and own the transformer platform and the high voltage cable which runs from the transformer platform to the shore and further on to the existing substation Trige, where it is connected to the existing transmission network via 220/440 kV transformer.

The transformer platform will be placed on a location with a sea depth of 12-14 metres. The length of the export cable from the transformer station to the shore of Djursland will be approximately 25 km. On the platform the equipment is placed inside a building. In the building there will be a cable deck, two decks for technical equipment and facilities for emergency residence.

The platform will have a design basis of up to 60 by 60 metres. The top of the platform will be up to 25 metres above sea level. The foundation for the platform will be a floating caisson, concrete gravitation base or a steel jacket.

4.1.2 Subsea cabling

The wind turbines will be connected by 33 kV submarine cables, so-called inter-array cables. The inter-array cables will connect the wind turbines in groups to the transformer platform. There will be up to 20 cable connections from the platform to the wind turbines. From the transformer platform a 220 kV export cable is laid to the shore at Saltbæk north of Grenå. The cables will be PEX insulated or similar with armouring.

The installation of the cables will be carried out by a specialist cable lay vessel that will manoeuvre either by use of a four or eight point moving system or an either fully or assisted DP (Dynamically Positioned) operation.

All the subsea cables will be buried in order to provide protection from fishing activity, dragging of anchors etc. A burial depth of minimum one meter is expected. The final depth of burial will be determined at a later date and will vary depending on more detailed soil condition surveys and the equipment selected.

The cables will be buried either using an underwater cable plough that executes a simultaneous lay and burial technique that mobilises very little sediment; or a Remotely Operated Vehicle (ROV) that utilises high-pressure water jets to fluidise a narrow trench into which the cable is located. The jetted sediments will settle back into the trench.

4.1.3 Onshore components

At sea the submarine cable is laid from a vessel with a large turn table. Close to the coast, where the depth is inadequate for the vessel, floaters are mounted onto the cable and the cable end is pulled onto the shore. The submarine cable is connected to the land cable close to the coast line via a cable joint. Afterwards the cables and the cable joint are buried into the soil and the surface is re-established.

On shore the land cable connection runs from the coast to compensation substation 2-3 km from the coast and further on to the substation Trige near Århus. At the substation Trige a new 220/400 kV transformer, compensation coils and associated switchgear will be installed. The onshore works are not part of the scope of the Environmental Statement for the Anholt Offshore Wind Farm. The onshore works will be assessed in a separate study and are therefore not further discussed in this document.

4.2 Environmental impacts

Establishment of an offshore cable is associated with a number of different disturbances during construction including traffic (vessels), preparation of the seabed and cable lying. These activities result in a number of different impacts on the biological communities.

4.2.1 Method

In order to generate an overview of the effects of the substation and offshore cable associated with the Anholt OWF on marine mammals all effects are rated using same criteria as outlined in Table 3-5.

4.2.2 Impacts during the construction phase

The potential impacts on marine mammals from the substation and offshore cable during construction fall under four main headings:

- Noise and vibration
- Suspension of sediments
- Habitat change
- Traffic

4.2.2.1 Noise and vibration

Assuming a worst-case scenario where the substation is constructed on monopole foundations the impacts on Harbour porpoise and Harbour seal will be similar to the impacts envisaged in relation to the pile-driving activities for the turbine foundations. Thus, at frequencies higher than app. 2 kHz construction noise will be below background noise and porpoises and seals will most likely not detect them at large distances. Accordingly, the zone of audibility is estimated at less than 50 km from the substation.

Masking of communication might occur in seals and Harbour porpoises over distances of more than 20 km from the source, while masking of echo location is not an issue. The zone of responsiveness in both species is estimated at approximately 20 km, thus overlapping with area of high habitat suitability to the Harbour seals from Totten, and areas of medium abundance of Harbour porpoise. It is expected that both species will move outside this zone during pile-driving operations, and return following these activities.

Temporal hearing loss might occur at 1,000 m in Harbour porpoises and 250 m in Harbour seals from a regulatory perspective. If frequency dependent hearing loss is taken into account, temporal hearing loss might occur at greater distances as predicted by a regulatory approach.

Noise impacts due to the construction of offshore cables are expected to be small and short range, due to overlapping sound pressure levels with background noise, including ferries, and hence general masking of the noise away from the actual site of cabling activity.

As the seasonal use of the Project Area by marine mammals has not been established, it is not known to which extend the potential displacement due to construction noise of the substation and offshore cables will depend on the timing of construction activities.

4.2.2.2 **Suspension of sediments**

The modelled sediment plumes (gravity foundations) are not expected to cause any direct impact on seals and porpoises, and concentrations of suspended material are not expected to reduce the availability of prey, especially juvenile fish. Hence, no significant negative effects are expected.

4.2.2.3 **Habitat change**

The establishment of the substation and cables implies destruction of existing habitats as well as generation of new habitats. The effected area is however very small and there are not to be expected to have any effects on the distribution of marine mammals.

The dominant substrate type at the wind farm area is sand. The erection of the substation with foundations and scour protections made from stones and rocks will introduce hard bottom substrate to the area, thus resulting in completely new habitats in the area. A colonisation similar to the one observed at the Horns Rev 1 Offshore Wind Farm is also likely to occur at the Anholt OWF. Although colonisation is fast, only the initial phases of the colonisation are expected to take place during the relatively short construction phase.

4.2.2.4 **Traffic**

The construction phase is associated with intense vessel traffic. Collisions involving small cetaceans and seals are normally limited to fast sailing boats like transport boats with service personnel. Collisions with Harbour porpoises and seals are most likely to happen in the high-use zones. In general, knowledge of the migratory routes of porpoises and seals in the central Kattegat is inadequate to evaluate to what degree the construction works will potentially act as barriers to those routes. It is judged as most likely that the barrier effect will be small due to the width of the area between Anholt and Djursland.

4.2.2.5 Conclusions of impacts during construction

As for construction of turbines the primary impact on marine mammals is pile driving activity, which is considered to have a moderate, temporary effect on the three species. However, due to that both seals and Harbour porpoise uses the area east of Anholt more frequently than the Project Area it is doubtful that the ecological functionality for the species over time is affected by the construction work.

Table 4-1. Summary of impacts on marine mammals during construction of the substation and offshore cables.

Impact	Intensity of effect	Scale/geographical extent of effect	Duration of effect	Overall significance of impact
Noise and vibrations	Medium	Regional	Medium-term	Moderate
Suspension of sediments	Minor	Local	Medium-term	Minor
Traffic	Minor	Local	Medium-term	Minor
Habitat changes	Minor	Local	Long-term	Minor

4.2.3 Impacts during the operation phase

Impacts during operation comprise the following parameters:

- Noise and vibrations
- Traffic
- Electromagnetic field
- Reef effect

4.2.3.1 Noise and vibrations

Elevation of underwater noise levels above background levels due to the operation of the substation is not expected, and hence no noise-induced effects on marine mammals are expected.

4.2.3.2 Traffic

Running maintenance of the turbines involves some vessel activities in the wind farm area. The traffic during the operational phase is restricted to smaller vessels participating in the maintenance operations. The possibility of collisions between marine mammals and maintenance vessels much be considered as marginal and restricted to fast sailing vessels such as speed boats.

4.2.3.3 **Electromagnetic fields**

During operation, the offshore cables connecting the wind farm to shore will generate a narrow zone of electromagnetism along the cables. Marine mammals are generally not regarded as sensitive to electromagnetic fields generated close to the cable, although the range of electromagnetism is detectable by electro-sensitive fish species /52/. Modelling, measurements and monitoring results show that the field of impact is narrow (< 1 m) and impacts on local fish stocks are non-significant /52/, /53/ with impacts on marine mammals deemed negligible.

4.2.3.4 **Reef effect**

Colonising of the foundation and scour protection of the substation will continue during the operation phase. New species will inhabit the hard structure habitats as the biomasses of sessile organisms and flora increase. Additionally, the artificial reefs are potential spawning and nursery areas for a number of species. The fish diversity is expected to increase during the operation phase. The increased availability of potential prey for porpoises and seals like cod (Gadus morhua) and whiting (Merlangius merlangus) within the wind farm may attract the animals to the wind farm site.

4.2.3.5 **Conclusions of impacts during operation**

There are considerable effect of the substation and cable, when in operation.

Table 4-2. Summary of impacts on marine mammals during the operation of the substation and offshore cables.

Impact	Intensity of effect	Scale/geographical extent of effect	Duration of effect	Overall significance of impact
Noise and vibrations	Minor	Local	Medium-term	Minor
Traffic	Minor	Local	Medium-term	Minor
Electromagnetic fields	Minor	Local	Long-term	Minor
Reef effects	Minor	Local	Long-term	Minor

4.3 Mitigation measures

None.

4.4 Cumulative effects

The joint impact of fisheries, ferry services and the Anholt OWF will considerably exceed the impacts from the substation and offshore cable.

4.5 Decommissioning

Impacts on marine mammals envisaged during decommissioning are similar to some of the noise-induced impacts expected during construction.

4.6 Technical deficiencies or lack of knowledge

None.

4.7 Conclusion of impacts related to the substation and cable

In this chapter the EIA evaluation of potential impacts are concluded for the substation and cable. Table 4-3 an example of the EIA evaluation of potential impact, significance rating of the assessed impact and the quality of data/documentation is given based on the principles from the memo describing "Method for Impact Assessment (May 2009)". These principles are resumed below as Table 4-4 .

Table 4-3. Impacts on marine mammals during construction and operation of the substation and offshore cables related to the Anholt Offshore Wind Farm.

Effect	Overall significance of impact	Significance rating for the assessment
IMPACTS ON MARINE MAMMALS		
Construction phase		
Noise and vibrations	Moderate	3
Suspension of sediment	Minor	2
Traffic	Minor	3
Habitat changes	Minor	3
Operational phase		
Noise and vibrations	Minor	3
Traffic	Minor	3
Electromagnetic fields	Minor	3
Reef effect	Minor	3

Table 4-4. Principles for the EIA evaluation of potential impact, the significance rating of the assessed impact and the quality of data/documentation (from the memo describing "Method for Impact Assessment (May 2009)".

Quality of availably data

In order to evaluate the quality and significance of data and documentation for the impact assessment a significance rating of data and documentation should be evaluated within the specific technical subject topics using the following categories:

- 1 – Limited (scattered data, some knowledge)
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For the EIA-document an impact arising from a planned activity will, depending on its magnitude and the environmental sensitivity, be given a significance rating as follows:

: No impact	*No impact*: There will be no impact on structure or function in the affected area;
: Minor impact	*Minor impact*: The structure or functions in the area will be partially affected, but there will be no impacts outside the affected area;
: Moderate Impact	*Moderate Impact*: The structure or function in the area will change, but there will be no significant impacts outside the affected area;
: Significant impact	*Significant impact*: The structure or function in the area will change, and the impact will have effects outside the area as well;

5. Decommissioning

The objectives of the decommissioning process are to minimize both the short and long term effects on the environment whilst making the sea safe for others to navigate. These obligations are stipulated in the United Nations Convention of the Law of the Sea (UNCLOS).

There are no specific international regulations or guidelines on the decommissioning of offshore installations. Decommissioning will have to consider individual circumstances, such as comparative decommissioning options, removal or partial removal in a way that causes no significant adverse effects on the environment, the likely deterioration of the material involved, possibilities for re-use or recycling as well as its present and future effect on the marine environment.

Based on current available technology, today's practice for decommissioning would imply to remove the wind turbines completely and to remove all other structures and substructures to the natural seabed level. Infield and export cables would be removed, left safely in-situ, buried to below the natural seabed level or protected by rock placement depending on the hydrodynamic conditions. Scour protection would be left in-situ.

The wind turbines, structures and cables would be dismantled using similar craft and methods as deployed during the construction phase. However the operations would be carried out in reverse order. The recovered materials would be transported to shore for later material reuse, recycle or disposal.

The decommissioning programme will be developed during the operations phase, as regulatory controls and industry practices most likely will have changed in 25 years' time, when the wind farm will be decommissioned. Regardless of decommissioning method, decommissioning will comply with all applicable legal requirements regarding decommissioning at that time.

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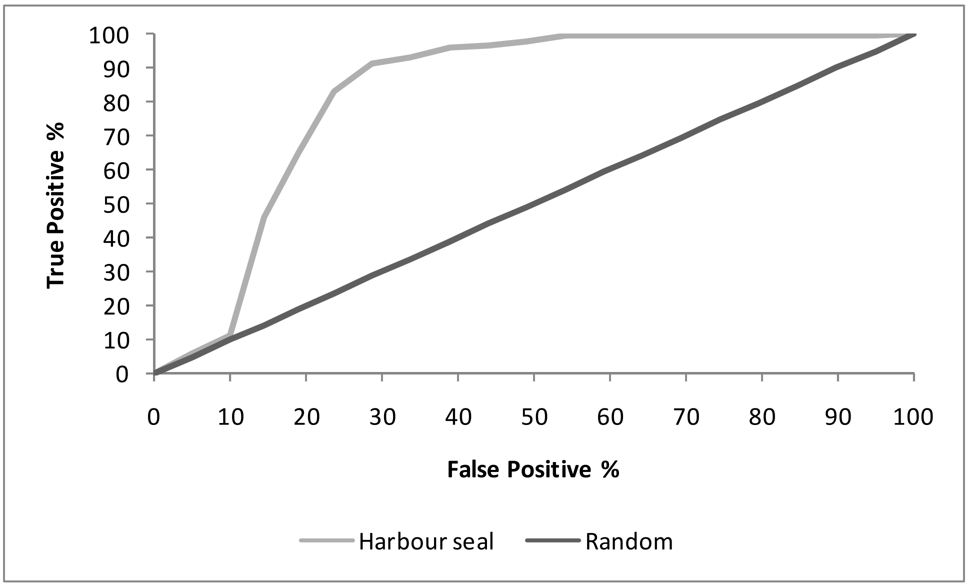
APPENDIX 1: VALIDATION OF HABITAT SUITABILITY MODELS

Relative-Operating-Characteristics (ROC) for the habitat suitability prediction model for Harbour porpoise based on satellite telemetry data in the central Kattegat, 1999-2008. The ROC assesses the validity of the suitability model by answering the general question, "How well does the predicted habitat suitability agree with the recorded animals in terms of the location of cells?".



Relative-Operating-Characteristics for the habitat suitability prediction model for Harbour seal based on satellite telemetry data in the central Kattegat, 1997-2007.