FEIA on behalf of Femern A/S

September 2016

UNDERWATER NOISE - HARBOUR PORPOISE

Third Party Review

PROJECT

Underwater noise - Harbour porpoise

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FEIA on behalf of Femern A/S

Issued 02 September 2016
Version: Final

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EXECUTIVE SUMMARY

The Environmental Impact Assessment for the Fehmarnbelt Fixed Link Project includes an assessment of the potential impact of temporary, non-pulse underwater noise from dredging (and related shipping activity) during construction upon harbour porpoise. An international group of experts in marine environmental impact assessment, marine mammals and underwater acoustics have reviewed this specific aspect of the impact assessment, including supporting baseline studies, and present their findings in this report.

The Expert Group concludes that the impact assessment is well informed by a strong set of baseline studies of harbour porpoise and underwater noise in and around the Project Area. Moreover, the precautionary principal is largely followed throughout the assessment resulting in a precautious worst-case assessment. Low numbers of individual harbour porpoise are expected to be temporarily disturbed but this is not anticipated to result in a significant impact at the population level. The Expert Group supports the conclusion of the impact assessment that dredging activities will have insignificant impact on both individuals and the population of harbour porpoise in the Fehmarnbelt area.

Disturbance of harbour porpoise by temporary non-pulse underwater noise is afforded substantially more attention in the impact assessment than would be expected in other countries of which the Expert Group are aware and the supporting baseline studies are also very much more detailed than would be anticipated for equivalent projects in those countries.

Within the impact assessment underwater noise thresholds levels are adopted to support the evaluation of effects upon harbour porpoise, including likely impact ranges. In relation to underwater noise of a temporary and non-pulse nature the Expert Group finds that it is not possible to substantiate, and thereby support, any one threshold for such a purpose since scientific knowledge specifically for these types of sound sources is lacking. However, this is not considered to undermine the assessment since a very minor impact is expected irrespective of the particular threshold adopted.

The Fehmarnbelt Fixed Link Project will pass through the 'Fehmarnbelt' Natura 2000 site in the German EEZ. Although this site is designated partly in relation to reproduction of harbour porpoise, the Expert Group considers that the baseline studies for the Project support the conclusion that the area does not have any especially important function for harbour porpoise reproduction or nursery. German N2000 areas adopt a 1% criterion, meaning that not more than 1% of

the area of a site may be affected by noise above 140 dB SEL during the most sensitive (breeding) period of May to August. The Expert Group is of the opinion that the 10% criterion which applies outside May to August is more appropriate due to the lack of reproduction and nursery areas. Also, due to the naturally high mobility of harbour porpoise, the availability of alternative habitat and fact that the population is highly unlikely to be at its carrying capacity, a limited temporary displacement due to the activities is considered very unlikely to represent a significant impact on the population.

1 INTRODUCTION

This report describes the findings of a third party review carried out by an international expert group for FEIA on behalf of Femern A/S, developer of the Fehmarnbelt Fixed Link Project. FEIA are in-house consultants to Femern A/S who assist by providing services such as, for example, reviews.

The report considers certain questions concerning assessments of potential impacts on harbour porpoise due to temporary non-pulse noise in the marine environment due to dredging works and related shipping activities.

The following key questions are addressed in the review:

1) Sensitivity criteria

- What is the scientific evidence concerning the sensitivity of harbour porpoise (the relevant disturbance range) to temporary non-pulse underwater noise?

2) General approach

- What is the international approach and experience with assessing impacts on harbour porpoise (species and population level) exposed to temporary non-pulse noise in the marine environment?

- Is the Fehmarnbelt Fixed Link approach relevant and well substantiated?

3) Natura 2000 protection

- What is international approach for assessing and excluding significant harmful impacts from temporary non-pulse underwater noise on designated harbour porpoise (individual and population level) in Natura 2000 areas and on harbour porpoise as an Annex 4 species?

- Which criteria are in use, e.g. affected/displaced number of animals, affected/displaced part of a population, affected part of a habitat or a Natura 2000 area?

- Is the noise protection and surveillance concept (Application Document 22.05) regarded as relevant and sufficient to exclude significant/harmful impacts on harbour porpoise as part of the Natura 2000 designation in the German EEZ (Natura 2000 site “Fehmarnbelt”)?

1.1 Document overview

The following documents are part of the review:

- Marine mammals studies – (Femern A/S & LBV-SH Niederlassung Lübeck 2013a, FEMM 2013a)
- Ambient noise in the Fehmarnbelt area (Cefas & Bioconsult SH 2011)
- Marine mammals – Impact assessment (Femern A/S & LBV-SH Niederlassung Lübeck (2013b, 2013c, FEMM 2013b, amended by Femern A/S & LBV Niederlassung Lübeck 2016a)
- Plan approval document 22.05: ,''Schallschutzkonzept zum Unterwasserlärm[1]" (Femern A/S & LBV-SH Niederlassung Lübeck 2016b); including related annexes:
    - Annex 1 ,''Begründung der Kriterien für die Bewertung der Störung von Schweinswalen durch Schallemission" (Femern A/S & LBV-SH Niederlassung Lübeck 2016c)
    - Annex 2, ''Modellierung der Unterwasserschallemissionen'' (Femern A/S & LBV-SH Niederlassung Lübeck 2016d)
- Feste Fehmarnbeltqueung Planfeststellung. Anlage 19, Teil B III: FFH-Verträglichkeitsstudie (FFH-VS) GGB DE 1332-301 „Fehmarnbelt". Femern A/S & LBV-SH Niederlassung Lübeck (2016e)

The German Noise Mitigation Concept (NMC), or Schallschutzkonzept (BMU 2013) is mentioned in this report because it is discussed in Plan Approval Document 22.05 (the noise protection and surveillance concept for the Project) and is of potential importance to the consenting of activities in German waters. However, this report does not review the NMC, only its applicability to the project.

1.2 Expert Group

The review is performed by a group of international experts from the United Kingdom, Germany and the Netherlands. All the experts are biologists and have extensive experience with assessments of environmental impacts on the marine environment, underwater acoustics or a combination of both.

The Expert Group:

- United Kingdom: Ian Gloyne-Philips (CMACS)

[1] Soundproofing concept for underwater noise

- Germany: Christian Ketzer, Helmut Wendeln, Michael Joost (IBL Umweltplanung GmbH)

- The Netherlands: Roelant Snoek (WaterProof BV), Ruben Fijn (Bureau Waardenburg bv).

1.3 Report outline

In Chapter 2, various noise threshold levels are reviewed in relation to disturbance of harbour porpoise, including the German Noise Mitigation Concept (BMU 2013), and considered for their applicability to the foreseen activities. International (UK, IRE, NL, GE) standards and guidelines are described together with a description of best practices in relation to continuous noise and EIAs in Chapter 3. Subsequently, in Chapter 4 key Fehmarnbelt background and assessment reports relating to non-pulse underwater noise are reviewed in the context of chapters 2 and 3. Conclusions and response to the key questions listed above are presented in Chapter 5.

2 EVALUATION OF NOISE THRESHOLD LEVELS

The differences between impulsive and continuous noise sources are described in Section 2.1, followed by an overview of the impacts that can occur due to underwater noise in general in Section 2.2. The German Noise Mitigation Concept (BMU 2013) and threshold levels therein are described in Section 2.3, followed by conclusions on the applicability of available threshold levels for the Fehmarnbelt project assessment (Section 2.4).

2.1 Impulsive versus continuous noise

Anthropogenic underwater noise is generally characterised as either impulsive or continuous, typically depending on its source. Examples of anthropogenic impulsive noise in the marine environment are impact pile driving and seismic surveys airguns, whereas activities such as shipping and dredging are associated with continuous noise.

The differences in character between impulsive and continuous noise have been described in Plan Approval Document 22-05 (Femern A/S & LBV-SH Niederlassung Lübeck 2016b) and illustrated in Figure 1, below.

Impulsive noise is characterized by high energy over a short duration. Typical metrics for impulsive noise are Sound Exposure Level (SEL) and Peak sound pressure level (SPL_{peak} or $SPL_{peak\text{-}peak}$). The SEL is calculated over the pulse duration, which is commonly defined as the time occupied by the central portion of the pulse, where 90% of the pulse energy resides (Robinson et al. 2014).

Continuous noise is characterized by acoustic energy which is spread over a significant time, typically many seconds, minutes or even hours. The amplitude of the sound may vary throughout the duration, but the amplitude does not fall to zero for any significant time. The metric most suitable for continuous sounds is Sound Pressure Level (SPL), although a SEL can be calculated for continuous noise as well (Robinson et al. 2014). SPL is time averaged and most commonly expressed as a root mean square (RMS) value.

Figure 1 shows the amplitude response of a measured piling sound (red) and a 200 Hz tone (blue) of one second duration. Both sounds have a similar SEL. A pulse with a shorter duration but more energy has the same SEL (since the energy is averaged over a duration of one second) as the continuous tone with a duration of a second. Obviously, the impulsive noise is perceived as being louder because it significantly exceeds the averaged value during the actual pulse.

Since the sound characteristics of impulsive and continuous noise are very different, SEL levels cannot be easily compared in relation to behavioural responses to apparently comparable levels of both types of sound.

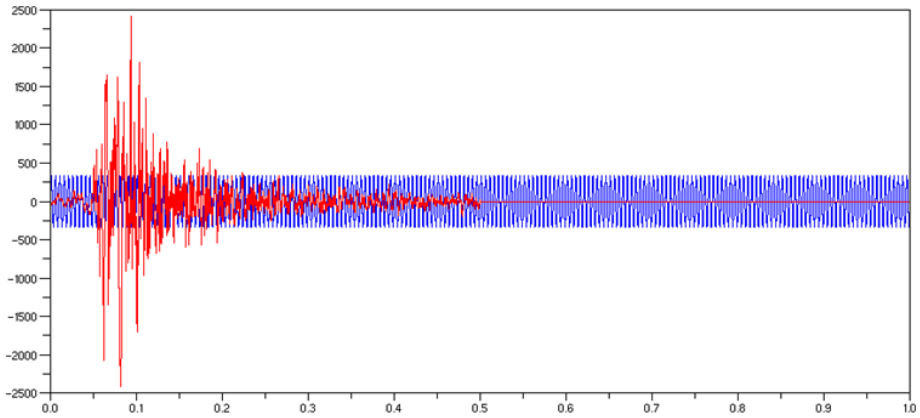

Figure 1 Schematization of sound pressure of a piling noise (red) and a continuous noise (blue) over a period of 1 second (from Femern A/S & LBV-SH Niederlassung Lübeck 2016b).

2.2 Impact categories

Underwater noise can lead to different effects on marine life. Although impacts have been increasingly studied over recent years, knowledge is still relatively limited (Hawkins et al. 2015, Todd et al. 2015).

Based on Richardson et al. (2013), five different impact categories on marine mammals that can be caused by underwater noise are discriminated (see also Figure 2):

Note that the impact categories presented below are not specifically described for the project at hand, the more severe impact categories (Injury, PTS and TTS) are likely to occur due to impulsive noise only.

1. The noise can be detected by marine mammals, but is too weak to induce an observable reaction (apparent tolerance for the noise);

2. The noise characteristics and the noise level impair a species' communication (masking).

3. The noise leads to a behavioural response, e.g. leaving or avoidance of an area (Response). There is potential for habituation after repetitive exposure.

4. Very loud noise and/or a long duration of exposure can lead to a temporary threshold shift (TTS) or a permanent threshold shift (PTS) in which the hearing threshold is (temporary or permanently) increased.

5. Physical damage (injury) as result of strong pressure changes, e.g. tissue rupture, which can lead to death of individuals.

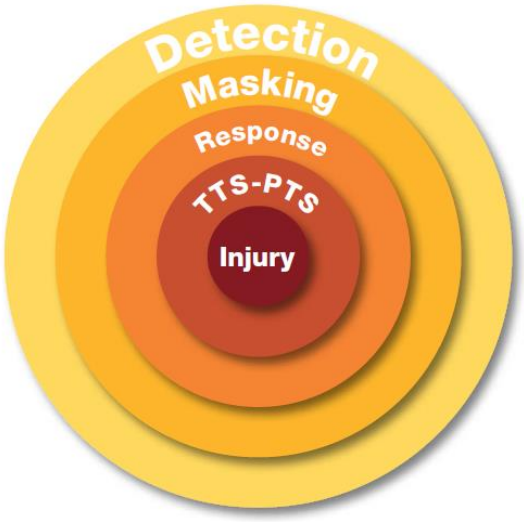

Figure 2 Effect categories for underwater noise based on Richardson et al. (2013).

The noise levels at which the different effects occur are species specific and depend also on various other factors such as the type of sound, source spectrum of the sound and/or duration of the sound.

The occurrence of the two most severe effect categories (Injury and PTS/TTS) are not included in this third party report since mitigation measures are in place for construction works to prevent the occurrence of physical effects from impulsive sound sources (a threshold of 160dB at 750m from the source, relevant local deterrent measures and slow start and ramp up period as stated in the Noise Mitigation Concept). No such effects are reasonably anticipated from continuous sound generated by project activities.

The threshold level for inducing behavioural response (Category 3 in Figure 2) by harbour porpoise is evaluated in this report. This is consistent with the NMC, in which behavioural response is identified as a potential impact due to construction related noise over certain time spans. More specifically, in this report this is considered to be the avoidance or leaving of an area by harbour porpoise due to an anthropogenic continuous noise source over a certain time span (hereafter termed 'avoidance').

2.3 German Noise Mitigation Concept (NMC) in the context of the project

The NMC (BMU 2013) was developed in relation to the Protection of harbour porpoise from sound exposures during the construction of offshore wind farms in the German North Sea. The report provides clarity with regard to the requirements placed on developers by nature conservation law based on evidence of impacts to harbour porpoise.

According to the NMC:

*"This Concept for the assessment of the ecological impacts of **underwater sound during the construction of offshore wind farms** is intended to create greater security for all parties in future with regard to the interpretation of the imprecise legal terms found in the relevant nature conservation standards ('injury' and '**significant disturbance**' in the context of the prohibitions on taking under species protection law, 'significant adverse impact' in the context of site protection). It is intended to **give the developers of offshore wind farms guidance concerning the application of these standards** during the construction phase as early as possible in their very long planning processes. …. The Concept, …, is intended to offer assistance in the interpretation of the requirements of harbour porpoise protection."*

Since the NMC is based on recent scientific insights on sound sources, propagation, threshold levels for various types of impacts and additionally provides guidelines to prevent impact and protect harbour porpoise, it appears obvious to consider this concept when assessing the impact of underwater noise. However, the concept is specifically written for the development of offshore wind farms (OWFs) in the German North Sea, only regarding impulsive noise and might therefore not be more generally applicable. The applicability of the NMC and threshold levels therein to the Fixed Link Project is evaluated in the paragraphs below.

2.3.1 Area of application

In the Noise Mitigation Concept, it is stated that the concept is limited to the German Exclusive Economic Zone (EEZ) in the North Sea, since at the moment no data on the occurrence and distribution of harbour porpoise in the German Baltic Sea is available. Without this information, no validated noise mitigation concept for the Baltic Sea can be developed. It is therefore specifically stated that the existing NMC should not be applied to the Baltic Sea.

This however does not imply that the NMC can be of no value for the impact assessment for the Fehmarnbelt which is situated in the Baltic Sea. The criteria and threshold levels for various types of impact as set by Southall et al. (2007) are based on research conducted worldwide and also applied in EIAs worldwide. Although variation in the behavioural response that can occur can depend on the area where the activities take place, this does not mean that criteria cannot be applied. Threshold levels described in literature and in the NMC based on studies in the German North Sea should be considered as indicative rather than absolute and can be used as such for the Baltic Sea area as well.

2.3.2 Impulsive vs. continuous noise in the Noise Mitigation Concept

The NMC refers to hearing impairment and disturbance of porpoise explicitly to impulsive noise in the North Sea, especially pile driving at offshore windfarms. It is stated that due to the lack of data available, other sound sources that (may) lead to noise exposures, such as the noise emitted by dredging and shipping activity, are not examined in the NMC.

2.3.3 Threshold levels in the Noise Mitigation Concept

The German noise mitigation concept is based on two thresholds: 160 dB SEL for potential health hazards (hearing impairment) and 140 dB SEL for significant disturbance of harbour porpoise. Since the threshold values refer to impulsive noise (pile driving), a threshold for the much higher peak level was also set (190 dB peak for health hazards). When exceeding the threshold 160 dB SEL/190 dB peak, the risk of a temporary threshold shift (TTS), that can affect food acquisition and communication is assumed.

The threshold values are mainly derived from sound experiments of Lucke et al. (2009) who detected a TTS in a captive harbour porpoise after single airgun sound pulses with a pressure of 164 dB SEL/199 dB peak. In the NMC these values are rounded down to 160/190 due to potential cumulative effects of repetitive sound pulses and are set as limit values that must be met in a 750 m distance. With reference to various modelling it is also pointed out in the NMC that low sound levels could lead to TTS due to accumulation of many sound pulses if exposed during a sufficiently long period of time.

The scientific basis of the NMC limit value of 160 dB SEL for harmful effects of impulse noise on harbour porpoise seems to be quite narrow, as the experiments of Lucke et al. (2009) were carried out on only one captive animal and cumulative effects of repeating sound pulses were not examined. Nevertheless, it is comprehensible that cumulative effects are not considered extensively in

the NMC value because wild porpoise will very likely move away from a noisy sound source and thus largely avoid cumulative impacts on their hearing.

The 140 dB SEL threshold used in the NMC for significant disturbance is based on the range of avoidance reactions determined by C-POD investigations during pile driving in Horns Rev II and Alpha Ventus (Diederichs et al. 2010a, Brandt et al. 2011). With the C-POD data, a statistically significant decline in porpoise activity was detected up to distances where it was estimated that a noise level of 138-140 dB SEL was achieved (sound propagation calculated with the formula TL = (14 + r * 0.0002) * LOG (r); derived from Thiele & Schellstede 1980). In contrast, no statistically significant decrease was observed at distances with a level of about 134 dB SEL. The threshold for disturbance during pile-driving is likely lower than the 145 dB SEL reaction threshold found by Lucke et al. (2009) in a captive harbour porpoise after single airgun sound pulses.

More recent C-POD studies could justify however slightly higher thresholds. The latest effect study of Brandt et al. (2016), based on continuous North-Sea-wide C-POD and aerial survey data comprising the construction of eight offshore wind farms from 2009 to 2013 revealed a range of 145 to 150 dB SEL at which porpoise detections declined only by about 25% compared to the baseline period before piling, whereas a 90% decline at noise levels above 170 dB SEL was modeled. Below 145 dB SEL the statistically significant decline could not clearly be related to piling noise any more.

Pehlke et al. (2014) suggested a threshold for disturbance of harbour porpoise by impulsive noise of 144 dB SEL.

2.3.4 Criteria for N2000 and species protection in the NMC

Based on the thresholds used for hearing impairment and disturbance, the NMC establishes criteria for N2000 areas and species protection. The criteria refer to the impaired area, but not to the number or proportion of affected animals. According to that, the prohibition of deliberate killing and injury is complied with if relevant local deterrent measures are established and the risk of injury (>160 dB SEL) is limited to a maximum distance of 750 m to the sound source. The prohibition of deliberate disturbance is complied with if generally not more than 10% of the German North Sea EEZ and, from May to August, not more than 1% of the ‘main concentration area’ near Sylt is affected by noise levels above 140 dB SEL.

Accordingly for the protection of N2000 areas it applies that not more than 10% of its surface may be exposed to sound levels above 140 dB SEL. For N2000 areas, where the reproduction of harbour porpoise is defined as a protection goal, the 1% criterion applies again for the period from May to August.

2.4 Applicability of noise threshold levels for foreseen activities

Both the NMC and the more recent findings of Brandt et al. (2016) are based on studies of impulsive noise and the reported threshold levels cannot be used directly for continuous noise. Additionally, the 140 dB threshold level defined in the NMC is mainly based on two C-POD-studies in the North Sea and slightly higher threshold levels have been suggested by more recent impulsive noise studies.

There is much room for interpretation when determining a disturbance threshold value based on C-POD results, as is the case with the aforementioned studies. First it has to be defined which aspect of decline of porpoise activity (measured as porpoise positive periods) is considered as a significant disturbance effect. The area within a defined radius of disturbance is not uniformly affected because the disturbance intensity and the proportion of animals that avoid the area decreases with distance.

However, C-POD data allow some room for interpretation and recent studies revealed a more complex view of porpoise behaviour with partial displacement and somewhat higher thresholds compared to the 140 dB.

The question is whether a suitable threshold level for continuous dredging and shipping noise at which avoidance of harbour porpoise occurs can be determined based on any substantial scientific evidence.

In Southall et al. (2007), criteria for both impulsive and non-impulsive noise for marine mammals are described. Based on a number of studies on harbour porpoise it is concluded that combined wild and captive animal data support the observation that harbour porpoise are quite sensitive to a wide range of human sounds at very low exposure RLs (~90 to 120 dB re 1 µPa), at least for initial exposures. According to the review by Southall et al. (2007), all recorded exposures exceeding 140 dB re 1 µPa induced clear avoidance behaviour in wild harbour porpoise. However, the sources at which these reactions occur consisted of acoustic mitigation devices (AMDs) which are specifically designed to emit sound in the frequency spectrum at which harbour porpoise are most sensitive

and no threshold levels for shipping or dredging noise were described or can be deduced or concluded from these studies.

Kastelein et al. (2015) quantified the effect of two AMDs on porpoise behavior using two captive animals. Behavioural reactions were found at SPLs of 117 and 121 dB re 1 µPa and avoidance reactions at SPLs of 139 and 151 dB re 1 µPa. As the mean received SPL increased displacement distance, surfacing frequency and swimming speed increased.

Habituation to sound exposure was noted in some but not all studies and it was concluded that strong initial reactions of high frequency cetaceans at relatively low levels may in some conditions decrease with repeated exposure and subject experience (Southall et al. 2007).

Diederichs et al. (2010) describe avoidance of harbour porpoise during dredging operations within 600m of the source, though unfortunately no sound measurements at this distance are available. Measured noise levels of dredging were 150 dB re 1 µPa at a distance of 300m from the operating vessel.

Dyndo et al. (2015) describe the mean onset level of observable behavioural response for harbour porpoise to shipping noise as 123 dB re 1 µPa (range 113-133 dB re 1 µPa), whereas Mortensen et al. (2011) observed no effects at sound pressure levels under 140 dB re 1 µPa.

Based on the available literature it is concluded that there is a clear lack of unequivocal threshold levels for shipping and dredging noise at which avoidance by harbour porpoise can be considered to occur. Both the described 140 dB re 1 µPa in the NMC, the 144 dB re 1 µPa in Brandt et al. (2016), or a lower value as suggested by research from Kastelein et al. (2015) and Dyndo et al. (2015), might be used in order to assess the potential effects of underwater noise. Since solid evidence for avoidance by harbour porpoise due to dredging and shipping in the wild is lacking, results calculated based on either of these threshold levels should be interpreted with caution and always contextualised with respect to the specific area and the unique environmental aspect under concern. It is therefore strongly advised not only to calculate the number of affected individuals based on a derived threshold level or general regulation schemes for another type of sound or noise sources, but to include the ecological context of such a disturbance in the assessment. For example, the low threshold value reported by Dyndo et al. (2015) at which avoidance behaviour is found proves not to be useable in an area where ambient noise levels due to

high ship traffic are already in the order of magnitude of > 135dB which is 12 dB higher than the avoidance threshold in question. The motivation of harbour porpoise to inhabit an area at which anthropogenic noise is present should be taken into account in the impact assessment.

3 PRESENTATION OF THE INTERNATIONAL APPROACH

The review in Chapter 2 of thresholds in the Noise Mitigation Concept and elsewhere concluded that there is no solid evidence base to apply any specific value for avoidance by harbour porpoise due to dredging and shipping noise. Since a similar lack of knowledge applies elsewhere, this chapter considers how other projects with potential to generate high levels of underwater noise are managed in a range of countries. The aim is to identify international best practice with respect to underwater noise assessments for harbour porpoise as a European Protected Species (EPS) under Annex IV of the Habitats Directive species and assessments for Natura 2000 sites supporting harbour porpoise as an Annex II species.

Where possible, projects generating continuous underwater noise are considered, although impulsive sound is also included where information on continuous noise is limited. Germany is included so that the Fehmarnbelt project can be put into context with other noise generating activities. There is extensive experience of sediment extraction through dredging in the Netherlands and the UK because of its relatively mature offshore renewable energy industry.

Having transposed the Habitats Directive into national laws, all EU countries have approaches to the protection of harbour porpoise and other EPS which are to some extent comparable; for example, potentially permitting derogations to Directive requirements if certain (common) conditions are met. There are however differences in interpretation of details such as criteria to define a significant number of animals and the approach taken to defining disturbance. Such differences are highlighted where identified.

3.1 Germany

Due to the implementation of the EU Habitats Directive and the Birds Directive in Germany, a number of marine protection areas have been reported to the European Natura 2000 network. In the North Sea three Special Areas of Conservation (SAC, according to the Habitats Directive) and in the Baltic Sea five SACs are situated.

The harbour porpoise, as a species listed under Annex II and Annex IV of the Habitats Directive, is a target of protection in most of the SACs in the German EEZ. In the SACs ‘Sylt Outer Reef’ (North Sea), ‘Dogger Bank’ (North Sea) and ‘Fehmarnbelt’ (Baltic Sea) the reproduction of the species is also noted in the site designation material.

The German Noise Mitigation Concept (NMC, BMU 2013) as discussed in Section 2.2 was primarily developed to assess the compliance of offshore-windfarm construction activities in relation to the protection of harbour porpoise under the Habitats Directive. This includes the protection of SACs and strictly protected species as defined in Article 34 and 44 of Federal German Nature Protection Act (Bundesnaturschutzgesetz).

3.1.1 Standards and Guidelines

The NMC is the only official guideline in Germany for marine mammal related noise thresholds in relation to human offshore activities. However, as the NMC focuses on pile driving during wind farm construction it solely refers to impulsive noise. There is no German guideline for other types of underwater noise – such as continuous noise emitted by vessels, e.g. dredgers.

Based on the thresholds used for hearing impairment and disturbance (see Section 2.3.4), the NMC establishes criteria for the Natura 2000 area and species protection. The criteria refer to the impaired area, but not to the number or proportion of affected animals. According to the NMC, a project complies with the prohibition of deliberate killing and injury if relevant local deterrent measures are established and the risk of injury (>160 dB SEL) is limited to a maximum distance of 750 m to the sound source. A project complies with the prohibition of deliberate disturbance if generally not more than 10% of the German North Sea EEZ and - from May to August - not more than 1% of the 'main concentration area' near Sylt is affected by noise levels above 140 dB SEL. According to the NMC, the aforementioned criteria apply for the North Sea; there are no specific criteria for the Baltic Sea presented in the NMC. The former area is defined in the NMC based on flight survey data collected in the last fifteen years. The concentration area was found to be the preferred breeding ground of harbour porpoise in German waters.

Accordingly, for the protection of Natura 2000 sites (SACs) a rule is applied that not more than 10% of a site's surface may be exposed to sound levels above 140 dB SEL. For SACs where the reproduction of harbour porpoise is defined as a target of protection, the 1% criterion applies for the period from May to August.

In the German approval procedure for offshore wind farms the permitting authority German Federal Maritime and Hydrographic Agency (BSH) has mentioned the threshold value of 160 dB (SEL) at 750 m for underwater noise since 2005. This threshold was considered to be non-mandatory in the first years. In

the course of the development and implementation of the NMC (BMU 2013), the critical values of 160 dB SEL and 190 dB peak at 750 m became mandatory. Porpoise have to be kept beyond 750 m by deterrence measures.

The two threshold values and all other noise-related obligations are stipulated under collateral clause 14 of each wind farm approval (e.g. approval document for 'OWP West', BSH 2014). This includes the demand to submit a noise prediction and a project-related noise mitigation concept in advance and to use the best available technology for noise mitigation during construction. Collateral clause 14 also demands an efficiency monitoring of noise mitigation and porpoise deterrence measures. Noise monitoring has to be carried out before, during and after construction, which includes the measurement and documentation of background noise as well as of wind farm related continuous noise from ship traffic and wind turbines in operation. With the NMC coming into effect, specific requirements regarding the monitoring design were added to ensure the consideration of nearby Natura 2000 sites (e.g. additional measuring points inside the protected area).

The BSH approvals for offshore cables and grid connections do not include any specific conditions regarding marine mammals and noise, as emitted by the cable ship or cable plough (e.g. COBRA cable approval, BSH 2015). Exceptions are explosions – if necessary for the clearance of unexploded ordnance on the cable route – and the installation of a converter platform if the latter is a part of the grid connection. For the construction of converter platforms the same threshold values apply as for the wind turbine installation (see above). If clearance of unexploded ordnance is necessary, noise mitigation measures are mandatory.

3.1.2 Best Practice

The BSH has in co-operation with scientists and consultants developed a standard for the 'Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment' (Standard-Untersuchungskonzept, "StUK") as a guideline for applicants to obtain the required data for the licensing application and to meet the conditions of an approval as mentioned above. The StUK was first released in 2001 and is currently valid in its fourth edition (StUK 4, BSH 2013).

The StUK sets a detailed framework for the practical implementation of the investigation programme baseline, construction and operational phase of wind farms in the German EEZ. The ecological monitoring described in the StUK is where relevant, applicable and sufficient also recommended by BSH for other

types of offshore installations (e.g. COBRA cable approval, BSH 2015). The current regulatory demands for projects in the German 12 nm-zone are increasingly orientated to take account of StUK contents.

To investigate the effects of wind farm related impulse noise on harbour porpoise and to check the efficiency of deterrence measures, StUK4 stipulates the deployment of passive acoustic monitoring devices (C-PODs). This includes a constant monitoring position ('POD station') in the wider surroundings of the wind farm during all project stages. If a Natura 2000 area is in the vicinity a second POD station has to be placed there. For the whole investigation period marine mammals also have to be registered via monthly aerial surveys that follow a constant transect design.

Besides the construction of wind farms, only a few human activities have been monitored regarding underwater noise and marine mammals in German waters. The installation of the Nord Stream gas pipeline in the Baltic and extensive extraction of sand near the island of Sylt (North Sea) are examples. In contrast to pile driving, the noise emitted by these activities is mainly of continuous character. However, the StUK is designed specifically for wind farm construction works at open sea, and the monitoring concept should therefore be seen serving as an overall guidance for the tailor made monitoring design of the two projects.

The approval of the Nord Stream gas pipeline includes the requirement for a relevant noise prediction for the installation works to check the requirement for sound mitigation measures (BSH 2009). It also demands passive acoustic monitoring for harbour porpoise in the vicinity of the pipeline during and after installation. In this case the approval does not follow a particular guideline because the installation of a pipeline is considered to be a rare event in German waters. During installation of the Nord Stream pipeline hydrophones were thus deployed at a 1 km distance to the route at six measuring points between the German coast and the Danish-German border of the EEZ for noise monitoring (Gehrke 2012). For harbour porpoise monitoring six C-PODs were deployed along the pipeline route and within 1 km (Wollheim & Diederichs 2012). Another 7 devices were deployed in the wider surroundings at measuring points that had been used before for a monitoring programme of Deutsches Meeresmuseum Stralsund (Gilles et al. 2010). As harbour porpoise have a rather low density in the Eastern Baltic no flight surveys were conducted. The monitoring

of harbour porpoise and noise did not reveal any influence of the pipeline installation on the average sound level around 1 km and no effects on porpoise activity in the affected waters could be documented.

To investigate the impact of extensive sand extraction activities on harbour porpoise near Sylt, Diederichs et al (2010c) used a combination of passive acoustic monitoring and aerial surveys similar to the wind farm monitoring programmes. No noise threshold levels were specified from the consenting authority, but monitoring was stipulated as a precautionary measure before plan approval by the regulating authority. Two T-PODs were deployed inside the actual extracting area, two at reference positions close to the coast and another one at a reference position 25 km off the coast in the EEZ (Natura 2000 area 'Sylt Outer Reef'). Transect flights were carried out monthly. The passive acoustic monitoring (POD registrations) revealed a short term avoidance of harbour porpoise in the vicinity of the dredging ship, whereas the results of the aerial surveys did not show a distinct effect. The porpoise numbers were generally low in coastal waters. At a distance of 300 m to the dredging a noise level of 150 dB (reference scale not stated in the paper) was measured. The authors concluded, that the effect were "only short-term and at a very small spatial scale", meaning that "sand extraction has only a minor effect on harbour porpoise" (Diederichs et al. 2010c).

Concerning further linear infrastructure projects (mainly cables) in the German 12 nm zone regulating authorities do not stipulate any noise threshold criteria or related mitigation measures to be complied with by the applicant. To the best of our best knowledge the provisions of the collateral clauses of the respective permits are limited to acoustic and visual monitoring during the construction phase because the licencing authorities act on the assumption that potential effects on marine mammal are restricted to a narrow spatial and temporal scale.

3.2 United Kingdom

Following devolution and the establishment of national parliaments in Northern Ireland, Wales and Scotland there are diverging approaches to regulating marine developments in the UK. Scotland in particular has developed 'The protection of Marine European Protected Species from injury and disturbance Guidance for Scottish Inshore Waters' (Marine Scotland 2014). For the purposes of this review approaches in Scotland are considered separately to those in England, Wales and Northern Ireland where JNCC (2008) has issued guidance for Annex IV species focusing on disturbance alone (separate guidance has been issued in relation to piling (JNCC 2010a) and seismic survey (JNCC 2010b) which consider injury effects).

To date the UK has not confirmed any Natura 2000 sites for the protection of harbour porpoise as Annex II species; however there is ongoing consultation on five possible Special Areas of Conservation (pSACs) for harbour porpoises. Draft guidance documents (e.g. JNCC & Natural England 2016) detail measures, which would potentially apply to ensure the protection of EPS within or adjacent to European Marine Sites. These documents suggest that dredging, and similar activities such as aggregate extraction , can cause disturbances, but the risk is considered relatively low and additional management measures (to ensure favourable conservation status of harbour porpoises within any future European Marine Site) is unlikely to be required.

3.2.1 Standards and Guidelines- Northern Ireland, England and Wales

JNCC (2008) guidance considers: what is *deliberate disturbance*; what are *significant* effects on the ability of the species to survive, breed, or rear or nurture their young, and what is a *significant* group of animals; and what are *significant* effects on the *local distribution or abundance* of a species.

The guidelines state that the onus is on the developer to assess the likelihood of a disturbance offence being committed (through their activity, including in combination with other activities), and whether mitigation and/or a wildlife licence are required. A wildlife licence is only issued '*where there is no satisfactory alternative and where the activity will not be detrimental to the maintenance of the populations of the species concerned at a Favourable Conservation Status* (FCS) *in their natural range.'* It is made clear that the majority of activities are expected not to require a wildlife licence since *'disturbance will fall below the threshold for an offence or because mitigation can be put in place to minimise the likelihood of a disturbance offence'*.

In a UK context, when considering populations of marine mammals the point is made that animals generally occupy large areas and individuals range widely. For harbour porpoise the guidance explicitly states that a significant group is likely to comprise a relatively large number of animals and contrasts with species such as coastal bottlenose dolphin with isolated sub-populations of 100-200 individuals where disturbance of a much smaller number of individuals could be significant.

Suggestions are made in the guidance as to what percentage of a population should be considered significant. The approach is to compare the potential annual rate of population increase for cetaceans (stated to be around 4%) and 'sustainable' mortality levels for (small) cetaceans from fisheries activities (stated to be around 1.7%) to arrive at threshold percentages of between 1 and 4% depending whether conservation status is favourable. The guidelines acknowledge that this would result in a relatively large number of individual harbour porpoise needing to be significantly disturbed before an offence was committed under European legislation, i.e. a relatively large area would need to be affected, or an activity be persistent over a relatively long period of time. For the British parts of the North Sea and adjacent waters, based on data from the SCANS II surveys a lower threshold of 4,600 animals per year is proposed to represent a significant group of harbour porpoise. This does not mean that disturbance (i.e. displacement) of smaller numbers of animals is acceptable; national legislation must also be considered.

Whilst it is left to individual projects to further justify figures for population numbers and threshold percentages the guidelines do state that for a significant effect on the local distribution or abundance of a species to occur, disturbance would need to produce *'more than a transient effect'* but would occur, for example, *'if a significant group of animals of a population were to become displaced from a large fraction of an essential habitat or a large fraction of their overall natural range*.' There are no suggested threshold levels for either continuous or impulsive noise to support assessments for disturbance by underwater noise and it is left to developers to justify assessments (likewise, no thresholds are enforced in relation to injury effects in the UK).

The guidelines consider a range of activities as potential sources of disturbance, including aggregate extraction, dredging and shipping/vessel movements. Dredging is recognised as a source of high intensity sound with the potential to have behavioural effects on cetaceans resulting in displacement in some cases

and habituation in others. Reference is made to ongoing work in this area; however, the potential for significant impacts is considered to be low. In relation to shipping there is very little information beyond an acknowledgment that continually expanding levels of noise may have consequences for marine mammals through effects such as masking.

3.2.2 Standards and Guidelines - Scotland

Recent guidance issued by Marine Scotland (2014) places the onus on developers to make an assessment in relation to their project. The guidance emphasises that trivial disturbance should not be considered significant and a certain negative impact likely to be detrimental must be involved.

The Scottish guidance explicitly recognises the variability in behavioural response to disturbance between individuals and does not attempt to establish any specific threshold for disturbance. Each project is required to undertake a cetacean risk assessment and these are considered on a case by case basis. The guidelines do however recognise the noise injury criteria of Southall et al. (2007) as 'currently the best available'. There are, therefore, no proposed or implied thresholds for disturbance by continuous noise. The Scottish guidance is general in its approach in that it does not focus on specific activities or provide advice in relation to particular industries.

3.2.3 Best Practice - UK

As indicated above, the UK's national guidelines do not identify specific limits for noise generating activities, whether for impulsive or continuous sound, and experience relates to species protection (Annex IV) rather than through Natura 2000 sites.

More generally in the UK, where potentially significant (at EIA level) impacts upon sensitive marine receptors are identified appropriate project specific mitigation is developed. For example, seasonal restrictions on piling activity in relation to fish spawning have been implemented at a number of UK offshore wind farms to avoid disturbance of important spawning aggregations.

Because significant disturbance to harbour porpoise by dredging activities is considered very unlikely there are no known examples of measures specifically addressing porpoise sensitivities to report. There are examples of enhanced mitigation where dredging has been required within SACs for bottlenose dolphin, e.g. dredging and disposal of arisings at the Port of Cromarty by Dredging International within Moray Firth SAC (CMACS, pers. obs.) but extended to all

marine mammal species although measures are focused upon the avoidance of physical impacts should soil disposal occur close to animals.

The dredging industry has supported research into sound levels generated by its activities (Lepper et al. 2012), but across the UK impact assessments have consistently highlighted impulsive noise as representing potentially the greatest magnitude impact for marine receptors. Assessments for continuous noise have generally been qualitiative and where occuring alongside impulsive activities such as piling or airgun survey, continuous noise has generally been concluded to represent a lower level of impact. The result is that impact assessments focus strongly on 'worst case' scenarios (e.g. piling) and evaluate activities such as dredging or vessel movements in the context of generally elevated levels of low frequency and continuous background noise from existing activities.

Burbo Extension Offshore Wind Farm in the Irish Sea near Liverpool provides a good example of how disturbance of harbour porpoise is currently managed at a practical level in the UK. The foundations to the wind farm were installed by hammer piling in spring-summer 2016. Various studies were undertaken to support the original Environmental Impact Assessment (DONG Energy, 2013) although these were relatively small in scale compared to those for the FB Fixed Link Project. The assessment concluded that disturbance (including displacement) of a European Protected Species, harbour porpoise, would occur as an inevitable consequence of hammer piling and as a result a Licence was issued by the Marine Management Organisation (MMO) to the developer, which authorised the disturbance of up to 248 harbour porpoise for 'imperative reasons of overriding public interest' in the absence of a suitable alternative approach.

The Burbo Extension project included significant shipping and seabed preparation activities, and potentially dredging using TSHD, which were not considered to represent any risk of significant disturbance to harbour porpoise so that no equivalent licencing, or any targeted marine mammal mitigation, was planned for such activities.

3.3 The Netherlands

The European Habitats Directive has been implemented in national law (Nature Protection Act/'Natuurbeschermingswet 1998') and seven coastal and offshore Natura2000 areas have been designated. For each of these areas, protected habitats and species have been assigned, for which impact due to anthropogenic activities is assessed at a population level. Additionally, the protection of

individual organisms as described in the European Habitats Directive is implemented in the Dutch Flora and Fauna Act. In this framework mortality of individual animals is assessed in relation to the favourable conservation status of a certain species.

Recently, the area of application of both acts has been extended to the entire EEZ, covering the entire Dutch Continental Shelf (DCS). Consequently, all activities on the DCS that can impact protected habitats and/or species must be assessed. Moreover, in the near future a new Nature Conservation Act (planned for January 2017) will be implemented in the Netherlands, in which both habitat protection and the protection of individual organisms will be covered.

3.3.1 Standards and Guidelines

Due to the development of offshore wind, impact of underwater noise on the marine ecosystem has been the subject of increased focus in environmental impact assessments. The awareness that underwater noise can have a negative impact on protected species at the individual and population level has caused a major increase in the number of studies at scientific, policy and consultancy levels in the Netherlands to address these impacts.

Until recently, there have been no standards or guidelines to assess the impact of underwater noise; each impact assessment had to be made based on the best knowledge available.

Because of the potential for cumulative impact of impulsive noise due to pile driving activities associated with offshore wind, the Dutch Government has initiated the Working Group on Underwater Sound with the objective to develop a framework to assess cumulative impact of impulsive underwater noise from Offshore Wind Farms (OWFs) at a local and regional (North Sea) scale on harbour porpoise and seals (Heinis & de Jong, 2015). Based on the latest scientific knowledge, population effects for North Sea harbour porpoise based on threshold levels for PTS, TTS and avoidance have been modelled for various development scenarios by means of the interim Population Consequence of Disturbance model (PCoD model). For more details see Heinis & de Jong 2015. Various assumptions have been made by the experts of the working group in order to be able to assess impacts, mostly substantiated with available literature, field survey observations and extensive acoustic research experience.

One of the results of the study is a clear step-wise approach for future environmental impact assessments, which are considered as guidelines for future developments. However, these guidelines are specifically developed for impulsive noise and are unsuitable to follow for continuous noise.

Impact caused by continuous noise such as from shipping and dredging works are considered to be subordinate to impulsive noise due to the limited range of specific sources at which impact can occur. For this reason, no standards or guidelines have been developed to date to assess the impact of continuous noise on harbour porpoise. Nevertheless, possible impacts have been assessed for specific projects according to best practice.

3.3.2 Best Practice

Dredging works along the Dutch coast are extensive and impact of underwater noise caused by dredging and shipping on harbour porpoise has been assessed in various projects. Examples of two projects are the construction of the industrial harbour Maasvlakte II (Heinis et al. 2013) and the sand extraction and supplementation for coastal maintenance (Rijkswaterstaat 2015). The best practice in the Netherlands is described on basis of both assessments.

For the Maasvlakte II project, an extensive underwater noise measurement and modelling study has been executed to characterize the sources of dredging and shipping in the area. Based on these studies, sound propagation in the area has been determined. The results of the study have also been used to assess the impact of sand extraction and supplementation in 2015, for which no additional measurements or modelling has been conducted due to the similar activities and environment of the projects.

For the Maasvlakte II report, the main criterion adopted to assume effects on animals was the sound exposure level (SEL) and TTS. It was concluded that for non-stationary harbour porpoise (as is realistic for a mobile species), TTS would not occur due to the dredging and shipping activities. Due to the lack of a threshold level for harbour porpoise due to dredging and shipping noise, avoidance due to the activities has not been included as a criteria in the assessment. The lack of this threshold level for avoidance has been explicitly addressed as a knowledge gap.

The source description of the activities for the sand extraction project is based on the measurement and modelling study for the Maasvlakte II project. In this assessment, all impact categories ranging from detection to injury have been

assessed. Similar to the Maasvlakte project, it is concluded that injury and PTS cannot occur as a result of the dredging activities. TTS in harbour porpoise can theoretically occur within a range a couple of hundred meters from the source, but only at an exposure duration of more than 24 hours. Due to the mobility of the species the occurrence of TTS is excluded.

Also in this study, the lack of threshold levels for avoidance due to continuous noise by dredging is acknowledged. However, based on threshold levels for higher frequency continuous noise from pool studies (Verboom, W.C. & Kastelein, R.A. 2005), an impact range of several kilometres is calculated with a basic propagation model. Considering also the findings of (Diederichs et al. 2010a) and Dyndo et al. (Dyndo et al. 2015), it is concluded that an impact range of up to several kilometres would be a worst-case scenario to assess the impact of the activities.

Both studies clearly describe the lack of threshold levels for continuous noise caused by dredging on harbour porpoise. Based on worst-case assumptions and expert judgement, the significance of effects have been determined.

Significance of effects

In the Netherlands, the impact on protected species is assessed at the population rather than individual level. For the mobile harbour porpoise, defining the population in the North Sea is challenging. Harbour porpoise are not bound to a specific location and are known to migrate over large distances. This implies that no local subpopulation can be defined to assess the impact. Generally, the effects on harbour porpoise in the Netherlands are made on the scale of the Dutch Continental Shelf (approx. 51,000 individuals), or the scale of the North Sea (approx. 230,000 individuals).

The percentage of the population affected by avoidance is calculated based on both the geographical and seasonal distribution of harbour porpoise. Additionally, the ecological context during impact is considered, such as whether mother and calves can be expected, the duration of impact and the expected response of porpoise to such sources, the potential barrier effect in relation to migration and possibilities to avoid areas of impact.

The significant population level at a North Sea scale is based on the ASCOBANS agreement (Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas). The ASCOBANS interim objective is to maintain the population

at 80% of its carrying capacity. Additionally, ASCOBANS set a limit for maximum annual anthropogenic induced mortality (incl. bycatch) for harbour porpoise which should not exceed 1.7% of the population size (Resolution No. 3, Incidental Take of Small Cetaceans, Bristol 2000). This limit cannot be directly used for the assessment of impact due to underwater noise where this affects the population by reduced reproduction and not by direct mortality such as in bycatch in fisheries. Assuming the population to be at its carrying capacity, it is – specifically for the cumulative impact assessment for impulsive noise – chosen that with a confidence of 95% (5th percentile of modelled results), the reduction of population shall not exceed 20%. For the Dutch Continental Shelf, this corresponds with an annual population decrease of approx. 1250 harbour porpoise due to cumulative anthropogenic impact. The assessment is thus made at the scale of the North Sea population level and not at the level of a local Natura 2000 site because harbour porpoise are considered to be mobile species.

Due to the very local scale of impact and avoidance within a limited radius from ships and dredgers, also taking into account the type of sound and possibilities for porpoise in time temporary avoid the impacted area, for both projects the impact of dredging on harbour porpoise have been concluded to be insignificant. The number of impacted harbour porpoise is negligible in relation to the population size, natural population dynamics and international agreed objectives regarding acceptable annual population decreases of harbour porpoise.

4 EVALUATION OF THE FEHMARNBELT EIA IN RELATION TO CONTINUOUS NOISE DISTURBANCE FOR HARBOUR PORPOISE

This chapter provides an evaluation by the Expert Group of the following key documents comprising the marine mammal impact assessment:

1. The survey-method part of the EIA in the approval documents (Femern A/S & LBV-SH Niederlassung Lübeck 2013a), whose content is equally stated in the english baseline study (FEMM 2013a, ammended by Femern A/S & LBV Niederlassung 2016a) which comprises methods as well as results and an 2015 amendment of the baseline survey). With the primary purpose of commenting whether the baseline is considered sufficient to inform the assessment.
2. The assessment method and methods of impact prediction as well as the actual impact assessment (Femern A/S & LBV-SH Niederlassung Lübeck 2013b, 2013c ammended by 2016a), whose content is equally stated in the impact assessment document (FEMM 2013b) and the Plan Approval Document 22.05 and annexes 1 & 2 (Femern A/S & LBV-SH Niederlassung Lübeck 2016b, 2016c, 2016d), which detail the approach to underwater noise mitigation adopted. With the primary purpose of stating whether the impact assessment relating to continuous noise impacts upon harbour porpoise can be supported, taking into account the international approaches described and expert judgement of the authors of this report.

For each evaluated part of the approval documents both the main outcomes of the documents and a related evaluation of the information and assessments relating to continuous noise disturbance for harbour porpoise are given.

4.1 Baseline study documents

4.1.1 Overview of baseline studies

The FB baseline investigation on marine mammals (Femern A/S & LBV-SH Niederlassung Lübeck 2013a, FEMM 2013a) comprises baseline studies concerning harbour porpoise as well as harbour and grey seals. The investigation area stretched from a line between Kiel and Langeland in the west to a line between Gedser and Dahmeshöved in the east covering the Fehmarnbelt project area and its adjacent waters. The general occurrence of harbour porpoise according to preceding studies is stated to reach 0.5 animals/km^2, with varying seasonal distribution patterns. The animals in the Fehmarnbelt area are suggested to belong to a separate population from that in the Skagerrak. These groups are postulated to form different subpopulations that live segregated from those in the

inner Baltic Sea. Harbour porpoise were counted during monthly aerial transect bird and mammal surveys from November 2008 to November 2010 following international standards and approximately the 'StUK' methodology to calculate seasonal density patterns by distance sampling. The observation flights were supplemented by 34 monthly ship counts from the Puttgarden-Rødby ferry directly in the alignment area and were recently updated by aerial video and observer-based studies in 2015 (Femern A/S & LBV Niederlassung Lübeck 2016a). Seasonal distribution patterns with a clear preference for spring and lowest densities in winter were concluded based on the survey data. Moreover, 27 C-PODs were deployed between January 2009 and January 2011 updated by references to the SAMBAH research project in the Baltic sea (Femern A/S & LBV Niederlassung Lübeck 2016a). Study results revealed a constant presence of harbour porpoise in the area but with an increasing abundance from east to west and only a "weak" seasonal component. A further baseline study obtained telemetry data for 82 animals, analysis of which supported the subpopulation theory as well as a seasonal migration of the species between Skagerrak and Belt seas.

A pressure analysis to investigate the effects of underwater noise on harbour porpoise was part of the baseline survey and concluded harbour porpoise to be affected by human activities, but did not show specific effects at population level. The effects of existing tunnels and bridges was discussed but could not reveal any specific effects on the species due to high spatial and temporal variability in harbour porpoise abundance. Specifically, underwater noise and vibration from tunnels could not be distinguished from ship noise emissions beyond a 400 m distance from the tunnel, and only train (not vehicle) passages caused a locally limited increase in underwater sound pressure.

Next to man-made noise and vibration emissions from existing tunnels and bridges, the pressure analysis considered also underwater noise emitted by shipping, sonar, seismic surveys and explosions and found that harbour porpoise in the Fehmarnbelt area are specifically exposed to relatively high sound pressure levels related to the extensive ship traffic. Most of the energy emitted by surface vessels is in the low frequency range and therefore overlaps mainly with the less sensitive part of the hearing range of harbour porpoise. Therefore a hearing threshold shift caused by shipping noise is not expected. Masking of the biologically important frequency range of the species is also discussed initially and the study states that masking was to be ruled out since harbour porpoise echolocate with ultrasounds in the range of 130 kHz, i.e. above the ship

sound frequency range. Furthermore it is stated that low frequency parts of high frequency clicks were not biologically relevant. On a general level the study considered behavioural changes such as avoidance to be possible with potential effects on foraging, navigation and reproduction and with energetic costs caused by such behavioural changes.

Next to the general approach concerning underwater noise, a dedicated ambient noise related part of the pressure analysis is based on a project-related systematic monitoring and analysis of ambient noise (Cefas % BioConsult SH 2011) in the Fehmarnbelt area. It is aimed at documenting the acoustic environment for marine mammals in the Fehmarnbelt through a one year survey together with the 27 C-POD stations deployed by the project. Not surprisingly, the highest underwater noise levels were measured next to the main shipping lanes reaching constant average noise levels of between 103 and 132 dB re 1µPa without seasonal variations. Most of the ambient sound energy was found to be "well below" 1 kHz where harbour porpoise hearing is less sensitive since the hearing threshold of the species is indicated to stretch between 80 dB re 1µPa (rms) at 1 kHz and 115 dB re 1µPa (rms) at 250 Hz. The study found most of the ambient sound to be clearly audible to porpoise. The study discusses masking to be biologically relevant to low frequency calls and low frequency perception of harbour porpoise. Furthermore it is stated that elevated levels of existing ambient noise could lead to stress and thus affect marine mammal health. The study links to the results of the C-POD investigation showing that ambient noise is able to affect the acoustic activity of porpoise at levels above 113 dB re 1µPa, although avoidance of the areas of extensive ship traffic was not detected.

Construction work of offshore wind farms around the Fehmarnbelt area is also considered in the pressure analysis and is seen to cause negative behavioural effect in harbour porpoise whereas the contribution of operational noise to the overall ambient noise is seen to be negligible.

The baseline investigation conclude that whilst calves may be present, the Study Area does not represent an important breeding or nursery area for harbour porpoise.

4.1.2 Evaluation of baseline studies

A very substantial amount of data has been acquired to inform the baseline study which far exceeds the level typically acquired for projects of this nature from an international perspective

The validity of the data, given that baseline studies commenced in 2008, is understood to subject to separate expert review. Notwithstanding this investigation the acquired data are in our experience more than sufficient to serve as a solid foundation in the planning consideration process even taking into account the large scale of the project. The baseline study is of a high scientific quality, but like many studies in the field of ecology it bears the general risk for the applicant of raising more questions than actually answering due to the high spatio-temporal variability of the founding data and wide-reaching research questions from in-depth individual to population approaches up to common questions concerning seasonal variability in habitat use.

We agree with the conclusion in the baseline study that TTS/PTS is very unlikely to occur due to the foreseen dredging and shipping activities. It is argued that TTS/PTS will not occur because of the absence the low frequency character of dredging and shipping noise lies below the peak sensitivity of harbour porpoise. Although we agree with this argument, it is not the only or main reason that TTS/PTS cannot occur. PTS/TTS are primarily unlikely to occur since with continuous noise emitted during the construction phase, harbour porpoise have the opportunity to leave the local area in time, in contrast to a sudden, impulsive emission of pile driving noise. During dredging and further construction activities, harbour porpoise might actually suffer from TTS, but after an exposure duration of approximately 24 hours (as was calculated in Heinis et al. 2013). Since it is a highly mobile species which will not be stationary exposed for such a long period, TTS is very unlikely to occur.

The pressure analysis itself is informed by a systematic monitoring of ambient noise whose merits lie in the detailed sound mapping of the area and the existing high levels of anthropogenic impact. A concerted effort was made to investigate for avoidance of shipping areas by porpoise; that this was not concluded may be due to the inherently limited range of detection of C-PODs (around 300m).

4.2 Environmental Impact Assessment (EIA)

4.2.1 Overview of EIA

In the FB marine mammal impact assessment document of the EIA (Femern A/S & LBV-SH Niederlassung Lübeck 2013b, 2013c, ammended 2016a, FEMM 2013b) the German NMC threshold for underwater noise of 160 dB SEL at 750 m is adopted as an assessment criterion regarding the risk of injury for marine

mammal species. It is used in the FB documents to assess the effects of impulsive noise during short-term sheet piling at Lolland and Fehmarn, but also for the effects of continuous noise emitted by ships and dredgers although this threshold value originates from impulse noise of wind farm piling activities in the North Sea. Any exceedance of the threshold is ranked as a 'very high' degree of impairment. The NMC value of 140 dB SEL as a threshold for significant disturbance of harbour porpoise is not adopted in the EIA.

A threshold of 150 dB SEL is used to define a 'medium' degree of impairment and a threshold of 144 dB SEL is used to define a 'minor' degree. The 150 dB SEL threshold is based on the findings of Diederichs et al. (Diederichs et al. 2010a) on reactions of harbour porpoise to offshore pile driving during the construction of 'Alpha Ventus'. It indicates 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 (i.e. a 6 dB reduction) and defines the zone at which short-term reactions from harbour porpoise are expected.

Regarding impulsive noise emissions during the construction of working harbours (sheet piling) the EIA refers to both the 144 dB SEL and the 140 dB SEL NMC threshold in relation to disturbance of harbour porpoise, of which the latter would approx. double the impact radius.

For the assessment of strictly protected species the NMC noise criteria are used in the EIA regarding deliberate killing and injury (max. 160 dB SEL in 750 m) but not regarding deliberate disturbance (affected area within >140 dB SEL). In the latter case the 144 dB SEL value is used, based on findings from Brandt et al 2014 and more recently Brandt et al. (2016).

A recent check of the applicant concerning the correctness of data (Femern A/S & LBV Niederlassung Lübeck 2016a) did not result in any modification of impact prediction or assessment conclusions drawn.

4.2.2 Evaluation of EIA

Continuous noise from dredging, backfilling and drilling operations as well as from construction and operational traffic and impulse noise from piling are seen to be among the five main pressures resulting from the tunnel option evaluated in the EIA but are not clearly separated from each other. The impact assessment regarding marine mammals is based on the underlying baseline study concerning this species which was conducted between 2009 and 2011 (Femern A/S &

LBV-SH Niederlassung Lübeck 2013a, FEMM 2013a), which to our opinion is a more than sufficient time span. Noise levels of construction and operational activities were modelled based on recorded measurements of similar activities, and although the modelled output should be interpreted with caution and as indicative we see no reason to doubt the results of the modelling when treated as such. None of the modelled noise levels of construction and operational activities exceed the German underwater noise threshold of 160 dB re 1µPa²s SEL at 750 m. The modelled spatial extent of project related construction activities was overlaid with abundance maps resulting from the baseline surveys of harbour porpoise, which is in line with international practice and is considered as a useful approach.

Since publication of the impact assessment, Todd et al. (2015) have issued a review of impacts of dredging activities on marine mammals. In relation to underwater noise the authors conclude that noise is "emitted broadband, with most energy below 1 kHz and unlikely to cause damage to marine mammal auditory systems", whereas masking and behavioural changes is seen to be possible. This confirms the approach and focus on avoidance as the main potential impact on harbour porpoise due to dredging as followed in the EIA. According to the review of Todd et al. (2015) sound pressure levels can vary depending upon dredger type, operational stage or environmental conditions. TSHDs (as the dredging method with highest source levels) could emit a maximum broadband source SPL of 189.9 dB re 1 µPa at 1 metre (calculated based on 1/3 octave band levels from 31.6 Hz to 39.8 kHz), whereas in the EIA the source level of the TSHD was (in line with CEDA, 2011) modelled at 184 dB re 1 µPa. Therefore a slightly lower source level was used in the EIA, which might be explained by the fact that the relatively high estimated 1/3 octave band source levels above 1 kHz in Todd et al. (2015) were seen as a result of the coarse aggregate pumped through the dredge pipe in their study. Since the modelled source level is in line with CEDA (2011) and comparable to results of international measurement campaigns on dredging noise (Heinis et al. 2013) we see no reason to question the used source level and accompanying modelled sound propagation if results are interpreted with caution.

A recent Study of Dyndo et al. (2015) cautions that the possible effects of vessel noise on small toothed whales such as harbour porpoise have been largely ignored due to their less sensitive low-frequency hearing. The study concluded that low sound levels will routinely be experienced by porpoise in the wild at ranges of more than 1000 m from vessels at which received levels of 123 dB re

1 µPa were measured, suggesting that vessel noise is forming a substantial source of disturbance in shallow waters. However, in the Fehmarnbelt region, the measured ambient noise due to the presence of intense ship traffic is in the order of 135 dB, while no significant differences in harbour porpoise density near shipping lanes were found. This emphasizes the fact that threshold values cannot be uniformly used and followed, as actual avoidance of harbour porpoise also depend on ecological factors, such as motivation for predation and reproduction. According to the baseline data, despite the intense shipping traffic, harbour porpoise are present in the area. We strongly doubt that the contribution of the noise due to the foreseen activities to the area, given the circumstances with intense ship traffic and high ambient noise levels, would in any form significantly impact the suitability of the habitat for harbour porpoise. Additionally, we see a potential positive influence through reduced ambient noise levels of a possible decline in ferry activity after finishing of the tunnel.

Concerning operational noise the EIA concludes that the severity of impact would be negligible and any increase in noise levels resulting from tunnel operation would be offset by an assumed decline of ferry traffic due to the tunnel. The project-related effect of noise on the population level of harbour porpoise is seen to be insignificant because of a disturbed maximum of 0.30% of the local Fehmarnbelt study area population (based on higher summer densities) and less than 0.1% of the Baltic subpopulation (resulting in 2 to 6 affected individuals at a time by noise in winter and summer respectively). The same is predicted for habitat loss (temporary displacement) during construction (1-2 individuals forming 0.12% and 0.1% of either population) and operational phase (0.81 individuals forming 0.1% of the local Fehmarnbelt study area population).

We conclude that based on the EIA a very low absolute number of individuals and an equally low proportion of every population forming the calculative basis is likely to be influenced by the foreseen project activities. The expected effects of construction phase are short-term, limited in spatial extent and expected to be insignificant at a population level. The effects of the operational phase are expected to be long-term but limited in spatial extent and also insignificant at the population level. Our judgement is therefore in line with the conclusions drawn in the EIA. There is no doubt that given the low numbers of temporarily disturbed harbour porpoise, impacts would be concluded to be insignificant if similar activities were proposed to take place in the countries currently involved in this report (UK and NL). Even with an impact area much larger than currently

calculated based on the 144 dB threshold level, e.g. based on a threshold level of 140 dB, we conclude the impact at population level would be negligible.

The EIA report does not recommend any specific mitigation measures due to the planned small spatial extent of the construction and operation of the tunnel and the relatively low importance of these areas for marine mammals and does even not consider mitigation measures for project-related piling works at this stage. Cumulative impacts of concurrent activities in adjacent wind farms are excluded comprehensively because of the distance between the projects. Given the limited impact, we see no need for the implementation of worksite specific mitigation measures in relation to impacts caused by continuous sound on harbour porpoise.

4.3 Application Document 22.05 (Project noise protection and surveillance concept)

4.3.1 Overview of Application Document 22.05

The NMC (BMU 2013) is acknowledged within Application Document 22.05 to serve as an additional part of the regulatory package to avoid or reduce a potential damage to marine mammals by appropriate measures. Since the sheet piling activities in particular are not expected to exceed 160 dB SEL at 750 m distance to the source, deterrence measures and monitoring but no additional passive acoustic mitigation system are proposed.

The NMC specifically proposes a threshold of 140dB SEL for significant disturbance of harbour porpoise. The main reasons for not using the NMC threshold of 140 dB SEL are stated to be the mainly continuous nature of the project related noise, taking place in shallow Baltic waters while the NMC applies to impulsive noise emissions (pile driving) in the German Bight. For continuous noise emissions such as expected to be generated by the project no assessment convention is stated to exist.

4.3.2 Evaluation of Application Document 22.05

In the EIA, 150 dB/144 dB thresholds are used for the assessment of both impulsive low frequency noise (piling) and continuous low frequency noise (dredging, shipping).

While Brandt et al. (2011) are referred to as the source of the 144 dB threshold used in the EIA, the specific origin of this value remains unclear. The value itself is not explicitly mentioned in Brandt et al. (2011), it may have been derived

from the 150 dB SEL threshold mentioned by Diederichs et al. (2010a), and calculated as half the energy of it. Possibly the value could also be based on a calculation of sound propagation at Horns Rev II and the minimum distance where no negative effects were detected. Diederichs (2013) mentions a calculated SEL of 144-147 dB at 22 km, where no avoidance was recorded.

Meanwhile, newer sources like Pehlke et al. (2012) or Brandt et al. (2016) support a 144 dB SEL threshold level for avoidance. But, as for most other studies, these threshold levels are found for impulsive noise (pile driving).

Based on the findings described in Chapter 2, we conclude that a solid threshold level for avoidance of harbour porpoise due to continuous dredging and shipping noise is principally lacking. The arguments provided in Application Document 22-05 regarding a relevant threshold level for determining avoidance ranges to be considered during construction works are not unreasonable and partially substantiated by scientific evidence, though assumptions and interpretations are made for key knowledge gaps. The assumption that the threshold level for continuous noise is higher than or equal to the threshold for impulsive noise seems obvious due to the character of the sound but this is based only on human reasoning and not specifically supported by scientific evidence so far. There is no direct evidence based insight into the potential behavioural response differences to impulsive and continuous noise for harbour porpoise in the wild, where many factors such as motivation and habituation may play a role.

As a result of the lack of evidence based knowledge on key information gaps, we cannot recommend the use of any specific threshold value to assess the relevant avoidance range for continuous low frequency underwater noise. Given the low level impact expected, as described and concluded above, the choice of the threshold is to our perception not critical, since even with a low threshold level, impacts at the population level are to our judgement expected to be insignificant.

4.4 Evaluation of impact assessment on N2000 designation with respect to Fehmarnbelt

4.4.1 Overview of impact assessment on N2000 designation

The proposed Fixed Link crosses the N2000 area 'Fehmarnbelt' in the German EEZ. The conservation objectives of the area include the protection of the harbour porpoise (including protection of reproductive activities according to the designation). According to the Fixed Link N2000 Document (Femern A/S & LBV-SH Niederlassung Lübeck 2016e), the construction, structure and operation of the fixed link will not lead to a significant impairment of marine mammals in the N2000 area.

To assess possible effects of pile driving at the working ports Lolland and Fehmarn (installation of sheet piles) in the N2000 area both the threshold of 144 dB SEL for minor disturbances (range up to 1.9 km) and the NMC threshold of 140 dB SEL (range 3.2 km) are used in the document. Neither disturbance radius is predicted to reach the N2000 area.

To assess the disturbance effects of continuous noise emissions of ships and dredgers only the 144 dB SEL threshold is used. According to that, disturbance (displacement or avoidance) is to be expected within a range of 400 m around a current working section in the worst case. However, to assess the physical injury risk, the NMC threshold value of 160 dB SEL in 750 m is used. Accordingly, the risk of hearing impairment is limited to a radius of a few meters around dredgers and ships.

Based on the 144 dB SEL threshold level used in the assessment a maximum area of 1.5 km² within the N2000 area 'Fehmarnbelt' is exposed to disturbance at any one time. That equates to a proportion of less than 0.55% of the N2000 area, where on average less than one porpoise would be affected in the form of temporary avoidance.

At this point the noise criteria of the NMC for N2000 areas in the North Sea (see chapter 3.1.1) are mentioned in the N2000 assessment, but it is also emphasized that the criteria are not applicable due to the continuous nature of noise emissions. Furthermore, the area-based approach of the NMC is considered as unsuitable for estimating the effects of continuous noise, since effects can be very different within the affected area due to the decrease of noise level with distance.

The conservation of the harbour porpoise population is defined as an objective of the N2000 area 'Fehmarnbelt'. As the area is considered (by the N2000 designation) to be a reproduction area of the harbour porpoise, this function is also mentioned as a protection objective (Bundesamt für Naturschutz 2008). Thus the 1% criterion could potentially apply for the period May to August if the NMC were to be used to assess the disturbance effects in the N2000 area (see Section 3.1.1).

4.4.2 Evaluation of impact study on N2000 designation

According to the N2000 document Fehmarnbelt (Femern A/S & LBV-SH Niederlassung Lübeck 2016e), the area is considered to be an area for living, migration and reproduction. For the reason of reproduction, the 1% criteria on impact should be followed to be consistent with the protection of porpoise in German N2000 areas, if the area is indeed important for reproduction.

Harbour porpoise are however highly mobile species which are not bound to a specific location. Species migrate over hundreds of kilometres and specific reproduction areas are unknown. There are however areas with significantly higher densities of harbour porpoise and areas where mother-calf combinations are observed frequently. It is generally assumed that such areas are more important for reproduction, which to our opinion is a reasonable assumption.

The extensive baseline study has neither shown a high population density nor a frequent observation of mother-calf combinations. In the environmental impact assessment it is concluded that no specific nursery areas are found in the project area, which is supported by the medium density of harbour porpoise in the area. Also, the densities found are comparable to medium densities found in the North Sea area, which suggests no specific function of the area for reproduction or nursery. Although mentioned as an objective in the Natura2000 document, we see no evidence that the area is of specific importance for harbour porpoise reproduction and therefore consider the 1% criteria for the assessment of impact over-precautious. Following the 10% criteria for Natura2000 area is considered to be more appropriate given the medium densities of harbour porpoise and lack of nursery areas found.

Additionally, it should be recognised that local avoidance of an area does not by definition impact activities such as foraging or reproduction of harbour porpoise. It is very unlikely that the current population is at its carrying capacity given the available circumstance and the impact of pressures such as by-catch on the harbour population. This means that avoiding an area will not lead to an

increased pressure at another location, e.g. as a result of competition for food. As such, the impact will only consist of the energy that it takes for an individual to avoid an area. Avoiding an area over a distance of approximate a kilometre equals a swimming time of approximate 15 minutes at a conservative cruising speed of 4 km/h. Given the fact that harbour porpoise are continuously swimming and have no specific resting sites in the study area, avoidance of relatively small areas inside the Natura 2000 site can hardly be seen as an impact. Given the very limited scale and sufficient remaining habitat to fulfil the ecological needs of harbour porpoise in the area, impacts on reproduction of the harbour porpoise which are not bound to this specific location are to our judgement insignificant.

5 CONCLUSION AND RESPONSE TO KEY QUESTIONS

In this chapter, the key questions of the review as presented in Chapter 1 will be answered based on the findings of the used threshold level (Chapter 2), international perspective (Chapter 3) and evaluation of the EIA documents (Chapter 4).

5.1 Sensitivity criteria

***Question:* What is the scientific evidence concerning the sensitivity of harbour porpoise (the relevant disturbance range) to temporary non-pulse underwater noise?**

Chapter 2 describes the lack of a solid threshold level for avoidance of harbour porpoise due to continuous underwater noise generated by dredging and shipping activities. The threshold level of 144 dB currently used in the EIA originates from research on impulsive noise sources (pile driving) which cannot be applied directly for continuous noise.

The assumption that the threshold level for continuous sounds is higher than or equals the threshold for impulsive noise purely due to the character of the sound and perception of this by harbour porpoise seems obvious and indirectly supported by general observations of deterrence from impulsive and non-impulsive noise sources, but is based on human reasoning only and not sufficiently supported by scientific evidence.

As a result of the lack of evidence based knowledge on this matter, we cannot expressly recommend the use of any specific threshold value to determine the relevant disturbance range for continuous low frequency under water noise. Given the very minor impact expected, the choice of the threshold in the FB case is to our perception not critical, since even with a relatively low threshold value, the impacts at the population level are to our judgement likely to be insignificant.

5.2 General approach

***Question:* What is the international approach and experience in assessing harbour porpoise and population related impacts from *temporary non-pulse* noise in the marine environment?**

Guidelines to assess impact on harbour porpoise due to continuous noise of dredging and shipping activities are lacking in the countries considered. According to the best practices described, the potential occurrence of TTS/PTS and the avoidance area around activities is calculated. In line with what is concluded in

the Femern EIA, the occurrence of TTS/PTS is very unlikely since harbour porpoise are mobile species and will not be exposed for the duration after which TTS would occur. According to best practice, avoidance of an area is calculated and put into perspective of the large scale habitat of the harbour porpoise. Due to the limited impact area and the fact that the species is highly mobile, impacts due to dredging activities are concluded to have insignificant impact on both individuals and on the population of harbour porpoise.

***Question:* Is the FBFL-approach relevant and well substantiated?**

To the opinion of the experts involved in this study, overall the FBFL-approach is very well substantiated and relevant. Although not all assumptions could be substantiated with direct scientific evidence, as is often the case in ecological studies, it is well supported with up-to-date and best available scientific knowledge where possible. According to international practice, the approach followed exceeds by far the typical standards for an EIA on this kind of activities. All relevant aspects have been studied and well documented and the (baseline) data gathered is complete and well used. The precautionary principle is largely followed throughout the assessment which to our judgement results in a very precautious worst-case assessment.

5.3 Natura 2000 protection

***Question:* What is international approach for assessing and excluding significant/harmful impacts from temporary non-pulse under water noise on designated harbour porpoise (individual and population level) in Natura 2000 areas and on harbour porpoise as an Annex 4 species?**

Due to the limited impact area in relation to the entire habitat of the harbour porpoise and given the fact that the species is highly mobile and easily capable of timely and temporary avoiding an area, the impact at the population level in comparable projects in other countries are concluded to be insignificant. On an individual level animals might be temporary and locally impacted, however there is sufficient habitat remaining that this would not be expected to represent a significant adverse impact.

***Question:* Which criteria are in use, e.g. affected/displaced number of animals, affected/displaced part of a population, affected part of a habitat or a Natura 2000 area?**

The international approach is to assess the impact for N2000 on the population level of harbour porpoise. Since harbour porpoise are highly mobile species

with a large habitat, they are not bound to drawn borders of a N2000 area. Internationally, the importance of an area is taken into account in the assessment, which is usually based on the densities found in a specific area. Since N2000 areas usually form only a fraction of the habitat of harbour porpoise, the mere calculation of avoidance area in relation to the area of the N2000 area near or in which the activities take place is regarded critically. However, the regulatory documents follows the current German consenting approach of calculating an area percentage influenced by the applied activity. But to our expert judgement this is an unnecessary and very precautionary approach.

There are generally and specifically in the Fehmarnbelt case only a few if any differences in suitable habitat for harbour porpoise within and outside the borders of a N2000 area, with the exception of areas where very high density of harbour porpoise are present. Impact is therefore commonly assessed on the larger scale.

If the impact assessment criteria were guided by the ASCOBAN approach this would put a different perspective on the assessment. The ASCOBANS interim objective is to maintain the harbour porpoise population at 80% of its carrying capacity. Additionally, ASCOBANS set a limit for maximum annual anthropogenic induced mortality (including fisheries bycatch) for harbour porpoise which should not exceed 1.7% of the population size. To illustrate, this implies an annual allowed population decrease of approximately 1,250 individuals on the Dutch Continental Shelf alone, although this represent the number due to all cumulative pressure and projects.

The very limited avoidance of only a small number of harbour porpoise in a very limited area which is not even expected to lead directly to a decline of the population would inevitably to the judgement of the experts be concluded insignificant. This is strengthened by the findings that the densities of harbour porpoise in the area are medium, indicating no specific reproduction or nursing areas that will potentially be impacted.

Question: **Is the noise protection and surveillance concept (application document 22.05) regarded as relevant and sufficient to exclude significant/harmful impacts on harbour porpoise as part of the Natura 2000 designation in the German EEZ (Natura 2000 site "Fehmarnbelt")?**

The document is generally well substantiated and in line with the judgement of the experts involved. Although the use of any specific fixed threshold level for

disturbance of harbour porpoise by continuous noise could not be directly supported, there is no doubt that the assessment made is very precautionary and the procedures described in the protection and surveillance concepts are in our opinion sufficient.

The experts fully agree with the concluded insignificance of impact on harbour porpoise due to continuous noise caused by dredging and shipping in the foreseen activities.

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