Final Report

FEHMARNBELT FIXED LINK
MARINE MAMMAL SERVICES (FEMM)

Marine Mammals – Impact Assessment

Marine Mammals of the Fehmarnbelt Area

E5TR0021

Prepared for: Femern A/S
By: BioConsult SH / Cefas Consortium
in association with IFAÖ, ITAP, SMRU Ltd. and DHI

Responsible editor:
BioConsult SH
Brinckmannstr. 31
D-25813 Husum
Germany

FEMM Project Director: Dr. Georg Nehls, BioConsult SH
www.bioconsult-sh.de

Please cite as:
FEMM (2013). Fehmarnbelt Fixed Link EIA.
Marine Mammals – Impact assessment.
Report no. E5TR0021.

Report: 276 pages

May 2013

ISBN 978-87-92416-58-2

Maps:
Unless otherwise stated:
DDO Orthofoto: DDO®, copyright COWI
Geodatastyrelsen (formerly Kort- og Matrikelstyrelsen), Kort10 and 25 Matrikelkort
GEUS (De Nationale Geologiske Undersøgelser for Danmark og Grønland)
HELCOM (Helsinki Commission – Baltic Marine Environment Protection Commission)
Landesamt für Vermessung und Geoinformation Schleswig-Holstein (formerly Landesvermessungsamt Schleswig-Holstein) GeoBasis-DE/LVermGeo SH

Photo: Caroline Höschle (Cover page)

Co-financed by the European Union
Trans-European Transport Network (TEN-T)

Table of contents

List of Figures

List of Tables

Note:

In this report the time for start of construction is artificially set to 1 October 2014 for the tunnel and 1 January 2015 for the bridge alternative (based on the data from Femern A/S). In the Danish EIA (VVM) and the German EIA (UVS/LBP) absolute year references are not used. Instead the time references are relative to start of construction works.

- In the VVM the same time reference is used for tunnel and bridge, i.e. year 0 corresponds to 2014/start of tunnel construction; year 1 corresponds to 2015/start of bridge construction etc.

- In the UVS/LBP individual time references are used for tunnel and bridge, i.e. for tunnel construction year 1 is equivalent to 2014 (construction starts 1 October in year 1) and for bridge construction year 1 is equivalent to 2015 (construction starts 1st January).

List of Abbreviations

Abbreviation	Meaning
AEP	Acoustically Evoked Potentials
AIS	Automatic Identification System
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
BHD	Backhoe Dredger
BSAP	Baltic Sea Action Plan
cd	Candle (unit of luminosity)
CEDA	Central Dredging Association
CFP	Common Fisheries Policy
CI	Confidence Interval
CITES	Convention on the International Trade in Endangered Species
C-POD	Click – Porpoise Detector
CV	Coefficient of Variation
dB re 1µPa	Decibel referred to 1 Micropascal
DDT	Dichlorodiphenyltrichloroethane
DoI	Degree of Impairment
ECA	Emission Control Area
EIA	Environmental Impact Assessment
EC	European Community
EcoQO	Ecological Quality Objective
EU	European Union
FeBEC	Fehmarnbelt Environmental Consortium Fish and Fisheries Services
FEHY	Fehmarnbelt Hydrographic Services
FEMA	Fehmarnbelt Marine Biology Services
FEMM	Fehmarnbelt Marine Mammal Studies
FL	Fixed Link
GD	Grab Dredger
GETM	A numerical model
GIS	Geographical Information System
GPS/GSM	Global Position System / Global System for Mobile
HCB	Hexacholorobenzene
HCH	Hexachlorocyclohexane
HELCOM	Helsinki Commission: "Convention on the Protection of the Marine Environment of the Baltic Sea Area"
HVPC	High Voltage Power Cables
IBM	Individual Based Modelling
ICES	International Council for the Exploration of the Sea

IDW	Inner Danish Waters
IMO	International Maritime Organization
ind.	individual(s)
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
km	Kilometre
L eq	Equivalent sound pressure level
m	metre
MIKE	A numerical model
mm	Millimetre
MMO	Marine Mammal Observer
ms	Millisecond
MSL	Mean Sea Level
MSP	Marine Spatial Planning
NERI	National Environment Research Institute
OSPAR	Oslo and Paris Conventions for the protection of the marine environment of the North-East Atlantic
PAH	Polycyclic aromatic hydrocarbons
PAM	Passive Acoustic Monitoring
PCB	Polychlorinated biphenyl
PDV	Phocine distemper virus
PTS	Permanent threshold shift
QSR	Quality Status Report
rms	Root mean square
SAC	Special Areas of Conservation
SCADA	Supervisory Control and Data Acquisition
SEA	Strategic Environmental Assessments
SEL	Sound Exposure Level
SL	Source Level
SoI	Severity of Impairment
SoI	Severity of Impact
SPL	Source Pressure Level
TBT	Tributyltin
TL	Transmission Loss
TSHD	Trailing Suction Hopper Dredger
TTS	Temporary threshold shift

1. SUMMARY

1.1. Introduction

The Fehmarnbelt Fixed Link between Germany and Denmark is being planned to comprise of a four-lane motorway and a double-track electrified railway. The link will run from Rødbyhavn on the Danish side of the Fehmarnbelt to Puttgarden on the island of Fehmarn on the German side over a distance of about 19 km. The three main scenarios being considered for the fixed link are:

- A cable-stayed bridge
- An immersed tunnel
- A zero alternative (do nothing)

As part of the EIA for the Fehmarnbelt Fixed Link, Femern A/S has commissioned the Fehmarnbelt Marine Mammals (FEMM) consortium to conduct baseline studies and undertake an impact assessment for marine mammals.

1.2. Marine mammals in the region

In the Fehmarnbelt area three species of marine mammals occur regularly: the harbour porpoise, *Phocoena phocoena*, a small cetacean which is widely distributed in the western Baltic Sea and the North Sea; the harbour seal, *Phoca vitulina,* with haul-out sites in the Rødsand lagoon holding a substantial proportion of the small subpopulation in the western Baltic Sea, and the grey seal, *Halichoerus grypus,* which occurs in low but growing numbers in Rødsand lagoon. The Fehmarnbelt is believed to provide important habitats for these species and to constitute a transit area for migration between the eastern and western parts of the Baltic Sea.

All three species are protected under various conventions and legislation. The harbour porpoise is listed in Annex 4 of the Habitats Directive (92/43/EEC as amended) and is thus subject to an assessment of strictly protected species in relation to Article 12 of the directive.

1.3. Methodology and approach to impact assessment

The baseline investigations undertaken by FEMM (2011) provide information on the spatial and temporal use of the Fehmarnbelt area and adjacent waters by marine mammal species. This area of investigation stretches from a line between Kiel and Langeland in the west, to a line between Gedser and Dahmeshöved in the east and forms the study area for the impact assessment. An assessment of importance of the study area was established for both the harbour porpoise and the two seal species within the baseline report.

Femern A/S provided all consortia with standard matrices for calculating severity of impact (both impairment and loss). The severity of any impact was assessed by combining the degree of impact (impairment/loss) with the importance of the area to harbour porpoise and seal species (using GIS tools where possible). The degree of impact describes a species response to the pressure, e.g. injury, behaviour change, mortality or removal of habitat. It can be calculated by adding the magnitude of the pressure to the sensitivity of the animal, or footprint of the pressure (if the impact constitutes loss). FEMM defined criteria and thresholds for the assessment of the impacts of the project to describe the degree of impact of each pressure:

Table 1.3—1 FEMM defined impact assessment criteria

Pressure	Impacts and Criteria	Duration	Range	Degree of impairment
Noise and vibration (construction, impulsive sounds)	Porpoises: Received sound levels are high enough to cause injury or PTS, SEL exceeds 198 dB re1µPa^{2}s (Southall et al., 2007) Seals: Received sound levels are high enough to cause injury or PTS, SEL 186 dB re 1 re1µPa^{2}s (seals)) (Southall et al., 2007)	Temporary	Local	Very High
	Porpoises: Received sound levels are high enough to cause TTS, SEL exceeds 183 dB re1 µPa^{2}s Seals: Received sound levels are high enough to cause TTS, SEL exceeds 171 dB re 1µPa^{2}s (Southall et al., 2007) All species: Sound levels at 750 m distance to source exceed 160 dB_{SEL} or 190 dB_{peak*}	Temporary	Local	High (Very High)*
	Sound levels are high enough to cause behavioural disturbance (received SEL exceeds 150 dB re 1µPa^{2}s (porpoises and seals) (Brandt et al., 2011)	Temporary	Regional	Medium
	Sound levels are high enough that some minor behavioural reactions might be expected (received SEL exceeds 144 dB re 1µPa^{2}·s (porpoises and seals) (Brandt et al., 2011)	Temporary	Regional	Low
Noise and vibration (operational phase)	Sound levels are high enough that some minor behavioural reactions might be expected (received SEL exceeds 144 dB re 1µPa^{2}s (porpoises and seals) (Brandt et al., 2011)	Permanent (operational phase)	Regional	Low
Habitat change (construction activities)	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biologically important proportion of the Belt population of seals and porpoises	Permanent	Local	Very High

Pressure	Impacts and Criteria	Duration	Range	Degree of impairment
	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biologically important proportion of the Belt population of seals and porpoises	Temporary – Long term	Local	High
	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biologically important proportion of the Belt population of seals and porpoises	Temporary – Short term	Local	Medium
	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biologically unimportant proportion of the Belt population of seals and porpoises	Temporary - Permanent	Local	Low
	Barrier effects lead to blocking of movements for a biologically important proportion of the Belt population of seals and porpoises	Permanent	Regional	Very High
	Barrier effects lead to blocking of movements for a biologically important proportion of the Belt population of seals and porpoises	Temporary – Long term	Regional	High
	Barrier effects lead to blocking of movements for a biologically important proportion of the Belt population of seals and porpoises	Temporary – Short term	Regional	Medium
Barrier effects (construction and structures)	Barrier effects lead to blocking of movements for a biologically unimportant proportion of the Belt population of seals and porpoises	Temporary - Permanent	Local	Low

* The German Federal Agency of the Environment proposes a threshold value for offshore pile driving of 160 dB_{SEL} or 190 dB_{peak} at 750 metres distance to the source in order to reduce disturbance and the risk of injury for all marine mammal species. The value is used to regulate underwater noise emissions from offshore pile driving. As demanded from the German authorities the threshold is adopted as assessment criteria and noise levels above the value are assessed as very high degree of impairment.

An assessment of the overall significance was then applied using expert judgement and the OSPAR ecological quality objective (EcoQO) thresholds of 1.7% reduction for harbour porpoises and a 10% reduction in grey and harbour seals. The 1.7% was agreed to be the 'total anthropogenic removal' from the population, so removals caused by multiple activities should not exceed that limit when combined. Therefore, a removal of >1% from a single activity has been assessed in conjunction with losses from other anthropogenic activities because the combined activities could have a significant effect at the population level. With this in mind, FEMM have considered ‘removal’ in terms of both 1% and 1.7% of the Fehmarnbelt study area population. The same assumptions can be applied to the seal criterion.

1.4. Description of the project

Zero Option

The zero alternative describes the future situation, without the establishment of a fixed link, for marine mammal populations in the Fehmarnbelt area. The assessment year for the operation phase of the fixed link is related to 2025 and 2030. The zero alternative, regards the human induced changes of 15 and 20 assessment years after the completion of the baseline study.

Within the Fehmarnbelt region, several human activities could take place without the establishment of a fixed link, including the establishment of new offshore wind farms, intensive fishing with gillnets and trawls, pollution of contaminants including toxic substances originating from a variety of different sources and eutrophication. The analysis of the available literature identified a variety of anthropogenic pressures, such as fisheries, shipping and tourism, acting on marine mammal species in the Baltic Sea and in the Fehmarnbelt. The introduction of new legislation (for example, energy efficiency) also has the potential to affect marine mammals in the region. Some forecast changes in pressures, such as amendments to environmental regulations, that are likely to result in improved ecological conditions and hence cause positive changes for marine mammals. Others, such as increased shipping traffic, are likely to be detrimental as a result of increased disturbance with an increased potential of collisions resulting in injury or death. It can be assumed that marine mammals in the Baltic Sea are at present negatively affected by human activities and the overall Baltic populations are probably well below carrying capacity. However, none of the future pressure changes assessed could be sufficiently quantified. No differences between 2025 and 2030 are elaborated. Hence, the status of marine mammals as determined by the baseline study is considered to be the most appropriate for the zero alternative assessment.

The zero alternative assessment for the Fehmarnbelt area identifies it as being of medium importance for harbour porpoises. Furthermore, its function as a feeding area and migration corridor has also been identified as of medium importance. The importance of the Rødsand lagoon and adjacent feeding areas for harbour seals is evaluated as very high, as this area is of significance to the whole Baltic population of harbour seals. The importance of the Rødsand area for grey seals is evaluated as high, as a substantial number of grey seals regularly use Rødsand as a breeding and pupping ground.

Tunnel option

The alignment for the immersed tunnel passes east of Puttgarden, crosses the Fehmarnbelt in a soft curve and reaches Lolland east of Rødbyhavn. The immersed tunnel will be constructed by placing tunnel elements in a trench dredged in the seabed. Reclamation areas are planned along both the German and Danish coastlines to accommodate the dredged material from the excavation of the tunnel trench. The landfall of the immersed tunnel passes through the shoreline reclamation areas on both the Danish and German sides. Temporary harbours will be integrated into these coastal reclamations to service tunnel construction operations from both the

German and Danish extremities of the immersed tunnel. The new dual carriageway and electrified twin track railway are to be constructed on Fehmarn for approximately 3.5 km south of the tunnel landfall, while they will extend for approximately 4.5 km north of the tunnel landfall at Lolland.

Bridge option

The main bridge is a twin cable-stayed bridge with three central pylons and two main spans of 724 m each. The superstructure of the cable-stayed bridge consists of a double deck girder with the dual carriageway road traffic running on the upper deck and the dual track railway running on the lower deck. The main bridge is connected to the coasts by two approach bridges. The southern approach bridge is 5,748 m long and consists of 29 spans and 28 piers. The northern approach bridge is 9,412 m long and has 47 spans and 46 piers. As for the tunnel option, temporary harbours and reclamation areas will be required.

1.5. Marine mammal sensitivity and project pressures

Five main pressures have been identified from the construction and operation of the tunnel and the bridge options:

- *Noise* (from dredging and backfilling, drilling and piling operations, and construction and operational traffic);
- *Habitat loss* (from dredging and backfilling, placement of tunnel sections/bridge piers and pylons, the temporary harbour and reclamation works);
- *Habitat change* (from dredging and backfilling, the temporary harbour, reclamation works and the bridge or tunnel in situ) and includes habitat structure change, siltation rate, hydrography and turbidity changes
- *Contaminants* (from the dredging and backfilling works);
- *Barrier effects* (from construction vessels; construction works taking place at the same time and the bridge in situ).

The sensitivity of marine mammals to man-made noise is not easy to understand as it depends on a number of inter-related internal and external factors. Effects change with varying sensitivities of individuals and there can also be effects at the population level. The sensitivity of marine mammals has been described according to available knowledge from literature and the defined assessment criteria refer to response types at different noise levels.

FEMM takes as standard assumption (unless evidence is provided for certain species), that animal populations are likely to be limited by availability of suitable habitats so that any loss of habitat or reduction in habitat quality will lead to an equivalent reduction in the number of animals living in this habitat. The sensitivity of marine mammals towards habitat loss or change is determined by a change in environmental key drivers which govern directly or indirectly the presence of these animals in a specific area; the latter is primarily driven through changes in prey availability and distribution. Any change in important key drivers may lead to a negative impact on marine mammals.

A contaminant can be a biological, chemical, physical or radiological substance which, in sufficient quantities, can have an adverse effect on living organisms through their environment and/or food. Contamination of marine mammals may be direct or through the process of biomagnification up the food chain. Given that marine mammals are top level predators, they accumulate the highest levels of biomagnifying contaminants.

Barrier effects arise when physical structures or perceived ‘barriers’ alter the behaviour of animals in their vicinity and may also prohibit movements across the barrier. Perceived barriers might include construction noise (e.g. extended dredging activity across a Strait) or operational noise (e.g. traffic crossing a bridge). Physical structures would include the artificial structures in the water column such as bridge supports. Barrier effects would be of particular concern in constrained areas utilised by migrating and foraging animals.

The sensitivity of harbour porpoises and seals is assessed on the basis of several studies at existing bridges and in relation to their behaviour against other artificial structures in the sea such as offshore windfarms. Harbour porpoises have been observed and recorded crossing under the bridge in the Great Belt and seals have been seen to cover large passages crossing several fixed links. The studies undertaken by FEMM (FEMM, 2011) show the presence of seals and harbour porpoises in the proximity of the Great Belt Bridge, with no evidence for changed behaviour. It is concluded that sensitivity against a barrier of a bridge is very low as available studies indicated that existing bridges in the Baltic Sea are freely passed.

1.6. Tunnel alternative impact assessment

Noise

Noise from various construction and operational activities were modelled, using recorded measurements of similar activities. The Degree of Impact (impairment/loss) was calculated and shown by GIS tools for each activity creating substantial noise, using the impact assessment criteria thresholds (Table 1.3—1). Each result was then compared to the German threshold for underwater noise of 160 dB re 1µPa²s SEL at 750 m. None of the modelled noise levels exceeded this threshold.

Each activity was assessed for severity by overlaying the noise modelling with the importance maps for the harbour porpoise and haul-out locations for the seal species. The number of porpoises affected by the construction work was determined in GIS by relating noise radii to modelled animal abundances. With regard to operational noise, it was concluded, using the results of the noise and vibration measurements near the Great Belt Bridge (and tunnel) that the severity of impact of operational underwater noise would be negligible and with no significant effects on marine mammals. Any small increase in noise from the use of the tunnel by road and rail traffic will be offset by the reduction in noise levels caused by the removal of the ferry service. As there is no overlap between the haul-out zone and the noise from either the construction or the operation, the only noise impact with regards to the seal species is the impact on food resource, which is discussed below. This loss of foraging habitat is of minor to negligible severity.

Overall, from all noise pressures, only a few individual porpoises (2.43 to 6.30 ind.) will be affected at a time by noise in winter and summer respectively, disturbing a maximum of 0.30% of the local Fehmarnbelt study area population (based on summer densities) and less than 0.1% of the Baltic subpopulation. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population) for the occurrence (staging) and nursery areas.

Habitat loss

The footprint of the tunnel project during the construction phase comprises 5.84 km^2. The footprint area of the tunnel during the construction period is regarded as an area of complete habitat loss since re-establishment within a short- or long-term period is expected to mostly take place after the construction period. Since habitat loss is defined to always result in a complete displacement of all marine mammals from the impact area, the degree of impact due to habitat loss is assessed to be very high. As for noise, GIS tools were used to calculate the severity of loss and the numbers of porpoises affected. Again for seals the only minor impact concerns food resource, as there is no overlap between the tunnel footprint and the haul-out locations and, therefore, **no direct impact** from habitat loss.

Overall, very few porpoises (1-2) will be affected by construction habitat loss, using the most precautionary scenario of summer construction works, with a maximum disturbance of 0.12% of the local Fehmarnbelt study area population and less than 0.1% of the Baltic subpopulation. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population).

Overall, a total of 0.81 porpoises will be affected by habitat loss during the operational stage, using the most precautionary scenario of summer construction works, with a maximum disturbance less than 0.1% of the local Fehmarnbelt study area population. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population).

Habitat change

Construction sediment spill (suspended sediment) and deposition (sedimentation) studies (FEHY, 2013d) undertook a numerical simulation of spreading of suspended concentration levels and sedimentation patterns. Results from the simulated spill concentrations have been compared with baseline conditions for suspended sediment concentrations. Suspended sediment concentrations are presented as exceedance time. The exceedance time is the percentage of time when the concentration has been above a given value. The results show that generally the background concentrations are higher and the exceedance times are much longer than the excess concentrations from the construction sediment spill. Suspended sediment concentrations of 50 mg/l are exceeded along the alignment, at coastal areas and within Rødsand Lagoon for less than 5% of the year, and 5-10% of the year in a very small area of Rødsand Lagoon. The sedimentation results show little or no sedimentation in the majority of the offshore area in the Fehmarnbelt away from the alignment. At the alignment, sedimentation is seen to be about 5 cm. Sedimentation is also seen in the sheltered part of the Rødsand Lagoon by up to 1cm.

Harbour porpoise hearing and echolocation are adapted for navigation and foraging in conditions where vision is limited or absent and seals successfully live and forage in turbid environments with vibrissae (whiskers) playing an important role when faced with reduced visibility. Therefore, given that the modelling demonstrates that elevated levels of suspended sediment only occur for a small amount (<5%) of the year and that all exceedance times for background concentrations are higher than the exceedance times due to spillage and there will be little or no sedimentation (if anything this will increase the habitat available for hauling out), the direct effect of sediment spill on harbour porpoise, harbour seal and grey seal is considered to have **no impact**

The hydrographic changes due to the tunnel option are assessed in FEHY (2013a) and FEHY (2013b). These assessed hydrographic changes include variance to the indicators: current, water level, salinity, water temperature, stratification and waves.

The permanent changes amount to a localised reduction in current of 0.02-0.06 m/s (up to 0.1 m/s very locally on the Fehmarn side). At the planned access channel to the production facility at Rødbyhavn, an increase in surface current speed of up to 0.08 m/s very locally is predicted. The baseline surface and bottom mean current speeds are 0.41 m/s (standard deviation = 0.23 m/s) and 0.13 m/s (sd = 0.09 m/s), respectively. Thus, the estimated changes in currents for the tunnel solution are negligible in comparison to the natural variability found in Fehmarnbelt. With respect to water level, salinity, water temperature and stratification, the permanent changes and changes during the construction period are predicted by FEHY to be negligible. With respect to waves, permanent changes and changes during construction are only seen in the immediate vicinity of the reclamations and appear mostly as lee effect on the eastern side of the reclamations.

It was concluded that the hydrological impacts are localised and lie within <50% of the natural change (standard deviation as defined within FEHY (2013b), therefore there will be **no direct impact** on marine mammal populations

Food supply effect from habitat change (indirect effect)

Harbour porpoise will be indirectly disturbed by the footprint through disturbance of benthic fauna and disturbance of pelagic (fish) species, which will reduce the prey availability to porpoise. FEBEC (2013) indicate that the construction of the immersed tunnel structure is deemed to have minor impairments on spawning and migration, but overall it is suggested that there will be no loss of function (i.e. spawning, egg-larvae-drift, nursery, feeding and migration) for the species analysed. It is concluded that impacts on the fish species which serve as food for harbour porpoises are low and only lead to **minor impacts** outside the footprint area.

In relation to the substrate with strong association to harbour and grey seal feeding behaviour, these substrate areas are relatively widespread throughout the Fehmarnbelt area. There is interaction of the impact footprint with areas of 'coarse sediment/boulders' and a small area of 'sand' that may be potential feeding areas for harbour seal. However, this interaction is very small in relation to remaining substrate in the area that is available for feeding. Grey seals have been seen to forage over much greater distances in the Fehmarnbelt region, and there is no interaction with any preferred 'mud' substrate. The area of interaction with 'sandy mud' is again small in relation to substrate available in their foraging range. Therefore, it has been assessed that there will be only **minor impacts** on seal foraging.

FEBEC (2013) suggest that the effects of hydrological pressure to fish communities in the Fehmarnbelt and local areas are insignificant. Therefore, no variation in prey distribution due to the hydrological effects of the immersed tunnel solution will occur and there will be no indirect impact on marine mammals.

FEBEC (2013) identifies that the physical loss of habitat from the operation phase of the tunnel will cause a minor severity of impact on the relevant harbour porpoise prey species: cod, herring and sprat. It has been assessed that there will be **no impact** on seal foraging.

Barrier effects

Barrier effects comprise of both the noise and the physical presence of construction vessels. It has been determined that noise is not a significant effect in terms of temporary habitat loss, but a determination is still required on whether the presence of vessels (i.e. dredge vessels) would cause a barrier to marine mammal movements. During construction, it was concluded that dredge vessels, rather than general construction vessels, had the largest potential to cause a physical barrier, given the level of shipping traffic which already exists in the region and the fact that marine mammals are regularly seen.

While multiple vessels may be dredging at the same time, the dredging work is going to be undertaken in sections, therefore dredging across the entirety of the channel will not occur. The worst barrier case for dredging on a spatial scale is about 5.2 km, which corresponds to ~30% of the line between Puttgarden and Rødby; however, this worst case case will only take place for a maximum of 10 weeks. Therefore, given the fact that approximately 70% of the channel remains free from barriers, it has been concluded that there will be only **minor impacts** from barrier effects during construction, as animals will easily be able to move around each dredging section.

There will be **no impact** from the tunnel during operation, as animals will be able to pass over the top of the tunnel once it is constructed. In addtion, there will be the removal of the ferry service across the channel, which will lessen the baseline vessel numbers in the region.

Contaminants

In the Fehmarnbelt seabed chemistry study (FEMA, 2011b), the results of the chemical analyses were compared against the German and Danish national and OSPAR Action Levels for a range of chemical contaminants, including key components from the OSPAR & HELCOM primary and secondary lists. It was concluded that the contaminant levels in the Fehmarnbelt study area were at or below the lowest sediment quality guideline (Action Level) at which the contaminant level is virtually certain to have no adverse effects. Therefore **no impacts** are predicted on marine mammals.

1.7. Bridge alternative impact assessment

Noise

The requirement for construction dredging is greatly reduced for the bridge option (890,000 m^3) compared to the tunnel option (18,750,000 m^3). As for the tunnel option, dredging will be done in sections, with the greatest amount of dredging activities occurring between June and October 2014. While not exact, each tunnel dredge section roughly corresponds to a bridge dredge section, therefore the previously modelled tunnel dredging was used (taking the appropriate tunnel dredge sections for each of the worst case bridge scenarios).

GIS analysis showed that the degree of impairment of construction dredging during June 2014 and October 2014 never exceeded the German threshold (160 dB re $1 \mu Pa^2$ s SEL at 750 m) despite the addition of extra dredge areas above those modelled in the tunnel dredge stages (extra sections to equate the worst case bridge scenarios). The worst case pile driving scenario consisted of two pile drivers working at the same time. However, even with an increased extent of noise impact, the German threshold was not exceeded. The bridge option also requires some bored pile work (drilling) to be undertaken. The modelling showed that bored piles were less noisy than impact pile driving, and again the German threshold was not exceeded. As there was some overlap between the pile driving and dredging works (which didn't occur for the tunnel option), a worst case scenario of dredging, pile driving and drilling was also assessed.

For the operation noise assessment, sound and vibration measurements from underneath and at a close distance to the Great Belt Bridge were taken. These measurements were a minimum of 12 dB lower than the ambient shipping noise for the region; therefore there is **no impact** on marine mammals from the operation of the bridge.

A maximum of 2.69 porpoises are predicted to be affected by the worst case construction scenario (dredging, piling and drilling) in winter, while 7.02 porpoises are predicted to be affected in summer (with no marine mammals impacted by operational noise). Therefore, a maximum disturbance of 0.34% of the local Fehmarnbelt study area population and less than 0.1% of the Baltic subpopulation is expected. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population).

Habitat loss

The footprint of the bridge covers a total of 0.79 km^2 of marine mammal habitat. The footprint area of the bridge during the construction period is regarded as an area of complete habitat loss since re-establishment within a short- or long-term period is expected to mostly take place after the construction period. Since habitat loss is defined to always result in a complete displacement of all marine mammals from the impact area, the degree of impact due to habitat loss is assessed to be very high. There will be no operational habitat loss. Overall, a total of 0.25 porpoises will be affected by construction habitat loss taking the worst case scenario of summer works, with a maximum disturbance of 0.01% of the Fehmarnbelt population. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population).

The only impact with regards to the seal species is the minor impact on food resource (discussed below), as there is no overlap between the haul-out zone and habitat loss from the construction works. Therefore, there is **no direct impact** on seals from habitat loss.

Habitat change

The placement of the bridge support structures and associated ship impact protection will introduce new hard substrate into the area. However, while the presence of bridge structures may introduce new habitat into the area, which may affect marine mammal food supply, it will have **no direct impact** on marine mammals.

With regards to sediment spill (suspended sediment and associated sedimentation) from dredging works, sediment concentrations are presented as exceedance time. The results show that excess concentrations are generally much shorter than the normal background concentrations and the exceedance times are also much smaller than the baseline background exceedance times. The sedimentation results show little or no sedimentation in the majority of the offshore area in the Fehmarnbelt away from the alignment. At the alignment, sedimentation is seen to be about 5 cm. Sedimentation is also seen in the sheltered part of the Rødsand Lagoon by up to 1 cm. In any case, there will be 95% less dredging occuring than for the tunnel option; therefore, given the results above and as sediment spill was concluded to have no impact on marine mammals from the tunnel option, it can be concluded that there will be **no direct**

impact on marine mammals from the bridge construction, with any indirect impacts on food resource discussed below.

The hydrographic changes due to the bridge option are assessed in FEHY (2013a) and FEHY (2013b). The permanent current changes amount to a reduction in surface current of up to 0.03 m/s at a 5 km distance from the main bridge structures and decreasing with distance from the bridge, however, the estimated changes in currents for the bridge option are negligible in comparison to the natural variability found in Fehmarnbelt. The assessed hydrographic changes include changes to currents, water level, salinity and water temperature, stratification and waves. With respect to water level, salinity, water temperature and stratification, the permanent changes and changes during the construction period are predicted by FEHY to be limited (mean water level change <0.01 m; mean salinity change <0.25 PSU; mean temperature change <0.25° C; mean stratification change <0.25 kg/m^3). With respect to waves, permanent changes and changes during construction are mainly seen on the eastern side of the bridge alignment. The changes predicted are reductions of 0.15 m to 0.30 m of the significant wave height exceeded 5% of the time within about 8 km of the bridge. However, the hydrological impacts are localised and lie within <50% of the natural change (standard deviation as defined within FEHY, 2013b. Therefore, the degree of impact is considered to be negligible and there will be **no direct impact** on harbour porpoises. Indirect impacts related to food resource discussed below. Hydrodynamic variables are only significant to harbour and grey seals in relation to prey distribution, therefore the direct degree of impact is considered to be negligible, with **no direct impact** on either seal species.

Food supply effect from habitat change (indirect effect)

Suspended sediment and sedimentation will impact and impair the function of marine mammal food resource. The deposition of spilled sediments can modify benthic habitats through smothering and by changing the sediment type. Change in benthic communities can influence the distribution of fish communities and prey items of marine mammals. FEBEC (2013) identify minor impacts of harbour porpoise prey species. It also indicates that the bridge pillars could provide a 'reef' effect for different fish species (e.g. cod, whiting, plaice and flounder) which may be attracted to the structures. Therefore, it is considered that the bridge alternative has the potential to affect and change the fish communities in the area of Fehmarnbelt. For marine mammals any 'reef' effect from the bridge is evaluated as neutral because FEBEC has identified a change but no decrease in their food supply, however, it is not possible to quantify such effects from the available evidence.

In this impact assessment there is predicted to be **no significant impact** from changes in food supply for either porpoise or seals.

Barrier effects

Dredging extends out into the Fehmarnbelt, but there is never a barrier across the whole channel. Therefore it has been concluded in this impact assessment that there will be **no significant impact** from barrier effects during construction, as animals may be able to move around each dredging section.

The severity of impairment from the bridge is assessed to be negligible and the function as a migration corridor will not be negatively affected. Therefore, in this impact assessment there is predicted to be **no significant impact** from the bridge acting as a barrier to either porpoise or seals.

Contaminants

In the Fehmarnbelt seabed chemistry study (FEMA, 2011b), the results of the chemical analyses were compared against the German and Danish national and OSPAR Action Levels for a range of chemical contaminants, including key components from the OSPAR & HELCOM primary and secondary lists. It was concluded that the contaminant levels in the Fehmarnbelt study area were at or below the lowest sediment quality guideline (Action Level) at which the contaminant level is virtually certain to have no adverse effects. Therefore **no impacts** are predicted on marine mammals.

1.8. Article 12 – Habitats Directive

For both the tunnel and the bridge options, there needs to be a determination on whether any of the pressures identified may lead to a violation of the objectives of Article 12 of the Habitats Directive: including the deliberate capture or killing of specimens (including injury) and the deliberate disturbance of marine mammals. Only underwater noise is assessed to be relevant to deliberate capture or killing or deliberate disturbance of animals (piling and dredging noise). However, given the degree and severity of impact, it is concluded that construction work will not lead to killing, injuring or significantly disturbing harbour porpoise and that the obligations of Article 12 habitat directive are not violated by the project.

1.9. Mitigation

The largest effects on marine mammals from the cable-stayed bridge and tunnel options are from the noise associated with the construction activities. Due to the relatively small spatial areas affected by the construction and operation of the bridge and tunnel and the relatively low importance of these areas for marine mammals, there are no specific recommendations for mitigation measures.

1.10. Cumulative effects

There are a number of projects in the Baltic Sea which have the potential to directly or indirectly act cumulatively with the fixed link to affect marine mammals.

All impacts from the immersed tunnel and bridge construction and operation have been shown to be local in extent (i.e. within a range of 500 m and 10 km). The nearest other project to the Fehmarnbelt fixed link is the Rødsand 2 offshore wind farm. At over 10 km distance between the tunnel and the wind farm the physical footprint of the projects and the potential zones of impact do not overlap.

Given there are similar pressures (noise and habitat loss) caused by the construction and operation of the above projects, it has been concluded that there will be a **minor** cumulative effect due to loss of habitat (disturbance due to noise and actual habitat loss). This conclusion was decided as a result of the effective loss of habitat for a biologically unimportant proportion of the Belt population of porpoise. As there was no impact on the seal species by any of the pressures described, there will be **no cumulative impact** on seals.

1.11. Trans-boundary impacts

The impacts from construction and operation of both the tunnel and bridge option lead to mainly temporal impacts which do not reach beyond the German-Danish study area and thus in the case of marine mammals no trans-boundary impacts occur. As the migration behaviour of marine mammals is not affected, no impacts on distant subpopulations of the three species living in the Fehmarnbelt arise. Therefore again, no trans-boundary impacts will occur.

1.12. Comparison of bridge and tunnel alternatives

It is thus concluded that both possible solutions of a fixed link lead to similar insignificant impacts on marine mammals and differences between the two options are too small to give one option a clear advantage against the other.

1.13. Conclusion

The impact assessment undertaken by FEMM concludes that any predicted impacts are insignificant at the local (Fehmarnbelt) and sub-regional population level.

2. INTRODUCTION

The Fehmarnbelt Fixed Link between Germany and Denmark is being planned to comprise of a four-lane motorway and a double-track electrified railway. It is being progressed under a State Treaty between the national Parliaments that was ratified by the two countries in 2009.

The 19 km link will run from Rødbyhavn on the Danish side of the Fehmarnbelt to Puttgarden on the island of Fehmarn on the German side. Whilst a number of options have been tabled, the three main scenarios now being considered for the fixed link are:

- A cable-stayed bridge
- An immersed tunnel
- A zero alternative (do nothing)

While the immersed tunnel has been chosen as the preferred solution, the EIA on the fixed link will also consider the alternatives and compare their environmental impacts. As part of the EIA for the Fehmarnbelt Fixed Link, Femern A/S has commissioned the Fehmarnbelt Marine Mammals (FEMM) consortium to conduct baseline studies and undertake an impact assessment for marine mammals. These assessments include the construction, operation and decommissioning phases for the cable-stayed bridge and construction and operation phases for the tunnel option. It is our understanding that when decommissioned the tunnel will be flooded with no direct impact on marine mammals and as such this phase has not been investigated.

In the Fehmarnbelt area three species of marine mammals occur regularly: the harbour porpoise, *Phocoena phocoena*; the harbour seal, *Phoca vitulina,* and the grey seal, *Halichoerus grypus*.

The methods applied for baseline studies and impact assessment for marine mammals follow international standards – many of them developed under participation of FEMM team members -

and comply with the German Standards for Environmental Impact Assessments for Offshore Wind Farms (StUK3) (Bundesamt für Seeschifffahrt und Hydrographie, BSH, 2007) as well as with the Danish standards for Environmental Impact Assessments (Agency for Spatial and Environmental Planning, 2009).

3. DATA AND METHODS

3.1. Description of the planning area

The fixed link across the Fehmarnbelt may be constructed as either a bridge or a submerged tunnel, leading to impacts in the marine habitats and on the land-approaches on Fehmarn and Lolland.

Since a final solution and the respective alignment had not been chosen at the start of the investigations, a project area, based on the investigations by Femern A/S, was defined between Puttgarden on Fehmarn and Rødby on Lolland (Figure 3.1-1). Chapters 6 and 7 of this Impact Assessment for marine mammals describe the locations of the chosen routes in greater detail. The Fehmarnbelt has a maximum depth of approximately 30 m. In the project area the width varies between 18 km (Rødbyhavn-Puttgarden) and 25 km. The seabed in the central parts is smooth with gentle slopes towards the coast of Lolland. On the Fehmarn side the slopes are slightly steeper.

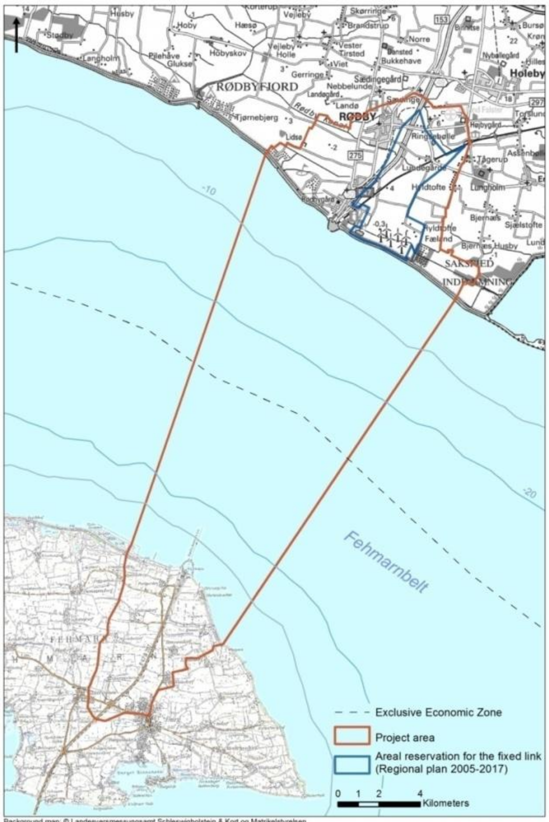

Figure 3.1-1 Demarcation of the project area for the planning of a fixed link

3.2. Demarcation of the study area

The baseline investigations provide information on the spatial and temporal use of the Fehmarnbelt area and adjacent waters by marine mammal species. The area of investigation stretches from a line between Kiel and Langeland in the west, to a line between Gedser and Dahmeshöved in the east (Figure 3.2-1). The area of investigation, i.e. the study area (Figure 3.2-1), fully encompasses the project area defined in Figure 3.1-1 but has been delineated to ensure that all Natura 2000 sites designated for the protection of marine mammals in the Fehmarnbelt and adjacent areas are covered. Also, the relatively wide extent to the east and west allows for the identification of possible distribution gradients and focal points of the different mammal species. In addition, the area of investigation covers the maximum area potentially influenced by suspended sediments as identified in earlier investigations.

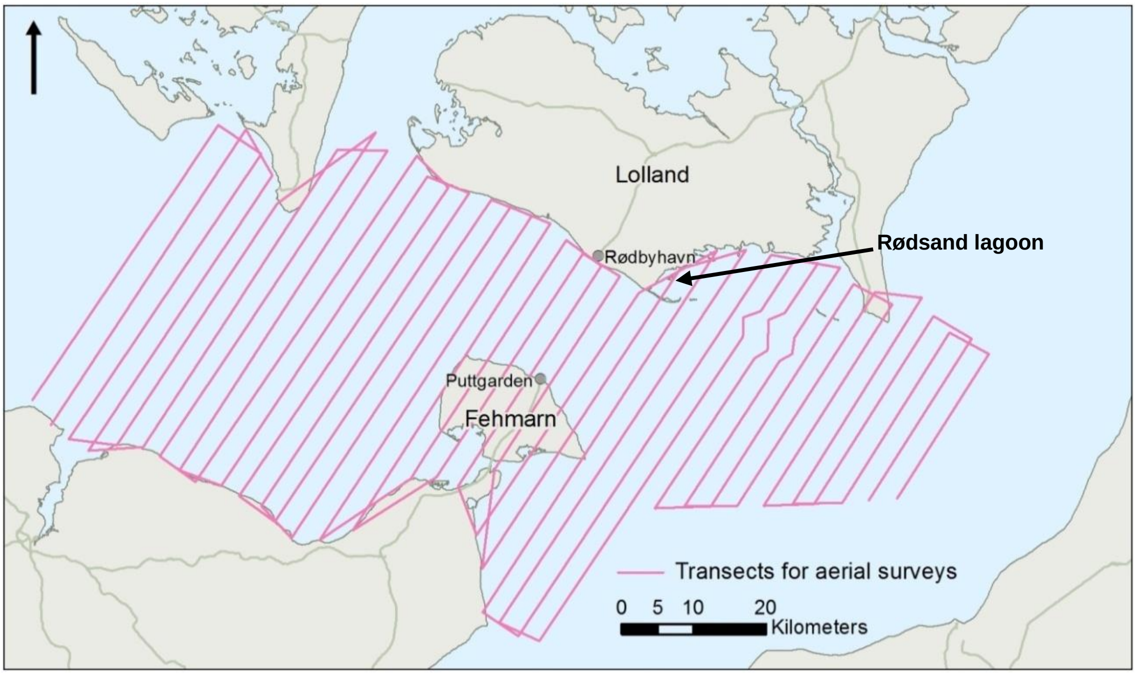

Figure 3.2-1 Demarcation of the study area for harbour porpoise as described by the extent of the aerial surveys (Source EIA Scoping Report: June 2010)

In the Fehmarnbelt area three species of marine mammals occur regularly: the harbour porpoise, *Phocoena phocoena*, a small cetacean which is widely distributed in the western Baltic Sea and the North Sea; the harbour seal, *Phoca vitulina,* with a haul-out site on Rødsand which holds a substantial proportion of the small subpopulation in the western Baltic Sea, and the grey seal, *Halichoerus grypus,* which occurs in low but growing numbers on Rødsand (Figure 3.2-1).

The Fehmarnbelt is believed to provide important habitats for these species and to constitute a transit area for migration between the eastern and western parts of the Baltic Sea (FEMM, 2011).

For harbour porpoises, the Fehmarnbelt represents the southern extent of their main distribution range in the western Baltic Sea. It is possible that separate populations inhabit the eastern and western parts of the western Baltic Sea, with an unknown exchange rate through the Fehmarnbelt (FEMM, 2011).

Fehmarnbelt provides an important haul-out habitat for harbour seals at the Rødsand sandbank south of Rødsand Lagoon, 25-30 km east of the project area. This is the most important haul-out and breeding site of the Baltic Sea. Currently, less used haul-out sites are Vitten and Skrollen in the Rødsand Lagoon.

Rødsand is also the location with the highest recorded number of grey seals in Denmark. Since the early 20th Century, the area has been used as a non-breeding haul-out site. However, breeding grey seals have recently been recorded there. This suggests that it is the most likely site for a re-establishment of the grey seal population in the western Baltic Sea. On the German side of the Fehmarnbelt there are no haul-out places for seals.

3.3. Species and habitat protection

There are a number of international and regional frameworks offering protection to harbour porpoise. These include: the IUCN Red List; CITES; Bonn Convention; ASCOBANS; HELCOM; EU Habitats Directive and the Bern Convention. Full details are provided in the FEMM baseline report (section 2.1.2, FEMM, 2011). Section 3.4 describes the protection of marine mammals under Article 12 of the Council Directive 92/43/EEC.

Both harbour and grey seals are listed on the HELCOM lists of threatened and/or declining species and habitats of the Baltic Sea area. They are also afforded protection by the Bern and Bonn international Conventions (HELCOM, 2009a).

Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora is the means by which the European Union meets its obligations under the Bern Convention.

Under Council Directive 92/43/EEC the harbour porpoise is listed in Annex II & IV, both grey seal & harbour seal are on Annex II and would also be covered by Annex V (under 'All species of Phocidae not mentioned in Annex IV').

The Directive promotes the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species listed on the Annexes to the Directive at a favourable conservation status, introducing robust protection for those habitats and species of European importance. In applying these measures, Member States are required to take account of economic, social and cultural requirements, as well as regional and local characteristics.

The provisions of the Directive require Member States to introduce a range of measures, including:

- Maintain or restore European protected habitats and species listed in the Annexes at favourable conservation status (defined in Articles 1 and 2);
- Contribute to a coherent European ecological network of protected sites by designating Special Areas of Conservation (SACs) for habitats listed on Annex I and for species listed on Annex II. Together SACs and Special Protection Areas (for birds) make up the Natura 2000 network (Article 3);

- Ensure conservation measures are in place to appropriately manage SACs and ensure appropriate assessment of plans and projects likely to have a significant effect on the integrity of an SAC. Projects may still be permitted if there are no alternatives and there are imperative reasons for overriding public interest. In such cases compensatory measures are necessary to ensure the overall coherence of the Natura 2000 network (Article 6);
- Member States shall also endeavour to encourage the management of features of the landscape that support the Natura 2000 network (Articles 3 and 10);
- Undertake surveillance of habitats and species (Article 11);
- Ensure strict protection of species listed on Annex IV (Article 12 for animals and Article 13 for plants);
- Report on the implementation of the Directive every six years (Article 17), including assessment of the conservation status of species and habitats listed on the Annexes to the Directive.

The Directive was amended in 1997 by a technical adaptation Directive and the annexes were further amended in 2003 by the Environment Chapter of the Treaty of Accession.

In the Fehmarnbelt area, three SACs have been declared and included into the Natura 2000 network to protect harbour porpoises, harbour and grey seals.

In the Fehmarnbelt, both bordering states have already declared marine areas as SACs in order to protect harbour porpoises. The declaration of these SACs was based on the findings of German and Danish research projects (see Scheidat et al., 2004; Teilmann et al., 2008) which investigated population and behaviour of harbour porpoises in the Baltic Sea.

3.4. Assessment of strictly protected species (Article 12 Habitats Directive)

Article 12 of the Council Directive 92/43/EEC on the protection of species states that:

1. Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV (a) in their natural range, prohibiting:

   a) all forms of deliberate capture or killing of specimens of these species in the wild;
   b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration;
   c) deterioration or destruction of breeding sites or resting places.

2. For these species, Member States shall prohibit the keeping, transport and sale or exchange, and offering for sale or exchange, of specimens taken from the wild, except for those taken legally before this Directive is implemented.
3. The prohibition referred to in paragraph 1 (a) and (b) and paragraph 2 shall apply to all stages of life of the animals to which this Article applies.

Member states are further requested to establish a system to monitor the deliberate capture or killing of species listed in Annex IV (a) and to make sure that this will not impair the conservation status of these species. The demands from the Habitats Directive concerning the strictly protected species have been transposed into national law in Germany (German Federal Nature Conservation Act 44 Bundesnaturschutzgesetz, BNatSchG) and in Denmark

(Naturbeskyttelsesloven). Further guidance on the application of the regulation of Article 12 is provided by the EU (http://ec.europa.eu/environment/nature/conservation/species/guidance/index_en.htm). In Germany, the states have frequently drafted guidelines for structuring assessments of strictly protected species in a special report (Artenschutzrechtlicher Fachbeitrag) and the guideline from the state of Schleswig-Holstein (LBV 2009) is also considered.

The strict protection obligations under Article 12 must be interpreted in terms of the overall aim of the Directive described in Article 2, to which they contribute. Some obligations of Article12 cover aspects of conservation which are also addressed in other parts of the directive, especially Article 6 and are thus also treated in the Appropriate Assessment in relation to Natura 2000 areas, which will be a separate document to the EIA reports. There is some discussion as to whether it is necessary to address impacts on strictly protected species within Natura 2000 areas in two different assessments in relation to the obligations of the Habitat Directive (BMVBS 2009). The following assessment will, therefore, not exclude the Natura 2000 areas but assess impacts on the relevant species irrespective of the legal status of the areas where they occur.

3.4.1. Approach and methodology of the assessment

The aim of the assessment of specially protected species as part of the level 2 EIA on marine mammals is to provide a contribution to the formal assessments in Germany and Denmark which are organised in different steps of the application documents:

- In Denmark the assessment of specially protected species is part of the EIA (VVM) and will cover both main alternatives of the project, which are the immersed tunnel and the cable-stayed bridge including all pressures during construction and operation.
- In Germany, the assessment of strictly protected species will be associated with the landscape management plan (Landschaftspflegerischer Begleitplan) and will only cover the preferred alternative, which is the immersed tunnel.

The approach and methodology to this part of the assessment is thus restricted to specific requirements of impacts on marine mammals. Within the Fehmarnbelt area, the only marine mammal species listed in Annex IV of the Habitats Directive which regularly occurs in the area is the harbour porpoise. It occurs all year round in the area and reproduces there.

As part of the Environmental Impact Assessment for a fixed link across Fehmarnbelt, it needs to be assessed whether any pressure, or the sum of all pressures of the project, might lead to a violation of these demands from the Habitats Directive, especially regarding the clauses under Paragraph 1, Article 12.

The pressures, which might be relevant for the assessment, will be described in sections 3.7 and Chapter 4. Harbour porpoises do not inhabit special breeding sites or use resting places in the way that seals do on their haul-out sites. The assessment is thus carried out in relation to the first two objectives of Article 12.1 (deliberate capture or killing and deliberate disturbance) but the third objective (deterioration or destruction of breeding sites or resting places) is not assessed separately.

1. Deliberate capture or killing of specimens

Deliberate killing is not restricted to intentional killing of individuals, for example, by hunting: 'Article 12(1)(a) prohibits all forms of deliberate capture or killing of specimens of Annex IV(a) species in the wild. The term "deliberate" has to be interpreted as going beyond "direct intention". A person who is reasonably expected to know that his action will most likely lead to an offence against a species, but intends the offence or, if not, at least accepts the results of his action, commits an offence' (EU guidance document). According to recent court cases it is generally accepted that a significant increase in the risk that an animal may be killed by a certain activity has to be regarded as violation of the regulations under Article 12. Although Article 12 is directed towards the conservation of species and populations, the prohibition of deliberate killing refers to the individuals of strictly protected species. In addition to killing, the German Federal Nature Conservation Act (BNatschG) is also prohibiting injuring protected animals, irrespective of whether or not this leads to death.

2. Deliberate disturbance, particularly during the period of breeding, rearing, hibernation and migration

With respect to deliberate disturbance, the term deliberate has to be understood in the same way as described above and is going beyond direct intention. In addition, unlike deliberate killing, deliberate disturbance does not refer to the individual and Article 12 does not prohibit any disturbance, but considers impacts on species and their populations: 'The intensity, duration and frequency of repetition of disturbances are important parameters when assessing their impact on a species' (EU guidance document). There is no definition of disturbance provided and the degree of disturbance which is regarded as a violation of the Directive is not defined. In general, disturbance is regarded as any effect which leads to the displacement of animals out of a natural habitat. This includes barriers for migrating animals (LBV 2009). The EU provides some additional guidance: 'The disturbance under Article 12(1)(b) must be deliberate (see chapter II.3.1) and not accidental. On the other hand, whilst "disturbance" under Article 6(2) must be significant, this is not the case in Article 12(1), where the legislator did not explicitly add this qualification'. According to the EU guidance document 'Disturbance does not need to affect the physical integrity of a species but can nevertheless have a direct negative effect. Disturbance is detrimental for a protected species e.g. by reducing survival chances, breeding success or reproductive ability. A species-by-species approach needs to be taken as different species will react differently to potentially disturbing activities'.

The German Federal Nature Conservation Act (BNatschG) provides further definition in Article 44 by specifying that a disturbance shall be deemed significant if it causes the conservation status of the local population of a species to worsen'. There is no definition of a local population which can be applied to harbour porpoises in the context of the planned fixed link across Fehmarnbelt. The biological definition of populations is not applicable and the term 'local population' refers to management units based on distinct centres of a distribution of a species and is most applicable to breeding or specific resting areas. In the practice of impact assessments, local population are sometimes defined by administrative rather than biological borders. Following Kiel (2007) the latter is also recommended by the state of Schleswig-Holstein (LBV SH, 2009). In the Fehmarnbelt area, haul-out sites for seals in the Rødsand lagoon, for example, would be regarded as a local population. However, in the case of the harbour porpoise, areas with higher abundance are included in the Natura 2000 network. It is, therefore, not feasible to define local populations below the level of large-scale genetically defined populations or subpopulations. As shown in the baseline study (FEMM, 2011), porpoises are highly mobile and average distances between daily positions, as determined by satellite tracking, differ by 20 to 30 km. Thus, even the large baseline study area of 4000 km^2 only covers a small part of the range of individual porpoises. In order to follow a practical approach, as recommended in various guidelines (e.g. LBV SH, 2009), the assessment of disturbance will be done taking the occurrence of harbour porpoises in the baseline study area as reference for the local population. Though the assessment of strictly protected species will feed into different stages of the assessment procedure in Germany and Denmark, it is not considered practical to separate local populations for both countries as the project of a fixed link should, in any case, be assessed as one unit.

3.5. Impact assessment approach and methods

To ensure a uniform and transparent basis for the environmental impact assessment (EIA), a general impact assessment methodology for the assessment of predictable impacts of the Fixed Link Project on the environmental factors (see box 3.1) has been prepared. The methodology is defined by the impact forecast methods described in the scoping report (Femern and LBV-SH-Lübeck 2010, section 6.4.2). In order to give more guidance and thereby support comparability, the forecast method has been further specified.

As the impact assessments cover a wide range of environs (terrestrial and marine) and environmental factors, the general methodology is further specified and in some cases modified for the assessment of the individual environmental factors (e.g. the optimal analyses for migrating birds and relatively stationary marine bottom fauna are not identical). These necessary modifications are explained in Section 3.2.2. The specification of methods and tools used in the present report are given in the following sections of Chapter 3.

The information provided in the German memorandum to the Danish authorities (dated 28th June 2011) in reference to Femern A/S, describes the assessment criteria. The FEMM consortium has interpreted the interactions of these criteria into a two stage process as follows:

3.5.1. Overview of terminology

To assist reading the background report as documentation for the German UVS/LPB and the Danish VVM, the Danish and German terms are given in the columns to the right.

Table 3.5—1 Terminology overview

Term	***Explanation***	***Term DK***	***Term DE***
Environmental factors	The <u>environmental factors</u> are defined in the EU EIA Directive (EU 1985) and comprise: Human beings, Fauna and flora, Soil, Water, Air, Climate, Landscape, Material assets and cultural heritage. In the sections below only the term environmental factor is used; covering all levels (factors, sub-factors, etc.; see below). The relevant level depends on the analysis.	Miljøforhold/-faktor	Schutzgut

Term	***Explanation***	***Term DK***	***Term DE***
Sub-factors	As the Fixed Link Project covers both terrestrial and marine sections, each environmental factor has been divided into three sub-factor: Marine areas, Lolland and Fehmarn (e.g. Marine waters, Water on Lolland, and Water on Fehmarn)	Sub-faktor	Teil-Schutzgut
Components and sub-components	To assess the impacts on the sub-factors, a number of components and sub-components are identified. Examples of components are e.g. Surface waters on Fehmarn, Groundwater on Fehmarn; both belonging to the sub-factor Water on Fehmarn. The sub-components are the specific indicators selected as best suitable for assessing the impacts of the Project. They may represent different characteristics of the environmental system; from specific species to biological communities or specific themes (e.g. trawl fishery, marine tourism).	Component/sub-komponent	Komponente
Construction phase	The period when the Project is constructed; including permanent and provisional structures. The construction is planned for 6½ years.	Anlægsfase	Bauphase
Structures	Constructions that are either a permanent elements of the Project (e.g. bridge pillar for bridge alternative and land reclamation at Lolland for tunnel alternative), or provisional structures such as work harbours and the tunnel trench.	Anlæg	Anlage
Operation phase	The period from end of construction phase until decommissioning.	Driftsfase	Betriebsphase
Permanent	Pressure and impacts lasting for the life time of the Project (until decommissioning).	Permanent	Permanent
Provisional	Pressure and impacts predicted to be recovered within the life time of the project. The recovery time is assessed as precise as possible and is in addition related to Project phases.	Midlertidig	Temporär

Term	*Explanation*	*Term DK*	*Term DE*
Pressures	A pressure is understood as all influences deriving from the Fixed Link Project; both influences deriving from Project activities and influences originating from interactions between the environmental factors. The type of the pressure describes its relation to construction, structures or operation.	Belastning	Wirkfaktoren
Magnitude of pressure	The magnitude of pressure is described by the intensity, duration and range of the pressure. Different methods may be used to arrive at the magnitude; dependent on the type of pressure and the environmental factor to be assessed.	Belastnings-størrelse	Wirkintensität
Footprint	The footprint of the Project comprises the areas occupied by structures. It comprises two types of footprint; the permanent footprint deriving from permanent confiscation of areas to structures, land reclamation etc., and provisional footprint which are areas recovered after decommissioning of provisional structures. The recovery may be due to natural processes or Project aided re-establishment of the area.	Arealinddragelse	Flächeninanspruchnahme
Assessment criteria and Grading	Assessment criteria are applied to grade the components of the assessment schemes. Grading is done according to a four grade scale: very high, high, medium, minor or a two grade scale: special, general. In some cases grading is not doable. Grading of magnitude of pressure and sensitivity is method dependent. Grading of importance and impairment is as far as possible done for all factors.	Vurderings-kriterier og graduering	Bewertungskriterien und Einstufung
Importance	The importance is defined as the functional values to the natural environment and the landscape.	Betydning	Bedeutung
Sensitivity	The sensitivity describes the environmental factors capability to resist a pressure. Dependent on the subject assessed, the description of the sensitivity may involve intolerance, recovery and importance.	Sårbarhed	Empfindlichkeit
Impacts	The impacts of the Project are the effects on the environmental factors. Impacts are divided into Loss and Impairment.	Virkninger	Auswirkung
Loss	Loss of environmental factors is caused by permanent and provisional loss of area due to the footprint of the Project; meaning that loss may be permanent or provisional. The	Tab af areal	Flächenverlust

Term	Explanation	Term DK	Term DE
	degree of loss is described by the intensity, the duration and if feasible, the range.		
Severity of loss	Severity of loss expresses the consequences of occupation of land (seabed). It is analysed by combining magnitude of the Project's footprint with importance of the environmental factor lost due to the footprint.	Omfang af tab	Schwere der Auswirkungen bei Flächenverlust
Impairment	An impairment is a change in the function of an environmental factor.	Forringelse	Funktionsbeeinträchtigung
Degree of impairment	The degree of impairments is assessed by combining magnitude of pressure and sensitivity. Different methods may be used to arrive at the degree. The degree of impairment is described by the intensity, the duration and if feasible, the range.	Omfang af forringelser	Schwere der Funktionsbe-einträchtigung
Severity of impairment	Severity of impairment expresses the consequences of the Project taking the importance of the environmental factor into consideration; i.e. by combining the degree impairment with importance.	Signifikans	Erheblichkeit
Significance	The significance is the concluding evaluation of the impacts from the Project on the environmental factors and the ecosystem. It is an expert judgment based on the results of all analyses.		

It should be noted that in the sections below only the term environmental factor is used; covering all levels of the receptors of the pressures of the Project (factors, sub-factors, component, sub-components). The relevant level depends on the analysis and will be explained in the following methodology sections (section 3.5.2 and onwards).

3.5.2. The Impact Assessment Scheme

The overall goal of the assessment is to arrive at the severity of impact where impact is divided into two parts; loss and impairment (see explanation above). As stated in the scoping report, the path to arrive at the severity is different for loss and impairments. For assessment of the *severity of loss* the footprint of the project (the areas occupied) and the *importance* of the environmental factors are taken into consideration. On the other hand, the assessment of severity of impairment comprises two steps; first the *degree of impairment* considering the magnitude of pressure and the sensitivity. Subsequently the severity is assessed by combining the degree of impairment and the importance of the environmental factor. The assessment schemes are shown below. More details on the concepts and steps of the schemes are given below. As mentioned above, modifications are required for some environmental factors and the exact assessment process and the tools applied vary dependent on both the type of pressure and the environmental factor analysed. As far as possible the impacts are assessed quantitatively; accompanied by a qualitative argumentation.

3.5.3. Assessment Tools

For the impact assessment the assessment matrices described in the scoping report have been key tools. Two sets of matrices are defined; one for the assessment of loss and one for assessment of impairment.

The matrices applied for assessments of severity of loss and degree of impairment are given in the scoping report (Table 6.4 and Table 6.5) and are shown below in Table 3.5—2 and Table3.5-3 respectively.

Table 3.5—2 The matrix used for assessment of the severity of loss. The magnitude of pressure = the footprint of the Project is always considered to be very high

Magnitude of the predicted pressure (footprint)	**Importance of the environmental factors**			
	Very high	High	Medium	Minor
Very High	**Very High**	**High**	**Medium**	**Minor**

Magnitude of the predicted pressure	**Sensitivity of the environmental factors**	
	Special	General
Very high	**General loss of function, must be substantiated for specific instances**	
High	**Very High**	**High**
Medium	**High**	**Medium**
Low	**Medium**	**Low**

The approach and thus the tools applied for assessment of the degree of impairment varies with the environmental factor and the pressure. For each assessment the most optimal state-of-the-art tools have been applied, involving e.g. deterministic and statistical models as well as GIS based analyses. In cases where direct analysis of causal-relationship is not feasible, the matrix based approach has been applied using one of the matrices in Table 3.5-3 (Table 6.5 of the scoping report) combining the grades of magnitude of pressure and grades of sensitivity. This method gives a direct grading of the degree of impairment. Using other tools to arrive at the degree of impairment, the results are subsequently graded using the impairment criteria. The specific tools applied are described in the following sections of Chapter 3.

Table 3.5—3 The matrices used for the matrix based assessment of the degree of impairment with two and four grade scaling, respectively

Magnitude of the predicted pressure	Sensitivity of the environmental factors			
	Very high	High	Medium	Minor
Very high	**General loss of function, must be substantiated for specific instances**			
High	**Very High**	**High**	**High**	**Medium**
Medium	**High**	**High**	**Medium**	**Low**
Low	**Medium**	**Medium**	**Low**	**Low**

To reach severity of impairment one additional matrix has been prepared, as this was not included in the scoping report. This matrix is shown in Table 3.5—4.

Table 3.5—4 The matrices used for assessment of the severity of impairment

Degree of impairment	Importance of the environmental factors			
	Very high	High	Medium	Minor
Very High	**Very High**	**High**	**Medium**	**Minor**
High	**High**	**High**	**Medium**	**Minor**
Medium	**Medium**	**Medium**	**Medium**	**Minor**
Low	**Minor**	**Minor**	**Minor**	**Negligible**

Degree of impairment	Importance of the environmental factors	
	Special	General
Very high	**Very High**	**Medium**
High	**High**	**Medium**
Medium	**Medium**	**Medium**
Low	**Minor**	**Minor**

3.5.4. Assessment Criteria and Grading

For the environmental assessment two sets of key criteria have been defined: Importance criteria and the Impairment criteria. The importance criteria is applied for grading the importance of an environmental factor, and the impairment criteria form the basis for grading of the impairments caused by the project. The criteria have been discussed with the authorities during the preparation of the EIA.

The impairment criteria integrate pressure, sensitivity and effect. For the impact assessment using the matrix approach, individual criteria are furthermore defined for pressures and sensitivity. The criteria were defined as part of the impact analyses (severity of loss and degree of impairment). Specific assessment criteria are developed for land and marine areas and for each environmental factor. The specific criteria applied in the present impact assessment are described in the following sections of Chapter 3 and as part of the description of the impact assessment.

The purpose of the assessment criteria is to grade according to the defined grading scales. The defined grading scales have four (very high; high, Medium; minor) or two (special; general) grades. Grading of magnitude of pressure and sensitivity is method dependent, while grading of importance and impairment is as far as possible done for all factors.

3.5.5. Identifying and quantifying the pressures from the Project

The pressures deriving from the Project are comprehensively analysed in the scoping report; including determination of the pressures which are important to the individual environmental sub-factors (Femern and LBV SH Lübeck 2010, chapter 4 and 7). For the assessments the magnitude of the pressures is estimated.

The magnitudes of the pressures are characterised by their type, intensity, duration and range. The *type* distinguishes between pressures induced during construction, pressures from the physical structures (footprints) and pressures during operation. The pressures during construction and from provisional structures have varying duration while pressures from staying physical structure (e.g. bridge piers) and from the operation phase are permanent. Distinctions are also made between direct and indirect pressures where direct pressures are those imposed directly by the Project activities on the environmental factors while the indirect pressures are the consequences of those impacts on other environmental factors and thus express the interactions between the environmental factors.

The *intensity* evaluates the force of the pressure and is as far as possible estimated quantitatively. The *duration* determines the time span of the pressure. It is stated as relevant for the given pressure and environmental factor. Some pressures (like footprint) are permanent and do not have a finite duration.

Some pressures occur in events of different duration. The *range* of the pressure defines the spatial extent. Outside of the range, the pressure is regarded as non-existing or negligible.

The magnitude of pressure is described by pressure indicators. The indicators are based on the modes of action on the environmental factor in order to achieve most optimal descriptions of pressure for the individual factors; e.g. mm deposited sediment within a certain period. As far as possible the magnitude is worked out quantitatively. The method of quantification depends on the pressure (spill from dredging, noise, vibration, etc.) and on the environmental factor to be assessed (calling for different aggregations of intensity, duration and range).

3.5.6. Importance of the Environmental Factors

The importance of the environmental factor is assessed for each environmental sub-factor. Some sub-factors are assessed as one unity, but in most cases the importance assessment has been broken down into components and/or sub-components to conduct a proper environmental impact assessment. Considerations about standing stocks and spatial distribution are important for some sub-factors such as birds and are in these cases incorporated in the assessment.

The assessment is based on *importance criteria* defined by the functional value of the environmental sub-factor and the legal status given by EU directives, national laws, etc. the criteria applied for the environmental sub-factor(s) treated in the present report are given in a later section.

The importance criteria are grading the importance into two or four grades (see section 3.2.4). The two grade scale is used when the four grade scale is not applicable. In a few cases such as climate, grading does not make sense. As far as possible the spatial distribution of the importance classes is shown on maps.

3.5.7. Sensitivity

The optimal way to describe the sensitivity to a certain pressure varies between the environmental factors. To assess the sensitivity, more issues may be taken into consideration such as the intolerance to the pressure and the capability to recover after impairment or a provisional loss. When deterministic models are used to assess the impairments, the sensitivity is an integrated functionality of the model.

3.5.8. Severity of loss

Severity of loss is assessed by combining information on magnitude of footprint, i.e. the areas occupied by the Project with the importance of the environmental factor (Figure 3.5-1). Loss of area is always considered to be a very high magnitude of pressure and therefore the grading of the severity of loss is determined by the importance (see Table 3.5—2). The loss is estimated as hectares of lost area. As far as possible the spatial distribution of the importance classes is shown on maps.

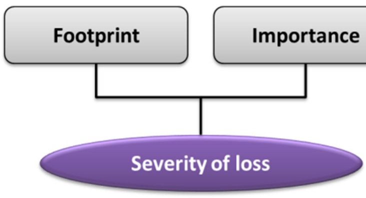

Figure 3.5-1 The assessment scheme for severity of loss

3.5.9. Degree of impairment

The degree of impairment is assessed based on the magnitude of pressure (involving intensity, duration and range) and the sensitivity of the given environmental factor (Figure 3.5-2). In the worst case, the impairment may be so intensive that the function of the environmental factor is lost. It is then considered as loss, for example, loss due to structures, etc.

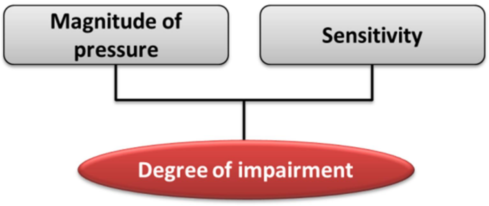

Figure 3.5-2 The assessment scheme for degree of impairment

As far as possible the degree is worked out quantitatively. As mentioned earlier the method of quantification depends on the environmental factor and the pressure to be assessed, and of the state-of-the-art tools available for the assessment. In this report, quantitative assessments of the degree of impairment are an intermediate step for the assessment of the severity and the resulting numbers of affected animals are given in Appendix II of the report.

No matter how the analyses of the impairment are conducted, the goal is to grade the degree of impairment using one of the defined grading scales (two or four grades). Deviations occur when it is not possible to grade the degree of impairment. The spatial distribution of the different grades of the degree of impairment is shown on maps.

Severity of impairment is assessed by grading the degree of impairment and the importance of the environmental factor (Figure 3.5-3) using the matrix in Table 3.5—4. If it is not possible to grade degree of impairment and/or importance an assessment is given based on expert judgment.

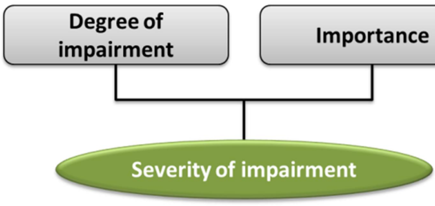

Figure 3.5-3 The assessment scheme for severity of impairment

3.5.10. Significance

The impact assessment is finalised with an overall assessment stating the significance of the predicted impacts. This assessment of significance is based on expert judgement. The reasoning for the conclusion on the significance is explained. Aspects such as degree and severity of impairment/loss, recovery time and the importance of the environmental factor are taken into consideration.

3.5.11. Range of impacts

Besides illustrating the impacts on maps, the extent of the marine impacts is assessed by quantifying the areas impacted in predefined zones. The zones are shown in Figure 3.5-4. If relevant the area of transboundary impacts are also estimated.

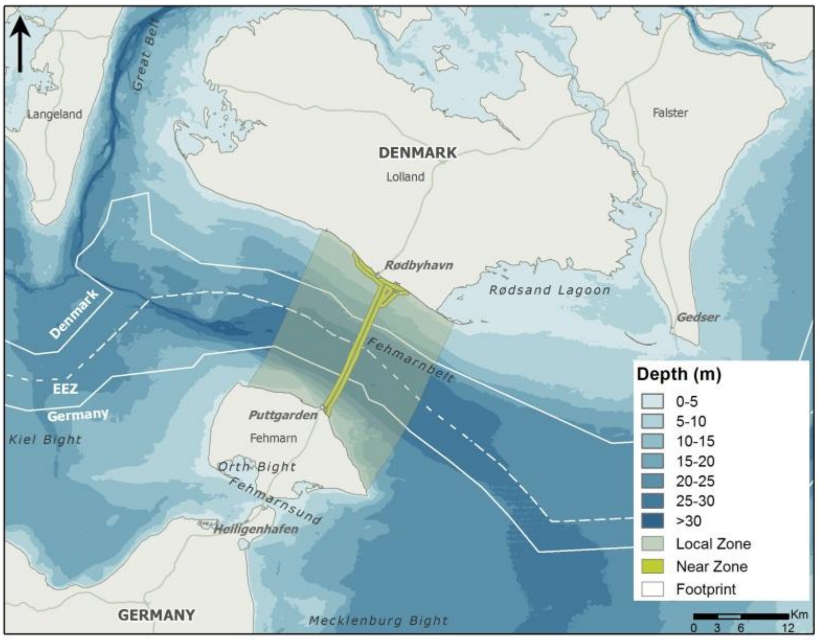

Figure 3.5-4 **The assessment zones applied for description of the spatial distribution of the impacts. The near zone illustrated is valid for the tunnel alternative. It comprises the footprint and a surrounding 500 m band. The local zone is identical for all alternatives of the fixed link.**

3.5.12. Duration of impacts

Duration of impacts (provisional loss and impairments) is assessed based on recovery time (restitution time). The recovery time is given as precise as possible; stating the expected time frame from conclusion of the pressure until pre-project conditions are restored. The recovery is also related to the phases of the project using Table 3.5—5 as a framework.

Table 3.5—5 **Framework applied to relate recovery of environmental factors to the consecutive phases of the Project**

Impact recovered within:	In wording
Construction phase+	recovered within 2 year after end of construction
Operation phase A	recovered within 10 years after end of construction
Operation phase B	recovered within 24 years after end of construction
Operation phase C	recovery takes longer or is permanent

3.6. Marine Mammal impact assessment approach and methods

In order to establish the 'contextual' parameters of the environmental pressures associated with the development of the fixed link, the sensitivity of marine mammals to those pressures and the importance of the Fehmarnbelt area for marine mammals were assessed.

3.6.1. Importance

The importance of environmental factors is defined by their functional values for the natural environment and the landscape. The levels of importance have to be derived from the legal framework, planning guidelines and expert opinions (intuitively the conservation status of an individual animal should be assessed in the context of the distribution and abundance of the species population(s)).

Table 3.6—1 Assessment criteria for the evaluation of the importance of the area for harbour porpoises

Importance level	Occurrence	Nursing	Migration corridor
Very high	>1/km^2	Exceptional high calf ratio, highest abundance during nursing time	Essential corridor between important staging or nursing areas, connection between subpopulations
High	>0.5/km^2	High calf ratio, high abundance during nursing time	One or more corridors between important staging or nursing areas, connection between subpopulations
Medium	>0.25/km^2	Medium calf ratio, no special function as nursing ground	Corridor between medium important staging or nursing areas
Minor	<0.25/km^2	Lower calf ratio than average, lower numbers in the nursing period	Minor function as corridor between medium important staging or nursing areas

Table 3.6—2 Assessment criteria for the evaluation of the importance of the area for seals

Importance Level	Environmental component harbour seal and grey seal
Very high	Breeding and/or pupping ground of importance for the Baltic population
High	Breeding and/or pupping ground of importance for the population in that area.
Medium	Breeding ground, but pupping rates not consistently higher than in other areas.
Minor	Area is of minor importance for seals in the Western Baltic and beyond.

The importance of marine mammals in the study area (Table 3.6—1 and Table 3.5—2) was established in the baseline report, and is set out in sections 4.2 (harbour porpoise) and 4.3 (seals) of the baseline report (FEMM, 2011),

Severity of impact is assessed by combining the degree of impact (impairment) with the importance of the area to harbour porpoises and seals. The summer and winter 2010 harbour porpoise importance maps (Figure 3.6-1) were used as they showed the highest densities of porpoise and, therefore, the worst case for impact assessment.

The harbour porpoise map is based on modelled density calculations of porpoise in the region, based on the aerial surveys undertaken for the marine mammal baseline study. It was hoped that a measure of function (e.g. importance as a nursery or feeding area) could be incorporated in these importance maps; however, there was no evidence from the baseline studies that spatially defined nursery / feeding areas exist in the wider Fehmarnbelt region. In addition, the number of calves seen over the two years of the baseline study was small (34 calves in total) and the inter-annual variability was high. Creating a map layer of calve sighting rates would, therefore, not be robust and potentially be misleading by suggesting 'calving areas' on little data.

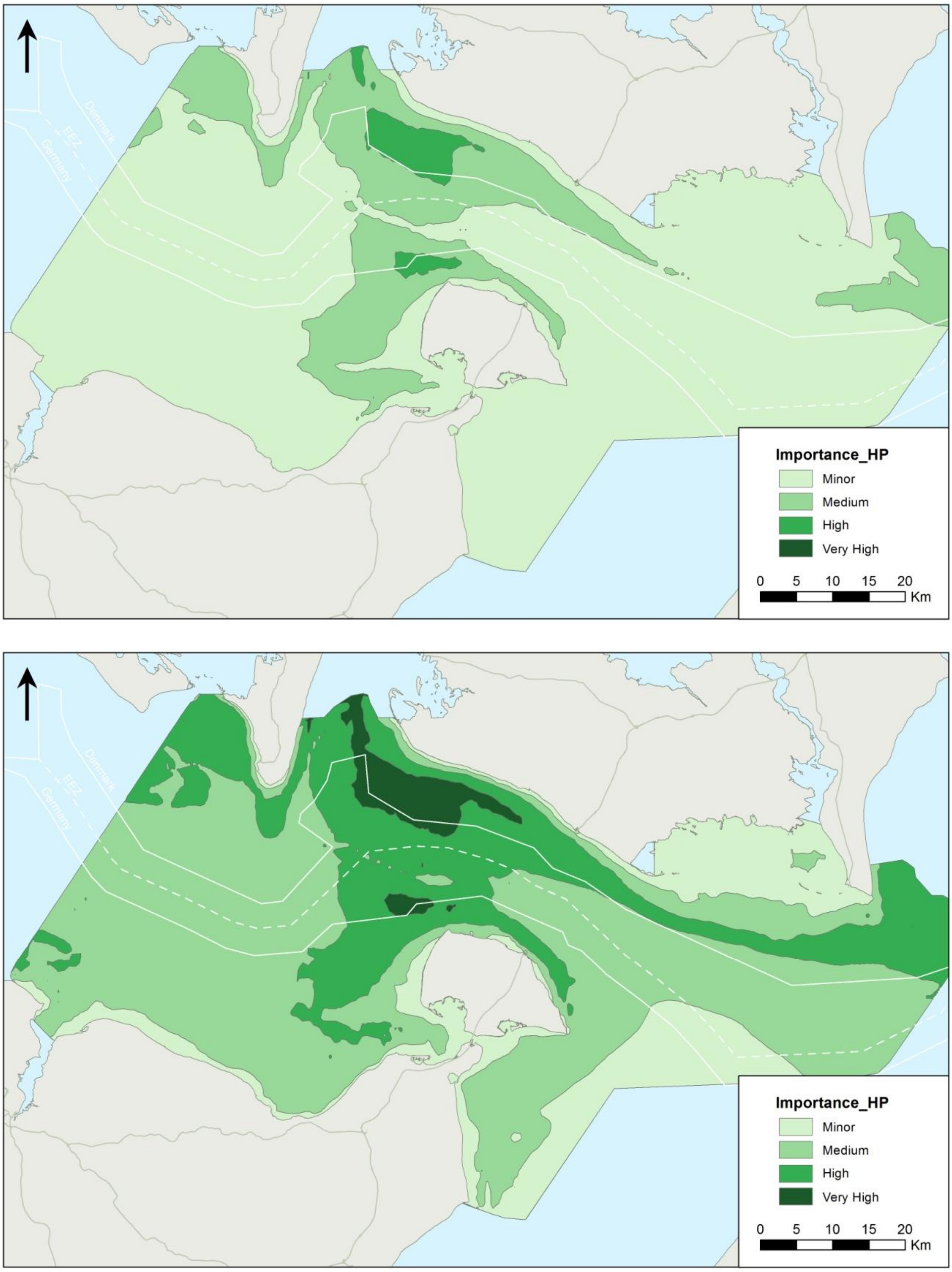

Figure 3.6-1 Importance of the study region to harbour porpoise in: A (top) - winter and B (bottom) – summer (based on data from 2010, FEMM, 2011).

It was not possible to produce an importance map for each seal species as no seal abundance data for the Fehmarnbelt area was available. Aerial surveys have been carried out in the Rødsand lagoon area east of the Fehmarnbelt region, which has been identified as a year round important haul-out area for both harbour and grey seals. Rødsand lagoon is thought to be the most important haul-out and breeding site for harbour seals in the western Baltic Sea, with about half of the population in Denmark found there (Teilmann & Heide-Jørgensen, 2001).

The entirety of the study area could be used by seals for feeding and so all analysis will take account of potential impact on feeding areas. Figure 3.6-2 shows that the nearest observed haul-out site (harbour seal only) is approximately 8.5 km away from the closest extent of the construction works, with the majority of the sightings (including both grey and harbour seals) over 25 km away from the works.

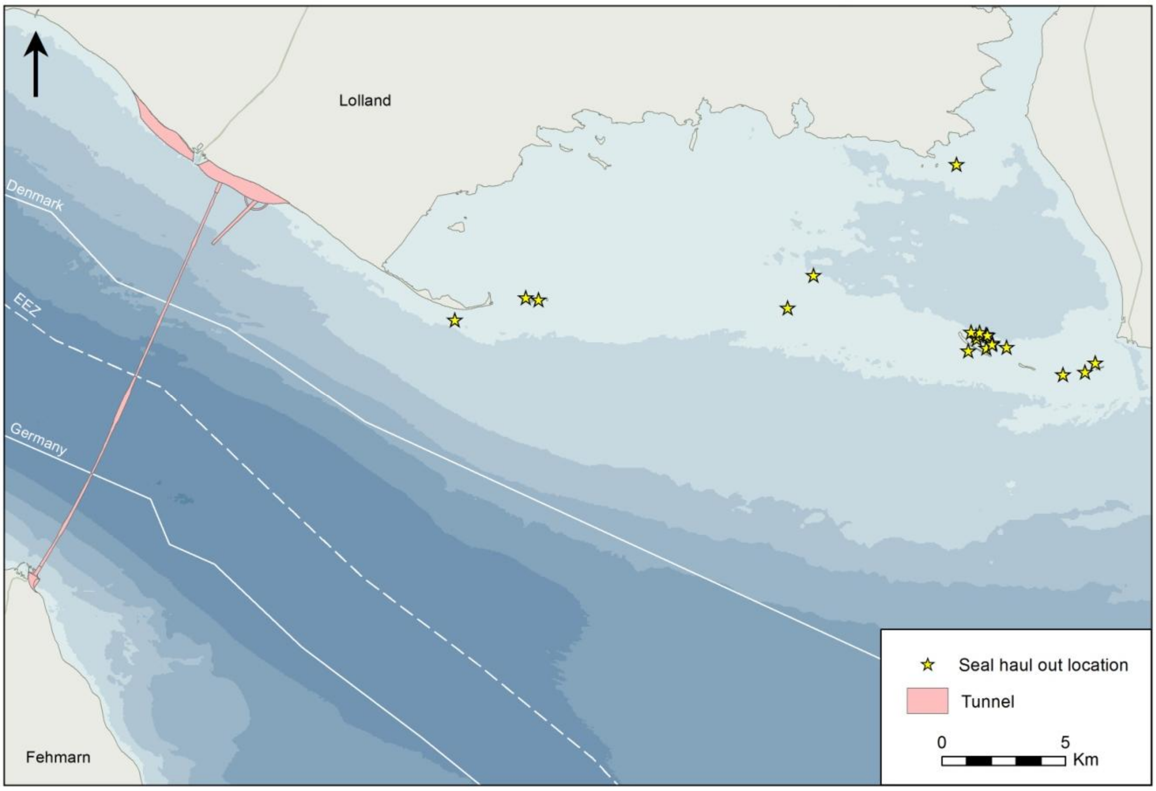

Figure 3.6-2 Harbour and grey seal haul out zone and location of the tunnel works

3.6.2. FEMM approach

For the FEMM IA these assessment criteria have been assembled to provide a logical sequence to the assessment in which each pressure is assessed for the immersed tunnel and bridge options.

The sequential approach that we have applied in the IA is presented in Table 3.6—3:

1. The **pressures** on marine mammals from the fixed link project are described in section 3.8.

2. The **sensitivity**[1] of marine mammals to those pressures described in Step 1 is described in Chapter 4.
3. The associated activities specific to the construction and operational phases are described in separate chapters for the immersed tunnel and bridge options. A **pressure** table is used to summarise the pressures attributable to these activities (See Table 6.2—4; Table 6.3—1; Table 7.2—2 and Table 7.3—1).
4. Using information from the baseline investigations, the project descriptions and the outputs of steps 3 and 4, the **Degree of Impact (impairment / loss)** is determined for each pressure in separate chapters for the immersed tunnel and bridge options. This also utilises the **Sensitivity** considerations of the three marine mammal species to the **pressures** established in Step 2 and consideration of the **magnitude of pressure**.

From the outputs of steps 1 to 4 the **Severity of impact** (loss or impairment) is determined. **Importance** was calculated in the baseline report (see chapters 4.2 (harbour porpoise) and 4.3 (seals); the outputs are also summarised in and

5. Table 3.6—2 of this Impact Assessment report).

Table 3.6—3 Step by step approach of FEMM to the impact assessment

Step Number	Task and relevant sections			
Step 1	Description of pressures associated with the construction and operation of the fixed link (section 3.7)			
Step 2	Description of the sensitivity of harbour porpoise, harbour seal and grey seal to the pressures described in step 1 (Chapter 4)			
Step 3	Description of the activities and associated pressures			
	Immersed tunnel		Cable-stayed bridge	
	Construction (section 6.2)	Operation (section 6.3.2)	Construction (section 7.2)	Operation (section 7.3)
Step 4	Determine the Degree of Impact			
	Immersed tunnel		Cable-stayed bridge	
	Construction (section 6.2)	Operation (section 6.3)	Construction (section 7.2)	Operation (section 7.3)
Step 5	Determine the Severity of Impact			
	Immersed tunnel		Cable-stayed bridge	
	Construction (section 6.2 & 6.4)	Operation (section 6.3 & 6.4)	Construction (section 7.2 & 7.4)	Operation (section 7.3 & 7.4)

Step Number	Task and relevant sections			
Step 6	An assessment of significance			
	Immersed tunnel		Cable-stayed bridge	
	Construction (section 6.5)	Operation (section 6.5)	Construction (section 7.5)	Operation (section 7.5)

FEMM Method for determining significance

OSPAR has established ecological quality objectives (EcoQO) for harbour porpoise and grey seals:

> **Harbour porpoise EcoQO:**
>
> Annual by-catch levels of harbour porpoise should be reduced to below 1.7% of the best population estimate. The EcoQO aims to reduce by-catch in the North Sea to a level that would allow the population to recover to at least 80% of the ecosystem's long-term carrying capacity for this species.
>
> **Grey seal EcoQO:**
> Taking into account natural population dynamics and trends, there should be no decline in pup production of grey seals of ≥10% as representative in a five-year running mean or point estimates (separated by up to five years) within any of a set of defined sub-units of the North Sea. The EcoQO aims to maintain healthy populations of seals by triggering management actions when needed.

FEMM has applied the principles of these EcoQO in determining the significance of the effects of the fixed link on harbour porpoise, harbour seal and grey seal (Table 3.6—4). Whilst the EcoQO only specifically names grey seals, FEMM conclude that this criterion is equally applicable for harbour seal.

Table 3.6—4 FEMM significance criteria

Overall assessment of significance	Description of Impact
Significant	Impacts due to the Fixed Link lead to loss of 'habitat' of more than 1.7% of the best population estimate for harbour porpoises and 10% of harbour and grey seals in the Fehmarnbelt study area
Insignificant	Impacts due to the Fixed Link lead to loss of 'habitat' of less than 1.7% of the best population estimate for harbour porpoises and 10% of harbour and grey seals in the Fehmarnbelt study area

The best population estimate for the Fehmarnbelt study area in this impact assessment is derived from the baseline investigations with the summer 2010 abundance data of between 1414 and 2709 harbour porpoise.

In applying these criteria to the outputs of the FEMM impact assessment, the assumption is that the amount of habitat loss equates to the same amount of porpoises lost (derived from the importance layers described in the baseline report (FEMM, 2011). In reality this is probably not the case because porpoise have the ability to move and occupy the remaining habitat space. However, in terms of deciding what a significant impact might equate to, it is important to put any effect in the context of the (sub) population. The 1.7% criteria for harbour porpoise (a removal above which is considered unsustainable) has been advocated by OSPAR, ASCOBANS and IWC. This percentage removal was derived from a consideration of the harbour porpoise population's theoretical ability to increase per annum. Although it was designed for assessing by-catch, there is no reason for it not to be applied to other 'removals', such as habitat loss from the fixed link development. The 1.7% was agreed to be the 'total anthropogenic removal' from the population, so removals caused by multiple activities should not exceed that limit when combined. Therefore, a removal of >1% from a single activity should really be assessed in conjunction with losses from other anthropogenic activities because the combined activities could have a significant affect at the population level. Therefore, it might be precautionary to state that a 'removal' above 1% should be treated as cause for concern. With this in mind, FEMM have considered 'removal' in terms of both 1% and 1.7% of the Fehmarnbelt study area population. The same assumptions can be applied to the seal criterion.

3.7. Assessment criteria for marine mammals

FEMM has defined criteria for the assessment of the impacts of the project (arising from the pressures described in section 3.8) as shown in Table 3.7—1:

Table 3.7—1 FEMM defined impact assessment criteria

Pressure	Impacts and Criteria	Duration	Range	Degree of impairment
Noise and vibration (construction, impulsive sounds)	Porpoises: Received sound levels are high enough to cause injury or PTS, SEL exceeds 198 dB re1µPa^{2}s (Southall et al., 2007) Seals: Received sound levels are high enough to cause injury or PTS, SEL 186 dB re 1 re1µPa^{2}s (seals)) (Southall et al., 2007)	Temporary	Local	Very High

Pressure	Impacts and Criteria	Duration	Range	Degree of impairment
	Porpoises: Received sound levels are high enough to cause TTS, SEL exceeds 183 dB re1 µPa^{2}s Seals: Received sound levels are high enough to cause TTS, SEL exceeds 171 dB re 1µPa^{2}s (Southall et al., 2007) All species: Sound levels at 750 m distance to source exceed 160 dB$_{SEL}$ or 190 dB$_{peak*}$	Temporary	Local	High (Very High)*
	Sound levels are high enough to cause behavioural disturbance (received SEL exceeds 150 dB re 1µPa^{2}s (porpoises and seals) (Brandt et al., 2011)	Temporary	Regional	Medium
	Sound levels are high enough that some minor behavioural reactions might be expected (received SEL exceeds 144 dB re 1µPa^{2}s (porpoises and seals) (Brandt et al., 2011)	Temporary	Regional	Low
Noise and vibration (operational phase)	Sound levels are high enough that some minor behavioural reactions might be expected (received SEL exceeds 144 dB re 1µPa^{2}s (porpoises and seals) (Brandt et al., 2011)	Permanent (operational phase)	Regional	Low
Habitat change (construction activities)	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biological important proportion of the Belt population of seals and porpoises	Permanent	Local	Very High
	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biological important proportion of the Belt population of seals and porpoises	Temporary – Long term	Local	High

Pressure	Impacts and Criteria	Duration	Range	Degree of impairment
	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biological important proportion of the Belt population of seals and porpoises	Temporary – Short term	Local	Medium
	Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biological unimportant proportion of the Belt population of seals and porpoises	Temporary - Permanent	Local	Low
	Barrier effects lead to blocking of movements for a biological important proportion of the Belt population of seals and porpoises	Permanent	Regional	Very High
	Barrier effects lead to blocking of movements for a biological important proportion of the Belt population of seals and porpoises	Temporary – Long term	Regional	High
Barrier effects (construction and structures)	Barrier effects lead to blocking of movements for a biological important proportion of the Belt population of seals and porpoises	Temporary – Short term	Regional	Medium
	Barrier effects lead to blocking of movements for a biological unimportant proportion of the Belt population of seals and porpoises	Temporary - Permanent	Local	Low

* The German Federal Agency of the Environment proposes a threshold value for offshore pile driving of 160 dB_{SEL} or 190 dB_{peak} at 750 m distance to the source in order to reduce disturbance and the risk of injury for all marine mammal species. The value is used to regulate underwater noise emissions from offshore pile driving. As demanded from the German authorities the threshold is adopted as assessment criteria and noise levels above the value are assessed as very high degree of impairment.

The following definitions of sound pressure level, sound exposure level, temporary threshold shift and permanent threshold shift are derived from Southall et al. (2007):

- The **sound pressure level** (SPL) is the expression of sound pressure which is described as a log ratio comparing the measured pressure (P) with the reference pressure, (P0): SPL (dB) = 20 log10 (P/P0). The reference pressure in underwater acoustics is defined as 1µPa. Using the logarithmic scale in dB, it results that doubling the pressure of a sound leads to a 6 dB increase in sound pressure level.

- The **sound exposure level** (SEL) is a measure of received sound energy and is proportional to the total energy of the signal. Specifically, it is the dB level of the time integral of the squared-instantaneous sound pressure normalized to a 1-s period (dB re $1\mu Pa^2 s$).
- **Temporary threshold shift** (TTS) is a temporary and reversible increase of the auditory thresholds following exposure to noise. At specific level, duration and spectral characteristics, sound can cause hair cells of the inner ear to fatigue.
- **Permanent threshold shift** (PTS) is considered to be auditory injury in which hearing does not fully return to normal after the noise exposure. Some of the apparent causes of PTS in mammals are severe extensions of effects underlying TTS (e.g., irreparable damage to the sensory hair cells). PTS is an irreversible elevation of the hearing threshold (i.e., a reduction in sensitivity) at a specific frequency (Yost, 2000). This permanent change following intense noise exposure results from damage or death of inner or outer cochlear hair cells. It is often followed by retrograde neuronal losses and persistent chemical and metabolic cochlear abnormalities (Saunders et al., 1991; Ward, 1997; Yost, 2000).
- The relationship between TTS and PTS depends on a highly complex suite of variables concerning the study subject and the exposure.

The criteria for ‘very high’ Degree of Impairment from underwater noise in Table 3.7—1 describe very different impacts on hearing impairment and are based on the exposure criteria for PTS and TTS published by a team of international experts (see Southall et al., 2007). Following recommendations from the German authorities any exceedance of the threshold value of 160 dB_{SEL} at a distance of 750 m, which is applied for offshore pile driving in Germany, is ranked as very high. The criteria for ‘medium’ was derived based on reactions of harbour porpoises to offshore pile driving (Brandt et al., 2011, Diederichs et al., 2010) and indicate a zone where behavioural response and displacement occur and last longer than the period of noise emission. The criterion for ‘minor’ indicates half of the sound exposure of the ‘medium’ category and defines the zone at which some short-term reactions from harbour porpoises are expected. It has to be noted that these criteria are only applicable to low frequency noise from piling or shipping.

3.8. General description of pressures

The EIA Scoping Report (June 2010) and the FEMM Baseline Report (FEMM, 2011) identified those pressures for marine mammals that should be evaluated in the impact assessment. The following pressure descriptions (sections 3.8.1 to 3.8.4) and the associated description of marine mammal sensitivity (Chapter 4) provide the foundation to this impact assessment.

3.8.1. Noise

Underwater sound pressures on marine mammals may be associated with:

- Construction activities (e.g. installation of piles, dredging);
- Operation activities (e.g. traffic movements, maintenance activities);
- Ship movements (e.g. construction, commercial and recreational vessels);
- Potential reduction of the noise pressure if the ferry services are discontinued;
- Potential change to noise profiles if shipping routes are changed.

This pressure relates to increases over and above background levels (consisting of environmental noise (ambient) and incidental/man-made noise (apparent)) at a particular location. The theoretical zones of noise influence on marine biota (Richardson et al., 1995) are hearing loss (permanent or temporary); injury; behavioural reactions; masking and detection (see section 4.1.2). In extreme cases noise may lead to fatalities. The effects of sound are dependent on a number of variables, including the sound pressure, duration of exposure, sound exposure level, rise time, spectral characteristics and frequency. High amplitude low- and mid-frequency impulsive sounds and low frequency continuous sound pose the greatest concern for effects on marine mammals (e.g. changes in migration, feeding or breeding patterns). Some species may be responsive to associated particle motion rather than the usual concept of noise. Sound propagation can be over large distances (tens of kilometres) but transmission losses can be attributable to factors such as water depth and seabed topography as well as abiotic factors such as temperature, salinity and pressure.

The background sound situation in the Fehmarnbelt area was monitored between September 2009 and November 2010. Underwater sound measurements were conducted with measurement buoys developed by ITAP. Low noise B&K 8106 hydrophones with built-in preamplifier were attached to the buoys. The resulting electrical signal, proportional to the sound pressure, was recorded on a SD-Card using a digital recorder (Marantz, PMD620). Inside the watertight steel housing of the buoys there were a controller unit and batteries.

The sound data were fed into the computer programme written in FORTRAN 90. In addition to the sound data, the model included:

- water depth;
- sediment type (classified by grain size); and
- AIS-Data (Automatic Identification System for ships) for the year 2010 with a monthly resolution.

The resolution of the sound maps is based on a grid size of 750 m according to the resolution of the data for bathymetry, sediment grain size and shipping intensity. NB. In some figures (e.g. Figure 6.2-12) where more than one dredger has been modelled in the same location, the coarse resolution of this grid size means that dredger point sources lie outside the footprint of the fixed link alignment.

Apparent transmission loss was modelled to be TL=22 * log10(distance), since this gave the best correlation between the model output and the noise measurements. For extremely shallow water, with water depths of less than 5 m, the modelled transmission loss rose to 25 * log10(distance). Sound absorption due to sediment constitution was modelled according to the data given by Kibblewhite (1989).

Several assumptions have been made concerning the modelling undertaken to investigate sound levels during the construction period. The sound level predictions were modelled in the same way as the background sound situation described above but instead of sound measurement and AIS-data, sound sources for pile driving or dredging, for example, were simulated by feeding in appropriate sound levels in certain positions of the map where construction work is planned.

In the absence of details about the number of vessels, FEMM considered that, although several different types of dredger might be used on the project, only Trailing Suction Hopper Dredgers

(TSHD) would be modelled because there is little published measured data for Grab Dredgers (GD) and Backhoe Dredgers (BD). Thus TSHDs would represent the worst case scenario, which is in agreement with Evans (1996). The Source Level (SL) for a TSHD was modelled as 184 dB re 1µPa. The construction vessels having a SL of 175 dB re 1µPa were not modelled as the contribution of these extra sound sources is negligible. These values for dredging and shipping are consistent with those summarised in the CEDA Position Paper on Underwater Sound in Relation to Dredging (CEDA, 2011).

For the pile driving at Lolland, a scenario of impact pile driving was assumed. The source level for piles of 1 m diameter was taken to be 202 dB SEL. This level has previously been measured during a port construction in Wilhelmshaven Jade-Weser-Port. This sound pressure level might even be slightly higher than the levels expected during pile driving at Lolland since energy of 200 kJ was used for piling in Wilhelmshaven while it is expected to be 25-40 kJ in Lolland (communication by COWI). Pile driving with an energy of 49 kJ during harbour works resulted in a SEL of 199 dB re 1µPa^{2}s (Salgado-Kent et al., 2009) and the 'Compendium of Pile Driving Sound Data' (Illinworth & Rodkin, 2007) states a maximum of 180 dB at a distance of 10 m for comparable pile driving (resulting in max. SEL of 200 dB calculated on 20*log(r1/r2).

The pile drilling for the bridge construction was modelled with a source level of 162 dB re 1µPa@1m. Sheet piling simulations are based on a source level of 190 dB re 1µPa@1m (as previously measured at the German ports of Brake and Cuxhaven (Rainer Matuschek, ITAP *pers comm.*)).

3.8.2. Habitat loss or change

1. Changes to seabed habitats affecting benthos and fish on which marine mammals feed.

   Physical loss: The permanent loss of marine habitats. Associated activities are land claim, new harbour infrastructure and the footprint of bridge pillars. This excludes changes from one marine habitat type to another (see below).

   Change in marine habitat type: the permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including man-made materials such as concrete. This involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (e.g. surface of bridge pillars, harbour walls and breakwaters). Considerations include the colonising fauna of hard substrates in areas characterised as marine sediment habitats (sometimes described as biological enhancement or artificial reef effects).

   Habitat structure changes: Unlike the change in habitat type and physical loss pressures, this pressure relates to scenarios where there is the potential for recovery of marine habitat, i.e. the placement of backfill material along the immersed tunnel trench where similar substrate to that present prior to the disturbance is replaced providing the potential for a similar (re)colonising benthic fauna.

   Siltation rate changes: Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include land claim and dredging. It can result in short-lived sediment concentration gradients and the accumulation of sediments on the sea floor which results in changes to the depth of vertical overburden affecting benthic communities. This can relate either to the placement of sediments of similar characteristics to the pre-disturbed state or different sediment types.

2. Changes to intertidal and terrestrial habitats (seals), e.g. land reclamation

   Physical loss/change: The permanent loss/change of marine habitats. An associated activity is land reclamation which may result in the removal of foraging area but may also provide new haul-out areas for seals.

3. Changes in the water column space that marine mammals occupy, e.g. changes in hydrography or turbidity, which may directly or indirectly affect marine mammals.

   Hydrography: This pressure relates to activities that have the potential to modify hydrological energy flows, e.g. bridge pillars or dredged trenches may modify water flow speeds and direction. This pressure will be spatially delineated and the extremes will be shifted from a high to a low energy environment (or vice versa).

   Turbidity: This pressure relates to activities that disturb sediment and/or particulate organic matter mobilising it into the water column. Changes in turbidity could be from 'natural' land run-off and riverine discharges or from anthropogenic activities such as all forms of dredging, sediment placements (e.g. land reclamation) or secondary effects of construction works (e.g. breakwaters). Particle size, hydrological energy (current speed and direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration of this pressure. Anthropogenic sources are mostly short-lived and over relatively small spatial extents.

   Marine mammal behaviour and use of an area may change as a result of such pressures, either directly or in response to changes imposed on prey species distribution and abundance.

3.8.3. Contaminants

Contamination of food sources with harmful substances resulting from sediment mobilisation during construction activities, e.g. release of previously deposited contaminants into the environment could potentially be assimilated or bioaccumulated by different marine mammals. The resulting effects from this mobilisation could potentially affect harbour porpoises, harbour seals and grey seals, if the contaminants reach them through the food chain. Marine mammals may also be directly affected by certain contaminants, potentially causing reduced fitness, health defects (such as skin lesions) or, in extreme cases, mortality. Contamination pressures on marine mammals (benthos and fish) may be associated with:

- Remobilisation from sediments (due to construction works, dredging),
- Operation of construction vessels / equipment (during construction),
- Run-off from the cable-stayed bridge (once operational),
- Decommissioning of both bridge and tunnel.

Investigation of contamination pressures should be closely related to those for hydrographic pressures (see 3.6.2). Contaminants can be broadly categorised as:

- Transition elements and organo metals,

- Hydrocarbons and PAHs,
- Synthetic compounds (including pesticides, antifoulants and pharmaceuticals),
- Radionuclides,
- Nutrient enrichment, organic enrichment and de-oxygenation.

3.8.4. Barrier effects (structures, light, visual disturbance and noise)

The movement of species might be affected by physical obstructions within and between areas of importance during the lifecycle of the species (e.g. breeding and feeding areas). In previous studies it is assumed that these physical obstructions could potentially also limit the regional/global migrations (e.g. the harbour porpoise has regional movements). This includes movements both across open waters and through straits. Reasons for animals not crossing structures like bridges or other anthropogenic constructions include:

- Underwater structures (physical presence) e.g. bridge piers, ventilation islands;
- Visual disturbance, e.g. shadow, lighting;
- Disturbance from construction vessels noise.

4. SENSITIVITY

The following chapter describes sensitivity; the general response of marine mammals to the pressures associated with construction and operation of a fixed link across the Fehmarnbelt. The analysis is based on peer-reviewed literature, data and the EIA studies of this project. In establishing the relationships between the pressures and the responses of marine mammals, the aim of the chapter is to conclude on the degree of impairment in relation to the magnitude of the pressures.

4.1. Noise

4.1.1. Importance of sound for marine animals

Sound is an important factor in the marine environment for many organisms. It is used for orientation and communication and contains biologically important information about the mammals short and long range surroundings, including information about waves indicating the location of the coast line, or the presence of prey or predators (Richardson et al., 1995). The speed of sound in water is about 4.5 times faster than in air (MacLennan & Simmonds, 1992) and low frequency sound can travel over very long distances (Wille, 1986). Due to poor visibility and low light conditions in deeper water layers, hearing ability is much better developed in many marine animals compared to eyesight (Tavolga, 1974;Kraan & van Etten, 1995). Additionally sound can be received in a 360° angle.

Marine mammals produce and perceive sounds over a wide range of frequencies for use in communication, orientation and navigation, foraging and predator avoidance (Tyack, 1998). The produced sounds vary in frequency and other sound characteristics depending on species and context (Southall et al., 2007). While baleen whales produce mainly social sounds (e.g. contact, mother-calf or mating calls), many toothed whales additionally use ultrasound for orientation and foraging (Southall et al., 2007). Due to the low frequencies used by baleen whales their sounds can be received over large distances of hundreds of kilometres.

In seals sound is used in different social contexts such as mating, mother-calf relation and territorial behaviour (Richardson et al., 1995). However, seals have also developed a very sensitive tactile sense with whiskers that can sense even the slightest water movements such as those produced by the movement of prey. Therefore, the range in which they can sense hydrodynamic movements can exceed their audible or visible range (Hanke et al., 2010).

4.1.2. Potential effects of anthropogenic sounds on marine mammals

It is presumed that marine mammals have evolved and adapted to natural sounds in the marine environment, but man-made noise is a relatively recent (and fast-paced) development (predominantly with the development of the steam engine in the late 18th century) and often substantially exceeds natural background levels. The sensitivity of marine mammals to man-made noise is not easy to understand as it depends on a number of internal and external factors that influence each other. Effects change with varying sensitivities of individuals and there can also be effects at the population level. The following section describes possible effects and the factors that influence the sensitivity of marine mammals to sound.

Shipping is by far the most important source of marine noise (Table 4.1—1). For example, the baseline noise assessment in Fehmarnbelt (2011a) recorded background noise levels of 103-132 dB re 1µPa, predominantly at frequencies below 1 kHz. Construction and operational activities also have the potential to affect marine mammals including harbour construction (e.g. installation of sheet piles), dredging (both navigational and for extraction of aggregate) and the construction and operation of offshore wind farms.

Table 4.1—1 Sound sources from various maritime activities (from Evans, 1996; * Robinson et al., 2011) (numbers are based on a transmission loss of 20*log(distance)).

Activity		Frequency Range (kHz)	Av. Source Level (dB/1µPa at 1m)	Estimated Received Sound Level at different ranges (km) by spherical spreading			
				0.1	1	10	100
Dredging							
-	Gravel island		130	90	70	49	28
-	Suction dredge	0.38	160	120	100	79	58
-	TSH dredger*	0.032 – 1 kHz 1 – 40 kHz	157 – 181 155 – 176	117 – 141 115 – 136	97 – 121 95 – 116	77 – 101 75 – 96	57 – 81 55 – 76
Vessels							
-	90hp outboard inflatable	0.8 – 20	105 –130	65 – 90	45 – 70	24 – 49	<25
-	240hp inboard fishing boat	0.1 – 20	110 – 130	70 – 95	50 – 75	29 – 54	<25
-	Large merchant vessel	0.05 – 0.9	160 – 190	120 – 150	100 – 130	79 – 109	58 – 88
-	Super tanker	0.02 – 0.1	187 – 232	147 – 192	127 – 172	106 – 151	85 – 130

-	Military vessel	190 – 203	150 – 163	130 – 143	109 – 122	88 – 101

Recent investigations into sound emission during dredging showed a considerable amount of high frequency sound emissions (Robinson et al., 2011). The frequency spectrum and sound pressure level largely depended on the material dredged, with gravel producing higher frequencies and sound levels than sand. Whilst dredging sand, third octave source levels of about 170 to 176 dB re 1µPa@1m were measured in a frequency range between 1 and 10 kHz with more than 165 dB re 1µPa@1m measured at 40 kHz (Robinson et al., 2011).

Due to the importance of natural sound to marine animals, they can be seriously affected by anthropogenic sound (e.g. shipping, seismic surveys, sonar, dredging, explosions and industrial activities). The detection and type of response to man-made noise by marine mammals will depend on the properties of the sound source, the habitat in which the sound propagates (Madsen et al., 2006), as well as the received levels at the receptor and internal factors of the receptor (for details see below). It is also worth noting that it is not only underwater noise that is an issue since seals haul out onto land and have good hearing in both air and water.

Richardson et al. (1995) distinguished different areas around a sound source in which (depending on distance and therefore decreasing sound levels) different effects could be expected. These effects span a range from severe physiological damage or death due to very high sound pressure levels, to the zone of audibility in which the sound can be heard but does not cause any effects. Based on this model the potential effects are categorised as follows.

4.1.2.1. Physiological damage

Very high sound pressure levels, for example, those produced during explosions, can cause tissue damage, especially in organs with air filled cavities. However, lower sound levels can also cause tissue damage.

Hearing damage can occur at various sound levels and affects the acoustical perception of marine animals' surroundings. Hearing thresholds can be reduced by loud and/or long-term sounds and can be temporary (temporary threshold shift, TTS) or permanent (permanent threshold shift, PTS) (Clark, 1991). While temporary threshold shift affects the animal for a limited time depending on the pressure level and the duration of sound, a permanent threshold shift continuously decreases the hearing ability of the animal as hair cells or nerves in the inner ear are damaged (Southall et al., 2007).

Information on PTS in marine mammals is sparse, due to the small number of available experimental animals and ethical reasons preventing permanent threshold shifts being induced (Kastak et al., 2008). Southall et al (2007) calculated PTS-thresholds on the basis of known TTS-thresholds in marine mammals and hearing damage in terrestrial mammals. Southall et al (2007) concluded that sound with a peak level of 230 dB re 1µPa or a SEL (sound exposure level) of 198 dB re 1µPa^{2}s during a 24 hour period could lead to a permanent threshold shift in harbour porpoises (Table 4.1—2). However, this conclusion was drawn on the basis of mid-frequency cetaceans, while harbour porpoises are classified as high-frequency cetaceans.

For seals lower values of 218 dB re 1µPa$_{peak}$ and 186 dB re 1µPa^2 s SEL were calculated (Southall et al., 2007).

4.1.2.2. Temporary threshold shifts

Temporary impairment of hearing reduces the ability of an individual to detect signals from the surroundings which can, amongst other effects, reduce hunting success or increase the risk from predators (MMC, 2007). Therefore thresholds for TTS have been used as feasible values to estimate the range of hearing damage in marine mammals (Tougaard & Henriksen, 2009;Tougaard et al., 2009). Southall et al. (2007) summarised available data on TTS and defined SEL thresholds for TTS in mid-frequency cetaceans and pinnipeds for both pulsed and non-pulsed sound. In harbour porpoises the onset of TTS might occur at a lower level as the results of Lucke et al. (2009) suggest, whose study showed TTS in a harbour porpoise after airgun simulation at a SEL of 164 dB re 1µPa^{2}s.

Table 4.1—2 Thresholds of received Sound Exposure Levels to induce temporary (TTS) and permanent threshold shifts (PTS) in marine mammals (after Southall et al., 2007* and Lucke et al., 2009).

Marine mammal group	Threshold shift	SEL (Pulsed sound)	SEL (Non-pulsed sound)
Pinnipeds*	Permanent	186 dB	203 dB
	Temporary	171 dB	183 dB
Cetaceans* (mid frequency)	Permanent	198 dB	215 dB
	Temporary	183 dB	195 dB
Harbour porpoise (Lucke et al., 2009)	Temporary	164 dB	

4.1.2.3. Behavioural effects

Behavioural effects range from a change of physiological features like heartbeat rate via brief disturbance of normal activities (e.g. feeding or resting) to long-term displacement from an area (Richardson et al., 1995). Behavioural changes are often connected with higher energy costs for the individual (Southall, 2005). Reactions are highly variable and depend not only on external but also on internal factors (NRC, 2003).

Internal factors influencing the reactions include:

- Hearing ability
- Motivation
- Individual tolerance towards sound
- Experience of earlier sound exposures that can amplify or reduce reactions
- Age and sex
- Presence of dependent juveniles

External factors include:

- Environmental factors
- Position of the animal (is its mobility in any way restricted?)
- Properties of the sound source (e.g. mobile or stationary)

Given the wide range of factors which affect any behavioural reaction, the type and strength of the behavioural reaction of an individual cannot be easily derived from its hearing ability.

The quality of a habitat is another important factor influencing possible behavioural changes. Lack of comparable suitable habitats might reduce the motivation to avoid areas with high sound levels. In addition, the quality of a habitat is not only defined by habitat properties (e.g. food availability, competition, predators) but by the amount of energy an individual has invested into the habitat (territorial defence, position in the hierarchy, gathering of information on the habitat) (Gill et al., 2001).

Habitat deterioration or displacement into less suitable habitats can have negative effects on population levels even if obvious impacts cannot be observed in the short term (Bain & Williams, 2006). Lusseau et al. (2009) observed orcas (*Orcinus orca*) being more active but spending less time foraging in the presence of ships. The authors assumed that reduced food intake might be a reason for the significant decrease of individuals in the observed group.

During construction of the offshore wind farm Horns Rev II, a significant decrease in acoustic activity of harbour porpoises was observed up to about 18 km away from the construction site, with less pronounced effects with increasing distance (Brandt et al., 2011). Also, the duration of the effect after sound exposure became shorter with increasing distance; 24-72 hours in the vicinity (2.5 km) of the sound source and 10-23 hours at approximately 18 km distance. The decrease of acoustical activity could be a real response (i.e. the animals are still present but quieter) or could signify avoidance behaviour (decrease of individual numbers in the area) (Brandt et al., 2011).

However, in other studies harbour porpoises have shown a relatively low reaction threshold towards different types of man-made noise such as shipping, acoustic pingers and offshore wind farms (Lucke et al., 2007b;Kastelein et al., 2010).

Seals may also avoid sound sources such as seismic surveys and acoustic pingers (Yurk & Trites, 2000; Bain & Williams, 2006; Kastelein et al., 2006, Kastelein et al., 2008). Conversely, studies have shown the attraction of seals to certain sounds that are intended to scare them away from fish farms. The sound cued the seals to explore the fish farms and exploit the rich food source nearby (Jefferson & Curry, 1996;Fertl, 2009).

4.1.2.4. Masking of biologically important signals

The detection threshold of a biological signal can be raised by the presence of another signal. This effect is called masking. The effect of masking increases the closer the frequencies of the two signals are together (Southall et al., 2000) and when both signals originate from the same direction (Holt & Schusterman, 2007). Masking occurs in a so-called critical bandwidth; in other words, a signal is only masked by another signal of a certain frequency band around the frequency of the signal to be detected (NRC, 2003). Very loud signals can also cause masking outside the frequency of the critical bandwidth (Richardson et al., 1995). The width of the critical band depends on frequency and seems to cover less than 11.6% of the central frequency of the band in mammals (Richardson et al., 1995). Therefore, animals with narrow critical bands are less prone to masking by other signals (Sveegaard et al., 2008). In contrast to many other mammals the critical band of harbour porpoises, above 22.5 kHz, is relatively constant with 3-4 kHz (Popov et al., 2006); therefore, the effects of masking do not increase with higher frequencies.

Masking can affect animals at sound levels below reaction thresholds; therefore the range around a sound source in which masking can occur can be larger than the range in which behavioural reactions can be observed (MMC, 2007).

For example, it is possible that:

- communication during the mating season is distracted and potential partners cannot be detected over larger distances
- communication between mother and calf is disturbed
- detection of prey or coordination of hunting activity in a group gets more difficult
- survival is threatened when the detection of predators or other dangers is impeded (MMC, 2007).

A number of studies showed that human generated sounds can mask biologically important signals e.g. (Clark et al., 2009, reviews in Richardson et al., 1995; NRC, 2003).

Some marine mammals have developed adaptations to reduce masking effects. A good directional hearing ability is one way to distinguish a signal from a masking sound and therefore reduce masking effects (Richardson et al., 1995). Toothed whales have a good directional hearing ability and are therefore less prone to masking than seals with a rather poor directional hearing ability (Richardson et al., 1995).

In some cases an increase of sound level and change of frequency range or signal pattern has been observed in sound production of marine mammals (MMC, 2007;Holt et al., 2009). However, whether adaptations are possible depends on the ability of the animal to change the signal characteristics and the energy that is necessary to do so (Jensen et al., 2009).

4.1.2.5. Stress

Stress is an alert state of the body connected with changes in hormonal balance and chemical processes that enables higher body performance. While short-term stress increases the performance of the body, chronic stress has negative effects and reduces fitness. McEwen and Stellar (1993) described adaptation processes in a body to external factors as allostasis. The organism shows both adaptations to natural changes (such as seasons, changes in food availability, reproduction) and unforeseen events such as injuries, diseases or anthropogenic disturbance. A moderate allostasis enables adaptations to changing environmental conditions, activates energy and the immune system. Strong or long-term reactions lead to overstressing which is called allostatic load by the authors. The concept of allostasis shows the dependency of effects on various factors that influence the state of the organism. The closer an organism comes to the threshold of allostatic load the smaller an additional stress factor needs to be to cause negative effects, meaning that the effects of a factor depends on the situation in which it appears (NRC, 2003).

The effects described so far, such as physiological damage, behavioural changes and masking, increase the stress level of individuals or can be triggered by an increased stress level. However, low level sound that does not cause obvious effects can also disturb animals and can cause stress (Wright et al., 2007).

Sound disturbance in an important seasonal feeding ground will cause more stress since avoidance of the feeding ground can cause malnutrition and therefore reduced fitness and reduced reproductive success. The same sound disturbance could have less effect on individuals or the population at other seasons or in other habitats (NRC, 2005). Sound can also disperse prey from certain areas and therefore deteriorate the food availability for marine mammals (MMC, 2007), which will especially affect mothers with dependent calves (Joint Links Oil and Gas Environmental Consortium, 2006).

In terrestrial mammals stress is known to cause cardio-vascular diseases, reduce immune defence, reduce reproduction rate and cause further health impairment (Jasny et al., 2005). Romano et al.(2004) showed increasing levels of neural-immune parameters as stress indicators after noise exposure (simulated air guns or sonar pings) in beluga whale (*Delphinapterus leucas*) and bottlenose dolphin (*Tursiops truncatus*). A recent study showed elevated stress hormone levels in right whales (*Eubalaena glacialis*) connected to sound exposure (Rolland et al., 2012) A significant decrease of low frequency (<150 kHz) background noise due to short-term reduction of shipping movements lead to a significant temporary decrease of glucocorticoid-metabolites in faecal samples of the whales. Stress hormones rose again with increasing noise levels. The authors interpret the results as evidence that shipping noise causes stress in whales. However, apart from this, reliable data on stress indicators in marine mammals are rare, especially with regard to long-term stress exposures (NRC, 2005).

4.1.2.6. Habituation

The reaction strength of marine mammals towards sound signals often decreases with length of exposure. While a new signal can be potentially dangerous, habituation occurs when the signal does not cause a threat or can even be connected to positive effects (Bejder et al., 2009). For example, Deecke et al. (2002) found that seals did not exhibit any reaction toward the sounds from known fish-eating orca populations while the signals of an unknown fish-eating orca population from another region caused strong avoidance reactions. It has been observed that the effect of acoustic harassment devices to keep seals away from fish farms often decreases over time since it does not cause an immediate danger to the animal. On the other hand, devices may attract seals who connect the signal with easily accessible food in the fish cage (Jefferson & Curry, 1996; Fertl, 2009).

But the term habituation is often misused for every change in tolerance and is interpreted as neutral or positive reaction towards the disturbance. This can lead to misinterpretations on the effects of disturbance on animals (Bejder et al., 2009). A change in tolerance against a disturbance might appear due to the lack of alternatives for individuals or populations to avoid a noisy area or the effort to avoid the sound might be higher than the effort to adapt to the new and noisy situation. Therefore, it is possible that the animals showing the smallest reaction are the ones that have no choice (Jasny et al., 2005). An increased tolerance against a sound source can therefore be connected to higher energetic costs, stress and reduced fitness (Lusseau & Bejder, 2007).

4.1.2.7. Barrier effect through noise

Barrier effects could be caused by the noise emissions of construction vessels during the works. Harbour porpoises avoid approaching vessels (Teilmann et al., 2006), a reaction which is thought to be connected to the noise emitted by the vessel. However, as the noise of a moving vessel with a normal cruise speed of > 5 kn is relatively short-term, locally it does not act as a barrier. Therefore, we have not considered the additional ship traffic caused by the construction works in the assessment of barrier effects due to noise. This situation could change if several exceptionally loud construction vessels, work for a longer time period at low speed in a specific area (e.g. an increase to the dredging schedule). In such cases the noise levels from these vessels may exceed the threshold where behavioural responses are expected. In line with assessment criteria (chapter 3.5), we define the lower threshold when only minor behavioural reactions occur, i.e. when sound exposure levels (SEL) exceed 144 dB re 1µPa²s. Even though only minor behavioural reactions are expected, it cannot be ruled out, that at least some individuals turn around to avoid coming closer to this kind of noise source. When several dredgers work in a row, the movement of animals from one part of the area into another part may be, at least partly, blocked.

4.1.3. Harbour porpoise

A number of studies investigated the hearing ability of harbour porpoises using behavioural or physiological (auditory brainstem) tests. Figure 4.1-1 shows deviating audiograms from different studies indicating large uncertainties about the hearing ability of harbour porpoises. Reasons for the different results are likely to be due to individual differences in hearing ability and sound tolerance and the different methods used. The behavioural study by Kastelein et al.,(2002) shows an audiogram with the widest frequency range (from 250 Hz to 180 kHz) and lowest thresholds. Kastelein's study shows best hearing ability (defined as the range up to 10 dB above the highest sensitivity) between 16 and 140 kHz with lowest hearing thresholds of 33 dB re 1µPa at frequencies between 100 - 140 kHz (Kastelein et al., 2002). This is also the frequency in which harbour porpoises produce ultrasound signals for echolocation (Kastelein et al., 1999).

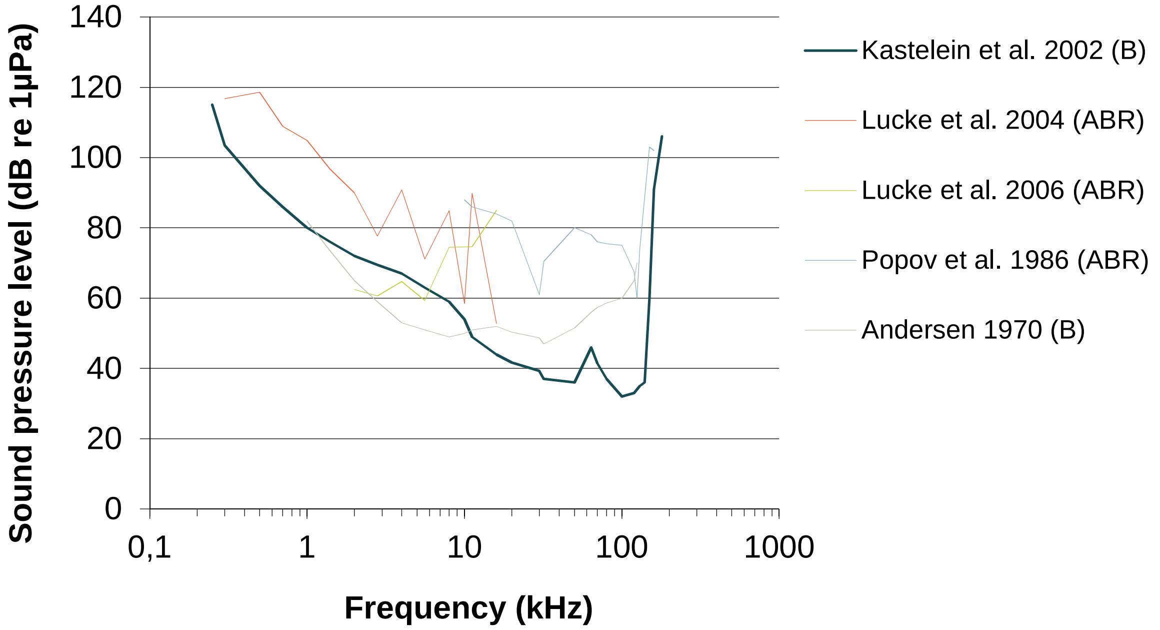

Figure 4.1-1 Audiograms of harbour porpoises determined by behavioural studies (B) (Andersen, 1970, in Thomsen et al., 2006, Kastelein et al., 2002) and auditory brainstem response (ABR) (Lucke et al., 2004, 2006, Popov et al., 2006 all summarised in Thomsen et al., 2006)

The hearing ability in the low frequency range from 1-10 kHz might be underestimated due to experimental conditions (Cummings et al., 1975 in Richardson et al., 1995).

Harbour porpoises are known to show aversive reactions to unfamiliar sounds (Teilmann et al., 2006), including vessels and more intense pulsed sounds such as pile driving and seismic airgun noise (Palka & Hammond, 2001, review in Lucke et al., 2007a;Kastelein et al., 2010).

Disturbance is mainly driven by the noise emitted by ships (from the engine, propeller, on board machinery etc.). Harbour porpoises are known to elicit a short-term response to vessels and will often swim away (Palka & Hammond, 2001; FEMM, 2011). Also, high levels of background noise due to shipping can affect the acoustic activity of porpoises at levels above 113 dB re 1µPa (FEMM, 2011). Even though it could be shown that both variables 'distance to main shipping lane' and 'background noise' had significant negative effects on the detection probability of porpoises during the PAM study (FEMM, 2011), this correlation could not be proved by aerial surveys. However, as the explanation power of both variables was rather low and since porpoises were regularly observed from ship based surveys on board ferry boats. Even though they were observed within the most trafficked shipping lane, it seems that long-term behavioural effects of noise emitted by shipping traffic tends to be weak and animals continue to use the area. Brandt et al. (2008) showed that porpoises avoided the close vicinity (600 m) of a dredging vessel during dredging operations but returned to the area only a few hours after the vessel had left the area. Noise levels of dredging vessels reached 150 dB re 1µPa at a distance of 300 m from the operating vessel (Brandt et al., 2008, Diederichs et al., 2010)

The effect of dredging sound on harbour porpoises is likely to be stronger than shipping noise since it contains more energy at higher frequencies (see Fig 6.2-11). This overlaps with the range of best hearing ability in harbour porpoises and could mask biologically important sounds. The faster attenuation of high frequencies means that the impact ranges are limited CEDA, 2011. Diederichs et al., 2010 reported temporary and short-scale avoidance reactions of harbour porpoises to sand extraction and therefore concluded a minor effect on the species. As previously discussed in sections 4.1.2.6, habituation as well as adaptation could allow porpoises to occur at noise levels higher than recorded for adverse reactions. For example, the ambient noise in the Fehmarnbelt region is between 103 and 132 dB re 1µPa, which is already higher than the discomfort threshold defined by Kastelein et al. (2005).

In studies of the responses of harbour porpoises to offshore pile driving, large response zones of up to 20 km have been documented (Tougaard et al., 2009; Diederichs et al., 2010;Brandt et al., 2011). The results of the studies of Diederichs et al. (2010) at the Alpha Ventus wind farm and of Brandt et al. (2011) at the Horns Rev 2 wind farm revealed (subtle and short-term) disturbance effects down to noise levels of 140 dB_{SEL} and stronger responses at 150 -160 dB_{SEL}. The duration of the response was clearly related to the strength of the noise emissions.

4.1.4. Harbour seal and grey seal

The frequency ranges of hearing for phocid seals differ between air and water, primarily due to the different ways that sound waves reach the cochlea (Hemilä et al., 2006). Most seals have their best hearing ability in water in a frequency range between 1 and 20 kHz (NRC, 2003). In harbour seals lowest hearing thresholds of about 58 to 60 dB were observed in the range from 1 to 50 kHz (Møhl, 1968; Kastak & Schusterman, 1998; Kastelein et al., 2008,Kastelein et al., 2009). Low frequency sensitivity extends to 100 Hz at 96 dB re 1µPa (Kastak & Schusterman, 1998, Richardson et al., 1995) and very high frequencies (~180kHz) can be detected if the sound is loud enough (Richardson et al., 1995). The high frequency limit of their underwater hearing is markedly greater than their hearing abilities on land (Hemilä et al., 2006). Figure 4.1-2 shows the varying audiograms for the harbour seal reported by various studies, while Figure 4.1-3 shows the only grey seal study available.

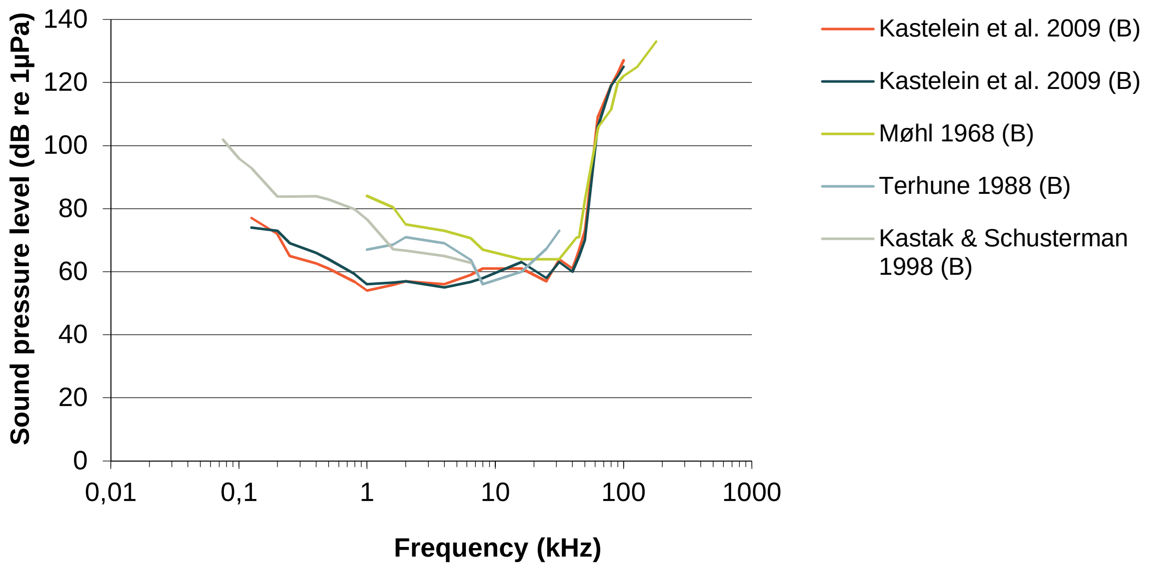

Figure 4.1-2 Audiograms of harbour seal determined by behavioural studies of different authors (B) (Kastelein et al., 2009;Møhl, 1968; Terhune, 1988;Kastak & Schusterman, 1998)

There is only one study relating to grey seals, which indicates that their best hearing ability is in a rather narrow frequency range between 10 to 40 kHz with lowest thresholds of more than 60 dB re 1µPa at 20-30 kHz (Ridgway & Joyce, 1975 in Nedwell et al., 2004).

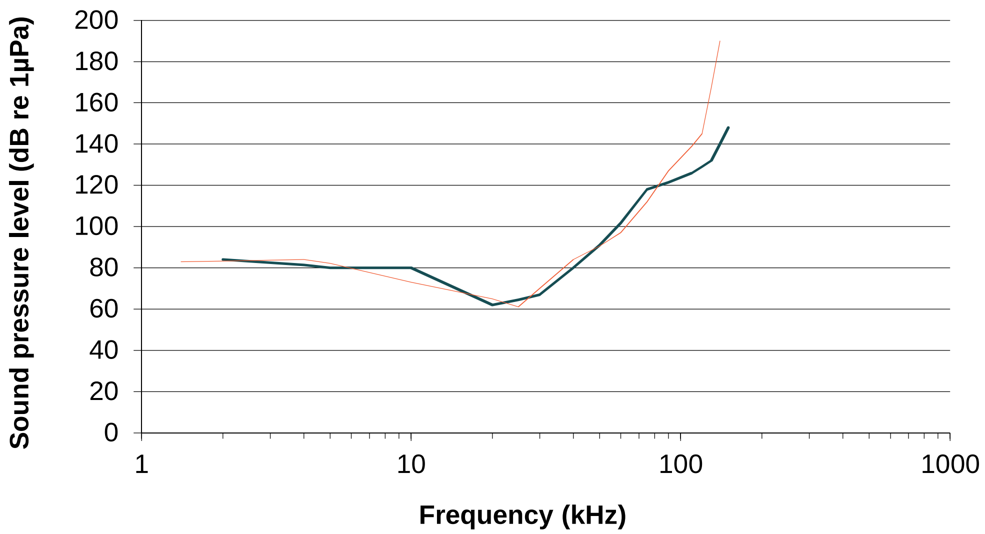

Figure 4.1-3 Audiograms of two female grey seals obtained by using the cortical evoked response method (Ridgway & Joyce, 1975 in Nedwell et al., 2004).

Seals produce a wide repertoire of sound both in air and underwater that is mainly related to mating behaviour and social communication (Schusterman et al., 1970; Asselin et al., 1993; Richardson et al., 1995;Schusterman et al., 2000;Schusterman & Van Parijs, 2003).

During the mating season, male harbour seals present themselves by making broadband roaring sounds in a frequency range between 0.5 and 4 kHz (Van Parijs & Kovacs, 2002 in Kastelein et al. (2009) in areas frequently visited by females (Bjorgesaeter et al., 2004). These sounds could be used both to attract females and to repulse competitors (Hanggi & Schusterman, 1994). Individual contact calls between mother and calf are in the frequency range between 0.2 and 0.6 kHz (Khan et al., 2006)

Therefore low frequency anthropogenic sound is likely to mask communication signals of harbour seals.

Noise may alter a seal's behaviour, interfere with communication, affect the auditory system by inducing a hearing threshold shift, induce physiological changes through stress and cause direct injury (Richardson et al., 1995; Kastak et al., 1995). The nature of the sound signal, in terms of its frequency, amplitude of modulation and duration, will determine the type of the response and the range at which animals will respond (Kastak et al., 1999; Götz & Janik, 2010).

There have been limited studies on the reaction of seals to dredging (which generates broadband noise with most energy at low frequencies but also considerable sound pressure levels at higher frequencies depending on the dredged sediment type). The impact on seals is probably low and in shallow water, low frequency noise attenuates rapidly (20-25km). Pile driving has been shown to cause behavioural responses in marine mammals at ranges of many kilometres (Madsen et al., 2006, Tougaard & Henriksen, 2009, Brandt et al., 2011). For harbour seals, a range of responses from none to departure from haul-out sites has been documented (Madsen et al., 2006). Short-term reactions of seals to pile driving activity were recorded during the ramming procedure of one foundation during the installation of the Nysted Offshore wind farm (Edren et al., 2010). A 10% to 60% reduction in the number of seals hauled out on a sand bank approximately 10 km away was recorded during pile driving (Edrén et al., 2004), although numbers returned to 'normal' during other construction activities (Teilmann et al., 2004), this in part may be associated with airborne noise. The reaction seemed to be short-term, as surveys did not show any decrease in the general abundance of seals during the construction period as a whole (Teilmann et al., 2004). However, it must be considered that only one foundation was driven into the seabed. All the other 79 wind turbines have gravity foundations, which did not cause a comparable sound emission.

Airborne noise is also of great relevance to nearby seals. Shipping noise (probably coupled with visual cues) can frighten seals and cause them to leave their haul-outs and enter the water. Such a behavioural response may be critical, especially during the breeding season (Dietz et al., 2000) and may lead to abandonment and reduced pup survival (Mees & Reijnders, 1994). The reaction tends to be indifferent to vessels that pass >200m away (Richardson et al., 1995), although the response is mediated by the type and activity of the vessel. However, seals may also be tolerant to repeated disturbance (such as that from ferries or operational wind farms) that do not pose any threat (Grøn & Buchwald, 1997). The Øresund Bridge, Denmark is just 1 km from a seal haul-out site yet despite decreased numbers of seals hauling out during its construction, numbers quickly returned to the previous levels at the favoured site once construction had finished (Teilmann et al., 2006).

Sound exposures that elicit TTS (range) have been studied in harbour seals (Kastak & Schusterman, 1996 Kastak et al., 1999,Kastak et al., 2005). Based on these results, Southall et al., 2007 derived PTS exposure criteria of 218 dB re 1µPa (SPL) and 186 re 1µPas (SEL) for pulsed sounds, and 218 dB re 1 µPa (SPL) and 203 re 1µPa^{2}s (SEL) for non-pulsed sounds (Table 4.1—2).

4.2. Habitat loss or change

Habitat in the context of the EIA for the fixed link is the ecological or environmental area that is inhabited by a particular marine mammal species. It is the entirely natural and physical environment in which a population lives and that surrounds and thus influences its living. It is generally accepted that animal populations are often limited by certain resources of their habitats. Even though other factors like predation or diseases also play a role, the animal population, or simply the abundance of animals in a given area, is often limited by the capacity of the available habitats which offer critical resources.

Habitat change encompasses changes in all structures which define the specific habitat for the particular marine mammal population such as substrate type, sediment dynamics, hydrographical features, bathymetry, chemistry (contaminants – see section 4.3), permanent loss and creation of new habitat. Ultimately, changes in habitat will affect the hydrography of the local environment and the fauna and flora within the affected ecosystem. The sensitivity of marine mammals towards habitat loss or change is determined by a change in environmental key drivers which govern directly or indirectly the presence of these animals in a specific area; the latter is primarily driven through changes in prey availability and distribution. Any change in important key drivers may lead to a negative impact on marine mammals.

As the relations between animal populations and habitat capacity are complex, it has been assumed that any habitat loss will lead to an equivalent reduction in the numbers of marine mammals sensitive to the loss occurring in the affected areas. With respect to habitat change this is more complex and, in the following sections, the type of habitat changes that might be regarded as pressures to marine mammals and how they might affect numbers and distribution are reviewed.

4.2.1. Habitat loss

Habitat loss from the footprint of a fixed link construction including land reclamation and landfall areas is not subject of the sensitivity analysis since every species is by definition sensitive to habitat loss. Whether the habitat loss of the project footprint is relevant for a particular species will be assessed later in the respective chapters to determine the severity of loss.

4.2.2. Habitat change

Following section 3.5.2, the pressure habitat change comprises different pressures related to the construction and operation of a fixed link and can be divided into three categories: change of seabed habitat; change of intertidal and terrestrial habitats and changes in hydrography and/or turbidity.

4.2.2.1. Change of seabed habitat

Habitat changes in seabed structure from dredging works, the deployment of extra hard bottom layers for scour protection or the erection of the bridge structure itself, lead to local changes in benthic communities and thus in food availability for higher tropic levels including marine mammals. This means change of seabed habitat from the construction and operation of a fixed link would primarily affect directly or indirectly the food resource of marine mammals. Harbour porpoises and both seal species common in the Baltic Sea are mainly fish-eaters (Benke et al., 1998).

Changes in the habitats of marine mammals have the potential to drive temporary or permanent shifts in behaviour leading to changes in distribution in response to modified foraging areas or haul-outs (seals). Loss of habitat also has the potential to affect fecundity and survival.

For the Fehmarnbelt area, habitat changes in terms of changes in substrate/bottom structure are expected through dredging of substrate within the impact zone. Whereas no information on direct impacts from changed bottom structure on marine mammals is available, the impacts of change in substrate/bottom structure on fish have been well studied. Effects due to certain fishing practices, particularly benthic trawling and dredging for fish and shellfish have been studied by de Groot (1984); Jones (1992); and Thrush (1995). The biological impacts of marine aggregate extraction using dredging have also been documented (Desprez, 2000; Wilber & Clarke, 2001). Species richness, biomass and abundance will be drastically reduced in dredged tracks (Desprez, 2000). Post-dredging colonisation studies, generally show that the community structure will differ according to the type of sediment that replaces the dredged material (Desprez, 2000). The changes in the benthic fauna and flora associated with particular sediment types will be reflected in the macrofauna associated with it, which may be using it to forage, as shelter or as a breeding/nursery area. The water column living zone is not directly affected by changes on the seabed, as the animals are still able to stay in or cross the area, but changes on the seabed could lead to possible effects on food availability for marine mammals.

The deployment of extra hard bottom layers for scour protection or the erection of the bridge structure itself leads to the creation of new habitats within the ecosystem. Such creation of artificial habitats through installation of industrial structures, such as oil rigs (Jørgensen et al., 2002) or renewable energy devices (Petersen & Malm, 2006; Inger et al., 2009) has also been studied in relation to impacts on fish and invertebrates. These studies showed that the introduction of hard substrate leads to an increase of epifauna. Even though such installations have the capacity to act as ‘artificial reefs’ and possibly as fish aggregation devices (Inger et al., 2009), it should be noted that marine mammals are sensitive to such habitat changes and the subsequent reactions cannot be predicted with any certainty.

4.2.2.2. Change of intertidal and terrestrial habitats

Seals utilise the intertidal area and terrestrial habitats to haul out. In the Fehmarnbelt area, both seal species use sandbanks in the Rødsand lagoon as haul-outs. As haul-out sites are important areas during the annual life cycle of seals for resting, breeding, pupping and nursing any change in terrestrial habitats are of concern for these animals. Since the nearest haul-out site to the planned fixed link is about 8.5 km away in the Rødsand lagoon, no change in terms of change in structure or substrate of this haul-out site is expected. Hence, no further sensitivity due to habitat change will be considered.

4.2.2.3. Changes in hydrography and/or turbidity

Ultimately, changes in habitat can affect the hydrography of the local environment and hence the fauna and flora within the affected ecosystem. The sensitivity of marine mammals towards changes in hydrography is influenced by changes in environmental key drivers which govern directly or indirectly the presence of these animals in a specific area; the latter is primarily driven through changes in prey availability and distribution. Any change in important key drivers may lead to a negative impact on marine mammals. Therefore, we assume the most significant habitat variables are those which are important in relation to marine ecological processes which enhance the concentration and prediction of fish prey (Iverson et al., 1979; Schneider & Duffy, 1985; Schneider, 1990; Fauchald, 2010). Thus, from an ecological efficiency viewpoint, we would expect the distribution of the three marine mammal species common in the Fehmarnbelt region to be linked to the distribution and abundance of prey and perhaps also other variables such as water depth and latitude. The distribution of prey species is, in turn, believed to be linked to hydrographical parameters such as salinity, temperature, hydrographic fronts etc. (see Reid et al., 2003,Johnston et al., 2005; Camphuysen et al., 2006;Fontaine et al., 2007; Skov & Thomsen, 2008b; Edren et al., 2010). However, all of these either direct or indirect relationships between marine mammal distribution and environmental (habitat) parameters are not well understood though baseline studies during the Fehmarnbelt EIA shed some light on this. On the other hand, possible impacts of changes in hydrography on fish communities are well documented as the production and distribution of fish depends strongly on environmental conditions. Changes in hydrographical and meteorological variables such as temperature, salinity, and severe weather conditions have all been shown to affect fish life history (e.g. success of reproduction, spatial distributions, migration patterns, growth and mortality rates) (Bakun, 1996;Stenseth et al., 2004). Variation in the abundance of southern fish species in the southern North Sea could be clearly related to hydrography and wind conditions (Corten & van de Kamp, 1996). Since changes in some of these hydrographic variables influence important prey species, an effect on marine mammals could also be expected.

4.2.3. Harbour porpoise

4.2.3.1. Change of seabed habitat

Direct threats to cetaceans from habitat loss/change are greatest for those species with a restricted and/or coastal range. Whilst the harbour porpoise, as a coastal species is highly susceptible to maritime and terrestrial anthropogenic activities, most of the subpopulations have a fairly extensive range (with the exception of the Baltic proper population).

The relationship between harbour porpoise distribution and water depth indicates a preference for shallow continental-shelf waters below 50 m (Hammond et al., 2002; Macleod et al., 2003). All modelling approaches of the baseline data, showed that water depth is the most important variable amongst others governing the distribution of porpoises (FEMM, 2011). Therefore, changes in seabed structure affecting water depth could directly lead to changes to the distribution of porpoises. In particular, in shallow waters close to the coastline (<10 m), porpoise density was lowest. However, the direct reaction of animals to changes in water depth would only be expected if changes of several metres took place.

Direct effects of habitat change on porpoises from sediment spill are not well studied. A study on the effect of sand dredging west of the island of Sylt, North Sea (Germany), could not show any significant difference in the long-term use of the impact area by harbour porpoises in comparison with three reference areas. The study was based on two methods, aerial surveys and passive acoustic monitoring (Brandt et al., 2009). Therefore, no direct sensitivity of porpoises towards sediment spill is expected.

Harbour porpoise distribution is presumed to be linked with the dispersal of prey (e.g. Sveegaard, 2011), which in turn is linked to parameters such as hydrography and bathymetry (Raum-Suryan & Harvey, 1998; Skov & Thomsen, 2008a; Embling et al., 2010). Activities that change or destroy habitat temporarily or permanently have the potential to either directly or indirectly affect porpoise distribution and density through impacts on potential prey. There is considerable variation in the diet of porpoises within the Baltic and adjacent regions and generally, they are opportunistic feeders known to forage on pelagic schooling fish and benthic fish (Santos & Pierce, 2003). Studies have shown a predominance of herring, sprat, cod and gobies in the diet of the Baltic porpoise (Lick, 1991; Santos & Pierce, 2003; Berggren, 1996; Benke & Siebert, 1996; Malinga & Kuklik, 1996; Malinga et al., 1997; Nabe-Nielsen et al., 2010). However, even though porpoises are considered as opportunistic feeders they do not forage equally on all available fish species.

Studies on prey species found in stomachs of stranded and by-caught animals of the Baltic showed a predominance of 13 fish species, amongst them herring, sprat, cod and gobies (Lick, 1991; Santos & Pierce, 2003; Berggren, 1996; Benke & Siebert, 1996; Malinga & Kuklik, 1996; Malinga et al., 1997;Nabe-Nielsen et al., 2010). Of these 13 fish species only eight were actually sampled during fish investigations within the Fehmarnbelt area (FEBEC, 2013): sandeel, herring, sprat, cod, whiting, saithe, goby and eelpout. From these species Nabe-Nielsen et al (2010) suggested that herring, whiting, cod and gobies were the most important species for harbour porpoises in terms of numbers and energy intake rates. Cod and whiting can be found in both pelagic as well as benthic habitats, while gobies are found during their whole life cycle only in benthic habitats and herring mostly in the pelagic area. Investigations on the pelagic fish community in the Fehmarnbelt showed the pelagic species herring and sprat and the semi-pelagic species whiting and cod as the most abundant.

A further aspect in habitat change occurs when bridge pylons provide artificial reefs. Additional hard substrates from man-made structures under water, such as bridge pillars, embankments or protection layers, result in a loss of the original hard-bottom communities and associated fauna, but provide new habitats for other composition. Artificial reefs may spatially reach further and affect the surroundings. Faecal pellets and organic substances may also impair adjacent benthic communities. The entry of additional solid substrates is assumed to enhance the risk of introducing invasive species to an environment (FEMA, 2011c). These secondary effects of additional hard substrates influencing on benthic communities in the Fehmarnbelt was assessed to be either very local in the case of the bridge solution or negligible in the case of the tunnel solution (FEMA, 2011c). It is known that reef structures are suitable habitats for different fish species and may aggregate fish from the surrounding area (e.g. Grossman et al., 1997, Inger et al., 2009, Lindeboom et al., 2011). FEBEC (2013) predicts that artificial reef structures in Fehmarnbelt would change the fish communities in the area permanently.

The effect has already been discussed in the aspect of offshore wind farms. A ‘reef effect’ at the Dutch offshore wind farm Egmond aan Zee was recently proposed by Scheidat et al. (2011).Stationary acoustic monitors (T-PODs) were used to monitor and compare harbour porpoise acoustic activity prior to construction and during normal operation within the wind farm site and against two reference areas. Porpoise acoustic activity was significantly higher in the wind farm areas compared to the reference sites. One possible explanation is that the abundance of fish within the wind farm site is greater (reef effect). Alternatively the wind farm may offer ‘shelter’ to harbour porpoises in an otherwise heavily trafficked and fished area of the

North Sea. Another positive effect of anthropogenic structures on the presence of harbour porpoises was shown by Todd et al. (2009). The study measured detection rates of porpoises with T-PODs close to oil rigs and could prove a higher detection rate of porpoises during the night, most probably due to higher prey resources close to the artificial reef structures of the oil platform. Similar results were shown by Diederichs et al. (2008b) at the offshore wind farms Horns Rev I (North Sea) and Nysted (Baltic Sea). No difference in acoustic activity measured by means of T-PODs could be seen at either wind farm. In contrast, at the wind farm Nysted, more activity occurred during the night close to the turbines. Leonhard et al. (2006) suggest that this could be related to higher fish abundance close to the turbines during the night (Leonhard et al., 2006). However, based on studies focusing on the effect of artificial hard substrate on porpoises, the sensitivity of porpoises to these artificial reef structures was assessed to be of minor importance or moreover even positive through increase of food resources.

4.2.3.2. Changes in hydrography and/or turbidity

Hydrodynamics and water structure are also important factors in determining the distribution of harbour porpoises. Some studies (Johnston et al., 2005; Skov & Thomsen, 2008b) have highlighted the importance of eddies on the distribution of harbour porpoises, particularly at the tips of islands and within Straits. Areas of consistently higher harbour porpoise densities have also been linked to areas of low current (Embling et al., 2009).

Results of the baseline study within the Fehmarnbelt project (FEMM, 2011) could prove different hydrographic variables as significant in terms of determining porpoise distribution within the Fehmarnbelt area. In turn, this means that a change in these variables may have some effects on the distribution of harbour porpoises. The main variables, which came out as significant in different datasets (e.g. aerial survey data, telemetry data and POD data), were bathymetry, geographical position (latitude/longitude), water temperature, strength of the east-west current and current gradient. Depending on the dataset used for modelling porpoise distribution, other hydrographic features could also be proved to have significant effect on porpoises. However, compared to static variables, all fine-scale hydrodynamic covariates, which are closely connected to inflow/outflow dynamics, had only weak effects. This means that the effects of hydrodynamic variables were rather small, which in turn shows that they do not act as key factors governing the distribution of harbour porpoises in the Fehmarnbelt area. No strong sensitivity of porpoises regarding these features is expected.

4.2.4. Harbour and grey seals

4.2.4.1. Change of seabed habitat, hydrography and/or turbidity

Hydrographic and seabed substrate changes, brought about by the construction of the fixed link and infrastructure, have the potential to lead to changes in fish distribution and abundance. Harbour seal adults tend to have a restricted foraging range, utilising the area close (<50 km) to their haul-out sites (Thompson et al., 1998; Dietz et al., 2003; Cunningham et al., 2009; Sharples et al., 2009). The foraging areas are generally characterised by particular environmental characteristics which may in turn influence the distribution and abundance of potential prey fish. Harbour seals in the Fehmarnbelt area (FEMM, 2011) were feeding predominantly on epibenthic prey, particularly sandeels (*Ammodytes marinus*) and cod (*Gadus morhua*). Associations between cod and seabed substrate are well documented. Juvenile cod tend to associate with more coarse substrates and deeper waters as they grow (Clark & Green, 1990;Gotceitas & Brown, 1993; Linehan et al., 2001) and older juveniles will utilise areas of cobble or larger structural features (rocks) to take shelter from predators (Gotceitas & Brown, 1993). Sandeel prefer shallow waters and seabed sediments of coarse sand and fine gravel (Macer, 1966; Reay, 1970; Wright & Begg, 1997).

Harbour seals tagged within the baseline study (FEMM, 2011) were observed to travel a mean maximum feeding trip extent of between 13.1 km to 26.6 km from the haul-out site, with all trips within 50 km from the departure haul-out site. Feeding studies (FEMM, 2011) also showed a strong association with substrate type, 96% of slow travel rate locations within the area where substrate data was available, were in either 'coarse sediment/boulders' or 'sand', finer substrates (those containing some quantity of mud) contained the remaining 4% of slow travel rate locations.

Grey seals also forage on epibenthic prey. Herring (*Clupea harengus*) and European sprat (*Sprattus sprattus*,) dominate the diet of Baltic grey seals (Lundström et al., 2007). The baseline study of grey seal diet in the Fehmarnbelt area (FEMM, 2011) also showed herring to be an important component, in addition to large cod and whiting (*Merlangius merlangus*). These prey species are also known to associate with particular habitats (e.g. herring are influenced by water temperature, seabed substrate, water depth and by boundaries between water masses that enhance local productivity (Maravelias, 1997 and Maravelias et al., 2000).

Individual grey seals show strong dietary preference for certain fish species (e.g. Grellier & Hammond, 2006), but the diet of grey seals is also known to be variable with respect to region and season (e.g. Thompson et al., 1996; Hall et al., 1998), and they can forage at distances of up to 82.5 km from their haul-out sites depending on food distribution (McConnell et al., 1999). Tagged studies undertaken in the Fehmarnbelt region (FEMM, 2011) showed that the tracks of two tagged juvenile grey seals showed more extensive movements and greater inter-individual variation than those of the adult harbour seals. Unlike harbour seals, the feeding relationship with substrate type showed that the feeding area of the tagged grey seals comprised only 'mud' or 'sandy mud' substrates. Therefore, harbour and grey seal feeding behaviour has a strong association to substrates which are relatively widespread throughout the Fehmarnbelt area. However, the fact that grey seals tend to travel further and forage at greater distances from their haul-outs suggests that they may be less susceptible to changes in habitat, which can affect prey.

4.3. Contaminants

A contaminant can be a biological, chemical, physical or radiological substance which, in sufficient quantities can have an adverse effect on living organisms through their environment and/or food. Contamination of marine mammals may be direct or indirect through the process of biomagnification up the food chain. Given that marine mammals are top-level predators, they accumulate the highest levels of biomagnifying contaminants. There is limited scientific evidence for the establishment of clear cause-effect relationships and causal links are difficult to establish due to likely cumulative impacts and combinatory effects with other factors. However, contaminants have been linked to reproduction effects (Murphy et al., 2010); death of first born calves (Reijnders & Aguilar, 2002); susceptibility / death from infectious disease (Jepson et al., 2005); reduced immune response (Reijnders & Aguilar, 2002), interference with natural hormones (Murphy, 2009) and impacts on renal function (Fujise et al., 1988). The release of contaminants throughout the construction activities, like dredging and land reclamation, and related contaminant exposure due to disturbance and remobilisation of contaminants in sediments would have a potential impact on marine mammals.

Contaminants in sediments in the Fehmarnbelt areas (FEMA, 2011b) indicated that concentration of heavy metals and persistent organic pollutants (also called POPs such as HCB, DDTs, PCBs, PAHs, TBT) in surface sediments was low compared to the lower range of the German, Danish and OSPAR sediment quality guidelines. Because the concentration of these pollutants approaches background concentrations, the spread and release of organic pollutants connected to dredging can be considered negligible. Less than one metre below the surface, seabed sediments are of pre-industrial origin and therefore represent soil types with only natural occurrence of heavy metals.

Increases in natural substances, such as nitrogen, are thought not to be significant. An additional small source of phosphate will most likely not lead to higher primary production, or stimulate blooms of cyanobacteria.

Baseline studies on the health of seals in the Fermanbelt area (FEMM, 2011) indicated that seals were in good physiological and nutritional health status. The fact that most metals (particularly the more toxic elements such as mercury and lead) were at very low levels in these samples indicates that their environment and foraging areas are not currently contaminated with these elements.

4.4. Barrier effects (noise, structures, light and visual disturbance)

Barrier effects are believe to arise when physical structures or perceived ‘barriers’ alter the behaviour of animals in their vicinity. Furthermore, it has been discussed by Nabe-Nielsen et al. (2010) that marine mammals might also cease movements across the evident barrier. Perceived barriers might also include noise emitted from construction vessels (e.g. extended dredging activity across a Strait, compare chapter 6.2.2.5. for construction of the immersed tunnel as well as the construction of the cable stayed bridge in chapter 7.2.2.4). Furthermore, the operational noise (e.g. traffic crossing a bridge) will also be considered in later chapters, in 6.3.2.4 for the immersed tunnel and in chapter 7.3.6 for the cable stayed bridge. Physical structures would include the artificial structures in the water column such as bridge supports. .

4.4.1. Harbour porpoise

Concerns have been raised that a fixed link may present a barrier effect and interrupt the natural movement patterns of harbour porpoises. Porpoises might sense a bridge as a disturbing structure thus restricting movements under it.

In assessing the sensitivity of porpoises to bridges as barriers it has to be considered how porpoises perceive the structure of a bridge in the water body. In the case of the bridge alternative in Fehmarnbelt, connecting structures between the pylons of the bridge would not be erected in the water body. Porpoises could sense the structure of the fixed link as individual structures of the pylons. Pylons of the main bridge will be constructed at a distance of 724 m, the outer pylon is 282 m away from the anchor pier, and the transition piers will be erected with a distance of 201 m between them.

The characteristics most relevant to the ability of marine mammals to detect underwater structures are echolocation, vision and hearing. Harbour porpoises perceive their environment by means of echolocation (e.g. Au et al., 1999) and it is the most important sensory component of the detection of structures. The structure may be sensed by porpoises directly from their echolocation or indirectly from noise emitted from the structure itself (e. g. traffic). A change in the hydrographic regime in close vicinity to the structure can also be noticed. Harbour porpoises are highly vocal animals and wild individuals in Danish waters have been shown to produce sonar-click trains on average every 12.30 seconds (Akamatsu et al., 2007). The echolocation click emitted by the harbour porpoise is highly directional with a narrow sound beam for a good target localisation and resolution (Au, 1993). The frequency influences the width of the sound beam and higher frequencies are used for a narrower beam (Au, 1993). The transmitted beam is more directional than the received beam. The harbour porpoise shows the highest sensitivity to receiving sounds coming from angles within 15 to 30 degrees of straight ahead (Kastelein et al., 2005).

The range of porpoise echolocation is rather short, about 400 m in the case of harbour porpoise (Villadsgaard et al., 2007). Thus, when a harbour porpoise approaches the bridge, it is assumed that the animal could only detect one of the pylons when it is within the detection range i.e. ~400 m.

Although marine mammals are well adapted to their underwater environment, porpoise vision is not the primary sense used for the detection of objects further away than several meters. One reason for this is the murky water of the Baltic Sea. Artificial light from the bridge lighting, illuminating the vicinity of the bridge, would only enter the top few metres of the water column. Therefore, it is thought that illumination of the bridge will have little bearing on the ability of harbour porpoises to detect it.

According to studies carried out in offshore wind farms, porpoises show little adverse responses to underwater structures. It was reported that porpoises are regularly found in close proximity to, and within, the wind farms (Diederichs et al., 2008a, Scheidat et al., 2011). It is further suggested that, at times, the porpoise activity close to the foundations may be higher than in surrounding waters (Diederichs et al., 2008a, Scheidat et al., 2011). It must be noted that harbour porpoises may be attracted to such three-dimensional habitat structures. Leonhard et al., (2006) have shown that foundations of wind farms became ‘biomass hotspots’ and might serve as artificial reefs, which might attract harbour porpoises, due to the presence of abundant prey species. Scheidat et al. (2011) found increased densities of harbour porpoises within an offshore wind farm. One of the reasons proposed to explain this was increased prey resources. There was no evidence that porpoises were deterred by the presence of the underwater wind farm structures and therefore, we suggest that structures of the bridge in the water will not be an obstacle to harbour porpoises.

Several studies on porpoise movements have been conducted in Inner Danish Waters, mostly in the area of the Great Belt where porpoises are present year-round and found in high densities (Sveegaard et al., 2008, 2010). Some studies were undertaken specifically in order to look at a potential barrier effect caused by the Great Belt Bridge (FEMM, 2011). These studies applied different methods and indicated no avoidance behaviour of porpoises to the bridge. Within the study (FEMM, 2011) land based observations were undertaken with a good view along the Great Belt Bridge with eight observation points, where four observation positions were on each side of the bridge. Porpoises were observed from land and high sighting rates were recorded in the vicinity of the Great Belt Bridge as well as at reference positions more than 5 km away during daylight. The authors observed individuals surfacing directly under the bridge and tracked them first on one side of the bridge, under and again on the other side of the bridge. No general difference in sighting rate was found between observation points underneath and further away from the bridge. According to the observations, there were no indications of avoidance behaviour or changes in behaviour in response to the bridge. A few studies proposed that, for example, Bottlenose dolphins do swim under bridges (Wilson et al., 1997, Hastie et al., 2004). There is little published evidence that dolphin or porpoise behaviour is influenced by the presence of bridges. Similarly, data gathered during aerial surveys suggest no barrier effect of the bridge on harbour porpoise.

A further study using a vertical hydrophone array to investigate fine scale movements of harbour porpoises in relation to the bridge was also carried out. Porpoises were regularly detected in close proximity to the bridge on either side of it. The swimming patterns of porpoises were measured with respect to the bridge, however, directional movements of the individual animals relative to the bridge varied on both sides of the bridge. No swimming pattern gave an indication of directional adverse movements and the study concluded that the bridge is unlikely to present a barrier effect.

Results of the passive acoustic monitoring (using 'PODs') around the Great Belt Bridge documented no differences in porpoise detection rates near the bridge compared to those at greater distances. Porpoises were predominately more acoustically active in the night during winter. During summer, recordings at POD-positions near the bridge remained higher during the night, while at positions further away acoustic activity varied between mainly night time and day time. These seasonal changes in porpoise acoustic activity may be related to seasonal changes in diet and the activity rhythms of available prey.

Baseline studies (FEMM, 2011) suggested that animals which remained in the area on one side of the bridge did so because of preferential habitat selection driven by environmental factors rather than a barrier effect. A comparison of straits used by porpoises showed that porpoises used both straits with and without a bridge in similar ways, providing no indications that porpoises would respond to bridges.

Previous analysis of movements of satellite tagged porpoises in the Belt Sea found some evidence that the Great Belt Bridge might impact the movement of porpoises because satellite tagged animals appeared to turn around in vicinity of the bridge. Nabe-Nielsen et al. (2010) investigated this further using individual based modelling (IBM) on 44 satellite tagged animals. The authors measured the strength of the barrier effect by taking into account how abruptly an animal turned around near the potential barrier. The authors described that behaviour of individuals differed as they approached the barrier. Some individuals stopped abruptly in the vicinity of the bridge and altered swim direction, never swimming under the bridge. Others needed several attempts before they rapidly moved under the bridge to get to the other side. It was proposed that animals changed swimming direction for reasons other than being deterred by the bridge. Relevant factors include prey availability and hydrographical/ physical parameters which are associated with resource availability. They concluded that there was no barrier effect from the bridge.

A further study was conducted to measure noise and vibrations emitted from the Great Belt Bridge (FEMM, 2011). Hydrophones and an acceleration sensor were deployed in the vicinity and further away from the operating bridge. Results showed that sea floor acceleration data revealed no sign of measureable vibrations of the ground. Underwater noise emissions measured from the bridge were of no consequence compared to the underwater noise emissions measured from the shipping lane, which was the main source of underwater noise in the vicinity of the bridge. The sound pressure levels measured under the bridge in such studies depended only on the distance to the shipping lane as well as north and south of it. There was no evidence found that porpoises avoid the Great Belt Bridge, or are reluctant to cross under it, because of underwater noise emitted by the bridge.

It was concluded that the Great Belt Bridge does not cause a barrier effect to harbour porpoise movement. Harbour porpoises were visually observed surfacing under the bridge and also individuals crossing under the bridge. Datasets gained from satellite-tagged harbour porpoises also proved that porpoises swim under bridges (FEMM, 2011). According to covered distance, telemetry data suggested that harbour porpoises crossed several bridges along their route. Nabe-Nielsen et al. (2010) reported that behavioural reactions of harbour porpoises to a bridge are dependent on each individual since some individuals were recorded changing swimming direction and moving under the bridge whilst others did not. Therefore, we have no direct indication from current data of a barrier effect. All available results show that porpoises are present in the close proximity of that bridge. Recordings from passive acoustic monitoring such as C-PODs and a hydrophone array support the assumption that porpoises remain in close proximity to the structure of the bridge. However, it is also important to consider possible individual behaviour of porpoises and results from future studies.

Consequently, harbour porpoises will be assigned a minor sensitivity to a barrier effect from a bridge since empirical data did not provide evidence for a barrier effect to harbour porpoise movement from the Great Belt Bridge.

4.4.2. Harbour and grey seals

The response of seals to barriers in the water coloumn has recently been assessed in relation to marine renewable energy installations. The physical presence of tidal turbines, in particular, and their operational noise could give rise to barrier effects. The potential for barrier effects in Strangford Lough, Northern Ireland arose from the presence of the device and the operational noise; comparable to a large vessel underway and, therefore, audible to marine mammals (Royal Haskoning, 2010). Telemetry studies of harbour seals were conducted prior to and throughout the operational phase (work carried out by SMRU Ltd, cited in Royal Haskoning, 2010). The presence of the turbine did not significantly reduce transit rate from baseline conditions and there was no evidence for barrier effect as seals still moved between the sea and lough. However, there was an apparent shift in transit location, showing some degree of local avoidance of the structure, irrespective of whether it was operational. Seals which regularly passed the turbine did so, on average, slightly less when the turbine was operating relative to when it was off, suggesting a minor sensitivity to its presence. The effect of noise during operation was also minor as seals regularly occurred within the zone of predicted behavioural disturbance (Royal Haskoning, 2010).

The physical presence of bridges also appears to have no/little effect on the behaviour of seals. Teilmann et al. (2006) cited in Édren et al. (2010) describes no barrier effect to seals while the construction of the Øresund Bridge between Sweden and Denmark from 1997 to 1999. This bridge was built at a distance of 1 km from the seal haul-out site and no apparent permanent effect on the seals could be detected. During construction the number of seals hauling out diminished. However, after the finalisation of the construction, the seals colonised their favourite haul-out sites again in the proximity to the bridge. In Scotland for example, harbour and grey seals utilise haul-outs that are accessed only by travelling under a bridge. These include those in the Montrose basin, upper Tay, Beauly, Cromarty and Dornoch Firths (Sparling, SMRU Ltd.

pers comm.). There are also examples of seals feeding directly under bridges (e.g.Yurk & Trites, 2000).

In Fehmarnbelt, telemetry studies (FEMM, 2011 & Appendix 7.7) showed that both harbour and grey seals swim through the Fehmarnbelt. Harbour seal juveniles travel more widely (Thompson et al., 1994; Lander et al., 2002; Small et al., 2005;) and the baseline showed them to travel through the fixed link area which may put them more at risk of impacts from barrier affects. Grey seals do make extensive passages through the Fehmarnbelt (see Appendix 7.7.4) to haul-outs in the north-west region and may also experience barrier effects depending on the extent and duration of the construction activities. Dietz et al. (2003) showed that adult grey seals tagged at Rødsand travelled as far as eastern Sweden, Latvia and Estonia. The effects of noise from shipping appears not to be perceived as a barrier and does not prevent seals from using the area, suggesting their tolerance and ability to adapt to noise in the environment is good.

4.5. Sensitivity of marine mammals to suspended sediment in the water column

Many marine mammal species, including harbour porpoises, grey and harbour seals, are known to forage in turbid inshore waters and estuaries where food resources are often abundant. Turbid waters, arising from suspended sediment in the water column, can affect marine mammal vision in a number of ways; suspended sediment scatters light and degrades the image contrast, it limits the visual range and also determines the spectral bandwidth and intensity of light available for vision at certain water depths (Weiffen et al., 2006). However, some marine mammal species live in extreme conditions of turbidity (e.g. Ganges river dolphin) and such species are functionally blind. Marine mammals will rely on the integration of information from any sensory channel providing relevant input (Schusterman, 1965; Weiffen et al., 2006). In this way, the animal is able to compensate for the loss of a sense in particular environmental conditions, including loss of vision in turbid waters. There is very limited information on the effects of turbidity on marine mammals and so a proxy for 'extreme turbidity' was considered: darkness. Both scenarios limit vision in marine mammals.

Indirectly, increased sediment suspension may affect the prey or marine mammals. Eventual settlement of sediment may smother areas of seabed with impacts on benthic fauna and flora, and subsequent effects up the food chain. It may also give rise to changes in the seabed topography and community structure and alter the suitability of habitats formerly used for vital functions; foraging, cover from predation, nursery ground etc.

4.5.1. Harbour porpoise

The hearing and echolocation of harbour porpoises are adapted for navigation and foraging in conditions where vision is limited or absent (Kastelein et al., 2002). They are highly vocal animals; in Danish waters they have been shown to produce sonar-click trains every 12.3 seconds (Akamatsu et al., 2007, in Todd et al., 2009). There have been experimental studies to test the abilities of captive harbour porpoises to catch live prey (Verfuß et al., 2009). The authors monitored the acoustic behaviour of the animals during the search, approach and 'close to' prey phases and repeated the experiments by covering their eyes with cups (blindfolds). The swim speed of blindfolded animals was halved but click-intervals remained virtually unchanged with the effect that they emitted more clicks per metre swum. The results of this study suggest that the animals used multi-modal sensory information from vision and echolocation when possible for searching and approach of prey, but compensated for lack of vision by adjusting their acoustic search behaviour (Verfuß et al. 2009). When vision is poor, one might expect that echolocation is the primary sense for navigation and foraging and this is supported by the results from studies on diel acoustic behaviour of porpoises. Diel patterns in echolocation activity have been recorded, with increased acoustical activity at night (e.g. Carlström, 2005; Todd et al., 2009; FEMM, 2011). The increased activity may reflect their dependence on this sense when vision is limited and/or increased foraging activity associated with diel patterns in prey availability.

4.5.2. Harbour and grey seals

Seals successfully live and forage in turbid environments, such as the Wadden Sea. However, like harbour porpoises, turbid waters will alter their ability to see objects underwater. The vibrissae (whiskers) are thought to play an important role in foraging seals and it has been proposed that they serve a particularly important role when faced with reduced visibility or when foraging at night (Renouf, 1980). Experiments using captive harbour seals suggested that foraging using vibrissae takes time to perfect and therefore vision and/or additional sensory cues are used. Yearlings were more adept at using their vibrissae than pups and when their vibrissae were removed they temporarily found it more difficult to capture prey. Conversely, when visibility was reduced, their foraging behaviour was unaffected (Renouf, 1980). However, in the Baltic (e.g. Sjöberg et al., 1995; Sjöberg et al., 1999) and in the Fehmarnbelt (FEMM, 2011), grey and harbour seals spent more time hauled-out during the night than in the day; most foraging trips occurred during the day. We can speculate that there may be an advantage to daytime foraging because vision does contribute to enhanced foraging efficiency. Alternatively, changes in prey distribution may also explain the nocturnal haul-out behaviour (Sjöberg et al., 1999).

Harbour seals and grey seals in the Rødsand lagoon have, at least in the short-medium term, proved to be resistant to the impacts of the installation and operation of the Nysted wind farm (Edren et al., 2010). The only short-term response (temporary reduction in number using the haul-outs) was to sheet piling activities during construction. The construction phase also included digging of cable furrows but there has been no measurable effect on the seals.

5. ZERO (DO NOTHING) ALTERNATIVE

The zero alternative specifies the future development without the establishment of the fixed link. FEMM has been asked to project the marine mammal population status to 2025 and 2030 to comply with the Danish and German authorities requirements. The current status is described in the FEMM baseline report which was performed from late 2008 to the end of 2010 (FEMM, 2011) Further reports, such as the HELCOM Biodiversity in the Baltic Sea report 2009 (HELCOM, 2009b) and OSPAR Quality Status report 2010 (OSPAR, 2010) have been reviewed for current status and future trends of marine mammals in the broader HELCOM and OSPAR areas. The zero alternative status of marine mammal populations is assessed by considering the influence of the changes in pressures due to man’s changing activities in the Baltic area and taking into consideration the natural variations in marine mammal populations.

5.1. Current status of harbour porpoise

In late 2008 FEMM started extensive baseline investigations; the studies included visual and acoustic surveys for mapping distribution and estimating abundance of harbour porpoises, harbour seals and grey seals. Further studies were conducted to assess movements and behaviour of these populations using telemetry techniques and seals at Rødsand were also sampled to assess health status.

5.1.1. Harbour porpoise, occurrence in the wider marine area

An evaluation of the status of harbour porpoise in the wider OSPAR Maritime Area (delineated in Figure 5.1-1) has been made by ICES, who state that harbour porpoises occur in all regions but are most abundant in OSPAR Regions II (the greater North Sea) and III (see Figure 5.1-1 for the extent of the OSPAR regions). The population structure in the OSPAR Maritime Area is complex and not yet fully understood. The ICES Working Group on Marine Mammal Ecology concluded in 2003 that there is good evidence of a past decline in harbour porpoise in the Channel and southern North Sea and more recently in the Baltic (ICES, 2003). The main threat to harbour porpoise is by-catch, particularly in bottom-set gillnets. HELCOM, 2009b concludes that the density and distribution of the Baltic harbour porpoise has declined considerably. The abundance of harbour porpoise in the Baltic. Proper has been estimated at 599 individuals (CV=57%; 95% CL = 200-3,300) (Hiby & Lovell, 1996). The SCANS-II survey (SCANS-II, 2008) estimated 23,227 (CV = 36%) individuals in the areas of the Kattegat, Beltsee and western parts of Inner Baltic Sea.

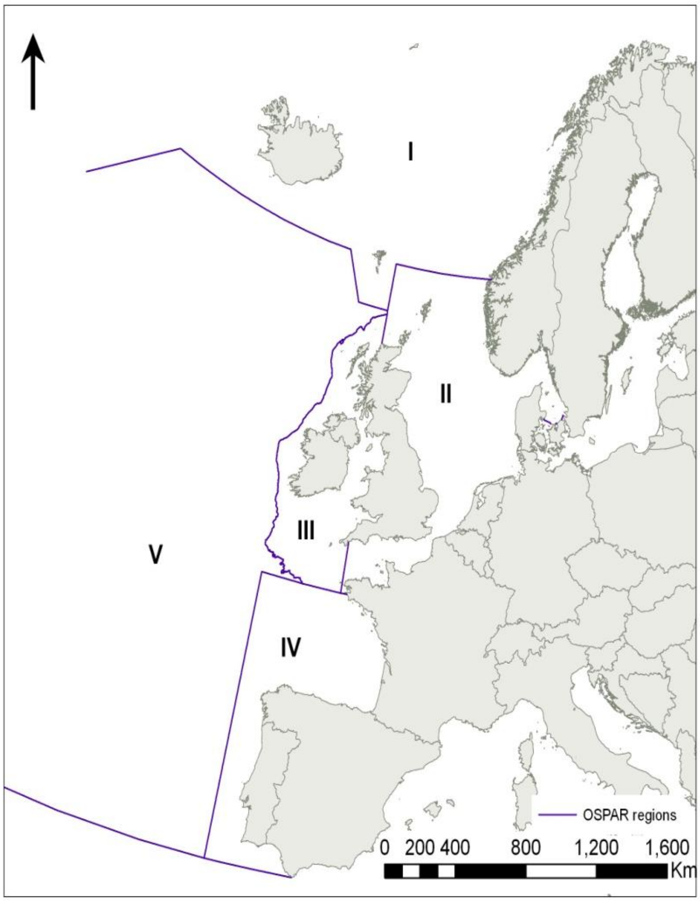

Figure 5.1-1 Map showing the OSPAR Regions

5.1.2. Harbour porpoise: general occurrence in Fehmarnbelt area

Historical data indicates that the Fehmarnbelt area is regularly populated by harbour porpoises with densities reaching up to 0.5 animals per km². The baseline investigations indicated a seasonal pattern with highest numbers during the summer months; however, there are uncertainties remaining about the seasonal occurrence of harbour porpoises in the area (see for example Scheidat et al., 2008). Analysis of telemetry data suggest that the animals occurring in the Fehmarnbelt area belong to the 'Inner Danish waters' (IDW) management unit which is separate from the one in the Skagerrak (Teilmann et al., 2008). Recent genetic studies indicate that both groups represent different subpopulations, which are, to some extent, also different from animals living in the Baltic proper (Wiemann et al., 2010). However, no final consensus on genetic distribution has been agreed.

5.1.3. Harbour porpoise: visual surveys

As part of the FEMM baseline studies, harbour porpoises were counted from aerial transect surveys between November 2008 and November 2010 at monthly intervals in a 4,800 km^2 study area. The results showed a marked seasonal pattern with lowest numbers during the winter months and higher numbers from spring to autumn. Highest densities in 2009 were recorded in April with 0.59 porpoises per km^2; however, numbers in summer and autumn were lower. In 2010, highest densities reached 0.94 porpoises/km^2 in May with numbers in summer 2010 generally higher compared to 2009.

Aerial survey data were analysed and porpoise distributions were modelled in relation to several environmental parameters. In the modelling, the variables position, water depth, sea temperature at depth and the strength of the east-west current component at depth best described the dataset. The model-based estimates of abundance (Table 5.1—1) compared well with the design-based results (for details on distance sampling methodology and design, see Buckland et al., 2001).

Table 5.1—1 Abundance estimates for harbour porpoise in summer (March-August) and winter (September – February) in the years 2009 and 2010. Percentage of coefficient of variation (%CV) and 95% confidence interval (CI)

Year	Season	Abundance	%CV	95%CI
2009	Summer	1456	19	782-1631
	Winter	921	31.1	436-1467
2010	Summer	2078	17.8	1414-2709
	Winter	931	31.9	521-1800

Monthly visual surveys from the ferries operating between Rødby, Denmark and Puttgarden, Germany provide evidence of year-round use of the alignment area by harbour porpoises. The seasonal pattern was less apparent than in the aerial surveys and sighting rates remained at more or less constant levels until mid-winter. The highest numbers were counted in spring / early summer and late autumn to winter.

5.1.4. Harbour porpoise: passive acoustic monitoring

Porpoise activity was monitored using passive acoustic monitoring (PAM) with autonomous porpoise click detectors (C-PODs). The baseline study found an almost constant presence of harbour porpoises in the Fehmarnbelt area over the whole study period (Jan 2009 – January 2011). A general west-east gradient, with more recordings in the northwest and fewest recordings in the southeast, is in line with former studies on the distribution of harbour porpoises in the western Baltic Sea. In the eastern part, and at some stations in the area around the planned link, a weak seasonal pattern with peaks in spring and late autumn / early winter could be seen. At most stations, in particular in the western part of the study area, no clear seasonal trend was recognisable in the POD data, at least at the daily scale being investigated in this study. As well as a high temporal oscillation in the POD data, a pronounced spatial variation with high variability between single stations could be detected. The high fluctuation of detected click activity at different times and stations might indicate more pronounced individual movements of porpoises across the study area. Several recent studies have shown that individual migration plays an important role in the annual life-cycle of the harbour porpoise in the Fehmarnbelt area (Teilmann et al., 2008; Sveegaard, 2011). From both the high temporal and high spatial variability it can be assumed that localised movements in response to small-scale ecological drivers may play an important role in the annual life-cycle of the harbour porpoise in the study region.

The modelling of C-POD data demonstrated a moderate effect of fine-scale hydrodynamic covariates, which are closely connected to inflow / outflow dynamics on porpoise click activity. However, compared to static covariates describing the geo-location of the specific POD-station, their effects were comparatively small, which in turn shows that they do not act as key factors governing the distribution of harbour porpoises in the Fehmarnbelt area.

The strongest hydrographic variable was water temperature, which is not, or only weakly, affected by the flow regime in the belt area. Porpoise acoustic activity decreased abruptly when temperature dropped below 4°C. This can be interpreted as harbour porpoises avoiding ice cover and, therefore, likely to retreat from areas before ice coverage starts.

Further static variables, which were important in the final model, were latitude, longitude, distance to main shipping lane, substrate and water depth. The power of these variables, which all describe station-specific features, indicate that the distribution of harbour porpoises in the Fehmarnbelt is influenced, either primarily or secondarily, by the location of specific environmental conditions.

5.1.5. Harbour porpoise: satellite telemetry

Movements of harbour porpoises in the study area have been investigated by means of satellite telemetry for more than a decade (Sveegaard, 2011). As part of the Fehmarnbelt Marine Mammal studies, available data from ongoing studies by the National Environmental Research Institute (NERI) were analysed, with additional harbour porpoises equipped with transmitters as part of the FEMM baseline study (FEMM, 2011). In total, data from 82 animals tagged between 1997 and 2010 were analysed. The aim of the analysis was to describe the function of the Fehmarnbelt area and habitat choice of harbour porpoises, especially in relation to large-scale movements of the animals which can only be investigated using telemetry. The analysis provides evidence that the harbour porpoises of the Fehmarnbelt area are part of the subpopulation of the Belt Sea which separated from the more northern Skagerrak subpopulation.

In addition, possible responses of porpoises to existing bridges in the western Baltic Sea were investigated (FEMM, 2011).

A substantial number of the animals tagged in the Belt Sea, however, migrated to the Skagerrak in the winter months. Seasonal movements were very pronounced and indicated that a substantial part of the population seasonally migrates between the Skagerrak and the Belt Sea, including Fehmarnbelt and the areas to the east of Fehmarn. Daily movements of tagged animals were considerably larger in winter than compared to the rest of the year. The analysis further indicated, and is also supported by the results from previous investigations (see Sveegaard et al., 2010), that porpoises are not evenly distributed over the Baltic Sea but show preferences for certain areas. On a large-scale, occurrence in straits, e.g. narrow waterways, is relatively high. It is likely that hydrographic features such as increased currents and turbulence, which in turn could affect fish movements, are driving this higher occurrence in narrow straits. On the more local scale of the Fehmarnbelt, areas of strong current gradients and westward moving surface water current appeared to increase the probability of a harbour porpoise occurring. Eddy activity at depth (vorticity) was also a predictor of harbour porpoise locations.

Based on the analysis of the telemetry tracks and the studies undertaken by others we concluded that although porpoises tend to cross areas with bridges less often than areas without bridges, no apparent avoidance behaviour was observed. Thus, bridges might not have much effect on the movement patterns of porpoises.

5.1.6. Harbour porpoise: protected status

Harbour porpoises are strictly protected under the EU Habitats Directive. They are listed in Annex II as species for which EU Member States must establish a network of Special Areas of Conservation (SACs). The Fehmarnbelt has been designated as a SAC in 2004 (SAC DE 1322-301) (EU Commission, 2007). In addition, all species of cetaceans are listed in Annex IV for which EU Member States must establish a system of “strict protection”, avoiding, among other things, “deliberate disturbance”.

The harbour porpoise is also the focus of much of the work being carried out under regional agreements, including ASCOBANS, HELCOM and OSPAR. The Jastarnia Plan was finalised in 2002 under the auspices of the ASCOBANS agreement which recommends an action plan for the recovery of harbour porpoise in the Baltic (proper). HELCOM includes harbour porpoise on its list of threatened/declining species.

Further protection for harbour porpoises may arise through the reform of the Common Fisheries Policy (Lutchman et al., 2009). The CFP is based on ecological sustainability and requires the application of the ecosystems-based approach and the precautionary principle to fisheries management as well as compatibility between the CFP and EU environmental policy.

5.1.7. Summary evaluation of the current status of the harbour porpoise

The current status of the harbour porpoise was evaluated using a four-scale matrix as developed for the Fehmarnbelt Baseline and Environmental Impact Assessment. The evaluation ranks the abundance of harbour porpoises in the Fehmarnbelt area to be of medium importance resulting from the mean of the winter and summer density maps. However, the uneven distribution of porpoises in the Fehmarnbelt further leads to the conclusion that certain sub-areas of higher densities are assessed to be of higher importance (see Figures 4.2-1 and 4.2-2 in section 4.2 of the baseline report, FEMM, 2011). The function as a nursing area is assessed to be of medium importance. Furthermore, the function of the Fehmarnbelt as a feeding area and migration corridor has also been assessed as being of medium importance. This evaluation is based on the present understanding that no discrete population in the eastern part of the Baltic Sea is dependent on migration through the Fehmarnbelt.

5.2. Current status of harbour and grey seals

5.2.1. Harbour seal and grey seal abundance in the wider marine area

Harbour seals are in abundance in the Skagerrak, Kattegat and Belt Sea area, with a population of about 15,000 in 2007 (Härkönen et al., 2008). In the eastern Baltic proper, they are restricted to three small breeding colonies and are a genetically distinct subpopulation from the Skagerrak/Kattegat and Southwest Baltic harbour seal populations (Stanley et al., 1996).

A census of grey seals in the Baltic in 2007, counted approximately 22,000 individuals. The population of grey seals in the region is steadily increasing (Harding et al., 2007).

5.2.2. Harbour seal and grey seal abundance in the Fehmarnbelt area

Sandbanks and rocks in the Rødsand lagoon provide haul-out sites for both seal species (see section 4.3 of the baseline report FEMM, 2011). Close to 200 harbour seals and a small but increasing number of grey seals are regularly counted in the lagoon. The Fehmarnbelt area forms the southern-most haul-out site for harbour seals in the Baltic Sea. Rødsand lagoon harbours about one third of the small subpopulation of harbour seals in the Baltic Sea.

5.2.3. Harbour seal and grey seal visual surveys

Seals were counted between January 2009 and September 2010 on the haul-out sites in Rødsand lagoon by aerial surveys at monthly intervals. Numbers obtained during our surveys were lower for harbour seals than those obtained during national surveys, but provided new maximum numbers for grey seals. Surveys indicate a seasonal pattern with highest numbers in summer and lowest in winter. However, in January 2009 an exceptionally high number of 107 harbour seals were counted. Grey seal counts reached a maximum of 57 animals in June 2010.

5.2.4. Harbour seal health status

In this study a number of different physiological parameters were measured in individual seals captured at Rødsand lagoon to indicate their current general health status. These included a standard set of haematology and clinical blood chemistry parameters, basic immunological measures to determine immune status and exposure to pathogens, and morphometric measurements. Parasite loads were investigated from faecal egg counts and examination of the animal for the presence of ectoparasites. The results indicate that the five harbour seals captured at Rødsand in October 2009 were in good nutritional and physiological health, with no signs of disease being detected, using the various blood parameters and morphological measures as indicators. The adult animals (three) had been exposed to a morbillivirus (probably PDV during the 2002 outbreak) and had protective levels of antibodies in their blood.

The two juvenile grey seals captured, sampled and released at the Rødsand haul-out were both in good general health with no signs of infection or other diseases.

From the small sample of animals captured at the Rødsand haul-out site it appears that both species were in good general health and body condition.

5.2.5. Seal telemetry

In October 2009 five harbour seals were tagged at Rødsand – four adult males and a female juvenile. The four males were fitted with GPS/GSM tags. The juvenile female was fitted with an Argos tag. The tracks from all four adult male harbour seals showed that the tracked seals remained within 50 km of the two haul-out sites (Rødsand and Vitten/Skrollen). The juvenile female harbour seal travelled much further. Overall the mean trip duration for the four adults was 66 hours (range from 56 to 79 hours). Mean dive duration for the four GPS/GSM tagged harbour seals was 2.8 min (range from 2.7 to 3.1 min). The overall mean maximum dive depth was 8.4 m (range from 7.7 to 10.0 m).

There was a strong association of feeding behaviour with substrate type. Almost all GPS locations that were associated with feeding (animals moving slowly and performing regular dives) were obtained from either ‘coarse sediment / boulders’ or ‘sand’. Finer substrates (those containing some quantity of mud) contained the remaining 4% of ‘slow travel rate’ locations indicative of feeding.

In October 2009 two juvenile grey seals were tagged with GPS/GSM tags at Rødsand – one male and one female. Both individuals travelled over large distances and commuted between other haul-out areas in Denmark and Sweden. The analysis of seal movements in relation to environmental variables indicated that distance to haul-out, bottom current strength and surface temperature determined the distribution of the tagged seals.

5.2.6. Summary evaluation of the current status of the harbour seal and grey seal

The current status of the harbour and grey seal was evaluated using a four-scale matrix as developed for the Fehmarnbelt Environmental Impact Assessment.

The importance of the Rødsand area and adjacent feeding areas for harbour seals is evaluated as very high, due to the high proportion of Baltic seals occurring in this area. Moreover, the Rødsand area provides an important breeding and pupping ground for the Baltic population of harbour seals.

The importance of the Rødsand area for grey seals is evaluated as high, as it holds a substantial part of grey seal numbers recorded for Danish territorial waters, but total numbers are low compared to the whole Baltic population. Recently, the Rødsand area is being used as a breeding and pupping ground by grey seals.

5.3. Current Pressures

Pressures on marine mammals in the wider North East Atlantic include acoustic disturbance through shipping traffic, oil exploration, constructions for the wind energy industry, tourism, fishing and the presence of toxic substances that can bio-accumulate in marine mammals and reduce reproductive fitness. Climate change may add additional pressures, for example, through changes in availability of prey species, morphological changes and sea level changes affecting the land/sea interfaces potentially affecting haul-out sites for seals. Rising sea temperatures will reduce ice-cover and impact harbour porpoise movements.

5.3.1. Harbour porpoise

The OSPAR QSR, 2010 (OSPAR, 2010) lists the main past, present and future threats to harbour porpoises in the North East Atlantic as:

- Incidental capture and drowning in fishing nets (The International Whaling Commission (IWC)/ASCOBANS working group on harbour porpoise advised a maximum annual anthropogenic removal (including by-catch), assuming no uncertainty in any parameter, of 1.7% of the population size per year if the population is to be non-declining (ASCOBANS, 2000);
- Marine pollution, for example from toxic substances that bioaccumulate and are known to reduce reproductive fitness (Jepson et al., 1999; Siebert et al., 1999; Das et al., 2004; Jepson et al., 2005);
- Acoustic disturbance (from shipping traffic, oil exploration, military activities, etc.) that may reduce available habitat or fitness due to stress;
- Impaired hearing - from seismic surveys, pile driving and underwater explosions;
- Reduction in prey species – since the diet of harbour porpoise includes herring, mackerel and sandeel that are also targeted by commercial fisheries;
- Human consumption of small cetaceans (illegal since 1970 (Klinowska, 1991),and no longer regarded as a substantive issue).

HELCOM, 2009 identifies a number of anthropogenic threats to harbour porpoise, including:

- Incidental by-catch (identified as the most serious threat);
- Prey depletion;
- Noise pollution;
- Chemical toxins.

The ICES Advisory Committee on Ecosystems concluded in 2003 that there is good evidence that the main threat to harbour porpoise is by-catch, particularly in bottom-set gillnets.

5.3.2. Harbour seals and grey seals

OSPAR Ecological Quality Objective for seals[1] aims to maintain healthy populations of seals by triggering management actions when needed, e.g. depletion of food stocks through fisheries, pollutants affecting reproductive ability or climate change. A cumulative effect may lead to deteriorated health and susceptibility to diseases in seals and in recent decades, virus infections have led to high mortality amongst seals. HELCOM, (2009b) states that HELCOM recommendation 27-28/2 (2006) requires that the long-term objectives for the management of Baltic seals are a natural abundance and distribution and a health status that ensures their future persistence.

[1] Taking into account natural population dynamics and trends, there should be no decline in offspring production of grey seals of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of nine subunits of the North Sea.

The HELCOM Seal Expert Working Group has made some recommendations on specific tasks to be considered by Ad Hoc HELCOM Seal Expert Group. The initial tasks include:

- to quantify the limit reference, precautionary approach and target reference levels for population size for the described Management Units;
- to define and quantify similar levels with regard to seal distribution and health status;
- to assist in harmonising National Management Plans for the cross-boundary Baltic Sea Seal Management Units;
- to draft HELCOM Guidelines for exemptions to the General Management Principles.

HELCOM, (2009b) lists the major threats to harbour and grey seals in the Baltic Sea as:

- Contaminants / diseases;
- Entanglement in fishing nets;
- Human disturbance;
- Food limitation.

5.3.3. Trends in pressures

HELCOM, 2009b states that a great number and variety of human activities are undertaken in the coastal zone and open seas of the Baltic which could affect marine mammals. These can be summarised as:

- Fisheries: adverse effects on marine mammals include direct killing of seals as competitors to the fishery; accidental drowning of seals in fishing gear; entanglement of seals in discarded netting; decrease in food resource for seals; by-catch of harbour porpoise.
- Maritime traffic: approximately 15% of the world's commercial fleet sails in the Baltic Sea; this equates to more than one tanker per hour that passes in the intensely trafficked areas (over 10000 passages annually). Maritime transport in the Baltic is expected to increase by 64% between 2003 and 2020 (Anonymous, 2006). Adverse effects on marine mammals may arise from physical disturbance, nutrient, chemical pollution and increased noise.
- Extraction of sand and gravel: the adverse effects of these activities on marine mammals relate to noise, re-suspension of nutrients and hazardous substances, increased turbidity, siltation and habitat loss. The extraction of sand and gravel from the seafloor has increased markedly in the HELCOM area in recent years.
- Dumping of dredged materials: the adverse effects of these activities on marine mammals relate to noise, re-suspension of nutrients and hazardous substances, increased turbidity, siltation and habitat loss. It is difficult to obtain an overview of the current volume of disposal of dredged material at sea in the HELCOM area and the volume of disposed dredged material varies annually depending on large construction projects, such as port enlargements.
- Construction activities: the adverse effects of these activities on marine mammals relate to noise, resuspension of nutrients and hazardous substances, increased turbidity, siltation and habitat loss. There is a growing number of construction works and different types of installations on the Baltic coasts but also in offshore areas and on the seabed: traffic links, high voltage power cables (HVPC), oil platforms, oil and gas terminals, pipelines, wind farms, marinas and ports, and numerous coastal protection barriers.

There is a growing number and scale of such activities in the Baltic Sea generating new pressures on the marine ecosystem.

- Recreational activities: an assessment of the impact of recreational activities is not available. Potential adverse effects include: the release of nutrients, physical disturbance and extraction of resources.

HELCOM, (2009b) states that gaining a regional overview of the extent, effects and future developments of the activities listed above is an important component of Marine Spatial Planning (MSP), launched by the Baltic Sea Action Plan (BSAP) (Recommendation 28E/9). The process of Baltic regional marine spatial planning aims to improve integration of regional environmental and sectoral policies using, for example, Strategic Environmental Assessments (SEA) and a long-term development perspective. There are a number of HELCOM recommendations which address these conflicts (28E/9; 24/10; 21/4; 19/1; 17/3; 16/3 and 15/1). A full national implementation and application of these recommendations would contribute to a sustainable performance of many human activities in the Baltic Sea area.

While such observations from HELCOM are useful to provide a background on potential changes in the broader geographic area, the purpose of the zero alternative focuses on particular changes in the Fehmarnbelt area. For the change to be included in the zero alternative the following pre-conditions must be met:

1. Very likely to occur;
2. Significant enough to influence the results of the EIA;
3. Predictable and quantifiable with an adequate level of certainty.

If the previous three conditions are applied, the possible change will be included in the zero alternative. Consequently, the following issues will be included:

- Development of landscape, nature, habitats and species;
- Changes due to new regulation;
- Current spatial planning;
- Forecasts of traffic intensity and demography;
- Technological development;

5.3.4. Development of landscape, nature, habitats and species

Human activities that could exert pressures influencing nature and habitats of marine mammals in the Fehmarnbelt area until 2025 and 2030 without a built fixed link are:

- Establishment of new offshore wind farms;
- Intensive fishing with gillnets and trawls;
- Pollution of contaminants including toxic substances originating from a variety of different sources;
- Eutrophication.

All the above mentioned human activities for future changes relevant to marine mammals cannot be predicted with certainty and are not quantifiable at present. Therefore, the results from the baseline study are used.

5.3.5. Changes due to the fulfilment of new regulation

New relevant regulations are taken into consideration with respect to implications for the zero alternative:

- EU rules on energy efficiency;
- EU rules on emissions from cars;
- IMO Baltic Sea emission control area (ECA);
- Water Framework Directive;
- Marine Strategy Framework Directive.

The implications for marine mammals of the EU rules on energy efficiency, the EU rules on emissions from cars and the IMO Baltic Sea ECA, lie in any improvement in marine water quality as a result of reduced emissions. Such impacts are not quantifiable and consequently the baseline study is used as the zero alternative. Similarly any changes as a result of the Marine Strategy Framework Directive and improvements to marine water quality as a result of the Water Framework Directive are not quantifiable at the moment. Reductions in toxic substances entering the marine environment will result in improved eco-toxicological responses but these are not quantifiable and hence the baseline scenario is used as the zero alternative.

5.3.6. Current spatial planning

The zero alternative is defined as status quo in land use, unless approved plans entail a change of use, in which case the zero alternative is defined as the situation after the change has occurred. For marine mammals, in the absence of definitive plans, the baseline study is used as the zero alternative.

5.3.7. Forecast changes to baseline

For 2025 and 2030 the following changes have been forecast:

- Traffic intensity and technological development;
- Demography.

Of these, the future changes of relevance for marine mammals are changes in traffic intensity and technological development of ferry traffic and ships.

5.3.7.1. Ferries

The forecast of road traffic predicts a 60% increase by 2025 and even higher by 2030. However, it is assumed that the ferries will have the same timetable as today and that the ferries will have been enlarged corresponding to the increase in traffic. Impacts on marine mammals may result from higher noise levels of larger ferries and an increased potential of collision with marine mammals. Up to now, no quantification can be made and hence the baseline study is used as the zero alternative.

5.3.7.2. Ships

A ship traffic forecast has been developed as an input to the operational risk analysis. Based on 2006 data, the yearly number of ships passing Fehmarnbelt in 2018 has been forecast. In this period the ship traffic is predicted to increase by 25%. According to the annual growth rates the forecasts show an increase of 40% in 2025 and 52% in 2030. The main implications for marine mammals are the increased risk of damage or death through collisions, and of increased disturbance. While such impacts are of concern, they have not been quantified, and hence the baseline study is used as the zero alternative.

Existing shipping routes are predicted to remain the same and changes in shipping traffic have been defined until 2030 within a high, medium and low scenario (source Navigational Studies of Vessel Traffic Conditions in the Fehmarn Belt Traffic Forecast Part 2 – Prognosis Final). Vessel traffic in the Fehmarnbelt region is predicted to grow until 2030 (Table 5.3—1), based on a continuously positive economic and trade growth. An increase in the size of vessels is also predicted, with a higher importance of dry cargo ships (Figure 5.3-1), which will lead to an increasing significance of the Great Belt Route as this is the only entry/exit of the Baltic Sea region for large vessels. This means that traffic in the Fehmarnbelt region will also grow considerably as the majority of the Great Belt traffic will have to pass the region.

Table 5.3—1 Predicted increases in shipping

	Kiel Canal	Great Belt	T-Route	Ferry (without FL)	Ferry (with FL)	Lübeck	Øresund
2006	33,200	21,200	48,700	40,400	40,400	16,900	35,600
2030 Low Case	63,280	34,435	83,558	42,466	4,338	24,834	56,479
2030 Medium Case	68,124	37,825	89,643	44,548	4,748	27,666	60,251
2030 High Case	81,928	47,561	110,078	45,086	6,101	32,973	60,485

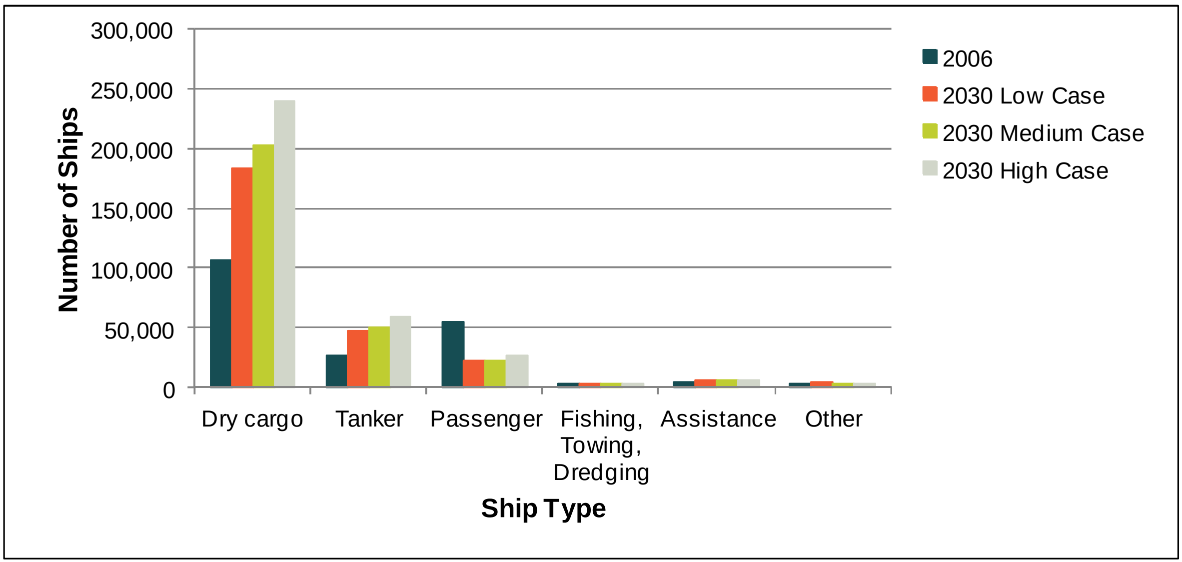

Figure 5.3-1 Predicted increases in type of vessel

Current ambient noise levels (baseline) are between 103 and 132 dB re 1ųPa (Figure 5.3-2). With the addition of the tunnel, noise levels within the ellipse marked on Figure 5.3-2 will decrease and reduce the ambient noise level in the locality of the tunnel route.

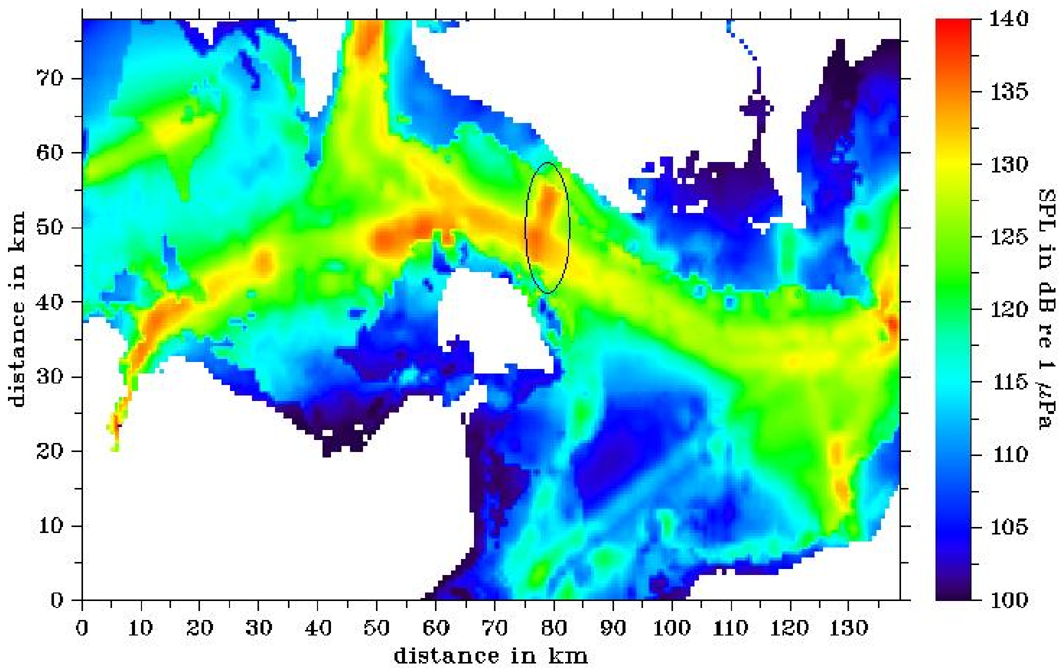

Figure 5.3-2 Baseline shipping noise with the noise caused by ferries marked in an ellipse (FEMM, 2011).

5.4. Zero alternative

The zero alternative describes the future situation, without the establishment of a fixed link, for marine mammal populations in the Fehmarnbelt area. The assessment year for the operation phase of the fixed link is related to 2025 and 2030. The zero alternative regards the human induced changes of 15 and 20 assessment years after the completion of the baseline study.

2025 is the chosen target year for the assessment. The construction phase will be completed and impacts going back to the operation of the fixed link will be apparent. German authorities have asked for the target year to be 2030. German standards have a 10 year time span from the opening to the assessment year and imply occurring impacts during the time after the completion of the construction and the operation phase.

5.4.1. Projection of status of harbour porpoise in 2025 and 2030 in response to trends in pressure

The analysis of the available literature identified a variety of anthropogenic pressures, such as fisheries, shipping and tourism, acting on harbour porpoises in the Baltic Sea and the Fehmarnbelt. It can be assumed that harbour porpoises in the Baltic Sea are affected by human activities and the overall Baltic population is probably well below carrying capacity. Harbour porpoises are exposed to underwater noise levels that are likely to affect their behaviour in the Fehmarnbelt area, but specific effects at population level are still unknown.

An analysis of the pressures and trends in pressures on marine mammals, (see section 5.3) provides insufficient quantitative information for changes in pressure to be used in the zero alternative scenario. Hence the baseline study is used for the zero alternative assessment for both target years 2025 and 2030. Currently, it remains difficult to assess an overall status of the harbour porpoise population and future trends (OSPAR, 2010).

For the zero alternative assessment the Fehmarnbelt area is identified as medium importance, i.e. with specific value for the Fehmarnbelt region and of importance for local ecosystem function. However, the uneven distribution of porpoises in the Fehmarnbelt further leads to the conclusion that certain sub-areas are assessed to be of higher importance (see Figures 4.2-1 and 4.2-2 in section 4.2 of the baseline report). Furthermore, the function of the feeding area and migration corridor has also been identified as medium importance. This evaluation is based on the current understanding that no discrete population in the eastern part of the Baltic Sea is dependent on migration through the Fehmarnbelt.

5.4.2. Projection of status of harbour seal and grey seal in 2025 and 2030 in response to trends in pressures

Current knowledge leads to the conclusion that several anthropogenic pressures, for instance fisheries, pollution and underwater noise emissions, influence the harbour seal and grey seal population in the Fehmarnbelt area. Seal abundance in the Baltic Sea is still influenced by human activities and probably below carrying capacity. Historic data on seal hunting indicates that seal numbers in the area were considerably higher in former times, and it remains to be predicted at which state the current increase might level off.

Since there is insufficient quantitative information on the changes in pressure on harbour seals and grey seals between the baseline study and the two assessment years of 2025 and 2030, the baseline study is used for the zero alternative assessment.

The importance of the Rødsand lagoon and adjacent feeding areas for harbour seals is evaluated as very high, i.e. of international importance, because a high proportion of Baltic seals occur in this area. Furthermore, the breeding and pupping ground at Rødsand is of importance for the whole Baltic population of harbour seals.

The importance of the Rødsand area for grey seals is evaluated as high, as a substantial number of grey seals regularly use Rødsand as breeding and pupping ground.

5.5. Summary of changes in pressures on marine mammals between the baseline study and 2025 and 2030

Some forecast changes in pressures, such as changes to environmental regulations, are likely to result in improved ecological conditions and hence positive changes for marine mammals. Others, such as increased shipping traffic, are likely to be detrimental as a result of increased disturbance with an increased potential of collisions resulting in injury or death. However, none of the future pressure changes assessed could be sufficiently quantified. No differences between 2025 and 2030 are elaborated. Hence, the status of marine mammals as determined by the baseline study is considered to be the most appropriate for the zero alternative assessment.

6. ASSESSMENT OF IMPACT – IMMERSED TUNNEL

6.1. Project description

The alignment for the immersed tunnel passes east of Puttgarden, crosses the Fehmarnbelt in a soft curve and reaches Lolland east of Rødbyhavn as shown in Figure 6.1-1 along with nearby NATURA2000 sites.

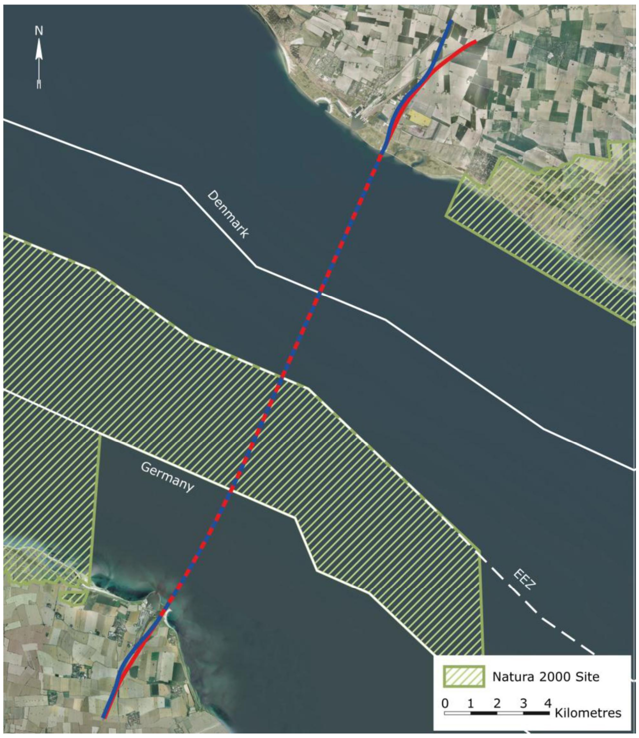

Figure 6.1-1 Conceptual design of tunnel alignment

6.1.1. Tunnel trench

The immersed tunnel is constructed by placing tunnel elements in a trench dredged in the seabed. The proposed methodology for trench dredging comprises mechanical dredging using Backhoe Dredgers (BHD) up to 25 metres and Grab Dredgers (GD) in deeper waters. A Trailing Suction Hopper Dredger (TSHD) will be used to rip the clay before dredging with GD. The material will be loaded into barges and transported to the near-shore reclamation areas where the soil will be unloaded from the barges by small BHDs. A volume of approximately 14.5 million m^3 sediment will be handled.

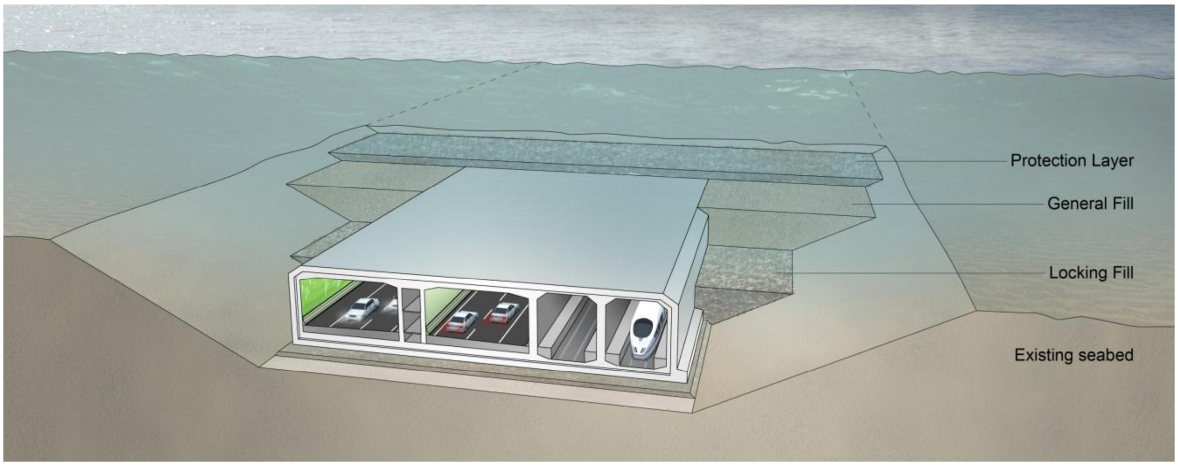

Figure 6.1-2 Cross section of dredged trench with tunnel element and backfilling

A bedding layer of gravel forms the foundation for the elements (Figure 6.1-2). The element is initially kept in place by placing locking fill followed by general fill, while on top there is a stone layer protecting against damage from grounded ships or dragging anchors. The protection layer and the top of the structure are below the existing seabed level except near the shore. At these locations, the seabed is locally raised to incorporate the protection layer over a distance of approximately 250 m from the proposed coastline. Here the protection layer is thinner and made from concrete and a rock layer.

6.1.2. Tunnel elements

There are two types of tunnel elements: standard elements and special elements (Figure 6.1-3). There are 79 standard elements. Each standard element is approximately 217 m long, 42 m wide and 9 m tall. Special elements are located approximately every 1.8 km providing additional space for technical installations and maintenance access. There are 10 special elements. Each special element is approximately 46 m, 45 m wide and 13 m tall.

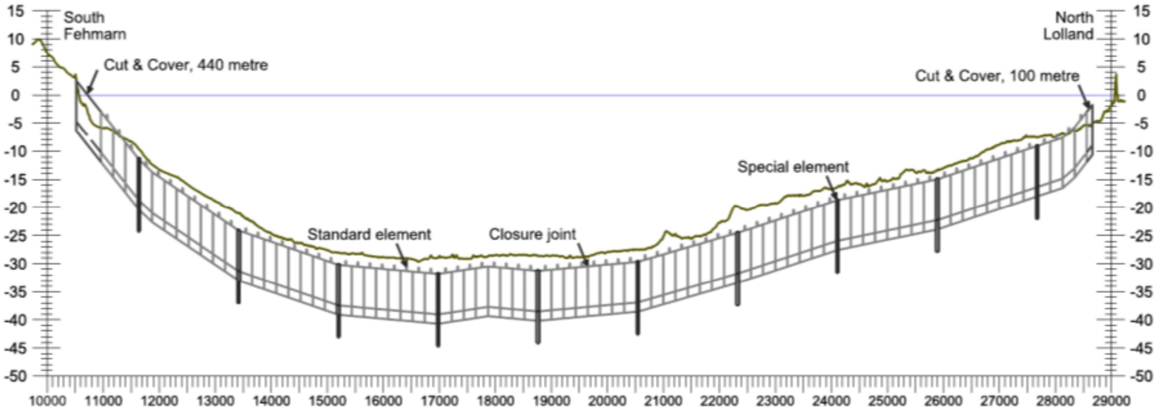

Figure 6.1-3 Vertical tunnel alignment showing depth below sea level

The cut and cover tunnel section beyond the light screens is approximately 440 m long on Lolland and 100 m long on Fehmarn. The foundation, walls and roof are constructed from cast in-situ reinforced concrete.

6.1.3. Tunnel drainage

The tunnel drainage system will remove rainwater and water used for cleaning the tunnel. Rainwater entering the tunnel will be limited by drainage systems on the approach ramps. Fire fighting water can be collected and contained by the system for subsequent handling. A series of pumping stations and sump tanks will transport the water from the tunnel to the portals, where it will be treated as required by environmental regulations before being discharged into the Fehmarnbelt.

6.1.4. Reclamation areas

Reclamation areas are planned along both the German and Danish coastlines to accommodate the dredged material from the excavation of the tunnel trench. The size of the reclamation area on the German coastline has been minimized. Two larger reclamations are planned on the Danish coastline. Before the reclamation takes place, containment dikes are to be constructed some 600 m out from the coastline.

The landfall of the immersed tunnel passes through the shoreline reclamation areas on both the Danish and German sides.

6.1.4.1. Fehmarn

The proposed reclamation at the Fehmarn coast does not extend towards north beyond the existing ferry harbour at Puttgarden. The extent of the Fehmarn reclamation is shown in Figure 6.1-4. The reclamation area is designed as an extension of the existing terrain with the natural hill turning into a plateau behind a coastal protection dike 3.5 m high. The shape of the dike is designed to accommodate a new beach close to the settlement of Marienleuchte.

Figure 6.1-4 Reclamation area at Fehmarn

The reclaimed land behind the dike will be landscaped to create an enclosed pasture and grassland habitat. New public paths will be provided through this area leading to a vantage point at the top of the hill, offering views towards the coastline and the sea.

The Fehmarn tunnel portal is located behind the existing coastline. The portal building on Fehmarn houses a limited number of facilities associated with essential equipment for operation and maintenance of the tunnel and is situated below ground level west of the tunnel.

A new dual carriageway is to be constructed on Fehmarn for approximately 3.5 km south of the tunnel portal. This new highway rises out of the tunnel and passes onto an embankment next to the existing harbour railway. A new electrified twin-track railway is to be constructed on Fehmarn for approximately 3.5 km south of the tunnel portal. A lay-by is provided on both sides of the proposed highway for use by German customs officials.

6.1.4.2. Lolland

There are two reclamation areas on Lolland, located either side of the existing harbour. The reclamation areas extend approximately 3.7 km east and 3.4 km west of the harbour and project approximately 500 m beyond the existing coastline into the Fehmarnbelt. The proposed reclamation areas at the Lolland coast do not extend beyond the existing ferry harbour at Rødbyhavn.

The sea dike along the existing coastline will be retained or reconstructed, if temporarily removed. A new dike to a level of +3 m protects the reclamation areas against the sea. To the eastern end of the reclamation, this dike rises as a till cliff to a level of +7 m. Two new beaches will be established within the reclamations. There will also be a lagoon with two openings towards Fehmarnbelt, and revetments at the openings. In its final form, the reclamation area will appear as three types of landscapes: recreation area, wetland, and grassland, each with different natural features and use.

The Lolland tunnel portal is located within the reclamation area and contained within protective dikes. The main control centre for the operation and maintenance of the Fehmarnbelt Fixed Link tunnel is housed in a building located over the Danish portal. The areas at the top of the perimeter wall, and above the portal building itself, are covered with large stones as part of the landscape design. A path is provided on the sea-side of the proposed dike to serve as recreation access within the reclamation area.

A new dual carriageway is to be constructed on Lolland to a distance approximately 4.5 km north of the tunnel portal. A new electrified twin-track railway is to be constructed on Lolland to a distance approximately 4.5 km north of the tunnel portal. A lay-by is provided in each direction off the landside highway on the approach to the tunnel for use by Danish customs officials.

A facility for motorway toll collection will be provided on the Danish landside.

Figure 6.1-5 Photomontage of the completed tunnel infrastructure and adjacent reclamation areas at Lolland

6.1.5. Marine construction works

The temporary construction works comprise of two temporary work harbours, the dredging of the portal area and the construction of the containment dikes. For the harbour on Lolland an access channel is also provided. These harbours will be integrated into the planned reclamation areas and upon completion of the tunnel construction works, they will be dismantled/removed and backfilled.

6.1.6. Production site

The current design envisages the tunnel element production site to be located in the Lolland east area in Denmark. Figure 6.1-6 shows one production facility consisting of two production lines. For the construction of the standard tunnel elements for the Fehmarn tunnel, four facilities with, in total, eight production lines, are anticipated.

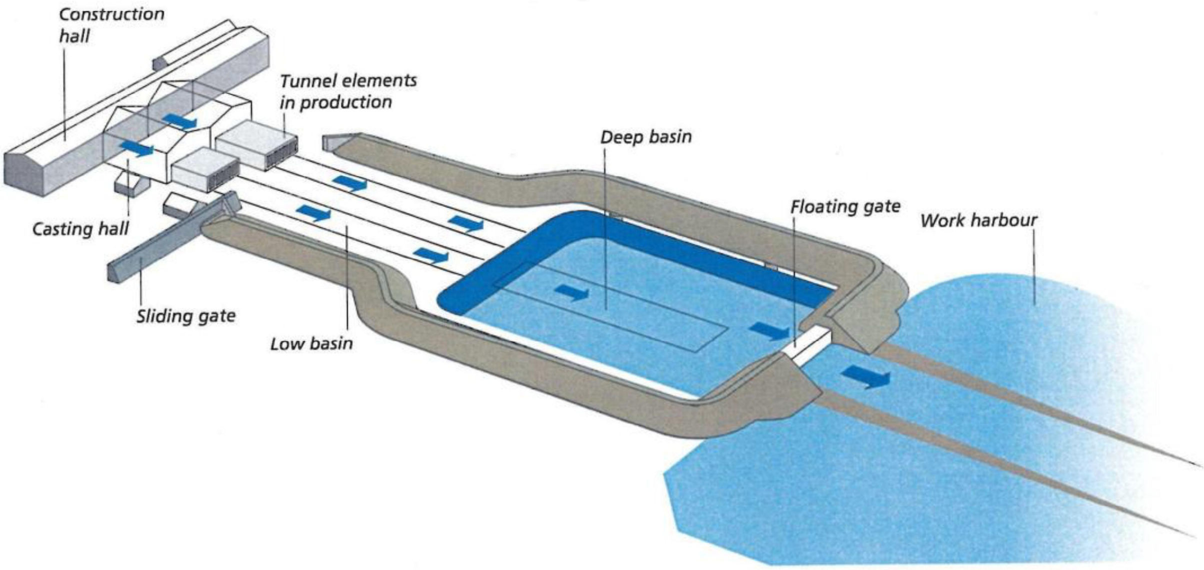

Figure 6.1-6 Production facility with two production lines

In the construction hall, which is located behind the casting and curing hall, the reinforcement is handled and put together to form a complete reinforcement cage for one tunnel segment. The casting of the concrete for the segments takes place at a fixed location in the casting and curing hall. After the concrete of the segments is cast and hardened enough the formwork is taken down and the segment is pushed forward to make space for the next segment to be cast. This process continues until one complete tunnel element is cast. After that, the tunnel element is pushed into the launching basin. The launching basin consists of an upper basin, which is located at ground level and a deep basin where the tunnel elements can float. In the upper basin the marine outfitting for the subsequent towing and immersion of the element takes place. When the element is outfitted, the sliding gate and floating gate are closed and sea water is pumped into the launching basin until the elements are floating. Once the elements are floating they are transferred from the low basin to the deep basin. Finally the water level is lowered to normal sea level, the floating gate opened and the element towed to sea. The proposed lay-out of the production site is shown in Figure 6.1-7.

Dredging of approx. 4 million m^3 of soil is required to create sufficient depth for temporary harbours, access channels and production site basins.

Figure 6.1-7 Proposed lay-out of the production site

6.2. Construction

6.2.1. Description of associated construction activities

The main activities of the construction of the immersed tunnel that have the potential to affect marine mammals and their habitats are:

- dredging of tunnel trench
- dredging at tunnel land-fall for portal and ramp area
- temporary harbours (construction & dredging)
- use of dredged material in coastal reclamation and coastal lagoon (Rødby) placement of tunnel sections, surface preparations and backfill
- permanent harbour (construction and operation)
- shipping

The dredging and reclamation methodology is summarised as (more detailed descriptions can be found in the Femern A/S Consolidated Technical Report Draft 3.3):

- tunnel – dredging of the trench where the immersed tunnel can be placed
- tunnel – dredging for the portals & ramps, reducing the need for land-based excavation prior to commencing the structural works
- harbour – dredging to create sufficient depth for temporary harbours & access channels (to be completed in advance of the start of the trench dredging for the immersed tunnel).

Figure 6.2-1 shows the profile of the immersed tunnel relative to the underlying geological formations. The majority of mechanical trench dredging will be undertaken using Backhoe Dredgers (BHD) and Grab Dredgers (GD). BHDs will dredge all of the material in water depths of 0 m to 25 m Mean Sea Level (MSL), while GDs will dredge the majority of all soils in waters deeper than 25 m MSL. Some of the deeper soils will be pre-treated by ripping the hardest soil with a Trailing Suction Hopper Dredger (TSHD) and can then be dredged mechanically with the GDs. The BHDs and GDs will load soil into hopper barges which will transport the soils to the shoreline reclamation areas located in both Germany and Denmark.

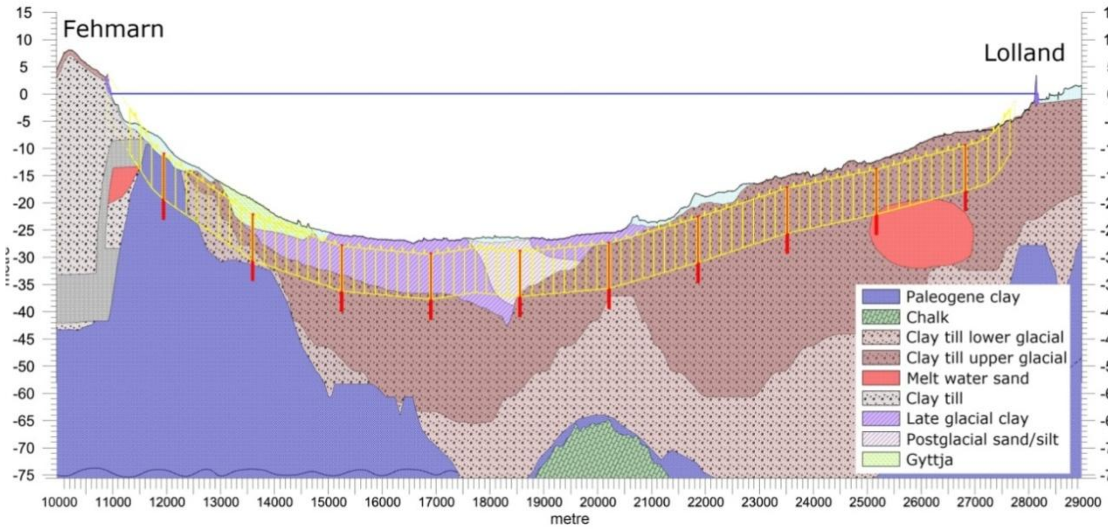

Figure 6.2-1 Geological and vertical profiles of the tunnel

Figure 6.2-2 (Fehmarn) and Figure 6.2-3 (Lolland) show the areas to be reclaimed using materials excavated from the tunnel trench, temporary harbour and portal and ramp areas.

Figure 6.2-2 Extent of proposed reclamation on Fehmarn (dashed white line)

Figure 6.2-3 Extent of proposed reclamation on Lolland (dashed white line)

Table 6.2—1 details the volumes of materials to be used in the coastal reclamations and the locations where such materials are to be deposited and profiled. As previously described 95% of this material will be sourced from the tunnel trench described in Figure 6.1-3 and Figure 6.2-1.

Table 6.2—1 Volumes of excavated material to be used in coastal reclamations [sourced from RAT-542-082-0B CD Description Dredging Reclamation and Soil Logistics 01-06-2011 contained in folder 4-1-4 Offshore Construction Activities]

Item	Quantity (In-situ m^3)
Re-use, dike construction	1,158,000
Re-use, fill portals and ramps	800,000
Re-use, stockpile future works	750,000
Re-use reclaimed land	1,042,000
Total	**18,750,000**

Temporary harbours will be integrated into these coastal reclamations to service tunnel construction operations from both the German and Danish extremities of the immersed tunnel. At Puttgarden, Germany the Fehmarn harbour is located within the reclamation area, directly between the existing harbour and the tunnel portal (Figure 6.2-4). This location removes the need for dredging to provide an access channel to the work harbour.

Figure 6.2-4 Fehmarn temporary harbour

Figure 6.2-5 Rødby temporary harbour

At Rødbyhavn, Denmark, the Lolland harbour is located within the reclamation area between the eastern breakwater of Rødbyhavn and the land-fall section of the immersed tunnel (Figure 6.2-5)

The Femern A/S Consolidated Technical Report Draft 3.3 states that:

- the harbours with work yards are established in the initial phase of the project and are used as working harbours for the subsequent offshore works and for the land works as well
- the harbours and work yards are considered temporary (4 years). After completion of the tunnel construction works they will be dismantled/removed and backfilled (i.e. quay walls, breakwaters, buildings and pavements).
- the bulk of the materials will be supplied from the sea.

Both the Fehmarn & Lolland temporary harbours will require:

- a navigable access channel (dredging activity)
- harbour basin with manoeuvring space for vessels (dredging activity)
- quay wall to load vessels (construction works)
- service jetty for handling of personnel (construction works)
- hard covered area for storage fronting onto the quay wall (construction works)

The Femern A/S Consolidated Technical Report Draft 3.3 details the quantities of material (shown in Table 6.2—2) to be dredged for all components of the immersed tunnel construction shown in Figure 6.1-1, Figure 6.1-2] and Figure 6.1-3. It can be seen from Table 6.2—2 that 95% of the material will come from the tunnel trench described in Figure 6.1-3. Table 6.2—3 shows the timetable of marine construction works.

Table 6.2—2 Volumes of material to be dredged during construction of the immersed tunnel [RAT-542-082-0B CD Description Dredging Reclamation and Soil Logistics 01-06-2011 contained in folder 4-1-4 Offshore Construction Activities contained in folder 4-1-4 Offshore

No.	Dredging Area	Quantity (m^3)
1	Trench	14,495,000
2	Lolland Temporary Work Harbour	4,010,000
3	Fehmarn Temporary Work Harbour	0
4	Lolland Portal and Ramp area	120,000
5	Fehmarn Portal and Ramp area	125,000
	Total	**18,750,000**

Table 6.2—3 Timetable of works for the dredging activities

Section	Dredger	Q4 2014	Q1 2015	Q2 2015	Q3 2015	Q4 2015	Q2 2016	Q3 2016	Q4 2016	Q1 2017
Tunnel Dredging		■	■	■	■	■	■	■	■	■
Section G1 (TE 1-10)	BH x2	■	■							
Section G1 (TE 1-10)	GD x 5						■			
Section G1 (TE 1-10)	TSHD x 1						■			
Section G2 (TE 11-20)	BH x2		■							
Section G2 (TE 11-20)	GD x 5	■	■				■			
Section G2 (TE 11-20)	TSHD x 1						■			
Section G3 (TE 21-30)	GD x 5		■	■			■			
Section G3 (TE 21-30)	TSHD x 1						■			
Section G4 (TE 31-41)	GD x 5			■	■	■				
Section G4 (TE 31-41)	TSHD					■				
Section D4 (TE 42-50)	GD x 5					■	■			
Section D4 (TE 42-50)	TSHD x 1					■	■			
Section D3 (TE 51-S8)	BH x2				■					
Section D3 (TE 51-S8)	GD x 5					■	■			
Section D3 (TE 51-S8)	TSHD x 1					■	■			
Section D2 (TE 60-69)	BH x2			■	■					
Section D2 (TE 60-69)	GD x 5					■	■			
Section D2 (TE 60-69)	TSHD x 1						■			
Section D1 (TE 70-79)	BH x2		■	■						
Containment dikes (DC)	BH	■	■							
Containment dikes (DC)	GD	■	■							
Lolland - East - Section 1 (1,250m)	BH	■								
	GD	■								
Lolland - East - Section 2 (2,350m)	BH		■							
	GD		■							
Lolland -West (1700m)	BH		■							
	GD		■							
Fehmarn - East (650m)	BH	■								
	GD	■								
Portal&Ramps (P&R) - Lolland	BH	■	■							
Portal&Ramps (P&R) - Fehmarn	BH	■								
Portal&Ramps (P&R) - Fehmarn	GD	■								
Working Harbour (WH) - Lolland	BH	■	■	■						
	GD	■								
Working Harbour (WH) - Fehmarn	BH	■								
	GD	■								
Reclamation/disposal	BH	■	■	■	■	■	■			

Section	Dredger	Q4 2014	Q1 2015	Q2 2015	Q3 2015	Q4 2015	Q2 2016	Q3 2016	Q4 2016	Q1 2017
Lolland	BH									
Fehmarn	BH									
Trench Backfilling	GD									
Restoring seabed Natura 2000	GD									
Landscaping reclamation area	TSHD									
Production facility sheet piling										

The total construction time for the offshore construction activities is approximately 200 weeks (4 years):

- 72 weeks for trench dredging (start week 1)
- 121 weeks for immersing the tunnel elements (start week 66)
- 14 weeks for making the closure joint (start week 187)

The tunnel trench dredging will take place in eight sections, over 72 weeks and seven stages (Figure 6.2-6). Three different types of dredger will be used; one Trailing Suction Hopper Dredger (TSHD) with a capacity of 13,200 m^3, five Grab Dredgers (GD), with grabs of 10 m^3 and two Backhoe Dredgers (BD), with buckets of 15 m^3 and 25 m^3 and each section of the tunnel (G1 – G4 and D1 – D4) may use all or a combination of each dredger type. The backfilling work will occur after the dredging and will also take place in stages, over 120 weeks and in 12 sections (1S – 6S and 1N – 6N). The schedule for the tunnel immersion and backfilling is shown in Figure 6.2-7.

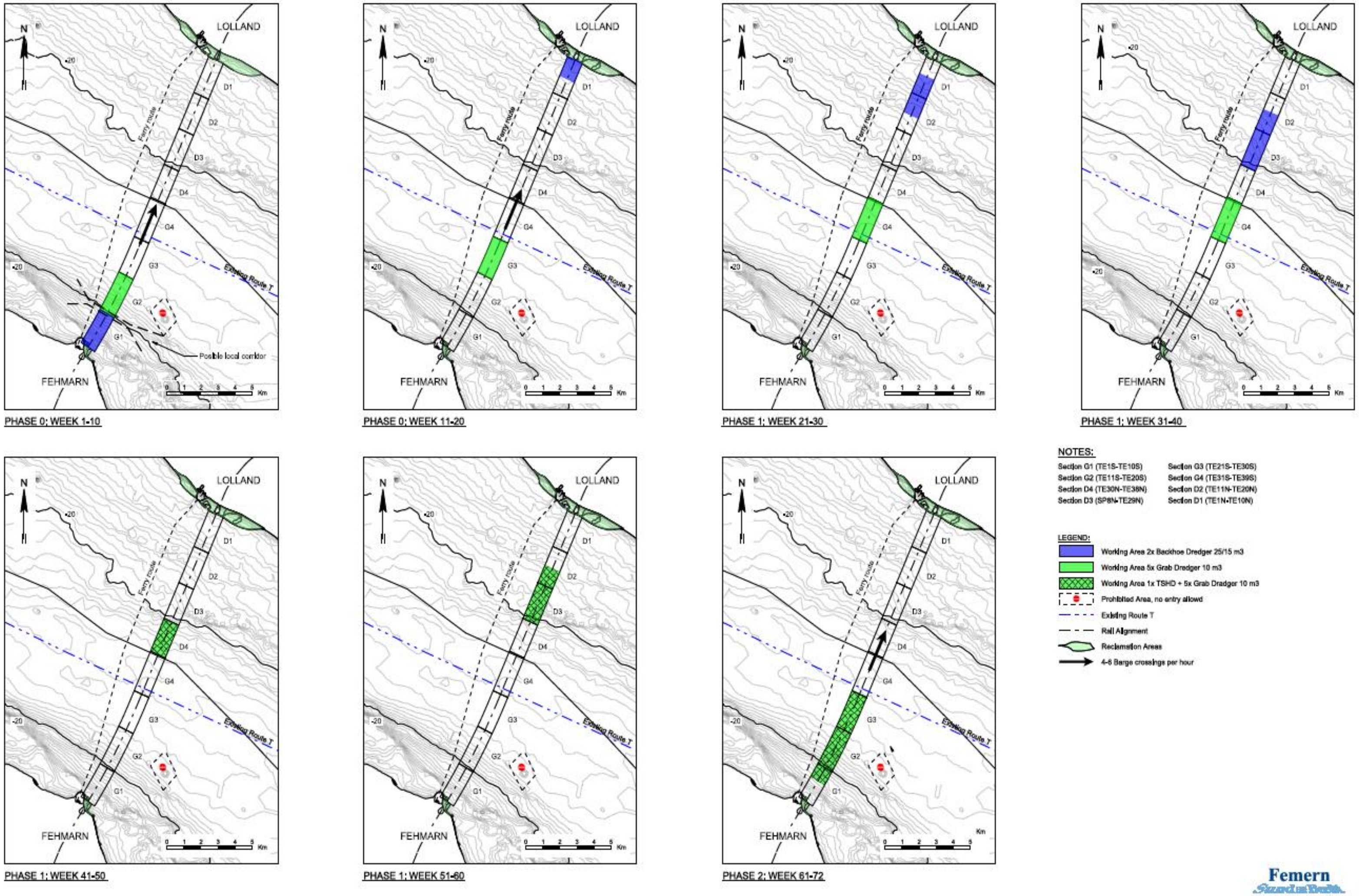

Figure 6.2-6 Seven stages of tunnel dredging works

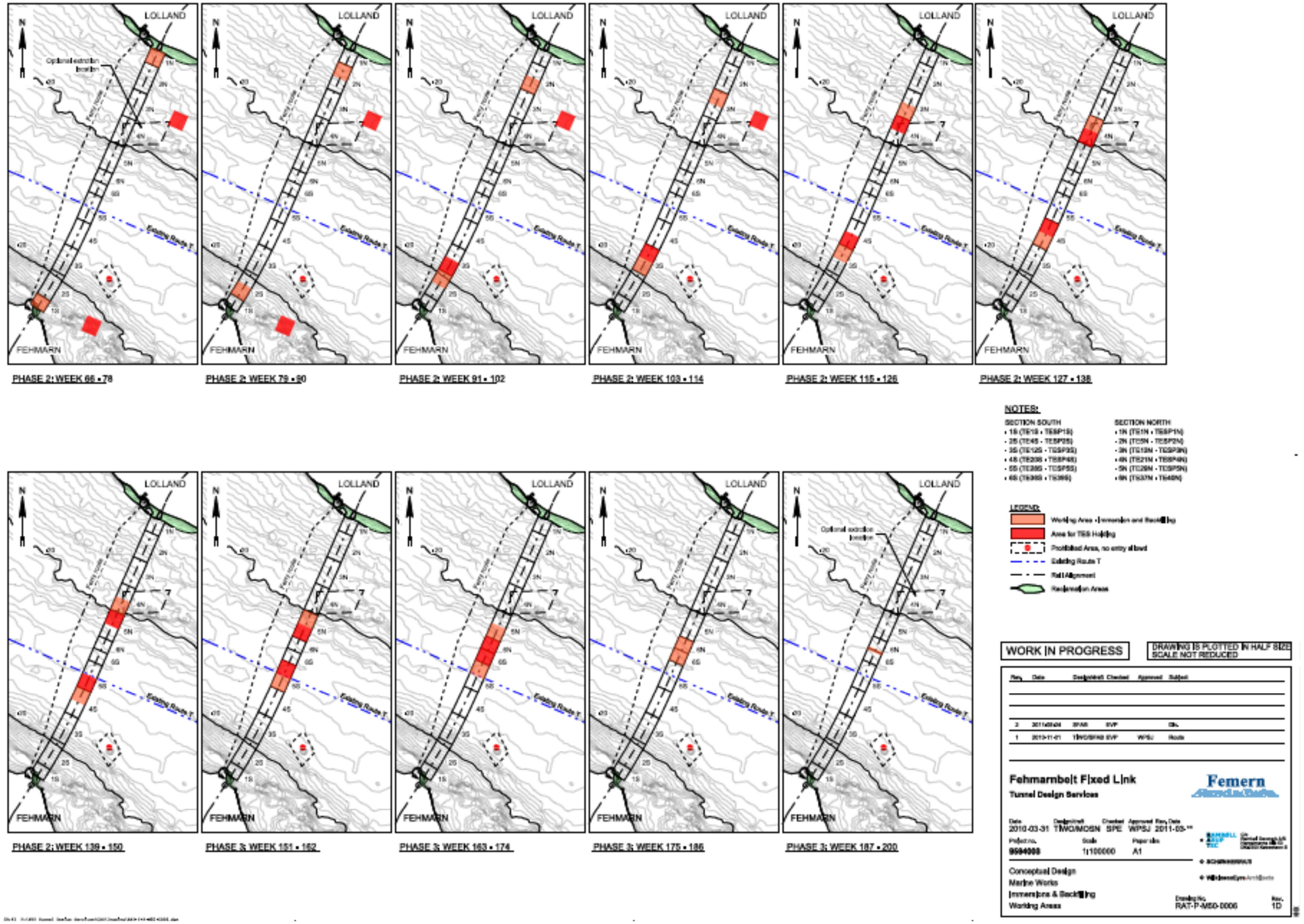

Figure 6.2-7 Eleven stages of immersing the tunnel and backfilling

Reclamation works will be carried out by a BD at both ends of the tunnel at Lolland and Fehmarn (Figure 6.2-2 and Figure 6.2-3). A small amount of sheet piling work will also take place at both temporary ports at Lolland (750 m of a quay wall, these are the red lines marked on Figure 6.2-8) and Fehmarn (200 m of a quay wall, these are the red lines marked on Figure 6.2-9). Construction vessels (e.g. dredgers, tugs and barges), will be constant during the works (as a worst case, from October 2014 until 2020) and could occur at any point within the footprint of the construction works. A large number of vessels are needed, but the exact numbers are not known as this depends on the contractor.

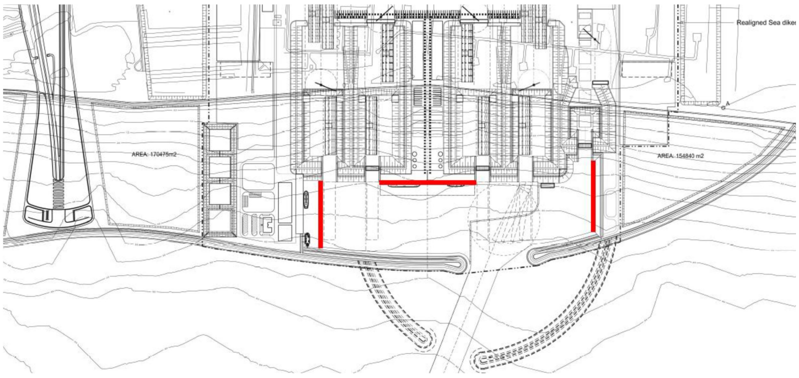

Figure 6.2-8 Piling works at Lolland

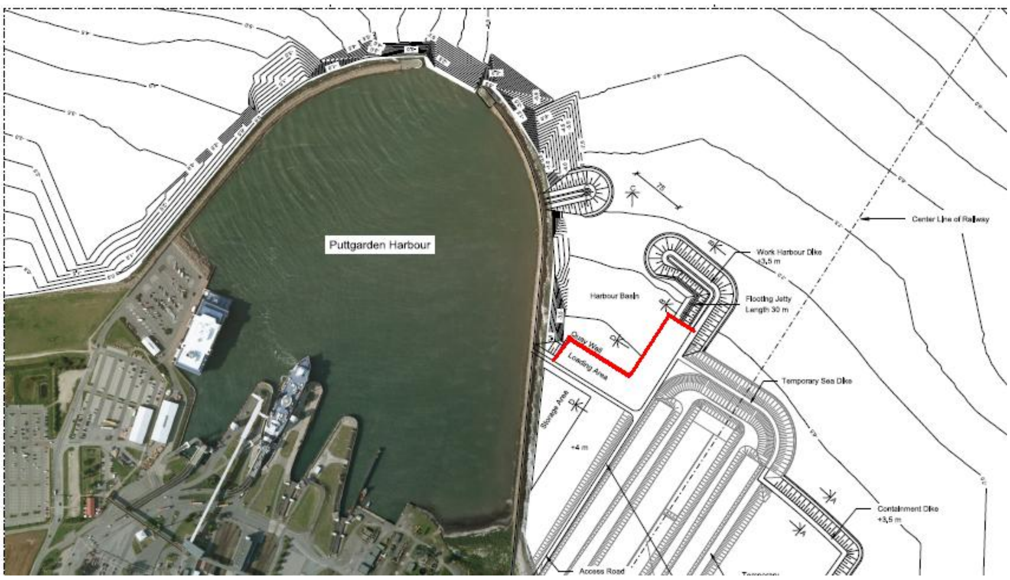

Figure 6.2-9 Piling works at Fehmarn

6.2.2. Description of pressures related to tunnel construction

The environmental pressures for marine mammals associated with the construction activities are summarised in Table 6.2—4

Table 6.2—4 Immersed tunnel construction activities and associated environmental pressures for marine mammals

Construction Activity	Pressure on Marine Mammals
Dredging & backfill of tunnel trench	Noise
	Habitat Loss and Change – physical loss; suspended sediment / sedimentation
	Barrier from dredging vessels
	Contaminants
Placement of tunnel sections	Habitat Loss and Change – physical loss/change; suspended sediment/sedimentation; hydrodynamics
	Barrier from construction vessels
Coastal land reclamation	Habitat Loss and Change – physical loss
	Barrier from construction vessels
Temporary harbour construction at Lolland and Fehmarn	Noise
	Habitat Loss and Change – physical loss; suspended sediment/sedimentation
	Barrier from construction vessels

6.2.2.1. Noise

As described in section 6.1.1 the dredging of the tunnel trench will utilise three different types of dredger (TSHD, GD & BH), in seven stages over a 72 week period. The backfilling work is in twelve sections over a 120 week period. For the purposes of this assessment, the noise from the dredging and backfilling has been modelled as the same pressure. Also, as stated in section 3.7.1, TSHD were used in all the modelling scenarios.

While it is expected that vibro piling will be carried out at Lolland, the worst case of percussive (impact) pile driving was assumed for the piling works, with a SL of 202 dB re 1µPa for a 1 m diameter pile (See section 3.7.1).

Vibration piling was not modelled, however, noise levels are approximately 12 dB lower than for impact pile driving (reducing the intensity (Wm^{-2}) of the noise by over an order of magnitude). The SL of the reclamation works were modelled at 180 dB re 1µPa, as these levels were previously measured during a port construction in Cuxhaven.

6.2.2.2. Habitat Loss

Habitat loss can occur due to changes to seabed habitats affecting benthos and fish on which marine mammals feed; changes to intertidal and terrestrial habitats (seals), e.g. land reclamation; and changes in the water column space that marine mammals occupy, e.g. changes in hydrography or suspended sediment. We distinguish that habitat change may directly impact marine mammals, i.e. through physical loss of habitat, suspended sediment (interference with feeding etc.).

The construction of two temporary work harbours (one on the German side at Puttgarden and one on the Danish side at Rødbyhavn, Figure 6.2-4 and Figure 6.2-5 (in section 6.2.1) will involve the dredging of the portal area and the construction of the containment dikes. The work harbours will be integrated into the planned reclamation areas and upon completion of the tunnel construction works they will be dismantled/removed and backfilled. The construction works and dredging of the harbours will cause a temporary modification of seabed habitat. The works to incorporate the harbour areas into the reclamation areas will result in a permanent loss of inshore habitat.

Dredged material from the trench will be used within reclamation areas along both the German and Danish coastlines and the material will be contained within containment dikes constructed with bunds of clay-till. The total area of loss is 5.84 km^2, among which dredged areas and land reclamations hold the largest areas (Table 6.2—13). Before the reclamation takes place, containment dikes are to be constructed with bunds of clay-till.

At near-shore areas adjacent to Fehmarn and Lolland, the seabed will be locally raised to incorporate the protection area over the tunnel from a distance of approximately 250 m out from the proposed coastline, this will be a permanent loss of shallow (<10 m) bathymetry and inshore seabed habitat. Figure 6.2-10 shows the footprint of the immersed tunnel construction operations.

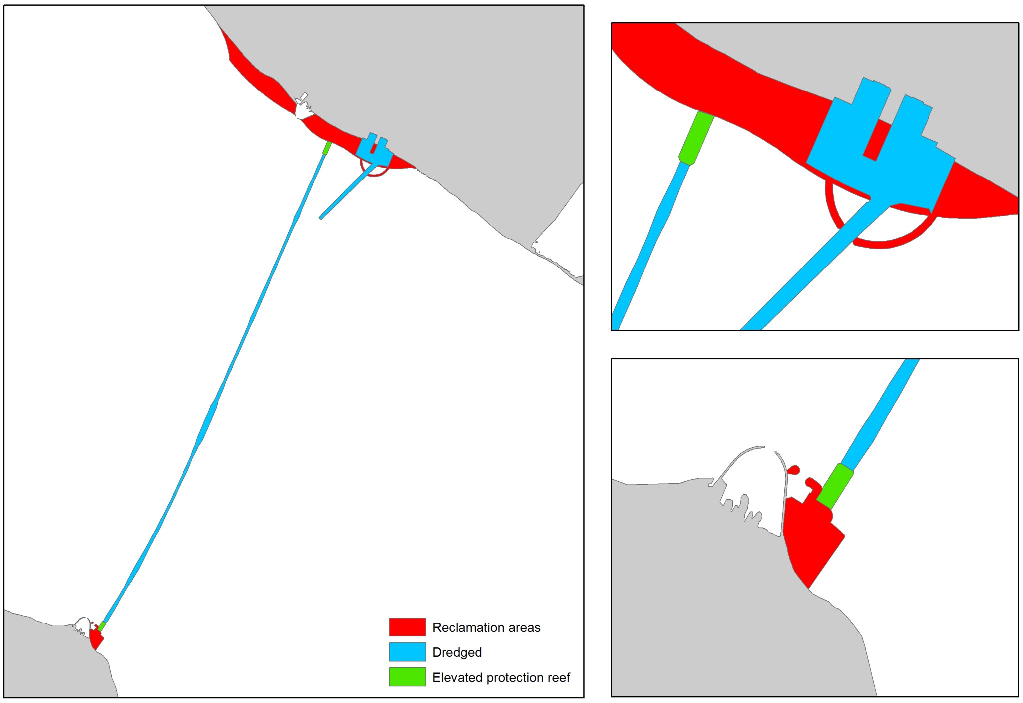

Figure 6.2-10 Footprint of the immersed tunnel during the construction period

Vessel presence and the dredging operation could potentially disturb marine mammals due to the physical presence of the vessel and/or the noise emitted by it (from the engine, propeller, onboard machinery etc.). Harbour porpoises are known to elicit a short-term response to vessels and will often swim away (Palka & Hammond, 2001). The assessment of potential disturbance due to noise is specifically dealt with in section 6.2.3. Disturbance occurring in the water column habitat during construction that may affect staging (occurrence), feeding or calving functions are considered as a loss of habitat.

6.2.2.3. Habitat Change - Suspended Sediment and Sedimentation

Habitat change may directly impact marine mammals, i.e. through physical loss of habitat, suspended sediment (interference with feeding etc.). Indirectly, habitat change can affect the benthos and fish on which marine mammals feed, i.e. physical loss/change, change in habitat structure, siltation rate changes, hydrography and suspended sediment.

The dredging operations involve three different types of dredger vessels; one Trailing Suction Hopper Dredger, five grab dredgers and two backhoe dredgers. Barges, tugs, rock carriers, anchor handling vessels and immersion/multi-purpose pontoons will be required to redistribute material, place the tunnel sections, protection material and backfill (see section 6.2.2.1). Backfilling on top of the placed tunnel elements, the amount of clay-till will vary along the trench. Additional material is required to complete the backfilling and sand from Kriegers Flak will be placed following the backfilling with clay-till. The dredging works will cause a temporary change in seabed habitat and associated benthic and fish habitats on which marine mammals feed.

During the tunnel construction sediment spill material will be suspended and re-deposited due to a number of construction processes. Dredging and reclamation will be undertaken by Backhoe and Grab Dredgers. Trailing Suction Hopper Dredgers may be required to rip up the hardest soils. During the dredging process sediment is released into the water column via the physical disturbance of seabed sediments by the drag head and excavator, as well as from the grab/bucket and dredger overflow whilst the vessel is loading. Sediment released into the water column through disturbance and overspill is dispersed by waves, tides and gravitational settling. The sediment spill scenario including the production facility at Rødbyhavn will involve sediment spill across the tunnel trench area between 11/2014 – 10/2018 (47 months) with additional coastal sediment spill during reclamation and restoration until 03/2019; in total sediment spill may occur for 52 months.

3.5% of the sediments dredged for the tunnel (540,000 m^3) are expected to be spilled (it has also been estimated that the total spill of sediment from the sum of all dredging activities is 750,000 m^3) (FEHY, 2013d). Modelling reported in FEHY (2013d) concludes that inflow of sediment into Rødsand Lagoon decreases during the last quarter of 2015 once the dredging has reached a distance of 2 km to 3 km offshore. Whilst the effects of dredging on the coasts is closely temporally correlated with the dredging activities, the models showed resuspension of sediments up to 9 months after dredging has stopped.

The sediment composition varies across the trench area, and predominantly consists of clay-till and late glacial till, with a proportion of later glacial sand/silt, sand types (post glacial, glacial melt water) and organic rich mud (gyttia). The transport of material before settlement will vary depending on the type of material, and the location of deposition within the local and regional area. Before final settlement, material will be temporarily deposited and transported across the local area due to natural resuspension and transport. Sediment resuspension can occur for a long time after dredging, and model simulations observed effects up to nine months after dredging stopped.

Suspended sediment can have a direct effect on marine mammals by hindering their visual capacity. Indirectly, suspended sediment and sedimentation can impact marine mammal benthic and pelagic prey. The tunnel alternative will have temporal and permanent changes to the marine habitats of the area, which will affect all individual and combined ecosystem components (e.g. benthic, fish and mammals). Prior to the installation of the tunnel it is foreseeable that the sea floor area will be dredged to allow the tunnel structure to be placed on the seabed. This scenario can be closely matched to the effects observed when conducting aggregate dredging on the seabed, which produces localised effects, mainly substratum removal, re-deposition of material and consequent alteration of the bottom topography (Newell et al., 1998; Desprez, 2000).

In Rødbyhavn and Puttgarden, which are the designated construction ports, there will be a localised disturbance on the adjacent habitats in the proximity of these areas. For the fish communities, the shallow water areas of the Fehmarnbelt are considered to be essential spawning and nursery sites for some economic (e.g. flatfish) and ecological (shallow water species) fish species. The area also hosts vegetated habitats along the coast of Fehmarn and Lolland, which perform important ecological services (e.g. spawning grounds, feeding and nursery areas) for some fish species. There are also sandy areas which sustain feeding and nursery grounds for flatfish species (FEBEC, 2013). There will be some localised disturbances on fish communities which could potentially affect the food sources for marine mammals in the areas.

6.2.2.4. Contaminants

The construction of the tunnel will require the dredging of approximately 18,750,000 m^3 of sediment, which will potentially release contaminants into the environment. Sensitivity to the contaminants pressure is described in Chapter 4.

6.2.2.5. Barrier

A barrier effect during construction of the immersed tunnel can only potentially be caused by noise emitted from dredging vessels as these vessels emit high sound pressure levels into the water and move at low speed, so that noise emission is more continuous than that from vessels moving at normal cruise speed. During the construction period dredgers will especially be used when material is removed from the seabed. These dredging works will take place in eight sections, over 72 weeks and seven stages with 8 dredgers altogether. The impact is described in detail in section 6.2.3 (Noise).

6.2.3. Construction Noise Impact Assessment

6.2.3.1. Degree of Impact

The criteria established in FEMM for noise (PTS, TTS and disturbance) implicitly relate magnitude of pressure (level of noise) to sensitivity (potential impact on marine mammals) (see

Table 3.5—3). As such we can establish the degree of impairment. The criteria for 'very high' and 'high' magnitudes of pressure are based on the exposure criteria for PTS and TTS published by a team of international experts (Southall et al., 2007). The criteria for 'medium' was derived, based on Brandt et al. (2011), by extrapolating their measured Sound Exposure Level (SEL) at 2.3 km to the distance where responses in porpoises would begin to occur (calculated with transmission loss, TL = 15 log (r)). The criteria for 'minor' indicate half of the sound energy of the 'medium' category and can be therefore viewed as precautionary.

All noise pressures will be assessed against background ambient noise levels which range between 103 – 132 dB re 1µPa in the region (FEMM, 2011) as this is the baseline environment which will be altered by the project.

Several assumptions have been made concerning the modelling undertaken to investigate noise levels during the construction period and details are provided in section 3.7.1. Noise modelling has been based on the dredging activities (in weeks 1 to 66). However, due to an absence of relevant data, as a precautionary measure we have assumed that the immersion of the tunnel sections and backfilling (in weeks 66 to 200) will have the same noise emissions.

Dredging

For dredging, the sound data are presented in SPL calculated on the rms (root mean square) voltage of the sound pressure. Since the dredging noise is continuous the SPL is not related to a certain period of time. On the contrary, in pile driving, data are presented in SEL levels which give the sound energy of a short signal normalised to one second. Since the dredging noise is going on for a longer period of time, normalisation is not necessary and in this case SPL can be equated with SEL and can therefore also be related to the SEL thresholds for marine mammals.

Figure 6.2-11 shows the 1/3 octave frequency spectrum of sound emitted during dredging of sand. While most anthropogenic sound sources such as shipping noise or pile driving sound contain mainly low frequencies, dredging sound also contains considerable amounts of sound energy at higher frequencies in which harbour porpoises have their best hearing ability. The sound pressure levels of higher frequencies increase when coarser material such as gravel is dredged. For the Fehmarnbelt project mainly sandy sediment will be dredged.

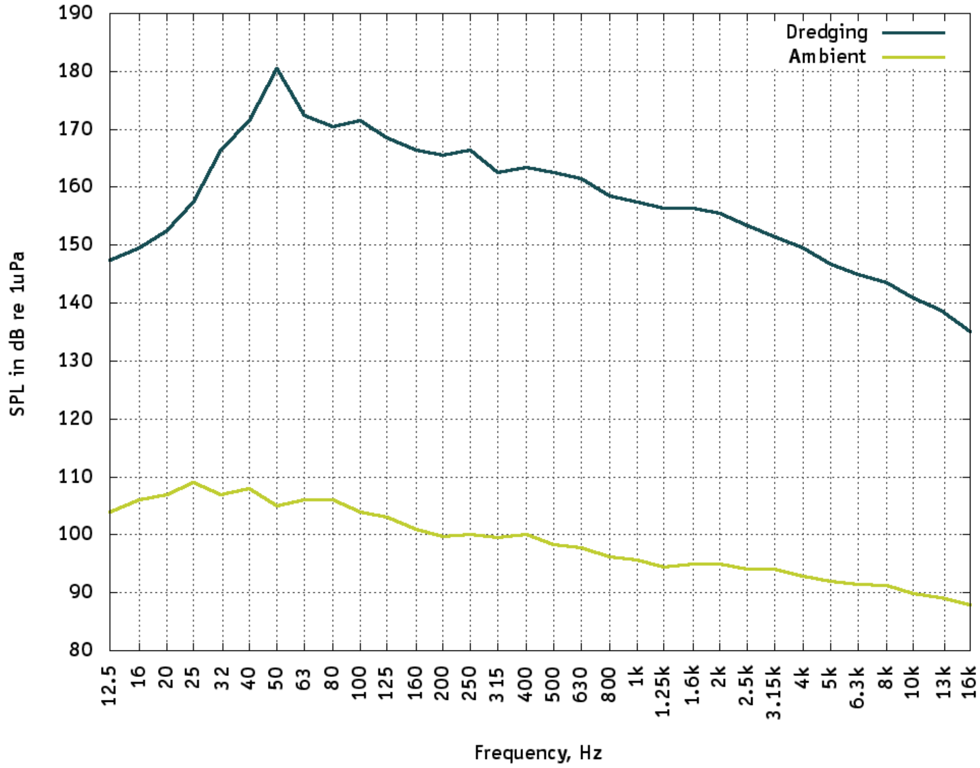

Figure 6.2-11 Source level 1/3-octave frequency spectrum of sand dredging using the trailing suction hopper dredger (TSHD) "Scelveringhe". The broadband sound pressure level is 184 dB re 1 µPa

The dredging stages (Figure 6.2-6) shows first work taking place within sections G1 and G2.

Figure 6.2-13A shows the modelling output for this dredging stage. The highest noise value predicted by the modelling is 184 dB re 1µPa. This SPL of 184 dB re 1µPa is only predicted at the dredging vessel, but this noise level falls within the high criteria, as it is likely to cause TTS in both porpoises and seals. However, noise from the dredging vessel quickly attenuates and it is reduced to a level below the 'low noise threshold' at a maximum of 540 m away from the source.

The German threshold of 160 dB re 1µPa²s SEL at 750 m is therefore never exceeded (Figure 6.2-12). It should be noted that dredging is modelled on a section over the footprint of the tunnel, which is why dredge noise centres are not always on the line of the tunnel footprint.

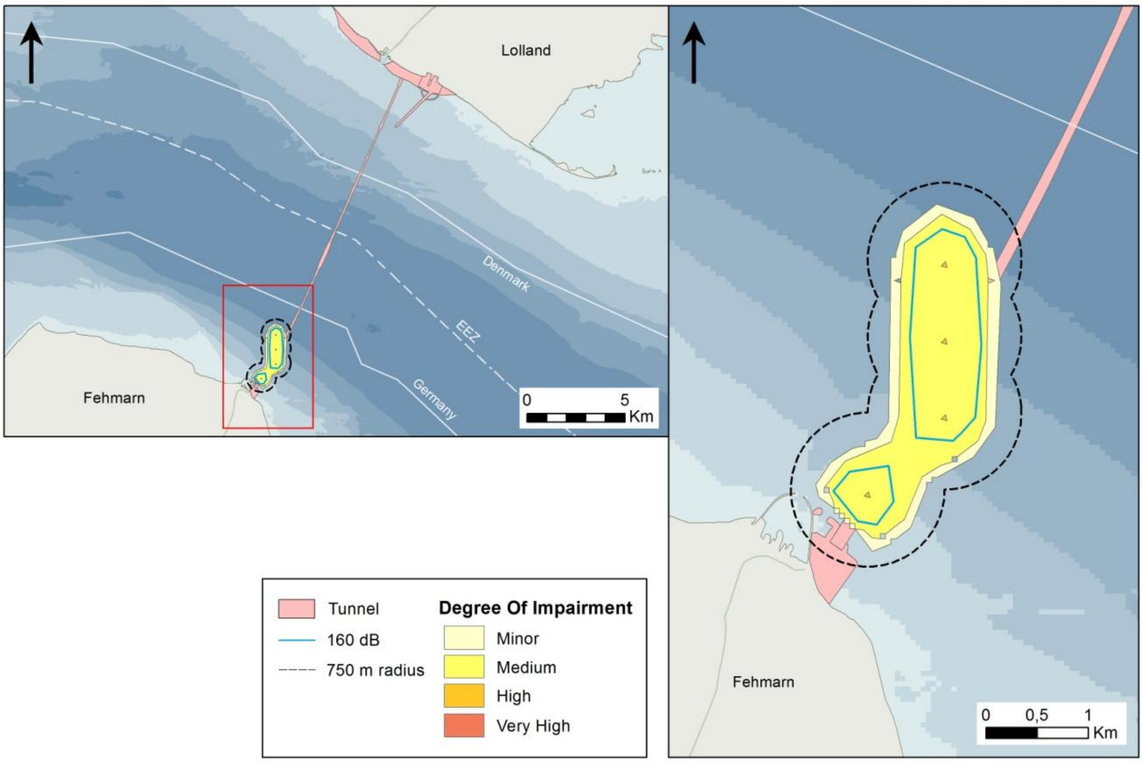

Figure 6.2-12 Degree of impairment of dredging. Boundary of the German 160dB re 1µPa²s SEL and the 750 m limit is also shown

Figure 6.2-13 to Figure 6.2-16 show the remaining dredge scenarios. Dredging stages two and three (G3 and D1, and D1, D2 and G4 respectively) have slightly higher source levels of 191 dB re 1µPa, again, only predicted at the dredging vessel. In this case, the noise level at the dredge vessel falls within the very high criteria for seals (see section 3.5), with a potential for seals located alongside the vessel to suffer PTS. However, again the noise attenuates quickly, with noise levels falling below the low noise threshold at a maximum of 870 m away from the vessel. In dredge stage 2, the noise levels fall below the medium threshold (behavioural impact, 150 dB re 1µPa) at 640 m, while for stage three this level is reached at 650 m. Therefore, even for the stages with more extensive dredging noise, the German threshold is not exceeded.

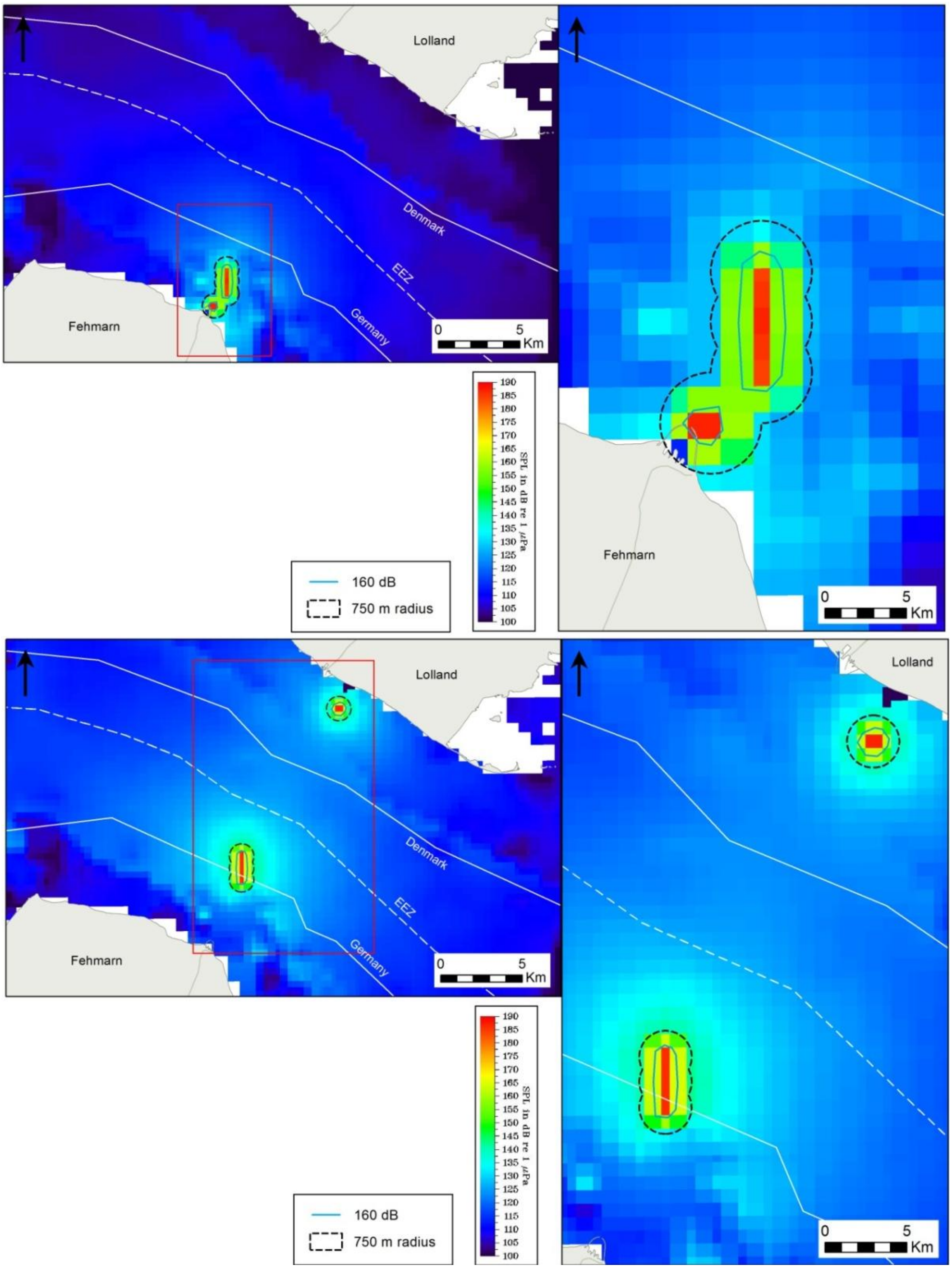

Figure 6.2-13 Upper map: Sound Pressure Level during first stage of dredging (G1 and G2). Lower map: Sound Pressure Level during second stage of dredging (G3 and D1)

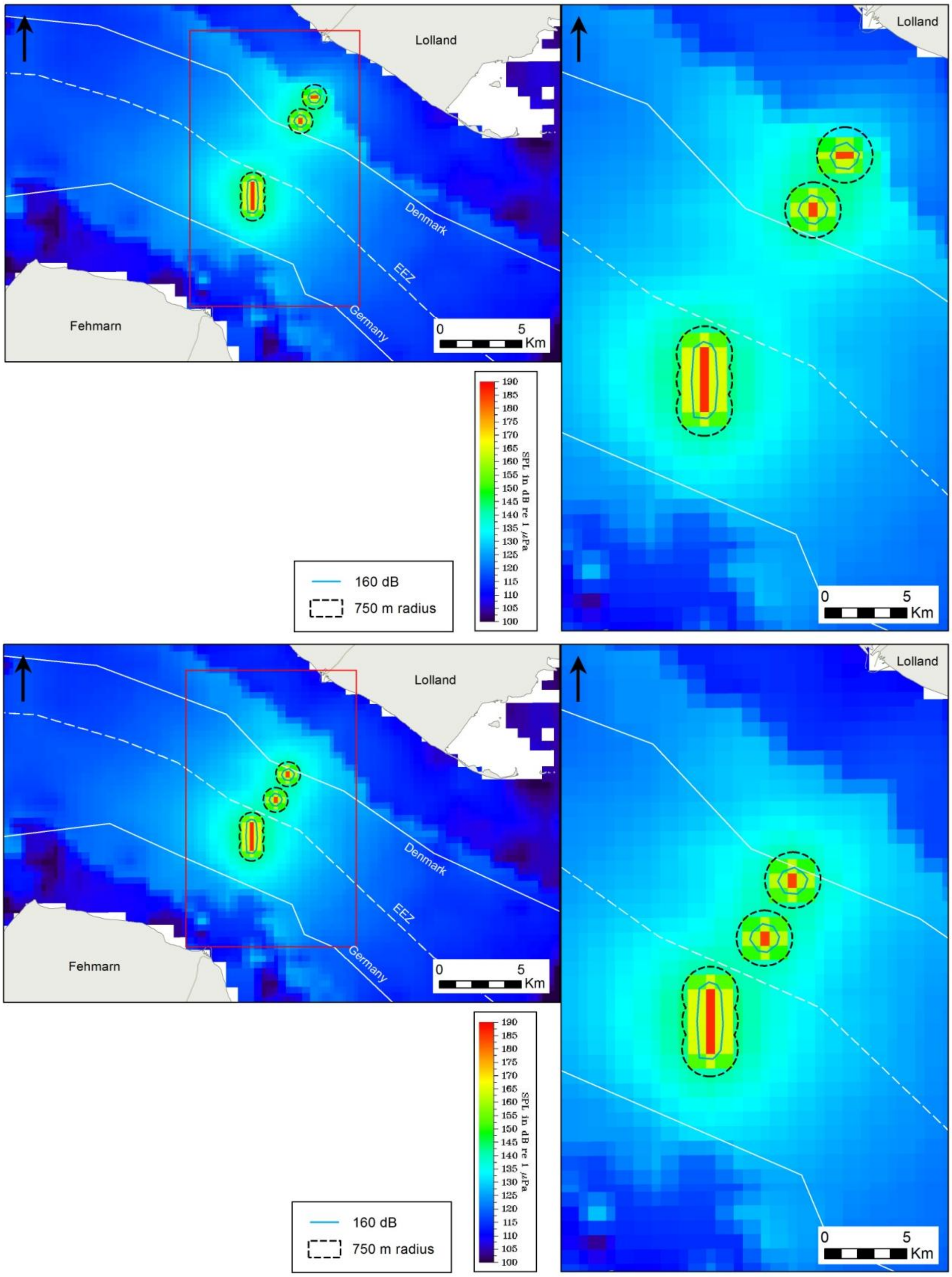

Figure 6.2-14 Upper map: Sound Pressure Level during third stage of dredging (G4, D1 and D2), Lower map: Five Dredgers working simultaneously in section G4 together with two dredgers in sections

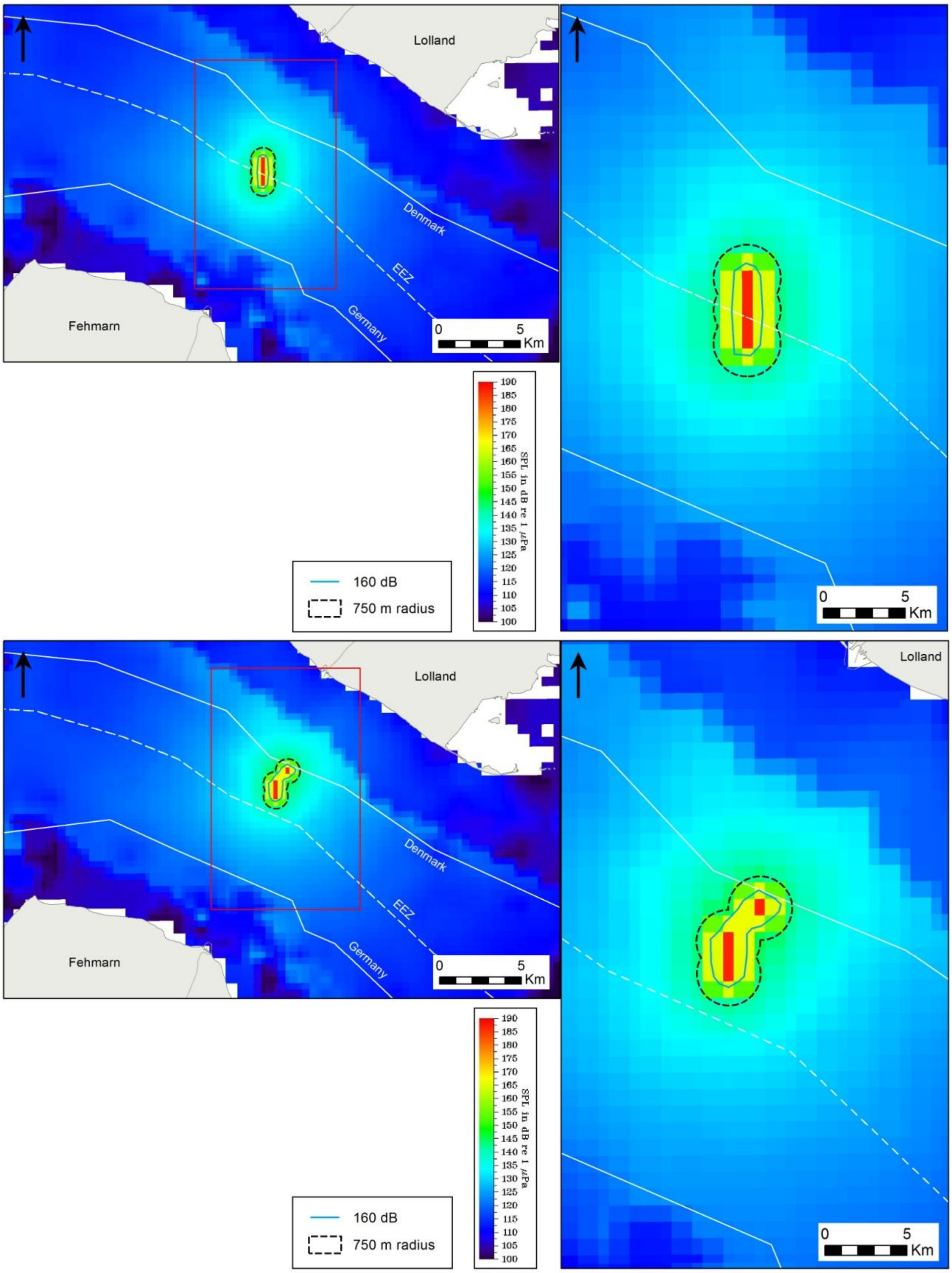

Figure 6.2-15 Upper map: Sound Pressure Level during fifth stage of dredging (D4). Lower map: Sound Pressure Level during sixth stage dredging (D2 and D3)

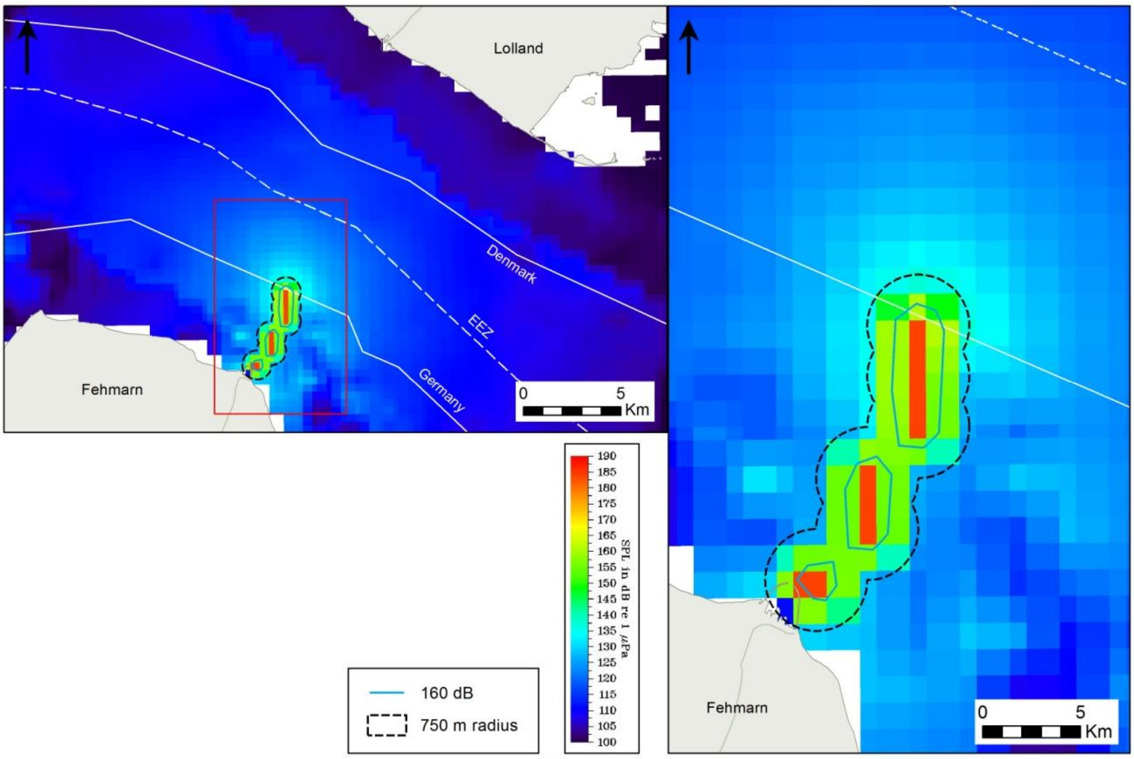

Figure 6.2-16 Sound Pressure Level during seventh stage of dredging (G1, G2 and G3)

Despite the noise level at the dredge vessel being within either the high (TTS) or very high noise threshold in the case of seals (PTS), it must be noted that values at one metre from the vessel (sound source) cannot be measured, but are back calculated/modelled from a greater distance away. There is, therefore, uncertainty concerning the calculated SPL, especially given physical theoretical uncertainties and complexities with the pressure variations and propagation of near-field sound waves. The noise level at the source is therefore generally overestimated unless a very sophisticated model is used to predict noise pressure variation National Physics Laboratory, 2010. This overestimation means that the noise source level is unlikely to be as high as modelled, but in any case, this noise level will only be present within a small circle of a few metres of the dredge vessel.

The data describing the noise emissions associated with each stage of dredging shown in Figure 6.2-13 to Figure 6.2-16 were imported into ArcGIS version 9.3 and the GIS measuring tool was used to approximate the distance from source to the noise thresholds described in Table 3.7—1. Then the sound pressure levels were back-calculated from the model outputs to give estimates on a smaller range than the 750 m used by the model and to define ranges for certain sound pressure levels.

Tunnel immersion and backfilling

As noted above, there is an assumption that the tunnel section placement and backfilling works (11 stages, weeks 66 - 200) and reclamation works, will generate the same (or lower) noise levels within the area, as other vessels may be used (e.g. barges / grab dredgers) instead or in addition to the TSHD (worst case noisiest vessel type).

It can also be seen that the dredging works do not, at any stage of dredging, cause a continuous barrier of noise across the strait between Lolland and Fehmarn. The implications of any barrier effects will be discussed within section 6.2.7.

Piling

Figure 6.2-17 shows the simulation for impact piling at Rødby harbour with a source level of 202 dB re 1µPa SPL as a worst case scenario. Pile driving sound can be heard over distances of about 9 km before it disappears in the background noise which can reach up to 132 dB in the area, mainly caused by heavy shipping traffic. It should be noted that even though noise appears to propagate into the Rødsand Lagoon, the noise levels at this point are already below the highest ambient noise levels for the region (132 dB).

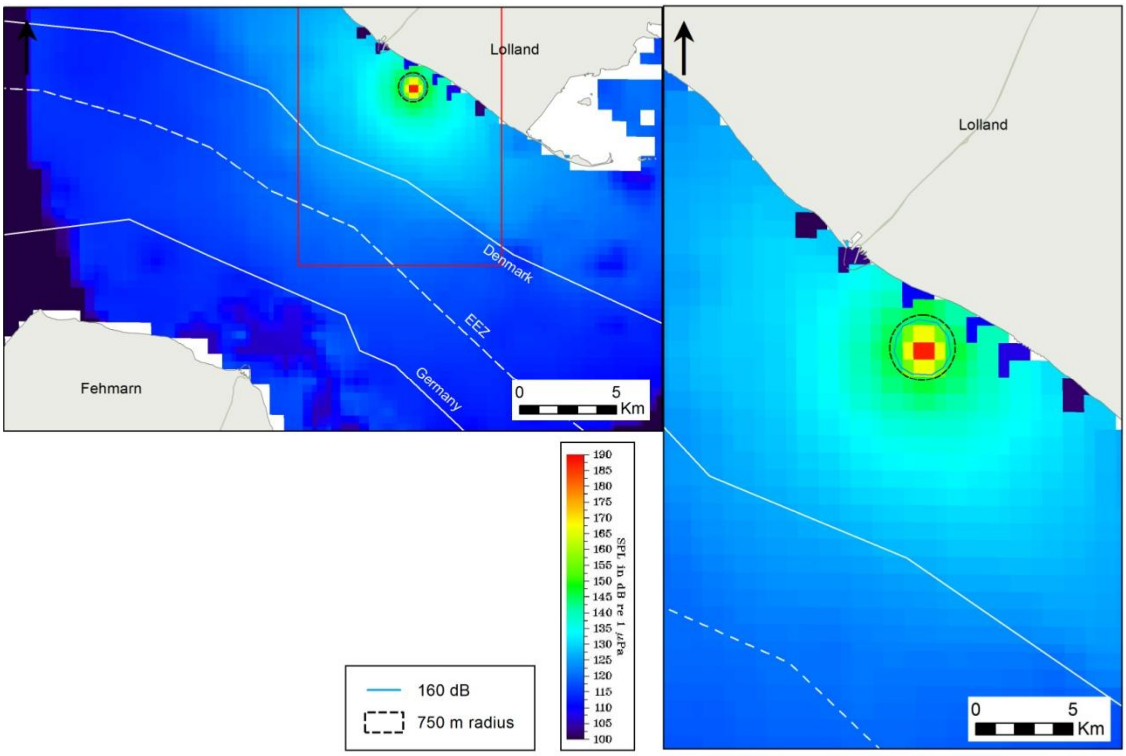

Figure 6.2-17 Sound exposure level during pile driving at Rødby Harbour

Sound emitted from pile driving contains mainly low frequencies. Figure 6.2-18 shows the 1/3 octave frequency spectrum during pile driving in Wilhelmshaven which contains most of the sound energy at the frequency range between 0.1 and 5 kHz. This is a range which overlaps with the best hearing ability of seals while the best hearing ability of harbour porpoises covers a higher frequency range (see Figure 4.1-1, Figure 4.1-2 and Figure 4.1-3).

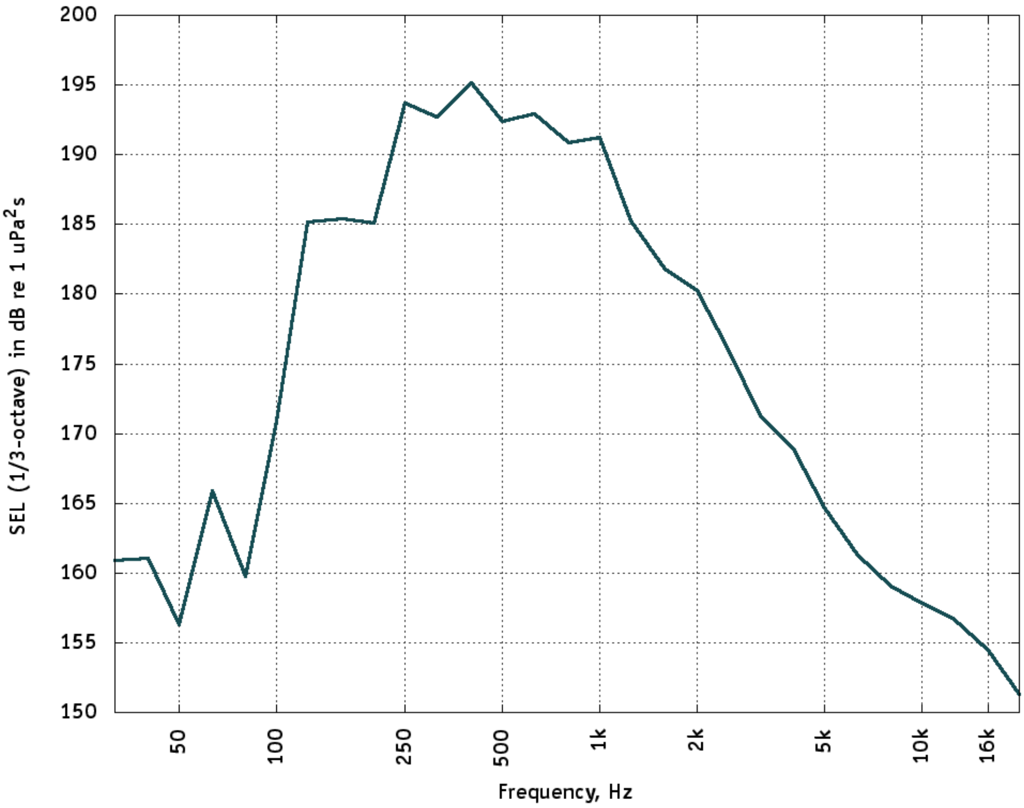

Figure 6.2-18 Source level 1/3-octave frequency spectrum during pile driving recorded during construction of the Jade-Weser-Port in Wilhelmshaven. Piling energy was 200 kJ, water depth 11 m. The broadband noise SEL level was 202 dB re 1µPa

In Figure 6.2-19 the simulated sound exposure levels are related to different thresholds used to estimate the effects of noise on marine mammals (Table 3.7—1). It can be seen from the Figure that the German threshold of 160 dB re 1µPa^{2}s at 750 m is not exceeded during pile driving in Rødby harbour. The noise level is only high (above 171 and 183 dB re 1µPa^{2}s, with a potential to cause TTS in seals and porpoises respectively) in an area of about 230 m distance from the pile driving activity. The area of medium magnitude with SELs of more than 150 dB re 1µPa^{2}s extends to approximately 1.1 km in which behavioural disturbance could be expected. Levels of more than 144 dB re 1µPa^{2}s would be expected up to a distance of about 1.9 km and may cause minor behavioural reactions.

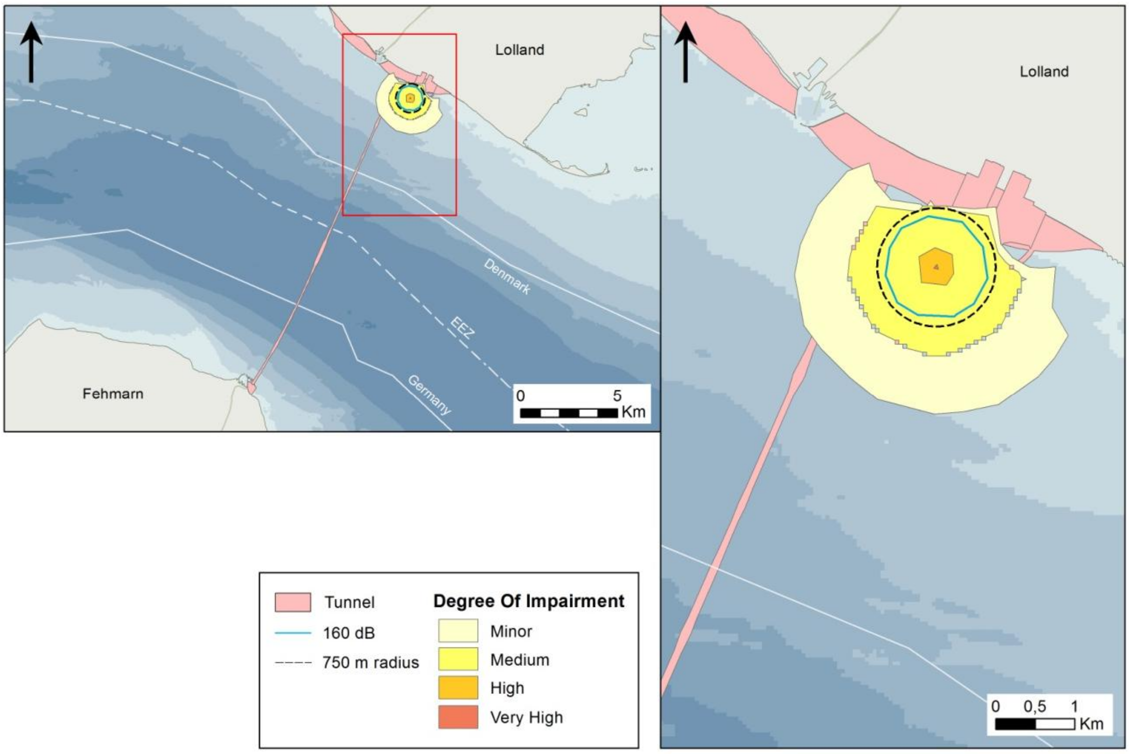

Figure 6.2-19 Degree of Impairment (DoI) during pile driving at Rødby harbour

Scenario of combined impacts for immersed tunnel noise generating construction activities

The timing of piling work during the construction period is not known. Therefore, a combined scenario of impact piling at Lolland and of dredging (stage 3, weeks 21 – 30, D1, D2 and G4), have been modelled to give a noise scenario of dredging and piling being undertaken at the same time (Figure 6.2-20).

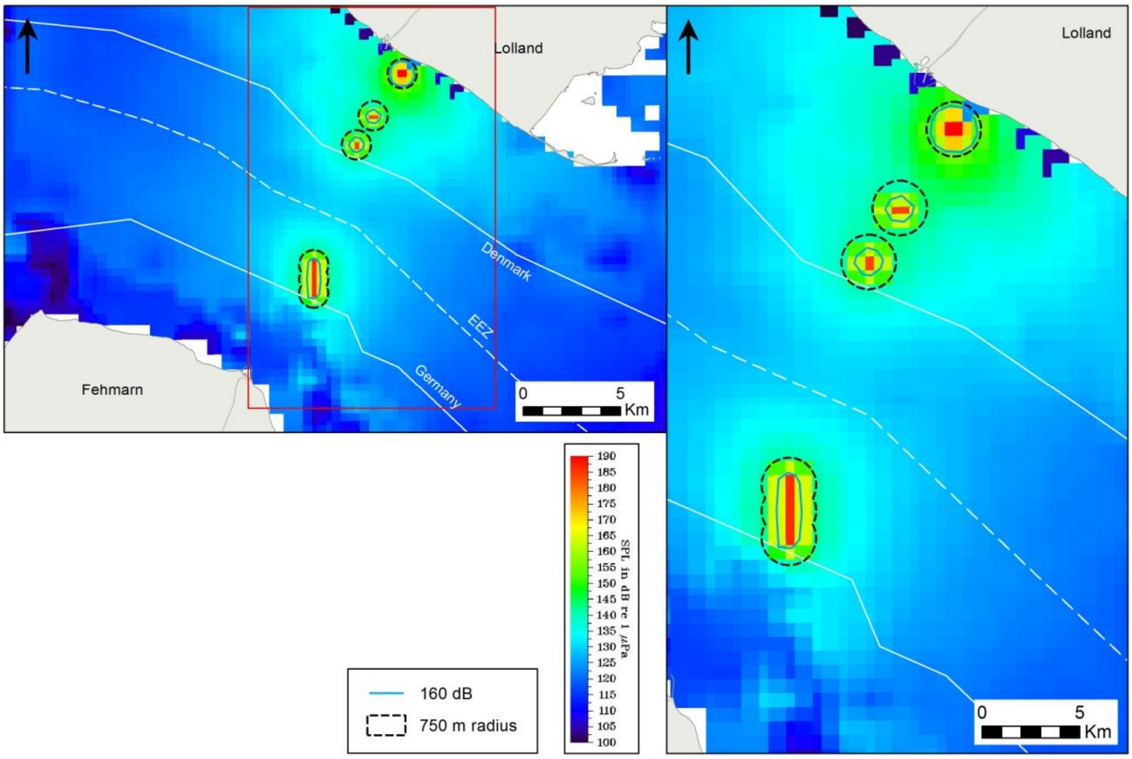

Figure 6.2-20 Sound Pressure Level for a scenario of combined impacts of dredging at stage 3 and piling at Lolland (N.B. Piling has been modelled as SEL)

The source level used for the modelling of pile driving was 202 dB re 1µPa at the source of the piling. Despite Figure 6.2-20 showing piling and dredging at D1 and D2 interacting together (model output), the GIS analysis in Figure 6.2-21 shows that this is not actually the case and there is no noise overlap between the piling at D1 and the pile driving. Therefore, it is possible to take dredging and pile driving separately when assessing the severity of impairment on harbour porpoise and seal species.

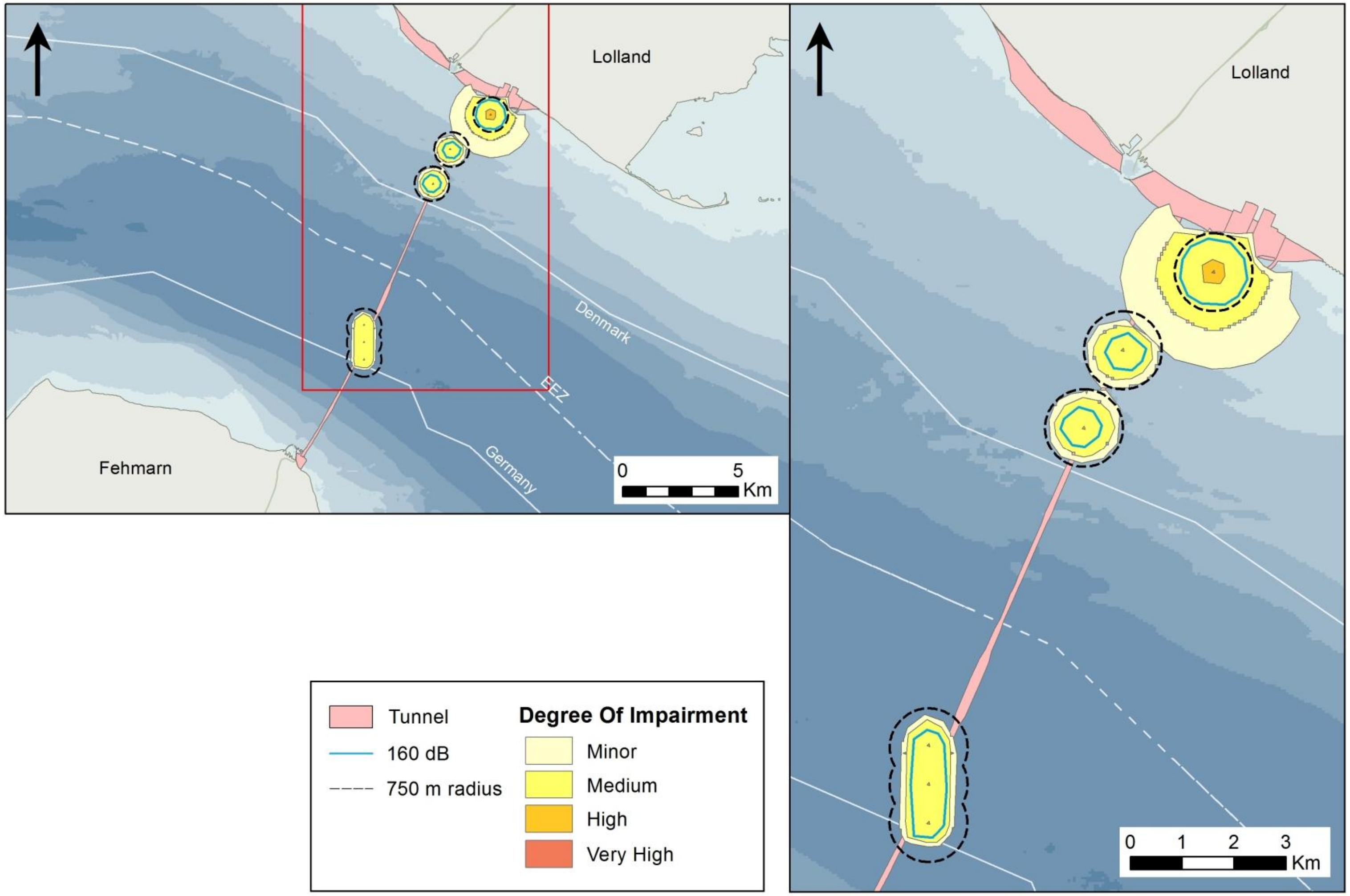

Figure 6.2-21 Degree of Impairment (DoI) showing a scenario of combined impacts of both dredging and pile driving taking place at the same time

Figure 6.2-22 gives an overall impression of the sound field in Fehmarnbelt with simultaneous dredging and pile driving on top of the baseline shipping noise. Figure 6.2-23 shows the baseline noise environment for comparison.

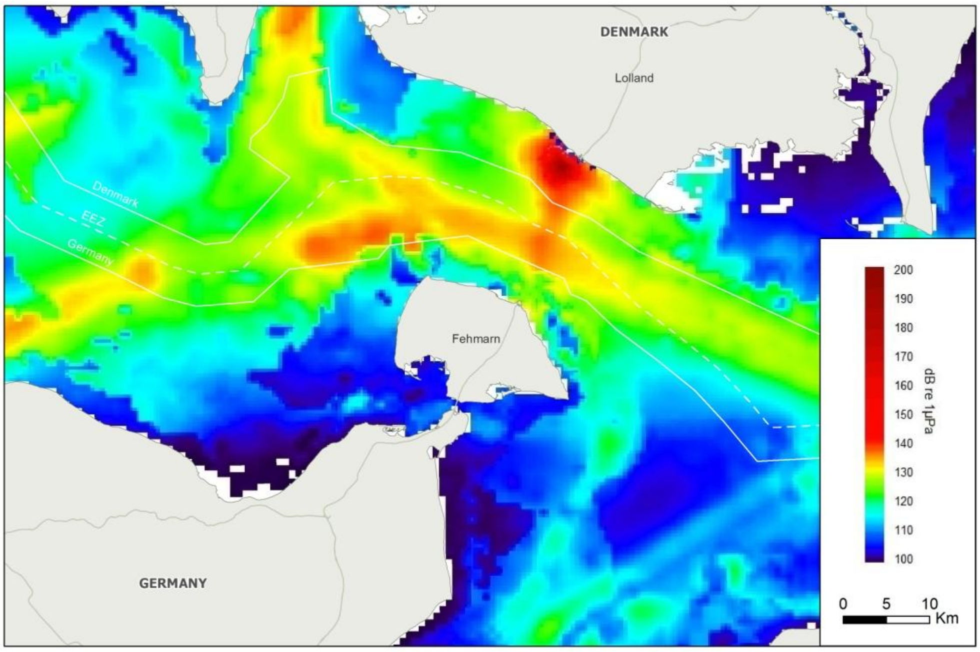

Figure 6.2-22 Sound pressure levels in Fehmarnbelt during dredging at G1 and G2, pile driving at Lolland combined with baseline shipping noise present in the area

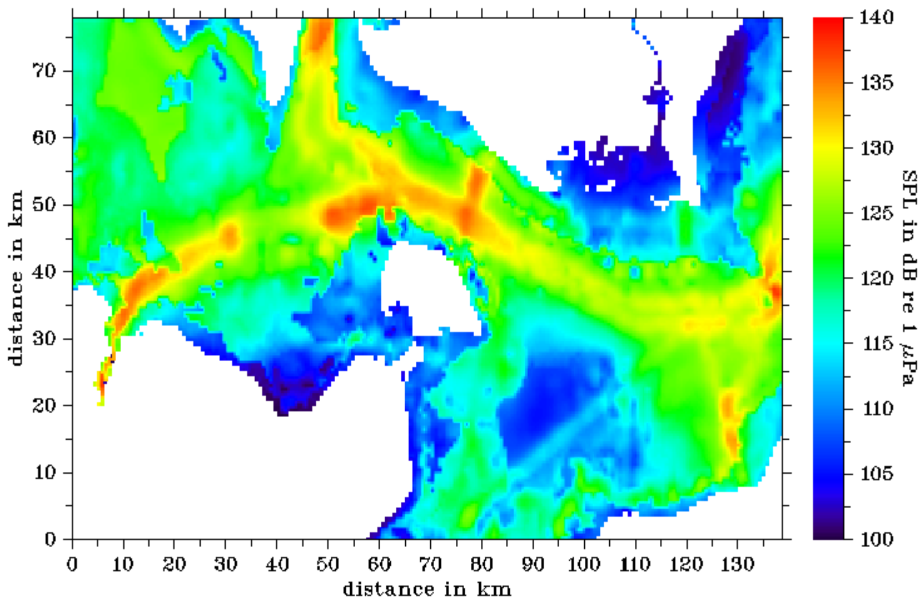

Figure 6.2-23 Sound pressure levels in Fehmarnbelt showing baseline shipping noise present in the area (FEMM, 2011)

6.2.3.2. Severity of Impact

Severity of impact is assessed by combining the degree of impact (impairment) with the importance of the area to harbour porpoises and seals. The summer and winter 2010 harbour porpoise importance maps (shown in section 3.4.1.1) were used as they showed the highest densities of porpoise and therefore the worst case for impact assessment.

As there was no abundance data for seals, it was not possible to produce an importance map for each seal species, and instead observed haul-out areas within Rødsand Lagoon were considered (shown in section 3.4.1.1) indicating that the nearest haul-out site is approximately 8.5 km from the nearest extent of the construction works.

Dredging

Winter

Figure 6.2-24 shows the severity of impairment during dredging of sections D1, D2 and G4 in winter. As can be seen from the Figure there is an overlap with areas which have both a medium and a minor importance for porpoises, leading to a severity of impairment ranging from medium to negligible. These overlaps equate to an area of 1.87 km², 2.91 km² and 0.60 km² for medium, minor and negligible severity of impairment respectively. These areas correspond to 0.04%, 0.06% and 0.01% of the available habitat for porpoises (Table 6.2—5).

Table 6.2—5 Severity of impairment for harbour porpoises during winter construction works (dredging)

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region
Medium	1.87	0.04
Minor	2.91	0.06
Negligible	*0.60*	*0.01*
TOTAL SoI	**4.78**	**0.10**

N.B. Negligible implies no impact, therefore this value has not been taken into account for the total Severity of Impairment (SoI).

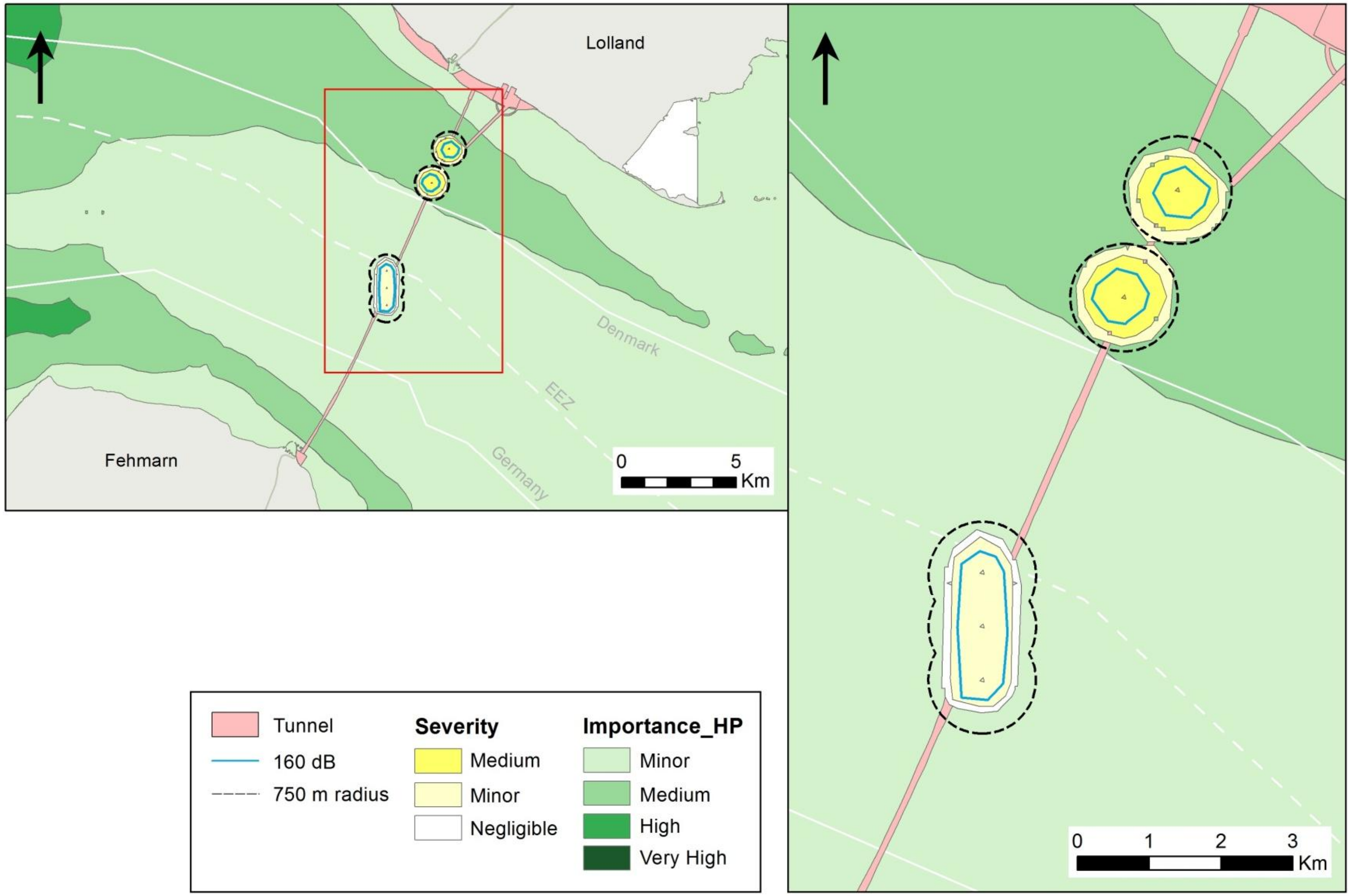

Figure 6.2-24 Severity of Impairment for porpoises during winter construction work

The overall abundance for porpoises during winter 2010 was estimated as 931 animals (95% CI 521 – 1,800 individuals (Table 5.1-1)). We can assume proportionally more porpoises were observed in the 'high' importance region compared to the 'medium' importance region, and similarly, proportionally more porpoises were observed in the 'medium' importance region compared to the 'minor' importance region. Using the average porpoise density data (Table 6.2—7) and the size of the impaired area for each importance level (Table 6.2—6) the number of porpoises affected can be calculated (Table 6.2—8).

Table 6.2—6 presents extended information from Table 6.2—5 showing the area of habitat (km^2) affected by noise levels above 144dB re 1µPa for each importance level, while Table 6.2—7 shows the average density for each importance level observed in winter 2010.

Table 6.2—6 Area of habitat loss for each importance level

Importance	**Severity of Impact (km^2)**		
	Medium	Minor	Negligible
Medium	1.87	1.09	0
Minor	0	1.82	0.60
Total	1.87	2.91	0.60

The severity of impact is a product of the degree of impact and the importance of the area for porpoises. The higher the importance of the area for marine mammals the higher the potential risk from the potential impacts. The severity is determined by applying the matrices (

Table 3.5—3 and Table 3.5—4).

Table 6.2—7 Average winter 2010 harbour porpoise density

Importance	Average density of harbour porpoises, ind./km^2
Very High	0
High	0.5905
Medium	0.3354
Minor	0.1492

It is now possible to calculate the number of animals affected based on the importance level. Table 6.2—8 shows that the overall spatial extent for the severity of impact is 1.87 km^2 (medium), 2.91 km^2 (minor) and 0.60 km^2 (negligible). These values are listed in the second column of Table 6.2—8. However, because the severity may be associated with different levels of importance it is important that the values are used in any calculation to determine the number of animals affected (ind.: individual(s) of porpoises), i.e.

Medium: 1.87 km^2 * 0.3354 ind./km^2= 0.63 ind.

Minor: (1.09 km^2 * 0.3354 ind./km^2 (medium) = 0.37 ind.) + (1.82 km^2 * 0.1492 ind./km^2 (minor) = 0.27ind.) = 0.64 ind.

If this calculation is not done, the result is a number of porpoises affected based on an even distribution throughout the study area (number of porpoises based on whole study area, irrespective of the numbers of animals found within each importance level). This analysis of spatial area and density of harbour porpoises results in the number of porpoises affected, however, these are not whole numbers hence the fractions in Table 6.2—8.

Table 6.2—8 Relationship between the severity of impairment and the number of porpoises affected

Severity of Impairment (SoI)	Impaired area (km^2)	% of Fehmarnbelt region	Number of porpoises affected
Medium	1.87	0.04	0.63
Minor	2.91	0.06	0.64
Negligible	*0. 60*	0.01	*n/a*
TOTAL SoI	**4.78**	0.10	**1.27**

N.B. Negligible implies no impact, and therefore this value has not been taken into account for number of affected porpoises

Overall, during the winter dredging works, 1.27 porpoises will be affected (Table 6.2-8). This number corresponds to 0,14% of the local population in winter 2010 (931 ind.,521 – 1800 ind. 95% CI). As detailed in the degree of impact section, the effect will range from minor to medium, potentially causing a behavioural reaction of a varying magnitude dependent on an animal's distance to the dredge vessel. Noise levels within the direct vicinity of the dredge vessel have the potential to cause TTS in porpoises but, as described previously, this figure is likely to be overestimated due to the complexities of near-field sound wave properties.

The dredging for each stage will be undertaken consecutively and, as noise levels are assumed comparable at all other dredging sections, we conclude that no more than 1.27 porpoises will be affected at any one time during the winter dredging works. This number of porpoises is negligible in terms of occurrence (staging) within the area and also in terms of effects on calving grounds (which have not been spatially defined within the wider area). The initial noise modelling (Figure 6.2-13 to Figure 6.2-16) shows that the noise levels never completely cover the strait between Lolland and Fehmarn. Therefore, given the low number of porpoises affected, dredging works are unlikely to cause an impact on porpoise migration through the area.

Tugs and barges were not modelled as they are nearly 10 dB quieter than TSHDs, which reduces the intensity of the noise by approximately an order of magnitude. The majority of the noise resulting from the modelling fell below ambient noise, and therefore it is likely that the noise from these quieter vessels would be entirely masked by current ambient noise levels in the region. It must also be noted that predominately backhoe and grab dredgers will be used for the dredging work, which are quieter than TSHDs, resulting in even less dredging noise and reducing the extent of behavioural impacts even further.

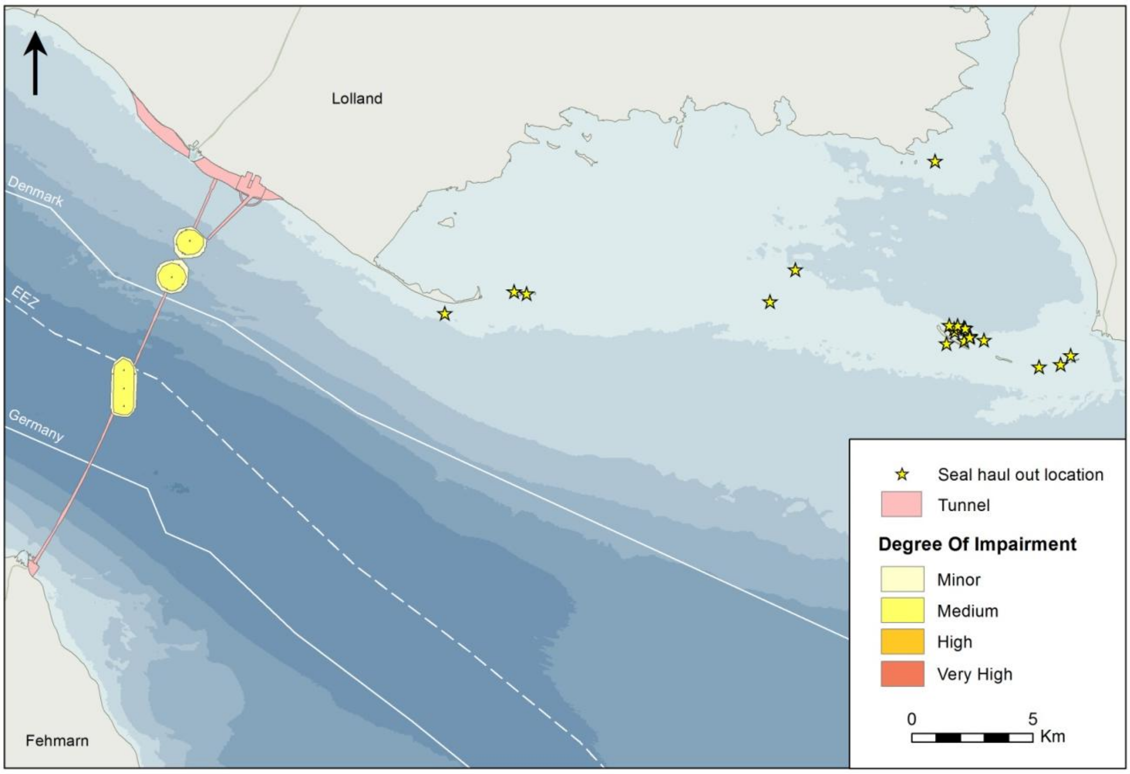

Figure 6.2-25 Location of seal haul-out zone and degree of impact during dredging

The nearest observed seal haul-out is approximately 10.5 km away from the minor noise level of 144 dB re 1µPa, with the majority of sightings lying over 30 km away from the lowest noise levels (Figure 6.2-25). Therefore, as far as the haul-out zone is concerned, there is no overlap and therefore no impairment to either seal species. With regards to potential feeding areas, grey seals are known to forage extensively from their haul-out sites. McConnell et al (1999) observed grey seals making short trips (0.5 – 3 days) ranging in distance from 20.4 km to 82.5 km from their haul-out site, which the authors attributed to foraging areas. While this is dependent on preferred foraging areas corresponding to preferred prey species, it does demonstrate that grey seals are capable of feeding anywhere up to 80 km away from their haul-out site; more than the extent of the Fehmarnbelt study area. Harbour seals have a smaller foraging spatial range than grey seals. The Fehmarnbelt baseline study found that tagged harbour seals travelled a maximum of 50 km away from the haul-out site, with an average trip distance of 17 km.

Within the study area, 4.78 km^2 of potential feeding habitat will be affected by the dredging works, corresponding to 0.10% of the available habitat. While this is a small percentage of the available habitat, the severity of impairment is assessed as minor to negligible, and therefore the possible impacts on foraging seals will be discussed in section 6.2.6.

Summer

Figure 6.2-26 shows the severity of impairment during summer dredging works in the dredging sections D1, D2 and G4. Despite a higher importance of the area during the summer, leading to increased densities of porpoises (Table 6.2—9), the severity of impairment remains similar to that experienced in winter, consisting of a combination of medium and minor severity, although there is a very small area of high severity (approximately 3,400 m^2).

Table 6.2—9 Average summer 2010 harbour porpoise density

Importance	Average density of harbour porpoises (ind./km^2)
Very High	1.26786
High	0.67007
Medium	0.36762
Minor	0.16888

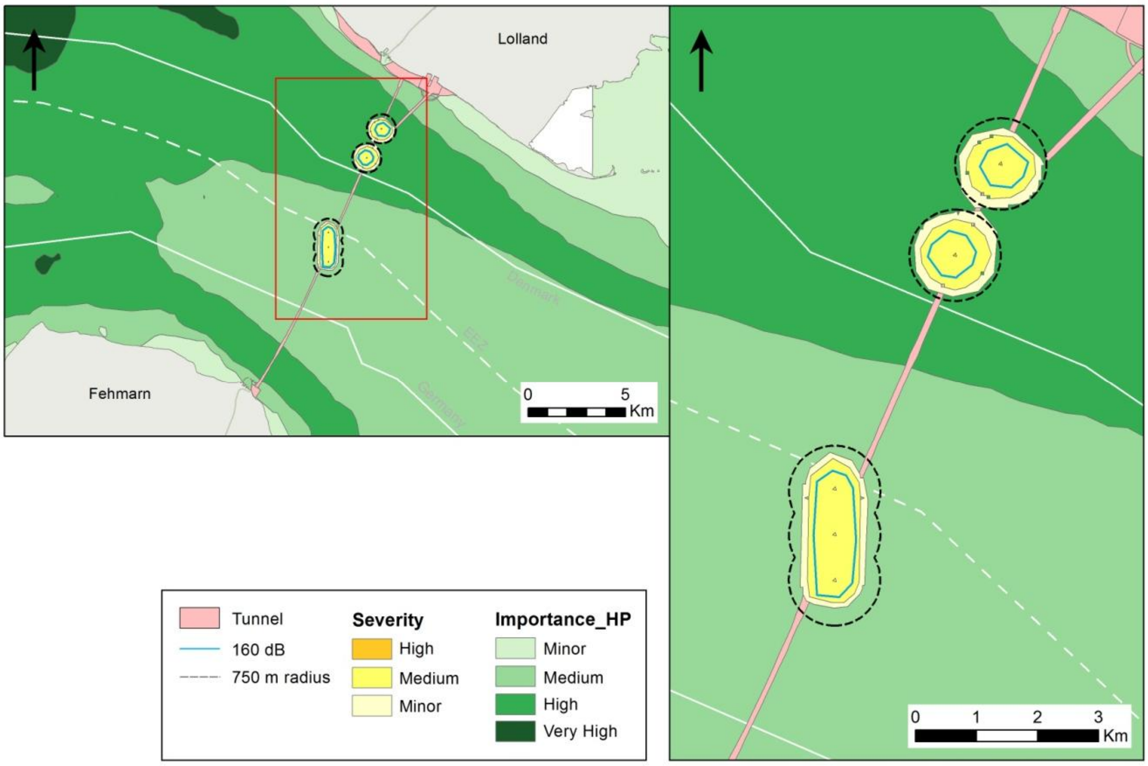

Figure 6.2-26 Severity of impairment for harbour porpoises during summer dredging works

Table 6.2—10 Severity of impairment of dredging on harbour porpoises in summer

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
High	0.003	0.00	0.00
Medium	3.69	0.08	1.92
Minor	1.69	0.03	0.95
TOTAL SoI	**5.38**	**0.11**	**2.87**

A total of 2.87 animals will be affected by the summer dredging works, more than twice than affected by the winter dredging works. However, many more porpoises were observed in summer 2010 (2,078 ind., 1414 – 2709 ind. 95% CI) compared to the winter 2010 (931 ind., 521 – 1.800 ind. 95% CI), due to shifts in their seasonal abundance. The number of affected porpoises corresponds to 0.14% of the local population in summer; the same proportion as calculated for winter (see above).

A total of 5.38 km² (0.11%) of potential seal feeding ground will be affected by the summer dredging works, the implications of this minor to negligible severity of impairment will be discussed in section 6.2.6.

Piling

Winter

Figure 6.2-27 shows the severity of impairment for harbour porpoises during winter pile driving works. Table 6.2—11 details the area of habitat affected by pile driving noise. A total of 0.23 km^2 (0.005% of the harbour porpoise area) of a medium importance area is impacted by medium sound levels from pile driving. A further 4.83 km² (0.10%) minor important habitat is impacted by high to low sound pressures.

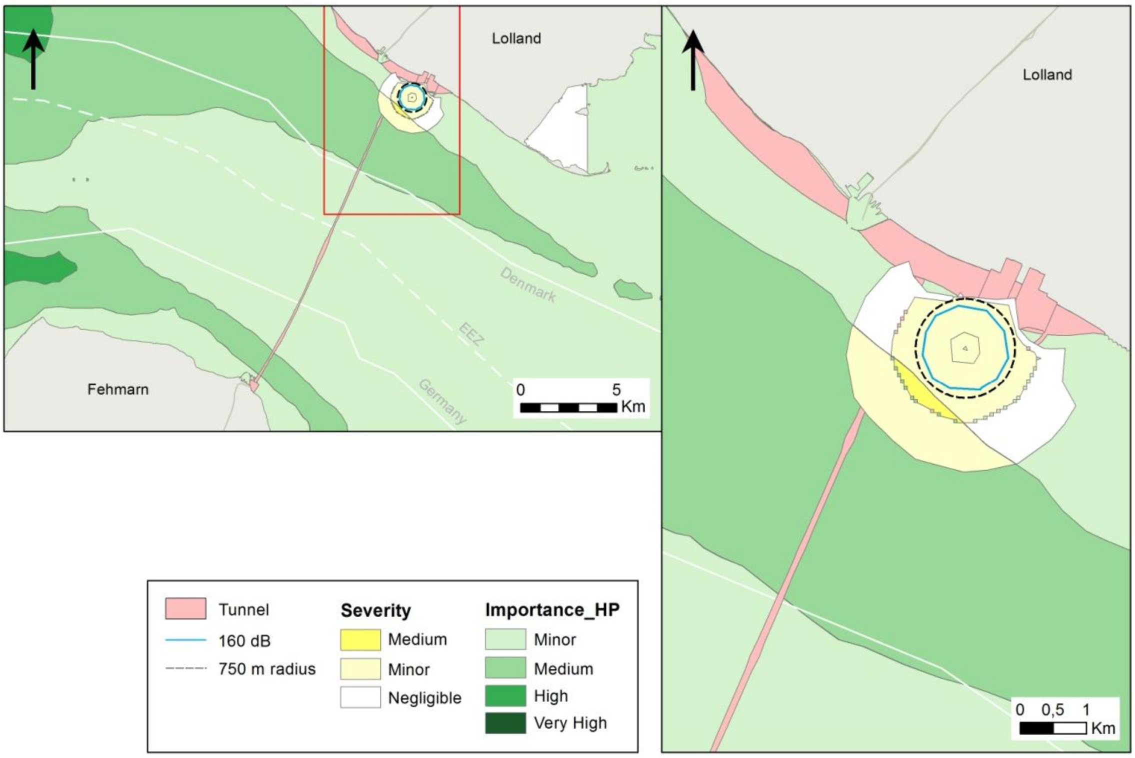

Figure 6.2-27 Overlap of important areas for harbour porpoises in winter in relation to the severity of sound exposure levels during pile driving

Table 6.2—11 Severity of impairment of pile driving on harbour porpoises in winter

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
Medium	0.23	0.00	0.08
Minor	4.83	0.10	1.08
Negligible	*2.22*	*0.05*	*n/a*
TOTAL SoI	**5.05**	**0.11**	**1.16**

N.B. Negligible implies no impact, therefore this value has not been taken into account for the total Severity of Impairment (SoI)

A total of 1.16 porpoises are predicted to be impacted by pile driving noise during the winter works; a proportion of 0.12% of the winter 2010 abundance. This proportion of animals impacted by winter pile driving is similar to that as predicted for winter dredging works. Except for a small area of high noise levels (received SEL exceeds 183 dB re 1µPa^{2}s for porpoise) only porpoise behaviour may be affected, to varying degrees, depending on their distance from the pile driving activity. Pile driving will take place at the coast, where the importance of the habitat to porpoises is mostly minor (low density) (Figure 6.2-28), therefore it is unlikely that any animals will be within the 230 m high noise level zone of possible TTS. It is also possible that porpoises will simply move further out into the channel during the period of these works.

The nearest observed seal haul-out location is approximately 8 km from the lowest noise threshold of 144 dB re 1µPa^{2}s (Figure 6.2-28), with the majority of sightings lying over 28 km away. Therefore, as for the dredging, as far as the haul out zone is concerned, there is no overlap with pile driving noise and therefore no impairment to either seal species.

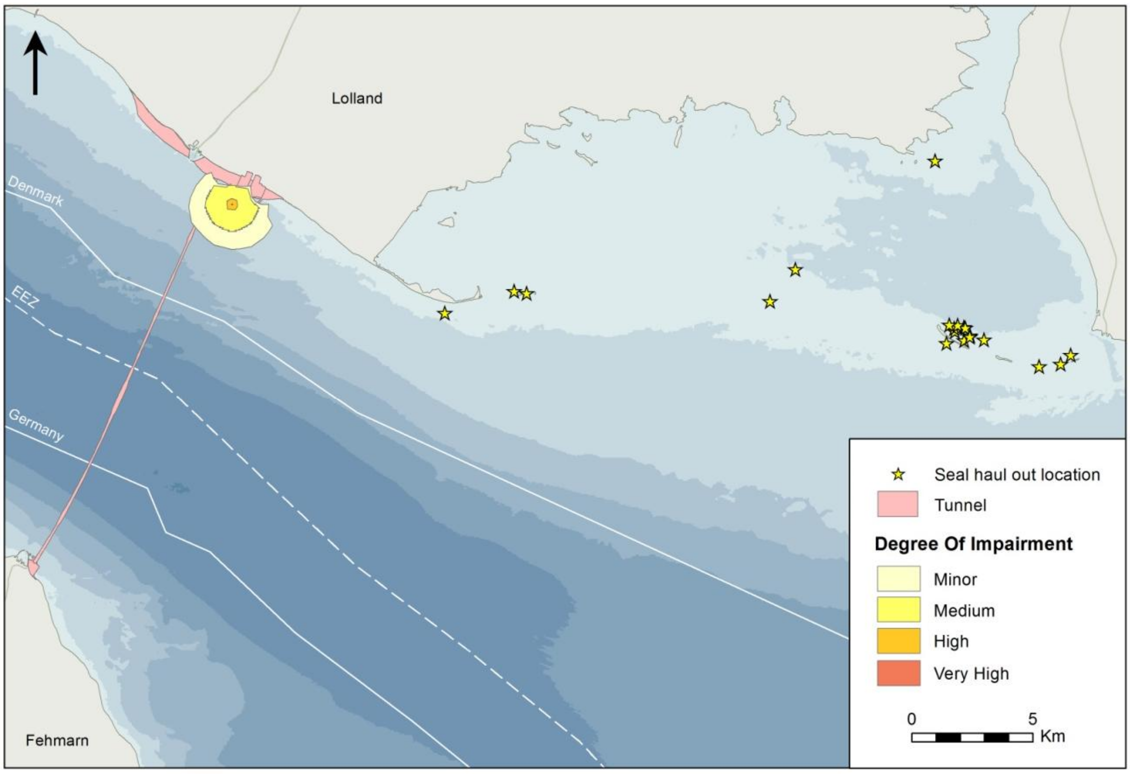

Figure 6.2-28 Location of seal haul-out zone and degree of impact of pile driving

Again, there is a percentage of possible feeding ground that will be affected by noise (5.05 km² and corresponding to 0.11% of the available habitat). The implication of this habitat removal is of minor to negligible severity of impairment and will be discussed in section 6.2.6.

Summer

In summer, areas of high importance for harbour porpoises overlap with areas of medium and minor noise levels (Figure 6.2-29). The results for summer pile driving works are summarised in Table 6.2—12. A total area of 2.96 km² (0.06% of the harbour porpoise area) is affected with a medium severity of impairment, while 4.13 km² (0.08% of habitat) is impacted by a minor severity of impairment.

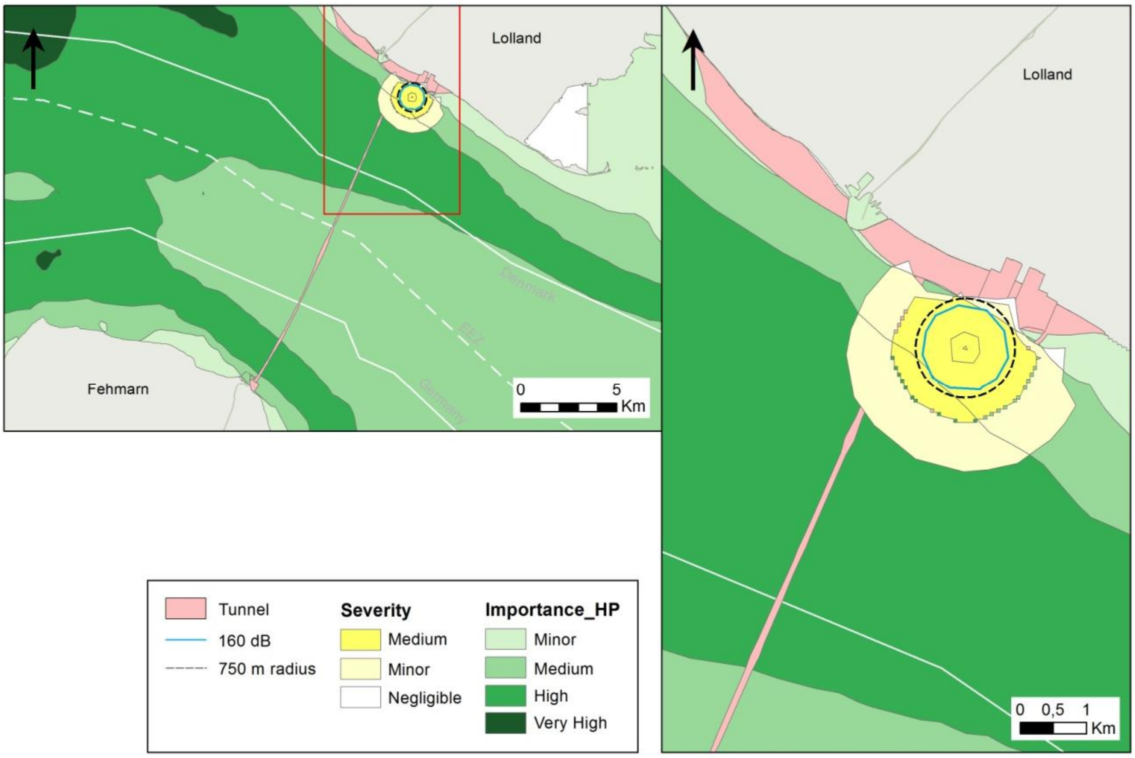

Figure 6.2-29 Overlap of important areas for harbour porpoises in summer in relation to the severity of sound exposure levels during pile driving

Table 6.2—12 Impact of pile driving on harbour porpoises in summer

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
Medium	2.96	0.06	1.26
Minor	4.13	0.08	2.18
Negligible	*0.17*	*0.00*	*n/a*
TOTAL SoI	**7.09**	**0.15**	**3.4**

N.B. Negligible implies no impact, therefore this value has not been taken into account for the total Severity of Impairment (SoI)

A total of 3.43 porpoises are predicted to be affected by summer pile driving works, three times those affected by the winter pile driving. This number corresponds to 0.17% of the summer harbour porpoise population, again similar to the numbers affected by summer dredging works.

The summer pile driving works correspond to a loss of 7.09 km² (0.15%) of potential seal feeding habitat. Again, this impairment is of minor to negligible severity and the implication of this habitat removal will be discussed in section 6.2.6, food supply effects from habitat changes.

6.2.4. Habitat Loss Construction Impact Assessment

6.2.4.1. Degree of impact: Loss

Habitat loss caused by the coastal land reclamation and physical habitat disturbance caused by dredging, tunnel placement and backfilling (as described in section 6.1.2.2) will directly impact porpoises and seals. Harbour porpoises, harbour seals and grey seals are mobile predators and use a wide range of habitats, water depths, sedimentary and hydrographic conditions (Tollit et al., 1998; Skov & Thomsen, 2008; Scott et al., 2010). Physical loss will affect staging (occurrence) areas through the direct loss of water column and the seabed.

The reclamation areas are planned to be located outside the breakwater constructions of the ferry harbours in Rødbyhavn (both sides of the harbour) and Puttgarden (east of the harbour) and cover mostly shallow water habitats. The larger reclamation area at Lolland, extending up to 4 km east and west of the ferry harbour, affects shallow water areas dominated by macro-algae (mainly Furcellaria; FEMA, 2011a) and Mytilus communities (FEMA, 2011a). These coastal areas are important habitats for shallow water fish communities composed of smaller species like gobies or sandeels, but these areas are also suitable habitats for juvenile stages of other fish species, e.g. cod and flounder (FEBEC, 2013). For immersion of the tunnel elements an approximately 200 m wide trench will be dredged. Together with construction harbours and access channels in total an area of 3.02 km² will be affected from dredging. From the tunnel trench, mainly areas of low vegetation cover (0-10%; FEMA, 2011a) with mostly Arctica, Corbula and Mytilus communities being affected (FEMA, 2011a).

The footprint of the tunnel project during the construction phase comprises in total 5.84 km² of marine areas, of which the loss from land reclamations holds the largest fraction of this total area (Table 6.2—13).

Table 6.2—13 Marine areas affected by habitat loss for harbour porpoises from the footprint of an immersed tunnel during the construction period. Please note: the total marine area lost for the footprint is 5.84 km²; the sum of different areas listed in this table would result in a higher value from double counts of some areas, e.g. protection reefs are built in the tunnel trench area, or parts of the harbour becomes land reclamation later.

Footprint area	**Size, km^2**
Dredged areas (tunnel trench, harbours, access channels)	3.02
Elevated protection reefs	0.12
Land reclamation and construction harbour Lolland	3.36
Land reclamation and construction harbour Fehmarn	0.22
TOTAL	**5.84**

The footprint area of the tunnel during the construction period is regarded as an area of complete habitat loss since re-establishment within a short- or long-term period is expected to mostly take place after the construction period. Since habitat loss is defined to always result in a complete displacement of all marine mammals from the impact area, the degree of impact due to habitat loss is assessed to be very high.

6.2.4.2. Severity of Loss: Habitat Loss

The severity of the habitat loss is determined by interaction of the degree of the physical loss, with the importance of a spatial area for harbour porpoises or seals, as shown in Table 6.2—14, Figure 6.2-30 and Figure 6.2-31. The determination of areas of importance to harbour porpoises, harbour seals and grey seals is discussed in detail in section 3.5.1.2. Construction works in the summer were taken as the most severe scenario for harbour porpoise effects from habitat loss (i.e. the period when the highest proportion of the population was likely to be affected). The impact is predicted to be lower in winter.

Table 6.2—14 Linking matrix for determining severity of loss and showing spatial extent (km^2)

Degree of impact (Loss / impairment)	**Importance**			
	Very High	High	Medium	Minor
Very High (caused by footprint – 5.84 km^2)	Very High (0 km^2)	High (0.90 km^2)	Medium (1.62 km^2)	Minor (3.32 km^2)

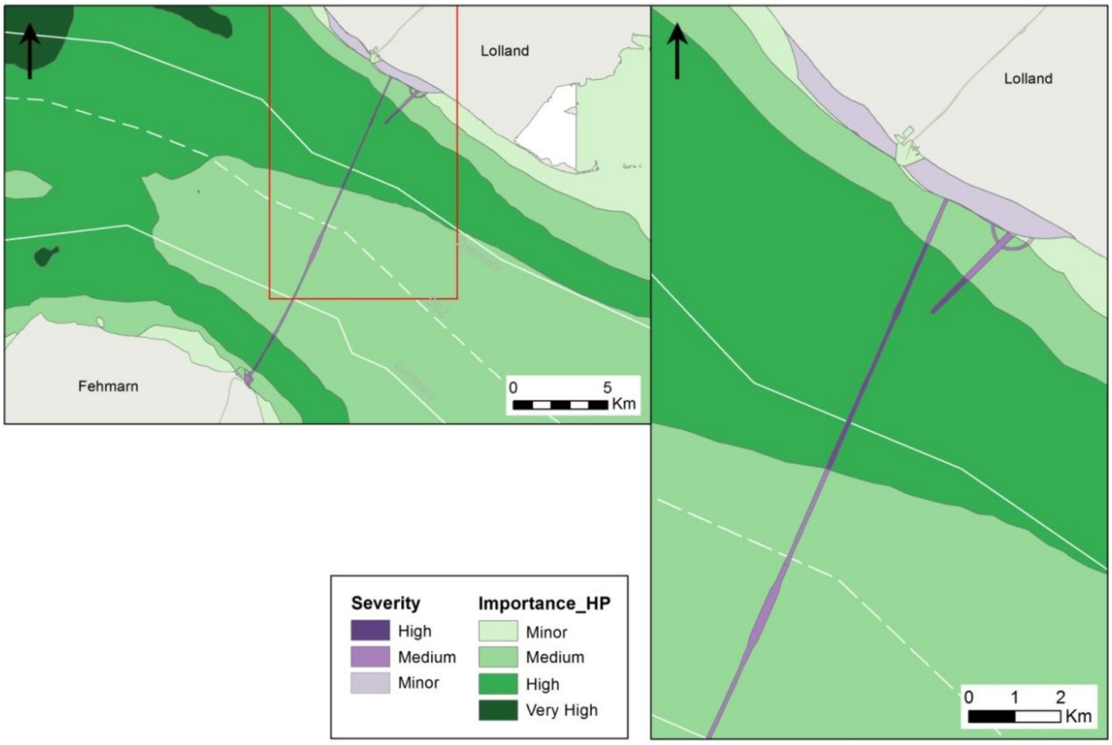

Figure 6.2-30 Severity of loss to harbour porpoises (based upon summer 2010 importance)

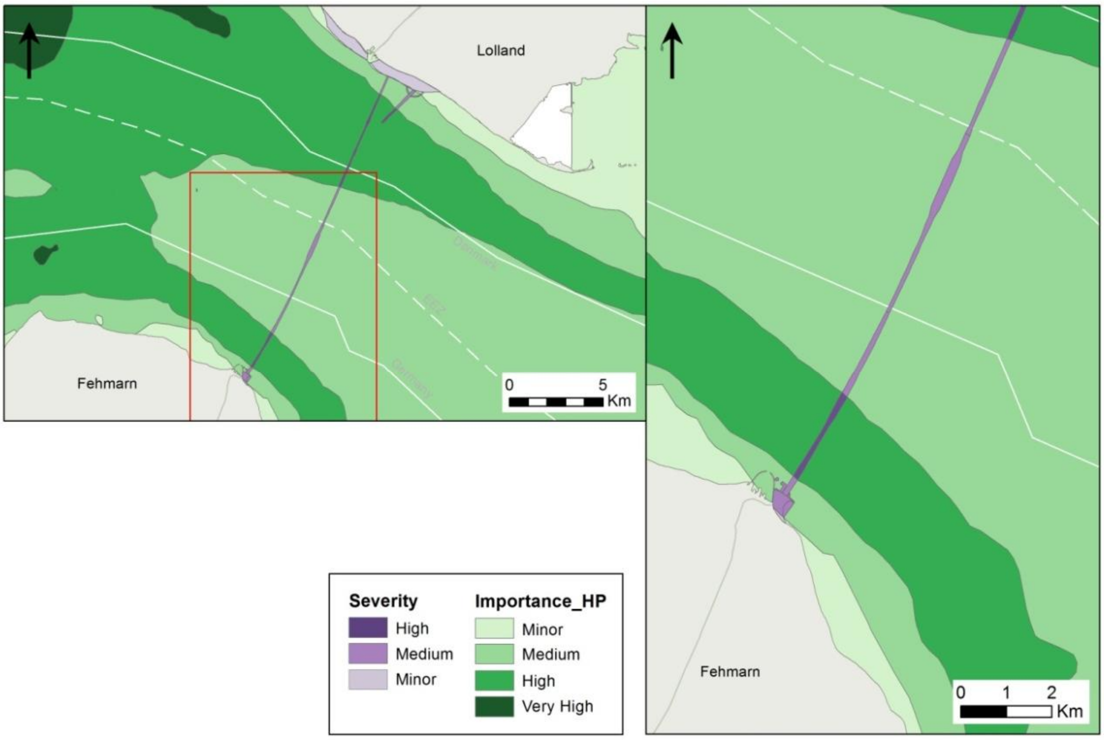

Figure 6.2-31 Severity of loss to harbour porpoises (based upon summer 2010 importance) at Fehmarn

As previously summarised in Table 6.2—13, the area of physical loss is caused by the land reclamation of coastal areas at Lolland and Fehmarn, the tunnel trench, construction harbours and access channels. As shown in Figure 6.2-30, this area of loss affects areas of minor, medium and high importance to the harbour porpoise in summer. In the baseline assessment (FEMM, 2011) the study area was determined to function as part of an area of very high to low occurrence of harbour porpoises and serves as a migration corridor and nursing also occurs in the area. The function of the area has been considered as part of the interpretation of the importance layers (density) in calculating the severity of impact. The other features that might define 'importance' in terms of function (feeding area, calving/nursing area) cannot be spatially referenced within this impact assessment because they are not spatially defined within the Fehmarnbelt region.

It is important to discuss the severity of loss in relation to the proportion of the local harbour porpoise population that occurs in the Fehmarnbelt region. Table 2.1-1 within the baseline (FEMM, 2011) provides modelled abundance estimates, and the predicted summer 2010 abundance of 2,078 harbour porpoises (95% CI 1,414 – 2,709 ind. (see Table 5.1—1)). A range of densities per km^2 has been applied to present the relative importance of an area to this local population.

The total footprint of loss is 5.84 km^2 and therefore 0.12% of the Fehmarnbelt harbour porpoise study area, the proportion of high, medium and minor severity of loss is presented in Table 6.2—15. The severity of loss is analysed as number of porpoises that will be impacted by each severity level of loss based upon abundance densities for summer 2010 within each area of importance. This method is described in detail in section 6.2.3.2.

Table 6.2—15 Proportion of Fehmarnbelt region and porpoise population

Severity of Loss	Footprint (km^2)	% of Fehmarnbelt region	Number of porpoises affected
High	0.90	0.02	0.60
Medium	1.62	0.03	0.60
Minor	3.32	0.07	0.56
Total	5.84	0.12	1.76

The relative areas of loss relate to areas of importance based upon abundance (and therefore defined as occurrence areas). This is represented by the relative number of porpoise affected by differing levels of habitat loss, in the area of high loss, higher numbers of porpoises are exposed to habitat loss. The function of the area as a migration corridor and nursing area cannot be spatially defined. Therefore, the loss of this function through habitat loss may apply to the total number of porpoises affected, i.e. 1.76 individuals. The total proportion of porpoises impacted equates to 0.08% of the local summer population.

The trench works will be undertaken at discrete 2 km sections at a time, no more than two separate sections will be dredged or backfilled at any time (see Figure 6.2-6). Dredging, harbour construction, tunnel placement, backfill and land reclamation will be undertaken concurrently for 52 months (November 2014 – March 2019). The impairment to harbour porpoises with regard to disturbance and barrier effects due to the construction works is assessed in chapter 6.2.7.

Seals

The area of physical loss is caused by land reclamation of coastal areas at Lolland and Fehmarn. As shown in Figure 6.2-33 this area of loss does not interact with the area of Rødsand Lagoon which is classified as being of very high importance to harbour seals and high importance to grey seals. The areas outside Rødsand Lagoon are not haul-out sites or pupping areas and are therefore of minor importance. The interaction between the footprint of loss and areas of minor importance results in a minor severity of loss.

The physical habitat changes and loss of water column habitat are local to the site of the construction works and will not act as a barrier to seals moving through the area, and are not used as a haul-out site. The footprint of loss is 5.84 km^2 and therefore 0.12% of the Fehmarnbelt seal study area.

Table 6.2—16 Linking matrix for determining severity of loss on Seals and sowing spatial extent (km^2)

Degree of Loss	Importance			
	Very High	**High**	**Medium**	**Minor**
Very High (caused by footprint – 5.84 km^2)	Very High (0 km^2)	High (0 km^2)	Medium (0 km^2)	Minor (5.84 km^2)

The severity of habitat loss to the harbour and grey seal is assessed to be minor. Direct habitat loss will not interact with areas of pupping (haul-out sites) and therefore will not impact the most important areas for harbour and grey seals.

6.2.5. Habitat Change – Suspended Sediment and Sedimentation Construction Impact Assessment

6.2.5.1. Harbour porpoise and seals

FEHY 2013 predicts that 0.75 million m^3 of sediment will be spilled during the immersed tunnel construction phase. The broad scale sedimentation and suspended sediment pressure in relation to marine mammal habitat change is discussed within section 6.2. The sediment spill (suspended sediment) and deposition (sedimentation) changes are assessed in detail in FEHY (2013d). The studies undertook a numerical simulation of spreading of suspended concentration levels and sedimentation patterns. Results from the simulated spill concentrations have been compared with baseline conditions for suspended sediment concentrations.

Suspended sediment concentrations are presented as exceedance time (FEHY, 2013d). The exceedance time is the percentage of time when the concentration has been above a given value (e.g. 2 mg/l). In order to assess the order of magnitude of the excess concentrations relative to the background concentrations, key statistical parameters are compared; the exceedance times and the "fractiles". The 90% fractile (f_{90}) is the concentration in one single point which is exceeded 10% of the time. Fractiles and exceedance times have been calculated for the full dredging period.

The results show that generally the background concentrations are higher and the exceedance times are much longer than the excess concentrations from the sediment spill. All background fractiles are generally a factor five or more than the excess concentrations due to spillage. Similarly, all exceedance times for background concentrations are higher than the exceedance times due to spillage. The largest excess concentrations occur in the last months of 2015 and the first months of 2016 (winter). The largest excess concentrations at mid-water are seen in the Rødsand Lagoon where excess concentrations reach above 150 mg/l for short periods of time. Away from the Rødsand Lagoon and offshore of the coastal areas, excess concentrations are lower. Figure 6.2-32 shows that suspended sediment concentrations of 50 mg/l are exceeded along the alignment, at coastal areas and within Rødsand Lagoon, for less than 5% of the year, and 5-10% of the year in a very small area of Rødsand Lagoon.

In Rødsand Lagoon concentrations are predominantly the result of resuspension driven by hydrodynamic conditions. According to FEHY (2013d) the natural median concentration levels are above 2 mg/l. In windy periods many of the stations have background concentrations above 100 mg/l/. In shallow areas like the Rødsand Lagoon suspended sediment is a natural part of the water environment.

The sedimentation results show little or no sedimentation in the majority of the offshore area in the Fehmarnbelt away from the alignment. At the alignment sedimentation is seen to be about 1.5 cm deposition. The sedimentation originates from the coarser part of the spill (sand fraction) and will deposit within 200 – 600 m from the dredging operation. Deposition is also seen in the sheltered part of the Rødsand Lagoon up to 1cm deep.

The presence of surface and sub-surface elevated suspended sediment concentrations caused by dredging operations has the potential to reduce the ability of visual-feeding marine mammals to locate their prey resulting in an impact upon feeding success. As discussed in section 4.2 -harbour porpoise hearing and echolocation are adapted for navigation and foraging in conditions where vision is limited or absent (Kastelein et al., 2002), and seals successfully live and forage in turbid environment with their vibrissae (whiskers) playing an important role when faced with reduced visibility (Renouf, 1980). Modelling demonstrates that elevated levels of suspended sediment only occur for a small part (<5%) of the year and that all exceedance times for background concentrations are higher than the exceedance times due to spillage.

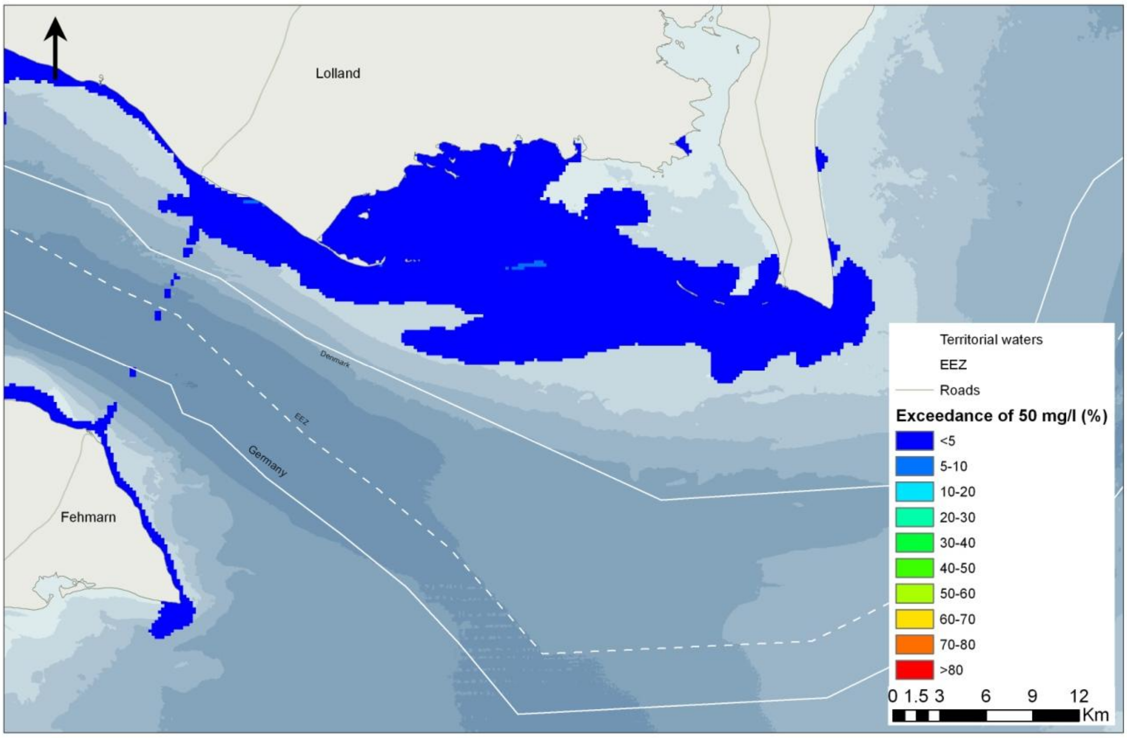

Figure 6.2-32 Exceedance time of 50 mg/l for full year 2015, depth averaged values

6.2.5.2. Degree of impact

There is **no impact** on the harbour porpoise and seal populations in the Fehmarnbelt study area from direct effects.

6.2.6. Food supply effects from habitat changes

6.2.6.1. Harbour porpoise

Harbour porpoises will not only be disturbed from the footprint, but may also be indirectly affected through reduced prey availability as a result of the sediment spill, which may impact the benthic fauna and also affect fish. Direct impacts of the sediment plume at the dredging sites are considered to be small and are assessed to be negligible for fish (FEBEC, 2013) and as such FEMM consider that there is no associated pressure to the harbour porpoises' food supply.

According to the impact assessment of marine fauna (FEMA, 2011c) the sediment spill leads to an impairment of the benthic communities over an area of 58,000 ha. However, the degree of impairment is mostly minor. Areas of very high and high magnitudes of pressure are restricted to areas close to the alignment or to shallow parts of the Fehmarnbelt due to resuspension of the spilled sediments. The latter areas are not important for harbour porpoises.

The sediment spill will lead to low impacts on the fish species which serve as food resource to harbour porpoises and other marine mammals. In calculating the impacts on fish, FEBEC based their assessment on 0.7 million m^3 of sediment being spilled from the construction of the immersed tunnel (FEBEC, 2013).

The severity of impairment of sediment spill from the construction of the immersed tunnel solution is assessed as minor for all fish indicators selected for the impact assessment (FEBEC, 2013). The only exception is egg and larvae drift among herring in the near zone of the 500 m corridor in the Danish territory and in the Lagoon of Rødsand. However, FEBEC 2013 concludes that no impacts are expected among fish and fish communities from the dredging activities related to the construction.

In the near zone (500 m) of the alignment, fish biomass will be reduced by up to 8% in the case of juvenile cod during the construction period with lower percentages for other species (Table 6.2-18). It should be noted that 10% of the near zone of the alignment is made from the footprint including harbours and land reclamation areas. There are thus only negligible reductions in fish abundance and biomass outside the footprint area. The footprint is already assessed in 6.2.4. Impacts outside the 500 m zone are very small and they are also expected to be very small within the 10 km zone on both sides of the alignment. It is thus concluded that impacts on the fish species that serve as food for harbour porpoises are low and only lead to negligible impacts outside the footprint area.

Table 6.2—17 Reduction (%) of the biomass of relevant fish species during construction and operation of an immersed tunnel in the local zone (10 km) and the near zone (500 m) to the alignment (data from FEBEC)

Species	Fish biomass reduction in the year (%)					
	2014	2015	2016	2017	2018	2019
Impairment area: Local zone 10 km						
Cod - juveniles	0,8	2,3	0,6	0,2	0,1	0,1
Cod – adults	0,1	0,4	0,1	0,0	0,0	0,0
Whiting – juveniles	0,2	0,7	0,2	0,1	0,0	0,0
Herring – juveniles	0,2	0,7	0,2	0,1	0,0	0,0
Herring – adults	0,1	0,4	0,1	0,0	0,0	0,0
Sprat – juveniles	0,2	0,7	0,2	0,1	0,0	0,0
Sprat – adults	0,1	0,4	0,1	0,0	0,0	0,0
Flatfish – juveniles	0,0	0,2	0,0	0,0	0,0	0,0
Flatfish – adults	0,0	0,0	0,0	0,0	0,0	0,0
Shallow water species – juveniles	0,0	0,4	0,2	0,1	0,0	0,0
Shallow water species – adults	0,0	0,4	0,2	0,1	0,0	0,0

Species	Fish biomass reduction in the year (%)					
	2014	2015	2016	2017	2018	2019
Impairment area: Near zone 500 m						
Cod - juveniles	3,9	27,4	23,1	21,3	21,5	21,4
Cod – adults	3,6	8,4	6,3	3,7	3,7	3,7
Whiting – juveniles	3,8	10,6	8,2	5,5	5,6	5,6
Herring – juveniles	1,4	3,3	0,9	0,1	0,2	0,1
Herring – adults	1,2	3,0	0,8	0,0	0,1	0,1
Sprat – juveniles	1,4	3,3	0,9	0,1	0,2	0,1
Sprat – adults	1,2	3,0	0,8	0,0	0,1	0,1
Flatfish – juveniles	1,7	21,8	21,5	21,2	21,2	21,2
Flatfish – adults	2,4	5,7	5,5	3,6	3,6	3,6
Shallow water species – juveniles	1,6	23,8	22,6	21,4	21,2	21,2
Shallow water species – adults	1,6	23,8	22,6	21,4	21,2	21,2

6.2.6.2. Seals

In relation to the substrate with strong association to harbour and grey seal feeding behaviour, these substrate areas are relatively widespread throughout the Fehmarnbelt area. Figure 6.2-33 shows that there is interaction of the impact footprint with areas of 'coarse sediment/boulders' and a small area of sand' that may be potential feeding areas for harbour seals. However, this interaction is very small in relation to the remaining substrate in the area that is available for feeding. Grey seals have been seen to forage over much greater distances in the Fehmarnbelt region. There is no interaction with any preferred 'mud' substrate. The area of interaction with 'sandy mud', is again small in relation to substrate available in their foraging range.

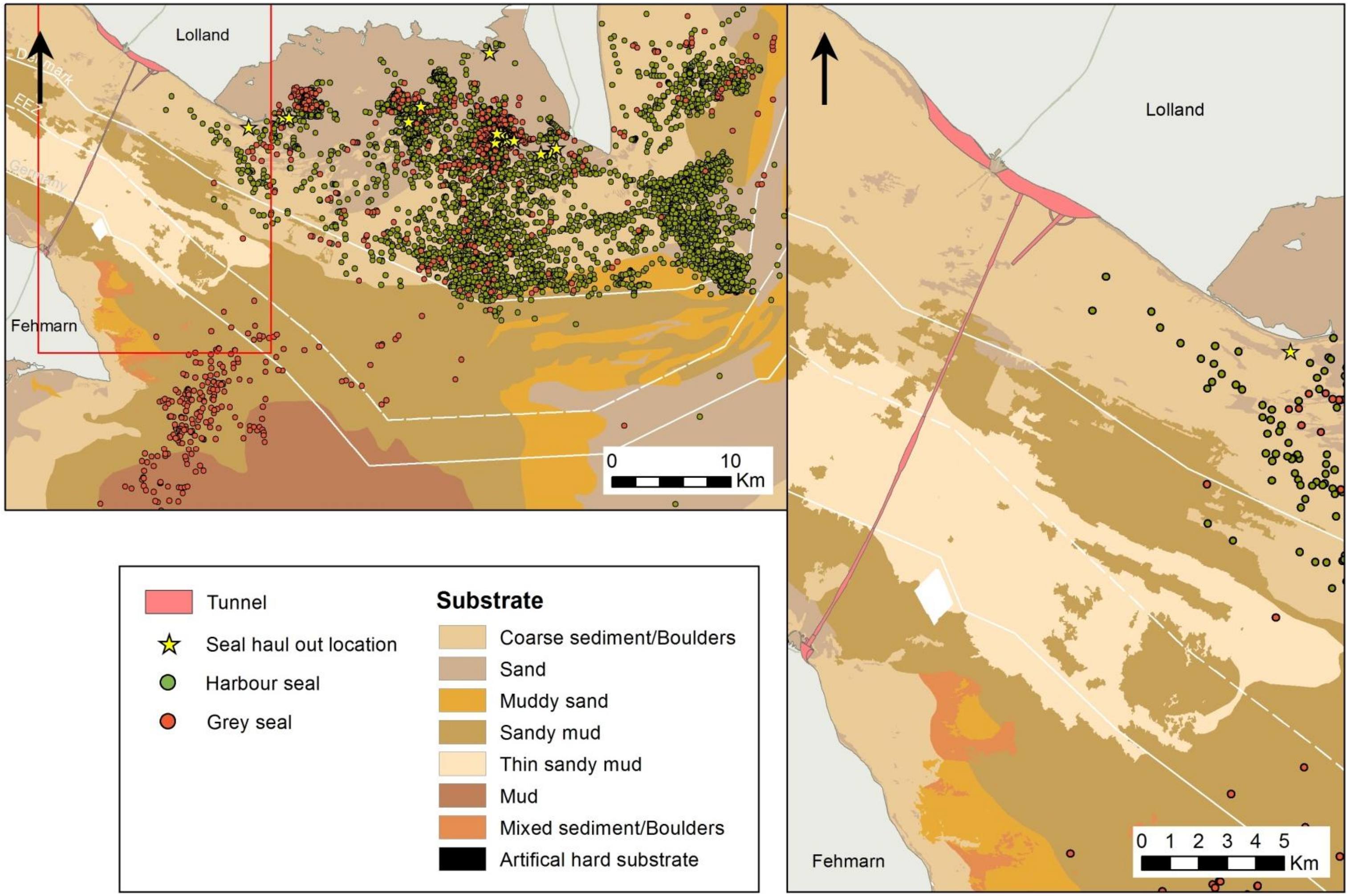

Figure 6.2-33 Severity of loss footprint in relation to substrate type and haul-out location, also showing baseline data of slow moving tagged seals.

6.2.6.3. Degree of impact

The degree of impairment of reduced food supply for marine mammals outside the footprint area is thus considered to be minor.

6.2.6.4. Severity of impact

The severity of impairment of reduced food supply for marine mammals outside the footprint area is thus considered to be minor.

6.2.7. Disturbance /barrier from construction vessels - construction impact assessment

6.2.7.1. Degree of Impact

The degree of impact in respect of a possible barrier effect caused by noise from dredgers has three dimensions: the noise level, the spatial extent and the temporal scale of the pressure.

This graduation in noise level follows the established noise criteria (section 3.5) with high to very high impact when noise levels exceed 160 dB re 1µPa²s SEL in 750 m distance to the sound source following the precautionary level from the German authorities. Medium impacts are expected when sound levels are high enough to cause behavioural disturbance (received SEL exceeds 150 dB re 1µPa²s (porpoises and seals) and minor impacts are defined when sound levels are high enough that some minor behavioural reactions might be expected (received SEL exceeds 144 dB re 1µPa²s (porpoises and seals).

The spatial scale is related to the number of dredgers working at the same time in a line at such a close distance to each other, that the noise levels overlap and form a closed noise field around the line of vessels. Highest degree of impact would be expected when the whole link is blocked by vessels working simultaneously. As the maximum number of dredgers working at the same time is about 8 vessels and maximum distance when noise levels decrease below 144 dB re 1µPa²s is about 870 m, the maximum length of a blocked area by dredgers would reach about 14 km if the distance between dredgers was around 1700 m. As described in chapter 6.2.2 dredging work will take place in seven sections. The maximum number of sections dredged at the same time will be three (G1, G2, G3) during construction week 61-72. Noise levels defined by the impact thresholds mentioned above are shown in Figure 6.2-34 for this situation. The figure shows that the worst barrier case on a spatial scale is about 5.2 km, which corresponds to ~30% of the line between Puttgarden and Rødby.

The temporal scale means the time span of how long dredging vessels remain in the area and possibly block the movement of animals. Highest degree of impact would be related to a permanent situation. This is, by definition, not possible to reach during construction as all works will be finite. The maximum time span for the scenario with spatially largest impacts when dredging works take place in sections G1, G2 and G3 (Table 6.2—3) is about 10 weeks.

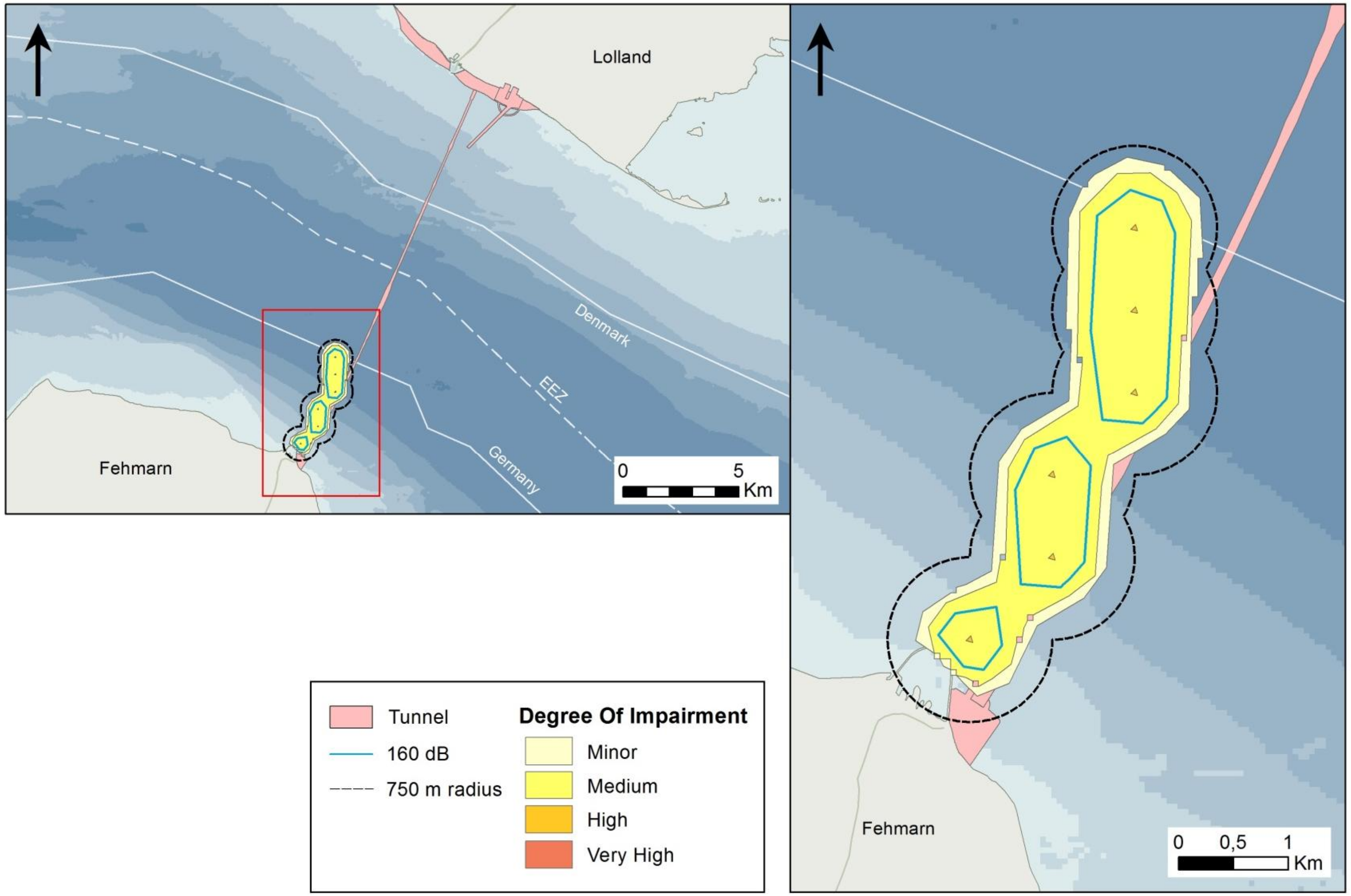

Figure 6.2-34 Noise levels from dredging vessels during construction week 61-72 defined by noise impact levels and degree of impairment.

As shown in Figure 6.2-34 noise levels beyond 160 dB re 1µPa²s defined as threshold of high magnitude overlap only partly even though all dredgers are working simultaneously. Although some animals are expected to avoid this area of high sound level, no absolute barrier effect would be expected and animals could still cross the area even within the working sections. Even with the worst case assumption that all animals avoid crossing the area when sound level exceeds 144 dB re 1µPa²s (= Minor DoI in Figure 6.2-34), a line with a length of approximately 5.2 km would be blocked for animals to cross from west to east and vice versa. Since 70% of the whole line between Puttgarden and Rødby will not be affected by any barrier, including the deep channel of the Fehmarnbelt, we expect that all animals that have the urge to cross the Fehmarnbelt from one side to the other will be able to do so. In order to avoid the sound levels emitted by the dredgers, the animals could be forced into a possible detour of a maximum of 5 km. It is not expected that this will hinder the animals' ability to pass through the Fehmarnbelt especially for migration to important areas (feeding/nursing/etc.). According to the assessment of significance there will be only **minor impacts** on marine mammals from a possible barrier effect.

6.2.8. Contaminants - construction impact assessment

As part of the baseline assessment for the Fehmarnbelt project an investigation into the seabed chemistry of the Fehmarnbelt Area was undertaken, including an assessment of the chemical risks of sediment suspension (FEMA, 2011b).

The Marine Soil – Baseline report (FEMA, 2011b) concludes that:

- Release of nitrogen is probably unproblematic
- An additional small source of phosphate will most likely not lead to higher primary production, or stimulate blooms of cyanobacteria
- Overall, the concentration of heavy metals and organic pollutants (HCB, DDTs, PCBs, PAHs, TBT) in surface sediments was low compared to the lower range of the German, Danish and OSPAR sediment quality guidelines
- Because the concentration of pollutants approaches background concentrations, the spread and release of organic pollutants connected to dredging can be considered as unproblematic
- Less than one metre below the surface, seabed sediments are of pre-industrial origin and therefore represent soil types with only natural occurrence of heavy metals
- Low concentrations of heavy metals in surface sediments (0 m to 1 m) and background levels at 1 m to 12 m depth mean that the spread and release of heavy metals connected to dredging must be considered as unproblematic
- Assuming a dredging rate of 20,000 m^3 per day and a spill rate of 3%, an average uptake of 93 kg of oxygen (63-181 kg of O_2) per day can be expected. Except for very local phenomena during calm periods, oxygen depression in the water column is not likely

In the Fehmarnbelt seabed chemistry study (FEMA, 2011b), the results of the chemical analyses were compared against the German and Danish national and OSPAR Action Levels for a range of chemical contaminants, including key components from the OSPAR & HELCOM primary and secondary lists. FEMA (2013b) concluded that the contaminant levels in the Fehmarnbelt study area were at or below the lowest sediment quality guideline (Action Level) at which the contaminant level is virtually certain to have no adverse effects. According to the assessment of significance no impacts on marine mammals are anticipated.

6.3. Operation

6.3.1. Description of associated operation activities

There are no offshore operation activities planned. All maintenance work will be conducted from inside the tunnel, so that no relevant maintenance activities with possible impacts on marine mammals are expected.

6.3.2. Description of pressures related to tunnel operation

With the operation of an immersed tunnel, a list of different (permanent) pressures on marine mammals can occur. These are either caused by operation activities or by the structure itself. Possible pressures are as follows:

A) Habitat change:

- Permanent changes through reclamation areas at Lolland and Fehmarn coastline necessary for the disposal of dredged material from the tunnel trench and to ensure a proper linking to each landfall
- Permanent changes through elevated protection layer (reef) at Lolland and Fehmarn coastline; seabed is locally raised to incorporate the protection layer of the tunnel over a distance of approximately 250 m from the proposed coastline
- Permanent changes through access channel to working harbour at Lolland. The channel has to be dredged down to 12 m water depth and will not be backfilled after construction. Part of the seabed will be deepened by almost 6 m depth and can be re-established naturally after construction. However, the time scale for the re-establishment is predicted to be more than 10 years on average (estimate provided by FEHY) and re-establishment is only possible for soft bottom not for hard bottom. Therefore the access channel is regarded as permanent habitat change
- Long-term temporary changes at dredged tunnel trench, outside NATURA 2000 area Fehmarnbelt DE1332-301. After lowering tunnel elements in the dredged trench and covering of elements with a stony protection layer, a trench of ~ 0.7 m depth and ~ 200 m width will be left open. The seabed can re-establish naturally after construction; the time scale for the re-establishment is predicted to be between 2–10 years on average (estimate provided by FEHY). Therefore this is regarded as temporary habitat change of long-term duration.

B) Noise

- Noise emission from the traffic passing through the tunnel into the water column.

Traffic noise is not expected to be completely absorbed by the foundation and therefore emitted permanently into the water column. Highest noise levels are expected during the crossing of trains as this traffic causes considerable vibration of concrete foundations.

Sound measurements carried out at the Drodgen tunnel (connecting Denmark and Sweden), just above and at 400 m distance, showed raised sound levels just above the tunnel (FEMM, 2011). At 400 m distance sound from the tunnel was still detectable, but did not add to the overall (broadband) noise level dominated by shipping. Above the tunnel peaks of low frequency sound (mostly in the range between 30 and 1000 Hz with a maximum at 50 Hz) at levels of 130 to 140 dB re 1µPa were measured that could be associated with train passages. While the sound emission from train passages is comparable with ship passages the train passage is much quicker and increases sound levels at one point for only 10 to 20 seconds while ship passages last for minutes. To ensure that the noise was originating from the trains, sea bottom vibrations were measured to show a frequency range of 100 Hz to 500 Hz which correlated well to the sound pressure level (FEMM, 2011).

If most of the traffic between Puttgarden and Rødby changes from ferry to the new fixed link, ferry services should be remarkably reduced. Since noise levels in the Fehmarnbelt area are clearly affected by the noise emitted from the loud ferry boats a reduction in background sound levels should be expected. In the case of simultaneous operation of the tunnel and the ferry service, noise levels in the direct vicinity of the tunnel can be slightly raised by train passages (FEMM, 2011) but at a distance of a few hundred metres it will stay the same.

The environmental pressures for marine mammals associated with the operation activities for the immersed tunnel described above are listed in Table 6.3—1.

Table 6.3—1 List of environmental pressures for marine mammals associated with the operation activities for the immersed tunnel.

Operation Activity	Pressure on Marine Mammals	Size in ha	Recovery time[2]
Permanent project structures offshore and coastal waters	Habitat loss from reclamation areas at Lolland and Fehmarn coastline	348.94	No recovery
	Habitat change at Lolland and Fehmarn coastline due to protection layer (reef)	12.29	No recovery
	Habitat change due to change in bathymetry for harbour access at Lolland	32.34	>10 years
	Habitat change at tunnel trench (outside Natura 2000 area)	126.75	2-10 years
	Habitat change in Natura 2000 area	32.34	>10 years
	Habitat change due to reconstructed harbours	14.46	<2 years
	In total	589.78	
Operation (Traffic)	Noise/Vibration	--	No recovery

6.3.2.1. Habitat Change - Habitat Loss

Reclamation areas will be constructed along both the German and Danish coastlines, using material from the tunnel trench; the material will be contained within containment dikes constructed with bunds of clay-till. The total area of loss is 3.63 km^2; this is comprised of 1.91 km^2 from the trench, 1.1 km^2 from the reclamation works at Lolland, 0.39 km^2 from the construction and dredging works at Lolland and 0.22 km^2 from the reclamation works at Fehmarn. At near-shore areas adjacent to Fehmarn and Lolland the seabed will be locally raised to incorporate the protection area over the tunnel at a distance of approximately 250 m from the proposed coastline, this will be a permanent loss of shallow (<10 m) bathymetry and inshore seabed habitat.

---

[2] The recovery times in Table 6.3—1 are taken from the "FEMA note as background for GIS files showing preliminary impact results_16SEP2011". FEMA based these conclusions on FEHY's data which refers only to the recovery times of the seabed. However, FEMA predicted that recovery times for benthic communities will take longer, but to date no specific times have been estimated.

Figure 6.3-1 shows the area of permanent habitat loss, as defined by the reclamation areas and elevated protection reef.

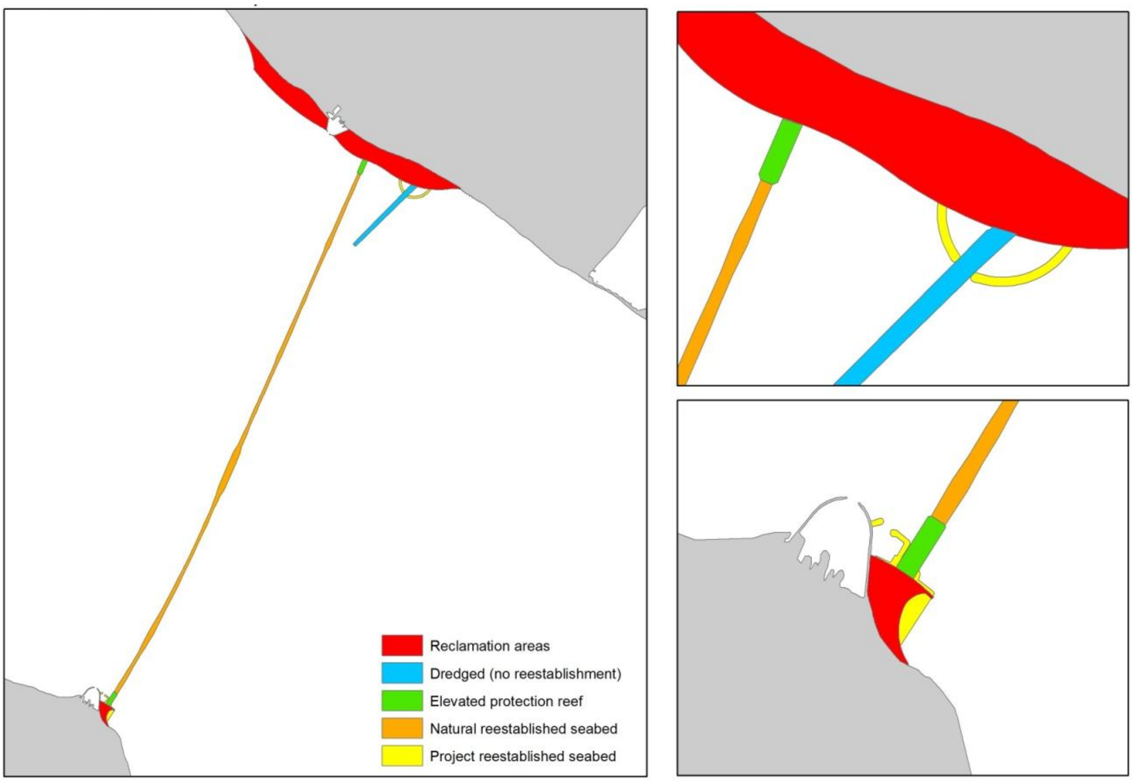

Figure 6.3-1 Footprint of habitat loss and change – permanent operational footprint

6.3.2.2. Habitat Change – Habitat Structure Change

The containment dikes are to be constructed approximately 600 m out from the coastline at a depth of MSL -4.5 m to MSL -6.5m (MSL = Mean Sea Level). The containment dikes will be constructed with bunds of clay-till, the seaward face of the dike is covered with geo-textile and two layers of rock. This will introduce new habitat substrate into these areas.

Once the tunnel element has been installed the trench will be backfilled with suitable materials and provide a cover layer for protection. For the surface protection layer, rock material will be used. The backfill and cover layer will not extend above the existing seabed level, except in the near-shore areas where the immersed tunnel connects with the landfall. The placement of rock material will introduce new habitat structure where the seabed previously consisted of sandy mud. The dredged channel at Rødbyhavn will not be artificially infilled, and will be allowed to naturally infill. This is expected to take as long as 30 years, and therefore is considered a permanent habitat change. Figure 6.3-1 shows the footprint of habitat change, as defined by the natural re-established seabed, project re-established seabed and dredged (no reestablishment) footprint.

6.3.2.3. Habitat Change - Hydrography

The presence of permanent structures and seabed/coastline changes can modify the hydrodynamics of the water column space that marine mammals occupy. The physical changes in structures or change in seabed/coastline can have a potential effect on the water level, currents, salinity, temperature and waves.

The permanent pressure elements for the hydrography include the reclamations at Lolland and Fehmarn, the protection reefs above the tunnel extending from the landfall to about 500 m offshore and the access channel to the production facility at Rødbyhavn which is planned to be left open for natural backfilling. The natural backfilling may take as long as 30 years in some parts and is therefore included as a permanent pressure. The potential impact on the water column has been assessed by FEHY using numerical modelling, the outputs are discussed further in section 6.3.5.

6.3.2.4. Barrier

There will be no barriers caused by the operation of the tunnel. Instead, ferry traffic will decrease by approximately 38,000 crossings reducing the physical presence of vessels in the area.

6.3.3. Noise operation impact assessment

The result of the noise and vibration measurements near the Great Belt Bridge (and tunnel) gave no evidence for the hypothesis that the tunnel serves as a significant additional source of underwater sound (FEMM, 2011). Noise emissions from passing trains will be low frequency and low intensity and are unlikely to disturb marine mammals. It is, therefore, not expected that marine mammals avoid the tunnel or are reluctant to cross over it because of underwater noise resulting from traffic in the tunnel.

Table 6.3—2 Definition of magnitude of pressure based on type, duration and range of pressure (Note: Durations during operation and by structures are in general set as 'permanent').

Pressure / impact	Type	Duration	Range	Magnitude
Noise emission by traffic in the tunnel				
The noise emission are comparable with shipping noise in the area and will locally increase sound pressure levels	Operation	Permanent	Local	Minor

6.3.4. Habitat Loss – Operation Impact Assessment

6.3.4.1. Degree of Impact

Physical loss will affect staging (occurrence) areas through the direct loss of water column or inter-tidal areas and disturbance due to vessel presence and dredging operations. The distribution of prey is an important factor in defining the distribution of marine mammals, loss of prey resource due to operational habitat loss will constitute a loss of feeding habitat.

The footprint of the tunnel project at the operation phase comprises in total 3.83 km^2 of marine areas (Table 6.3—3. This excludes the area of the of the tunnel trench (Table 6.2—13) which are not lost to marine mammals under operational conditions. The reclamation areas are planned to be located outside the breakwater constructions of the ferry harbours in Rødbyhavn (both sides of the harbour) and Puttgarden (east of the harbour) and cover mostly shallow water habitats. The larger reclamation area at Lolland, extending up to 4 km east and west of the ferry harbour, will cause a permanent loss of shallow water areas dominated by macroalgae (mainly Furcellaria; FEMA, 2011a) and Mytilus communities (FEMA, 2011a). These coastal areas are important habitats for shallow water fish communities composed of smaller species like gobies or sandeels. These areas are also suitable habitats for juvenile stages of other fish species, e.g. cod and flounder (FEBEC, 2013).

Table 6.3—3 Marine areas affected by habitat loss from the footprint of an immersed tunnel during the operation period

Footprint area	Size, km^2
Lolland harbour dredge trench (no re-establishment)	0.39
Land reclamation Lolland	3.22
Land reclamation and construction harbour Fehmarn	0.22
TOTAL	**3.83**

The footprint area in the reclamation areas is no longer suitable habitat for marine mammal function. Therefore, as habitat loss is defined to always result in a complete displacement of all marine mammals from the impact area, the degree of impact due to habitat loss is assessed to be very high.

6.3.4.2. Severity of Loss: Habitat Loss

The severity of loss is shown for the summer season only since this is the season when the harbour porpoise is the most abundant in the area. The impact is predicted to be lower in winter.

The severity of the habitat loss is determined by combining the degree of the physical loss with the importance of a spatial area for harbour porpoises or seals, as shown in Figure 6.3-2 and Table 6.3—4. The determination of areas of importance to harbour porpoises, harbour seals and grey seals is discussed in detail in section 3.5.1.2.

Table 6.3—4 Linking matrix for determining severity of loss and showing spatial extent (km^2)

Degree of impact (Loss / impairment)	Importance			
	Very High	High	Medium	Minor
Very High (caused by footprint – 3.83 km^2)	Very High (0 km^2)	High (0.13 km^2)	Medium (0.48 km^2)	Minor (3.22 km^2)

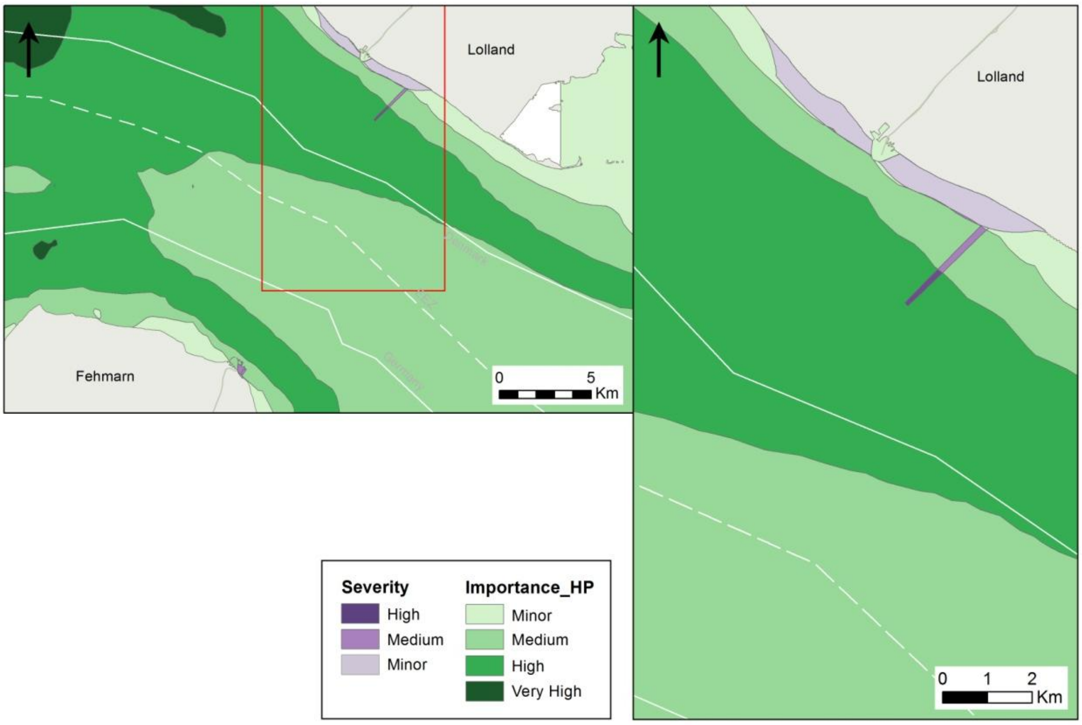

Figure 6.3-2 Severity of loss to harbour porpoises (based upon summer 2010 importance) at Lolland

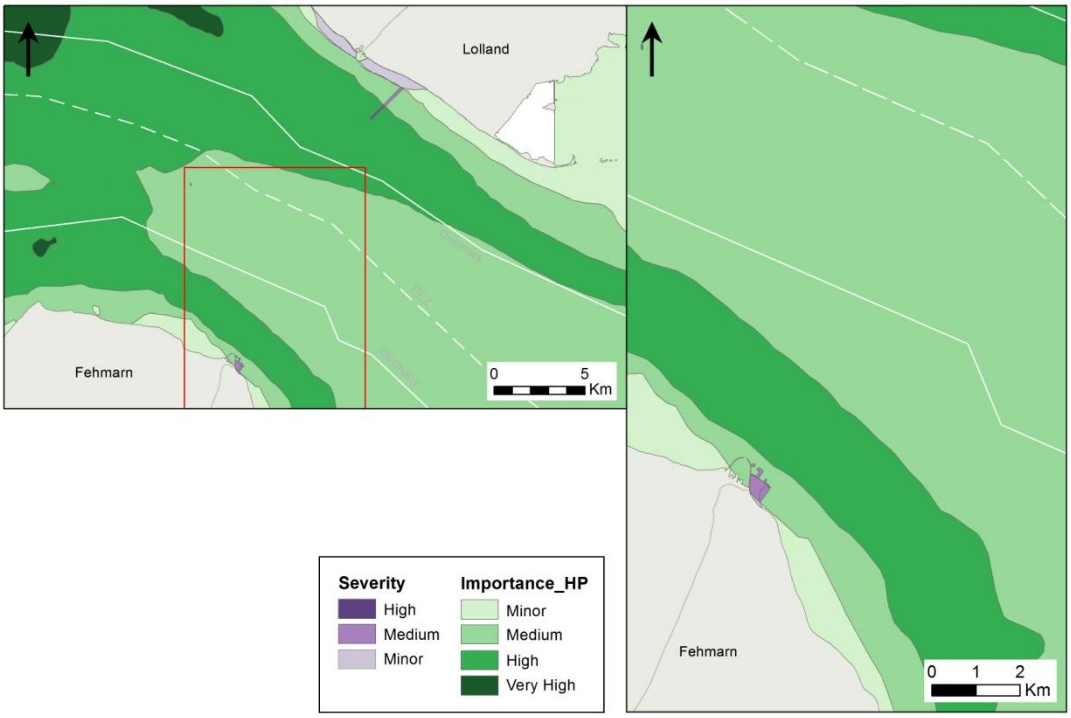

Figure 6.3-3 Severity of loss to harbour porpoise (based upon summer 2010 importance) at Fehmarn

As shown in Figure 6.3-2 this area of loss interacts with areas of high, medium and minor importance to the harbour porpoise based upon porpoise density. Figure 6.3-2 and Figure 6.3-3 shows in detail the differences between high, medium and minor severity of loss.

It is important to discuss the severity of loss in relation to the proportion of the harbour porpoise population that use the Fehmarnbelt region. The footprint of loss is presented in Table 6.3—5 with the percentage of the Fehmarnbelt region and the proportion of harbour porpoise affected. Table 2.1-1 within the baseline (FEMM, 2011) provides modelled abundance estimates, and the predicted summer 2010 abundance ranges from 1414 – 2709 harbour porpoises (based upon 95% CI).

Table 6.3—5 Proportion of Footprint in the Fehmarnbelt region and number of porpoises being affected (based on summer distribution).

Severity of Loss	Footprint	% of porpoise in Fehmarnbelt region	Number of porpoise affected
High	0.13 km^2	0.003%	0.09
Medium	0.48 km^2	0.010%	0.18
Minor	3.22 km^2	0.067%	0.54
Total	**3.83 km^2**	**0.079%**	**0.81**

The total footprint of loss is 3.83 km^2 and therefore only 0.08% of the Fehmarnbelt harbour porpoise study area is affected. The proportion of the porpoise population (based upon summer 2010 densities) that will be impacted by high, medium and minor severity of loss is presented in Table 6.3—5.

The relative areas of loss relate to areas of importance based upon abundance (and therefore defined as occurrence areas). This is represented by the relative number of porpoises affected by differing levels of habitat loss, in the area of high loss, higher numbers of porpoises are exposed to habitat loss. The function of the area as a migration corridor and nursing area cannot be spatially defined. Therefore, the loss of this function through habitat loss may apply to the total number of porpoises affected, i.e. 0.81 individuals. The total proportion of porpoises impacted equals to 0.04% of the local population.

Seals

The area of permanent physical loss is caused by land reclamation of coastal areas at Lolland and Fehmarn. As shown in Figure 6.3-5 this area of loss does not interact with any observed haul-out sites, or the general area of Rødsand Lagoon which is classified as being very high importance to harbour seals and high importance to grey seals. The areas outside Rødsand Lagoon are not breeding or pupping areas and are therefore of minor importance. The interaction between the footprint of loss and areas of minor importance results in a minor severity of loss. The footprint of loss is 3.83 km^2 and therefore 0.08% of the Fehmarnbelt seal study area.

Table 6.3—6 Linking matrix for determining severity of loss on Seals and showing spatial extent (km^2)

Degree of Loss	Importance			
	Very High	High	Medium	Minor
Very High (caused by footprint – 3.83 km^2)	Very High (0 km^2)	High (0 km^2)	Medium (0 km^2)	Minor (3.83 km^2)

The severity of habitat loss to the harbour and grey seal is assessed to be minor. Direct habitat loss will not interact with areas of pupping (haul-out sites) and therefore will not impact the most important areas for harbour and grey seals.

Habitat change caused by the permanent bathymetric change at coastal reclamation sites will have an indirect impact to the seals via the impact to prey resource (see chapter 6.3.5). .

6.3.5. Habitat Change – Hydrography – Operation Impact Assessment

6.3.5.1. Degree of Impact

Hydrodynamics and water structure are important factors in determining the distribution of harbour porpoises. The broad scale hydrographic pressure in relation to marine mammal habitat change is discussed within section 6.2.

The hydrographic changes due to the tunnel alternative are assessed in detail in FEHY (2013a) and FEHY (2013b). The assessed hydrographic changes include changes to the indicators current, water level, salinity, water temperature, stratification and waves. The main tool for the FEHY hydrography assessment is numerical modelling. The FEHY numerical models (MIKE and GETM), applied to assess the tunnel alternative in Fehmarnbelt and adjacent waters, operate at a horizontal grid resolution in the potential tunnel alignment area of 400-700 m offshore and 100 m near the coast. Since only hydrographic changes of similar or larger scales than the grid resolution are captured by the models, it is implied that very localised hydrographic changes with scales that are smaller than the grid resolution are not included in the FEHY hydrography assessment.

FEHY have assessed three scenarios: the 0-alternative (“ferry”), the tunnel only alternative (“tunnel”) and the combined ferry and tunnel alternative (“ferry+tunnel”). The results show that the differences in hydrographic changes related to the “tunnel” and “ferry+tunnel” scenarios are very limited (FEHY, 2013b). Therefore only changes related to the “ferry+tunnel” scenario are described here.

The change in current conditions due to the tunnel solution is assessed by FEHY in terms of the annual mean surface and bottom current speeds. These are limited to the areas in the vicinity of the two landfalls. In Figure 6.3-4 the permanent change in annual mean surface current speed as predicted by the MIKE model is shown. The permanent changes amount to a localised reduction in current of 0.02-0.06 m/s (up to 0.1 m/s very locally on the Fehmarn side). At the planned access channel to the production facility at Rødbyhavn, an increase in surface current speed of up to 0.08 m/s very locally is predicted. Outside the vicinity of the reclamations, the effects on current conditions are negligible. In the construction period the temporary work harbour at Fehmarn and the production facility and its breakwaters at Lolland will impose additional local changes to the current conditions. In the lee of the breakwaters of the production facility the current speed is reduced additionally, but elsewhere an effect similar to the permanent effect is predicted.

In order to evaluate the changes in current conditions, it may be useful to compare them to the natural variability in the current conditions in Fehmarnbelt. The natural variability of the current speed in Fehmarnbelt is presented in FEHY (2013b) in terms of the mean and standard deviation of measured current speed in the FEHY main station 02. The surface and bottom mean current speed for 2009-2010 was 0.41 m/s and 0.13 m/s, respectively, and the corresponding surface and bottom standard deviation was 0.23 m/s and 0.09 m/s, respectively. Thus, the estimated changes in currents for the tunnel solution are negligible in comparison to the natural variability found in Fehmarnbelt.

With respect to water level, salinity, water temperature and stratification, the permanent changes and changes during the construction period are predicted by FEHY to be negligible (mean water level change <0.0001 m; mean salinity change <0.2PSU; mean temperature change <0.05°C; mean stratification change <0.04 kg/m^3). With respect to waves, permanent changes and changes during construction are only seen in the immediate vicinity of the reclamations and appear mostly as lee effect on the eastern side of the reclamations. At the access channel a slight tendency to increased waves is predicted.

The hydrological impacts are localised and lie within <50% of the natural change (standard deviation as defined within FEHY (2013b). The results of the baseline study demonstrated that hydrodynamic variables do not act as key factors governing the distribution of harbour porpoises, harbour seals or grey seals in the Fehmarnbelt area.

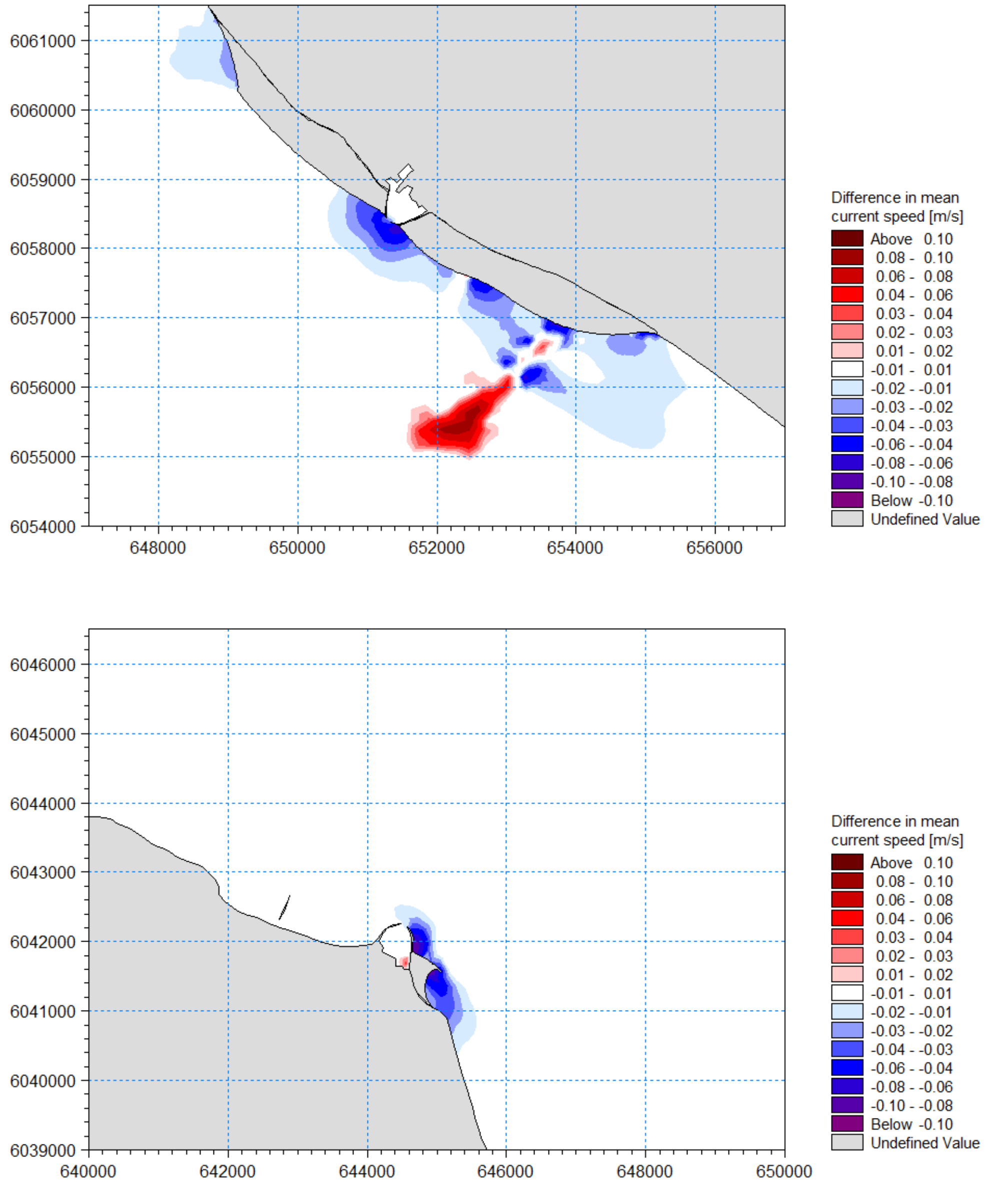

Figure 6.3-4 Modelled effect of "ferry+tunnel" scenario on annual mean surface current speed at the Lolland side (upper panel) and at the Fehmarn side (lower panel) (FEHY, 2013b).

Hydrodynamic variables may also be relevant to harbour and grey seals in relation to prey distribution. The FEBEC (2013) assessment indicates potential sensitivity of fish species to hydrological fluctuations, with eggs and larval stages being the most sensitive. FEBEC (2013) assessed the effects of hydrological pressure to fish communities in the Fehmarnbelt and local areas as insignificant. Therefore no variations in prey distribution due to the hydrological effects of the immersed tunnel solution are expected.

The hydrological impacts are considered to be localised and within natural variability of the area, and will not affect prey fish species, so there will be **no impact** on marine mammals and this conclusion forms our assessment of significance**.**

6.3.6. Food supply effects from habitat changes

6.3.6.1. Harbour porpoises

Harbour porpoises will be indirectly disturbed by the coastal due to the disturbance of benthic fauna and of pelagic (fish) species which will reduce the prey availability to porpoises. Preliminary studies by FEMA identify a range from minor to very high severity of impairment with both a permanent and temporary loss of benthic fauna over a combined area of 4.76 km^2. The preliminary studies by FEBEC identify that the physical loss of habitat will cause a minor severity of impact on the relevant harbour porpoise prey species; cod, herring and sprat. Studies have shown a predominance of herring, sprat, cod and gobies in the diet of the Baltic porpoise, however there is a considerable variation in the overall diet of porpoise within the Baltic and adjacent regions (Lick, 1991;Santos & Pierce 2003; Benke & Siebert, 1996; Malinga & Kuklik, 1996; Malinga et al., 1997, Nabe-Nielsen et al., 2010).

6.3.6.2. Seals

Substrate with strong associations to harbour and grey seal feeding behaviour is relatively widespread throughout the Fehmarnbelt area. Figure 6.3-5 shows that there is a small interaction of the impact footprint with areas of ‘coarse sediment/boulders’ and ‘sand’ that may be potential feeding areas for harbour seals. However, this interaction is very small in relation to remaining substrate in the area that is available for feeding. Grey seals have been seen to forage over much greater distances in the Fehmarnbelt region, and there is no interaction with any preferred substrate.

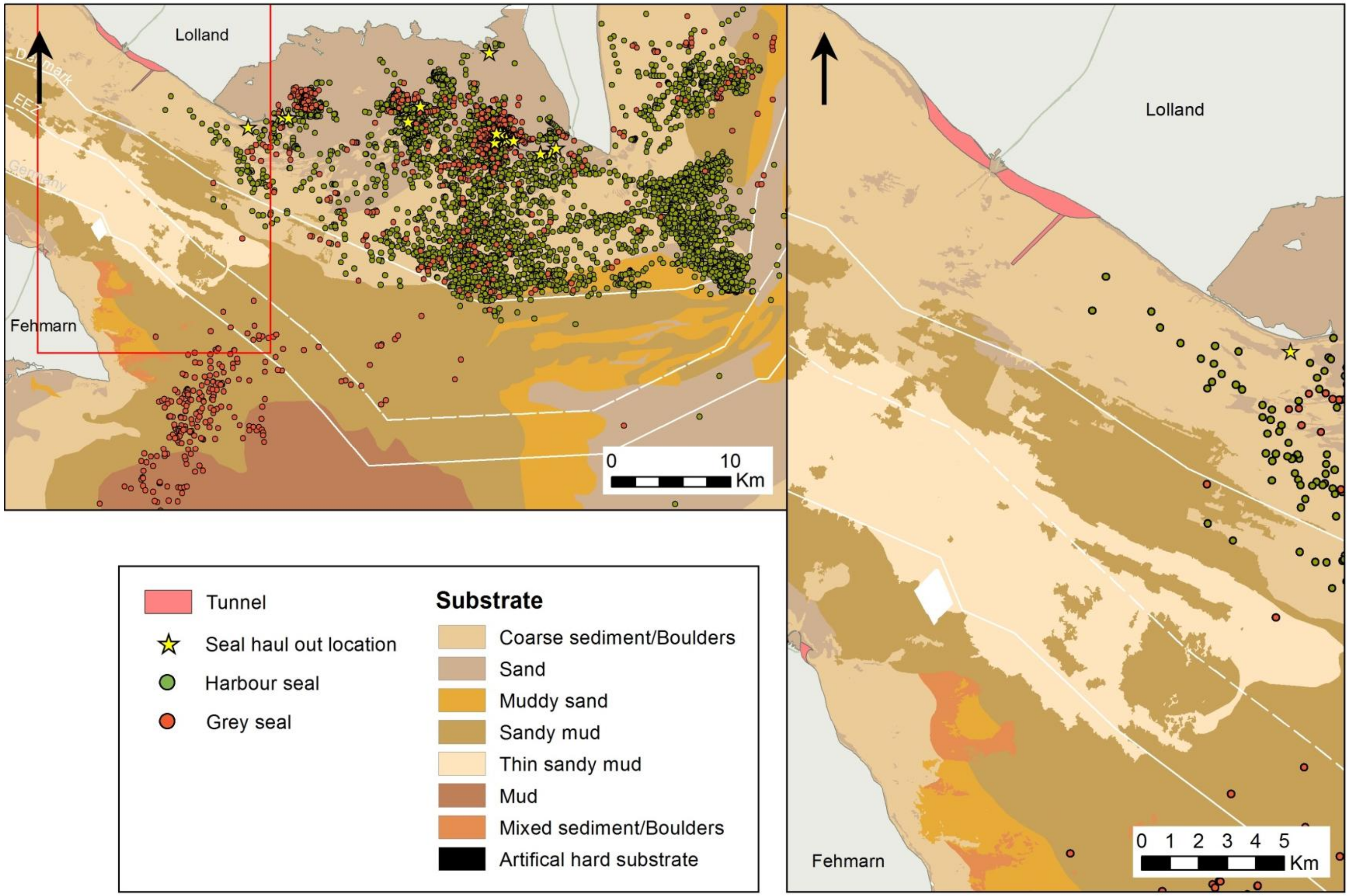

Figure 6.3-5 Tunnel footprint in relation to substrate type and haul out location, also showing baseline data of slow moving tagged seals.

6.4. Overall assessment of severity

Table 6.4—1 Summary of severity of impact for marine mammals from the construction of the immersed tunnel

Pressure	Severity of impact			
	Harbour porpoises		Harbour seal	Grey seal
	Winter	Summer		
Noise from dredging		High 0.00		
	Medium 0.63	Medium 1.92		
	Minor 0.64	Minor 0.95	Minor	Minor
Noise from piling	Medium 0.08	Medium 1.26		
	Minor 1.08	Minor 2.18	Minor	Minor
Habitat loss - direct	High 0.60		Minor	Minor
	Medium 0.60			
	Minor 0.56			
Habitat change (all pressures)	Minor		No impact	No impact
Food supply effect from habitat change (indirect effect)	Minor		Minor	Minor
Barrier effects	Minor		Minor	Minor
Contaminants	No impact		No impact	No impact

Table 6.4—2 Summary of severity of impact for marine mammals from the operation of the immersed tunnel

Pressure	Severity of impact		
	Harbour porpoise	Harbour seal	Grey seal
Noise from operation	Minor QA	No direct impact	No direct impact
Habitat loss - direct	High 0.09 Medium 0.18 Minor 0.54	Minor	Minor
Habitat change (all pressures)	Minor	No impact	No impact
Food supply effect from habitat change (indirect effect)	No impact	No impact	No impact
Barrier effects	No impact	No impact	No impact
Contaminants	No impact	No impact	No impact

6.5. Determination of significance – immersed tunnel

The methods for determining significance described in section 3.5.3 have been applied to the assessment of the impacts on marine mammals from the construction and operation of the immersed tunnel.

6.5.1. Construction Noise – harbour porpoise

Overall, on average, only a few individual porpoises (2.43 to 6.30) will be affected in winter and summer, taking both dredging and piling into account. The obtained values correspond to between 0.26% of the local population abundance in winter and 0.30% of the local population (Fehmarnbelt study area) abundance in summer. The harbour porpoise population of the Kattegat, Belt Sea and Inner Baltic Sea was estimated at 23,227 during the SCANS II survey, and with a maximum disturbance of 6.30 porpoises, this equates to an impairment of 0.03% of the Baltic subpopulation. The effect is therefore **insignificant** (<1% of both the Fehmarnbelt study area population and the Baltic population).

6.5.2. Construction Habitat loss – harbour porpoise

Overall, a total of 1.76 porpoises will be affected by habitat loss, using the most precautionary scenario of summer construction works. This value corresponds to 0.08% of local population abundance in summer. The harbour porpoise population of the Kattegat, the Belt Sea and Inner Baltic Sea was estimated at 23,227 during the SCANS II survey, and with a maximum disturbance of 1.76 porpoises, this equates to an impairment of 0.007% of the Baltic subpopulation. The effect is therefore **insignificant** (<1% of both the Fehmarnbelt study area population and the Baltic population).

6.5.3. Operation Habitat Loss – harbour porpoises

Overall, a total of 0.81 porpoises will be affected by habitat loss during the operational stage, using the most precautionary scenario of summer construction works. These values correspond to 0.04% of local population abundance in summer. The harbour porpoise population of the Kattegat, Belt Sea and Inner Baltic Sea was estimated at 23,227 during the SCANS II survey, and with a maximum disturbance of 0.81 porpoises, this equates to an impairment of 0.003% of the Baltic subpopulation. The effect is therefore **insignificant** (<1% of both the Fehmarnbelt study area population and the Baltic population).

6.5.4. Food supply - harbour porpoise, harbour seal and grey seal

The immersed tunnel option would lead to no impacts on fish outside the footprint area and thus no effects due to changes in food supply are predicted for marine mammals.

6.5.5. All other pressures - harbour porpoise, harbour seal and grey seal

For all other pressures no impact was identified in the impact assessment for marine mammals so effects are judged to be **insignificant** (i.e. <1% of the harbour porpoise Fehmarnbelt study area population and <10% of pup production).

6.5.6. Overall assessment of significance

In all cases the FEMM impact assessment has shown minor impacts which are unlikely to cause physical impairment to marine mammals. However, a low number of individuals would be disturbed by construction activities of the immersed tunnel option. Even with a maximum impact, only a small number of porpoises (6.30 for construction noise, 1.76 for habitat loss (construction) and 0.81 for habitat loss (operation)) are affected. The worst case would be to assume that different porpoises are affected by these three impacts so in total a maximum of 8.87 porpoises may be impacted at a time. This equates to 0.43% of the local Fehmarnbelt summer population or 0.038% of the population of the Kattegat, the Belt Sea and Inner Baltic Sea. Although the construction activities would commence for several years, the overall effect is insignificant (<1% of both the Fehmarnbelt study area population and the population of the Kattegat, Belt Sea and Inner Baltic Sea. Even if the same porpoises were exposed to all pressures associated with the immersed tunnel, these are not considered by FEMM to be at levels that would be detrimental to the long-term fitness of the animal.

6.6. Assessment of strictly protected species (Article 12 Habitats Directive)

There needs to be a decision, determining whether any of the pressures described in the chapters above may lead to a violation of the objectives of Article 12 of the Habitats Directive as outlined in section 3.6.

6.6.1. Deliberate capture or killing of specimens, including injury

Of the pressures described in the chapters above, only underwater noise could potentially cause injury to harbour porpoises. All other pressures may only affect harbour porpoises indirectly by affecting their natural habitat and are thus not treated in the assessment of strictly protected species.

Noise levels predicted for the construction of an immersed tunnel are associated with dredging activities, shipping and pile driving:

6.6.1.1. Underwater noise from dredging and shipping

Noise levels predicted for dredging and shipping activities are in the range of usual shipping noise which occur regularly in the area and are too low to cause any form of injury or even temporal impairment of hearing abilities. Noise levels of the dredgers are described in Chapter 6. In contrast to most shipping noise, dredging also contains considerable amounts of high frequency sound of 40 kHz and above and can reach source levels of 184 dB re 1µPa (Robinson et al., 2011). Sound pressure levels fall below 160 dB at a distance of 456 m to the source and the German threshold for underwater noise emissions of 160 dB SEL at a distance of 750 m is not exceeded. The construction vessels with a SL of 175 dB re 1µPa, which is nearly 10 dB lower than the TSHD, were not modelled since the contribution of these extra sound sources is negligible.

The noise emissions lead to medium and minor impairment and cause disturbance at a maximum range of 870 m. As the noise emitted from the dredgers, and other ships is continuous and no high and impulsive noise emissions will occur, harbour porpoises can easily avoid the small range of high noise levels.

6.6.1.2. Underwater noise from sheet piling

Sheet piling during the construction of harbours on Lolland and Fehmarn will be carried out by vibro-piling with low energy (40 kN). Noise emission from sheet piling will be comparably low but has been estimated with a source level of 190 dB re 1µPa as a worst case scenario. Sound pressure levels fall below 160 dB at a distance of 653 m to the source and the German threshold for underwater noise emissions of 160 dB SEL at a distance of 750 m is not exceeded. The piling of the sheets may require the application of deterrents to avoid porpoises remaining in the direct vicinity of the construction work. Such devices have proven to be highly efficient and will deter porpoises out of the small area where there is a very high degree of impairment (Brandt et al 2011).

It is thus concluded that construction work will not lead to killing or injuring of harbour porpoises and that the obligations of Article 12 habitat directive are not violated by the project.

6.6.2. Deliberate disturbance

Noise emissions from construction activities lead to small-scale disturbance. Disturbance from individual construction vessels is estimated to reach no further than 500 m. According to the predicted noise levels from dredgers, disturbance of harbour porpoises will occur at a range of a few hundred meters, depending on prevailing ambient noise levels. Most construction activities will occur in areas which are subject to high shipping intensities and have high ambient noise levels. The number of harbour porpoises which will be exposed to medium or minor noise levels from dredging or other shipping activities will be very low and the disturbance will be of similar type and duration as experienced by the animals regularly from other shipping activities in the area. It is thus concluded that the disturbance will not cause a displacement of a significant proportion of harbour porpoises. No specific impacts regarding the function of the area for breeding, rearing or migration are expected and it is concluded that the overall function of the Fehmarnbelt area for harbour porpoises will not be affected by the project.

Noise emissions from piling at the construction harbours will affect a larger area, but will be of limited duration. The total number of porpoises exposed to noise levels which may lead to disturbance is very low. From other studies it can be inferred that the recovery time to noise levels below 160 dB re 1µPa is very short.

It is thus concluded that construction work will not lead to significant disturbance of the local population of harbour porpoises in the Fehmarnbelt area and that the obligations of Article 12 habitat directive are not violated by the project.

6.7. EU Marine Strategy Framework Directive and Water Framework Directive

Implications for the assessment of the impacts on marine mammals as a result of the EU Marine Strategy Framework Directive (MSFD) and improvements to marine water quality as a result of the Water Framework Directive (WFD) are not quantifiable at the moment. However, FEMM concludes that the principles of the MSFD and WFD (e.g. underwater noise and contaminants) are implicit in the assessment criteria applied in this impact assessment.

6.8. Mitigation

The impacts from the construction and operation of the immersed tunnel are summarised in section 6.4. The impacts can be broadly summarised as affecting relatively low numbers of marine mammals.

The largest effects on marine mammals from the immersed tunnel are from the noise associated with the construction activities. Section 6.2.3.2 shows that a maximum of 6.22 porpoises are potentially disturbed by noise from the dredging, fill and piling operations, however, no physiological impacts are predicted.

For all scenarios, there is at present no indication that threshold levels for underwater noise are exceeded, thus no noise mitigation is regarded as necessary. However, it is noted that the German authorities require the use of standard deterring devices (pinger, seal-scarer) before piling starts to prevent marine mammals approaching the near zone of the piling operations.

6.9. Cumulative impacts - immersed tunnel

This section describes the probable and significant cumulative impacts of the fixed link in conjunction with other projects.

6.9.1. Included projects and possible interactions

When more projects within the same region affect the same environmental conditions at the same time, there are cumulative impacts. Cumulative impacts are considered, if the following criteria are fulfilled

The project:

- is within the same geographic area
- has some of the same impacts as the fixed link
- affects some of the same environmental conditions
- creates new environmental impacts during the period from when the environmental investigations were completed to the fixed link being operational.

The following projects at sea are considered relevant to include in the assessment of cumulative impacts on different environmental conditions (Table 6.9—1). All of them are offshore wind farms:

Table 6.9—1 Summary of relevant offshore windfarms

Project	Placement	Phase	Possible interactions
Arkona Becken Südost	Northeast of Rügen	Construction	Sediment spill, displacement, collision risk, barrier effect
EnBW Windpark Baltic II	Southeast of Kriegers Flak	Construction	Sediment spill, displacement, collision risk, barrier effect
Wikinger	Northeast of Rügen	Construction	Sediment spill, displacement, collision risk, barrier effect
Rødsand II	In front of Lolland's southern coast	Operation	Coastal morphology, collision risk, barrier effect
Kriegers Flak II	Kriegers Flak	Construction	Sediment spill, displacement, collision risk, barrier effect
GEOFReE	Lübeck Bay	Construction	Sediment spill, displacement, collision risk

Rødsand II (Figure 6.9-1) is specifically included, as this is a project that went into operation, while Femern A/S conducted its environmental investigations, whereby a cumulative effect in principle cannot be excluded.

The status of these projects is an important consideration in the assessment of cumulative effects. The proposed construction schedule for the immersed tunnel is between January 2015 and the end of 2020. Therefore, the direct construction cumulative impacts from the immersed tunnel will only become an issue if the construction schedules for the not yet constructed projects overlap. However, given the minor and insignificant impacts identified in the FEMM impact assessment this is determined to be of low importance.

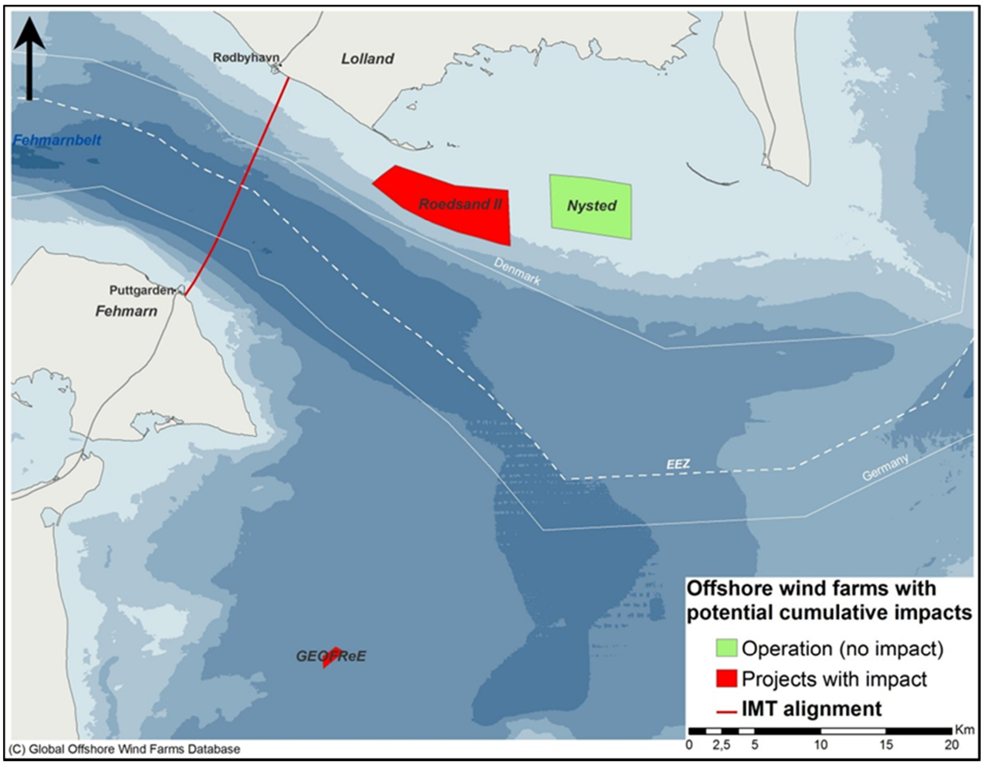

Figure 6.9-1 Locations of Rødsand II, Nysted and GEOFreE

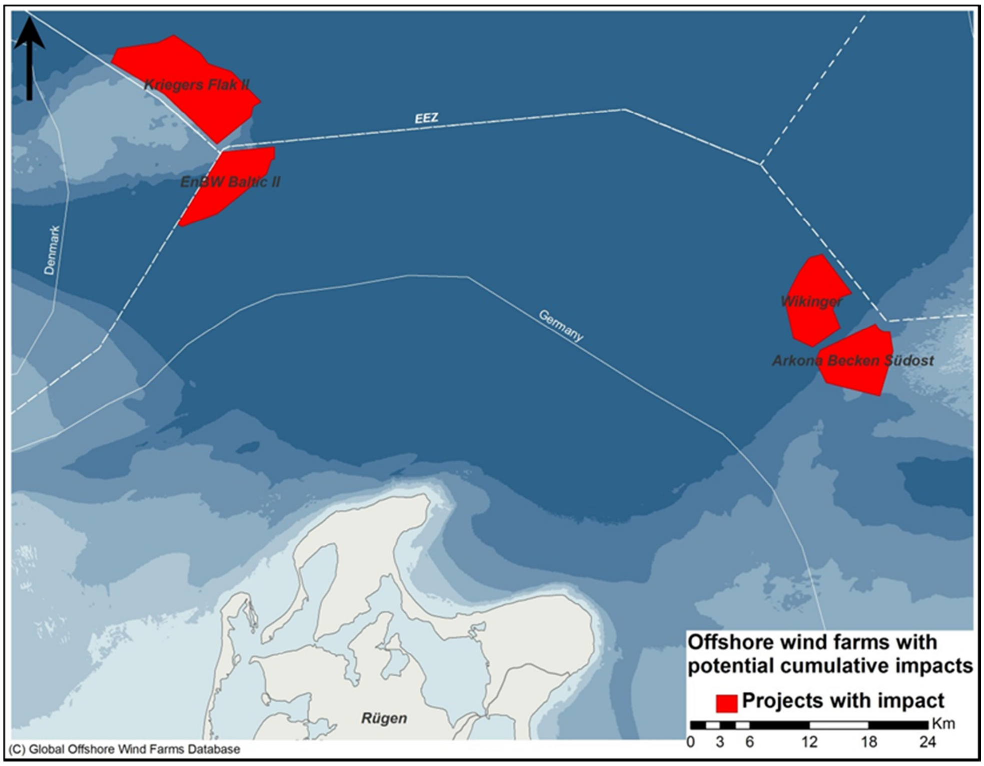

Figure 6.9-2 Locations of Kriegers Flak II, EnBW Baltic II, Wikinger and Arkona Becken Südost

All impacts from the immersed tunnel construction and operation have been shown to be local in extent (i.e. within a range of 500 m and 10 km). The nearest other project to the Fehmarnbelt fixed link is the Rødsand 2 offshore wind farm. With over 10 km of distance between the tunnel and the wind farm the physical footprint of the projects and the potential zones of impact do not overlap.

Noise

Noise emissions from pile driving during the construction of steel foundations for offshore wind farms may disturb harbour porpoises over a range of up to 20 km but for a short period only (Brandt et al. 2011). This range will be reduced, however, by noise mitigation measures which have to be applied for the German projects as a condition of the granted permits. Cumulative impacts of offshore wind farm construction and the noise emissions of a fixed link through Fehmarnbelt are expected to be negligible for the following reasons:

- There is no spatial overlap of disturbance zones
- Noise emissions from construction work in Fehmarnbelt only have local impacts (the highest noise levels from pile-driving attenuate to ambient levels within 1.1 km of the source).
- Noise emissions from the approved offshore wind farm projects will only affect few porpoises as the wind farms are located outside the main distribution range of the porpoises occurring in the Fehmarnbelt area (identified in this study).

No impacts are to be considered for the construction of the Rødsand 2 wind farm, which has already been constructed on gravity foundation and no relevant impacts during its operation are predicted to occur.

This impact assessment concluded that there would be no impact on harbour and grey seal breeding and pupping grounds. Cumulative effects for noise associated with other projects can therefore be discounted for harbour and grey seals.

Habitat loss

Harbour porpoise habitat losses from the construction and operation of the immersed tunnel have been assessed as minor and no relevant cumulative effects from offshore wind farms are predicted in this respect. This impact assessment has also calculated that harbour and grey seal habitat losses do not interact with areas of pupping (haul-out sites) and will therefore not impact the most important areas for seals (Rødsand). Due to the near zone (±500 m) scale of these effects cumulative impacts with other projects are calculated as minor for marine mammals because they will lead to loss of habitat for a biologically unimportant proportion of the Belt population of seals and porpoises.

Habitat change

Direct effects on marine mammals from habitat changes (increased suspended sediments, sedimentation and hydrographic changes) have been demonstrated in this impact assessment to be of negligible severity. The direct cumulative effects for habitat change associated with other projects can therefore be discounted.

Indirect effects on marine mammals from habitat changes (changes to food supply) have been derived from FEBEC (2013). FEBEC (2013) suggests a minor impact on fish from the construction and operation of the immersed tunnel. This leads FEMM to conclude a minor or negligible impact on marine mammals from changes in food supply, where a biologically unimportant proportion of the Belt population of seals and porpoises is affected. The indirect cumulative effects for habitat change associated with other projects can therefore be discounted.

Contaminants
Based on the FEMA and FEHY consortia assessments the FEMM impact assessment concludes that the severity of contaminant impacts from the immersed tunnel construction and operation are negligible. Cumulative effects for contaminants associated with other projects can therefore be discounted.

Barrier effects
Based on the noise modelling in this impact assessment no evidence of barrier effects on marine mammals from the construction and operation of the immersed tunnel have been identified. Cumulative effects of barriers from other projects can therefore be discounted.

Cumulative impact conclusions
For the noise pressures associated with the tunnel construction a minor impact for harbour porpoise is assessed and no relevant cumulative impacts from approved offshore wind farm projects are predicted. This impact assessment concludes that there is no impact on harbour and grey seal breeding and pupping grounds from underwater noise. For habitat loss no relevant cumulative impact are predicted for marine mammals. For all other pressures (habitat change, contaminants and barrier effects) this impact assessment concludes that there are no cumulative impacts on marine mammals.

6.10. Trans-boundary impacts - immersed tunnel

The impacts from construction and operation of an immersed tunnel lead to mainly temporal impacts which do not reach beyond the German-Danish study area and thus in the case of marine mammals no trans-boundary impacts occur. As the migration behaviour of marine mammals is assessed to be only impaired at minor severity no impacts on distant sub-populations of the three species occurring in Fehmarnbelt ensue. Thus, in the case of marine mammals, no trans-boundary impacts will transpire.

6.11. Decommissioning

Decommissioning is foreseen to take place in the year 2140, when the fixed link has been in operation for the design lifetime of 120 years. Whilst there is a detailed schedule of works for decommissioning of the tunnel it is only the subsea components that have the potential to affect marine mammals and which are assessed in this impact assessment.

6.11.1. Tunnel sections

The tunnel elements will remain under the seabed. The near shore components of the tunnel will be filled with inert material from other parts of the decommissioning programme. These filling activities will take place from land and as such there are no impacts on marine mammals.

6.11.2. Reclamation areas

The reclamation areas are designed to remain in place as permanent features and as such will not be decommissioned. There are no impacts on marine mammals.

All other decommissioning activities for the tunnel do not take place in the marine environment and as such will have no effect on marine mammals.

7. ASSESSMENT OF IMPACT – CABLE-STAYED BRIDGE

7.1. Project description

The alignment for the marine section passes east of Puttgarden harbour, crosses the belt in a soft S-curve and reaches Lolland, east of Rødbyhavn.

7.1.1. Bridge concept

The main bridge is a twin cable-stayed bridge with three pylons and two main spans of 724 m each. The superstructure of the cable-stayed bridge consists of a double deck girder with the dual carriageway road traffic running on the upper deck and the dual track railway traffic running on the lower deck (Figure 7.1-1). The pylons have a height of 272 m above sea level and are V-shaped in a transverse direction. The main bridge girders are made up of 20 m long sections with a weight of 500 to 600 tonnes. The standard approach bridge girders are 200 m long and their weight is estimated to be approximately 8,000 tonnes.

Caissons provide the foundation for the pylons and piers of the bridge. Caissons are prefabricated and placed 4 m below the seabed. If necessary, soils are improved with 15 m long bored concrete piles. The caissons in their final position extend 4 m above sea level. Prefabricated pier shafts are placed on top of the approach bridge caissons. The pylons are cast in situ on top of the pylon caissons. Pier protection works are prefabricated and installed around the pylons and around two piers on both sides of the pylons. These works protrude above the water surface. The main bridge will be connected to the coasts by two approach bridges. The southern approach bridge is 5,748 m long and consists of 29 spans and 28 piers. The northern approach bridge is 9,412 m long and has 47 spans and 46 piers.

Figure 7.1-1 Photomontage of cable-stayed bridge

7.1.2. Land works

A peninsula is constructed both at Fehmarn and Lolland to use the shallow waters east of the ferry harbour breakwater to shorten the Fixed Link Bridge between its abutments. The peninsulas consist partly of a quarry run bund and partly of dredged material and are protected towards the sea by revetments of armour stone.

7.1.2.1. Fehmarn

The peninsula on Fehmarn is approximately 580 m long, measured from the coastline (Figure 7.1-2). The gallery structure on Fehmarn is 320 m long and enables a separation of the road and railway alignments. A 400 m long ramp viaduct bridge connects the road from the end of the gallery section to the motorway embankment. The embankments for the motorway are 490 m long. The motorway passes over the existing railway tracks to Puttgarden Harbour on a bridge. The profile of the railway and motorway then descend to the existing terrain surface.

7.1.2.2. Lolland

The peninsula on Lolland is approximately 480 m long, measured from the coastline. The gallery structure on Lolland is 320 m long. The existing railway tracks to Rødbyhavn will be decommissioned, so no overpass will be required. The viaduct bridge for the road is 400 m long. The embankments for the motorway are 465 m long and for the railway 680 m long. The profile of the railway and motorway descends to the natural terrain surface.

Figure 7.1-2 Photomontage of cable-stayed bridge landfall at Fehmarn

7.1.3. Drainage on main and approach bridges

On the approach bridges the roadway deck is furnished with gullies leading the drain water down to combined oil separators and sand traps located inside the pier head before discharge into the sea.

On the main bridge the roadway deck is furnished with gullies and sand traps. The drain water passes an oil separator before it is discharged into the sea through the railway deck.

7.1.4. Marine construction work

The marine works comprise soil improvement with bored concrete piles, excavation for and the placing of backfill around caissons, grouting as well as scour protection. The marine works also include the placing of crushed stone filling below and inside the pier protection works at the main bridge.

Soil improvement will be required for the foundations for the main bridge and for most of the foundations for the Fehmarn approach bridge. A steel pile or reinforcement cage could be placed in the bored holes and thereafter filled with concrete.

The dredging works are one of the most important construction operations with respect to the environment, due to the spill of fine sediments. It is recommended that a grab hopper dredger with a hydraulic grab be employed to excavate for the caissons, both for practical reasons and because such a dredger minimises the sediment spill. If the dredged soil cannot be backfilled, it must be relocated or disposed of.

7.1.5. Production sites

The temporary works comprise the construction of two temporary work harbours with access channels. A work yard will be established in the immediate vicinity of the harbours, with facilities such as a concrete mixing plant, stockpile of materials, storage for equipment, preassembly areas, workshops, offices and labour camps.

The proposed lay-out of the production site is shown in Figure 7.1-3.

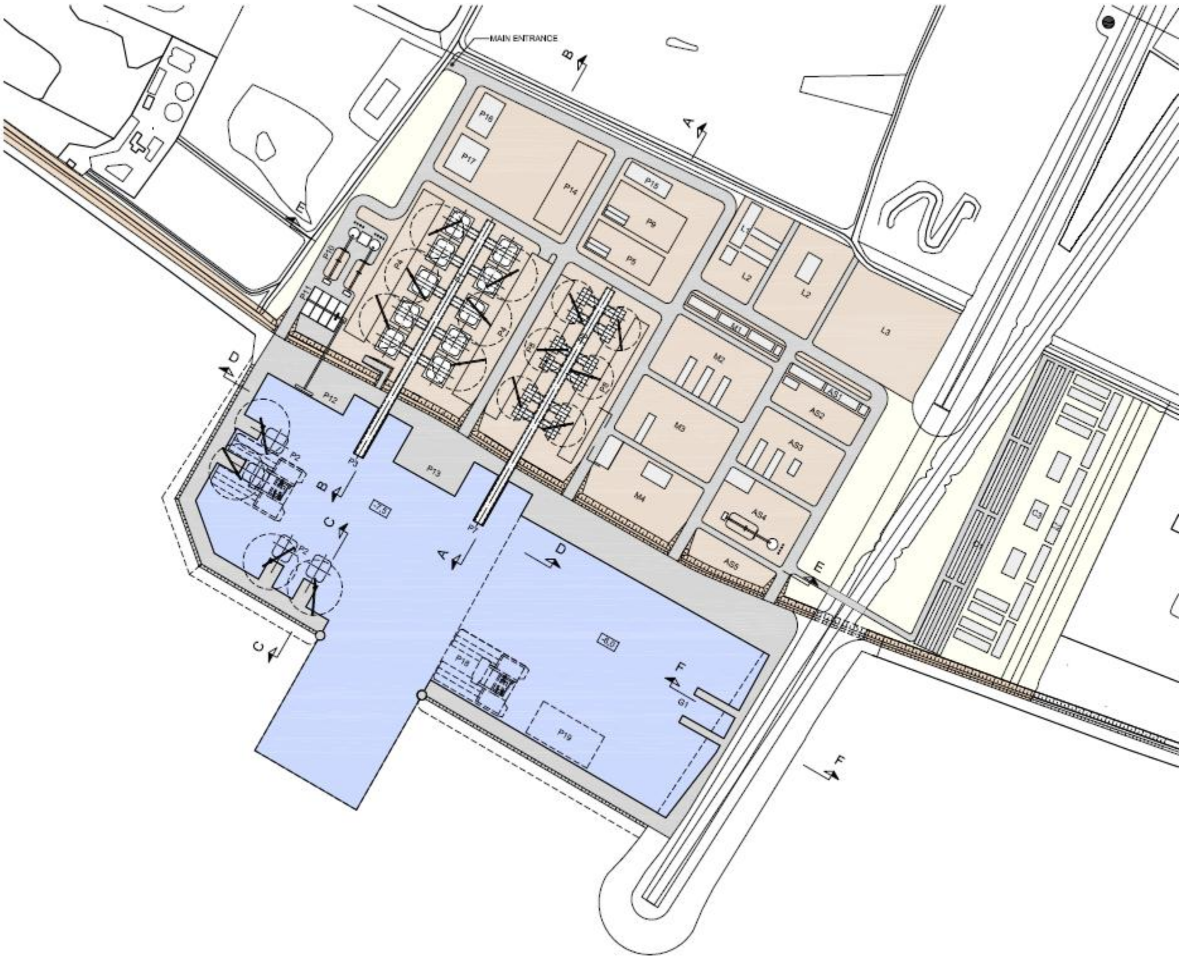

Figure 7.1-3 Proposed lay-out of the production site (Lolland)

7.2. Construction

7.2.1. Description of associated construction activities

Caissons provide the foundation for the pylons and piers of the main bridge (e.g. Figure 7.2-1 and Figure 7.2-2). The overall shape of the caisson for the centre pylon in plan view is circular in order to minimize the water blockage. The diameter of the base slab (diameter of caisson + 2 x 0.5 m) is 75 m corresponding to an area of 4,418 m^2.

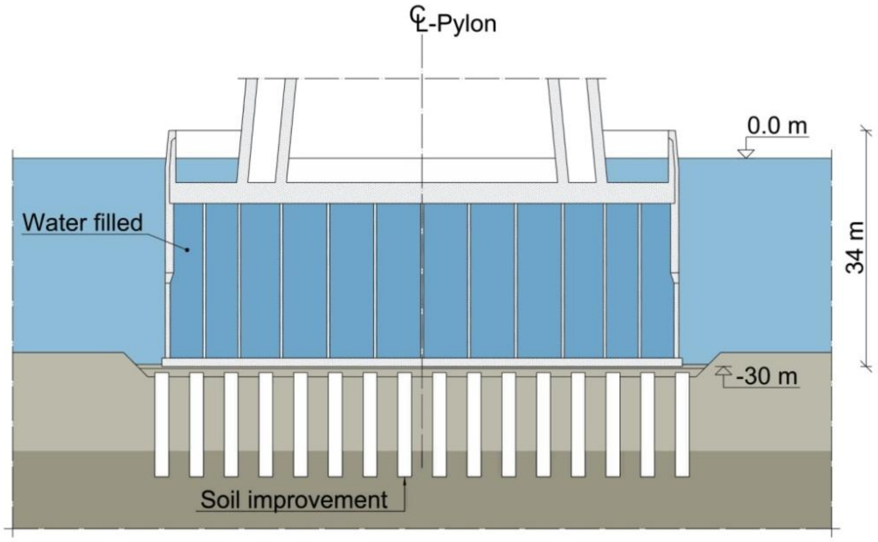

Figure 7.2-1 Section of the centre pylon caissons

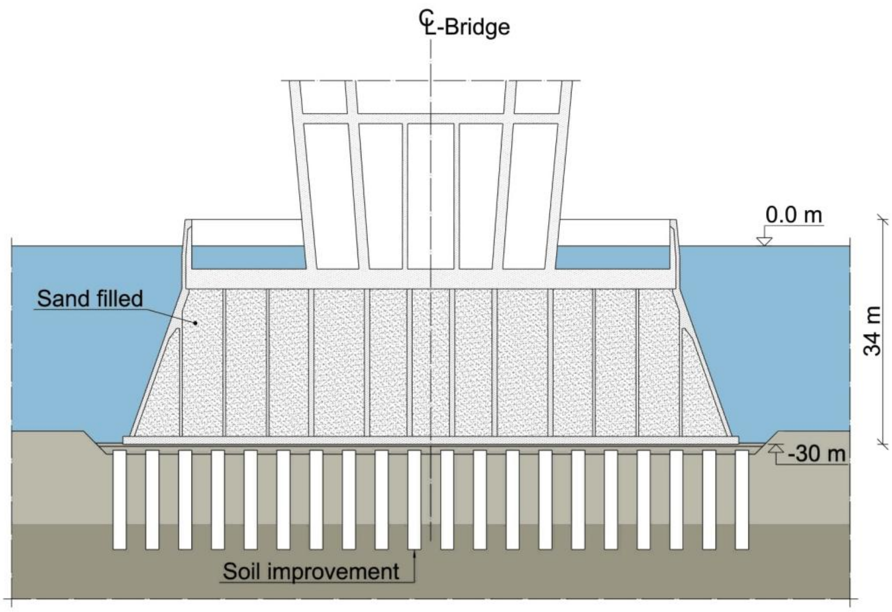

Figure 7.2-2 Section of the outer pylon caissons

The caissons for the foundations of the anchor and transition piers are smaller than those for the pylons, see Figure 7.2-3 for the section view. The footprint area is only approximately 720 m^2 and extends 4 m above the seabed. The caissons are filled with sand and the piers are surrounded by ship protection structures.

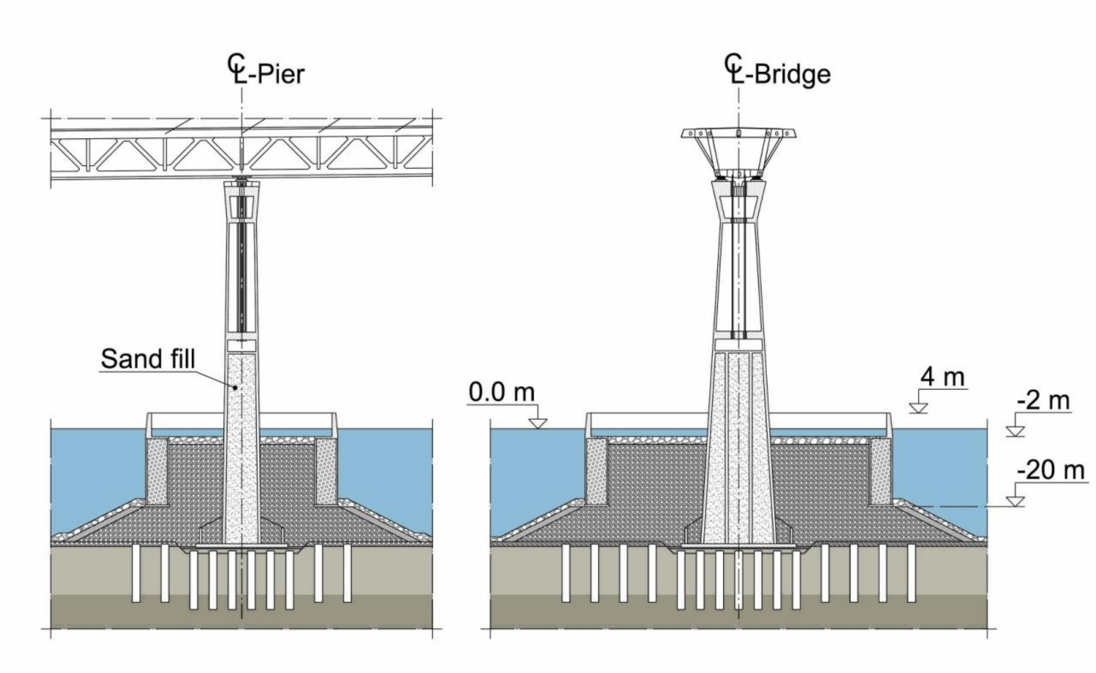

Figure 7.2-3 Layout of the anchor piers

The substructure concept assumes that all piers can be directly founded on shallow foundations. This means that soil improvement will be required for some sections of the Fehmarn approach bridges.

It is proposed that the piers are pre-fabricated on shore in two parts: a lower caisson and an upper pier shaft, which will then be transported to the site and installed by a heavy lift vessel. All piers, from the short ones near the coast to the tallest close to the main bridge, are based on the same overall design principle with some variations, mainly relating to their size and ability to absorb ship collision loads.

The pier shafts are formed as hollow, slender supporting structure elements, see Figure 7.2-3.

The caissons for the approach bridges are almost identical to those for the anchor and transition piers. The principal difference is that the caissons will be founded approximately 4 m below the seabed.

The following foundation methods will be employed:

- Pier L46 to Pier L5 (from the Lolland coast southwards): Caisson placed directly on quaternary glacial deposits 4 m below the seabed (Figure 7.2-5).
- Pier L1 to L4 (closest to main bridge on the Lolland side): Caisson placed on a 2 m to 3 m thick gravel bed, 4 m below the seabed, or lowered 2 m or 3 m to a foundation depth of 6 m to 7 m below the seabed.

- Centre pylons, outer pylons, anchor piers and transition piers for the main bridge: Caissons are placed 2 m below the seabed. The unsuitable or inadequate soils are improved with 15 m long bored concrete piles, each with a diameter of 2 m. The pile heads are embedded in a crushed stone bed, and the piles are not connected structurally to the substructure.
- Pier F1 to F28 (from the main bridge to Fehmarn): Caissons are placed 4 m below the seabed. The unsuitable or inadequate soils are improved with 15 m long bored concrete piles, each with a diameter of 2 m (Figure 7.2-6). The pile heads are embedded in a crushed stone bed, and the piles are not connected structurally to the substructure.

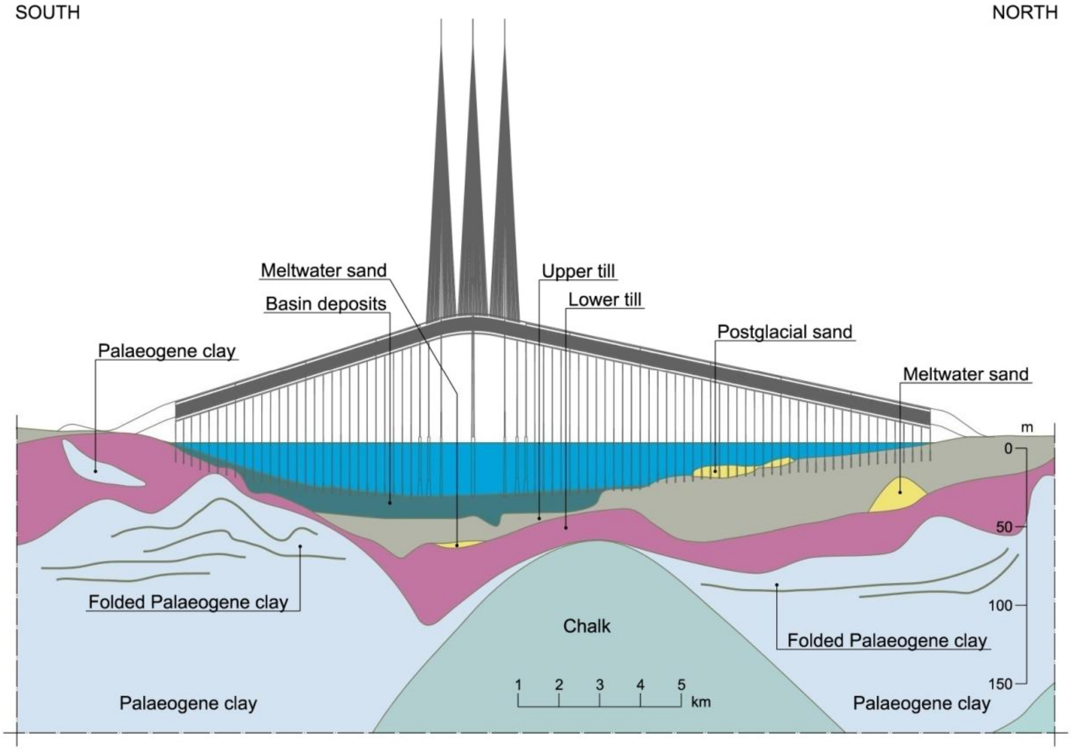

Figure 7.2-4 General overview of soil conditions along the bridge alignment

A simple geological overview is presented in Figure 7.2-4. Piling will, in general, be carried out in the Palaeogene clay and basin deposits, mainly located on the southern part of the alignment and at the location of the main bridge.

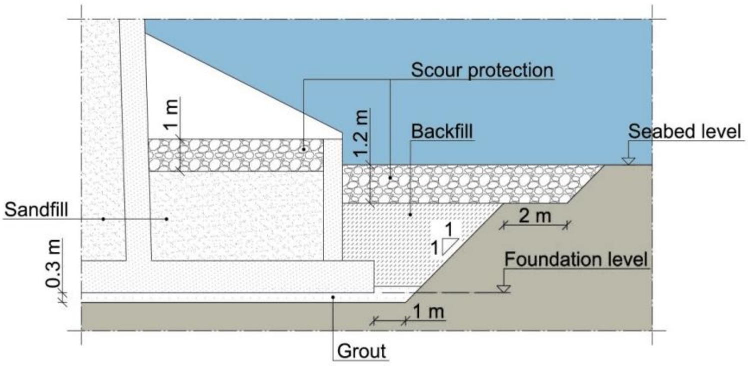

Figure 7.2-5 Layout of pier foundations for piers L46 to L5

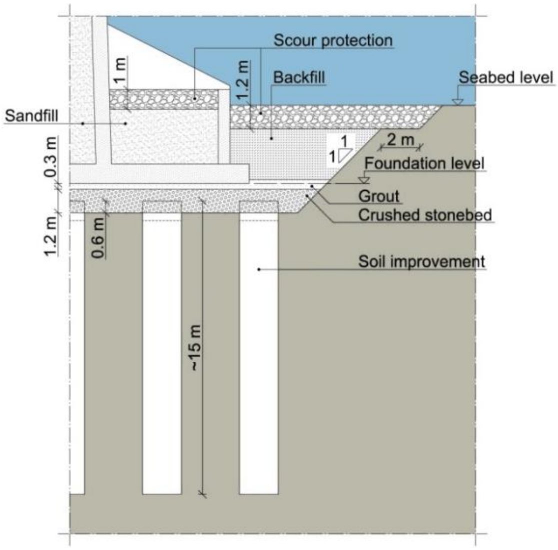

Figure 7.2-6 Layout of pier foundations for piers F1 to F28

The Fehmarnbelt link's architectural lighting will be an important part of the character and visual impact of the bridge. In general terms, the main span will represent the highlight of the lighting project with the girder forming a lit element floating above the water below.

Illumination of the bridge will be focused on the following five components:

- Main span pylons
- Piers adjacent to main pylons
- Cable stays
- Girder/deck
- Staircases

The basic illumination is white coloured floodlighting, which provides a uniform luminance of the pylons' surfaces, decreasing towards the top with soft gradients. The average luminance will be 5-10 cd/m^2.

The schedule for the known bridge marine construction works (dredging and backfilling) is given in Table 7.2—1

Table 7.2—1 Schedule of marine dredging and backfilling works

Bridge connection Year 2014 2015 2016	Q1 2014	Q2 2014	Q3 2014	Q4 2014	Q1 2015	Q2 2015	Q3 2015	Q4 2015	Q1 2016	Q2 2016	Q3 2016	Q4 2016
All bridge dredging		■	■	■		■	■	■	■	■	■	
Dredging and backfilling for piers L49 - L38			■	■								
Dredging and backfilling for piers L37 - L26							■	■				
Dredging and backfilling for piers L25 - L14									■			
Dredging and backfilling for piers L13 - L01											■	
Dredging and backfilling for piers F31 - F28				■								
Dredging and backfilling for piers F27 - F25		■										
Dredging and backfilling for piers F24 - F22				■								
Dredging and backfilling for piers F21 - F19						■						
Dredging and backfilling for piers F18 - F01		■	■									
Pylons		■	■	■								
Dredging of access channels	■											
Backfilling of access channels						■	■					
Scour protection etc.		■	■	■								
Work harbour, Rødby	■	■										
Piling												

7.2.2. Description of pressures related to harbour construction

The environmental pressures for marine mammals associated with the construction activities are summarised in Table 7.2—2.

Table 7.2—2 Cable-stayed bridge construction activities and associated pressures for marine mammals

Construction Activity	Pressure on marine mammals
Placement of pylons	Habitat loss and change – physical loss; suspended sediment / sedimentation; new substrate
	Noise – bored piles
Dredging & soil improvement	Habitat loss and change – physical loss; suspended sediment; new substrate (crushed gravel)
	Noise – dredgers & construction vessels
Placement of piers	Habitat loss and change – physical loss; suspended sediment / sedimentation; new substrate
	Noise – bored piles
Coastal land reclamation	Habitat loss and change – physical loss
	Barrier from noise
Temporary harbour construction at Lolland & Fehmarn	Habitat loss and change = physical loss; suspended sediment / sedimentation
	Barrier from noise

7.2.2.1. Noise

Dredging for the piers is scheduled for June 2014 to September 2016 (four months dredging per pier section). Cutter suction dredgers are to remove 540,000 m^3 of sediment. Backfilling of the piers with 180,000 m^3 of sand will occur concurrently with the dredging schedule. Dredging of 350,000 m^3 of sediments for the access channels will be by backhoe dredger taking one month starting in January 2014. Backfilling of these channels with 350,000 m^3 of sediment by backhoe dredger is scheduled to take 5 months between May 2015 and September 2016. Number and capacity of dredgers have not been specified, so it has been assumed that these will be similar to those planned for use in the immersed tunnel option (see section 6.1.2.1).

Limited information is available for the scheduling of the installation of the bored piles, piers and pylons.

Information on the construction schedule for the work harbours is also limited, so the same specifications for works harbours for the immersed tunnel option have been assumed and applied to the determination and assessment of noise pressures for the bridge (see section 6.1.2.1).

7.2.2.2. Habitat loss and change

Habitat loss can occur due to changes in seabed habitat affecting the benthos and fish on which marine mammals feed; changes to intertidal and terrestrial habitats (seals), e.g. land reclamation; and changes in the water column space that marine mammals occupy, e.g. the bridge pylons and piers and changes in hydrography or suspended sediment. Habitat loss and change may directly affect marine mammals, i.e. through physical loss of habitat, suspended sediment (interference with feeding etc.).

There are a number of different types of dredging works that need to be performed for the temporary works harbours, access channels and seabed preparations for the piers and pylons. The proposed scheduling is described in section 7.1.2.1. Limited information on dredger numbers and capacities have been provided, therefore, we have assumed similar specifications as those to be used for the tunnel option (see section 6.1.2.1) and applied this to the impact assessment for noise (7.2.3) and habitat change from sediment spill (7.2.5).

The bridge consists of 83 structures (piers and pylons), the placement of which will result in the permanent loss of habitat (the physical footprint of the structures). To construct the piers, dredging is required for ground preparation and backfilling around the pier (taking approximately two weeks after dredging is completed). The backfilling uses a mixture of sand from Kriegers Flak, local clay-till and rocks for scour protection. In areas of backfill this will be a modification of existing sediment substrate.

For the temporary works harbours the same specifications as those for the tunnel option have been applied (section 6.1.2.2).

During the bridge construction sediment spill material will be suspended and re-deposited due to dredging and backfilling around the 83 structures. Dredging is expected to be undertaken by a cutter suction dredger, and seabed placement will be done using a fall pipe to minimise spill. During the dredging process sediment is released into the water column via the physical disturbance of seabed sediments by the drag head, as well as from overflow and spill whilst the vessel is loading and backfilling. Sediment released into the water column through disturbance and overspill is dispersed by waves, tides and gravitational settling.

Dredging for the piers is scheduled for June 2014 to September 2016 (four months dredging per pier section). Cutter suction dredgers will remove 540,000 m^3 of sediment. Backfilling of the piers with 180,000 m^3 of sand will occur concurrently with the dredging schedule. Dredging of 350,000 m^3 of sediment for the access channels will be done using backhoe dredgers taking one month starting in January 2014. Backfilling of these channels with 350,000 m^3 of sediment by backhoe dredgers is scheduled to take five months between May 2015 and September 2016. Number and capacity of dredgers has not been specified, so it has been assumed that these will be similar to those planned for use in the immersed tunnel option (see section 6.1.2.1). This was applied to the impact assessment for habitat change from sediment spill (7.2.5). This assumption has been applied through comparing the dredging scenarios for tunnel and bridge (Table 7.2-1). The periods when the greatest amount of dredging occurs are in June and October 2014. While the sections are not exact, each tunnel dredge section does roughly correspond to a bridge dredge section (Table 7.2-3 and Figure 7.2-7).

The bridge construction will involve sediment spill across the bridge alignment between January 2014 and September 2016 (33 months), however, sediment spill is also associated with a number of other operations during this time and will occur consistently during this period.

7.2.2.3. Contaminants

The construction of the bridge will require the dredging of approximately 890,000 m^3 of sediment, which will potentially release contaminants, described in Chapter 4, into the environment.

7.2.2.4. Barrier

Barrier effects could be caused by the physical presence of construction vessels during the works. Approximately 530,000 m^3 of sediment is due to be re-used within the backfilling works. This material will have to be re-distributed by tugs and barges – no details have been provided for the bridge option so the details described in 6.1.2.4 are taken as an assumed worst case scenario.

As described in chapter 4.2.1.6, a barrier effect could be caused by the noise emissions of construction vessels during the works. Information on specifications in piling and dredging works during construction of the cable-stayed bridge, which are related to a possible barrier effect, are described in chapter 7.1.2.1 and 7.1.2.2.

7.2.3. Noise - construction impact assessment

7.2.3.1. Degree of Impact

The criteria for degree of impact are the same as section 6.1.3.1. All assumptions made within Chapter 6 remain the same for the bridge option.

Dredging

As described in Chapter 6, SPL can be equated with SEL in terms of continuous noise (dredging, bored piles) and can therefore be related to the SEL thresholds for marine mammals.

The requirement for dredging is greatly reduced for the bridge option (890,000 m^3) compared to the tunnel option (18,750,000 m^3). However, there is a lack of information concerning the number and capacity of dredgers being utilised. It is known that cutter suction dredgers and backhoe dredgers will be used for the dredging works, but there is a lack of data concerning the noise levels of these types of vessels. Although studies have shown they are quieter than trailing suction hopper dredgers (TSHD) Richardson et al., 1995; Nedwell & Brooker, 2008; Robinson et al., 2011.

As for the tunnel option, dredging will be done in sections. Many of the sections do not overlap temporally, but there are periods when dredging will take place in more than one area (Table 7.2—1). The worst of these periods are June and October 2014 when dredging will take place at three different sections (June being F27-F25, F18-F1 and pylons; October being

L49-L38, F31-F28 and pylons). While the sections are not exact, each tunnel dredge section does roughly correspond to a bridge dredge section (Table 7.2—3 and Figure 7.2-7).

Table 7.2—3 Bridge dredge sections which equate to tunnel sections

Bridge Dredge Sections	Approximate Tunnel Dredge Sections
L49 - L38	D1
L37 – L26	D2
L25 – L14	D3
L13 – L1	D4
F31 – F28	G1
F27 – F25	G1
F24 – F22	G1
F21 – F19	G1
F18 – F1 and piers STP, SAP and SOP	G2 and G3
Pylons (CP, NOP, NAP and NTP)	G4

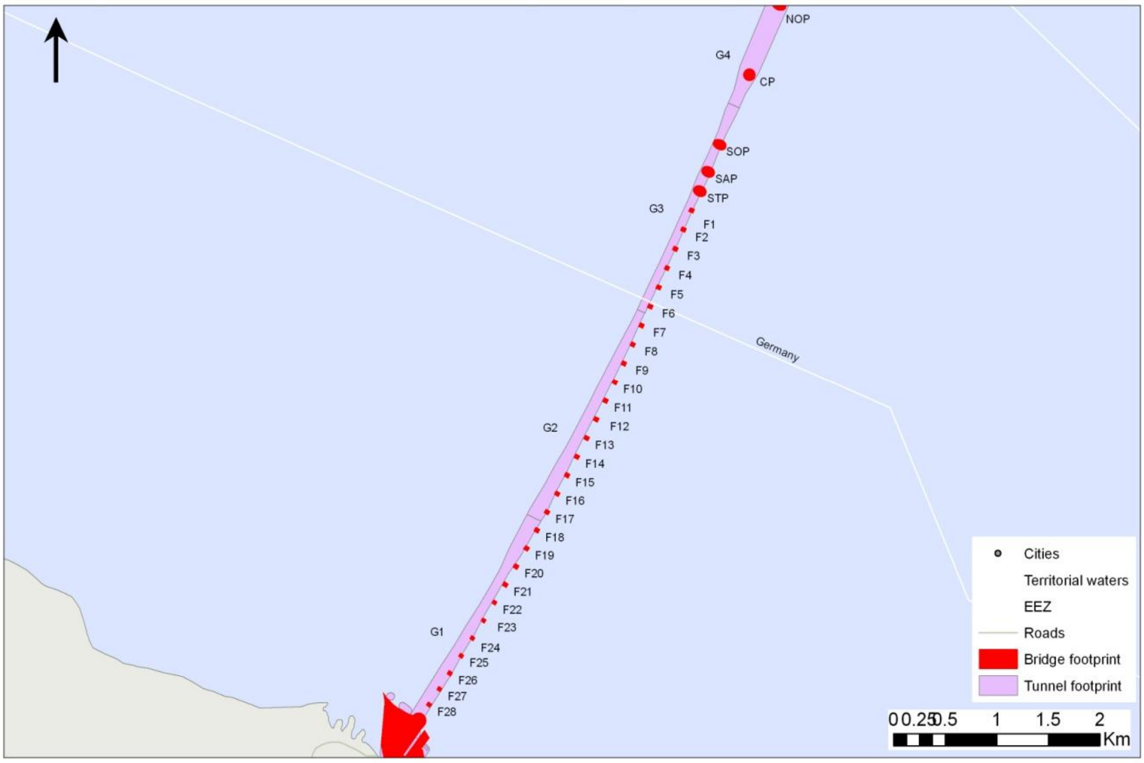

Figure 7.2-7 Bridge dredge sections of the south part of the bridge which equate to tunnel sections (STP = South Transition Pier; SAP = South Anchor Pier; SOP = South Outer Pylon; CP = Central Pylon; NOP = North Outer Pylon)

For GIS analysis, as shown in Table 7.2—3 and Figure 7.2-7, the modelling for tunnel dredge sections (G1 – G4 and D1 – D4) have been used as a proxy for dredging the bridge sections in June 2014 (dredging at F27-F25, F18-F1 and pylons) and October 2014 (dredging at L49-L38, F31-F28 and pylons) which were scenarios with combined impacts. GIS analysis shows that the degree of impairment of dredging during June 2014 and October 2014 never exceeds the German threshold (160 dB re 1µPa²s SEL at 750 m) despite the addition of extra dredge areas above those modelled in the tunnel dredge stages (Figure 7.2-8 and Figure 7.2-9). It is dredging around G4 (equating to the central pylon) which causes the most extensive noise. The threshold of medium impact (150 dB re 1µPa²s, causing behavioural disturbance) is reached at 650 m, while the low impact noise threshold (144 dB re 1µPa²s) is reached at approximately 870 m distance from the sound source.

However, the noise levels generated will be an over estimation of the dredging noise given the type of dredge vessels to be used (cutter suction and backhoe) compared to what was modelled (TSHD). The reduced amounts of material to be dredged should also correspond to lower noise levels given that four TSHDs were modelled for each section of the tunnel dredge and this many vessels is unlikely for the bridge dredge works, given the small amount of material and the timescales provided.

It can also be seen that, as for the tunnel, the bridge dredging works do not, at any stage of dredging, cause a continuous barrier of noise across the strait between Lolland and Fehmarn. The implications of any barrier effects will be discussed fully within section 7.1.6.

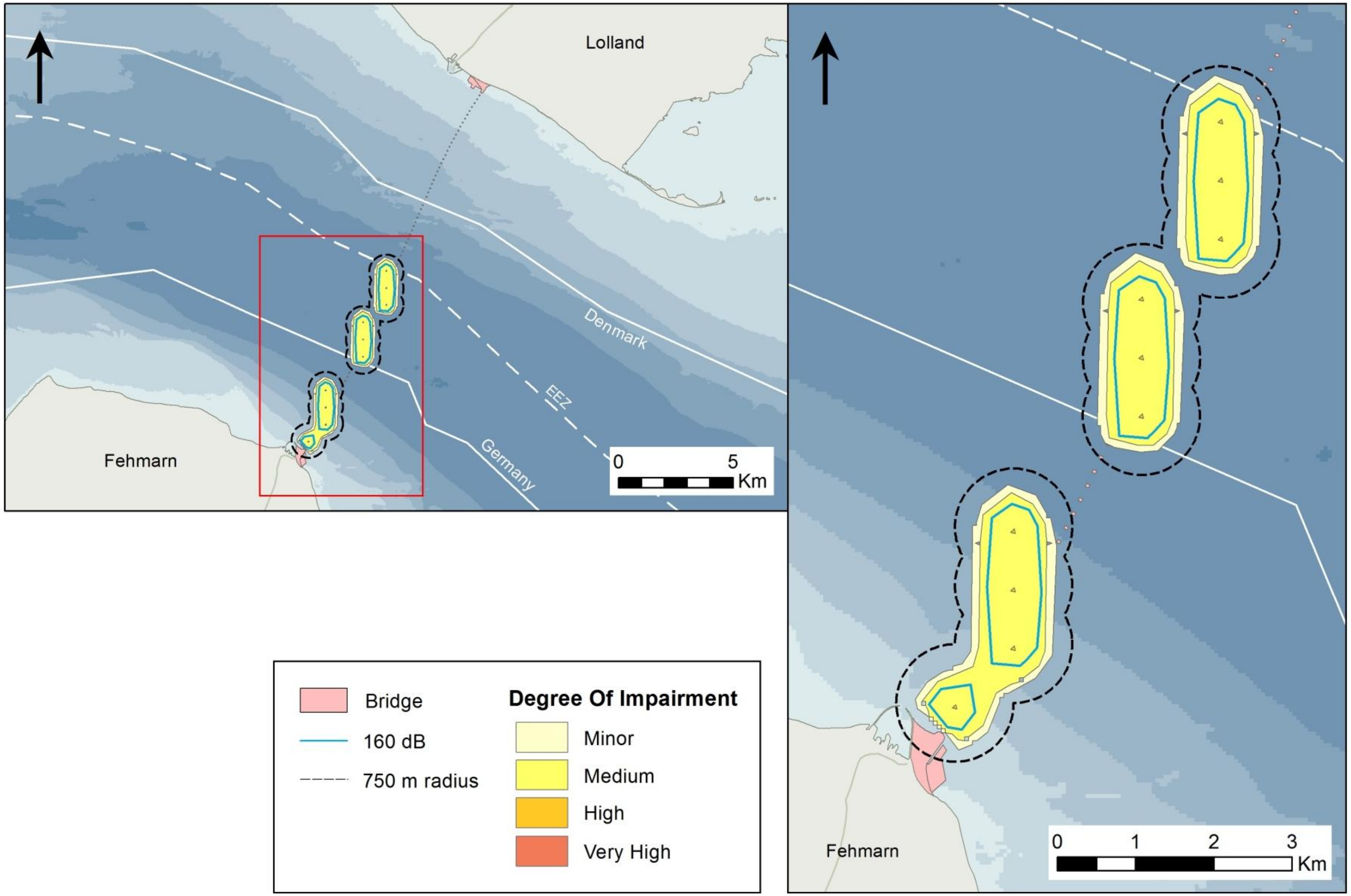

Figure 7.2-8 Degree of Impairment of the bridge dredging, scenario for, June 2014. Dredging at G1, G2, G3 and G4, which were used as a proxy for F27-F25, F18-F1 and pylons (Table 7.2—3).

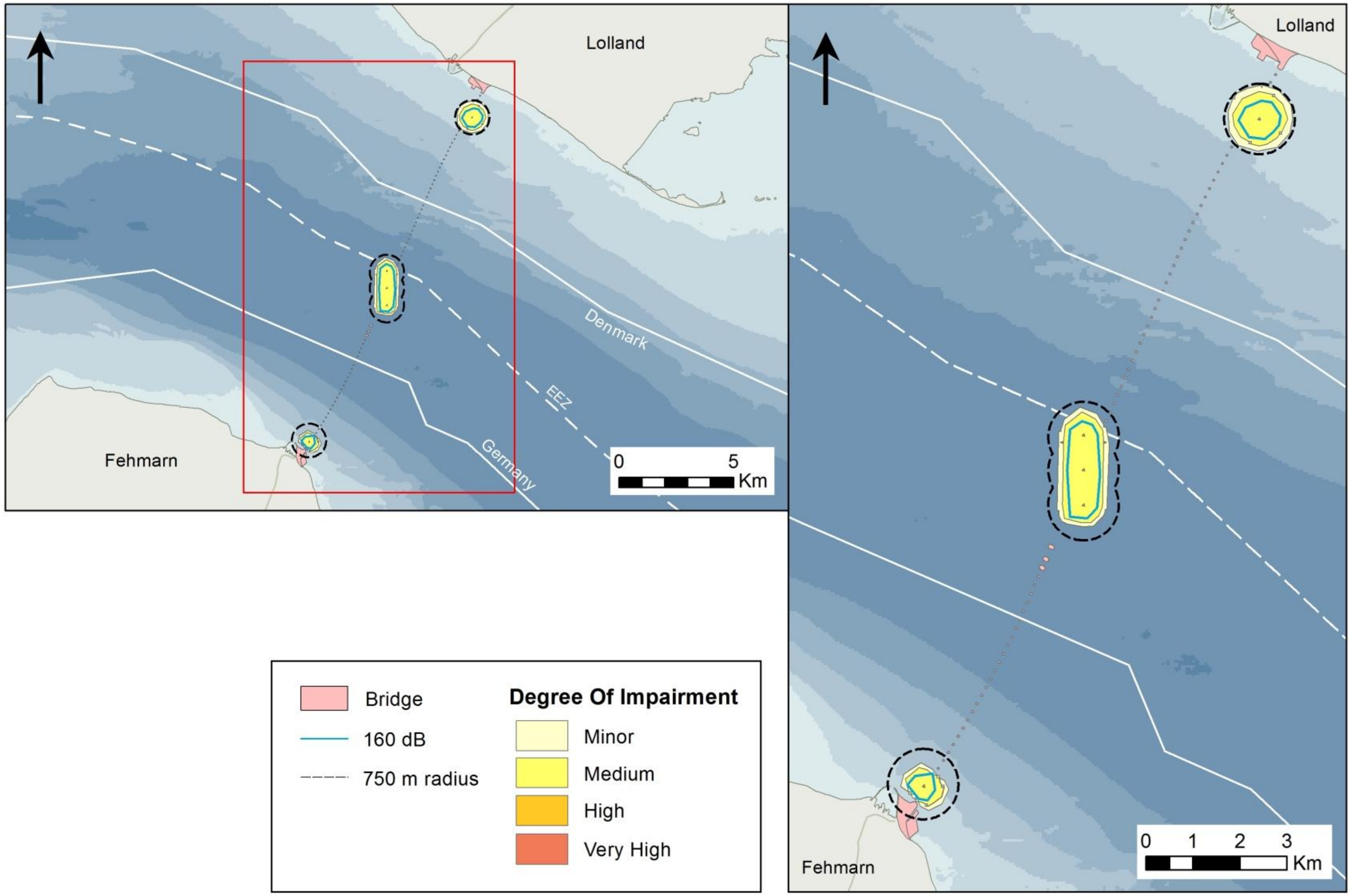

Figure 7.2-9 Degree of impairment of the bridge dredging scenario for, October 2014. Dredging at D1, G1 and G4, which were used as a proxy for L49-L38, F31-F28 and pylons (Table 7.2—3).

Piling

Pile driving

Piling activities for the temporary harbours will be the same as those described for the tunnel option. Therefore, the German threshold of 160 dB re 1µPa^{2}s at 750 m is not exceeded and the degree of impact will be the same. The noise level is only high (above 171 and 183 dB re 1µPa^{2}s, with a potential to cause TTS in seals and porpoises respectively) in an area of about 230 m distance around the pile driving activity. The area of medium magnitude with SEL levels of more than 150 dB re 1µPa^{2}s extends to approximately 1.1 km in which behavioural disturbance could be expected. Levels of more than 144 dB re 1µPa^{2}s would be expected up to a distance of about 1.9 km and may cause minor behavioural reactions. However, with the bridge option, there is also the possibility that two pile drivers may be used at the same time (Figure 7.2-10).

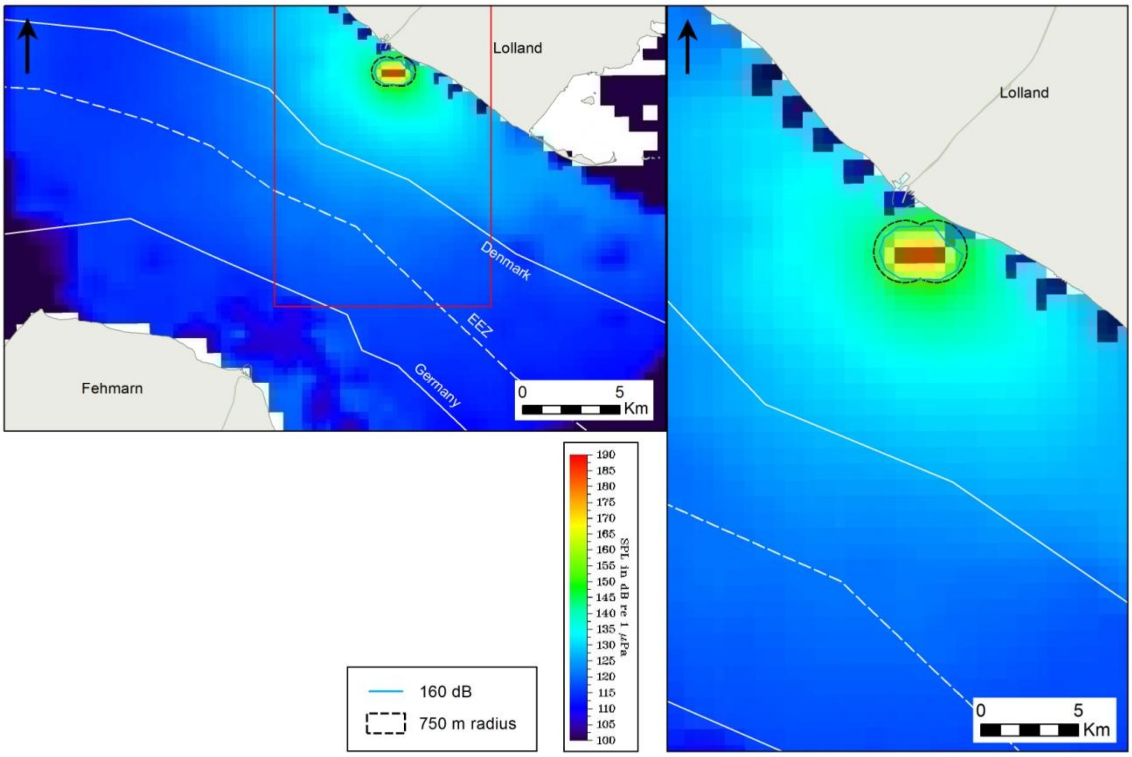

Figure 7.2-10 Sound exposure level at Rødby Harbour with two pile drivers working concurrently

Despite two pile drivers being used at the same time, the noise levels are no louder and only extend out further for: approximately 150 m for the medium and 250 m for the low degree of impairment thresholds previously modelled (Figure 7.2-11). The German threshold is still not exceeded.

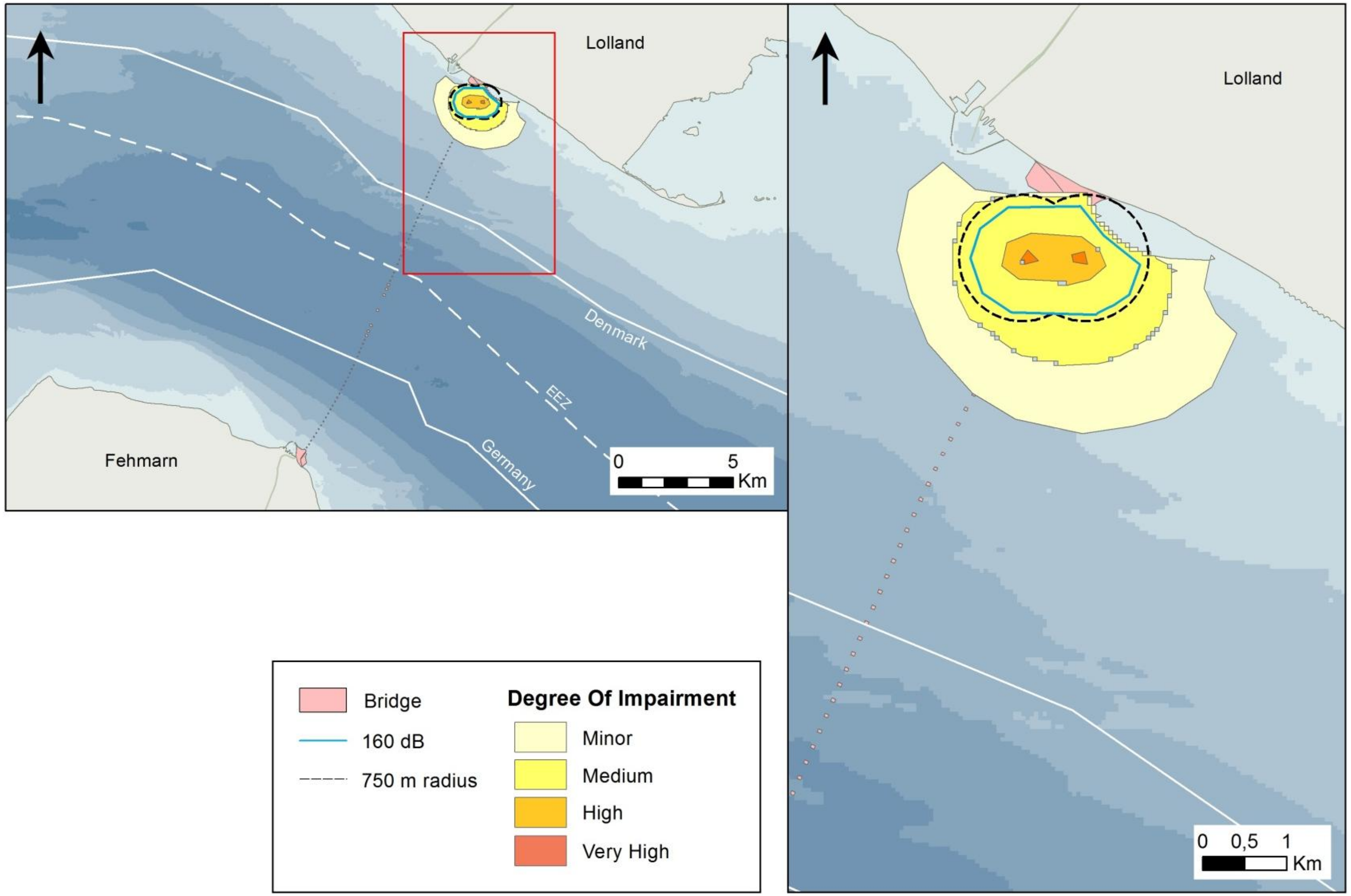

Figure 7.2-11 Degree of impairment of two pile drivers working simultaneously

Bored piles

For the bridge construction a large number of concrete piles (15 m in length and 2 m in diameter) will be drilled into the seabed for soil improvement. A total of 2,155 piles (concrete and sheet) are required for the bridge and the associated structures. However, it is not clear how many of them will be concrete piles. It is known that all the piles on the Fehmarn side (F28 – F1) as well as the central pylons will be bored concrete piles (Figure 7.2-12).

There is little data available on the use of bored (drilled) piles. Noise levels will depend on the structure used for drilling (e.g. ship, platform). Nedwell & Howell, 2004 summarised the sparse data available on shallow water drilling. One study showed low sound pressure levels of 125 dB re 1µPa at 130 m and 86 dB re 1µPa at 480 m, where drilling took place from an ice pad. Another study showed very low frequencies of 1 to 2 Hz at a SPL of 121-124 dB re 1µPa at a distance of 222-259 m from drilling activity while constructing a concrete caisson. These SPL are lower than the background noise caused by heavy shipping in the Fehmarnbelt area. Higher SPL have been reported from drill ships and semi-submersible drill rigs with 145 to 191 dB re 1µPa source level. However, Nedwell & Howell (2004) thought that it was unlikely that these would be used for wind farm development in shallow water and, therefore, the same is likely to be true for the bridge construction in shallow water. For the FEMM modelling, to make sure the noise level was not under-estimated, a source level for platform drilling measured by Hannay in 2004 (reported in Genesis Oil and Gas Consultants Ltd, 2010) of 162 dB was chosen.

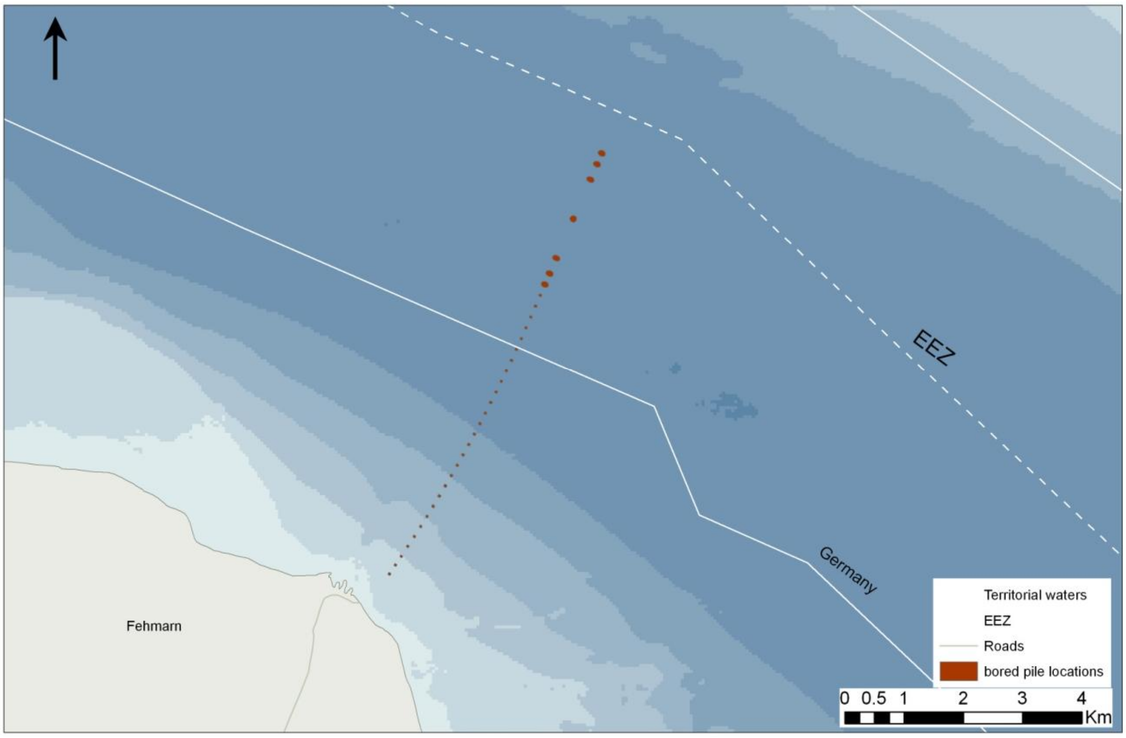

Figure 7.2-12 Location of bored piles

Figure 7.2-13 shows the degree of impairment from the bored piling works. As can be seen, the noise levels are very local to the piling location. The German threshold is reached within 140 m and the extent of the minor noise threshold is reached at 545 m. Therefore it can be seen that despite the potentially larger number of bored piles (Figure 7.2-12), these noise levels will only cause a minimal impact.

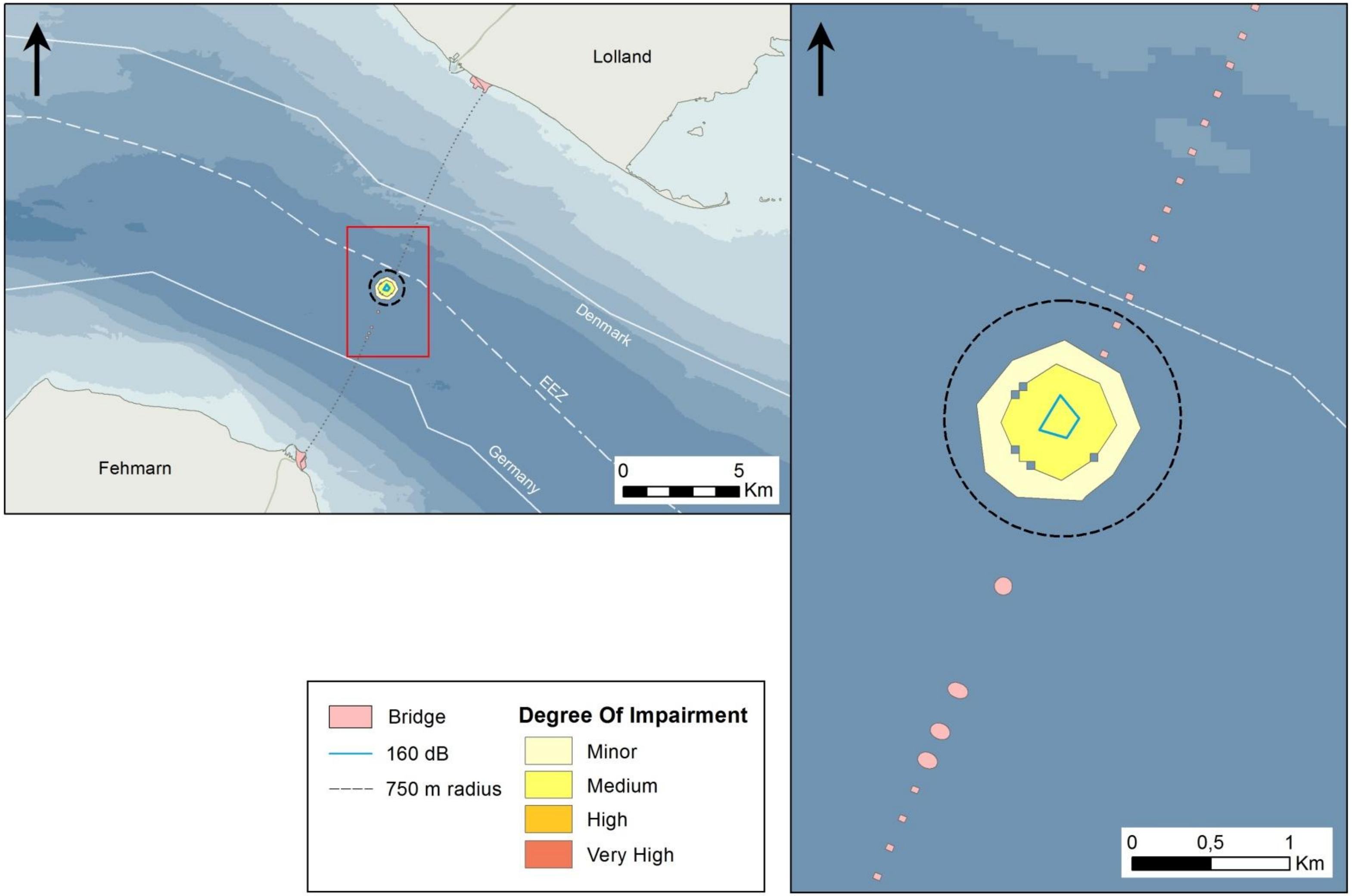

Figure 7.2-13 Degree of Impairment of bored piling works

Scenario of combined noise impacts

The timing of the piling (both pile driving and drilling) is not known. Therefore, a scenario of impact for pile driving (two pile drivers working simultaneously), drilling and dredging has been modelled at Lolland (Figure 7.2-14).

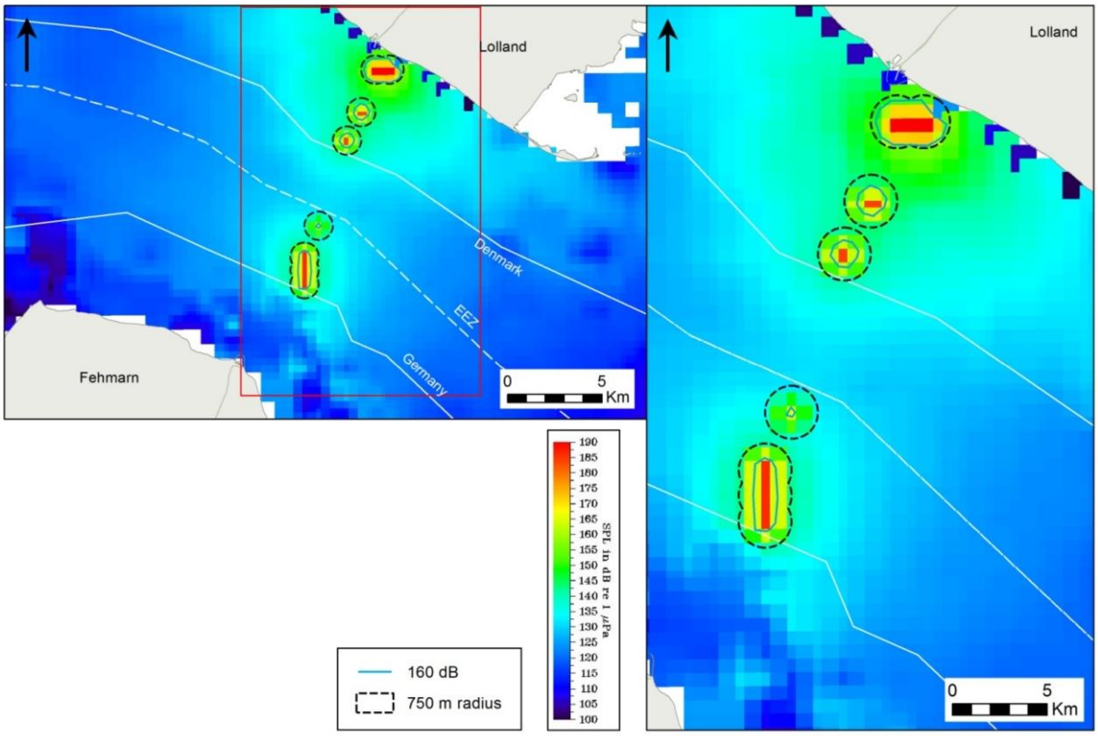

Figure 7.2-14 Sound exposure level comprising dredging, drilling and pile driving.

As can be seen from Figure 7.2-15, there is a minor overlap for the minor degree of impairment between the two pile drivers and the dredging at D1. This may mean that slightly more porpoises may be affected (minor changes in behaviour) if dredging and pile driving occur at the same time, rather than occurring separately. There is a small overlap between dredging at D1 and the pile driving so this scenario has been used in the assessment of severity. There are no other overlaps within the spatial footprint.

It should be noted that the dredging modelled represents the dredging from the tunnel option, rather than bridge dredging (section 7.2.3.1 provides the explanation for how this assumption has been applied). However, in terms of impact, more of the tunnel dredging occurs close to the piling works, therefore this scenario will show a higher spatial extent and higher impact and severity. In any case, the only overlap occurs between the pile driving and dredging within D1, which is part of the bridge dredging scenario in winter.

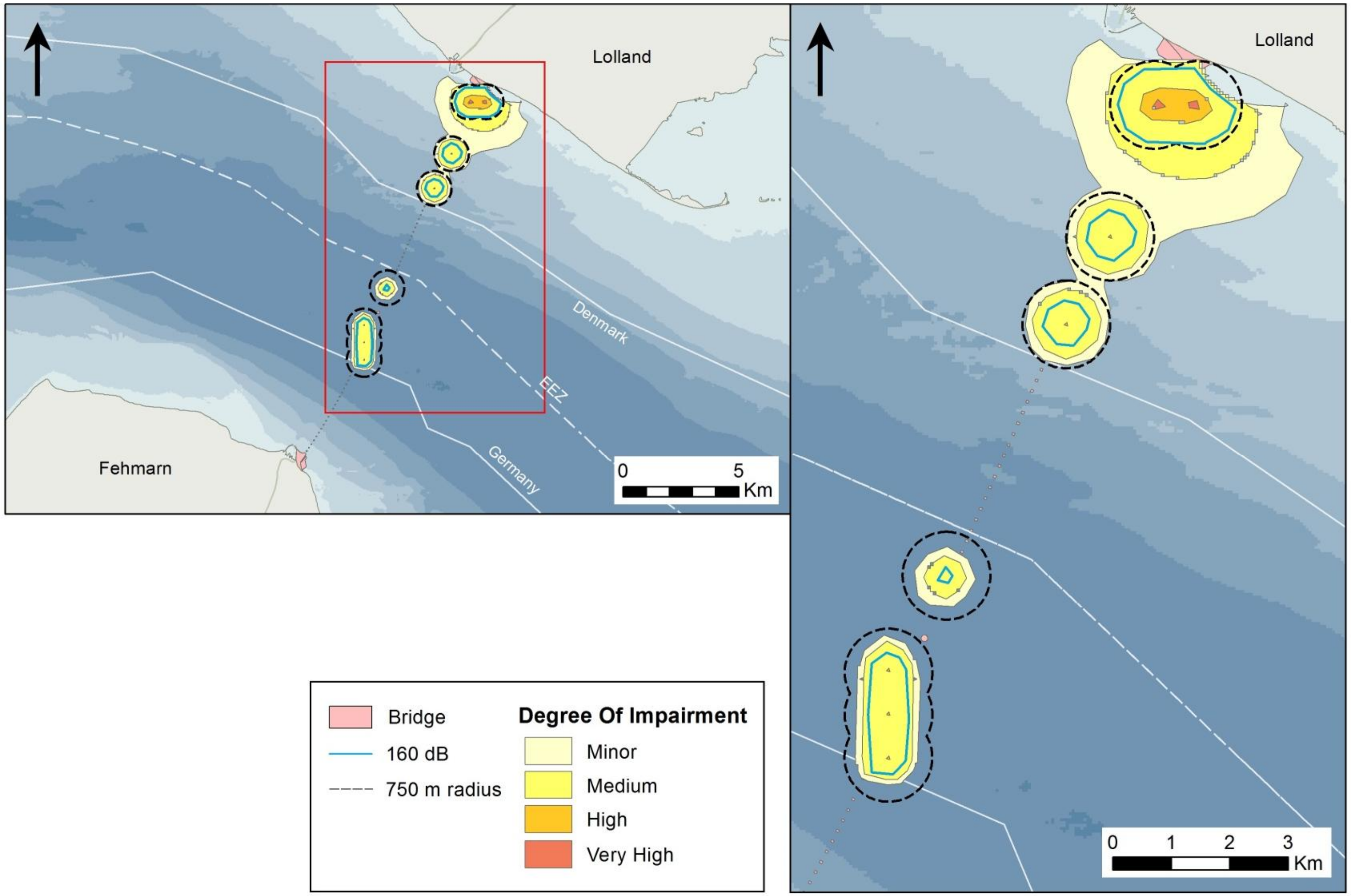

Figure 7.2-15 Degree of impairment of all noisy activities occurring at the same time (driven piles, bored piles and dredging)

7.2.3.2. Severity of Impact

As described in Chapter 6, the importance maps generated for the baseline report (FEMM, 2011) were used in the severity of impact assessment for harbour porpoise. Figure 7.2-16 shows the seal haul-out locations for both seal species and the bridge footprint. There are less reclamation works for the bridge option, the site of the works is slightly further away from the nearest observed seal haul-out site, which is approximately 10.5 km away. The majority of sightings were recorded 31 km away from the site of the works. All analysis takes account of potential impacts to feeding areas.

The harbour porpoise densities are described in the methods in Chapter 3 and are not repeated in this chapter. In addition, the method of calculating the number of porpoises affected is already fully described within section 6.2.3 and will not be repeated in this chapter.

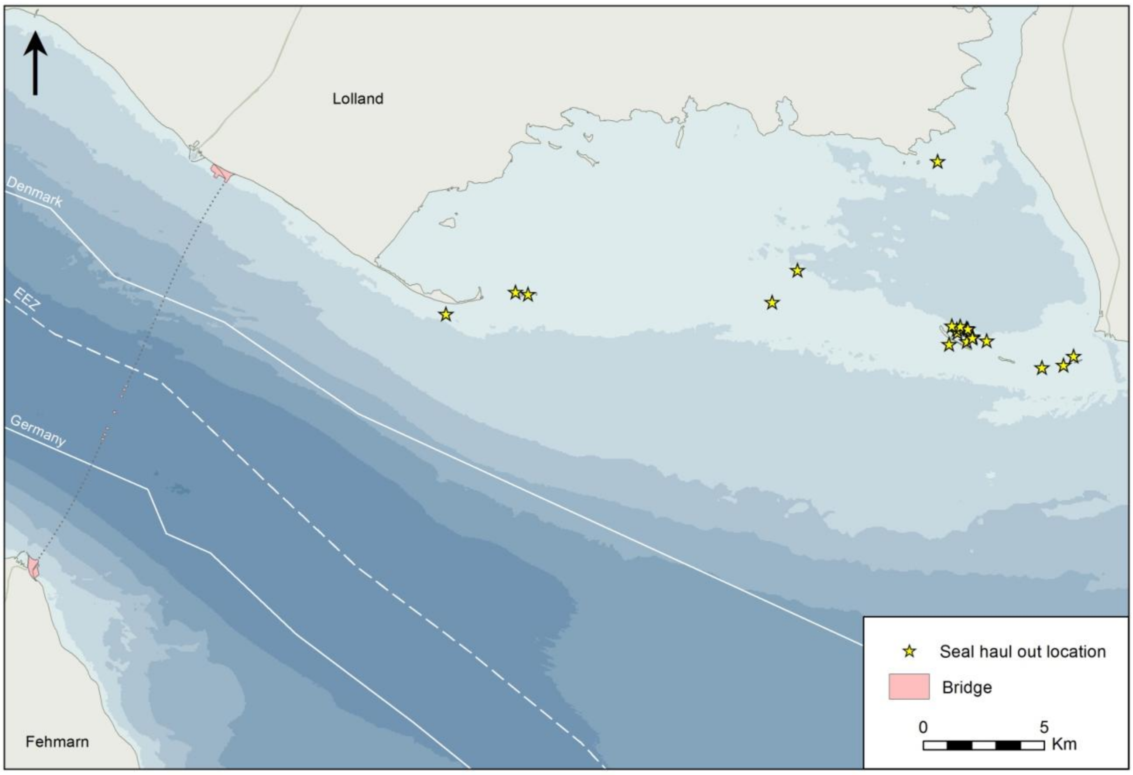

Figure 7.2-16 Harbour and grey seal haul-out zone and location of the bridge works

Dredging

Winter

Figure 7.2-18 shows the severity of impairment for the dredging stage in October (equating to G1, G4 and D1). As can be seen from the figure, there is an overlap with areas which have a medium and minor importance for porpoises, leading to a severity of impairment ranging from medium to negligible. The overall abundance for porpoises during winter 2010 was estimated at 931 animals (521 – 1,800 animals 95 % CI) as described in chapter 3. Based on this, the number of animals affected and the severity of impact have been calculated (Table 7.2—4).

Table 7.2—4 Severity of impairment of winter bridge dredging work

Severity of Impairment	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
Medium	1.04	0.02	0.35
Minor	5.04	0.10	0.75
Negligible	*1.94*	*0.04*	*n/a*
TOTAL SOI	**6.09**	**0.12**	**1.10**

N.B. Negligible implies no impact, therefore this value has not been taken into account for SoI or number of affected porpoise

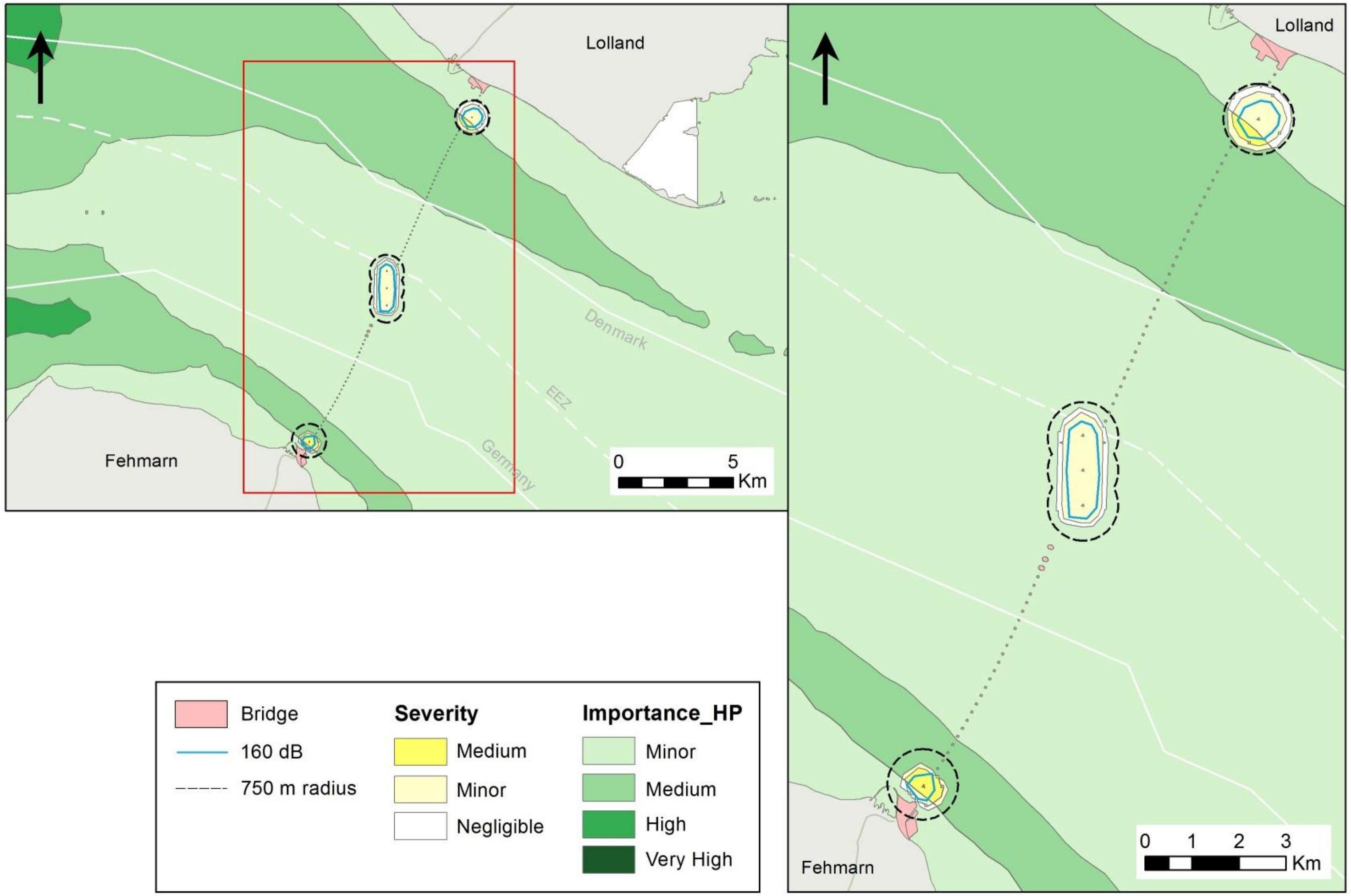

Figure 7.2-17 Severity of Impairment for porpoise during winter bridge dredging works

Overall, during the winter dredging works, 1.10 animals would be affected around the dredging works. This number corresponds to 0.12% of the local population in winter (931 ind.;521 – 1,800 ind. 95 % CI). As detailed in the degree of impact section, the effect will range from low to medium, potentially causing a behavioural reaction of a varying magnitude dependent on an animal's distance to the dredge vessel. Noise levels within the vicinity of the dredge vessel have the potential to cause TTS in porpoises, but as described in section 6.2.3.1, this figure is likely to be overestimated due to the complexities of near-field sound wave properties. The other reason for possible overestimation is that quieter dredge vessels (cutter suction and backhoe) are being used compared to those that were modelled (TSHD).

The dredging for each stage will be undertaken consecutively. The number of 1.10 porpoises is minor in terms of occurrence (staging) within the area and also in terms of effects on calving grounds (which have not been spatially defined within the wider area). As previously shown (Chapter 6 and Figure 7.2-19) dredging noise levels never completely cover the strait between Lolland and Fehmarn. Therefore, given the low number of porpoises affected, dredging works are unlikely to cause an impact on porpoise migration through the area.

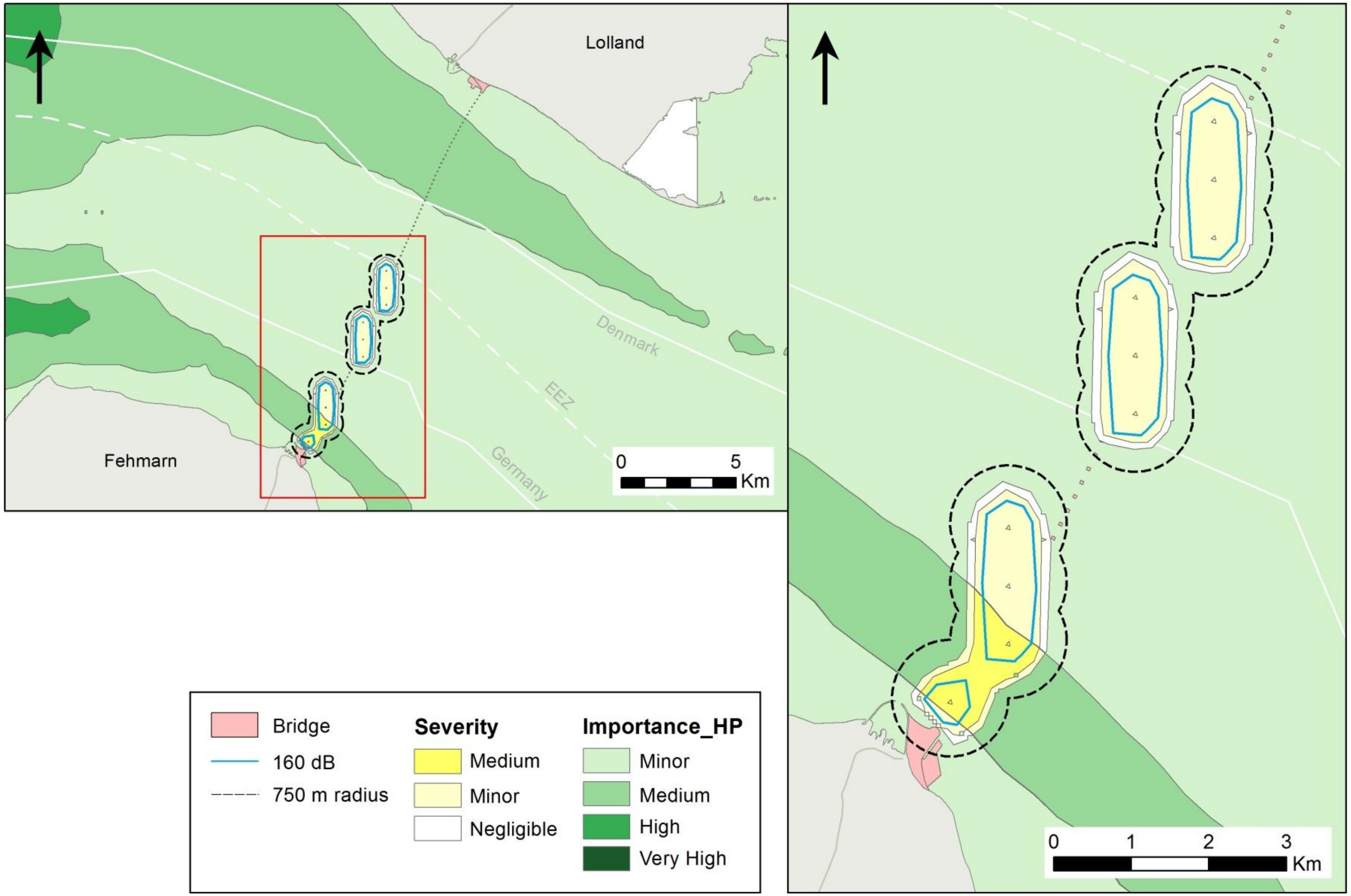

Figure 7.2-18 Severity of Impairment for harbour porpoise during winter bridge dredging works

As previously stated in Chapter 6, tugs and barges were not modelled as they are nearly 10 dB quieter than TSHDs, which reduces the intensity of the noise by approximately an order of magnitude. The majority of the noise resulting from the modelling fell below ambient noise. Therefore, it is likely that the noise from these quieter vessels would be entirely masked by current ambient noise levels in the region.

The nearest observed seal haul-out from the dredging is approximately 10.5 km away from the minor noise level of 144 dB re 1µPa, with the majority of sightings lying over 30 km away from the lowest noise levels (Figure 6.2-28). Therefore, as far as the haul-out zone is concerned, there is no overlap and therefore no impact to either seal species. With regards to potential feeding area, as described in Chapter 6, grey seals are known to forage extensively and are capable of feeding anywhere up to 80 km away from their haul-out site. Harbour seals do not forage as extensively as grey seals, but may travel as far as 50 km away from their haul-out site (averaging 17 km).

Within the study area, a maximum of 6.09 km² of potential feeding habitat will be affected by the dredging works, corresponding to 0.12% of the available habitat. While this is a small percentage of the available habitat (of minor to negligible severity of impairment), the possible impacts on foraging seals will be discussed in section 7.2.6

Summer

Figure 7.2-19 shows the severity of impairment during the dredging works in June 2014. Table 6.2—9 shows the summer 2010 porpoise densities, which have been used along with the method described in section 6.1.3.2 to calculate the number of porpoises affected by the summer dredging works (Table 7.2—5).

Figure 7.2-19 Severity of Impairment for harbour porpoise during summer bridge dredging works

Table 7.2—5 Severity of impairment of dredging on harbour porpoises in summer

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
High	0.01	0.00	0.00
Medium	6.08	0.12	2.77
Minor	1.94	0.04	0.84
TOTAL SoI	**8.02**	**0.16**	**3.61**

A number of 3.61 animals are affected by the summer dredging works (Table 7.2—5), nearly three times that affected by the winter dredging works. There were also more porpoises observed in summer 2010 (2,078 ind.; 1,414 – 2,709 95 % CI) compared to the winter 2010 (931 ind.; 521 – 1,800 95 % CI), due to shifts in their seasonal abundance. The number of affected porpoises corresponds to 0.17% of the local population in summer; which is very similar to the proportion calculated to be affected in winter (0.12%). The effects of noise on both harbour porpoises and seals in summer are comparable to those previously described for winter.

A total of 8.02 km² (0.16%) of potential seal feeding ground will be affected by the summer dredging works, the implications of this impairment (of minor to negligible severity) will be discussed in section 7.2.6

Piling

Pile driving – Winter

As Chapter 6 gave the result of one working pile driver, this chapter will only assess the scenario of two pile drivers working simultaneously on the bridge construction.

Figure 7.2-20 shows the severity of impairment of winter pile driving. There is an overlap with areas which have a medium and minor importance for porpoises, leading to a severity ranging from medium to negligible.

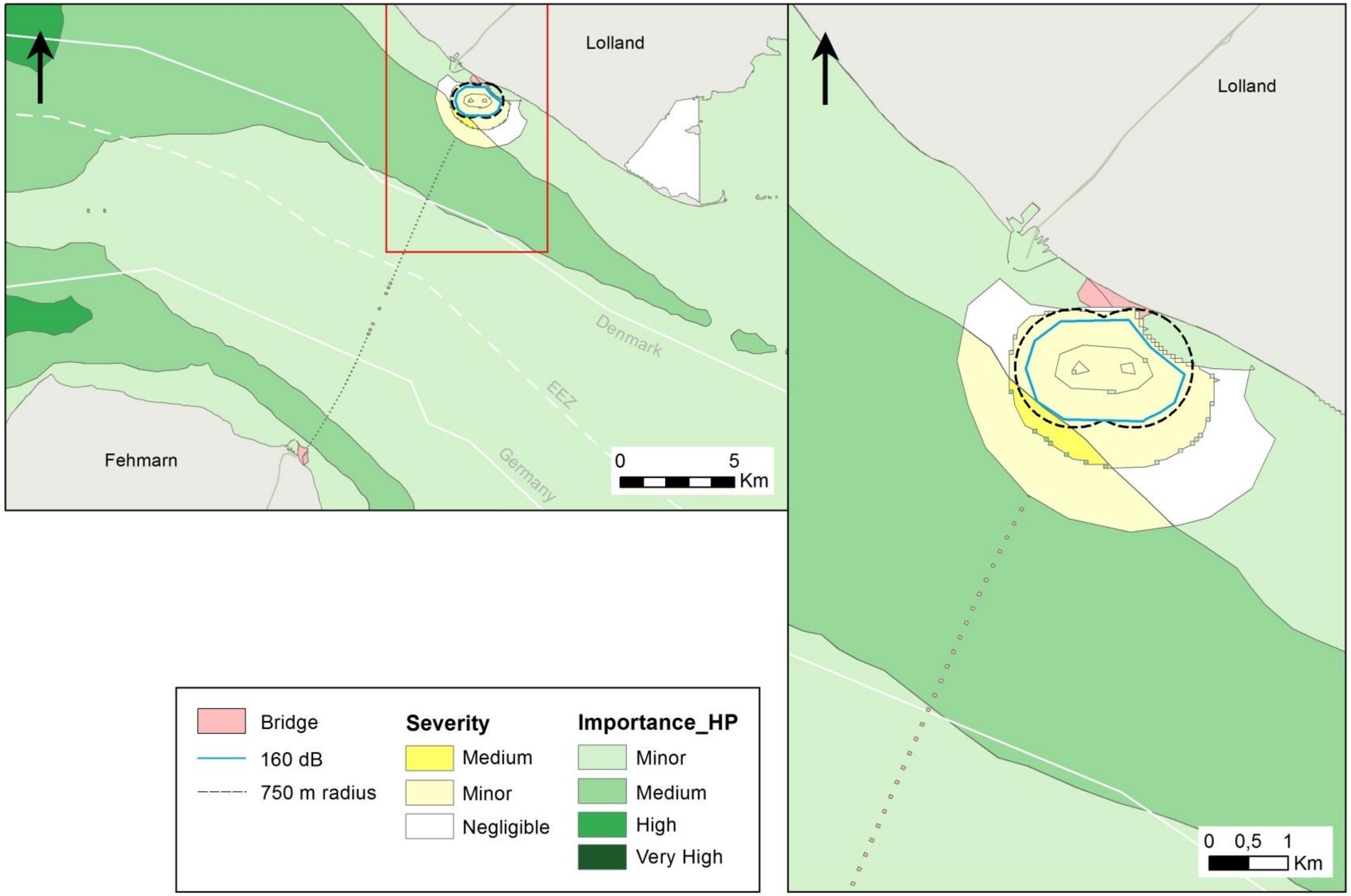

Figure 7.2-20 Severity of Impairment for harbour porpoises during winter bridge piling works (based on two pile drivers working simultaneously.

Table 7.2—6 shows that a total of 0.87 km^2 (0.02% of the harbour porpoise area) are affected by a medium severity of impact (constituting entirely of habitat which is of medium importance for porpoises). A further 5.5 km² (0.11%) of habitat is impacted by a minor severity of impairment, comprising a mix of both medium and minor important habitat.

Table 7.2—6 Severity of impairment of piling on harbour porpoises in winter

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoise affected
Medium	0.41	0.01	0.14
Minor	5.68	0.12	1.24
Negligible	*2.36*	*0.05*	*n/a*
TOTAL SoI	**6.08**	**0.12**	**1.38**

N.B. Negligible implies no impact, therefore this value has not been taken into account for SoI or number of affected porpoises.

1.38 porpoises are predicted to be impacted by pile driving noise during the winter works; a proportion of 0.15% of the winter 2010 abundance. This proportion of animals impacted by winter pile driving is slightly higher than those affected by winter dredging works. A small area of high noise levels is expected (received SEL exceeds 183 dB re1µPa^{2}s for porpoise) which suggests that only porpoise behaviour may be affected, to varying degrees, depending on their distance from the pile driving activity. Pile driving will take place at the coast, where the importance of the habitat to porpoises reduces to minor; therefore it is unlikely that animals will be within the 320 m high noise level zone of possible TTS. It is also possible that porpoises will simply move further out into the channel during the period of these works.

The nearest observed seal haul-out location is approximately 9 km from the lowest noise threshold of 144 dB re 1µPa^{2}s, with the majority of sightings lying over 29 km away. Therefore, as for the dredging, as far as the haul-out zone is concerned, there is no overlap with pile driving noise and therefore no impairment to either seal species. Again, there is a percentage of possible feeding ground that will be affected by noise (6.08 km² and corresponding to 0.12% of the available habitat). The implication of this habitat removal will be discussed in section 7.2.6

Summer

In summer, areas of high importance for harbour porpoises overlap with areas of medium and minor severity of impairment (Figure 7.2-21). The results for summer pile driving works are summarised in Table 7.2—7. A total area of 3.65 km² (0.08% of the harbour porpoise area) is affected with a medium severity of impairment, while 4.54 km² (0.09% of habitat) is impacted by a minor severity of impairment. The severities calculated for summer are slightly higher than for winter due to the increasing importance of the region for cetaceans during the summer months.

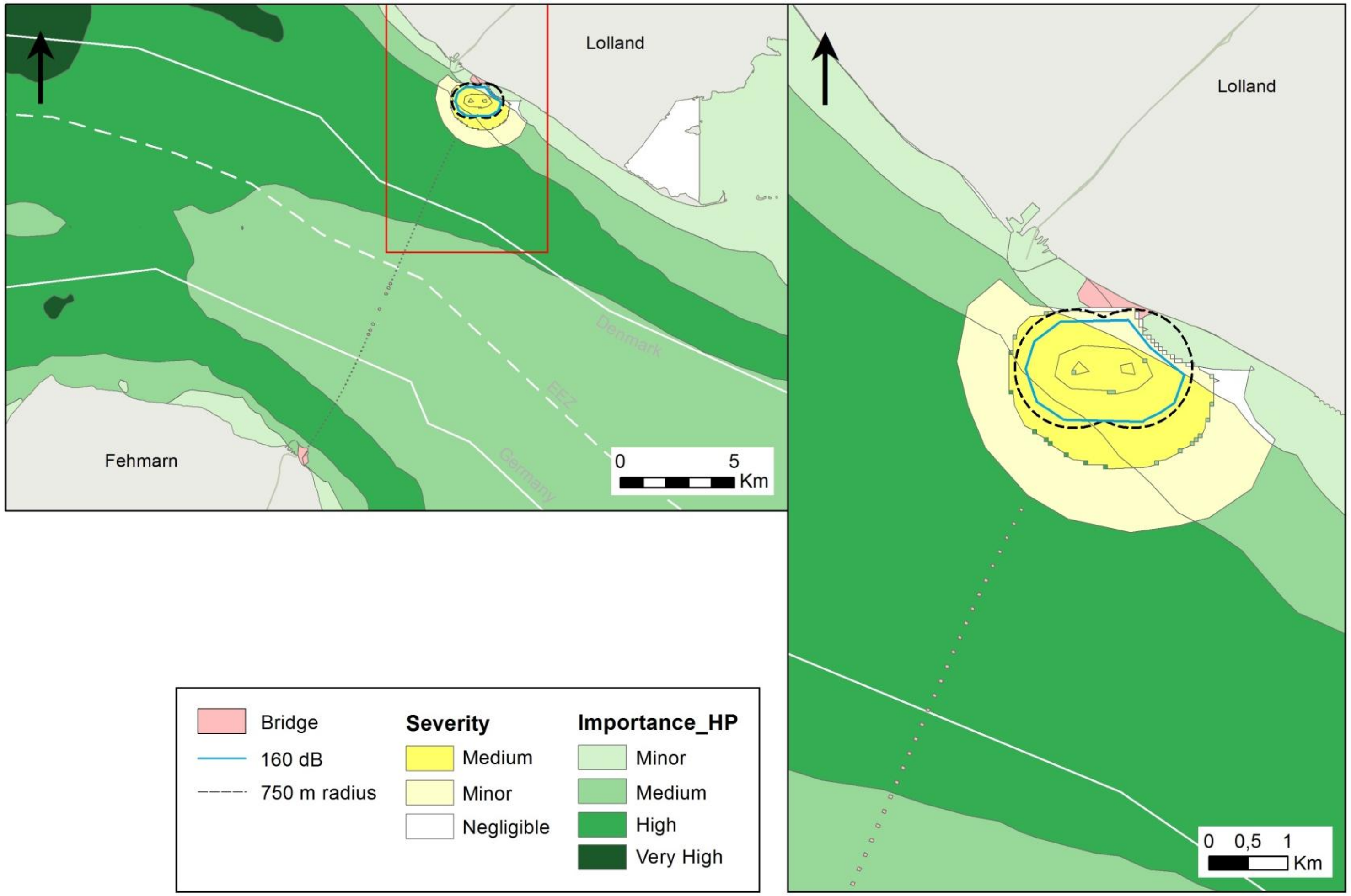

Figure 7.2-21 Severity of impairment for harbour porpoises during summer bridge piling works (based on two pile drivers working simultaneously)

Table 7.2—7 Severity of impairment of piling on harbour porpoises in summer

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
Medium	3.50	0.07	1.51
Minor	4.62	0.09	2.36
Negligible	*0.31*	*0.01*	*n/a*
TOTAL SoI	**8.12**	**0.17**	**3.87**

N.B. Negligible implies no impact, therefore this value has not been taken into account for SoI or number of affected porpoises.

A total of 3.87 porpoises are predicted to be affected by summer pile driving works, approximately 2.5 times the number affected by the winter pile driving. This corresponds to 0.19% of the summer harbour porpoise population, and is similar to the proportion of the local population affected by winter pile driving works.

The summer pile driving works correspond to impairment (of minor to negligible severity of impairment) of 8.12 km² (0.17%) of potential seal feeding habitat. Again, the implication of this habitat removal will be discussed in section 7.2.6

Bored piles - Winter

As can be seen from Figure 7.2-13, the noise from the bored piles does not attenuate as far as the driven piles. Figure 7.2-22 shows the severity of impairment from the bored piling works. It is acknowledged that bored piling could take place from the modelled position southwards to Fehmarn (and thus passes through a small area of medium important habitat). However the majority of drilling will take place in minor important habitat and therefore will have only a minor to negligible severity of impairment on harbour porpoises.

Figure 7.2-22 Severity of impairment for harbour porpoises during winter bridge drilling works

Table 7.2—8 Severity of Impairment of drilling works on harbour porpoises in winter

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
Minor	0.35	0.007	0.05
Negligible	*0.41*	*0.009*	*N/A*
TOTAL SoI	**0.35**	**0.007**	**0.05**

N.B. Negligible implies no impact, therefore this value has not been taken into account for SoI or number of affected porpoises.

A maximum of 0.05 porpoises are affected by the winter drilling works (Table 7.2—8), which corresponds to 0.01% of the local winter population. Reactions of marine mammals to drilling activities are mostly anecdotal with animals observed in the vicinity of drilling activities. Richardson et al 1995 reported some reactions of cetaceans and seals to drilling noise but the data is rather sparse. A few studies were carried out on belugas which showed some avoidance and behavioural changes towards drilling activity in one study, but in another study, the animals did not obviously react to the sound (summary in Richardson et al., 1995). Other studies have observed long-finned pilot whales, common, Risso's and bottlenose dolphins around drill-rigs, all of which have indicated tolerance towards the sound (summary in Richardson et al., 1995). Ringed seals and bearded seals were reported within 50 m of a drilling noise source and exposed to low frequency sound of about 130 dB re 1µPa. In another study the number of ringed seals was reduced in an area of 3.7 km around a drilling activity (Frost & Lowry, 1988 in Richardson et al., 1995). It can be seen from the FEMM modelling results that any reaction will only be behavioural and of minor severity.

The nearest seal haul-out is approximately 13 km away from the nearest point of the bored piling works. Therefore there is no overlap or impact on pupping and haul-outs. However, a total of 0.35 km² (0.007% of the available feeding habitat) will be impacted at any one time by the bored piling works. This area and percentage of habitat affected will be the same in summer as in winter.

The severity of the drilled piling works in summer comprises both medium and minor impairment. The majority of the drilling will take place in a medium importance habitat for porpoises, although a small amount will take place in a high importance habitat (Figure 7.2-23).

Figure 7.2-23 Severity of impairment of summer bored piling works on harbour porpoises

The summer bored piling works (Table 7.2—9) will affect a total of 0.28 porpoises, which corresponds to 0.01% of the summer population. The impacts on porpoises will result in behavioural reactions only, and will be the same as previously described for winter bored piling works.

Table 7.2—9 Severity of Impairment of bored piling works on harbour porpoises in summer

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
Medium	0.35	0.007	0.13
Minor	0.41	0.009	0.15
TOTAL SoI	**0.76**	**0.016**	**0.28**

The impacts on seal species will be exactly the same as for the winter works. There is no overlap between the drilling works and the seal haul-outs, and a total of 0.76 km² (0.016%) of seal feeding habitat will be affected by medium to minor noise levels (leading to a minor to negligible severity of impact).

Scenario of combined impacts

Winter

Figure 7.2-24 shows the severity of impact of the combined scenario including dredging, bored piling and two pile drivers working at the same time. Despite all these activities taking place, the severity of impairment ranges from medium to negligible, with the majority of the works being of minor to negligible severity.

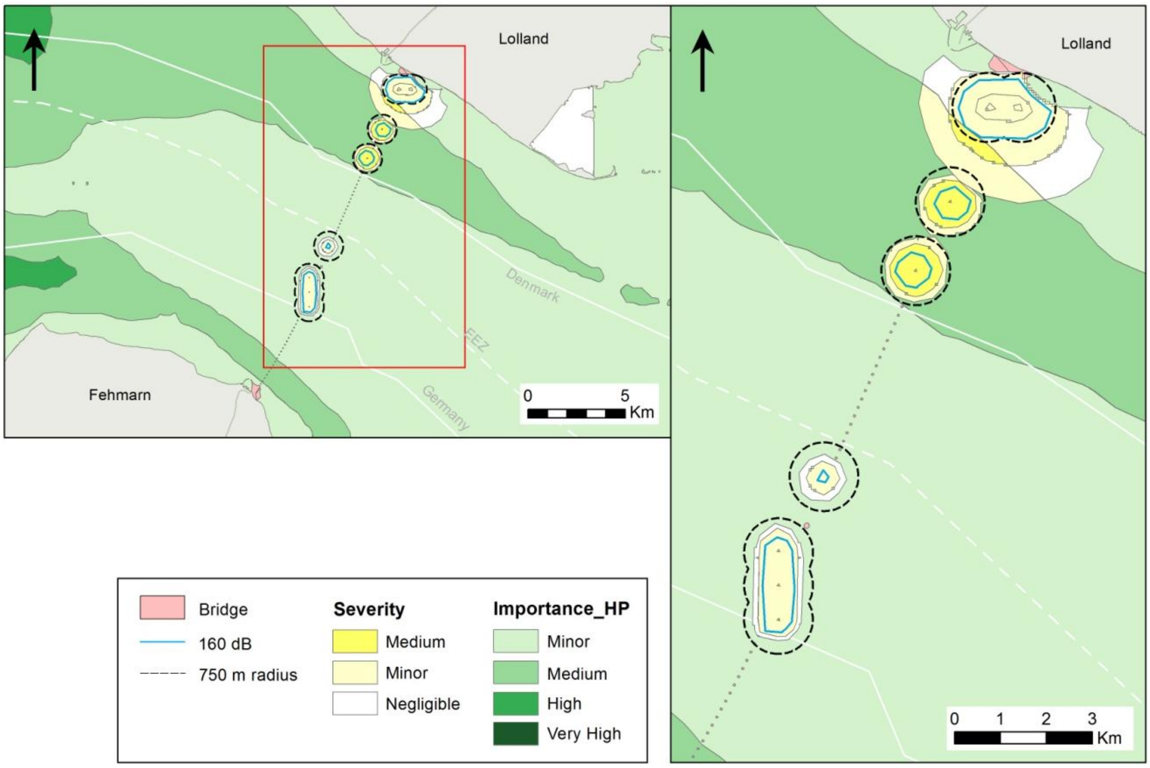

Figure 7.2-24 Severity of Impairment of the scenario of combined impacts in winter

Table 7.2—10 Severity of Impairment of the scenario of combined impacts on harbour porpoises in winter

Severity of Impairment (SoI)	Footprint (km²)	% of Fehmarnbelt region	Number of porpoises based on importance level
Medium	2.29	0.05	0.77
Minor	8.91	0.18	1.92
Negligible	*3.37*	*0.07*	*N/A*
TOTAL SoI	**11.20**	**0.23**	**2.69**

N.B. Negligible implies no impact, therefore this value has not been taken into account for number of affected porpoises.

Table 7.2—10 shows that a maximum of 2.69 porpoises would be affected during the combined scenario in winter. This number corresponds to 0.29% of the local winter porpoise population.

According to the previous scenarios, the seal haul-outs will not be affected by the noise levels as they do not overlap spatially. However, a total of 11.20 km² (0.23%) of their feeding habitat will be impacted by a minor to negligible severity of impairment. The full implications of this impact will be discussed in section 7.2.6

Summer

The severity of impairment ranges from high to negligible for the scenario of combined impacts during the summer (Figure 7.2-25). The habitat affected varies from minor to high importance, with the majority of impact taking place in medium and high importance habitat.

Figure 7.2-25 Severity of Impairment of the scenario of combined impacts in summer

A total of 7.86 porpoises will be affected by the combined summer scenario (Table 7.2—11), which is 1.07 more porpoises than the total porpoises affected, by each noise pressure added up separately. This total corresponds to between 0.29% and 0.56% of the local summer population. It should be noted that this is not loss, but impairment and porpoises will be displaced from the 15.01 km² of habitat. Despite this scenario comprising the largest affected area, it can be seen that the works still do not form a barrier across the channel. Barrier effects will be further discussed in section 7.1.6.

Table 7.2—11 Severity of Impairment of the scenario of combined impacts on harbour porpoises in summer

Severity of Impairment (SoI)	Impaired area (km²)	% of Fehmarnbelt region	Number of porpoises affected
High	0.00	0.00	0.00
Medium	7.54	0.15	3.56
Minor	6.70	0.14	3.45
Negligible	*0.31*	*0.01*	*N/A*
TOTAL SoI	**14.24**	**0.29**	**7.02**

N.B. Negligible implies no impact, therefore this value has not been taken into account for number of affected porpoises.

As for previous noise impacts, there is no overlap with seal haul-out zones. A total of 14.24 km² (0.29%) of potential feeding habitat of seals will be impaired (by a minor to negligible severity of impairment). The effects of this will be described within section 7.2.6

7.2.4. Habitat Loss – construction impact assessment

7.2.4.1. Degree of Impact

Habitat loss caused by the coastal land reclamation and physical habitat disturbance caused by dredging, tunnel placement and backfilling (as described in section 7.1.2.2), will directly impact porpoises and seals. Harbour porpoises, harbour seals and grey seals are mobile predators and use a wide range of habitats, water depths, sedimentary and hydrographic conditions (Tollit et al., 1998; Skov & Thomsen, 2008; Scott et al., 2010).Physical loss will affect staging (occurrence) areas through the direct loss of water column or inter-tidal areas and disturbance due to vessel presence and dredging operations. The distribution of prey is an important factor in defining the distribution of marine mammals; loss of prey resource during the construction period will constitute a loss of feeding habitat. The footprint of the bridge construction covers a total area of 0.79 km^2 of marine mammal habitat (Table 7.2—12).

Table 7.2—12 Marine areas affected by habitat loss from the footprint of the cable-stayed bridge during the construction period

Footprint area	Size, km^2
Bridge piers and pylons	0.20
Coastal peninsulas	0.12
Construction harbour Lolland	0.25
Land reclamation and construction harbour Fehmarn	0.22
TOTAL	**0.79**

The footprint area of the bridge during the construction period is regarded as an area of complete habitat loss since re-establishment within a short- or long-term period is expected to mostly take place after the construction period. Since habitat loss is defined to always result in a complete displacement of all marine mammals from the impact area, the degree of impact due to habitat loss is assessed to be **very high.**

The degree of loss, as shown in Table 7.2—12 can be seen spatially in Figure 7.2-26 below.

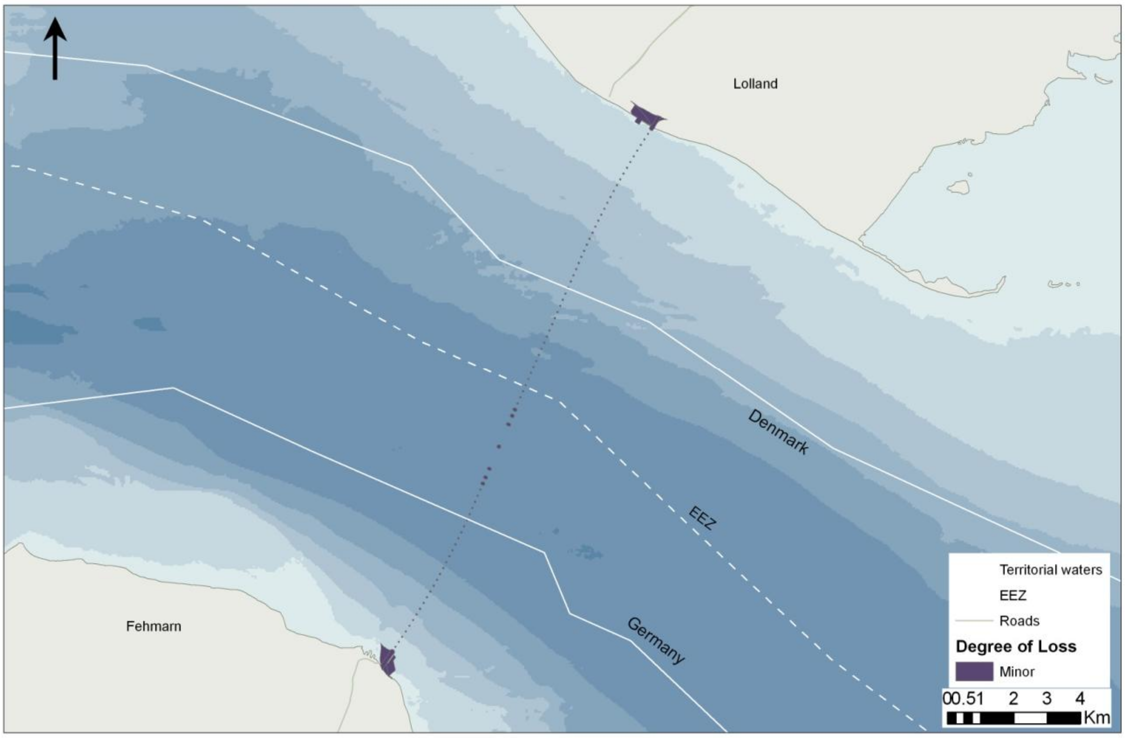

Figure 7.2-26 Degree of loss footprint for cable-stayed bridge construction

The areas disturbed during dredging for access channels and to construct the temporary work harbours at Fehmarn and Lolland will be a temporary loss in habitat. The areas overlain by the piers, pylons and land reclamation will be a permanent habitat loss.

7.2.4.2. Severity of Impact

The severity of the habitat loss is determined by interaction of the degree of the physical loss with the importance of a spatial area for harbour porpoises or seals, as shown in **Table 7.2—13.** The determination of areas of importance to harbour porpoises, harbour seals and grey seals is discussed in detail in Chapter 3.

The severity of loss is shown for the summer season only since this is the season when the harbour porpoise is the most abundant in the area. The impact is predicted to be lower in winter.

Table 7.2—13 Linking matrix for determining severity of loss and showing spatial extent (km^2)

Degree of impact (Loss / impairment)	Importance			
	Very High	High	Medium	Minor
Very High (caused by footprint – $0.79km^2$)	Very High ($0\ km^2$)	High ($0.06\ km^2$)	Medium ($0.40\ km^2$)	Minor ($0.33\ km^2$)

Figure 7.2-27 Severity of loss to harbour porpoise (based upon summer 2010 importance) - Lolland

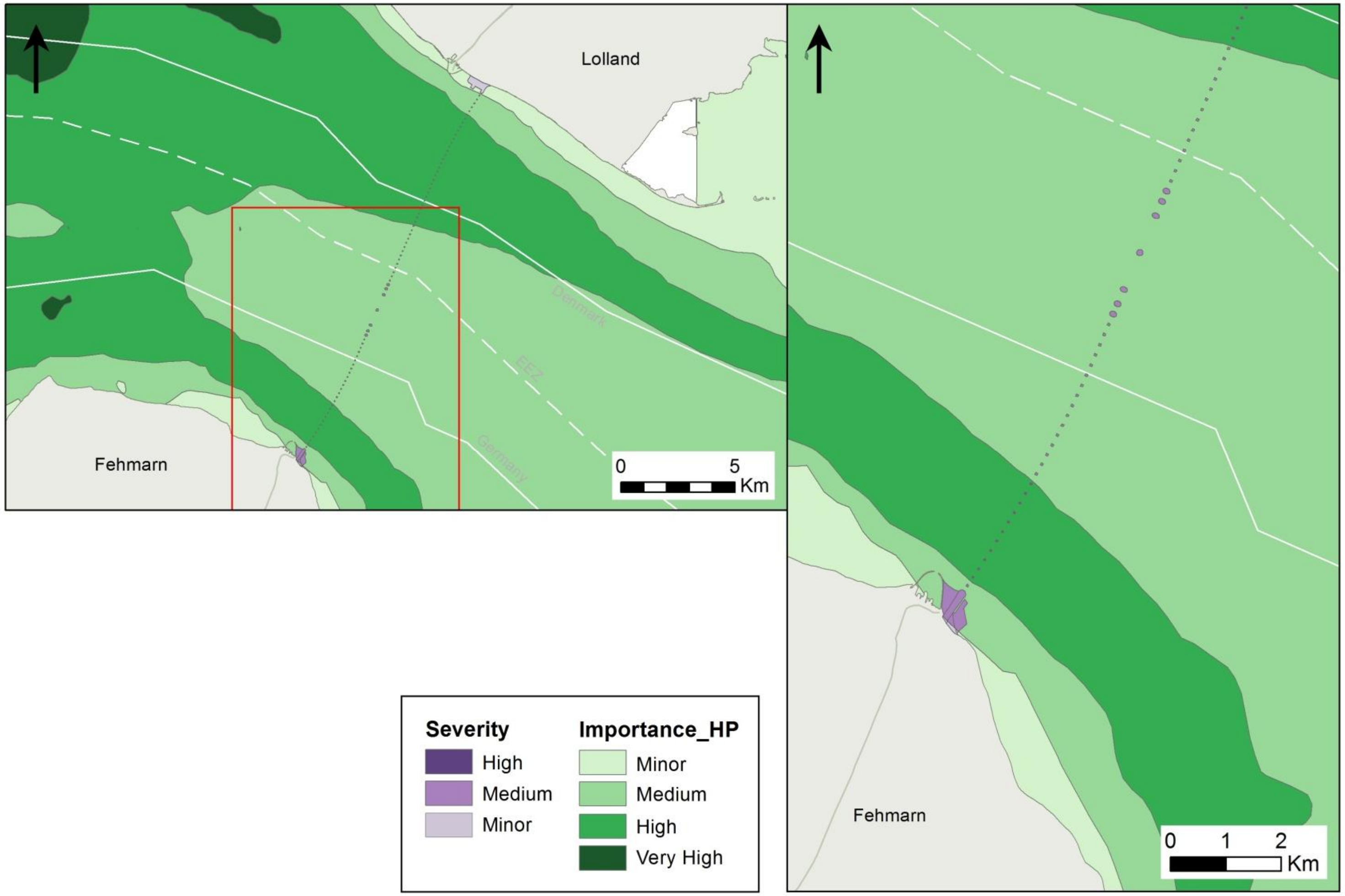

Figure 7.2-28 Severity of loss to harbour porpoise (based upon summer 2010 importance) - Fehmarn

As previously summarised in Table 7.2—12, the area of physical loss is mainly caused by the land reclamation of coastal areas at Lolland and Fehmarn. As shown in Figure 7.2-27, the areas of loss concern minor, medium and high important areas for harbour porpoises (Figure 7.2-27, Figure 7.2-28). In the baseline assessment (FEMM, 2011) the study area was determined to function as part of an area of very high to low occurrence of harbour porpoises and also serves as a migration corridor. The function of the area has been considered as part of the interpretation of the importance layers (density) in calculating the severity of impact. The other features that might define 'importance' in terms of function (feeding area, calving/nursing grounds) cannot be spatially referenced within this impact assessment because they are not spatially defined within the Fehmarnbelt region.

It is important to discuss the severity of loss in relation to the proportion of the harbour porpoise population that use the Fehmarnbelt region. Table 2.1-1 within the baseline (FEMM, 2011) provides modelled abundance estimates. The predicted summer 2010 abundance was estimated at 2,078 harbour porpoises (1,414 – 2,709 ind. 95 % CI). A range of densities has been applied to present the relative importance of an area to this local population.

Table 7.2—14 Proportion of Fehmarnbelt region and porpoise population

Severity of Loss	Footprint	% of Fehmarnbelt region	Number of porpoises affected
High	0.06 km^2	0.001%	0.04
Medium	0.40 km^2	0.008%	0.15
Minor	0.33 km^2	0.007%	0.06
Total	0.79 km^2	0.016%	0.25

The total habitat loss from the footprint is 0.79 km^2 and therefore 0.02% of the Fehmarnbelt harbour porpoise study area. The proportion of high, medium and minor severity of loss is presented in Table 7.2—14. The footprint of the bridge is converted into a percentage of the Fehmarnbelt study area, from which the number of porpoise affected is calculated to determine the severity of loss. This is based upon abundance densities for summer 2010 within each area of importance. This method is described in detail in Chapter 6.

The areas of loss relate to areas of different importance based upon abundance (and therefore defined as occurrence areas). This is represented by the relative number of porpoises affected by differing levels of habitat loss. The function of the area as a migration corridor and nursing area cannot be spatially defined. Therefore, the loss of this function through habitat loss may apply to the total number of porpoises affected, i.e. 0.25. The total proportion of porpoises impacted corresponds to 0.01% of the local population.

The bridge works will be undertaken in sections of piers and pylons. Ground preparation (dredging), harbour construction, foundation placement, backfill and land reclamation will be undertaken as discrete operations over 33 months (January 2014 – September 2016) per section. Construction vessels, dredgers, barges and tugs will be operating across the construction footprint throughout this period. The loss of habitat is not considered to be a barrier, and this is discussed further in section 7.2.7. Therefore, while there will be localised disturbance from the footprint of habitat loss, harbour porpoises will still be able to pass through the Fehmarnbelt, and the areas function as a migration corridor will not be lost to the population. In total 0.016% of the habitat in the Fehmarnbelt region will be lost for harbour porpoises.

Seals

The area of physical loss is caused by placement of bridge structures and land reclamation of coastal areas at Fehmarn. As shown in Figure 7.2-29 this area of loss does not interact with the area of Rødsand Lagoon which is classified as being very high importance to harbour seals and high importance to grey seals. The areas outside of Rødsand Lagoon are not haul-out sites or pupping areas and are therefore of minor importance. The interaction between the footprint of loss and areas of minor importance results in a minor severity of loss.

The physical habitat changes and loss of water column habitat are local to the site of the construction works and will not act as a barrier to seals moving through the area. The areas affected are not used as a haul-out site. The footprint of loss is 0.79 km^2 and therefore 0.016% of the Fehmarnbelt seal study area.

Table 7.2—15 Degree of loss on seals caused by footprint of the bridge and infrastructure

Degree of Loss	Importance			
	Very High	High	Medium	Minor
Very High (caused by footprint – 0.79km^2)	Very High (0 km^2)	High (0 km^2)	Medium (0 km^2)	Minor (0.79 km^2)

The severity of habitat loss to the harbour and grey seal is assessed to be minor. Direct habitat loss will not interact with areas of pupping (haul-out sites) and therefore will not impact the most important areas for harbour and grey seals.

7.2.5. Habitat change from sediment spill - construction impact assessment

The presence of surface and sub-surface elevated suspended sediment concentrations caused by dredging operations has the potential to reduce the ability of visual-feeding marine mammals to locate their prey resulting in an impact upon feeding success. Harbour porpoises can rely on echolocation to detect prey (Santos & Pierce, 2003; Akamatsu et al., 2005; Villadsgaard et al., 2006) and commonly occur in areas of high turbidity, such as the Southern North Sea. Therefore, there will be **no direct effect** of sediment spill on harbour porpoises and this conclusion forms our assessment of significance.

7.2.6. Food supply effects from habitat changes (indirect impact)

The broad scale sedimentation and suspended sediment pressure in relation to marine mammal habitat change is discussed within section 6.2 in relation to the larger sediment spill from tunnel construction. The sediment spill (suspended sediment) and deposition (sedimentation) changes are assessed in detail in (FEHY, 2013d). The studies undertook a numerical simulation of the spreading of suspended sediment concentration levels and sedimentation patterns. Results from the simulated spill concentrations have been compared with baseline conditions for suspended sediment concentrations.

Suspended sediment concentrations are presented as exceedance time. The exceedance time is the percentage of time when the concentration has been above a given value (e.g. 2 mg/l). In order to assess the order of magnitude of the excess concentrations relative to the background concentrations, key statistical parameters are compared: the exceedance times and the “fractiles”. The 90% fractile (f_{90}) is the concentration in one single point which is exceeded 10% of the time. Fractiles and exceedance times have been calculated for the full dredging (ground preparation) period.

The construction of the bridge results in very small excess concentrations. Sediment will only be visible at the surface for less than 10% of the time. Even at the seabed, sediment concentrations will rarely exceed 10 mg/l. Temporal maximum concentration levels at mid-water are shown at about 20 mg/l in the Rødsand Lagoon and are lower further away from the lagoon.

The results show that excess concentrations are generally much smaller than the normal background concentrations and the exceedance times are also much smaller than the baseline background exceedance times. According to FEHY (2013d) the natural median concentration levels are above 2 mg/l; in windy periods many of the stations have background concentrations above 100 mg/l/. In shallow areas like the Rødsand Lagoon suspended sediment is a natural part of the water environment.

The results show that only very small amounts of disturbed sediments are left at the alignment and this sediment consists mainly of the sand fraction. The finer fractions are spread over a wider area. Final sedimentation areas are seen to be the Arkona Basin, the edge of the Bay of Mecklenburg and the sheltered parts of the Rødsand Lagoon. Note that the sediment is spread in a very thin layer over a large area. Generally, maximum deposition heights are below 1 mm.

The sedimentation results show little or no sedimentation in the majority of the offshore area in the Fehmarnbelt away from the alignment. At the alignment, sedimentation is seen to be about 5 mm. The sedimentation originates from the coarser part of the spill (sand fraction) and will deposit 200 – 600 m from the dredging operation.

The deposition of sediment spill can modify benthic habitats through smothering and change in sediment type. Change in benthic communities can influence the distribution of fish communities and prey items of the harbour porpoise.

The substrate types of the Fehmarnbelt region (Figure 7.2-29) support a range of pelagic and benthic fish communities. Baseline studies (FEBEC, 2013) have identified that the pelagic fish community of Fehmarnbelt includes at least 10 species, with sprat, herring, whiting and cod as the most numerous. Considerable seasonal variability was present, and the density of pelagic fish in Fehmarnbelt was lower than observed in other areas including the Øresund. The shallow water fish community (<2 m) was dominated by small fish such as sticklebacks, gobies and sandeels. Cod was the dominant species along the coast of Lolland, in the habitats with vegetation, stones and mussels, while dab and whiting were most numerous in sandy habitat. In the Rødsand Lagoon extensive eelgrass habitat was dominated by small fish species such as the three- and nine-spined stickleback, eelpout and several species of gobies. Larval and juvenile stages of pelagic fish such as herring and sprat were frequently registered. Sub-areas along the coasts of both Fehmarn and Lolland were shown to function as nursery grounds for several fish species.

7.2.6.1. Harbour porpoises

Harbour porpoises will not only be disturbed by the footprint but may also be indirectly affected through reduced prey availability as a result of the sediment spill, which may impact the benthic fauna and also affect fish.

According to the impact assessment of marine fauna (FEMA, 2013c) the sediment spill leads to an impairment of the benthic communities over an area of 58,000 ha. However, the degree of impairment is mostly minor. Areas of very high and high magnitudes of pressure are restricted to areas close to the alignment or to shallow parts of the Fehmarnbelt due to resuspension of the spilled sediments. The latter areas are not important for harbour porpoises.

The sediment spill will lead to low impacts of the fish species which serve as food resources to harbour porpoises and other marine mammals. In calculating the impacts from sediment spill on fish, FEBEC based their assessment on 0.11 million m^3 being spilled from the construction of the cable-stayed bridge (FEBEC, 2013). The severity of impairment of sediment spill from the construction of the cable-stayed bridge is assessed as minor on all fish indicators selected for the impact assessment (FEBEC, 2013).

FEBEC, 2013 predict that the direct impact from the construction of the cable-stayed bridge on different life stages of fish from suspended sediment and sedimentation would result in less than a 1% reduction of fish biomass within a 500 m zone around the construction site (near zone). No direct effects are predicted for areas beyond the near zone. Indirect effects from changes in benthic vegetation are predicted to result in reductions for shallow water fish species in the Danish near zone in 2015 of up to 3.1%. FEBEC, 2013 concludes that there are only minor impacts from the dredging activities on fish and fish communities. Thus, FEMM considers minor impacts on marine mammals, since there is no change in food resources.

7.2.6.2. Seals

The substrates which are used by harbour and grey seals for foraging are relatively widespread throughout the Fehmarnbelt area. Figure 7.2-29 shows that there is interaction of the impact footprint with areas of ‘coarse sediment/boulders’ and a small area of ‘sand’ that may be potential feeding areas for harbour seals. However, this interaction is very small in relation to remaining substrate in the area that is available for feeding. Grey seals have been seen to forage over much greater distances in the Fehmarnbelt region, and there is no interaction with any preferred ‘mud’ substrate. The area of interaction with ‘sandy mud’, is again small in relation to substrate available in their foraging range.

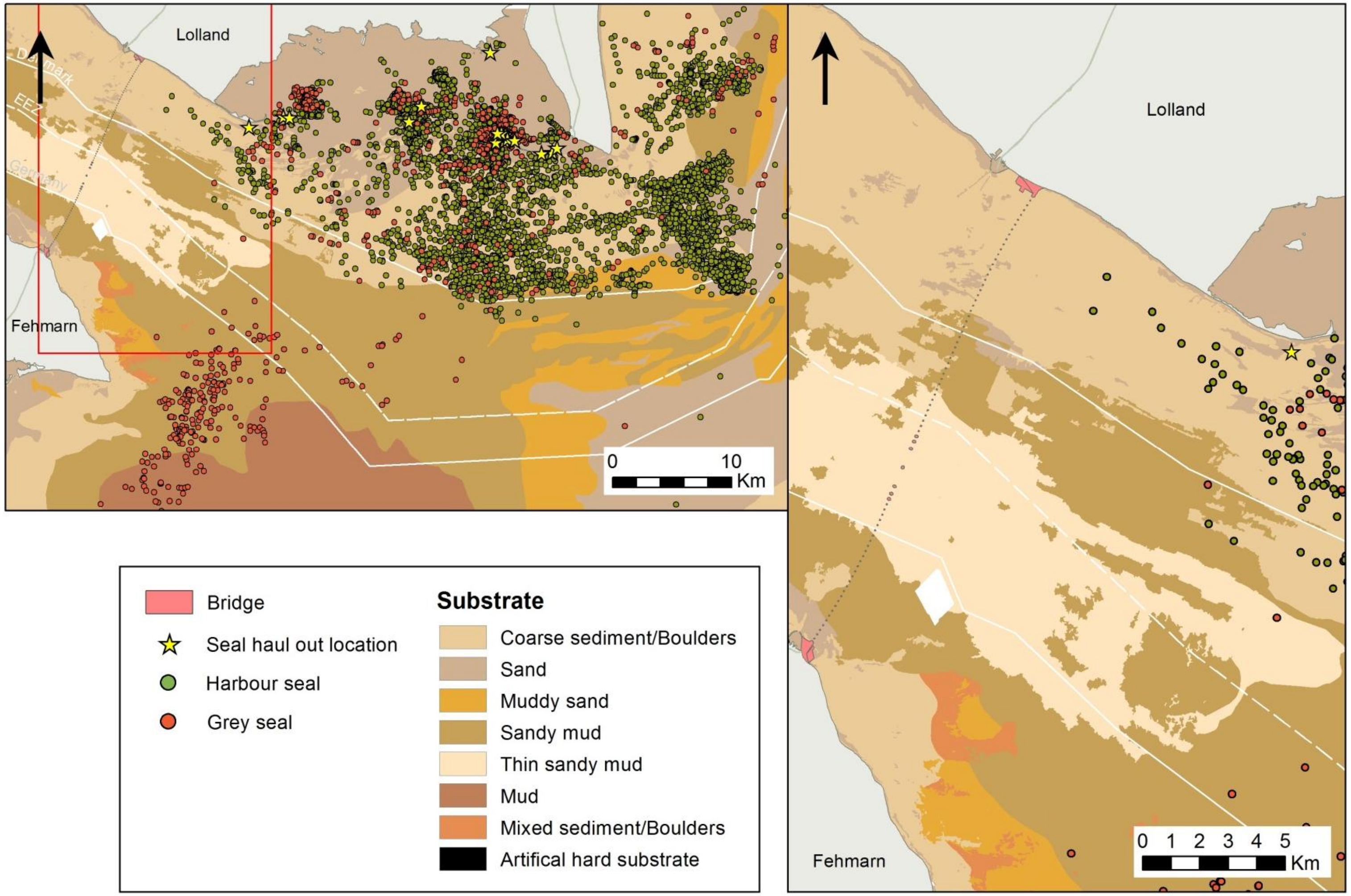

Figure 7.2-29 Severity of loss footprint in relation to substrate type and haul-out location, also showing baseline data of slow moving tagged seals.

7.2.6.3. Degree of impact

Using the data displayed above: the degree of impairment from reduced food supply for marine mammals outside the footprint area is thus considered to be low.

7.2.6.4. Severity of impact

Using the data displayed above: he severity of impairment from reduced food supply for marine mammals outside the footprint area is thus considered to be **minor**.

7.2.7. Disturbance /barrier from construction vessels - construction impact assessment

As the information on the construction of a bridge was not detailed enough to make an assessment, the potential impacts associated with the construction activities are assumed to be similar to the tunnel solution described in chapter 6.2.2.5.

7.2.7.1. Degree of Impact

As discussed in section 7.2.3.1 it is proposed that the modelling of noise for tunnel dredge sections (G1 – G4 and D1 – D4) can be used as a proxy for dredging the bridge sections in June and October 2014.

Further estimation of the degree of impact follows chapter 6.2.2.5. The only adaptation is that the impact of simultaneously working dredgers is based specifically on information on dredging works for the construction of the bridge pillars which is described in detail in section 7.2.3.1. Following this chapter the scenario with most intensive dredging work will take place in June 2014 (Figure 7.2-30) with dredging works at F27-F25, F18-F1 and at the central pylons and piers (tunnel dredge sections G1, G2, G3 and G4). Dredging in all these sections gives a slightly extended dredge area compared to the most extensive tunnel construction dredging works). As can be seen by Figure 7.2-30 over half the strait between Lolland and Fehmarn is open water and free from dredging barriers. However, where the dredging work occurs, there is a small potential barrier of approximately 5 km, although this section does have at least two gaps of several hundred metres,

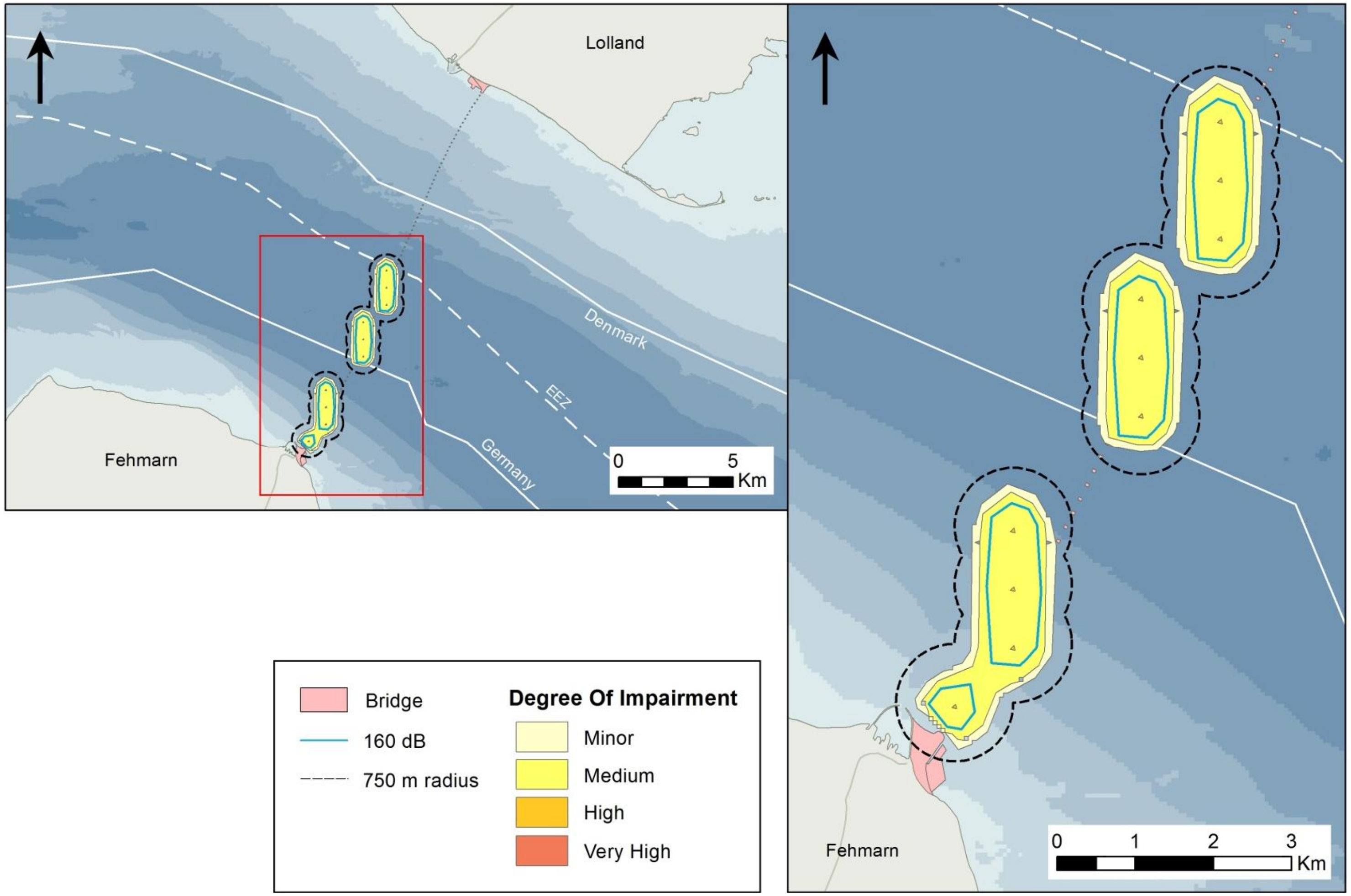

Figure 7.2-30 Degree of Impairment of the bridge dredging in June 2014

The barrier effect caused by noise emitted from dredging vessels is deduced from the scenario shown in Figure 7.2-30, when all dredgers are working simultaneously in sections F27-F25, F18-F1 and at the central pylons and piers (tunnel sections G1, G2 G3 and G4).

Following the same arguments presented in section 6.2.7.1 the degree of impairment for the scenario is assessed to be negligible, given that mammals can detour around the dredging operation and still pass from one side of the Fehmarnbelt to the other. Hence, there are only minor impacts predicted to marine mammals.

7.2.8. Contaminants

As part of the baseline assessment for the Fehmarnbelt project an investigation into the seabed chemistry of the Fehmarnbelt area was undertaken, including an assessment of the chemical risks of sediment suspension (FEMA, 2013b).

The Marine Soil – Baseline report (FEMA, 2013b) concludes that:

- Release of nitrogen is probably unproblematic;
- An additional small source of phosphate will most likely not lead to higher primary production, or stimulate blooms of cyanobacteria;
- Overall, the concentration of heavy metals and organic pollutants (HCB, DDTs, PCBs, PAHs, TBT) in surface sediments was low compared to the lower range of the German, Danish and OSPAR sediment quality guidelines;
- Because the concentration of pollutants approaches background concentrations the spread and release of organic pollutants connected to dredging can be considered as unproblematic;
- Less than one metre below the surface, seabed sediments are of pre-industrial origin and therefore represent soil types with only natural occurrence of heavy metals;
- Low concentrations of heavy metals in surface sediments (0 m to 1 m) and background levels at 1 m to 12 m depth mean that the spread and release of heavy metals connected to dredging must be considered as unproblematic;
- Assuming a dredging rate of 20,000 m3 per day and a spill rate of 3 %, an average uptake of 93 kg of oxygen (63-181 kg of O2) per day can be expected. Except for very local phenomena during calm periods, oxygen depressions in the water column are not likely.

In the Fehmarnbelt seabed chemistry study (FEMA, 2013b) the results of the chemical analyses were compared against the German and Danish national and OSPAR Action Levels for a range of chemical contaminants, including key components from the OSPAR & HELCOM primary and secondary lists. FEMA (2013b) concluded that the contaminant levels in the Fehmarnbelt study area were at or below the lowest sediment quality guideline (Action Level) at which case the contaminant level is virtually certain to have no adverse effects.

7.3. Operation

7.3.1. Description of associated operation activities

After completion of the construction works for a cable-stayed bridge, the structures affect marine habitats during operation. Pressures relating to the operation phase of the cable-stayed bridge:

1. Three-dimensional area covered by bridge structures
2. Dimensions of the approach bridges
3. Dimensions of the main bridge
4. Illumination of the bridge
5. Noise induced by the traffic crossing the bridge

During operation of the cable-stayed bridge no offshore activities are planned. All maintenance work will be conducted from land and therefore possible impacts on marine mammals are not expected. The bridge will be illuminated with indirect and direct illumination of construction details such as the main span pylon, the piers adjacent to main pylons, the cable stays, the girder and staircases. The basic illumination is white coloured flood lighting with an average luminance of 5-10 cd/m² and uniform luminance surface of pylons. However, no further influence is expected (compare to barrier effect, Chapter 4 Sensitivity). Traffic noise is transferred through the concrete pylons and piers and consequently emitted permanently into the water column. Measurements from emitted sound from the Great Belt Bridge indicated that the shipping lane is the main and loudest sound source of underwater noise in the vicinity of the bridge (FEMM, 2011). During the operation phase, the new fixed link will be used by the main traffic and the pressure of sound emission into the water column will be diminished if the ferry schedule is reduced.

7.3.2. Description of pressures related to cable-stayed bridge operation

With the operation phase of the cable-stayed bridge, pressures on marine mammals can be divided into (permanent) operation activities and the presence of the bridge structure itself. Possible pressures are listed as follows:

A) Habitat change:

- Permanent changes through coastal land reclamation areas east of Rødbyhavn and Puttgarden induce changes in habitat structures and hydrography. Reclaimed areas extend from the coastline and occupy an area of 0.2 km² at Fehmarn and an area of 0.16 km² at Lolland (Table 7.3—1);
- Permanent changes through the bridge peninsula east of Rødbyhavn and Puttgarden inducing changes in habitat structures and hydrography;
- Permanent changes through a re-established seabed east of Rødbyhavn and Puttgarden inducing changes in habitat structures and hydrography;
- Permanent changes in the offshore areas due to the 74 piers of the two approach bridges, as well as the four piers and three pylons of the main bridge. This is

considered as a habitat change in structure and hydrography since hard substrate will be introduced into the water column. The foundations and scour protection will introduce rock substrate onto fine seabed sediment.

B) Noise

- Noise emission into the water column from traffic crossing the bridge is considered to be a permanent pressure on marine mammals.

Table 7.3—1 Size of marine areas affected by the permanent footprint of a cable-stayed bridge and predicted recovery times of the seabed in different areas (FEHY 2013c).

Operation activity	Pressure on marine mammals	Size in km²	Recovery time
Permanent project structures	Land reclamation and bridge peninsula Lolland	0.16	No recovery
	Land reclamation and bridge peninsula Fehmarn	0.20	No recovery
	Bridge pylons and piers	0.20	No recovery
	Project re-established seabed (harbour Lolland)	0.15	<2 years
	Project re-established seabed (harbour Fehmarn)	0.09	<2 years
	In total	0.79	
Operation (traffic)	Noise/vibration	--	No recovery
Reduction in ferry service	Noise	--	

7.3.3. Noise operation impact assessment

For the identification of noise levels originating from the bridge traffic, sound and vibration measurements from underneath and at a close distance to the Great Belt Bridge were undertaken (FEMM, 2013). The average sound levels for the median varied between 104 dB re 1µPa, 112 dB re 1µPa and 119 dB re 1µPa. Comparisons between measurement positions indicated that the absolute level at a given location only depends on its distance to the shipping lane. Consequently the bridge provides no significant additional source of underwater sound. Therefore, there is no impact on marine mammals from the operation of the bridge.

7.3.4. Habitat change - operation impact assessment

7.3.4.1. Degree of Impact

The total height of the completed caisson is 34 m. After completion the caisson will have a draft (depth below water line) of 14 m. Ship impact protection is placed as a concrete caisson ring with a water depth of 16 m.

The placement of the bridge support structures and associated ship impact protection will introduce new hard substrate into the area, increasing the surface area for epifaunal colonisation. Preliminary investigations by FEBEC suggest that the bridge pillars could provide a 'reef' effect for different fish species (e.g. cod, whiting, plaice and flounder) which may be attracted to the structures (Keller et al., 2006). Keller et al. (2006) state that fish communities in the area of 'artificial reefs' are similar to those at natural reefs. Therefore, the bridge alternative has the potential to affect and change the fish communities in the area of Fehmarnbelt permanently (until such time that it is decommissioned). FEBEC also surmise that the increase of small fish densities at these 'artificial reefs' will also entail an attraction effect on bigger fish species (e.g. cod, whiting) (Lindeboom et al., 2011). The fish communities at the coastal areas could permanently change from species-poor communities at sandy bottoms to species-rich communities at structured artificial substrate. However, the original structure and function of the sandy habitats would be lost. Therefore, this habitat change would result in loss of habitat for fish species which are closely associated to these kinds of sandy habitats (e.g. flatfish). For marine mammals any 'reef' effect from the bridge is suggested by FEMM to be neutral because FEBEC has identified a change but no decrease in marine mammal food supply, however, it is not possible to quantify such effects from the available evidence.

7.3.5. Habitat change – Hydrography - operation impact assessment

7.3.5.1. Degree of Impact

Hydrodynamics and water structure can be important factors in determining the distribution of harbour porpoises. The broad scale hydrographic pressure in relation to marine mammal habitat change is discussed within section 7.1.

The hydrographic changes due to the bridge alternative are assessed in detail in FEHY 2013a and FEHY 2013b. In this section an extract of the reported hydrographic changes relevant to marine mammals is presented. The assessed hydrographic changes include changes to the indicators current, water level, salinity, water temperature, stratification and waves. It should be noted that changes associated with sediment spill during the construction process are not included here. It should also be noted that water quality related changes are assessed by FEMA and are not included here. Only hydrographic changes within the investigation area for marine mammals are included.

The main tool for the FEHY hydrography assessment is numerical modelling. The FEHY numerical models (MIKE and GETM) applied to assess the bridge alternative in Fehmarnbelt and adjacent waters operate at a horizontal grid resolution of 400-700 m in the potential bridge alignment area, and the effect of bridge piers and pylons are included by means of a sub-grid parameterisation. Since only hydrographic changes of similar or larger scales than the grid resolution are captured by the models, it is implied that very localised hydrographic changes, with scales of less than a few hundred metres, are not included in the FEHY hydrography assessment.

FEHY have assessed three scenarios: the 0-alternative (“ferry”), the bridge alternative only (“bridge”) and the combined ferry and bridge alternative (“ferry+bridge”). The results show that the differences in hydrographic changes related to the “bridge” and “ferry+bridge” scenarios are very limited (FEHY, 2013b). Therefore, only changes related to the “ferry+bridge” scenario are described here.

The change in current conditions due to the bridge solution is assessed by FEHY in terms of the annual mean surface and bottom current speeds. In Figure 7.3-1 the permanent change in annual mean surface current speed, as calculated by the MIKE model, is shown. The permanent changes amount to a reduction in surface current of up to 0.03 m/s at 5 km distance from the main bridge structures and decreasing with distance from the bridge. Off the Fehmarn coast an increase of up to 0.02 m/s is predicted. At the sea bed the modelled effect in annual mean current speed is of the same order of magnitude or lower. In the construction period the temporary work harbour and the production facility and its breakwaters will impose additional local changes to the current conditions. FEHY has not quantified these changes, but state that there will be considerable reduction in the current speed between the Lolland production facility and the Rødbyhavn breakwater.

In order to evaluate the changes in current conditions, it may be useful to compare them to the natural variability in the current conditions. The natural variability of the current speed in Fehmarnbelt is presented in FEHY (2013b) in terms of the mean and standard deviation of measured current speed in the FEHY main station 02. The 2009-2010 surface and bottom mean current speed is 0.41 m/s and 0.13 m/s, respectively, and the corresponding surface and bottom standard deviation is 0.23 m/s and 0.09 m/s, respectively. Thus, the estimated changes in currents for the bridge solution are negligible in comparison to the natural variability found in Fehmarnbelt.

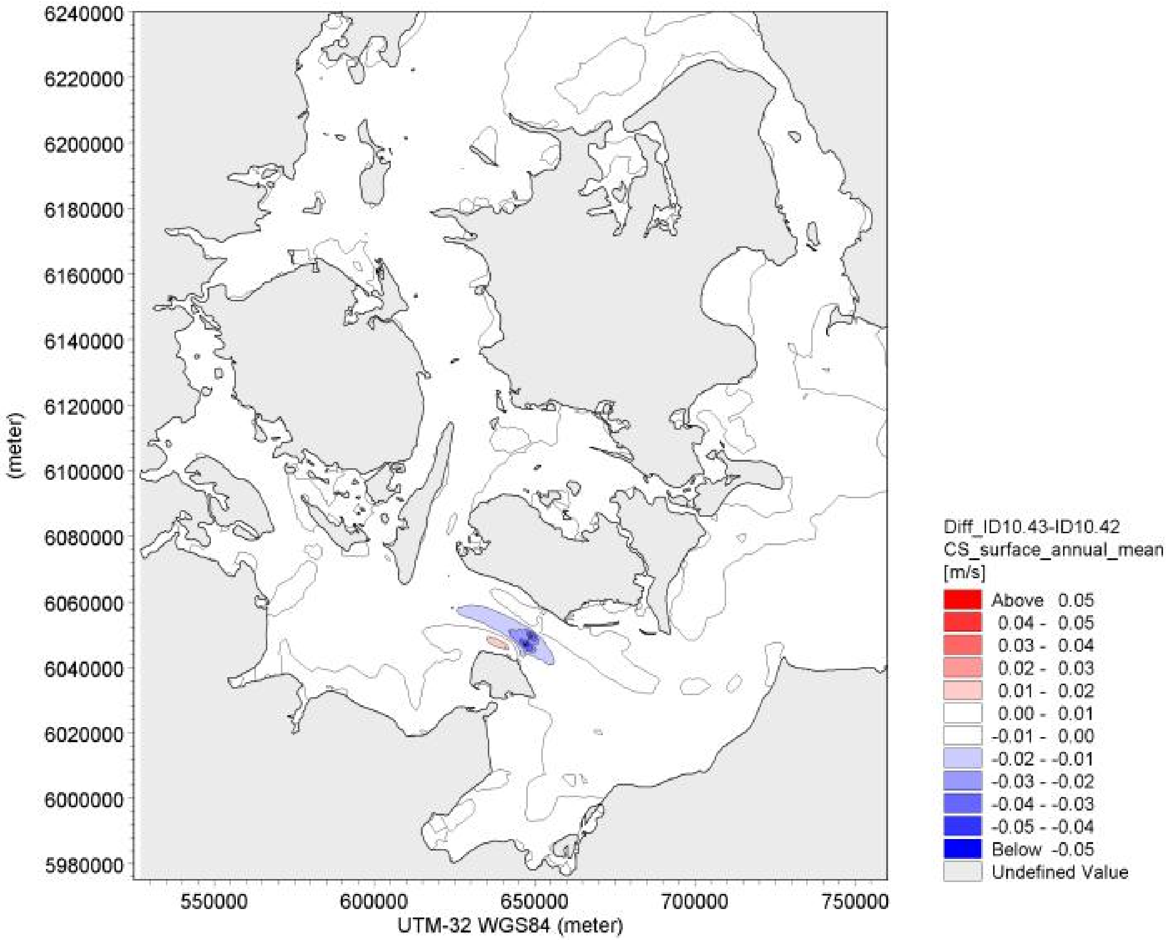

Figure 7.3-1 Modelled effect of "ferry+bridge" scenario on annual mean surface current speed (FEHY, 2013b).

With respect to water level, salinity, water temperature and stratification, the permanent changes and changes during the construction period are predicted by FEHY to be limited (mean water level change <0.01 m; mean salinity change <0.25 PSU; mean temperature change <0.25° C; mean stratification change <0.25 kg/m^3). With respect to waves, permanent changes and changes during construction are mainly seen on the eastern side of the bridge alignment. The changes predicted are reductions of 0.15 m to 0.30 m of the significant wave height exceeded 5% of the time within about 8 km of the bridge.

The hydrological impacts are localised and lie within <50% of the natural change (standard deviation as defined within FEHY, 2013b. While hydrodynamic variables can be important factors in governing the distribution of harbour porpoises, the results of the baseline study demonstrated that they are not key factors in the Fehmarnbelt area. Therefore as the hydrological impacts are considered to be localised and within natural variability of the area, and will not affect prey fish species, so there will be **no impact** on marine mammals and this conclusion forms our assessment of significance**.**

7.3.6. Barrier effects - operation impact assessment

The cable-stayed bridge presents a structure across the Fehmarnbelt. We have considered whether the structure itself may display a barrier effect for marine mammals; Chapter 4 “Sensitivity” deals intensively with the issue. Current knowledge leads to the conclusion that a bridge across Fehmarnbelt would not present a barrier for harbour porpoises, harbour seals or grey seals.

7.3.6.1. Severity of impact

Harbour porpoises have been observed and recorded crossing under the bridge across the Great Belt. The studies undertaken by (FEMM, 2013) show the presence of harbour porpoises in the proximity of the bridge and with no evidence for changed behaviour due to the bridge. Consequently, for the harbour porpoise, the severity of impairment from the bridge is assessed to be negligible and the function as a migration corridor will not be negatively affected.

Harbour seals and grey seals have been documented travelling and feeding under the bridge. Telemetry data from the Fehmarnbelt area has also shown seals covering large passages crossing several fixed links. Movements of seals between distant haul-out sites are documented showing them swimming under bridges. Neither harbour seals nor grey seals are expected to be impaired by the bridge as a barrier; therefore the severity of impairment from the bridge footprint in Fehmarnbelt was assessed to be negligible. Therefore overall, there is predicted to be **a minor impact** from the bridge acting as a barrier to either porpoise or seals.

7.3.7. Contaminants - operation impact assessment

The cable-stayed bridge infrastructure includes drainage, storm water treatment (sand trap - oil separators), rain water storage basin, and waste water pipes. There are **no direct impacts** on marine mammals predicted from contaminant spills from the cable-stayed bridge.

7.4. Overall assessment of severity of impact

Table 7.4—1 Summary of severity of impact for marine mammals from the construction of the cable-stayed bridge

	Severity of impact			
	Harbour porpoise			
Pressure	Winter	Summer	Harbour seal	Grey seal
Noise from the scenario of combined impacts (dredging, pile driving and bored piles)	Medium 0.77 Minor 1.92	High 0.00 Medium 3.56 Minor 3.45	Minor	Minor
Habitat loss	High 0.04 Medium 0.15 Minor 0.06		Minor	Minor
Habitat change (all pressures)	Minor		No impact	No impact
Food supply effect from habitat change (indirect effect)	Minor		Minor	Minor
Barrier effects	Minor		Minor	Minor
Contaminants	No impact		No impact	No impact

Table 7.4—2 Summary of severity of impact for marine mammals from the operation of the cable-stayed bridge

	Severity of impact		
Pressure	Harbour porpoise	Harbour seal	Grey seal
Habitat change(all pressures)	Minor	No impact	No impact
Food supply effect from habitat change (indirect effect)	Minor	Minor	Minor
Barrier effects	Minor	Minor	Minor
Contaminants	No impact	No impact	No impact

7.5. Determination of significance – cable-stayed bridge

The methods for determining significance described in Chapter 3.5.3 have been applied to the assessment of the impacts on marine mammals from the construction and operation of the cable-stayed bridge.

7.5.1. Construction noise – harbour porpoises

Overall, on average a small number of 2.69 and 7.02 porpoises would be affected in winter and summer respectively, assuming the combined scenario of dredging, pile driving and bored pile works all take place at the same time. These values correspond to 0.29% of the Fehmarnbelt abundance in winter and 0.34% in summer. The harbour porpoise population of the Kattegat, the Belt Sea and Inner Baltic Sea was estimated at 23,227 during the SCANS II survey. A maximum disturbance of 7.02 porpoises corresponds to an impairment of 0.03% of the Baltic subpopulation. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population).

7.5.2. Construction habitat loss – harbour porpoises

Overall, a total of 0.25 porpoises will be affected by habitat loss. This value corresponds to 0.01% of the Fehmarnbelt population abundance in summer. The harbour porpoise population of the Kattegat, the Belt Sea and Inner Baltic Sea was estimated at 23,227 during the SCANS II survey, and with a maximum number of 0.25 porpoises affected from habitat loss, this equates to an impairment of 0.001% of the Baltic subpopulation would be affected. The effect is therefore **insignificant** at the population level (<1% of both the Fehmarnbelt study area population and the Baltic population).

7.5.3. Food supply - harbour porpoises, harbour seals and grey seals

The cable-stayed bridge option would lead to small impacts on fish outside the footprint area. Therefore there will only be minor effects on harbour porpoises. These effects are not considered to be significant.

7.5.4. All other pressures - harbour porpoises, harbour seals and grey seals

For all other pressures no impact was identified in the impact assessment for marine mammals so effects are judged to be **insignificant** at the population level (i.e. <1% of the harbour porpoise Fehmarnbelt study area population and <10% of pup production).

7.5.5. Overall assessment of significance

In all cases the FEMM impact assessment has shown minor impacts which are unlikely to cause physical impairment to marine mammals. However, a low number of individuals would be disturbed by the cable-stayed bridge option (7.02 porpoises due to construction noise and 0.25 due to habitat loss). Thus, in total a maximum of 7.27 porpoises might be impacted at a time from loss and impairment. This equates to 0.031% of the Baltic subpopulation. Although the construction activities would commence for several years, the overall effect is insignificant (<1% of both the Fehmarnbelt study area population and the harbour porpoise population of the Kattegat, the Belt Sea and Inner Baltic Sea.) Even if the same porpoises were exposed to all pressures associated with the cable-stayed bridge, these are not considered by FEMM to be at levels that would be detrimental to the long-term fitness of the animal.

7.6. Assessment of strictly protected species (Article 12 Habitats Directive)

It needs to be determined whether any of the pressures described in the chapters above may lead to a violation of the objectives of Article 12 of the Habitats Directive as outlined in chapter 3.6.

7.6.1. Deliberate capture or killing of specimens, including injury

Of the described pressures described in the chapters above, only underwater noise could potentially cause injury in harbour porpoises. All other pressures may affect harbour porpoises only indirectly by affecting their natural habitat and are thus not treated in the assessment of strictly protected species.

Noise levels predicted for the construction of a cable-stayed bridge are associated with dredging activities, shipping and piling:

7.6.1.1. Underwater noise from dredging and shipping

Noise levels predicted for dredging and shipping activities are in the range of usual shipping noise which occurs regularly in the area and is too low to cause any form on injury or even temporal impairment of hearing abilities. Noise levels of the dredgers are described in chapters 6 and 7. Compared with shipping noise dredging emits a broader frequency band with frequencies of 40 kHz and above at source levels that can reach up to 184 dB re 1µPa. Sound pressure levels fall below 160 dB at a distance of 456 m to the source and the German threshold for underwater noise emissions of 160 dB SEL at a distance of 750 m is not exceeded. The construction vessels with a SL of 175 dB re 1ųPa, which is nearly 10 dB lower than the TSHD, were not modelled since the contribution of these extra sound sources is negligible.

The noise emissions lead to medium and minor impairment and cause disturbance at a maximum range of 870 m. As the noise emitted from the dredgers, as well as those of other ships used during the construction process is continuous, and no high and impulsive noise emissions will occur, harbour porpoises can easily avoid the small area of high noise levels.

7.6.1.2. Underwater noise from piling

Sheet piling during the construction of harbours on Lolland and Fehmarn will be carried out by vibro-piling with low energy (40 kN). Bored piles are also to be installed at certain locations as part of the foundations for the bridge pillars. Noise emission from sheet piling will be comparably low but has been estimated with a source level of 190 dB re 1µPa as a worst case scenario. Sound pressure levels fall below 160 dB at a distance of 685 m to the source and the German threshold for underwater noise emissions of 160 dB SEL at a distance of 750 m is not exceeded. The piling of the sheets may require the application of deterrents to avoid porpoises remaining in the direct vicinity of the construction work. Such devices have proven to be highly efficient and will deter porpoises out of the small area which has a very high degree of impairment.

It is thus concluded that construction work will not lead to killing or injuring of harbour porpoises and that the obligations of Article 12 habitat directive are not violated by the project.

7.6.2. Deliberate disturbance

Noise emissions from construction activities lead to small-scale disturbance. Disturbance ranges from individual construction vessels are estimated to reach not further than 500 m. According to the predicted noise levels from dredgers, disturbance of harbour porpoises will occur at a range of a few hundred metres, depending on prevailing ambient noise levels. Most construction activities will occur in areas which are subject to high shipping intensities and have high ambient noise levels. The number of harbour porpoises which will be exposed to medium or minor noise levels from dredging or other shipping activities will be very low and the disturbance will be of similar type and duration as experienced by the animals regularly from other shipping activities in the area. It is thus concluded that the disturbance will not cause a displacement of a significant proportion of harbour porpoises. No specific impacts regarding the function of the area as a breeding, rearing or migration area are expected and it is concluded that the overall function of the Fehmarnbelt area for harbour porpoises will not be affected by the project.

Noise emissions from piling at the construction harbours will affect a larger area, but are of limited duration. The total number of porpoises exposed to noise levels which may lead to disturbance is very low. From other studies it can be inferred that the recovery time to noise levels below 160 dB re 1µPa is very short.

It is thus concluded that construction work will not lead to significant disturbance of the local population of harbour porpoises in the Fehmarnbelt area and that the obligations of Article 12 habitat directive are not violated by the project.

7.7. EU Marine Strategy Framework Directive and Water Framework Directive

Implications for the assessment of the impacts on marine mammals as a result of the EU Marine Strategy Framework Directive (MSFD) and improvements to marine water quality as a result of the Water Framework Directive (WFD) are not quantifiable at the moment. However, FEMM conclude that the principles of the MSFD and WFD (e.g. underwater noise and contaminants) are implicit in the assessment criteria applied in this impact assessment.

7.8. Mitigation

The impacts from the construction and operation of the cable-stayed bridge are summarised in section 7.4. The impacts can be broadly summarised as affecting relatively low numbers of marine mammals.

The largest effects on marine mammals from the cable-stayed bridge are from the noise associated with the construction activities. Section 7.2.3.2 shows that a maximum of 3-8 porpoises (corresponding to 0.29 to 0.34% of the FB population) will be affected at a time assuming a combined scenario of dredging, pile driving at two locations and pile boring taking place simultaneously.

For all scenarios, there is at present no indication that threshold levels for underwater noise are exceeded, thus no noise mitigation is regarded a necessary

7.9. Cumulative impacts - cable-stayed bridge

This section describes the probable and significant cumulative impacts of the fixed link in conjunction with other projects.

7.9.1. Included projects and possible interactions

When more projects within the same region affect the same environmental conditions at the same time, there are cumulative impacts. Cumulative impacts are considered, if the following criteria are fulfilled.

The project:

- is within the same geographic area
- has some of the same impacts as the fixed link
- affects some of the same environmental conditions
- creates new environmental impacts during the period from the environmental investigations were completed to the fixed link is in operation.

The following projects at sea are considered relevant to include in the assessment of cumulative impacts on different environmental conditions (Table 7.9—1). All of them are offshore wind farms:

Table 7.9—1 Summary of relevant offshore windfarms

Project	Placement	Phase	Possible interactions
Arkona Becken Südost	Northeast of Rügen	Construction	Sediment spill, displacement, collision risk, barrier effect
EnBW Windpark Baltic II	Southeast of Kriegers Flak	Construction	Sediment spill, displacement, collision risk, barrier effect
Wikinger	Northeast of Rügen	Construction	Sediment spill, displacement, collision risk, barrier effect
Rødsand II	In front of Lolland's southern coast	Operation	Coastal morphology, collision risk, barrier effect
Kriegers Flak II	Kriegers Flak	Construction	Sediment spill, displacement, collision risk, barrier effect
GEOFReE	Lübeck Bay	Construction	Sediment spill, displacement, collision risk

Rødsand II (Figure 7.9-1) is specifically included, as this is a project that went into operation, while Femern A/S conducted its environmental investigations, whereby a cumulative effect in principle cannot be excluded.

The status of these projects is an important consideration in the assessment of cumulative effects. The proposed construction schedule for the immersed tunnel is between January 2015 and the end of 2020. Therefore, the direct construction cumulative impacts from the immersed tunnel will only become an issue if the construction schedules for the not yet constructed projects overlap. However, given the minor and insignificant impacts identified in the FEMM impact assessment this is determined to be of low importance here.

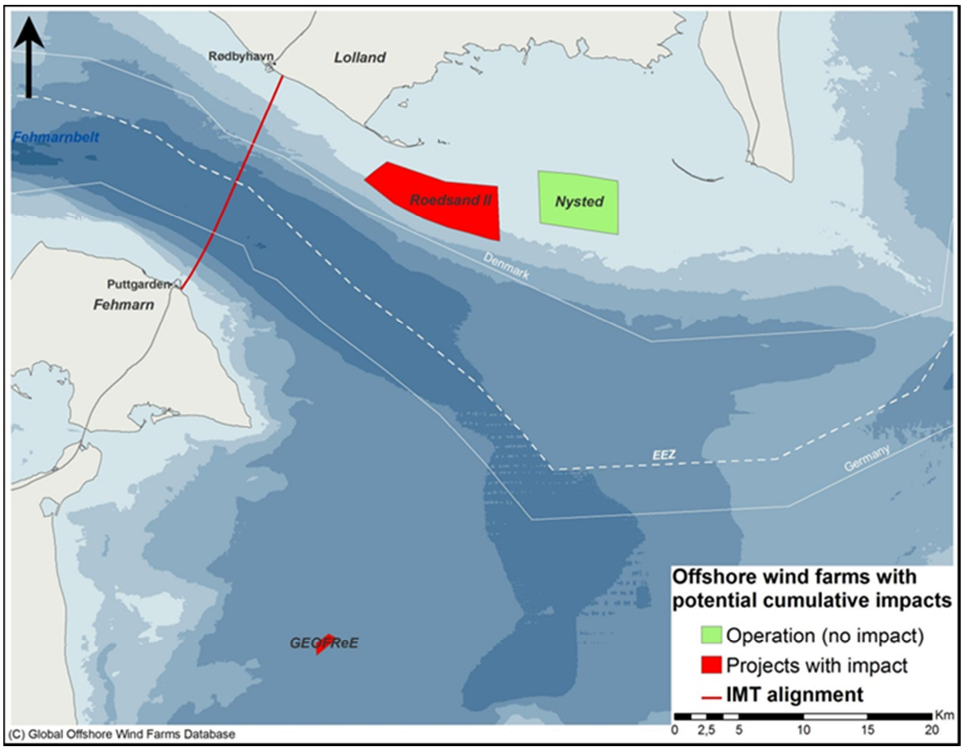

Figure 7.9-1 Locations of Rødsand II, Nysted and GEOFreE

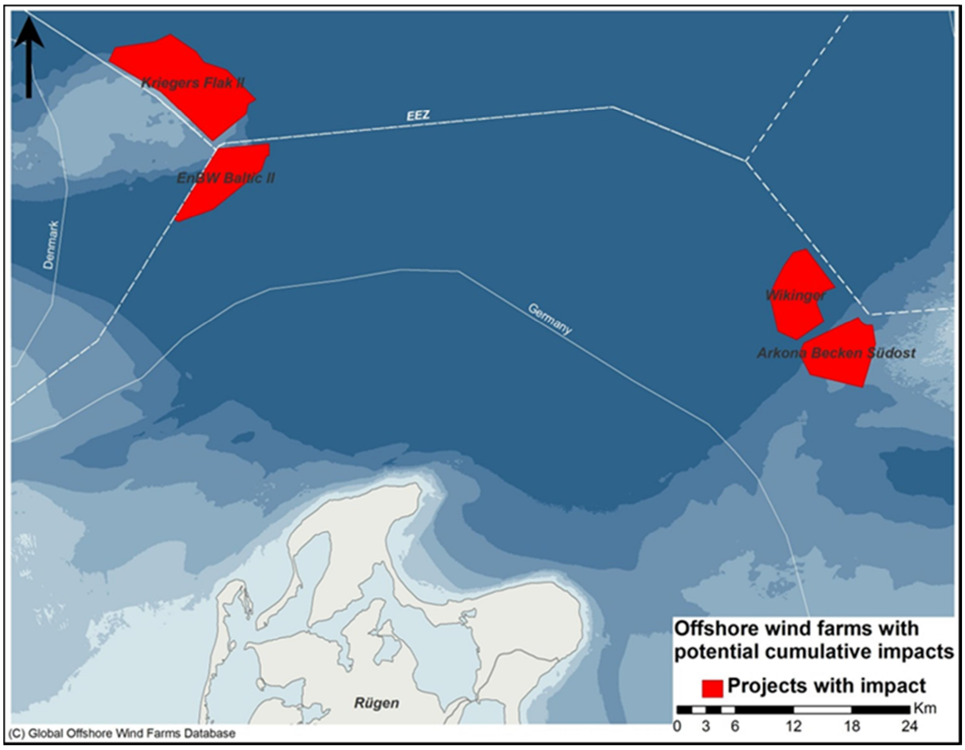

Figure 7.9-2 Locations of Kriegers Flak II, EnBW Baltic II, Wikinger and Arkona Becken Südost

All impacts from the cable-stayed bridge construction and operation have been shown to be local in extent (i.e. within a range of 500 metres and 10 kilometres). The nearest other project to the Fehmarnbelt fixed link is the Rødsand 2 offshore wind farm. At a distance of over 10 km between the tunnel and the wind farm the physical footprint of the projects and the potential zones of impact do not overlap.

Noise

Noise emissions from pile driving while constructing steel foundations for offshore wind farms may disturb harbour porpoises over a range of up to 20 km but for a short period only (Brandt et al. 2011). This range will be reduced considerably by noise mitigation measures which have to be applied for the German projects as a condition of the granted permits. Cumulative impacts of offshore wind farm construction and the noise emissions of a fixed link through Fehmarnbelt are expected to be negligible for the following reasons:

- There is no spatial overlap of disturbance zones
- Noise emissions from construction work in Fehmarnbelt only have local impacts (pile-driving noise predicted to attenuate to ambient levels within 1.1 km of source).
- Noise emissions from the approved offshore wind farm projects will only affect a few porpoises as they are located outside the main distribution range of the porpoises occurring in the Fehmarnbelt as identified in this study.

No impacts are to be considered for the construction of the Rødsand 2 wind farm, which has already been constructed on gravity foundation and no relevant impacts during operation are predicted to occur.

This impact assessment concluded that there would be no impact on harbour and grey seal breeding and pupping grounds. Cumulative effects for noise associated with other projects can therefore be discounted for harbour and grey seals.

Habitat loss

Harbour porpoise habitat losses from the construction and operation of the cable-stayed bridge have been assessed as minor and no relevant effects from offshore wind farms are predicted in this respect. This impact assessment has also calculated that harbour and grey seal habitat losses do not interact with areas of pupping (haul-out sites) and will therefore not impact on the most important areas for seals (Rødsand). Due to the near zone (±500 metres) scale of these effects, cumulative impacts with other projects are calculated as minor for marine mammals because they will lead to loss of habitat for a biologically unimportant proportion of the Belt population of seals and porpoises.

Habitat change

Direct effects on marine mammals from habitat changes (increased suspended sediments, sedimentation and hydrographic changes) have been demonstrated in this impact assessment to be of negligible severity. The direct cumulative effects for habitat change associated with other projects can therefore be discounted.

Femern A/S Vester Søgade 10 DK-1601 Copenhagen V Tel +45 33 41 63 00 Fax +45 33 41 63 01 www.femern.com CVR 28 98 65 64

Indirect effects on marine mammals from habitat changes (changes to food supply) have been derived from the preliminary outputs from FEBEC. FEBEC suggest a minor impact on fish from the construction and operation of the cable-stayed bridge. This leads FEMM to conclude a minor or negligible impact on marine mammals from changes in food supply, where a biologically unimportant proportion of the Belt population of seals and porpoises are affected. The indirect cumulative effects for habitat change associated with other projects can therefore be discounted.

Contaminants
Based on the FEMA and FEHY consortia assessments, the FEMM impact assessment concludes that the severity of contaminant impacts from the cable-stayed bridge construction and operation are negligible. Cumulative effects for contaminants associated with other projects can therefore be discounted.

Barrier effects
Based on the noise modelling in this impact assessment, no evidence of barrier effects on marine mammals from the construction and operation of the cable-stayed bridge have been identified. Cumulative effects for barriers with other projects can therefore be discounted.

Cumulative impact conclusions
For the noise pressures associated with the cable-stayed bridge construction a minor impact for harbour porpoise is calculated and no relevant cumulative effects are predicted to occur from approved offshore wind farm projects. This impact assessment concludes that there is no impact on harbour and grey seal breeding and pupping grounds from underwater noise. For habitat loss no relevant cumulative impact are predicted for marine mammals. For all other pressures (habitat change, contaminants and barrier effects) this impact assessment concludes that there are no cumulative impacts on marine mammals.

7.10. Trans-boundary impacts - cable-stayed bridge

The impacts from construction and operation of a cable-stayed bridge lead to mainly temporal impacts which do not reach beyond the German-Danish study area and thus, in the case of marine mammals, no trans-boundary impacts occur. As the migration behaviour of marine mammals is not affected no impacts on distant sub-populations of the three species occurring in Fehmarnbelt will ensue. Thus, in the case of marine mammals, no trans-boundary impacts will occur.

7.11. Decommissioning - cable-stayed bridge

Decommissioning is foreseen to take place in the year 2140, when the fixed link has been in operation for the design lifetime of 120 years. It is likely that methods for removing structures and reuse of materials will evolve over a time span of more than 100 years. Also it is likely that new methods will be less polluting as a result of development of green technologies. However, it is not possible to predict these changes, and therefore it is assumed that decommissioning will be carried out using methods similar to the ones available today. This will result in a conservative estimate of the environmental impacts.

The cable-stayed bridge consists of the following main elements: bridge superstructure, pylons, caissons, piers, ship collision protection, peninsulas, gallery, ramp viaduct and embankment, motorway overpass over railway tracks on Fehmarn, road, railway and toll plaza.

The majority of bridge components are foreseen to be transported to shore for further dismantling. This will require a designated facility, possibly a shipyard, harbour area or a purpose-built installation. A significant part of the environmental impacts will arise at this location.

The decommissioning and removal of the Fehmarnbelt Bridge structures and installations is considered to comprise the following:

7.11.1. Bridge superstructure

The bridge superstructure will be stripped of all technical equipment. This comprises: power supply, architectural lighting, drainage on main and approach bridges, communication, traffic management system, SCADA system, fire fighting and security systems.

Reuse and recycling will be applied to a great extent in accordance with waste legislation. Metals like copper, steel etc. shall be recycled as scrap metal and turned into new raw materials. Dismantling of the bridge superstructure will be done by reversal of the construction methods and transportation of the bridge girder components to shore for further demolition and scrapping.

7.11.2. Pylons

The pylons will be cut in-situ into elements with a reasonable weight that can be handled by cranes. Cutting methods like water jetting and flame cutting of rebar or diamond wire cutting are foreseen. The elements are transported to shore for further demolition.

7.11.3. Caissons

The pylon caissons are removed by in-situ demolition of the plinth, de-ballasting and re-floating of the caisson and towing it to a near shore location for further demolition. Demolition of the base plate and lower parts of the walls will require a dry dock or earth basin.

The pier caissons are removed by removal of internal ballast material, removal of scour protection and backfill material around the caisson and lifting of the caissons with a Heavy Lift Vessel and transportation to shore for further demolition.

Pile inclusions for soil improvement are situated below the natural seabed. Removal is therefore not required.

7.11.4. Piers

Piers will be cut from their caissons using cutting methods like water jetting and flame cutting of rebar or diamond wire cutting and transported to shore with a Heavy Lift Vessel for further demolition.

7.11.5. Ship collision protection

Ship collision protection structures are provided around the anchor and transition piers. The ship collision protection structures are removed by reversing the construction method. This involves emptying the crushed stone from the central compartment and in-situ cutting the outer ring into the four original sections. The gravel in the outer ring is grouted and therefore re-floating the elements is not possible. The elements are lifted with a Heavy Lift Vessel and towed to a near shore location for further demolition.

7.11.6. Gallery

The gallery is constructed as an in-situ cast concrete element supported by piers. The gallery will be cut into elements with a reasonable weight that can be handled by cranes. Cutting methods like water jetting and flame cutting of rebar or diamond wire cutting are foreseen.

7.11.7. Ramp viaduct and embankment

Roadway surfacing asphalt will be removed and reused as raw material for new asphalt. Road bases will be removed and reused for new roads or taken for landfill. Railway tracks will be recycled as scrap metal and ballast material will be cleaned and reused. In industrial areas, no further activities are carried out and the area is sold as industrial site. In farming areas, the remaining embankment will be levelled.

7.11.8. Peninsulas

The peninsulas are removed by reversing the construction method. After removing the gallery, the high quality sand core and stone revetments are removed and reused. Finally the quarry run dikes on either side are excavated and reused.

7.11.9. Final state of the area

At sea, all parts of the construction are removed, leaving only the pile inclusions.

7.11.10. Impact of decommissioning on marine mammals

The above project description for the decommissioning of the cable-stayed bridge in 2140 is effectively the reverse of the construction activities described in section 7.1 of this impact assessment. It is the conclusion of FEMM that the environmental pressures and the severity of impacts associated with the decommissioning will be the same as those assessed for construction of the cable-stayed bridge and summarised in section 7.3.

The main difference will be that in its 100+ year lifetime the structure may have an ecological significance in the area. However, it is impossible to accurately predict this ecological status at this time and as such it is recommended that a decommissioning environmental impact assessment is undertaken to inform the decommissioning programme prior to any decisions being undertaken.

8. CLIMATE CHANGE

With an expected lifetime of 120 years, climate change may have an impact on the design of the Fehmarnbelt Fixed Link and also on marine mammals in the Fehmarnbelt even under the zero alternative. Although research to date has demonstrated that a number of robust changes are emerging within the global warming picture, uncertainties remain about detailed change at the local scale. This is mainly due to an incomplete knowledge of the climate system and its variability, errors in models, as well as lack of certainty in future greenhouse gas emissions.

Prospective changes of environmental parameters induced by climate change are assessed for the target year, 2100. The assessment focuses on how climate change may affect species and their habitats and therefore marine mammals. Changes of approximately 80 years after the completion of the baseline study have been considered.

8.1. Climate change scenarios

Femern A/S conducted a workshop “Climate change and the Fehmarnbelt Fixed link” concentrating on climate scenarios and to identify foreseen climate changes in the following environmental parameters. The main points are summarised in sections 8.1.1 to 8.1.9.

8.1.1. Temperature

In 2100, annual mean temperatures in Denmark could increase between 1°C and 4°C in a warm climate scenario, whereas global temperatures will rise by 2.8°C. Higher values cannot be ruled out, but seem unlikely, in the event of the adoption of even modest mitigation measures by the international society as a result of COP15 in Copenhagen in December 2009. It is thought that the annual mean temperature in Denmark (and presumably also in northern Germany) is rising faster (by a factor of approximately two) than the observed global temperature. This is known to be linked with the complex modulations in the North Atlantic Ocean, the sea surface temperatures and the overall global temperature rise. There are also potentially less known remote influential sources. There is no definitive analysis of how much these individual components are attributable to the total change. Climate models generally agree on an annual temperature increase over northern Europe of approximately 1°C over the last century. For Denmark, regional climate change results suggest that the projected annual warming is well represented by the mean for northern Europe. Detailed modelling for Denmark carried out at the Danish Climate Centre (DMI) indicates that the annual modulation of the temperature increase is modest, but with a tendency for larger warming during autumn and winter compared to the rest of the year.

8.1.2. Sea ice cover

Sea ice is a rare phenomenon around Denmark and only shows up under periods with long-lasting cold air outbreaks such as during the winter of 2009/2010. Model simulations clearly indicate that the chance for a winter with such conditions decreases as the global temperature increases. Some studies foresee that most of the Baltic Sea (with the exception of Bothnian Bay and Finish Bay) will be ice free in all winters by the target year 2100 if global temperatures increase by up to 4°C.

8.1.3. Precipitation

Model scenarios show an increase of annual precipitation amounts with a pronounced change in the seasonality. Across Europe, in a warmer climate, winters will be dominated by increased atmospheric moisture, including increased, extreme precipitation, and summers will most likely be drier.

8.1.4. Wind speeds

It is assumed that wind speed will increase and, therefore, result in more extreme wave heights locally. To date, no models have considered this parameter.

8.1.5. Sea level

According to current knowledge it seems likely that the sea level may rise about one metre. An extreme storm surge may result in even higher levels, although the knowledge for the parameter is very limited. Changes in sea level for the Danish waters should be seen as a combination of contributions from global sea level changes, regional changes in the northeast Atlantic Ocean, as well as local changes. Sea level changes show geographical variation due to several factors, including the distribution of changes in ocean temperature, salinity, winds and ocean circulation. Temperature recordings from recent decades show the thermal expansion of seawater as it warms has contributed substantially to sea level rise.

8.1.6. Snow

Several studies have demonstrated that the increased wintertime temperatures around Denmark will dominate over the increase in precipitation. Snow cover will be totally diminished by the target year 2100.

8.1.7. Freezing surfaces

With a general warming trend, the number of frost days will also decrease. However, night time temperatures may still frequently be below freezing, particularly under clear sky conditions.

8.1.8. Ice

With an increasing temperature in winter, the general temperature conditions would be less favourable for temperatures below freezing, even at atmospheric levels several hundred of metres above sea level, than under current conditions.

The revision of the current literature highlights several parameters that will change over the years in the Baltic Sea and the Fehmarnbelt. However, the analyses of the climate change drivers provide insufficient knowledge and a general uncertainty about the parameters. When it comes to a detailed assessment of the most likely impacting factors, the evidence for hard numbers and in-depth analyses are not carried out to a satisfactory state. Therefore, no reliable prognosis exists and the development of factors which are heavily influenced by humans is unpredictable.

8.2. Harbour porpoise

The only environmental parameters which affect the given conditions for harbour porpoises are temperature, ice cover and freezing surfaces. Warmer temperatures in the Fehmarnbelt will presumably change the regional and local fish distribution and food availability. However, harbour porpoises are known to be opportunistic feeders and the effects of a change in food composition in the Fehmarnbelt area may be limited. Current telemetry data indicate that harbour porpoises cover great distances within the Baltic Sea. Compared to recent winters in the Fehmarnbelt, reduced freezing surfaces and ice coverage of the Baltic in the target year 2100 will not present any additional restrictions to harbour porpoises. This will therefore mean they will still be able to travel large distances and toreach important feedings areas.

Therefore, the climate change assessment in the Fehmarnbelt area is identified to be of minor importance for harbour porpoises.

8.3. Seals

For both harbour seals and grey seals, the analysis of changing environmental factors up to the target year 2100 is still based on insufficient qualitative information. Currently, it remains difficult to assess the future trends of the status of harbour and grey seal populations in the Fehmarnbelt. The current knowledge leads to the conclusion that changing water temperatures indicate a change of food composition and food availability for seals. Both seal species are known to be opportunistic feeders and it is assumed that a change in food composition will not impair seals. Therefore, future trends in the Fehmarnbelt area are considered to be of minor importance for harbour and grey seals; however, reduction of haul-out areas is the main likely impact of rising sea levels associated with climate change.

9. COMPARISION OF BRIDGE AND TUNNEL

The comparison of the bridge and tunnel options is addressed by providing a summary on the impact for each option against construction and operation pressures (Table 9—1) and a further assessment on impact differences between both options in relation to relevant functions of marine mammals (Table 9—1).

The severity and significance of impact for the tunnel and bridge options for each pressure in construction and operation phases is described in detail in Chapters 6 and 7. A summary of the significance level for impact obtained for both options is provided in Table 9—1.

Table 9—1 Summary of significance of impact for Bridge and Tunnel construction and operation phases on marine mammals

PRESSURES	TUNNEL Significance of Impact			BRIDGE Significance of Impact		
	Harbour porpoise	**Harbour seal**	**Grey Seal**	**Harbour porpoise**	**Harbour seal**	**Grey Seal**
Construction						
Dredging Noise	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Piling Noise	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Barrier effect	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Habitat Loss	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Habitat change	Insignificant impact	No Impact	No Impact	Insignificant impact	No Impact	No Impact
Food supply (indirect effect)	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Contaminants	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact
Operation						
Noise	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Barrier Effect	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Habitat Loss	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Habitat change	Insignificant Impact	No Impact	No Impact	Insignificant Impact	No Impact	No Impact
Food supply (indirect effect)	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact	Insignificant Impact
Contaminants	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact

It can be seen in Table 9—1 that the tunnel and bridge options have similar types of impacts.

The same methodology was used to assess the impact for the bridge and tunnel options (as provided by Femern A/S). When comparing both options, it is important to note that although the final assessment of severity and significance of impact for each pressure might have the same category, there might be some differences in relation to marine mammals function or to the level of uncertainty or risk.

In the comparison of the tunnel and bridge, the severity level and the impacted area have to be taken into account.

Table 9—2 Comparison of impacts on harbour porpoises from the two main alternatives of a fixed link across Fehmarnbelt. Zeros (0) in cells mean: no difference between alternatives; no differences in severity of impairment levels (negligible and minor severity of impairments are assumed to be the same level); (+): slight advantage; noticeable different numbers of mammals affected, but difference within the same severity of impairment level; +: advantage results in one level difference between severity of impairment levels; ++: strong advantage results in two levels of difference between severity of impairment levels; ++ (bold): two levels of difference between severity levels and difference regarding assessment of significance.

Environmental component: Harbour porpoise	Result of comparison of main alternatives	
	Bridge	**Tunnel**
Assessment criteria: occurrence		
Permanent habitat loss to footprint (land reclamation, harbours)	**(+)**	
Temporary habitat loss during construction	**(+)**	
Risk of injury from noise emissions during construction	**0**	**0**
Disturbance from noise emissions during construction	**0**	**0**
Barrier during construction	**0**	**0**
Barrier from structure	**0**	**0**
Habitat change from sediment spill	**+**	
Assessment criteria: nursing area		
Permanent habitat loss to footprint (land reclamation, harbours)	**(+)**	
Temporary habitat loss during construction	**(+)**	
Risk of injury from noise emissions during construction	**0**	**0**
Disturbance from noise emissions during construction	**0**	**0**
Barrier during construction	**0**	**0**
Barrier from structure	**0**	**0**
Habitat change from sediment spill	**0**	**0**
Assessment criteria: migration corridor		
Barrier effect during construction	**0**	**0**
Barrier effect from structure	**0**	**0**

The size of the permanent footprint from structures, construction harbours and land reclamation areas is clearly different between the bridge and tunnel options. However, as the footprint does not affect marine mammal habitats of higher importance, this is considered as only a slight advantage for the bridge which would lead to smaller habitat losses as compared to the tunnel. In addition, the lost area does not hold any special function as a nursing area or as a migration corridor; therefore, the function of the Fehmarnbelt for these purposes is not affected.

Construction works are considered to cause noise emissions and disturbance to harbour porpoises which are in the same order of magnitude and duration for both alternatives and are assessed to be of minor severity. Thus, small differences arising from lower dredging activities for the bridge solution are not considered as relevant, and impact from both options is considered as insignificant (no differences for noise, score 0 - Table 9—2.).

For both options, habitat changes which arise from construction works, especially concerning the sediment spill, do not lead to any significant impacts on marine mammals. However, higher levels of sediment spill for tunnel dredging are expected indicating a slight advantage for the bridge option.

Although the bridge is the only option where a barrier through the physical structure could exist, this is not regarded as a significant issue as no barrier effect could be shown from studies in relation to existing bridges (e.g. in the Great Belt).

It is thus concluded that both possible options for a fixed link lead to similar insignificant impacts on marine mammals and differences between them are too small to give one a clear advantage over the other.

Regarding mitigation measures for bridge and tunnel options, it is important to note that the largest effects on marine mammals are from the noise associated with the construction activities. However, there are no specific recommendations for mitigation measures because the spatial areas affected by the construction and operation of the bridge and tunnel are relatively small and also of relatively low importance for marine mammals (see sections 6.5 and 7.5).

10. CONCLUSION

10.1. Method

The Fehmarnbelt impact assessment on marine mammals has considered the assessment criteria provided by Femern A/S and interpreted the interaction of these criteria into two stages. Stage 1 establishes the environmental pressures associated with the development of a fixed link, the sensitivity of marine mammals to those pressures and the importance of the area for marine mammals. Stage 2 determines the degree and severity of impact. FEMM has defined criteria for the assessment of impacts considering the following pressures: noise, habitat loss and change, contaminants and barrier effect for the three species, harbour porpoise, harbour seal and grey seal.

10.2. Zero alternative

The zero alternative considers the future development without the establishment of a fixed link, and a projection of the status for marine mammals to 2025 and 2030 (to comply with the Danish and German authorities requirements). The zero alternative status for marine mammal populations takes into account the influence of the changes in pressures due to both natural variations and anthropogenic activities. The current status for harbour porpoise in the study area as defined in the baseline study is medium importance for abundance (with certain sub-areas of higher importance) and medium importance as a nursing area, feeding area and migration corridor. The current status for harbour and grey seals in the study area is of very high importance for the Rødsand area and adjacent areas for feeding, and of high importance as a breeding area. Changes in pressures on marine mammals between the baseline study and 2025 and 2030 such as fisheries, shipping, and tourism might result in improved ecological conditions in some cases and in detrimental for others. However, since quantification of pressure changes was not possible and differences between 2025 and 2030 are not distinctive, the status of marine mammals described by the baseline is considered to be most appropriate for the zero alternative assessment.

10.3. Overall assessment of severity – immersed tunnel

The severity of impact for habitat loss is assessed as ranging from minor to high for harbour porpoises. For habitat change the assessment for harbour porpoises is a minor severity of impact. We have assessed that there are no impacts on marine mammals from contaminants and barrier effects. For noise the severity of impact ranges from minor to high for construction and minor for operation. For seals there are no impacts from noise, habitat loss and habitat change. The severity of food supply impacts for all three species are determined to be minor.

However, overall, this assessment has identified **no significant impact** from the construction and operation of the immersed tunnel on all three species of marine mammals.

10.4. Overall assessment of severity – cable-stayed bridge

The severity of impact for habitat loss is assessed as ranging from minor to high for harbour porpoises. For habitat change the assessment for harbour porpoises is a minor severity of impact. We have assessed that there are no impacts on marine mammals from contaminants and barrier effects. For noise the severity of impact ranges from minor to high for construction and no impact for operation. For seals there are no impacts from noise, habitat loss and habitat change. The severity of food supply impacts for all three species are determined to be minor.

However, overall, this assessment has identified **no significant impact** from the construction and operation of the cable-stayed bridge on all three species of marine mammals.

10.5. Assessment of strictly protected species (Article 12 Habitats Directive)

It is concluded that construction work will not lead to killing or injuring of harbour porpoises and that the obligations of Article 12 of the Habitats Directive are not violated by the project. It is also concluded that construction work will not lead to significant disturbance of the local population of harbour porpoises in the Fehmarnbelt area and that the obligations of Article 12 of the Habitats Directive are not violated by the project. Operation effects have been concluded to be insignificant for marine mammals.

10.6. Mitigation measures

FEMM are not recommending specific mitigation measures because of the relatively small spatial areas affected by the construction and operation of the tunnel and bridge options, in combination with the relatively low importance of these areas for marine mammals. As the largest effect on marine mammals is related to noise associated with the construction activities, for both bridge and tunnel options it is suggested that the construction works consider the use of techniques that minimise noise emissions.

10.7. Cumulative impacts

Projects which have the potential to directly or indirectly act cumulatively to affect marine mammals are planned offshore wind farms. Cumulative impacts are assessed as insignificant for marine mammals because they will lead to disturbance and loss of habitat for a biologically unimportant proportion of the population of seals and porpoises. Cumulative effects for barriers with other projects are discounted because no evidence of barrier effects on marine mammals from the construction and operation of the immersed tunnel or bridge have been identified.

10.8. Trans-boundary effects

Construction and operation of an immersed tunnel and bridge lead to mainly temporal impacts which do not reach beyond the German-Danish study area and therefore no trans-boundary impacts are expected. As the migration behaviour of marine mammals is not expected to be affected, no impacts on distant sub-populations of the three species occurring in Fehmarnbelt would occur. We can conclude that on marine mammals, no trans-boundary impacts will occur for any of the two options.

10.9. Comparison of bridge and tunnel options

It is concluded that both possible solutions of a fixed link lead to similar insignificant impacts on marine mammals and differences between solutions are too small to give one solution a clear advantage against the other.

10.10. Conclusion

The impact assessment undertaken by FEMM concludes that there are either no impacts on marine mammals from the construction and operation of the fixed link, or that any predicted impacts are insignificant at the local (Fehmarnbelt) and sub-regional population level.

10.11. Gaps of knowledge and uncertainties

In the framework of an EIA, it is of common use to provide an indication of difficulties which occurred during the compilation of documents at the current knowledge. Therefore, technical gaps and missing knowledge for a valuable assessment of possible environmental impacts are presented here. The following main pressures are considered:

Noise
Current knowledge leads to the conclusion that temporary and permanent thresholds of marine mammals are set to specific sound exposure levels. There is some debate about the definitions of such levels and limited data are available for the species of concern in this EIA. The implication of such uncertainties are considered to be small as no high noise levels are expected for the type of construction work planned for Fehmarnbelt fixed link.

Habitat change and sediment spill
Existing knowledge for habitat change, sediments spill and fish composition is based on the results and calculations of FEMA (2013a) and FEBEC (2013). Uncertainties of the predictions will be assessed in the mentioned studies. Changes that might affect the significance levels on the scale of marine mammals can only be made later.

Barrier effect
According to all studies which were investigated to describe a possible barrier effect, there was no indication of such an effect. However, the different methods applied to investigate such an effect have limitations either in their abilities to follow the movements of animals or in restricted sample sizes. Other methods of these studies have limitations for a quantitative assessment and identification of passing animals (passive acoustic monitoring). The implications of the uncertainties might be high as even a small barrier effect might have strong implications for a local population if an important migration corridor would be affected.

11. REFERENCES

Agency for Spatial and Environmental Planning (2009) Guidelines for Environmental Impact Assessments, Ministry of Environment

Akamatsu T, Teilmann J, Miller LA, Tougaard J, Dietz R, Wang D, Wang K, Siebert U, Naito Y (2007) Comparison of echolocation behaviour between coastal and riverine porpoises. Deep Sea Research II 54:290-297

Akamatsu T, Wang D, Wang K, Naito Y (2005) Biosonar behaviour of free-ranging porpoises. Proceedings of the Royal Society B: Biological Sciences 272:797-801

Andersen S (1970) Auditory sensitivity of the harbour porpoise *Phocoena phocoena*. In: Pilleri G (ed) Investigations on Cetacea, Vol II. Institute of Brain Anatomy, Bern, Switzerland, p 255-259

Anonymous (2006) Baltic Maritime Outlook 2006 (by Institute of Shipping Analysis in Sweden, BMT Transport Solutions GmbH in Germany and the centre for Maritime Studies in Finland). 112 pp. Available at: http://www.sjofartsverket.se

ASCOBANS (2000) Resolution on Incidental Take of Small Cetaceans. Resolution No. 3, Bristol, UK. 26 - 28 July

Asselin S, Hammill MO, Barrette C (1993) Underwater vocalisations of ice breeding grey seals. Canadian Journal of Zoology 71:2211–2217

Au WWL (1993) The Sonar of Dolphins. Springer, New York

Au WWL, Kastelein RA, Rippe T, Schooneman NM (1999) Transmission beam pattern and echolocation signals of a harbor porpoise (*Phocoena phocoena*). Journal of the Acoustical Society of America 196:3699-3705

Bain H, Williams R (2006) Long-range effects of airgun noise on marine mammals: Response as a function of received sound level and distance., Report no. SC/58/E35, International Whaling Comission, www.iwcoffice.org/_documents/sci_com/SC58docs/SC-58-E35.pdf

Bakun A (1996) Patterns in the ocean: Ocean Processes and Marine Population Dynamics. Cal. Sea Grant System, NOAA and Centro de Investigaciones Biologicas del Noroeste. La Paz, BCS Mexico

Bejder L, Samuels A, Whitehead H, Finn H, Allen S (2009) Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. Marine Ecology Progress Series 395:177-185

Benke H, Sichert U, Lick R, Bandomir B, Weiss R (1998) The current status of harbour porpoises (Phocoena phocoena) in German waters. Archive of Fishery and Marine Research 46:97-123

Benke H, Siebert U (1996) The current status of harbour porpoises (Phocoena phocoena) in German waters, International Whaling Commission, Cambridge, UK

Berggren P (1996) A preliminary assessment of the status of harbour porpoises (Phocoena phocoena) in the Swedish Skagerrak, Kattegat and Baltic Seas, International Whaling Commission, Cambridge, UK

Bjorgesaeter A, Ugland KI, Bjørge A (2004) Geographic variation and acoustic structure of the underwater vocalization of harbor seal (Phoca vitulina) in Norway, Sweden and Scotland. Journal of the Acoustic Society of America 116:2459-2468

BMVBS (2009) Leitfaden zur Berücksichtigung des Artenschutzes bei Aus- und Neubau von Bundeswasserstraßen. Bundesministerium für Verkehr, Bau und Stadtentwicklung.

Brandt MJ, Diederichs A, Betke K, Nehls G (2011) Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series 421:205-216

Brandt MJ, Diederichs A, Honnef C, Nehls G (2009) Effects of pile driving on the distribution patterns of harbour porpoises in the North Sea (poster), BioConsult SH 2009

Brandt MJ, Diederichs A, Nehls G (2008) Fachgutachten Meeresaueger - Im Rahmen der Umweltvertraeglichkeitsstudie fuer das Sandentnahmegebiet Westerland II westlich von Sylt.

BSH (2007) German Standards for Environmental Impact Assessments for Offshore Wind Farms (StUK3). Bundesamt für Seeschifffahrt und Hydrographie

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

Camphuysen KC, Scott BE, Wanless S (2006) Distribution and foraging interactions of seabirds and marine mammals in the North Sea: multi-species foraging assemblages and habitat-specific feeding strategies. In: Boyd IL, Wanless S, Camphuysen CJ (eds) Top predators in marine ecosystem: Their role in monitoring and management, Conservation Biology No 12. Cambridge University Press, Cambridge

Carlström J (2005) Diel variation in echolocation behaviour of wild harbour porpoises. Marine Mammal Science 21:1-12

CEDA (2011) Underwater Sound in Relation to Dredging, CEDA Position Paper - 7 November 2011

Clark CW, Suydam R, George C (2009) Acoustic Monitoring of the Bowhead Spring Migration off Pt. Barrow, Alaska: Results from 2009 and Status of 2010 Field Effort. Barrow Acoustics SC/62/BRG17

Clark DS, Green JM (1990) Activity and movement patterns of juvenile Atlantic cod. Gadus morhua, in Conception Bay Newfoundland, as determined by sonic telemetry. Canadian Journal of Zoology 68:1434-1442

Clark WW (1991) Recent studies of temporary threshold shift (TTS) and permanent threshold shift (PTS) in animals. Journal of the Acoustical Society of America 90:155-163

Corten A, van de Kamp G (1996) Variation in the abundance of southern fish species in the southern North Sea in relation to hydrography and wind. ICES Journal of Marine Science 53:1113-1119

Cummings WC, Holzmann JM, Thompson PO (1975) Underwater sound pressure minima in bioacoustic test tanks. NUC TP 450, U.S. Naval Undersea Cent

Cunningham L, Baxter JM, Boyd IL, Duck CD, Lonergan M, Moss SE, McConnell B (2009) Harbour seal movements and haul-out patterns: implications for monitoring and management. Aquatic Conservation 19:398–407

Das K, Siebert U, Fontaine M, Jauniaux T, Holsbeek L, Bouquegneau JM (2004) Ecological and pathological factors related to trace metal concentrations in harbour porpoises Phocoena phocoena from the North Sea and adjacent areas. Marine Ecology Progress Series 281:283-295

De Groot SJ (1984) The impact of bottom trawling on benthic fauna of the North Sea. Ocean Management 9:177-190

Deecke VB, Slater PJB, Ford JKB (2002) Selective habituation shapes acoustic predator recognition in harbour seals. Nature 420

Desprez M (2000) Physical and biological impact of marine aggregate extraction along the French coast of the Eastern English Channel: Short-and long-term post-dredging restoration. ICES Journal of Marine Science 57:1428-1438

Diederichs A, Brandt M, Nehls G (2010) Does sand extraction near Sylt affect harbour porpoises? Wadden Sea Ecosystem 26:199-203

Diederichs A, Grunkorn T, Nehls G (2008a) Offshore wind farms – disturbance or attraction for harbor porpoises? First results of T-POD investigations in Horns Rev and Nysted. Evans, P.G.H. (Ed.) Proceedings of the Ascobans/ECS Workshop: Offshore Wind Farms and

Marine Mammals: Impacts & Methodologies for Assessing Impacts. San Sebastian, Spain: European Cetacean Society Publication Series 2008
Diederichs A, Hennig V, Nehls G (2008b) Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms, Horns Ref, North Sea and Nysted, Baltic Sea, in Denmark, Part II: Harbour porpoises. Final report, Supported by the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (FKZ 0329963 and FKZ 0329963A). 96 pp.
Dietz R, Teilmann J, Henriksen OD (2000) EIA study of offshore wind farm at Rødsand. Technical report about seals, Miljø- og Energiministeriet, National Environmental Research Institute
Dietz R, Teilmann J, Henrikson OD, Laidre K (2003) Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry - Relative importance of the Nysted Offshore Wind Farm area to the seals
Edren SMC, Andersen SM, Teilmann J, Carstensen J, Harders PB, Dietz R, Miller LE (2010) The effect of a large Danish offshore wind farm on habor and gray seal haul-out behavior. Marine Mammal Science 26:614-634
Edrén SMC, Teilmann J, Dietz R, Carstensen J (2004) Effects from the construction of Nysted Offshore Wind Farm on seals in Rødsand seal sanctuary based on remote video monitoring. Report request. Commissioned by ENERGI E2 A/S, National Environmental Research Institute.
Embling C, Gillibrand P, Gordon J, Shrimpton J (2009) Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (Phocoena phocoena). Biological Conservation 143:267-279
Embling CB, Gillibrand PA, Gordon J, Shrimpton J, Stevick PT, Hammond PS (2010) Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (Phocoena phocoena). Biological Conservation:267–279
EU Commission (2007) Commission Decision of 13 November 2007 adopting, pursuant to Council Directive 92/43/EEC, a first updated list of sites of Community importance for the Continual biogeographical region (notified under document number C(2007) 5403) (2008/25/EC)
Evans PGH (1996) Human disturbance of cetaceans. In: N. Dunstone, V. Taylor (eds) The exploitation of mammals – principals and problems underlying their sustainable use. Cambridge: Cambridge University Press, p 374–394
Fauchald P (2010) Predator–prey reversal: a possible mechanism for ecosystem hysteresis in the North Sea? Ecology 91:2191–2197
FEBEC (2013) Environmental Impact Statement Fish Ecology. E4-TR-41. Version 1. 19/12/2011.
FEHY (2013a) Fehmarnbelt Fixed Link EIA. Marine Water - Hydrodynamic and Water Quality Modelling. Scenario Modelling. E1TR0052. September 2011 Draft
FEHY (2013b) Fehmarnbelt Fixed Link EIA. Marine Water. Hydrography of the Fehmarnbelt Area – Impact Assessment. E1TR0058. October 2011 Draft
FEHY (2013c) Fehmarnbelt Fixed Link EIA. Marine Soil – Impact Assessment Volume II. E1TR0059. October 2011 Draft
FEHY (2013d) Fehmarnbelt Fixed Link EIA. Marine Water. Baseline for Suspended Sediment, Sediment Spill, related Surveys and Field Experiments. E1TR0038. March 2011 Draft
FEMA (2013a) Fehmarnbelt Fixed Link EIA. Marine Biology Baseline report XXXX
FEMA (2013b) Fehmarnbelt Fixed Link EIA. Marine Soil – Baseline. Seabed Chemistry of the Fehmarnbelt Area, including Assessment of Chemical Risks of Sediment Suspension. E1TR0056 Volume II. XXX pp
FEMA (2013c) Fehmarnbelt Fixed Link EIA. Marine Biology Impact Assessment.XXX
Femern A/S and LBV-SH-Lübeck 2010. Proposal for environmental investigation programme for the fixed link across the Fehmarnbelt. EIA Scoping Report. Femern A/S, Copenhagen, DK. 183 p.

FEMM (2013) Fehmarnbelt Fixed Link EIA. Marine Mammals - Baseline Report no. E5TR0014. Report commissioned by Femern A/S. 417 pp.
Fertl D (2009) Fisheries, Interference with. In: Thewissen JGM (ed) Encyclopedia of Marine Mammals. Academic Press, p 439-443
Fontaine MC, Baird SJE, Piry S, Ray N., Tolley KA, Duke S, Birkun A. Jr., Ferreira M, Jauniaux T, Llavona A, Oztürk B, Oztürk AA, Ridoux V, Rogan E, Sequeira M, Siebert U, Vikingsson GA, Bouquegneau J, Michaux JR (2007) Rise of Oceanographic barrier in continuous populations of a cetacean: the genetic structure of harbour porpoises in old world waters. BMC Biology 5:30
Frost KJ, Lowry LF (1988) Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys. In: Sackinger WM, Jeffries MO, Imm JL, Treacy SD (eds) Port and Ocean Engineering Under Arctic Conditions, Vol II: Symposium on Noise and Marine Mammals Geophysical Institute, University of Alaska Fairbanks, p 15–25
Fujise Y, Honda K, Tatsukawa R, Mishima S (1988) Tissue distribution of heavy metals in Dall's porpoise in the northwestern Pacific. Marine Pollution Bulletin 19:226-230
Genesis Oil and Gas Consultants Ltd (2010) Review and assessment of underwater sound produced by oil and gas activities and potential reporting requirements under the Marine Strategy Framework Directive', Document No. J71656-Final Report –G1 November 2010
Gill JA, Norris K, Sutherland WJ (2001) Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation 97:265-268
Gotceitas V, Brown JA (1993) Substrate selection by juvenile Atlantic cod (Gadus morhua): effects of predation risk. Oecologia 93:31-37
Götz T, Janik VM (2010) Aversiveness of sounds in phocid seals: psycho-physiological factors, learning processes and motivation. Journal of Experimental Biology 213:1536–1548
Grellier K, Hammond PS (2006) Robust digestion and passage rate estimates for hard parts of grey seal (halichoerus grypus) prey. Canadian Journal of Fisheries and Aquatic Sciences 63:1982-1998
Grøn P, Buchwald E (1997) Effekter af hurtigfærgesejlads på havfugle, sæler og marsvin. Slutrapport. Skov- og Naturstyrelsen. Carl Bro & Bio/consult, Copenhagen. (Effects of highspeed ferries on seabirds, seals and harbour porpoises.)
Grossman GD, Jones GP, Seaman WJ (1997) Do artificial reefs increase regional fish production? A review of existing data. Journal of Fisheries 22:17–23
Hall AJ, Watkins J, Hammond PS (1998) Seasonal variation in the diet of harbour seals in the south-western North Sea. Marine Ecology Progress Series 170:269-281
Hammond PS, Berggren P, Benke H, Borchers DL, Collet A, Heide-Jorgensen MP, Heimlich S, Hiby AR, Leopold MF, Oien N (2002) Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39:361-376
Hanggi EB, Schusterman RJ (1994) Underwater acoustic displays and individual variation in male harbour seals Phoca vitulina. Animal Behaviour 48:1275-1283
Hanke W, Witte M, Miersch L, Brede M, Oeffner J, Michael M, Hanke F, Dehnhardt G (2010) Harbor seal vibrissa morphology suppresses vortex-induced vibrations. Journal of Experimental Biology 213:2666-2672
Harding KC, Härkönen T, Helander B, Karlsson O (2007) Status of Baltic grey seals: Population assessment and extinction risk analysis. NAMMCO Scientific Publications 6:33-56
Härkönen T, Bäcklin BM, Barrett T, Bergman A, Corteyn M, Dietz R, Harding KC, Malmsten J, Roos A, Teilmann (2008) Mass mortality in harbour seals and harbour porpoises caused by an unknown pathogen. J Veterinary Record 162:555-556
Hastie GD, Wilson B, Wilson LJ, Parsons KM, Thompson PM (2004) Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging. Marine Biology 144:397-403

HELCOM (2009a) Biodiversity in the Baltic Sea - An integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea. Baltic Sea Environmental Proceedings No 116B

HELCOM (2009b) Biodiversity in the Baltic Sea: An integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea. Baltic Sea Environment Proceeding No. 116B

Hemilä S, Nummela S, Berta A, Reuter T (2006) High-frequency hearing in phocid and otariid pinnipeds: An interpretation based on inertial and cochlear constraints. Journal of the Acoustical Society of America 120:3463-3466

Hiby L, Lovell P (1996) Baltic/North Sea aerial surveys – final report

Holt MM, Noren DP, Veirs V, Emmons CK, Veirs S (2009) Speaking up: Killer whales (Orcinus orca) increase their call amplitude in response to vessel noise. Journal of the Acoustical Society of America 125:EL27-EL32

Holt MM, Schusterman RJ (2007) Spatial release from masking of aerial tones in pinnipeds. Journal of the Acoustical Society of America 121:1219-1225

ICES (2003) Report of the Working Group on Marine Mammal Ecology (WGMME). Hel, Poland, 25-29 March 2003. ICES CM 2003/ACE:03. 75 pp

Illinworth & Rodkin (2007) Compendium of pile driving sound data Report to The California Department of Transportation, 129 pp

Inger R, Attrill MJ, Bearhop S, Broderick AC, Grecian WJ, Hodgson DJ, Mills C, Sheehan E, Votier SC, Witt MJ, Godley BJ (2009) Marine renewable energy: potential benefits to biodiversity? an urgent call for research. Journal of Applied Ecology 46:1145-1153

Iverson RL, Whitledge T.E, Goering JJ (1979) Chlorophyll and nitrate fine structure in the southeastern Bering Sea shelf break front. Nature 281:664–666

Jasny M, Reynolds J, Horowitz C, Wetzler A (2005) Sounding the depths II: the rising toll of sonar, shipping and industrial ocean noise on marine life, Natural Resources Defence Council, New York, USA

Jefferson TA, Curry BE (1996) Acoustic methods of reducing or eliminating marine mammal-fishery interactions: do they work? . Ocean & Coastal Management 31:41-70

Jensen FH, Bejder L, M W, Aguilar Soto N, Johnson M, Madsen PT (2009) Vessel noise effects on delphinid communication. Marine Ecology Progress Series 395:161-175

Jepson PD, Bennett PM, Allchin CR, Law RJ, Kuiken T, Baker JR, Rogan E, Kirkwood JK (1999) Investigating potential associations between chronic exposure to polychlorinated biphenyls and infectious disease mortality in harbour porpoises from England and Wales. Science of the Total Environment 243/244:339-348

Jepson PD, Bennett PM, Deaville R, Allchin CR, Baker JR, Law RJ (2005) Relationships between PCBs and health status in harbour porpoises (*Phocoena phocoena*) stranded in the United Kingdom. Environmental Toxicology and Chemistry 24:238-248

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

Joint Links Oil and Gas Environmental Consortium (2006) Polluting the offshore environment. The practices and environmental effects of Britain's offshore oil and gas industry, produced 1995, partially updated by Friends of the Earth Cymru and WDCS 2006

Jones JB (1992) Environmental impact of trawling on the seabed: A review. New Zealand Journal of Marine and Freshwater Research 26:59-67

Jørgensen T, Løkkeborg S, Soldal AV (2002) Residence of fish in the vicinity of a decommissioned oil platform in the North Sea. ICES Journal of Marine Science 59:S288-S293

Kastak D, Mulsow J, Ghoul A, Reichmuth C (2008) Noise-induced permanent threshold shift in a harbour seal. Journal of the Acoustical Society of America 123:2986

Kastak D, Schusterman RJ (1996) Temporary threshold shift in a harbor seal Phoca vitulina. Journal of Accoustic Society of America 100:1905–1908

Kastak D, Schusterman RJ (1998) Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise and ecology. Journal of the Acoustical Society of America 103:2216-2228

Kastak D, Schusterman RJ, Kastelein RA, Thomas JA (1995) Aerial and underwater hearing thresholds for 100Hz pure tones in two species of pinnipeds. In: Nachtigall PE (ed) Sensory Systems of Aquatic Mammals. De Spil Publishers, Woerden, Netherlands

Kastak D, Schusterman RJ, Southall BL, Reichmuth CJ (1999) Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of Acoustical Society of America 106:1142-1148

Kastak D, Southall BL, Schusterman RJ, Kastak CR (2005) Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. Journal of the Acoustical Society of America 118:3154-3163

Kastelein R, Hoek L, Jennings N, de Jong C, Terhune J, Dieleman M (2010) Acoustic mitigation devices (AMDs) to deter marine mammals from pile-driving areas at sea: Audibility and behavioural response of a harbour porpoise and harbour seals, COWRIE Limited, London (www.offshorewind.co.uk)

Kastelein RA, Au WWL, Rippe HT (1999) Target detection by an echolocating harbor porpoise (Phocoena phocoena). Journal of the Acoustical Society of America 105:2493-2498

Kastelein RA, Bunskoek P, Hagedoorn M, Au WWL (2002) Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrow-band frequency modulated signals. Journal of the Acoustical Society of America 112:334-344

Kastelein RA, Heul Svd, Terhune JM, Verboom WC, Triesscheijn RJV (2006) Deterring effects of 8-45 kHz tone pulses on harbour seals (Phoca vitulina) in a large pool. Marine Environmental Research 62:356-373

Kastelein RA, Verboom WC, Muijsers M, Jennings NV, van der Heul S (2005) The influence of acoustic emissions for underwater data transmission on the behaviour of harbour porpoises (Phocoena phocoena) in a floating pen. Marine Environmental Research 59:287-307

Kastelein RA, Wensveen P, Hoek L, Verboom W, Terhune J, Hille Ris Lambers R (2008) Underwater hearing sensitivity of harbour seals for tonal signals and noise bandsC040.08 OWEZ_R_254_T1_20080530 IMares p31

Kastelein RA, Wensveen P.J, Hoek L, Verboom W.C, Terhune J.M (2009) Underwater detection of tonal signals between 0.125 and 100 kHz by harbor seals (Phoca vitulina). Journal of the Acoustical Society of America 125:1222-1229

Keller O, Lüdemann K, Kafemann R (2006) Literature review of offshore wind farms with regard to fish fauna. BfN-Skripten 186:47-130

Khan CB, Markowitz H, McCowan B (2006) Vocal development in captive harbor seal pups, Phoca vitulina richardii: Age, sex, and individual differences. Jounral of the Aacoustical Society of America 120:1684 -1694

Kibblewhite AC (1989) Attenuation of Sound in Marine Sediments: A review with Emphasis on New Low-Frequency Data. Journal of Accoustic Society of America 86:716–738

Kiel EF (2007) Geschützte Arten in Nordrhein-Westfalen. Planen nach dem neuen Artenschutzrecht. Landesamt für Natur, Umwelt und Verbraucherschutz NRW, Fachbereich 24 Artenschutz & Vogelschutzwarte

Klinowska M (1991) Dolphins, Porpoises and Whales of the World. The IUCN Red Data Book. IUCN, Gland, Swotzerland and Cambridge, UK. Viii + 429pp

Kraan S, van Etten Y (1995) Die Unterseite des Wattenmeeres. Wattenvereinigung Harlingen

Lander ME, Harvey JT, Hanni KD, Morgan LE (2002) Behavior, movements, and apparent survival of rehabilitated and free-ranging harbor seal pups. Journal of Wildlife Management 66:19-28

LBV SH (2009) Beachtung des Artenschutzrechtes bei der Planfeststellung. Vermerk des Landesbetriebs Straßenbau und Verkehr Schleswig-Holstein, Betriebssitz Kiel.

Leonhard SB, Hvidt CB, Klaustru M, Pedersen J (2006) Hydroacoustic monitoring of fish communities at offshore wind turbine foundations, Nysted Offshore Wind Farm at Rødsand. Annual Report 2005 for Energy E2 A/S.

Lick RR (1991) Untersuchungen zu Lebenszyklus (Krebse-Fische-Marine Säuger) und Gefrierresistenz anisakider Nematoden in Nord- und Ostsee. Berichte aus dem Institut für Meereskunde an der Christian- Albrechts-Universität zu Kiel 218:195

Lindeboom HJ, Kouwebhoven HJ, Bergman MJN, Bouma S, Brasseur S, Daan R, Fijn RC, de Haan D, Dirksen S, van Hal R, Hille Ris Lambers R, ter Hofstede R, Krijgsveld KL, Leopold M, Cheidat M (2011) Short-term ecological effects of an offshore farm in the Dutch coastal zone; a compilation. Environmental Research Letters 6:13p

Linehan JE, Gregory RS, Schneider DC (2001) Predation risk of age-0 cod (Gadus morhua) relative to depth and substrate in coastal waters. Journal of Experimental Marine Biology and Ecology 263:25– 44

Lucke K, Hanke W, Denhardt G (2004) Untersuchungen zum Einfluß akustischer Emissionen von Offshore-Windkraftanlagen auf marine Säuger im Bereich der deutschen Nord- und Ostsee. In: Marine Warmblüter in Nord- und Ostsee: Grundlagen zur Bewertung von Windkraftanlagen im Offshore-Bereich Endbericht (FKZ: 0327520). Nationalpark schleswig-holsteinisches Wattenmeer und Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Buesum, Germany, p 23-76

Lucke K, Lepper PA, Blanchet MA, Siebert U (2007a) Testing the acoustic tolerance of harbour porpoise hearing to impulsive sound. 17th Biennial Conference of the Society for Marine Mammalogy, Cape Town, South Africa, 2007

Lucke K, Lepper PA, Hoeve B, Everaarts E, van Elk N, Siebert U (2007b) Perception of low-frequency acoustic signals by a harbour porpoise (*Phocoena phocoena*) in the presence of simulated offshore wind turbine noise. . Aquatic Mammals 33:55-68

Lucke K, Siebert U, Lepper PA, Blanchet MA (2009) Temporary shift in masked hearing thresholds in a harbor porpoise (Phocoena phocoena) after exposure to seismic airgun stimuli. Journal of the Acoustical Society of America 125:4060-4070

Lucke K, Siebert U, Sundermeyer J, Benke H (2006) TP1- Weiterführende Untersuchungen zum Einfluß akustischer Emissionen von Offshore Windenergieanlagen auf marine Säuger in Nord- und Ostsee. In: Minos/Plus – Weiterführende Arbeiten an Seevögeln und marinen Säugern zur Bewertung von Offshore-Windkraftanlagen Zweiter Zwischenbereicht, April 2006 Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer, Tönning, Germany, p 10-27

Lundström K, Hjerne O, Alexandersson A, Karlsson O (2007) Estimation of grey seal (Halichoerus grypus) diet composition in the Baltic Sea. NAMMCO Scientific Publications 6:177-196

Lusseau D, Bain DE, Williams R, Smith JC (2009) Vessel traffic disrupts the foraging behavior of southern resident killer whales Orcinus orca. Endangered Species Research 6:211-221

Lusseau D, Bejder L (2007) The Long-term Consequences of Short-term Responses to Disturbance Experiences from Whalewatching Impact Assessment. International Journal of Comparative Psychology 20:228-236

Lutchman I, Grieve C, Des Clers S, De Santo E (2009) Towards a reform of the Common Fisheries Policy in 2012 - A CFP Health Check. IEEP, London. pp.80

Macer CT (1966) Sandeels (Ammodytidae) in the south-western North Sea; their biology and fishery. Fisheries Investigation Series II 24:1–55

MacLennan DN, Simmonds EJ (1992) Fisheries Acoustics. Chapman & Hall, London

Macleod K, Simmonds MP, Murray E (2003) Summer distribution and relative abundance of cetacean populations off north-west Scotland. Journal of the Marine Biological Association of the UK 83:1187-1192

Madsen PT, Wahlberg M, Tougaard J, Lucke K, Tyack PL (2006) Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Marine Ecology Progress Series 309:279-295

Malinga M, Kuklik I (eds) (1996) Food consumption of harbour porpoises (Phocoena phocoena) in Polish waters of the Baltic Sea, Vol 10. European Cetacean Society, Cambridge

Malinga M, Kuklik I, Skóra KE (1997) Food composition of harbour porpoises (Phocoena phocoena) bycaught in Polish waters of the Baltic Sea. In: Evans PGH, Parsons ECM, Clark SL (eds) Eleventh Annual Conference of the European Cetacean Society, Stralsund, Germany, p 144

Maravelias CD (1997) Trends in abundance and geographic distribution of North Sea herring in relation to environmental factors. Marine Ecology Progress Series 159:151–164

Maravelias CD, Reid DG, Swartzman G (2000) Seabed substrate, water depth and zooplankton as determinants of the prespawning spatial aggregation of North Atlantic herring. marine Ecology Progress Series 195:249–259.

Mcconnell B, Fedak M, Lovell P, Hammond P (1999) Movements and foraging areas of grey seals in the North Sea. Journal of Applied Ecology 36:573–590

McEwen B, Stellar E (1993) Stress and the Individual. Mechanisms Leading to Disease. Archives of Internal Medecine 153:2093-2101

Mees J, Reijnders PJH (1994) The harbour seal, Phoca vitulina, in the Oosterschelde: decline and possibilities for recovery. Hydrobiologia 282/283:547-555

MMC (2007) Marine mammals and noise - A sound approach to research and management, Marine Mammal Commission, Bethesda, Maryland, USA

Møhl B (1968) Auditory sensitivity of the common seal in air and water. The Journal of Auditory Research 8:27-38

Murphy S (2009) Effects of Contaminants on Reproduction in Small Cetaceans. Final Report of Phase One to ASCOBANS Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas, ASCOBANS

Murphy S, Pierce G, J,, Law RJ, Bersuder P, Jepson PD, Learmonth JA, Addink M, Dabin W, Santos MB, Deaville R, Zegers BN, Mets A, Rogan E, Ridoux V, Reid RJ, Smeenk C, Jauniaux T, López A, Alonso Farré JM, González AF, Guerra A, García-Hartmann M, Lockyer C, Boon JP (2010) Assessing the Effect of Persistent Organic Pollutants on Reproductive Activity in Common Dolphins and Harbour Porpoises. Journal of Northwest Atlantic Fisheries Science 42:153–173

Nabe-Nielsen J, Tougaard J, Sveegard S, Dromph KM, Teilmann J, Dietz R (2010) Modelling the effect of bridges on porpoise behaviour, Report commissioned by Fehmarnbelt A/S, National Environmental Research Institute, Department of Arctic Environment, Aarhus University, Roskilde, Denmark

National Physics Laboratory (2010) Calculation of absorption of sound in seawater

Nedwell JR, Brooker AG (2008) Measurement and assessment of background underwater noise and its comparison with noise from pin pile drilling operations during installation of the SeaGen tidal turbine device, Strangford Lough, COWRIE, Newbury

Nedwell JR, Edwards B, Turnpenny AWH, Gordon J (2004) Fish and marine mammal audiograms: a summary of available information, Subacoustech report ref. 534R0214, submitted to Chevron Texaco Ltd

Nedwell JR, Howell D (2004) A review of offshore windfarm related underwater noise sources - Report No. 544 R 0308, COWRI Newbury

Newell RC, Seiderer LJ, Hitchcock DR (1998) The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: an Annual Review 36:127-178

NRC (2003) Ocean noise and marine mammals, The National Academies Press, Washington, D.C. USA

NRC (2005) Marine mammal populations and ocean noise - determining when noise cuases biologically significant effects. The National Academics Press, Washington, DC

OSPAR (2010) Quality Status Report 2010, OSPAR Commission, London

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

Petersen JK, Malm T (2006) Offshore windmill farms: Threats to or possibilities for the marine environment. Ambio 35:75-80

Popov VV, A.Y S, Wang D, Wang K (2006) Nonconstant quality of auditory filters in the porpoises, Phocoena phocoena and Neophocaena phocaenoides (Cetacea, Phocoenidae). Journal of the Acoustical Society of America 119:3173-3180

Raum-Suryan KL, Harvey JT (1998) Distribution and abundance of and habitat use by harbor porpoise (Phocoena phocoena) off the Northern San Juan Islands, Washington. Fisheries Bulletin 96:808-822

Reay PJ (1970) Synopsis of Biological Data on North Atlantic Sand Eels of the Genus Ammodytes, FAO, Rome

Reid JB, Evans PGH, Northridge SP (2003) Atlas of cetacean distribution in north-west European waters. Joint Nature Conservation Committee, Peterborough, UK

Reijnders PJH, Aguilar A (eds) (2002) Pollution and Marine Mammals, Vol. Academic Press, San Diego, California, USA

Renouf D (1980) Fishing in Captive Harbour Seals (Phoca Vitulina Concolor): A Possible Role for Vibrissae Source. Netherlands Journal of Zoology 30:504-509

Richardson WJ, Malme CI, Green Jr CR, Thomson DH (1995) Marine mammals and noise. Academic Press, San Diego, California, USA

Ridgway SH, Joyce PL (1975) Studies on seal brain by radiotelemetry. Rapports et Proces Verbaux des Reunions - Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranee 169:81-91

Robinson SP, Theobald PD, Hayman G, Wang LS, Lepper PA, Humphrey V, Mumford S (2011) Measurement of noise arising from marine aggregate dredging operations - MALSF (MEPF Ref no. 09/P108)

Rolland RM, Parks SE, Hunt KE, Castellote M, Corkeron PJ, Nowacek DP, Wasser SK, Kraus SD (2012) Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B: Biological Sciences 8.02.2012

Romano TA, Keogh MJ, Schlundt C, Carder D, Finneran J (2004) Anthropogenic sound and marine mammals health: measures of the nervous and immune systems before and after intense sound. Canadian Journal of Fisheries and Aquatic Sciences 61:1124-1134

Royal Haskoning (2010) SeaGen Environmental Monitoring Programme March - October 2010. SeaGen Biannual Report. 40 pp.

Salgado-Kent C, McCauley RD, Duncan AJ (2009) Environmental Impacts of Underwater Noise Associated With Harbour Works, Port Hedland

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

Saunders, P. M., K-H. Mahrt and R. T. Williams (1991) Methods of Laboratory calculations. WHP Operations and Methods WHP 91-1. Woods Hole.

SCANS-II (2008) Small cetaceans in the European Atlantic and North Sea., Final report submitted to the European Commission under project LIFE04NAT/GB/000245, SMRU, St Andrews

Scheidat M, Gilles A, Kock KH, U. S (2008) Harbour porpoise Phocoena phocoena abundance in the southwestern Baltic Sea. Endangered Species Research 5:215-223

Scheidat M, Gilles A, Siebert U (2004) Erfassung der Dichte und Verteilungsmuster von Schweinswalen (*Phocoena phocoena*) in der deutschen Nord- und Ostsee. In: Marine Warmblüter in Nord- und Ostsee: Grundlagen zur Bewertung von Windkraftanlagen im Offshore-Bereich. FKZ 0327520. Final report. Investment-in-future program of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). (Hrsg.) Kellermann, A. *et al.* , Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer. Tönning.

Scheidat M, Tougaard J, Brasseur S, Carstensen J, van Polanen Petel T, Teilmann J, Reijnders P (2011) Harbour porpoises (Phocoena phocoena) and wind farms: a case study in the Dutch North Sea. Environmental Research Letters 6

Schneider DC (1990) Seabirds and fronts: a brief overview. Polar Research 8:17-21

Schneider DC, Duffy D, C, (1985) Scale-dependent variability in seabird abundance. Marine Ecology Progress Series 25:211-218

Schusterman RJ (1965) Orienting responses and underwater visual discrimination in the California sea lion. Proc Amer Psychol Assn 1:139-140

Schusterman RJ, Balliet RF, John SS (1970) Vocal displays under water by the gray seal, the harbor seal, and the stellar sea lion. Psychon Science 18:303-305

Schusterman RJ, Kastak D, Levenson DH, Reichmuth CJ, Southall BL (2000) Why pinnipeds don't echolocate. Journal of the Acoustical Society of America 107:2256-2264

Schusterman RJ, Van Parijs SM (2003) Pinniped vocal communication: an introduction. Aquatic Mammals 29:177-180

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

Sharples R, Arrizabalaga B, Hammond PS (2009) Seals, sandeels and salmon: diet of harbour seals in St. Andrews Bay and the Tay Estuary, southeast Scotland. Marine Ecology Progress Series 390:265-276

Siebert U, Joiris C, Holsbeek L, Benke H, Failing K, Frese K, Petzinger E (1999) Potential relation between mercury concentrations and necropsy findings in cetaceans from German waters of the North and Baltic Seas. Marine Pollution Bulletin 38:285-295

Sjöberg M, Fedak MA, McConnell BJ (1995) Movements and diurnal behaviour patterns in a Baltic grey seal (Halichoerus grypus). Polar Biology 15:593-595

Sjöberg M, McConnell B, Fedak M (1999) Haulout patterns of grey seals Halichoerus grypus in the Baltic Sea. Wildlife Biology 5:37-47

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

Small RJ, Lowry LF, Hoef JMV, Frost KJ, Delong RA, Rehberg MJ (2005) Differential movements by harbour seal pups in contrasting Alaska environments. Marine Mammal Science 21:671-694

Southall BL (2005) Shipping noise and marine mammals: a forum for science, management, and technology. Final report of the NOAA International Symposium. NOAA Fisheries Acoustics Program, p 40

Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Greene CRJ, Kastak D, Ketten DR, Miller JH, Nachtigall PE, Richardson WJ, Thomas JA, Tyack P (2007) Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33:411-521

Stanley HF, Casey S, Carhahan JM, Goodman S, Harwood J, Wayne R. K (1996) Worldwide patterns of mitochondrial DNA differentiation in the harbour seal (Phoca vitulina). Molecular Biology and Evolution 13:368-382

Stenseth NC, Ottersen G, Hurrell JW, Belgrano A (2004) Marine ecosystems and climate variation. Oxford University Press, Oxford

Sveegaard S (2011) Spatial and temporal distribution of harbour porpoises in relation to their prey. PhD Thesis Aarhus Universitet. 128 pp.

Sveegaard S, Teilmann J, Tougaard J, Dietz R, Mouritsen KN, Desportes G, Siebert U (2010) High-density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. Marine Mammal Science 27:230-246

Sveegaard S, Tougaard J, Teilmann J (2008) Sprogø Wind Farm. Environmental Impact Assessment - Background Report on Marine Mammals. NERI Commissioned Report to Sund&Bæl.

Tavolga WN (1974) Signal/noise ratio and the critical band in fishes. Journal of the Acoustical Society of America 55:1323-1333

Teilmann J, Carstensen J, Dietz R, Edrén SME (2004) Effect on seals at Rødsand seal sanctuary from the construction of Nysted offshore wind farm based on aerial surveys. Technical report to Energy E2 A/S. National Environmental Research Institute, Roskilde

Teilmann J, Heide-Jørgensen MP (2001) Tællinger af spættet sæl og gråsæl 2000, Østersøen, Kattegat og Limfjorden. In: Laursen K (ed) Overvågning af fugle og sæler 1999-2000. Danmarks Miljøundersøgelser

Teilmann J, Sveegaard S, Dietz R, Petersen IK, Berggren P, Desportes G (2008) High density areas for harbour porpoises in Danish waters - NERI Technical Report No. 657

Teilmann J, Tougaard J, Carstensen J, Dietz R, Tougaard S (2006) Summary on seal monitoring 1999–2005 around Nysted and Horns Rev Offshore Wind Farms, Report to Energi E2 A/S and Vattenfall A/S. National Environmental Research Institute, Denmark

Terhune JM (1988) Detection thresholds of a harbour seal to repeated underwater high-frequency, short-duration sinusoidal pulses. Canadian Journal of Zoology 66:1578-1582

Thompson PM, Kovacs KM, McConnell BJ (1994) Natal dispersal of harbour seals (Phoca vitulina) from breeding sites in Orkney, Scotland. Journal of Zoology 234:668-673

Thompson PM, Mackay A, Tollit DJ, Enderby S, Hammond PS (1998) The influence of body size and sex on the characteristics of harbour seal foraging trips. Canadian Journal of Zoology 76:1044-1053

Thompson PM, McConnell BJ, Tollit DJ, Mackay A, Hunter C, Racey PA (1996) Comparative distribution, movements and diet of harbour and grey seals from the Moray Firth, NE Scotland. Journal of Applied Ecology 33:1572-1584

Thomsen F, Lüdemann K, Kafemann R, Piper W (2006) Effects of offshore wind farm noise on marine mammals and fish, biola, Hamburg, Germany on behalf of COWRIE Ltd, Newbury, UK

Thrush SF, Hewitt JE, Cummings VJ, Dayton PK (1995) The impact of habitat disturbance by scallop dredging on marine benthic communities: what can be predicted from the results of experiments? Marine Ecology Progress Series 129:141–150

Todd VLG, Pearse WD, Tregenza NC, Lepper PA, Todd IB (2009) Diel echolocation activity of harbour porpoises (Phocoena phocoena) around North Sea offshore gas installations. ICES Journal of Marine Science 66:734–745

Tollit DJ, Black AD, Thompson PM, Mackay A, Corpe HM, Wilson B, Van Parijs SM, Grellier K, Parlane S (1998) Variations in harbour seal Phoca vitulina diet and dive-depths in relation to foraging habitat. Journal of Zoology 244:209–222

Tougaard J, Damsgaard Henrisken O, Miller LA (2009) Underwater noise from three types of offshore wind turbines: estimation of impact zones for harbour porpoises and harbour seals. Journal of the Acoustical Society of America 125:3766-3773

Tougaard J, Henriksen OD (2009) Underwater noise from three types of offshore wind turbines:Estimation of impact zones for harbor porpoises and harbor seals. Journal of the Acoustical Society of America 25 3766-3773

Tyack PL (1998) Acoustic communication under the sea. In: Hopp SL, Owren MJ, Evans CS (eds) Animal acoustic communication. Springer-Verlag, Berlin, p 163-220

Van Parijs SM, Kovacs KM (2002) In-air and underwater vocalizations of the eastern Canadian harbour seals, Phoca vitulina. Canadian Journal of Zoology 80:1173-1179

Verfuß UK, Miller LA, Pilz PKD, Schnitzler H-U (2009) Echolocation by two foraging harbour porpoises (Phocoena phocoena). The Journal of Experimental Biology 212:823-834

Villadsgaard A, Wahlberg M, Tougaard J (2006) Echolocation signals of wild harbour porpoises, Phocoena phocoena. Journal of Experimental Biology 210:56-64

Villadsgaard A, Wahlberg M, Tougaard J (2007) Echolocation signals of wild harbour porpoises, Phocoena phocoena. Jourral of Experimental Biology 210:56-64

Ward, W. D. (1997) Effects of high intensity sound. Pp 1497-1507. Encyclopedia of Acoustics.

Weiffen M, Möller B, Mauck B, Dehnhardt G (2006) Effect of water turbidity on the visual acuity of Harbour seals (Phoca vitulina). Vision Research 46:1777-1783

Wiemann A, Andersen LW, Berggren P, Siebert U, Benke H, Teilmann J, Lockyer C, Pawliczka I, Skóra K, Roos A, Lyrholm T, Paulus K, Ketmaier V, Tiedemann R (2010) Mitochondrial Control Region and microsatellite analyses on harbour porpoise (Phocoena phocoena) unravel population differentiation in the Baltic Sea and adjacent waters. Conservation Genetics 11:195-211

Wilber DH, Clarke DG (2001) Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21:855–875

Wille P (1986) Acoustical properties of the ocean. In: Landolt-Bornstein (ed) Zahlenwerte und Funktionen aus Naturwissenschaft und Technik, Oceanography, Vol 3, subvolume 3

Wilson B, Thompson PM, Hammond PS (1997) Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. Journal of Applied Ecology: 34

Wright AJ, Soto NA, Baldwin AL, Bateson M, Beale CM, Clark C, Deak T, Edwards EF, Fernández A, Godinho A, Hatch LT, Kakuschke A, Lusseau D, Martineau D, Weilgart LS, Wintle BA, Notarbartolo-di-Sciara G, Martin V (2007) Do Marine Mammals Experience Stress Related to Anthropogenic Noise? International Journal of Comparative Psychology 20:274-316

Wright PJ, Begg GS (1997) A spatial comparison of common guillemots and sandeels in Scottish waters. ICES Journal of Mrine Science 54:578–592

Yost, W. A., Fundamentals of hearing; An introduction, Academic press, San Diego, 2000

Yurk H, Trites AW (2000) Experimental attempts to reduce predation by harbour seals on out-migrating juvenile salmonids. Transactions of the American Fisheries Society 129:1360 - 1366, 2000

12. Appendix 1

12.1. FEMM GIS methodology for calculating Severity of Impact (loss or impairment)

12.1.1. Severity Layers

To calculate the severity of impact the areas where importance and degree of impairment (DOI) or degree of loss (DOL) overlap need to be calculated.

1. This was done using the intersect method within ArcGIS version 9.3.

   The resulting GIS layer contains each overlapping area as a separate polygon and the associated attribute table contains the attribute fields from both of the layers.
2. A field was added to the attribute table called “Severity_Impairment”.
3. This field was populated in edit mode, the “Severity_Impairment” field needs to be highlighted, then right click and select the ‘field calculator’.
4. In the new window, the advanced tick box needs to be checked and an ‘IF’ calculation is set to compare the values of the DOI and Importance weighting. These were classified following the severity levels outlined in the table below, e.g. very high DOI and very high Importance = Very high SOI/SOL.

The field names (those enclosed in square brackets) were amended to ensure that all associated fields had the same name (this is because the code will only work if the field names are the same).

```
Dim s as string

IF [GRIDCODE] = 4 and [GRIDCODE_1]=4 then

s = "Very High"

elseIF [GRIDCODE] = 4 and [GRIDCODE_1]=3 then

s = "High"

elseIF [GRIDCODE] = 3 and [GRIDCODE_1]=4 then

s = "High"

elseIF [GRIDCODE] = 3 and [GRIDCODE_1]=3 then

s = "High"

elseIF [GRIDCODE]=4 and [GRIDCODE_1]=2 then

s = "medium"
```

```
elseIF [GRIDCODE]=2 and [GRIDCODE_1]=4 then
s = "medium"
elseIF [GRIDCODE]=3 and [GRIDCODE_1]=2 then
s = "medium"
elseIF [GRIDCODE]=2 and [GRIDCODE_1]=3 then
s = "medium"
elseIF [GRIDCODE]=2 and [GRIDCODE_1]=2 then
s = "medium"
elseIF [GRIDCODE]=4 and [GRIDCODE_1]=1 then
s = "minor"
elseIF [GRIDCODE]=1 and [GRIDCODE_1]=4 then
s = "minor"
elseIF [GRIDCODE]=3 and [GRIDCODE_1]=1 then
s = "minor"
elseIF [GRIDCODE]=1 and [GRIDCODE_1]=3 then
s = "minor"
elseIF [GRIDCODE]=2 and [GRIDCODE_1]=1 then
s = "minor"
elseIF [GRIDCODE]=1 and [GRIDCODE_1]=2 then
s = "minor"

Else s = "negligible"
end if
```

Where [GRIDCODE] is the scored weighting of the importance layer

And [GRIDCODE1] is the DOI weighting for the activity/impact in question.

5. Once the calculation is complete click run.

NB if any values in the table are amended the field will not automatically update so you will need to re-run the calculation.

Table 12.1—1 An example of the attribute table produced by the intersect methodology.

OBJECTID	Importance	DOI	DOI_HP	Shape_Length	Shape_Area	Severity_Impairment
1	1	Very High	4	0.083042	0.000073	medium
2	1	Very High	4	0.121022	0.000181	medium
3	1	High	3	0.040547	0.000027	medium
4	1	Medium	2	0.025186	0.000013	minor
5	1	Minor	1	0.009519	0.000003	negligible
6	1	Minor	1	0.023035	0.000006	negligible
7	2	High	3	0.030523	0.000018	medium
8	2	Medium	2	0.116085	0.000073	medium
9	2	Medium	2	0.049832	0.000033	medium
10	1	Very High	4	0.01953	0.000015	medium
11	1	Medium	2	0.050468	0.000029	minor

6. Steps 2 to 5 are repeated to calculate “Severity_Loss”.
   NB severity of loss calculation will be based on degree of loss.

13. Appendix II

This appendix gives the numbers of porpoises affected by different levels of degree of impairment from construction noise (not accounting for the importance of the affected areas), while the results in the EIA chapters above show the numbers of porpoises affected by different levels of severity of impairment (accounting for the importance of affected areas).

Immersed tunnel

Noise from dredging (based on scenario shown in Figure 6.2-24 and Figure 6.2-26)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	0.462	0.898	0.02	-	1.362

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	0.966	1.919	0.004	-	2.889

Noise from pile driving (based on scenario shown in Figure 6.2-19)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	0.985	0.480	0.024	-	1.490

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	2.182	1.215	0.060	0.001	3.458

Noise from combined scenario (dredging and pile driving) (scenario shown in Figure 6.2-21)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	1.437	1.107	0.296	0.000	2.841

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	3.126	3.135	0.064	0.001	6.326

Cable-stayed bridge

Noise from dredging (based on scenario shown in Figure 7.2-9 and Figure 7.2-8)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	0.253	0.582	0.001	-	0.837

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	0.844	2.762	0.008	-	3.614

Noise from pile driving (based on scenario shown in Figure 7.2-11)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	1.063	0.556	0.079	0.005	1.704

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	2.335	1.356	0.196	0.013	3.901

Noise from bored piling (drilling) works (based on scenario shown in Figure 7.2-13)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	1.063	0.556	0.079	0.005	1.704

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	2.335	1.356	0.196	0.013	3.901

Noise from combined scenario (dredging, pile driving and drilling) (based on scenario shown in Figure 7.2-15)

- Winter

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	1.063	0.556	0.079	0.005	1.704

- Summer

DoI	Minor	Medium	High	Very High	Total
Number of affected porpoises	2.335	1.356	0.196	0.013	3.901