MARINE MAMMALS IN THE SWEDISH AND DANISH BALTIC SEA IN RELATION TO THE NORD STREAM 2 PROJECT

Expert Assessment

Report commissioned by Rambøll

Scientific Report from DCE – Danish Centre for Environment and Energy No. 237 2017

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Signe Sveegaard
Jonas Teilmann
Jakob Tougaard

Aarhus University, Department of Bioscience

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Data sheet

Series title and no.: Scientific Report from DCE – Danish Centre for Environment and Energy No. 237

Title: Marine mammals in the Swedish and Danish Baltic Sea in relation to the Nord Stream 2 project
Subtitle: Expert Assessment

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Authors: Signe Sveegaard, Jonas Teilmann & Jakob Tougaard
Institution: Aarhus University, Department of Bioscience

Publisher: Aarhus University, DCE – Danish Centre for Environment and Energy ©
URL: http://dce.au.dk/en

Year of publication: September 2017
Editing completed: September 2016

Referee: Line Kyhn
Quality assurance, DCE: Jesper Fredshavn

Financial support: Rambøll

Please cite as: Sveegaard, S., Teilmann, J. & Tougaard, J. 2017. Marine mammals in the Swedish and Danish Baltic Sea in relation to the Nord Stream 2 project. Expert Assessment. Aarhus University, DCE – Danish Centre for Environment and Energy, 68 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 237
http://dce2.au.dk/pub/SR237.pdf

Abstract: Nord Stream 2 AG (NSP2) is planning the construction of a second gas pipeline in the Baltic running from Russia to Germany. In this report, the potential impacts on marine mammals of the gas pipeline in Danish and Swedish waters, are assessed. The relevant marine mammal species are harbour porpoise and grey seal in Danish waters and harbour porpoise, grey seal, harbour seal and ringed seal in Swedish waters. The assessment is based on information and studies conducted during the Environmental Impact Assessments for marine mammals for Nord Stream, the NSP2 baseline report for marine mammals, models on sedimentation and underwater noise in Danish and Swedish waters as well as relevant literature. No new fieldwork was conducted. In the report, the pressures related to the periods of construction, precommissioning, commissioning and operation of the gas pipeline are described and assessed in relation to the sensitivity of marine mammals. The main impacts from planned activities are underwater noise, sediment spill and changes to the habitat. Impacts from unplanned activities are munition clearance, oil spill, gas leaks, and noise and disturbance from ice breaking support vessels. All impacts, except munition clearance, are assessed to have a negligible to minor impact. In case munition clearance is required, the noise from the explosions could have major impact, depending on the area and species.

Keywords: Nord Stream 2, gas pipeline, marine mammals, harbour porpoise, harbour seal, ringed seal, grey seal, underwater noise, construction, operation, rock placement, sediment spill

Layout: Graphic Group, AU Silkeborg
Front page photo: Photo: Signe Sveegaard

ISBN: 978-87-7156-280-4
ISSN (electronic): 2245-0203

Number of pages: 68

Internet version: The report is available in electronic format (pdf) at
http://dce2.au.dk/pub/SR237.pdf

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1 Introduction

1.1 Purpose and structure of this report

The purpose of this report is to assess the potential impacts on marine mammals in Danish and Swedish waters in relation to the proposed gaspipeline Nord Stream 2 (Nord Stream 2 Pipeline system – NSP2). The relevant marine mammal species are harbour porpoise (*Phocoena phocoena*) and grey seal (*Halichoerus grypus grypus*) in Danish waters and harbour porpoise, grey seal, harbour seal (*Phoca vitulina*) and ringed seal (*Pusa hispida botnica*) in Swedish waters.

This report is based on the following:

- The information and studies conducted during the Environmental Impact Assessments for marine mammals from Nord Stream (NSP)
- The information described in the NSP2 baseline report for marine mammals (Teilmann et al. 2017)
- The models on sedimentation and underwater noise in Danish and Swedish waters performed by Rambøll
- Relevant literature. No new fieldwork was conducted.

The report describes the pressures related to the periods of construction, pre-commissioning, commisioning and operation of the gas-pipeline (chapter 2, 3, 4 and 5). This is followed by a review of the sensitivity of marine mammals with regard to the potential impacts including criteria for noise levels (Chapter 6). Chapter 7 briefly summarises the impact magnitude due to underwater noise and sediment spill as modelled by Rambøll. Chapter 8 and 9 provide the impact on the relevant marine mammals before, during and after the construction of the pipeline (including the Pre-Commissioning, the Commisioning period and the operation period). Chapter 10 provides an assessment of impact in Natura 2000 areas. Chapter 11 holds summary tables for each species in which the information and assessment presented in this report are displayed.

Rambøll has informed that NSP2 do not foresee that it will be needed to conduct munitions clearance in Swedish and Danish waters. Impacts related to munition clearance is therefore only assessed as a potential unplanned event in this report. Should the project plans change, munition clearance should be dealt with in a separate assessment since potential impacts from underwater explosions can be severe for both harbour porpoises and seals, although the effect is heavily dependent on a range of factors such as exact location and time of year.

Assessment of impact during decommissioning are not included here, since this depends upon practice / methodology available at the time decommissioning becomes relevant (approx. 50 years from construction).

This report includes two additional memos, produced after the original expert assessment was concluded to clarify and extrapolate on the subjects of TTS and PTS (Appendix 1) and Munition clearance in relation to the Nord Stream 2 project near Gotska Sandön (Appendix 2).

2 Introduction to impacts

The central question in the context of the NSP2 project and marine mammals is whether the construction and operation of the pipeline will have a net impact (positive or negative) on the local abundance of a species in the area and ultimately an impact on the population size, and in the end whether this impact is acceptable or not from a conservation point of view.

Assessing the impact at the population level is often difficult unless all factors related to the population structure and abundance of the animals, as well as all other factors affecting their survival in relation to direct and indirect impacts are known. In this report, information on the animals using the impacted areas and the status of the populations are relatively well known. Nevertheless, the assessment of the impacts from the construction and operation of the pipeline is based on assumptions about links from immediate impact to population level consequences and hence associated with uncertainty.

The main pressures on marine mammals during construction of the gas pipeline are assumed to be underwater noise from construction activities, sediment spill from seabed intervention activities and potential oil spill.

Underwater noise is a potentially significant disturbing factor. The pipe laying itself will consist of various noisy activities, such as operation of cranes and winches, anchor handling, trenching and placement of rocks or other material on top of or next to the pipeline. The ship engines and propellers will also be a source of noise. Munition clearance (detonation of munition dumped on the sea bed) has by far the largest impact on marine mammals including potential casualties and permanent hearing damage, but Nord Stream 2 plan to avoid any munition clearance in Danish and Swedish waters.

Sediment spill will occur primarily during trenching, but also from the pipe laying, anchor handling and rock placement activities (and if performed: munition clearance). The consequences of sediment spill on marine mammals relate to the increased turbidity of the water, possible release of toxic contaminants to the water column and a possible decrease in prey availability through secondary effects of the resuspended sediment on fish. Secondary effects on prey availability are not assessed in this report.

The main potential impacts during the pre-commissioning and commissioning phases are disturbances from ship traffic and other activities such as flooding, cleaning and gauging of the pipelines, system pressure tests, dewatering and drying of the pipelines and filling the pipelines with natural gas.

The main pressures on marine mammals during operation of the pipeline are noise from the pipeline itself (due to flowing gas) as well as from service vessels. In addition there will inevitably be a change to the benthic habitat, due to the introduction of hard substrates (pipeline and scour protection) to the otherwise (in many places) soft bottom habitat.

In the following chapters each potential impact will be described.The impact methodology and terminology follows that of the national environmental studies.

3 Potential impacts during construction

3.1 Underwater noise

Many of the activities related to construction of the pipeline will generate underwater noise. The most significant ones are described below.

3.1.1 Rock placement and Trenching

Rock placement means that the pipeline remains on top of the seabed but is covered with (or supported by) a layer of rock. Installation of subsea rock will take place by using a rock placement vessel with a fall pipe.

Noise measurement data indicate that the dominating underwater noise from rock placement activity is from the surface activities (ship motors, thrusters, conveyors, rock pouring) rather than the noise from the actual placement of the rock on the seabed.

Source noise levels for vessels depend on the vessel size and speed as well as propeller design and other factors. There can be considerable variation in noise magnitude and character between vessels even within the same class. An example of frequency spectrum from rock placement is shown in fig. 3.1.1.

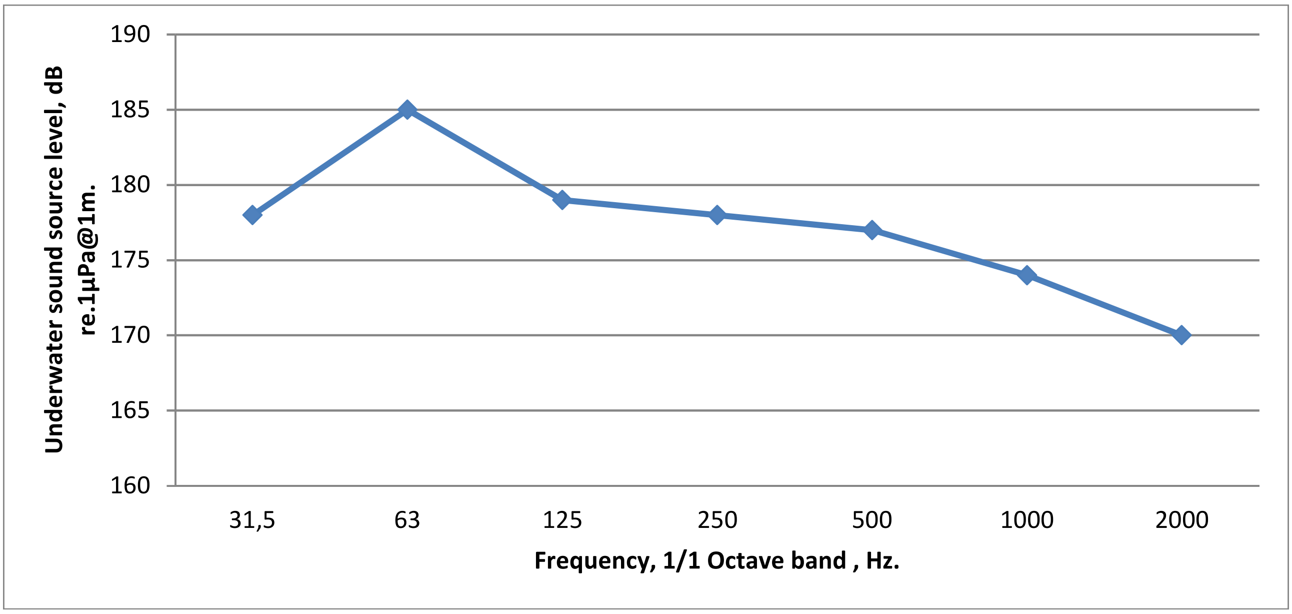


Figure 3.1.1. Example of frequency spectrum from rock placement. Source levels expressed as octave band levels backcalculated to a distance of 1 m from the work site (from Rambøll 2016d).

Modelling results of propagation of underwater noise from rock placement during construction of NSP2 are presented in section 8.

3.1.2 Pipe-laying /anchor handling

The noise emitted from pipe-laying and anchor handling is expected to be lower than that from rock placement and therefore noise from rock placement is used as worst case proxy for impacts on marine mammals from pipelaying and anchor handling activities.

3.1.3 Ship noise

Ship noise originates though several mechanisms. Large amounts of low frequency noise can be generated by the engine and propeller shaft, transmitted through the hull into the water. At higher frequencies the dominating source is cavitation around propellers, which can be very loud in case of high speed propellers on smaller vessels and damaged propeller blades. Additional sources of noise can be ancillary machinery, such as generators, hydraulic pumps, winches and ventilation systems.

In general there is a monotonic relationship between ship speed and noise level: higher noise levels are generated at higher speed. This does not always hold, however. For ships with variable pitch propellers, where the speed of the ship is adjusted not only by the speed of the engine but also with the pitch of the propellers, it is possible to have a maximum in noise emission at intermediate speeds, caused by heavy cavitation due to a (deliberately) inefficient setting of the pitch. Also ships equipped with dynamic positioning systems can be very noisy at slow speed or while maintaining constant position, due to the rapidly changing speed of the powerful ducted propellers.

3.2 Sediment spill

Seabed disturbance through pipe-laying, anchor handling, trenching and rock placement can result in increased turbidity and the creation of sediment plumes. Sediment plumes have the ability to extend the impact of seabed disturbance over larger areas that would otherwise remain unaffected physically. Research has shown that effects are generally short lived, lasting a maximum of two to three days and are confined mainly to an area of a few hundred metres from the point of discharge (Hitchcock and Bell, 2004, Rambøll 2016a-b). Modelling results of sediment spill during NSP2 are presented in section 8.

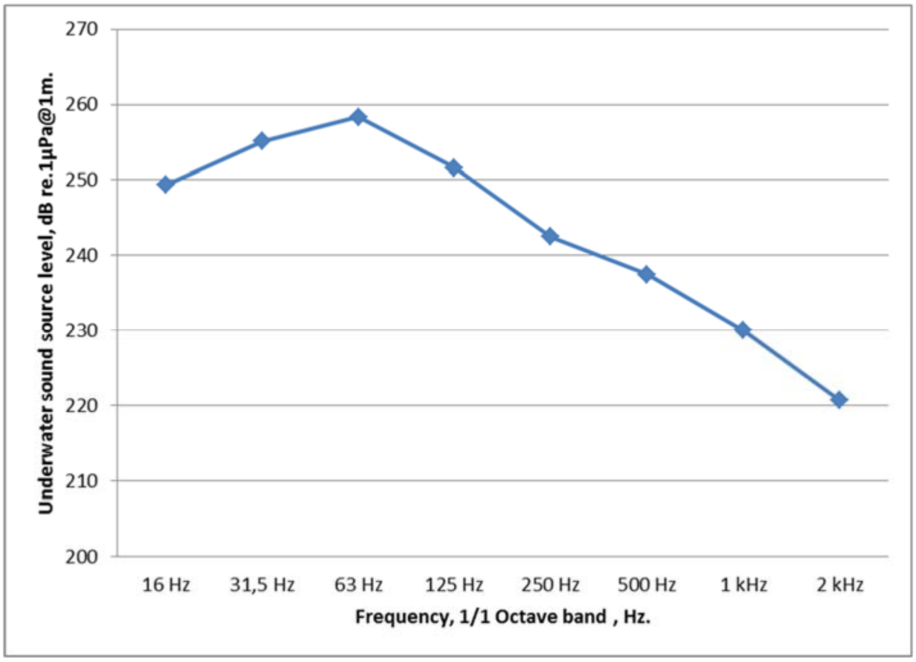
The main impacts on marine mammals from sediment spill are visual impairment, behavioural impacts such as avoidance of sediment plumes and health deterioration caused by mobilization of contaminants from the sediment in to the food chain. Marine mammals are not affected directly by the suspended sediment, in contrast to fish, where suspended sediment can clog the gills with suffocation as a consequence.

3.3 Unplanned events – Munition clearance

Underwater explosions, such as munition clearance, generate very large sound pressures with an extremely steep onset (shock wave). The peak pressure relates primarily to type and amount of explosives (higher peak pressure with higher detonation speed), but also water depth of the detonation is of importance (the deeper the water depth where the explosion is, the higher peak pressures generated) and the condition of the munition. The frequency spectrum of noise pulses from explosions is dominated by energy at low frequencies, also with a dependence on charge size. See e.g. Urick (1983) for methods to estimate peak pressure and power density spectrum from charge type and depth. An example spectrum from measurements on an actual explosion is shown in figure 3.1.1. The peak energy is at very low frequencies, around the 63 Hz octave band and drops steeply with about 10 dB/octave at higher frequencies. The spectrum is also affected by charge weight and water depth (Urick 1983).

Under favourable conditions the noise from an explosion can be transmitted over distances of hundreds of kilometres. Actual transmission range depends, as with other types of sound, on the bathymetry, hydrography and sediment types at and around the detonation site. Transmission of noise from explosives is greatly reduced in shallow waters (tens of meters or shallower) due to the poor propagation of low frequencies in shallow water (Urick 1983).

Figure 3.3.1. Example of frequency spectrum of the pulse generated by an underwater explosion. Source levels expressed as octave band levels backcalculated to a distance of 1 m from the explosion (actual measurement; from Rambøll 2016d).



3.4 Unplanned events - Oil spill

The event of an oil-spill caused by a collision or accident during construction work may impact marine mammals as would any other oil discharge at sea. The impact depends on the size of the oil spill, type of oil, weather conditions, etc.

The chemical constituents of spilled oil are poisonous and exposure to oil through ingestion or inhalation or from external exposure through skin and eye irritation, may thus harm marine mammals. Oil can also smother the fur of seals and thereby reduce their ability to maintain body temperatures.

4 Potential impacts during pre-commissioning and commissioning

4.1 Pre-commissioning

After installation of the pipelines, pre-commissioning (and possibly tie-ins) will be performed before the pipeline system can enter into operation. The pre-commissioning activities can include: flooding, cleaning and gauging of the pipelines, a system pressure test, and dewatering and drying of the pipelines.

None of the activities during the pre-commisioning phase are assessed to have a significant impact on marine mammals and are thus not further discussed although they are included in the summary tables in Chapter 11.

4.2 Commissioning

Commissioning comprises all activities that take place after the pre-commissioning and until the pipelines are ready for gas filling and transport. After pre-commissioning the pipelines will be filled with dry air. To avoid an inflammable mixture of atmospheric air and natural gas, the pipelines will be partially filled with nitrogen gas (inert gas) immediately prior to natural gas-filling. The nitrogen gas will create a separation zone moving through the pipeline and as such act as a buffer between the atmospheric air and the natural gas, to ensure no interaction between gas and air during the gas-in phase (from Nord Stream 2009).

None of the activities during the commisioning phase are assessed to have a significant impact on marine mammals and are thus not further discussed although they are included in the summary tables in Chapter 11.

5 Potential impacts during operation

5.1 Underwater noise

5.1.1 Noise from pipeline

Gas that flows through the pipeline will generate low levels of noise at low frequencies. The radiated noise power from the Nord Stream pipeline was estimated by modelling sound pressure at four different ranges from the compressor as part of the EIA for the project (NSP, Nord Stream 2009) and is shown in figure 4.1 for four different segments of the pipeline. The radiated noise power can be converted to sound pressure levels knowing that the energy flux density I through an area of 1 m^2 is given as:

$$I = \frac{p^2}{\rho c} \qquad \text{Eq. 1}$$

Where p is the pressure and ρc is the acoustic impedance. Rearranging and adjusting for the surface area of a 1 m long cylinder with radius 1 m around the gas pipe gives the sound pressure level L_{eq}:

$$L_{eq} = 10\log_{10}(p^2) = L_w + 10\log_{10}\left(\frac{\rho c}{2\pi}\right) \qquad \text{Eq. 2}$$

Assuming $\rho c = 1.5\times106$ $kgm^{-2}s^{-1}$ this gives a correction factor of 54 dB to be added to the radiated power to obtain sound pressure level.

Close to the compressor, which is located in Russia, the noise level is highest, and exceeds the ambient noise level at low winds (approx. 60 dB re. 1 µPa per one-third octave band, Nord Stream 2009) with about 50 dB, whereas it is at or below ambient for the other three positions (figure 5.1.1).

5.2 Changes in the habitat

The introduction of hard bottom substrates, in form of the gas pipeline on the bottom represent a change in the habitat and may indirectly have an effect in the longer run as it may be colonised by algae and filter feeding epifauna and thereby create an artificial reef (Petersen & Malm, 2006). The establishment of epibenthic communities on the hard substrates will increase the food available to fish. This means that the species composition around the pipeline may be altered and the number of individuals increased. Depending on the species, this may lead to an increase in the food available to marine mammals. For instance, Mikkelsen et al. (2013) examined the effect of construction of an artificial stony reef on the presence of harbour porpoises. They found that echolocation activity increased significantly after the reconstruction, likely as a result of increased prey availability. Such reef structures are likely to attract fish, although whether these fish species are important prey for porpoises or seals and thus constitute an improvement of the quality of the area to marine mammals, is difficult to conclude and will need to be examined.

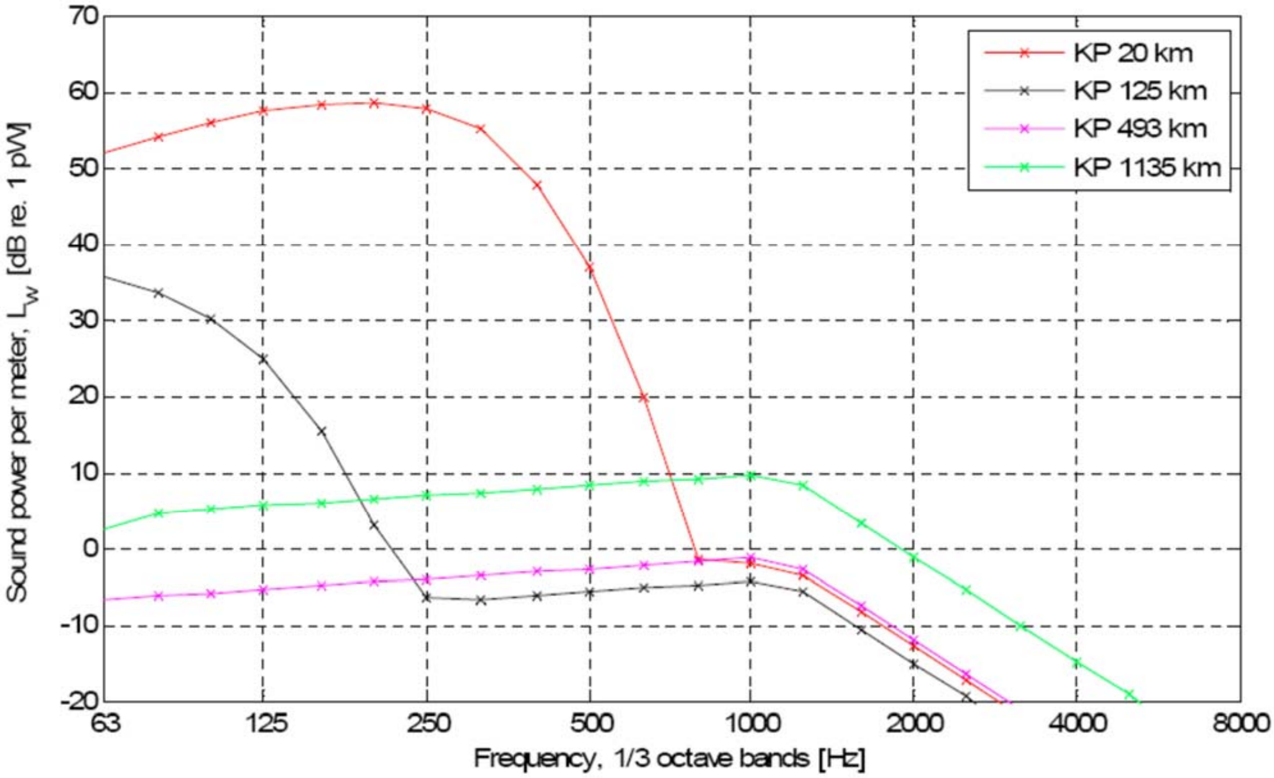


Figure 5.1.1. Modelled radiated noise power from an underwater pipeline at four different Kilometer Points (KP 20 km, KP 125 km, KP 493 km and KP 1135 km) from the compressor station in Russia. Noise is given as radiated power referenced to 1pW per meter pipe line and is thus not a sound pressure level. Add 54 dB (10 log(ρc/2π)) to get sound pressure level (dB re. 1 μPa) per third octave band (see text for further explanation). From Nord Stream (2009).

5.3 Unplanned events

5.3.1 Potential gas release

During operation of the pipeline, there are a number of low risks which may result in pipeline failure and lead to subsea gas release such as corrosion, natural hazards, and external interference related to ship traffic such as dragged and dropped anchors.

In the event of gas release, marine mammals within the gas plume or the subsequent gas cloud may die if positioned directly in the plume or flee from the influenced area and thereby causing a behavioural effect (Nord Stream 2008).

6 Sensitivities of marine mammals

Noise, sediment spill, turbidity, ship traffic and changes in the habitat may have either a negative or a positive impact on the behaviour of marine mammals by either detering or attracting the animals from the site of impact or by disturbing the normal behaviour e.g. foraging or socializing. For instance, during visual boat surveys harbour porpoises have been shown to either dive down or swim away when the boat is less than 50 m away (SCANS-II). It is also likely that marine mammals will move away from the area when hearing an unfamiliar or loud noise or experiencing visual impairment or increased turbidity caused by sediment spill. In addition, there are more specific effects of noise and sediment spill. These impacts are assessed for noise and sediment spill in the following.

6.1 Underwater noise

Underwater noise is well known as a source of impact on the marine ecosystem, including marine mammals (e.g. National Research Council 2005, Tyack 2009). This impact can occur through a number of processes and usually three main issues are considered:

- Physical injury (incl. blast injury) and hearing loss (incl. PTS / TTS)
- Disturbance of animal behaviour
- Masking of other sounds.

In addition to the above three issues, are more general physiological reactions to noise such as elevated stress hormone concentrations in the blood following exposure to loud noise (Romano et al. 2004) and possibly also long term exposure. However due to the limited number of experimental studies physiological impacts are most often excluded from impact assessments. A fourth type of impact is also often considered: the zone of audibility (Richardson et al. 1995). However, as audibility in itself does not imply an impact, this zone is really not an impact zone, although it can be used in absence of other information as a worst case estimate of the extent of other acoustic impact.

6.1.1 Blast injury

At close range, the shock wave from an explosion can cause tissue damage. Tissue damage arises because of differential acceleration of tissue with different density and can thus literally tear tissue apart, leading to anything from insignificant small bleedings to death. The relevant metric used to judge the risk of tissue damage is *acoustic impulse*, measured in Pa·s and is effectively the time integral of the positive pressure pulse of the shock wave. Exposure limits have been determined by Yelverton et al. (1973) through a series of experiments with live sheep and dogs submerged in a lake. As the most significant factor for scaling impact from one animal to another appears to be the lung volume, the thresholds are considered to be transferable to small marine mammals, such as seals and porpoises. Yelverton et al. (1973) derived four limits, listed in table 6.1.1.

The sensitivity of marine mammals to blast injury is **high** because of the risk of fatal injuries.

Table 6.1.1. Blast injury thresholds for mammals. From Yelverton et al. (1973). As harbour porpoises have no functional ear drum, this measure is irrelevant for them.

Acoustic impulse	Description
280 Pa·s	No mortalities, but frequent incidence of moderately severe blast injuries, including ear drum rupture. Animals considered capable of recovering on their own.
140 Pa·s	High incidence of slight blast injuries, including ear drum rupture.
70 Pa·s	Low incidence of trivial blast injuries. No ear drum rupture.
35 Pa·s	Safe level

6.1.2 Hearing threshold shift (TTS/PTS)

For marine mammals it is generally accepted that the auditory system is the most sensitive organ to acoustic injury, meaning that injury to the auditory system will occur at lower levels than injuries to other tissues (see e.g. Southall et al. 2007). Furthermore, noise induced threshold shifts are likewise accepted as precautionary proxies for more widespread injuries to the auditory system. Noise induced threshold shifts are temporary reductions in hearing sensitivity following exposure to loud noise (commonly experienced by humans as reduced hearing following rock concerts etc.). This temporary threshold shift (TTS) disappears with time, depending on the severity of the impact. Small amounts of TTS will disappear in a matter of minutes, extending to hours or even days for very large TTS. A schematic illustration of the time course of TTS is shown in figure 6.1.2.1. The amount of TTS immediately after end of the noise exposure is referred to as initial TTS. It expresses the amount by which the hearing threshold is elevated and is measured in dB. The larger the initial TTS, the longer the recovery period.

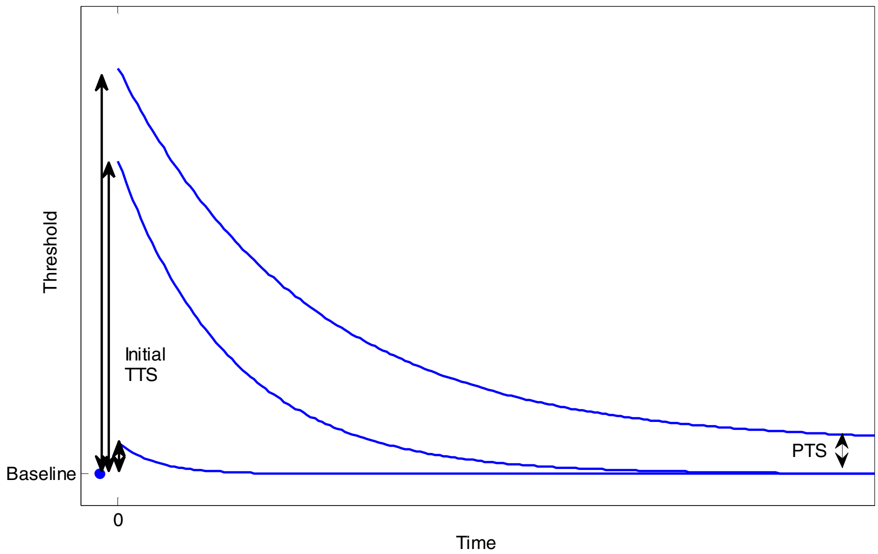


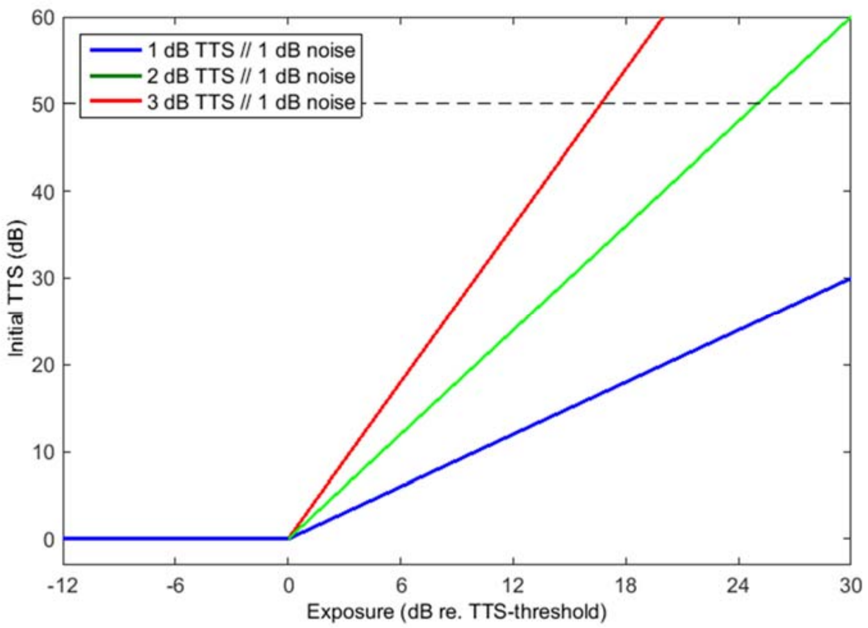
Figure 6.1.2.1. Schematic illustration of the time course in recovery of TTS. Zero on the time axis is the end of the noise that caused the TTS (often referred to as the fatiguing noise). Gradually the threshold returns to baseline level, except for very large amounts of initial TTS where a smaller permanent shift (PTS) may persist. From Skjellerup et al. (2015).

At higher levels of noise exposure the hearing threshold does not recover fully, but leaves a smaller or larger amount of permanent threshold shift (PTS), see figure 6.1.2.1. This permanent threshold shift is a result of damage to the sensory cells in the inner ear (Kujawa and Liberman 2009). An initial TTS of 50 dB or higher is generally considered to constitute a significantly increased risk of generating a PTS (Ketten 2012). Lower levels of TTS can, if repeatedly induced, also lead to PTS (Kujawa and Liberman 2009), which is also well known in humans.

In order to evaluate the output of the exposure model in terms of impact on animals, it is required to have thresholds for TTS and PTS to compare against. Deriving such has been the subject of a large effort from many sides (see reviews by Southall et al. 2007, Finneran 2015). No current consensus on general thresholds for TTS and PTS can be said to exist. Matters are simplified somewhat, however, if one restricts to only one type of sounds, such as airgun noise or pile driving noise and limits the discussion to only species for which sufficient data is available. A comparatively large effort has gone into investigating TTS caused by low frequency noise, including from pile driving, in harbour seals and harbour porpoises, as these species are key species in many impact assessments. TTS is in general localised to frequencies around and immediately above the frequency range of the noise, which caused the TTS. This means that TTS induced by low frequency noise typically only affects the hearing at low frequencies (Kastelein et al. 2013b).

As PTS thresholds for ethical reasons cannot be measured deliberatly in experiments, the agreed approach to estimate thresholds for PTS is by extrapolation from TTS thresholds to the noise exposure predicted to induce 50 dB of TTS and thus a significant risk of PTS. This extrapolation is not trivial, however, as it is complicated by the fact that the relationship between exposure and amount of initial TTS is not proportional (see e.g. review by Finneran 2015). Thus, one dB of added noise above the threshold for inducing TTS can induce more than one dB of additional TTS, see figure 6.1.2.2 The slope of the TTS growth-curve differs from experiment to experiment and slopes as high as 4 dB of TTS per dB of additional noise has been observed in a harbour porpoise (Lucke et al. 2009).

Figure 6.1.2.2. Schematic illustration of the growth of initial TTS with increasing noise exposure. Three different slopes are indicated. Note that the real curves are not necessarily linear. Broken line indicate threshold for inducing PTS, assumed to be at 50 dB initial TTS. From Skjellerup et al. (2015).



Two aspects of TTS and PTS are of central importance. The first aspect is the frequency spectrum of the noise causing TTS / PTS, which leads to the question of how to account for differences in spectra of different types of noise through frequency weighting. The second aspect is the cumulative nature of TTS / PTS. It is well known that the duration of exposures and the duty cycle (proportion of time during an exposure where the sound is on during intermittent exposures, such as pile driving) has a large influence on the amount of TTS / PTS induced, but no simple model is available that can predict this relationship.

Importance of frequency

Substantial uncertainty is connected to the question of how the fact that animals do not hear equally well at all frequencies should be handled when assessing risk for inflicting TTS and PTS. Southall et al. (2007) proposed that frequencies should be weighted with a fairly broad weighting function (M-weighting) which only removes energy at very low and very high frequencies, well outside the range of best hearing for the animals. Separate weighting functions were developed for different groups of marine mammals. Others have proposed a more restrictive weighting with a weighting filter function resembling the inversed audiogram (e.g. Terhune 2013, Tougaard et al. 2015) or other intermediate weightings, with increased emphasis on higher frequencies over lower, less audible frequencies (Finneran and Schlundt 2013). As long as this remains unsettled it is unclear how frequency weighting should be performed and much caution should be taken when extrapolating results from one frequency range to another (Tougaard et al. 2015). The approach taken in the following is thus to restrict extrapolation across frequencies and use unweighted levels from the same frequency range as the assessed noises (explosions and rock dump). This approach will limit possible errors caused by an improper weighting of signals (Tougaard et al. 2015).

Equal energy hypothesis

A substantial effort has gone into quantifying sound levels required to elicit TTS in marine mammals. The initial experiments were primarily conducted on bottlenose dolphins, belugas and sea lions (all reviewed by Southall et al. 2007), but recently also a large number of results are available from other species, most notably harbour seals and harbour porpoises (see comprehensive review by Finneran 2015). The initial recommendations of Southall et al. (2007) reflected an uncertainty as to what single acoustic parameter best correlated with amount of TTS induced and resulted in a dual criterion: one expressed as instantaneous peak pressure and another as acoustic energy of the sound (integral of pressure squared over time, see below). In the reviews of Tougaard et al. (2015) and Finneran (2015) this uncertainty is no longer present and it is generally accepted that everything else being equal the amount of TTS correlates better with the acoustic energy than with the peak pressure. The acoustic energy is most often expressed as the sound exposure level (SEL), given as:

$$SEL = 10 \log \int_0^T \frac{p^2(t)}{p_0^2} dt \qquad \text{Eq. 3}$$

Where p(t) is the instantaneous pressure at time t of a signal of duration T and p_0 is the reference pressure (1 µPa, in water). The unit of SEL is thus dB re. 1µPa^{2}s. It is possible to show that this unit is indeed a unit of energy, being proportional to Jm^{-2} by means of a constant depending on the acoustic impedance of water.

The integration period T should equal the duration of the fatiguing noise up to some limit. This limit is debated. In human audiometry, it is customary to use 24 hours, in conjuction with the sensible assumption that people are often exposed to loud noise during their workday and then spend the night resting in a quiet place. This assumption is less relevant for marine mammals, but the 24 h maximum was retained by Southall et al. (2007), stressing that it is likely to be very conservative (in the sense that it leads to overprotection). For exposures with a known duration, less than 24 hours the actual duration should of course be used, as was done below with the rock placement noise (SEL integrated over 2 hours).

6.1.3 TTS and PTS in harbour porpoises

Several studies on TTS in harbour porpoises are available. One study is relevant for explosions, namely the study of Lucke et al. (2009). Lucke et al. (2009) measured TTS induced by exposure to single airgun pulses, generated from a small 20 in^3 sleeve gun at a received SEL of 164 dB re. 1 $\mu Pa^2 s$. This threshold is markedly lower than other thresholds for TTS measured by repeated pulses (Kastelein et al. 2015 measured TTS induced by a 1h sequence of pile driving pulses) or longer sounds (Kastelein et al. 2012, Kastelein et al. 2013b, Kastelein et al. 2014). The difference is likely due to the impulsive nature of the airgun pulse of Lucke et al. (2009). Different observations support that thresholds for single pulses, intermittent noise and continuous noise cannot be compared directly and thus that the simple assumption that total noise SEL determines the TTS induced (the *equal energy hypothesis* described above) does not hold for all sounds. See e.g. Finneran et al. (2010) for an example of differences in thresholds between single pulses, repeated pulses and continuous noise. The recent demonstration of a rapid reduction in hearing sensitivity in dolphins after being conditioned to a loud noise by a warning signal (Nachtigall and Supin 2014) also means that the noise exposure experienced by the inner ear to a single transient noise could be significantly higher than to a longer noise or a repeated series of pulses. Thus, as transients from explosions are single pulses it appears prudent to use the only threshold derived from a single pulse stimulus, i.e. the threshold of 164 dB re. 1$\mu Pa^2 s$ from Lucke et al. (2009), as also used by von Benda-Beckmann et al. (2015) in their assessment of impact from munition clearance on porpoises in the southern North Sea.

For continuous noise, such as noise from rock dumping, it is more appropriate to derive a TTS threshold from the numerous studies using fatiguing noise of various durations (Kastelein et al. 2012, Kastelein et al. 2013b, Kastelein et al. 2014). These studies have been condensed into one threshold of 188 dB re. 1$\mu Pa^2 s$ by Finneran (2015).

A threshold for inducing PTS in high-frequency cetaceans, including harbour porpoises, was proposed by Southall et al. (2007). However, this threshold was based solely on experimental data from mid-frequency cetaceans (bottlenose dolphins and beluga) and is no longer considered representative. Only one study is directly relevant to PTS and this was performed on a sister species to the harbour porpoise, the finless porpoise. Popov et al. (2011) were able to induce very high levels of TTS (45 dB), likely close to the level required to induce PTS, by presenting octaveband noise centred on 45 kHz at a received SEL of 183 dB re. 1 $\mu Pa^2 s$. This signal was of much higher frequency than the main energy of explosions and rock placement noise, however, and of longer duration (3 min) than a blast pulse (milliseconds). Furthermore, the experiment was performed on another species (although closely related). It is thus questionable whether this result can be transferred to impulsive sounds or rock placement noise. In line with Southall et al. (2007) the PTS threshold was here instead extrapolated from TTS thresholds by adding 15 dB, equal to 179 dB re. 1 $\mu Pa^2 s$ for explosions and 203 dB re. 1 $\mu Pa^2 s$ for rock dump noise.

6.1.4 TTS and PTS in seals

Southall et al. (2007) estimated TTS and PTS thresholds for seals in general, but these estimates were based on data from bottlenose dolphins, beluga and California sea lions. However, since 2007 actual measurements from harbour seals have become available and are used here instead to estimate thresholds.

PTS was induced due to an experimental error by Kastak et al. (2008), where a harbour seal was exposed to a 60 s tone at 4.1 kHz at a total SEL of 202 dB re. 1 μPa^2s. This means that an actual measurement is available. In fact, a second experiment (in a different facility and on a different animal) produced a very strong TTS (44 dB) by accident by exposure to 60 minutes of 4 kHz octave band noise at an SEL of 199 dB re. 1 μPa^2s (Kastelein et al. 2013a). The level of TTS is considered to have been very close to inducing PTS. By combining the two experiments a threshold for PTS in harbour seals for continuous noise (rock placement) is set to 200 dB re. 1 μPa^2s.

A number of experiments have determined TTS in harbour seals for various types of noise of shorter and longer duration, summarized by Finneran (2015) and producing an average threshold estimate of 188 dB re. 1 μPa^2s, which is considered as the appropriate threshold for rock dump noise.

No experiments have been performed on harbour seals with single noise impulses. The thresholds estimated for rock dump are very similar to the thresholds for porpoises, however. This leads to an adoption of the same TTS and PTS thresholds for single impulsive noises for seals as for porpoises, i.e. 164 dB re. 1 μPa^2s and 179 dB re. 1 μPa^2s for TTS and PTS, respectively.

There are no results available from grey or ringed seals, or any other phocine seal of similar size. Results from California sea lions (Finneran et al. 2003) are considered less likely to be representative for grey and ringed seals than the harbour seal data. Consequently the results from harbour seals should until actual data becomes available be considered valid for grey seals and ringed seals as well.

6.1.5 Summary of TTS and PTS thresholds

The sensitivity of marine mammals to hearing threshold shifts (TTS and PTS) is **high**, because of the comparatively low thresholds and hence high likelihood of inflicting TTS and PTS by exposure to high-intensity sounds and the permanent nature of PTS (by definition).

Table 6.1.3. Estimated thresholds for inducing TTS and PTS from single explosions and continuous noise from rock dump. See text for justification and references to experiments underlying these thresholds.

Species	Explosions		Rock dump	
	TTS	PTS	TTS	PTS
Harbour porpoise	164 dB SEL	179 dB SEL	188 dB SEL	203 dB SEL
Seals	164 dB SEL	179 dB SEL	188 dB SEL	200 dB SEL

6.1.6 Noise induced disturbance of behaviour

Permanent or temporary changes in marine mammal hearing may not necessarily be the most detrimental effect of noise. Noise levels below the TTS threshold may affect and alter the behaviour of animals, which can carry implications for the long-term survival and reproductive success of individual animals, and thereby ultimately on the population status if a sufficiently high proportion of the population is affected (NRC 2003) see figure 6.1.6. Effects can occur directly for severe reactions for example panic or fleeing (negative phonotaxis), by which there is an increased risk of direct mortality due to for example bycatch in gill nets (as suggested for porpoises in response to military sonar excercises

(Wright et al. 2013) or separation of dependent calves from mothers. More common, however, is probably less severe effects where animals may be displaced or their foraging and mating behaviour altered due to noise. Seals are generally considered less sensitive to displacement by noise (see e.g. Blackwell et al. 2004), but this assertion is largely without experimental evidence.

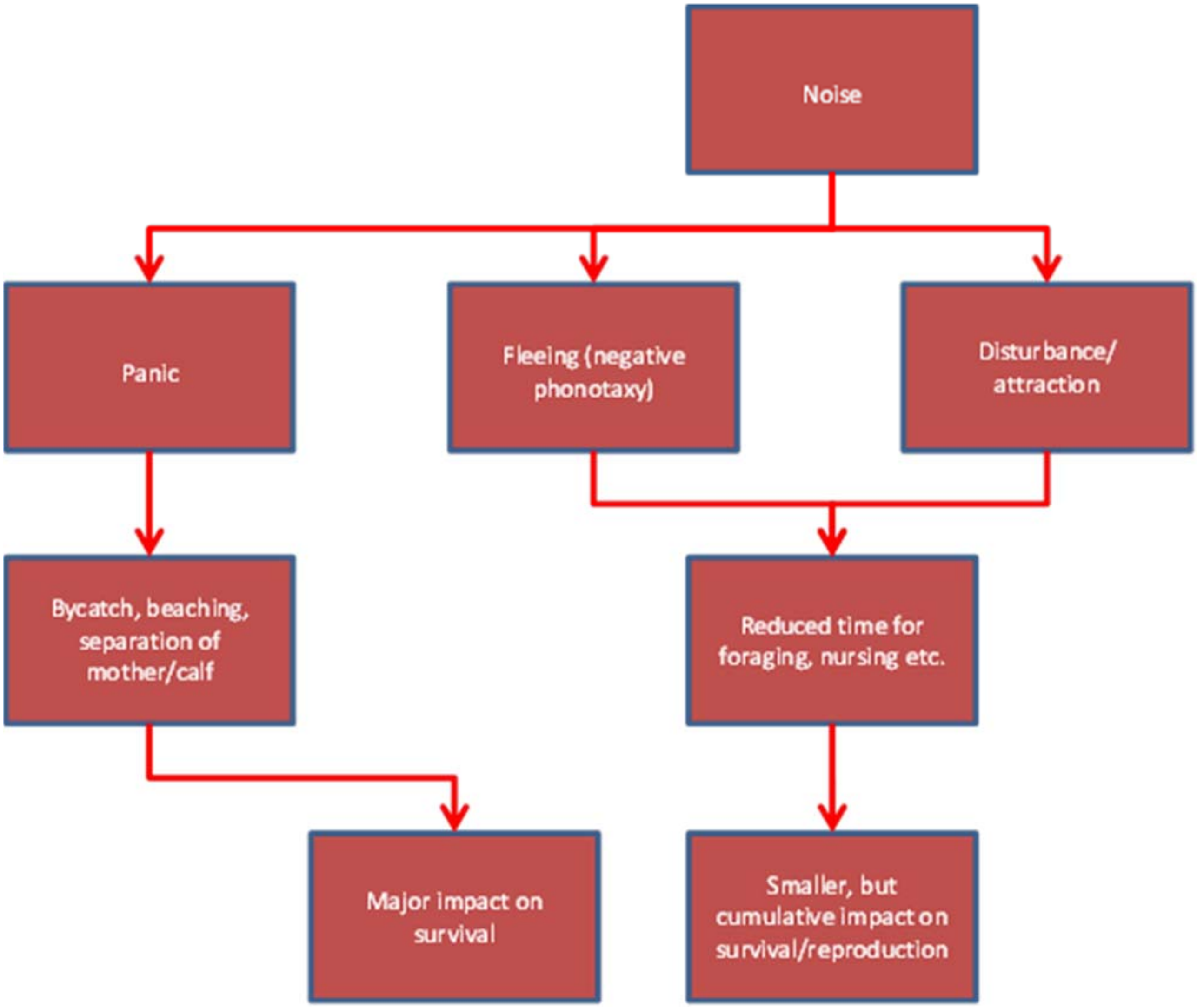


Figure 6.1.6. Schematic illustration of mechanisms by which noise-induced changes to behaviour can lead to effects on short-term and long-term survival and reproduction (fitness) in marine mammals. From Skjellerup et al. (2015).

Based on independent information about the conservation status of the focal population an acceptable limit of disturbance may be determined for a specific species and within agreed management objectives for the given population. Again based upon the status of the considered population additionally some small mortality may also be considered acceptable for the activity under evaluation. However, at present the knowledge about how immediate, short-term behavioural changes translate into population level effects is very incomplete for marine mammals and to a degree where inference to population level is not possible (NRC 2003). At present, it is therefore not possible to derive exposure limits based on management objectives for the conservation status of a population and assessment can only be based on the immediate disturbance from the noise. The sensitivity of marine mammals to behavioural changes or disturbances are assessed to be **low**.

6.1.7 Masking

Masking is the phenomenon that noise can negatively affect the ability to detect and identify other sounds. The masking noise must be audible, roughly coincide with (within tens of ms), and have energy in roughly the same frequency band, as the masked sound. Due to the singular nature of the noise from explosions, they have essentially no ability to mask other sounds and this effect is thus not assessed. For sounds of longer duration, such as rock dumping and ship noise the potential for masking of low frequency sounds is clearly present. However, as the current level of knowledge about conditions where masking occur outside strictly experimental settings and how masking affects short term and long term survival of individuals, it is not possible to assess masking, except noting that the zone of audibility can be used as a very precautionary indicator to the possible extent of the zone of masking. See Erbe et al. (2016) for a current review.

6.2 Sediment spill

6.2.1 Visual impairment

The harbour porpoise use echolocation for orientation in the environment as well as for prey localisation. Studies of porpoises tagged with acoustic / satellite transmitters have shown that they often hunt at night and move into depth of complete darkness with or without an accompanying calf (Wisniewska et al. 2016, Teilmann et al. 2007). Consequently, the sensitivity of harbour porpoise to the visual impairment caused by the sediment plumes is assessed to be **low**.

Other studies have explored the effects of sediment plumes on seals, which do not use sonar for prey detection or orientation. If vision is used to locate prey, increased turbidity could affect their ability to hunt succesfully. In a captive environment, Weiffen et al. (2006) tested the visual acuity of harbour seals to increasing levels of turbidity, finding that it decreased substantially, as turbidity increased. However, they also reported to the existence of blind but well nourished seals in the wild and the obvious poor image transmission at high levels of turbidity in natural conditions indicates that seals are able to forage even in conditions of poor light.

Similar assumptions were made by McConnell et al. (1999), who used satellite relay data loggers (SRDLs) to describe foraging areas and trip durations of grey seals in the North Sea. One blind seal was included in the study, but no significant difference in foraging behaviour was found. These results indicate that vision is not essential to seal survival, or ability to forage.

The sensitivity of seals to visual impairment from sediment spill is assessed to be **low**.

6.2.2 Behavioural impacts from sediment spill

Activities causing increased turbidity or sediment plumes and the presence of boat traffic, may affect the behaviour of the four Baltic marine mammal species. Behavioural changes are, however, inherently difficult to evaluate due to the vast distances at which they may occur and due to the paucity of studies looking at their effects at a population level (NRC 2003). Potential behavioual effects range from very strong reactions, such as panic or flight, to more moderate reactions where the animal may orient itself towards the sound or move slowly away or will cease an on-going behaviour. Additionally, the animals' reaction may vary greatly depending on season, behavioural state, age, sex, as well as in response to the intensity, frequency and time structure of impact causing behavioural changes.

At the population scale, the four marine mammal species in the Baltic may thus be sensitive to permanent or long-term large-scale changes or disturbances in their habitat if a large percentage of the population should be displaced into areas of poor quality or where they would have to compete with conspecifics or other marine mammal species. On the other hand, they may be relatively unaffected by short-term avoidance behavior, although some physiological impacts have been shown (see 6.1.6). However, since the spatial scale of the NSP2 activities causing behavioural impacts is limited, the sensitivity of marine mammals to changes in behaviour is assessed to be **low**.

6.2.3 Contaminants

Contaminant mobilization may have an impact if the level is severe enough for the contaminants to magnify through the food chain and end in marine mammals that are top-predators. Marine mammals make up the highest trophic levels and have large lipid stores. Environmental contaminants such as persistent organic pollutants (POPs) and heavy metals are therefore biomagnified in their tissues, leading to an increased risk of individual and population level toxicity (Vos et al. 2003). High contaminant levels have been linked to immune system depression; disease breakouts, reproductive alterations, developmental effects, and endocrine disruption (see Vos et al., 2003 for a review of toxins and marine mammals). The impact is determined by the level of contaminants and the length of the increased exposure (generations as well as in individuals).

To examine this impact will, however, be challenging, since marine mammals accumulate high levels of contaminants irrespective of whether sediment spill occurs. Thus, linking remobilization of contaminants from sediment spill from the construction of a pipeline to effects in marine mammals will be impossible. Levels of toxins in blubber before, during, and after seabed disturbance are unknown, marine mammals are mobile and exposed to contaminants throughout their entire range, and effects are only likely to be discovered long after the sediment spill ceases (Todd et al. 2015).

The sensitivity of marine mammals to contaminants from sediment spill is assessed to be **low**.

6.3 Unplanned events – Munition clearence

The sensitivity of marine mammals to munition clearance is covered under 6.1 Underwater noise.

6.4 Unplanned events – Oil spill

The impact of oil spill on marine mammals have been measured and investigated in the past following large scale oil releases at sea e.g. the ‘Deepwater Horizon’ oil spill in the Northern Gulf of Mexico with a total spill of 210 million US gallons and the ’Exxon Valdez’ oil spill in Prince William Sound, Alaska with a total spill of 11 to 38 million US gallons. These examples are extreme and in general, the magnitude of the spill from colissions of ships is somewhat lower. For instance, in a review of oil spills from ships, Dalton and

Jin (2010) concluded that the maximum oil spill from a tanker or freight ship in the US from 2002 to 2006 was 321,000 gallons.

Cetaceans appear to be able to detect oil but do not necessarily avoid it in the wild (Dalton and Jin 2010). Thus they may be exposured to oil through direct contact at the surface and in the water column, through incidental ingestion from water or sediments while feeding, and through ingestion of contaminated prey (Schwacke et al. 2014). Furthermore, they may inhale volatile petroleum-associated compounds. For seals, the same threats are relevant and furthermore, oil may smother their fur and thereby reduce their ability to maintain body temperatures.

The resultant health effects from oil via any of these exposure routes have been shown to cause significant decreases in cetacean reproductive success and high mortality rates (Lane et al. 2015), poor body condition, a high prevalence of lung disease, and abnormally low adrenal hormone levels that are consistent with previous studies of petroleum toxicity (Schwacke et al. 2014).

Thus, the sensitivity of marine mammals to oil spill is assessed as **medium**.

6.5 Changes in the habitat

The physical presense of the pipeline alter the existing habitat. In the construction phase most sessile benthic flora and fauna will be disturbed and likely destroyed in the immediate vicinity of the pipeline and non-sessile animals displaced. Once in operation, however, the solid substrate of the pipeline and the overlaying rocks may introduce the possibility of increased bentic diversity and consequently fish diversity and abundance, in particular in areas with soft bottom substrate without possibility for settlement of sessile animals. The main prey of the Baltic marine mammals is fish and consequently if the suggested changes in the fish community are significant this may positively impact the prey availability for marine mammals. However, the environmental impact assessment of fish in relation to the NSP2 concluded that any impacts on the fish community would be restricted to the very close vicinity of the pipelines and be of minor impact (Rambøl 2016e). Thus, the **sensitivity** of marine mammals to changes in the habitat at the scale of the NSP2 is assessed to be **low**.

6.6 Unplanned events – Gas release

During the assessment of NSP the risk of gas release during operation was calculated to be on average once every 293,500 years. However, in the unlikely event of gas release it is judged that all marine mammals within the gas plume or the subsequent gas cloud will die or flee from the influenced area (Nord Stream 2008). However, since a potential gas release will likely be associated with some noise, it is likely that marine mammals will have time to avoid the plume. The impact will be of limited time and space and the sensitivity of marine mammals to gas release are thus assessed to be **low**.

6.7 Seasonal sensitivity (Denmark and Sweden)

The most vulnerable periods for seals in the Baltic Sea are primarily during their moulting, breeding and lactation periods. Harbour porpoises are also vulnerable in the breeding period, but the calves are dependent on their mother for at least 10 months and may be vulnerable throughout the first year and especially in the first period after leaving their mother. Table 6.7.1 below summarises these vulnerable periods over a year per species based on the low, medium, high sensitivity matrix used for this assessment. For more details, see baseline report (Teilmann et al. 2017). The actual sensitivity for a given activity is found as the combination of the sensitivity to the activity itself and the sensitivity related to the period.

Table 6.7.1. Sensitivities of marine mammals in Danish and Swedish waters during the year.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Harbour porpoise	High	High	High	Med	High	High	High	High	High	High	High	High
Harbour seal	Med	Med	Med	Med	High	High	High	High	Med	Med	Med	Med
Grey seal	Med	High	High	Med	High	High	Med	Med	Med	Med	Med	Med
Ringed seal	Med	High	High	High	High	Med	Med	Med	Med	Med	Med	Med

7 Modelling of impact

Determining the magnitude of each potential impact is important in order to assess the significance of the impact on marine mammals. Some impacts such as the extend of noise from rock placement and the extend of sediment spill may be estimated through models, while others require field studies or expert judgement. This chapter summarizes the results of models predicting underwater noise and sediment spill in relation to the Baltic marine mammals.

7.1 Underwater noise

Transmission of underwater noise were modelled in order to estimate impact ranges for the noise. Details are given in the reports "Underwater noise modelling Denmark", document number W-PE-EIA-PDK-REP-805-010300EN (Rambøll 2016c) and "Sweden Underwater Noise Modelling", document number W-PE-EIA-PSE-REP-805-020300EN (Rambøll 2016d).

7.1.1 Rock placement – TTS/PTS (Denmark and Sweden)

Modelled noise levels from rock placement were low. Cumulated SEL was estimated at two different positions along the Nord Stream corridor: one east of Gotland (RP1) and one southeast of Gotland (RP5). See Rambøll 2016d, figure 3-1 for precise location). Estimated extent of TTS and PTS zones under a very conservative assumption that animals would remain stationary at the same distance from the rock dump for 2 hours, are given in table 7.1.1. Modelled noise levels were not sufficiently high to induce PTS, even if the receiving animal is right next to the rock placement, whereas TTS could hypothetically be induced if a seal or a porpoises lingered within a distance of 80 m from the rock dump ship for a period of 2 hours or more.

Table 7.1.1. Maximum extent of the TTS and PTS zones for rock placement at the Danish position RP1 (Rambøll 2016c) and the Swedish position RP5 (from Rambøll 2016d).

Marine group	Effect	RP1 Threshold distances, max	RP5 Threshold distances, max
Seals	PTS	0 m	0 m
	TTS	80 m	80 m
Porpoises	PTS	0 m	0 m
	TTS	80 m	80 m

Impact ranges from rock placement and other vessel-based activity are very small and spatial scale of the impact is thus local. Effects are **temporary** and **reversible**, as PTS is considered unlikely to occur.

7.2 Sediment spill

The magnitude of the sediment spill is given for Danish waters in the document "Modelling of sediment spill in Denmark" (Rambøll 2016a) and for Swedish waters in the document "Modelling of sediment spill in Sweden" (Rambøll 2016b).

The results are summarized below for Danish and Swedish waters.

7.2.1 Danish waters

In short, the modelled trenching scenarios show that the sediment plumes is generally limited to the areas near the pipeline. Only in section 1-5 (area east of Bornholm), an additional plume directed approx. 20 km toward south east starting from trenching is found. Concentrations of suspended sediment is 2 mg/l-10 mg/l.

Sedimentation is limited to the area at the vicinity of the pipeline route and no sedimentation above 40 g/m^2 away from the pipeline.

For the rock placement scenarios the maximum concentrations of suspended sediment is not exceeding 2 mg/l. In neither of the scenarios any significant concentrations or sedimentation is seen away from the pipeline.

Sedimentation is not exceeding 75 g/m^2 at any location after trenching operations. Sedimentation is not exceeding 20 g/m^2 at any location after rock placement operations. Considering that the settled material is forming fluffy sediment with a low density the above maximum results is causing sedimentation of less than 1 mm.

Due to the potentially long distance the plume can reach from the pipeline the scale of sediment spill is thus **national**, the duration is **temporary** and the impact is **reversible**.

7.2.2 Swedish waters

Results from modelling of seabed sediment dispersal are presented in Rambøll (2016b). The widest spreading of suspended sediments in the water mass will occur where trenching will be carried out and during winter conditions. Concentrations of suspended sediments could exceed 25 mg/l on an area of 31 km2 around the pipeline but concentrations exceeding 25 mg/l will only last in maximum 14 hours.

For the rock placement scenarios, the area with concentrations of suspended sediment exceeding 25 mg/l is limited to a small area approximately less than 0.02 km2 around the rock placement sites.

Sedimentation of any significance is, however, limited to the area at the vicinity of the pipeline route. Maximum sedimentation, barely exceeding 1 000 g/m2, could only occur within 200 m from the pipelines.

Due to the potentially long distance the plume can reach from the pipeline the scale of sediment spill is thus **national**, the duration is **temporary** and the impact is **reversible**.

8 Assessment of impact in the construction period

8.1 Underwater Noise

8.1.1 TTS/PTS from rock placement

Even with very precautionary assumptions regarding impact of noise from rock placement the impact is strictly **local**, **temporary** and of **low intensity** (PTS unlikely). The magnitude is thus **low** and the significance of the impact is assessed as **negligible** for all species of marine mammals.

8.1.2 Behavioural reactions to noise

Noise from the rock placement was used as a proxy for construction related noise from vessels in general, as the rock placement is considered one of the noisiest activities arising from the project (except for munitions clearance). Behavioural reactions to underwater noise from rock placement and other vessel related activities around the pipeline are expected to occur only in the vicinity of the vessels and remain only for the time when the vessels are present. The duration are thus **temporary** and the scale is **local**. Disturbance is considered of minor importance. Disturbances are likely to be of similar magnitude as disturbance from passing merchant vessels, which are very abundant along the pipeline corridor (see figure 8.1.1). The intensity and impact magnitude from vessel noise and rock placement is therefore rated **low** impact magnitude and the overall significance **minor**.

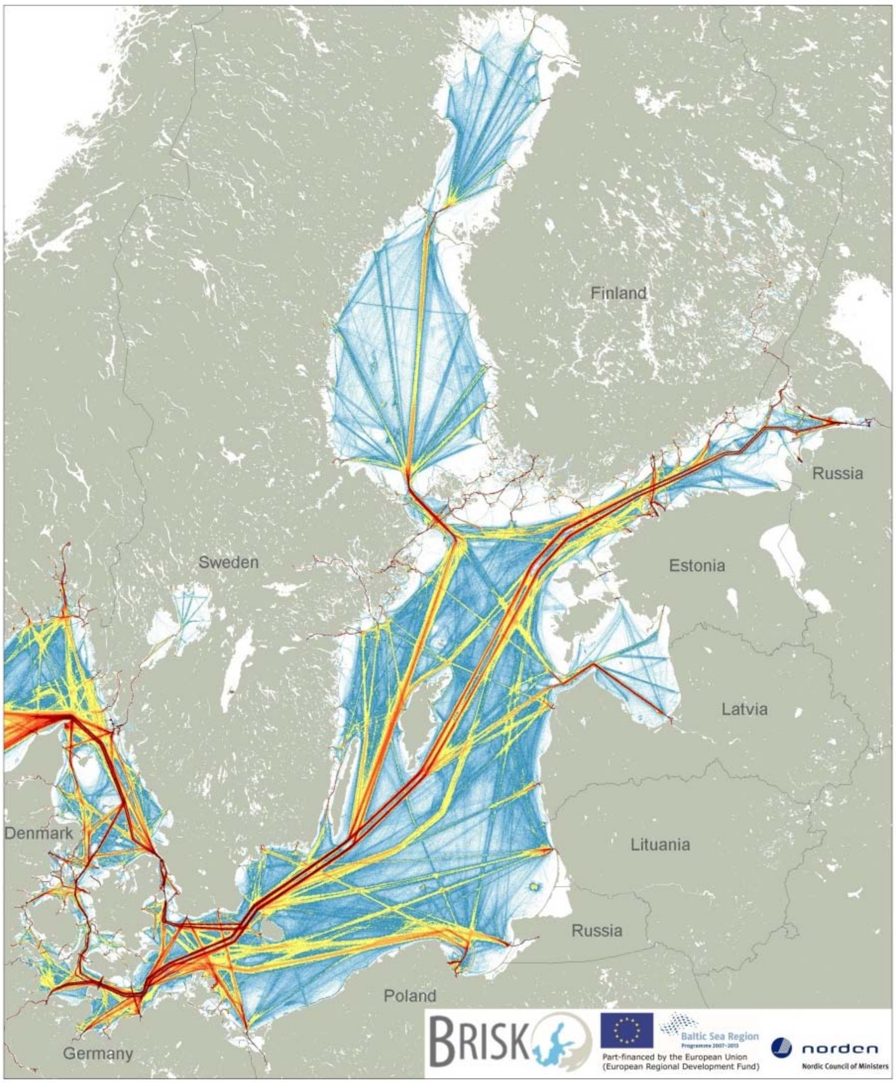
8.2 Sediment spill

Suspended sediment may have a direct effect on marine mammals by either hindering their visual capacity or by affecting their vision since suspended sediment scatters light, degrades the image contrast, limits the visual range and also determines the spectral bandwidth and intensity of light available for vision at certain water depths (Weiffen et al. 2006).

Indirectly, suspended sediment and sedimentation can impact the benthic and pelagic prey of marine mammals by covering the sea bed with sediment, by increasing turbidity and releasing contaminants.

If the area exposed to sedimentation is relatively small, this impact is assessed to be of minor importance to marine mammals. In the case of NSP2 sedimentation will only occur in relative proximity to the pipeline and no detrimental impacts (especially not on measurable level) are expected on marine mammals.

Figure 8.1.1. Density of ship traffic based on AIS data in the Baltic in 2009. (Downloaded from http://www.brisk.helcom.fi/risk_analysis/traffic/). AIS includes all commercial vessels above 300 tons and additional fishing vessels and pleasure boats.



8.2.1 Visual impairment

Since the harbour porpoise use echolocation for orientation in the environment as well as prey localisation, the visual impairment caused by sediment plumes, is not assessed to have a significant impact at an individual nor at a population level.

The spatial and temporal extend of a sediment spill and hence visual impairment is **national** and **temporary**, with **low** intensity and impact magnitude and consequently the significanse on seals and porpoises in the Baltic is **negligible**.

8.2.2 Increased turbitity

Except for the creation of sediment plumes that may affect marine mammal vision, increased turbidity is unlikely to affect marine mammals, in contrast to fish and invertebrates, which can be severely affected by clogging of gills and feeding apparatus. Evidence that turbidity affects cetaceans or seals directly is not evident in the literature, and since marine mammals often inhabit naturally turbid or dark environments, turbidity is assessed to have a **low** impact magnitude and a **negligible** overall significance.

8.2.3 Behavioural impacts of sediment spill

The duration of behavioural responses caused by noise, ship traffic or sediment spill are **temporary** and the scale **national** meaning that the animals will return or assume their normal behaviour once the activity has ceased. The behavioural impacts are all assessed to be **reversible** and the **intensity** and **magnitude** is **low**. And since the sensititivy also is **low**, the overall significance is **minor**.

8.2.4 Contaminants

Over time, sediments accumulate toxins and pollutants such as hydrocarbons and heavy metals. Disturbance of sediments can release contaminants into the water column, which has the potential to change chemical properties of the sediment, and reduce water quality. Once suspended, contaminants can become available to marine organisms, and potentially accumulate up the food chain and end up in marine mammals (Todd et al. 2015). However, literature on dredging release of contaminants suggests that remobilization is restricted in both time and space, and that as long as highly contaminated sediments are managed strictly, concentrations are not high enough to have detrimental effects on the environment (Roberts 2012). And furthermore it was assessed that impacts on fish and fish stocks and bioaccumulation of contaminants in fish species will be of minor importance (Rambøl 2016e).

The spatial scale of contaminant remobilization is **national** and the duration is **temporary**. The intensity of the impact is **low to insignificant**, which in combination gives the impact magnitude **low**. The sensitivity is also low and the overall significance is therefore **negligible-minor**.

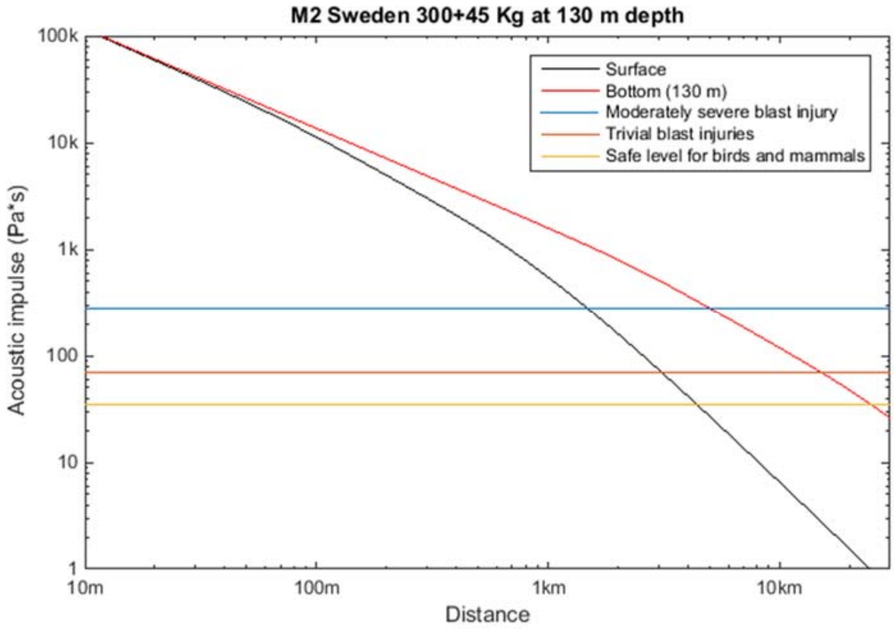
8.3 Unplanned events

8.3.1 Munition Clearance

A low number of unexploded mines can be expected to be encountered in Swedish waters during construction of the pipeline. Nine such mines were encountered during contruction of the Nord Stream pipeline, it was assessed that only seven needed to be cleared. Currently, Nord Stream expect that detonation of the mines can be avoided by rerouting the pipeline slightly (mitigation measures and alternative clearance techniques are also being looked in to). Should one or more detonations become relevant they can have a significant negative impact on the marine mammals in the Swedish waters, depending strongly on the exact circumstances. Figure 8.3.1 shows an example of estimation of a blast injury zone around a 300 kg mine detonated at 130 m, illustrating that the blast injury zone can extend many kilometers out from the blast site.

Hearing damage (TTS and PTS) can be expected at lower received levels and the PTS and TTS zones are expected to extend even further.

Figure 8.3.1. Example of estimated acoustic impulse with range for a 300 kg mine + 45 kg donor charge and detonated on the bottom at a depth of 130 m. Black line is for animals at the surface, red line close to the bottom. Three horizontal lines indicate the injury thresholds defined by Yelverton et al. (1973). A worst case scenario is assumed in which the total charge explodes together with the donor charge and that the explosion is with access to open water (directly on the sea bed). Predictions and injury thresholds from Yelverton et al. (1973) (See table 6.1.1).



The actual impact of an explosion will depend critically on the number of animals present within the zones of impact at the time of detonation. The abundance of seals and porpoises varies with geographical position and time of year. In the northern part of the pipeline corridor ringed seals can be expected to occur during winter months, associated with ice cover. In the southern part of the pipeline corridor harbour porpoises can be encountered during summer months, in particular in the area around the Midsjö Banks, where recent monitoring data have shown that most of the population of Baltic porpoises aggregate during the mating and breeding period in summer (SAMBAH, 2016). Munition clearance by detonation in those areas in the summer (May – Oct) thus has potential for significant impact on the populations of especially harbour porpoises. Detonations in other areas and at other times of the year may have significantly smaller impact.

The impact of muntion clearance is thus **irreversible** and potentially **transboundary** (depending on location). The duration is **long-term** and the intensity is **high**, since the impacts may be severe on both individual and population level. The Impact magnitude is thus high for all marine mammals. Sensitivity and significance is assessed below for each species.

Harbour Porpoise: The sensitivity of harbour porpoises to munition clearance depends on the location and season: In the northern part of the Swedish NSP2 corridor the density of harbour porpoises is very low all year round and the sensitivity is **low** and the overall significance is thus **minor**. The southern part of the Swedish NSP2 corridor, however, intersects the major aggregation and presumed breeding area (around Midsjö Bank) for the Baltic harbour porpoise population and the impact and significance of munition clearance in the summer is thus **high** and will likely lead to permanent hearing damage in animals and potential casualties. In order to estimate the likely number of affected porpoises a noise propagation map should be compared with the porpoise distribution maps (found in the NSP2 baseline report). During the winter months much fewer porpoises are present is the southern area and the sensitivity and significance of munition clearance would thus be **medium** and **moderate**, respectively.

Harbour seal: The significance of munition clearance depends on the location and season: No harbour seals are present in the northern part of the Swedish NSP2 corridor and the sensitivity is thus **negligible**. In the southern part of NSP2, harbour seals may be present, although in low numbers and the sensitivity is thus **medium**. The impact magnitude in this area and the overall significance level is **medium** and **moderate**, respectively.

Grey seal: The significance of munition clearance depends on the location. Grey seals can be found everywhere in Swedish waters, but densities are possibly lower at open sea. The Baltic population of grey seals have been increasing over the last decades and the sensitivity are therefore assessed as **medium** and the overall significance **moderate**.

Ringed seal: The significance of munition clearance depends on the location and season. Ringed seals are only found in the northern part of Swedish waters where they breed during the winter. The sensitivity is thus **negligible** in the southern part of the NSP2 corridor and **high** in the northern part. The overall significance will accordingly vary from **negligible** to **major** depending on location.

8.3.2 Oil spill

Major oil spill accidents such as the 'Amoco Cadiz' oil spill in Brittany, France and the 'Exxon Valdez' oil spill in Prince William Sound, Alaska will have a major impact on marine mammals. In general, however, the amount of oil spilled in ship accidents is much smaller (typically involving only bunker oil) and the actual risk of the NSP2 service ships contribution to a collision involving oil spill is negligible and thus, although the sensitivity of marine mammals to oil spill is assessed as medium, the scale is **transboundary** and the duration **long-term**, the intensity and magnitude is assesed as **low** and consequently the significance of the impact is assessed as **minor**.

8.3.3 Icebreaking caused by service vessels

A potential impact from service vessels is the breaking of ice in the northern part of the Swedish waters. The impact of ice breaking by service vessels is **local** and is mainly relevant for the construction period. Ice breaking will have no influence on harbour porpoises and harbour seals since they will not be present in ice-covered waters and their sensitivity is therefore **negligible**. Grey seal and ringed seal, however, use the ice for breeding, relaxing and socializing and may thus be present and affected by the breaking of ice.

The impact may range from disturbance of natural behaviour (**short-term** and **low magnitude**) to the potential death of seals pups by hypothermia, as their fur coat is not waterproof for the first months of their life, where they are restricted to stay on the ice (**long-term** and **high magnitude**). However, since the number of seals affected is likely very small and since the likelyhood of NSP2 contributing significantly to the current level of ice breaking activity in the Baltic, the sensitivity is assessed to be **medium** and the overall significance is to **low**.

9 Assessment of impact in the operation period

9.1 Underwater noise from pipeline

The noise emitted from the pipeline itself, due to the gas flow inside is expected to be of very low intensity and only be audible to marine mammals very close to the pipeline and only close to the compressor station. The impact is **irreversible** and **long-term**, but **local**. The intensity and magnitude is **low** and the overall significance of this impact in Swedish and Danish waters is thus considered **negligible**.

9.2 Underwater noise from service vessels

The level of ship activity in relation to inspection and servicing of the pipeline is considered to be insignificant in comparison to the general level of shipping activity in the central Baltic (figure 8.1) and any disturbance from these ships will be local and temporary. The intensity and magnitude is **low** and the overall significance of this source of disturbance is thus considered **minor**.

9.3 Changes in the habitat

The physical presense of the pipeline alter the existing habitat and consequently the flora and fauna inhabiting the area. In the construction phase, all benthic flora and fauna will be eliminated, but in the operation phase, the solid material of the pipeline may introduce the possibility of increased bentic diversity. However, it has been assessed for fish that any impact – negative or positive - from the NSP2 will have a negligible to minor impact (Rambøll 2016e). Thus, it is unlikely that the habitat changes although **long-term** and **irreversible** will have any significant impact on marine mammals on a population level since the scale is **local**, the intensity **low** and the magnitude therefore is **negligible**. The overall sensitivity is **low** and the significance therefore **negligible**.

9.4 Unplanned events

9.4.1 Gas release

During the assessment of NSP the risk of gas release during operation was calculated to be on average once every 293,500 years. However, in the unlikely event of gas release it is judged that all marine mammals within the gas plume or the subsequent gas cloud will die or flee from the influenced area (Nord Stream 2008). However, since a potential gas release will likely be associated with some noise, it is likely that marine mammals will have time to avoid the plume. The impact will be **temporary** and **local**. The intensity and the magnitude of the impact is **low**. Since the sensitivity of marine mammals to gas release are assessed to be **low** the overall significanse of gas release is assessed to be **minor**.

10 Assessment of impact in Natura 2000 areas

10.1 Natura 2000 sites

10.1.1 Construction phase

In Danish waters there are currently no designated or proposed Natura 2000 sites for any marine mammals close enough to the pipeline corridor to be affected by the construction and operation of the pipeline. Impact is thus **not significant**.

In Swedish waters, however, 138 km of the NSP2 pipeline are within the newly proposed Natura 2000 area “Hoburgs Bank and Midsjöbankerna”. This area holds the majority of the endangered Baltic harbour porpoise population in the summer season, when calving and mating take place and is thus likely to be the main breeding area for the Baltic harbour porpoise population (SAMBAH 2016). However, as impacts from unplanned events (munition clearance and oil spill, see 8.3.1) is not inluded here, the assessed impact is **not significant**.

Natura 2000 sites for seals are not located close to the pipeline corridor. It is considered unlikely that noise or other impacts from construction will have any effect on seals inside the Natura 2000 areas and the significance of the impact is thus **not significant**.

The significance of impacts during the construction phase (assuming munition clearance by detonation is not performed, see 8.3.1) are assessed as **not significant** due to the **low** impact magnitude and distance to the Natura 2000 sites for the Baltic marine mammals.

10.1.2 Operation phase

It is not expected that any of the potential impacts in the operation phase will have a significant impact on marine mammals within the Natura 2000 sites in Denmark or Sweden listed in the baseline report (Teilmann et al. 2017). As outlined above in section 8.1.3 the additional noise and potential disturbance from vessels and pipeline are likely to be strictly local, temporary and reversible. Significance of impacts inside the Natura 2000 areas is thus considered **not significant**, as effects are unlikely to have any consequences for the long-term survival of the population (conservations status).

10.2 Annex IV species

Harbour porpoise is on the Annex IV of the Habitat Directive and thus, the impact assessment of the Nord Stream Pipeline needs to determine whether any of the pressures identified may lead to a violation of the objectives of Article 12 of the Habitats Directive, namely the deliberate capture or killing of specimens (including injury) and the deliberate disturbance of marine mammals. However, none of the planned or unplanned impacts described in this report are assessed to contribute to a violation of these objectives in Sweden or Denmark.

11 Summary tables

This chapter presents summary tables of activity, impact, sensitivity, assessment the countries relevant for each activity for harbour porpoise, harbour seal, grey seal and ringed seal.The assessment values refers to the text in section 8 and 9.

11.1 Harbour porpoise

HARBOUR PORPOISE														
	Impact	Phase	Activity	Impact	Nature	Type	Reversibility	Impact magnitude				Value/ Sensitivity	Significance	Country
								Scale	Duration	Intensity	Magni-tude			
Planned	Noise	Construction	Seabed intervention works (Rock placement)	PTS/TTS	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
			Seabed intervention works (Rock placement, Pipe-laying, Anchor handling)	Avoidance, masking	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
			Construction and support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
		Commisioning	Pipeline flooding, Pressure-test water discharge, Commissioning	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
		Operation	Routine inspections, maintenance, support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
			Pipeline presence	Avoidance	Negative	Direct	Irreversible	Local	Long-term	Low	Low	Low	Negligible	S / DK
	Sediment spill	Construction	Trenching, Rock placement	Visual impairment	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Negligible	S / DK
				Avoidance, disturbance of natural behaviour	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Minor	S / DK
	Release of contaminants	Construction	Seabed intervention works, Pipe-laying, Anchor handling	Health deterioration	Negative	Direct	Irreversible	National	Temporary	Low	Low	Low	Negligible -Minor	S / DK
	Habitat change	Operation	Pipeline presence	Posible change in prey diversity/abundance	Positive/negative	Indirect	Irreversible	Local	Long-term	Low	Insignificant	Low	Negligible	S / DK
Unplanned	Noise	Construction	Munition clearence	Death, TTS, PTS, avoidance	Negative	Direct	Irreversible	Trans-boundary	Long-term	High	High	Low - High*	Minor - Major*	S
	Release of contaminants	Operation	Gas release	Death, avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
		Construction / Operation	Oil spill	Death, health problems, avoidance	Negative	Direct	Irreversible	Trans-boundary	Long-term	Low	Low	Medium	Minor	S / DK
	Ice breaking	Construction / Operation	Construction and support vessel movement	Avoidance	Negative	Direct	Irreversible	Local	Short-term	Low	Low	Negligible	Negligible	S

*The impact magnitude and level of significance depends on season and location, see 8.3.1.

11.2 Harbour seal

HARBOUR SEAL								Impact magnitude						
	Impact	Phase	Activity	Impact	Nature	Type	Reversibility	Scale	Duration	Intensity	Magni-tude	Value/ Sensitivity	Significance	Country
Planned	Noise	Construction	Seabed intervention works (Rock placement)	PTS/TTS	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
			Seabed intervention works (Rock placement, Pipe-laying, Anchor handling)	Avoidance, masking	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
			Construction and support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
		Commisioning	Pipeline flooding, Pressure-test water discharge, Commissioning	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
		Operation	Routine inspections, maintenance, support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
			Pipeline presence	Avoidance	Negative	Direct	Irreversible	Local	Long-term	Low	Low	Low	Negligible	S / DK
	Sediment spill	Construction	Trenching, Rock placement	Visual impairment	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Negligible	S / DK
				Avoidance, disturbance of natural behaviour	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Minor	S / DK
	Release of contaminants	Construction	Seabed intervention works, Pipe-laying, Anchor handling	Health deterioration	Negative	Direct	Irreversible	National	Temporary	Low	Low	Low	Negligible - Minor	S / DK
	Habitat change	Operation	Pipeline presence	Posible change in prey diversity/ abundance	Positive/negative	Indirect	Irreversible	Local	Long-term	Low	Negligible	Low	Negligible	S / DK
Unplanned	Noise	Construction	Munition clearence	Death, TTS, PTS, avoidance	Negative	Direct	Irreversible	Transboundary	Long-term	High	High	Insignificant - Medium*	Negligible - Moderate*	S
	Release of contaminants	Operation	Gas release	Death, avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
		Construction / Operation	Oil spill	Death, health problems, avoidance	Negative	Direct	Irreversible	Transboundary	Long-term	Low	Low	Medium	Minor	S / DK
	Ice breaking	Construction / Operation	Construction and support vessel movement	Avoidance	Negative	Direct	Irreversible	Local	Short-term	Low	Low	Low	Insignificant	S

*The impact magnitude and level of significance depends on season and location, see 8.3.1.

11.3 Grey Seal

GREY SEAL														
	Impact	Phase	Activity	Impact	Nature	Type	Reversibility	Impact magnitude				Value/ Sensitivity	Signifi-cance	Country
								Scale	Duration	Intensity	Magni-tude			
Planned	Noise	Construction	Seabed intervention works (Rock placement)	PTS/TTS	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
			Seabed intervention works (Rock placement, Pipe-laying, Anchor handling)	Avoidance, masking	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
			Construction and support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
		Commisioning	Pipeline flooding, Pressure-test water discharge, Commissioning	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
		Operation	Routine inspections, maintenance, support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
			Pipeline presence	Avoidance	Negative	Direct	Irreversible	Local	Long-term	Low	Low	Low	Negligible	S / DK
	Sediment spill	Construction	Trenching, Rock placement	Visual impairment	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Negligible	S / DK
				Avoidance, disturbance of natural behaviour	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Minor	S / DK
	Release of contaminants	Construction	Seabed intervention works, Pipe-laying, Anchor handling	Health deterioration	Negative	Direct	Irreversible	National	Temporary	Low	Low	Low	Negligible - Minor	S / DK
	Habitat change	Operation	Pipeline presence	Posible change in prey diversity/abundance	Positive/ negative	Indirect	Irreversible	Local	Long-term	Low	Negligible	Low	Negligible	S / DK
Unplanned	Noise	Construction	Munition clearence	Death, TTS, PTS, avoidance	Negative	Direct	Irreversible	Trans-boundary	Long-term	High	High	Medium*	Moderate*	S
	Release of contaminants	Operation	Gas release	Death, avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
		Construction / Operation	Oil spill	Death, health problems, avoidance	Negative	Direct	Irreversible	Trans-boundary	Long-term	Low	Low	Medium	Minor	S / DK
	Ice breaking	Operation	Construction and support vessel movement	Avoidance, loss of pack ice for breeding, disturbance/death of baby seals on the ice	Negative	Direct, secondary	Reversible	Local	Short-term - Long term	Low - High	Low - High	Medium	Low	S

*The impact magnitude and level of significance depends on location, see 8.3.1.

11.4 Ringed seal

RINGED SEAL														
	Impact	Phase	Activity	Impact	Nature	Type	Reversibility	Impact magnitude				Value/Sensitivity	Significance	Country
								Scale	Duration	Intensity	Magnitude			
Planned	Noise	Construction	Seabed intervention works (Rock placement)	PTS/TTS	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
Planned	Noise	Construction	Seabed intervention works (Rock placement, Pipe-laying, Anchor handling)	Avoidance, masking	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
Planned	Noise	Construction	Construction and support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
Planned	Noise	Commisioning	Pipeline flooding, Pressure-test water discharge, Commissioning	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Negligible	S / DK
Planned	Noise	Operation	Routine inspections, maintenance, support vessel movement	Avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
Planned	Noise	Operation	Pipeline presence	Avoidance	Negative	Direct	Irreversible	Local	Long-term	Low	Low	Low	Negligible	S / DK
Planned	Sediment spill	Construction	Trenching, Rock placement	Visual impairment	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Negligible	S / DK
Planned	Sediment spill	Construction	Trenching, Rock placement	Avoidance, disturbance of natural	Negative	Direct	Reversible	National	Temporary	Low	Low	Low	Minor	S / DK
Planned	Release of contaminants	Construction	Seabed intervention works, Pipe-laying, Anchor handling	Health deterioration	Negative	Direct	Irreversible	National	Temporary	Low	Low	Low	Negligible - Minor	S / DK
Planned	Habitat change	Operation	Pipeline presence	Posible change in prey diversity/abundance	Positive/negative	Indirect	Irreversible	Local	Long-term	Low	Negligible	Low	Negligible	S / DK
Unplanned	Noise	Construction	Munition clearence	Death, TTS, PTS, avoidance	Negative	Direct	Irreversible	Trans-boundary	Long-term	High	High	Negligible - High*	Negligible - Major*	S
Unplanned	Release of contaminants	Operation	Gas release	Death, avoidance	Negative	Direct	Reversible	Local	Temporary	Low	Low	Low	Minor	S / DK
Unplanned	Release of contaminants	Construction / Operation	Oil spill	Death, health problems, avoidance	Negative	Direct	Irreversible	Trans-boundary	Long-term	Low	Low	Medium	Minor	S / DK
Unplanned	Ice breaking	Operation	Construction and support vessel movement	Avoidance, loss of pack ice for breeding, disturbance/death of baby seals on the ice	Negative	Direct, secondary	Reversible	Local	Short-term - Long term	Low - High	Low - High	Medium	Low	S

*The impact magnitude and level of significance depends on season and location, see 8.3.1.

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Appendix 1

Memo on thresholds for TTS and PTS in marine mammals

Prepared by Jakob Tougaard, Senior Scientist, DCE/Aarhus University, Feb. 2017.

The following memorandum is an addition to the expert assessment of effects of the proposed Nord Stream 2 (NSP2) pipeline through Swedish waters (Sveegaard et al. 2017, this report). It deals with the choice of thresholds for temporary and permanent thresholds shifts used in the assessment and has been made following a request from the Swedish authorities to clarify these issues, in particular the choice of threshold for noise from rock dumping. The text is to be read in conjunction with the assessment report (NSP2 - Environmental Study Appendix 9: Marine mammals in the Baltic Sea in relation to the Nord Stream 2 project) and parts of the introduction has been copied from this report.

Introduction and background

For marine mammals it is generally accepted that the auditory system is the most sensitive organ to acoustic injury, meaning that injury to the auditory system will occur at lower levels than injuries to other tissues (see e.g. Southall et al. 2007). Furthermore, noise induced threshold shifts are likewise accepted as precautionary proxies for more widespread injuries to the auditory system. Noise induced threshold shifts are temporary reductions in hearing sensitivity following exposure to loud noise (for example commonly experienced by humans as reduced hearing following rock concerts etc.). Temporary threshold shifts (TTS) disappear with time, depending on the severity of the impact. Small amounts of TTS will disappear in a matter of minutes, extending to hours or even days for very large TTS. At higher levels of noise exposure the hearing threshold does not recover fully, but leaves a smaller or larger amount of permanent threshold shift (PTS).

Central in assessment of impact from TTS and PTS is threshold levels of exposure, above which TTS and PTS are induced. Deriving such has been the subject of a large effort from many sides, summarized in the reviews by Southall et al. (2007) and Finneran (2015). A considerable number of experimental results are available from harbour porpoises, fewer from harbour seals and none from grey and ringed seals. General for these experiments is that there is substantial variation in thresholds, depending on the exact type of noise used as fatiguing stimulus. No general thresholds are thus available and since none of the experiments have used a noise resembling the noise from rock dumping, thresholds from other types of noise had to be used.

Two general types of sounds have been used as fatiguing sounds: very short pulses (less than 1 s) and continuous or intermittent sound over longer periods (minutes to hours). The lowest thresholds have been measured for exposures of harbour porpoises to single pulses from an air gun (Lucke et al. 2009), where TTS was induced at 164 dB re. 1 $\mu Pa^2 s$. This threshold, however, is unlikely to be relevant for noise exposure of a more continuous or intermittent nature, such as the noise from rock dumping. The primary reason is that the sensitivity of the auditory system, at least in harbour porpoises, can be lowered upon experiencing loud noise (Nachtigall et al. 2016). This means that the fatiguing effect of a series of pulses or a longer, continuous noise will be lower than the effect of the first pulse the animal is exposed to and thus that

7 the cumulated sound exposure required for a multi-pulse or continuous signal to induce TTS will be higher than for a single pulse. This increase in thresholds for longer duration signals is seen in the harbour porpoise data, where much higher thresholds are found when signals lasting minutes to hours are used (Kastelein et al. 2012, Kastelein et al. 2013, Kastelein et al. 2014, Kastelein et al. 2015a, Kastelein et al. 2015b).

The frequency spectrum of noise from rock dumping is dominated by energy at low frequencies (Figure 1). As frequency has a significant influence on TTS thresholds, in general with lower thresholds at higher frequencies (Finneran 2015, Tougaard et al. 2015) it is important to select experiments with similarly low frequencies for derivation of a representative threshold. For harbour porpoises the lowest frequency used in fatiguing signal is 1-2 kHz FM sweeps (Kastelein et al. 2014). All data from this study is shown in Figure 2.

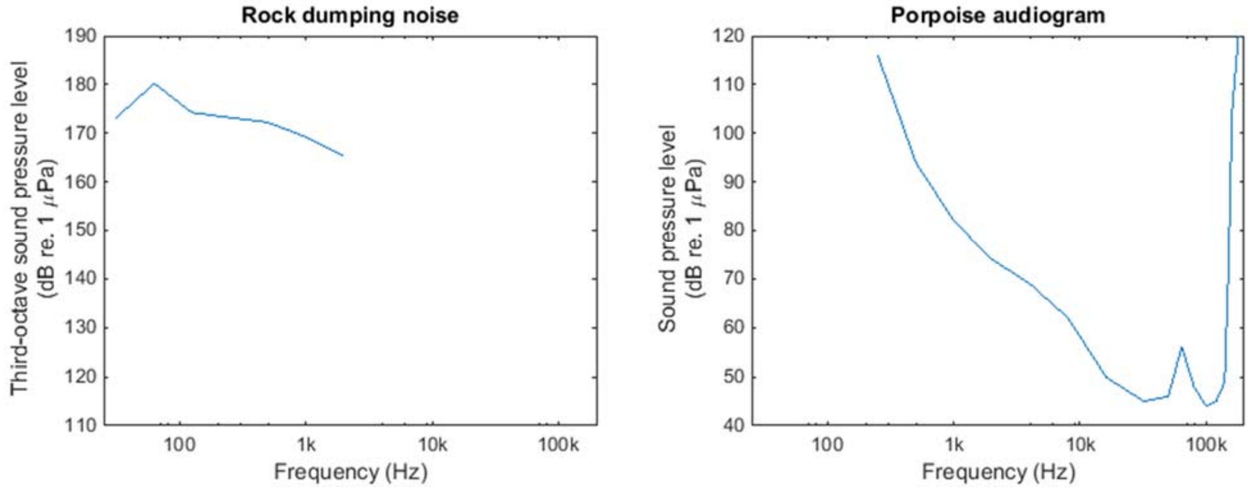

Figure 1. Left: One-octave band levels for rock dumping noise. From Maxon (2015), adjusted to third-octave levels. Right: Porpoise audiogram. From Kastelein et al. (2010).

A commonly used criterion for determining TTS-thresholds is the cumulated sound exposure level capable of inducing 3 dB of TTS. Judging from the curves in Figure 2, a precautionary threshold of 188 dB re. 1 μPa^{2}s was selected as average threshold for the 1-2 kHz sweeped signal. As the main energy of the rock dump noise is present at frequencies well below 1 kHz and thus at frequencies where the slope of the porpoise audiogram is very steep (Figure 1), this threshold based on 1-2 kHz sweeps is likely to be lower than the threshold for rock dump noise (i.e. additionally precautionary), as the audibility of the 1-2 kHz sweep to porpoises is higher than for the rock dump noise.

As evident from the above it is not straight-forward to select a TTS-threshold and quite a bit of informed expert judgment is involved in final selection. It can thus be useful to consider additional scenarios. In the context of noise from pile driving, a threshold of 175 dB re. 1 μPa^{2}s has been proposed for harbour porpoises (Skjellerup and Tougaard 2016) and even though this threshold is considered inappropriate to apply to noise from rock dumping, due to the pulsed nature of the pile driving noise, it can be instructive to include it in an additional, precautionary assessment. Adjusted threshold distances for porpoises at the two locations assessed in Swedish waters (RP2 and RP5) are shown in Table 1.

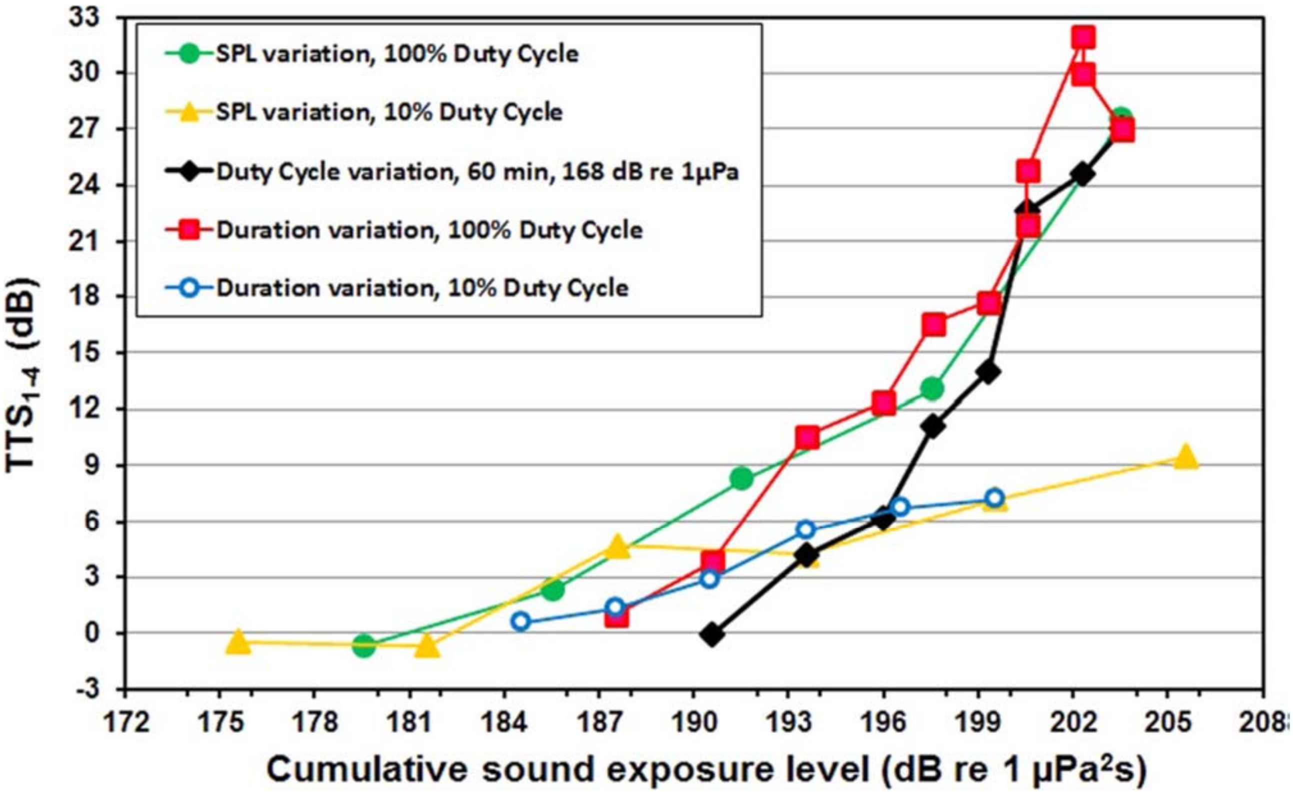

Figure 2. TTS induced in a porpoise by different levels of cumulative sound exposure and under various exposure regimes, all using frequency modulated sweeps in the range 1-2 kHz. From (Kastelein et al. 2014).

Table 1. Revised impact distances for rock placement, using a TTS-threshold for porpoises of 175 dB re. 1 μPa^{2}s, calculated under the assumption that animals remain stationary for 2 hours during exposure to the noise.

Rock placement			**RP2$_{Sweden}$**	**RP5$_{Sweden}$**
		Assessment levels	**Threshold distances (summer/winter)**	**Threshold distances (summer/winter)**
Marine group	**Effect**	**SEL$_{Cum}$ dB re 1μPa^{2}s**	**SEL$_{Cum}$ dB re 1μPa^{2}s**	**SEL$_{Cum}$ dB re 1μPa^{2}s**
Seals	PTS	200 dB	0 meters	0 meters
	TTS	188 dB	80 meters	80 meters
Porpoises	PTS	203 dB	0 meters	0 meters
	TTS	175 dB	410 meters	420 meters

Impact assessment revisited

From Table 1 it can be seen that the impact range for TTS in porpoises increases from 80 m with a threshold of 188 dB re. 1 μPa^{2}s to 410/420 m with a precautionary threshold of 175 dB re. 1 μPa^{2}s. In the original assessment (Sveegaard et al. 2017, this report) the impact from TTS on harbour porpoises was assessed as **negligible** and although the impact area is larger with the lower threshold (0.5 km^2 vs. 0.02 km^2), the likelihood that a number of porpoises will be encountered within 420 m of the rock dumping ship for the entire duration of a single rock dumping operation (set to be 2 h) is considered to be very low and hence the assessment of impact remains unaltered as **negligible**.

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Appendix 2

Memorandum from DCE – Danish Centre for Environment and Energy

Munition clearance in relation to the Nord Stream 2 project near Gotska Sandön

Expert Assessment regarding potential effects on seals

Jakob Tougaard

Aarhus University, Department of Bioscience

Draft: 2017.06.08

Preface

This memo was commissioned by Nord Stream 2 (through Rambøll Sweden) and constitutes expert assessments regarding possible effects on seals by possible clearing of unexploded munition (UXO's) in the waters off Gotska Sandön in the Swedish Baltic.

The assessments build upon exsisting knowledge, and draws on distribution data for marine mammals obtained from HELCOM as well as exsisting knowledge regarding effects on marine mammals. Assessments of impact from underwater noise is based on predictive modelling of spatial extent of noise conducted by Rambøll and documented in separate reports.

Conclusions in this memo are not intended to stand alone, but should be read in proper context of the full environmental impact assessment of the project, including the report on other potential effects of the Nord Stream 2 project on marine mammals (Sveegaard et al. 2017, this report).

Potential impact of munition clearance

The key question in this report is whether munition clearance in connection with construction of the NS2 pipeline is likely to have a negative impact on individual marine mammals as well as on the populations (i.e. on abundance and distribution), with particular emphasis on the Natura2000 area Gotska Sandön. Whether a given impact is acceptable or not is a political consideration, and is not addressed here.

Assessing the impact at the population level is often difficult unless all factors related to the population structure and abundance of the animals, as well as all other factors affecting their survival in relation to direct and indirect impacts are known. In this report, information on the animals using the impacted areas and the status of their populations are not well known. The assessment of the impacts is based on assumptions about links from immediate impact to population level consequences and hence associated with uncertainty.

Munitions have to be cleared from the seabed prior to construction to ensure a safe installation of the pipelines and this munition clearance has potentially a very large impact on marine mammals including potential casualties and permanent damage to the hearing of individuals.

Underwater explosions generate very large sound pressures with an extremely steep onset (shock wave). The peak pressure relates primarily to type and amount of explosives (higher peak pressure with higher detonation speed), but also water depth of the detonation is of importance (the deeper the water depth where the explosion is, the higher peak pressures are generated) and the chemical condition of the munition. The frequency spectrum of noise pulses from explosions is dominated by energy at low frequencies, also with a dependence on charge size. See e.g. Urick (1983) for methods to estimate peak pressure and power density spectrum from charge type and depth. An example spectrum from measurements on an actual explosion is shown in Figure 1 . The peak energy is at very low frequencies, around the 63 Hz octave band and drops steeply with about 10 dB/octave at higher frequencies. The spectrum is also affected by charge weight and water depth (Urick 1983).

Under optimal conditions the noise from an explosion can be transmitted over distances of hundreds of kilometres due to the low frequency content and high source level. Actual transmission range depends, as with other types of sound, on the bathymetry, hydrography and sediment types at and around the detonation site. Transmission of noise from explosives is effectively reduced in shallow waters (tens of meters or shallower) due to the poor propagation of low frequencies in shallow water (Urick 1983).

The duration of a single explosion is less than a second, which means that for single explosions the main concern relates to immediate damage to tissue and hearing, whereas effects on for example behaviour is limited. Repeated explosions in the same area can change this and the cumulative effect of damage and behavioural disturbances must be considered in those situations.

A considerable number of unexploded mines can be expected to be encountered along the proposed corridor of NSP2, in particular in Finnish and Russian waters, but also where the NS2 pipeline corridor crosses known WW2 mine lines in the waters east of Gotland and Öland.

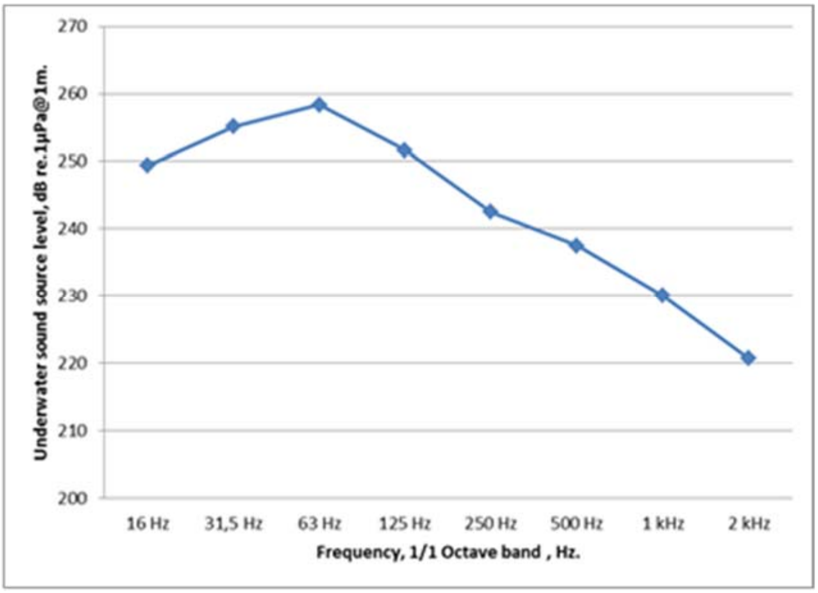

Figure 1 Example of frequency spectrum of the pulse generated by an underwater explosion. Source levels expressed as octave band levels back-calculated to a distance of 1 m from the explosion (actual measurements, from Rambøll 2016).

Assessment methodology

The overall aim of the assessment is to determine the significance of the potential impact. This is done by combining the sensitivity of the receptor with the magnitude of the impact (Table 1) and follows the methodology used in the overall assessment of effects on marine mammals (Sveegaard et al. 2017, this report).

Table 1 Indicative table of the methodology to evaluate overall significance of an impact (From Rambøll 2016a). Negative impacts to the left, positive impacts to the right.

Impact significance		Impact magnitude						
		High	Medium	Low	None or negligible	Low	Medium	High
Sensitivity of receptor	Low	Moderate	Minor	Minor	None or negligible	Minor	Minor	Moderate
	Medium	Major	Moderate	Minor	None or negligible	Minor	Moderate	Major
	High	Major	Moderate	Moderate	None or negligible	Moderate	Moderate	Major

The impacts of munition clearance has been assessed at two different scales:

1. Significance at the population level in relation to distribution and abundance.
2. Significance at the individual level: although injury to or death of individual seals may not impact populations and the environment significantly, individual injuries to or deaths of large mammals may have profound ethical implications.

Cumulative impact from repeated exposures to explosions can be assessed both at the level of individuals (of particular importance for TTS/PTS and behavioural reactions) and at the population level. Cumulative impact at the population level arises because for each additional explosion, there will be a risk that one or more animals are injured by the noise and thus even if a single explosion is assessed to have insignificant impact on the population, the cumulated risk will at some point become so large that the impact must be considered above insignificant. However, as it appears unlikely that a large number of mines are encountered and needs to be detonated in Swedish waters the cumulative impact has not been assessed.

Seal species of relevance

Three species of seals are found regularly in the Swedish Baltic: harbour seal, grey seal and ringed seal (see baseline report Teilmann, Galatius, and Sveegaard 2017 for in depth coverage).

Harbour seal (*Phoca vitulina*)

In the Baltic proper, east of Bornholm, harbour seals are only found locally in the southern part of Kalmarsund. They are thus not of relevance for munition clearance taking place in the waters north-east of Gotland.

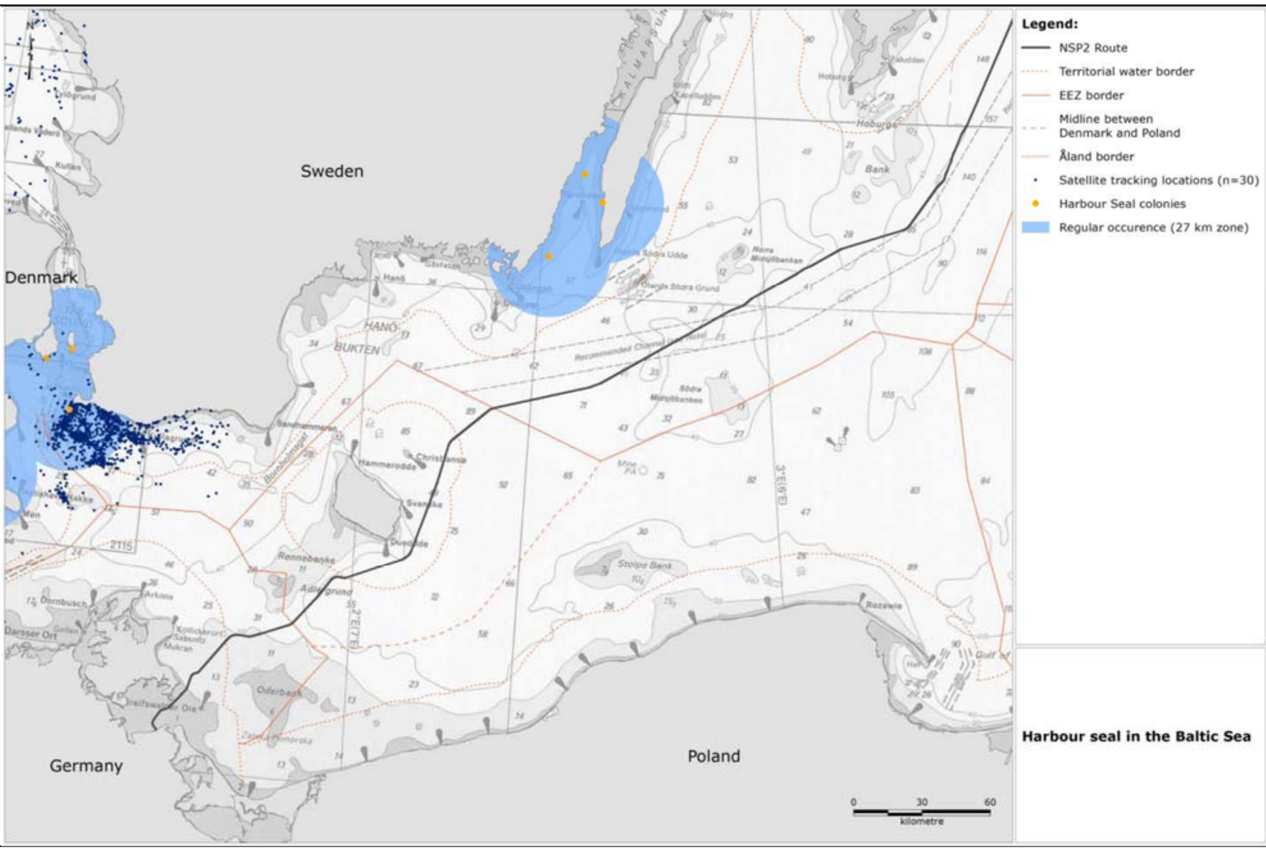

Figure 2 Map of haul-out sites (colonies) in the Baltic used by harbour seals for resting, breed-ingand moulting. Only sites used by seal populations in Kalmarsund and the south-western Bal-tic are included. The zone of regular occurrence (blue areas) was estimated from the maximum distance animals moved from the tagging. Dark blue dots indicate positions of tagged seals. From (Teilmann et al. 2017).

Grey seal (Halichoerus gryphus)

Grey seals are present in the entire Baltic, as indicated in Figure 3. The distribution shown on the map is biased by the tagging sites in the western Baltic (Denmark and Skåne) and Estonia. Known grey seal haulouts are found on Gotska Sandö and the northern tip of Gotland.

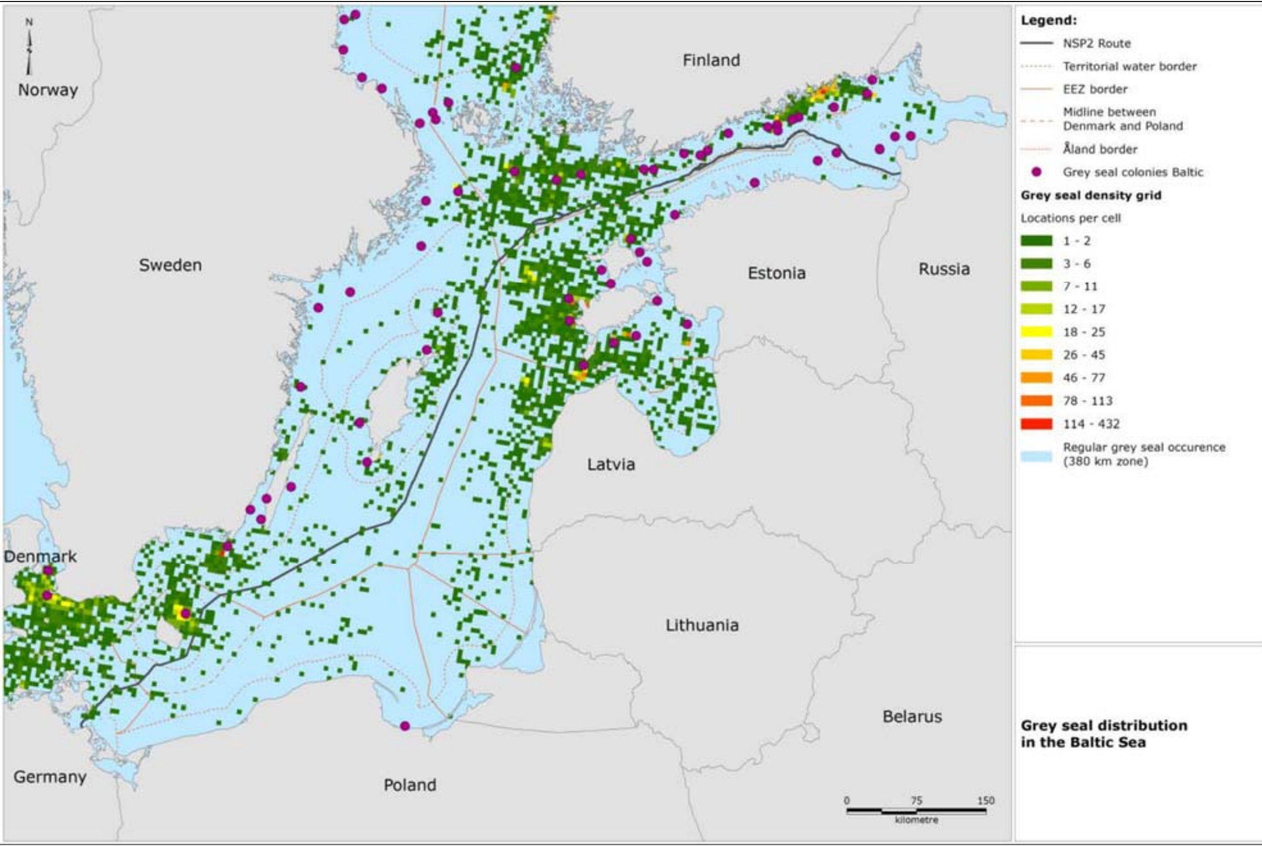

Figure 3 Map of haulout sites (colonies) used by grey seals for resting, breeding and moulting, zone of regular occurrence and density grid.The zone of regular occurrence is taken as the maximum distance moved from tagging sites and covers the entire Baltic (blue). Grey seal density is indicated as number of locations from GPS tracked grey seal per grid cell. Note that the distribution is biased by the sites where seals were tagged and thus does not show the distribution of the whole population. From (Teilmann et al. 2017).

Ringed seal (*Phoca hispida*)

Ringed seals are predominantly found near the breeding sites in the Gulf of Riga, Gulf of Finland and Bothian Bay, but can be found offshore in waters as far west and south as Gotland.Thus, although Gotska Sandö is not an important haulout site for ringed seals, they can be expected to be encountered in the waters east of Gotland.

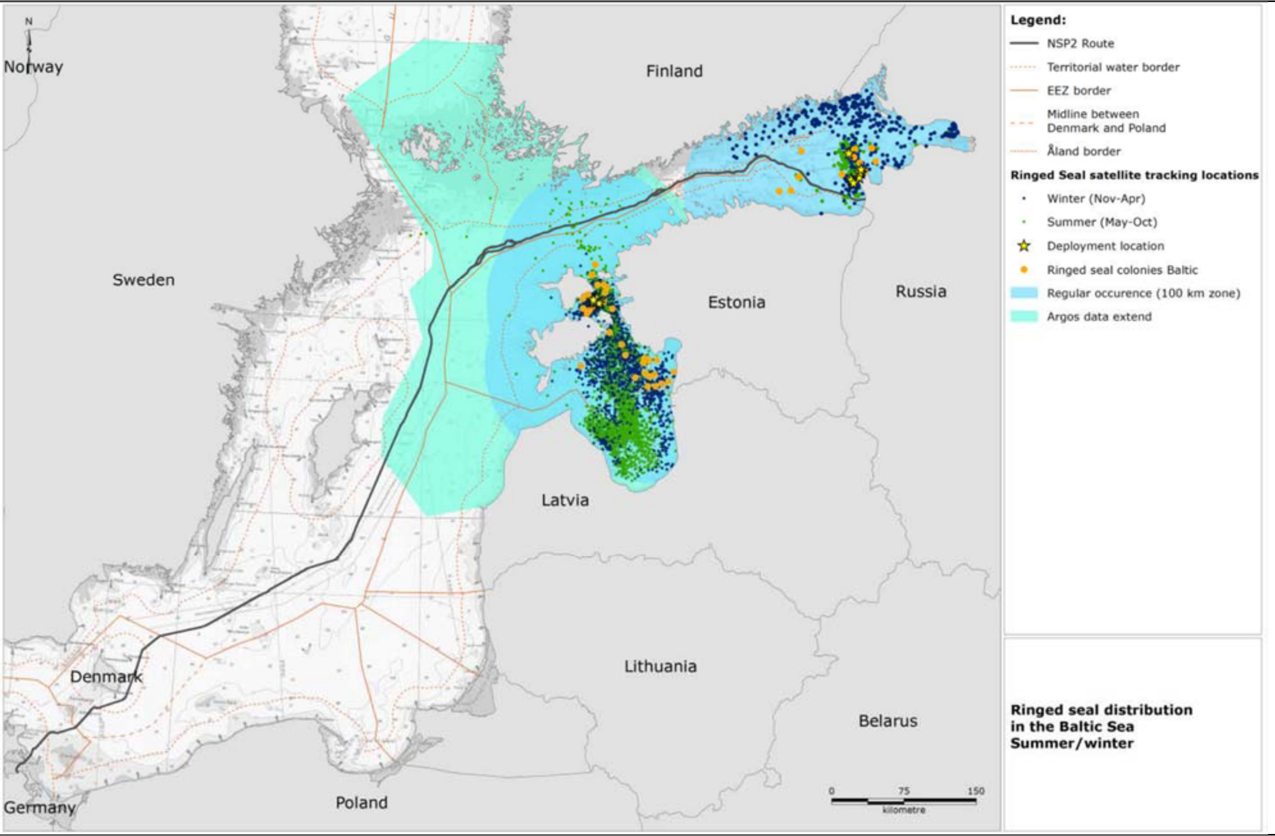

Figure 4 Map of haul-out sites (colonies) used by ringed seals for resting, breeding and moulting and satellite derived positions of tagged individuals. Regular occurrence is displayed as 100 km zones around each colony, based on estimated home range size. There is a strong bias in the telemetry data towards the tagging sites in inner Gulf of Finland and nortern Gulf of Riga (indicated by stars). From (Teilmann et al. 2017

Sensitivities of marine mammals to underwater explosions

Underwater noise is well known as a source of impact on the marine ecosystem, including marine mammals (e.g. Tyack 2009; National Research Council 2005). This impact can occur through a number of processes and usually three main issues are considered:

- Physical injury (incl. blast injury) and hearing loss (incl. PTS/TTS)
- Disturbance of animal behaviour
- Masking of relevant sounds to the animal

In addition to the above three issues are more general physiological reactions to noise such as elevated stress hormone concentrations in the blood following exposure to loud noise (Romano et al. 2004) and possibly also cronic stress due to long term exposure. However due to the limited number of experimental studies physiological impacts are most often excluded from impact assessments. A fourth type of impact is also often considered: the zone of audibility (Richardson et al. 1995), which is simply the zone where the noise is audible above ambient noise. However, the fact that a noise can be heard does not by itself imply an impact and is thus not considered further in this context.

In terms of severity, there is a gradual transition from temporary heearing loss (TTS) over permanent hearing loss (PTS) to acoustic trauma and tissue damage (Figure 5). Some authors, such as von Benda-Beckmann et al. (2015), provide estimates of these transition borders, aligned along a common SEL axis. As acoustic trauma appears to be better correlated with acoustic impulse than SEL (Yelverton et al. 1973; Lance et al. 2015) this direct alignment along a common axis is considered very difficult from a quantitative point of view and has thus not been attempted. In the end, only three levels, translated into impact ranges, are thus considered: Onset of TTS, Onset of PTS and onset of tissue damage. It is important to keep in mind that the effects are graded and not discrete and that thresholds are statistical too. Thus at sound exposures right around the threshold for TTS as an example, there is an increased risk that some animals will develop small amounts of TTS and as the sound exposure increases, the risk and the severity of the TTS increases.

Blast injury

At close range the shock wave from an explosion can cause tissue damage. Tissue damage arises because of differential acceleration of tissue with different density and can thus literally tear tissue apart, leading to anything from insignificant small bleedings to death. The relevant metric used to judge the risk of tissue damage is *acoustic impulse*, measured in Pa·s (see footnote**[1]**) and is effectively the time integral of the positive pressure pulse of the shock wave. Exposure limits have been determined by Yelverton et al. (1973) through a series of experiments with live sheep and

[1] Note that this unit is different from the unit for acoustic pressure (Pa) and the unit for Sound Exposure Level (SEL, Pa^2s). These units are not related in simple ways and it is thus not possible to convert between them in a simple way and hence also not permissible to compare them directly. This also means that the extent of the blast injury zone must be modelled separately from the TTS/PTS-zones, described in section 0. An example of such modelling is shown in section 0.

dogs submerged in a lake. As the most significant factor for scaling impact from one animal to another appears to be the lung volume the thresholds are considered to be transferable to small marine mammals, such as seals and porpoises. Yelverton et al. (1973) derived four limits, listed in Table 7-1.

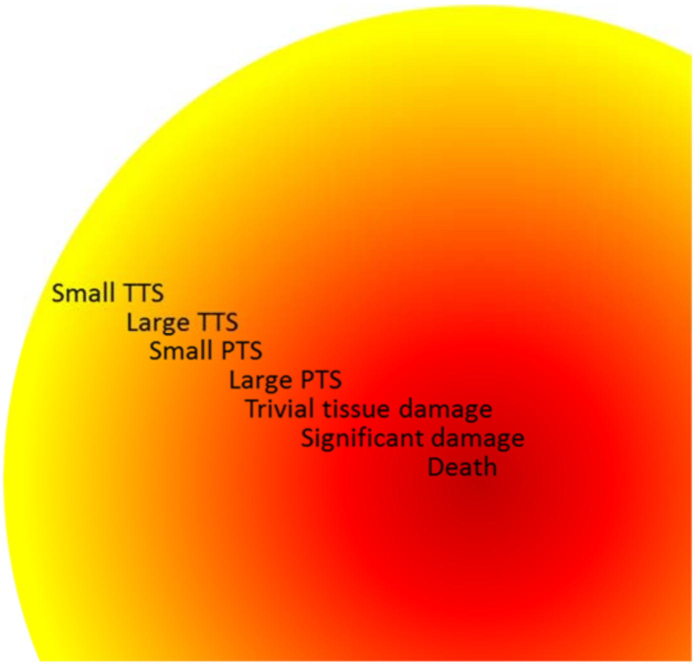

Figure 5 *Schematic severity scale, away from sound source. The exact distribution of transitions away from the center depends critically on the type of sound involved and is not to scale. Note that the area exposed to low levels is much larger than the area exposed to high levels.*

Table 2 *Blast injury thresholds for mammals. From* Yelverton et al. (1973). Note that harbour porpoises, as all cetaceans, have no functional ear drum.

Acoustic impulse	**Description**
280 Pa·s	No mortalities, but frequent incidence of moderately severe blast injuries, including ear drum rupture. Animals considered capable of recovering on their own.
140 Pa·s	High incidence of slight blast injuries, including ear drum rupture.
70 Pa·s	Low incidence of trivial blast injuries. No ear drum rupture.
35 Pa·s	Safe level

A recent review and compilation of a large number of human medical cases involving blast injury (Lance et al. 2015) reviewed safety limits for human divers. This study included a sufficient number of cases to derive proper risk functions (475 individual exposures, dating back to WW2, a substantial number of which were fatal). The resulting thresholds for a 10% chance of (recoverable) injury and fatal injury was 30 Pa·s and 240 Pa·s, respectively. The injury threshold thus corresponds well with that of Yelverton et al. (1973), whereas the threshold for fatal injuries is substantially lower than what can be derived from Yelverton et al. (1973), as it is comparable to the latters threshold for moderately severe, but survivable injuries. It is unknown to what degree the human data (Lance et al. 2015) and the data from dogs and sheep (Yelverton et al. 1973) can be compared and which of the two datasets is best transferable to marine mammals.

Figure 6 shows an example of estimation of a blast injury zone around a 300 kg mine detonated at 40 m depth, illustrating that the blast injury zone can extend many kilometers out from the blast site.

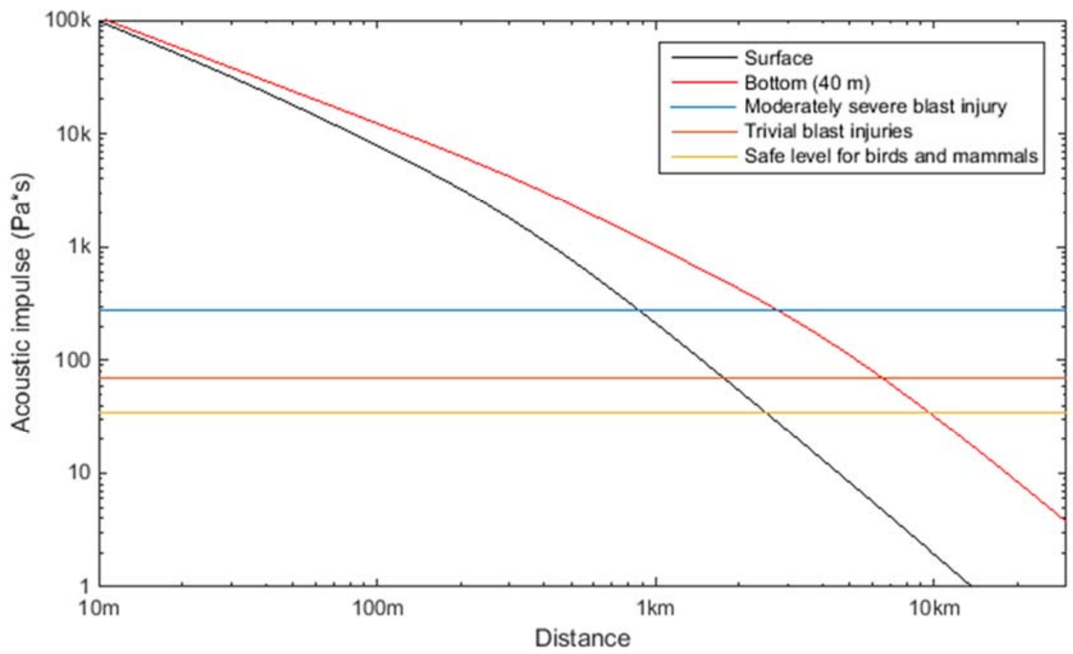

Figure 6 *Example of estimated acoustic impulse with range for a 300 kg detonation (mine + donor charge) at the bottom at a depth of 40 m. Black line is for animals at the surface, red line close to the bottom. Three horizontal lines indicate the injury thresholds defined by Yelverton et al. (1973). A worst case scenario is assumed in which the total charge explodes together with the donor charge and that the explosion is with access to open water (directly on the sea bed). Predictions and injury thresholds from Yelverton et al. (1973).*

Hearing threshold shift (TTS/PTS)

For marine mammals it is generally accepted that the auditory system is the most sensitive organ to acoustic injury, meaning that injury to the auditory system will occur at lower levels than injuries to other tissues (see e.g. Southall et al. 2007). Furthermore, noise induced threshold shifts are likewise accepted as precautionary proxies for more widespread injuries to the auditory system. Noise induced threshold shifts are temporary reductions in hearing sensitivity following exposure to loud noise (For example commonly experienced by humans as reduced hearing following rock concerts etc.). Temporary threshold shifts (TTS) disappear with time, depending on the severity of the impact. Small amounts of TTS will disappear in a matter of minutes, extending to hours or even days for very large TTS. A schematic illustration of the time course of TTS is shown in Figure 7. The amount of TTS immediately after end of the noise exposure is referred to as initial TTS. It expresses the amount by which the hearing threshold is elevated and is measured in dB. The larger the initial TTS, the longer the recovery period.

At higher levels of noise exposure the hearing threshold does not recover fully, but leaves a smaller or larger amount of permanent threshold shift (PTS), see Figure 7. This permanent threshold shift is a result of damage to the sensory cells in the inner ear (Kujawa and Liberman 2009). An initial TTS of 50 dB or higher is generally considered to constitute a significantly increased risk of generating a PTS (Ketten 2012). Lower levels of TTS can, if repeatedly induced, also lead to PTS (Kujawa and Liberman 2009), which is also well known in humans. This cumulative effect has, however, not been included in the assessment, as there is no experimental evidence from marine mammals that can help quantify this effect.

In order to evaluate the output of the exposure model in terms of impact on animals, it is required to have thresholds for TTS and PTS to compare against. Deriving such has been the subject of a large effort from many sides (see reviews by Finneran 2015; Southall et al. 2007). No current consensus on general thresholds for TTS and PTS can be said to exist. Matters are simplified somewhat, however, if one restricts to only one type of sound, such as airgun noise or pile driving noise and limits the discussion to only species for which sufficient data is available. A comparatively large effort has gone into investigating TTS caused by low frequency noise, including from pile driving, in harbour seals and harbour porpoises, as these species are key species in many impact assessments. TTS is in general localised to frequencies around and immediately above the frequency range of the noise which caused the TTS. This means that TTS induced by low frequency noise typically only affects the hearing at low frequencies (Kastelein et al. 2013).

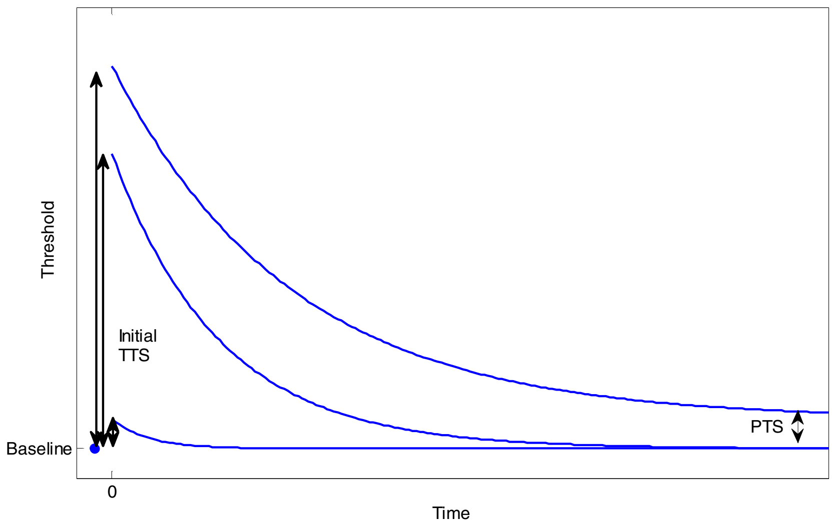

Figure 7 *Schematic illustration of the time course in recovery of TTS. Zero on the time axis is the end of the noise that caused the TTS (often referred to as the fatiguing noise). Gradually the threshold returns to baseline level, except for very large amounts of initial TTS where a smaller permanent shift (PTS) may persist. From Skjellerup et al. (2015). As the figure is schematic, there are no scales on the axes. Time axis is usually measured in hours to days, whereas the threshold shift is measured in tens of dB.*

As PTS thresholds for ethical reasons cannot be measured deliberatly in experiments, the agreed approach to estimate thresholds for PTS is by extrapolation from TTS thresholds to the noise exposure predicted to induce 50 dB of TTS and thus a significant risk of PTS. This extrapolation is not trivial, however, as it is complicated by the fact that the relationship between exposure and amount of initial TTS is not proportional (see e.g review by Finneran 2015). Thus, one dB of added noise above the threshold for inducing TTS can induce more than one dB of additional TTS, see Figure 8.

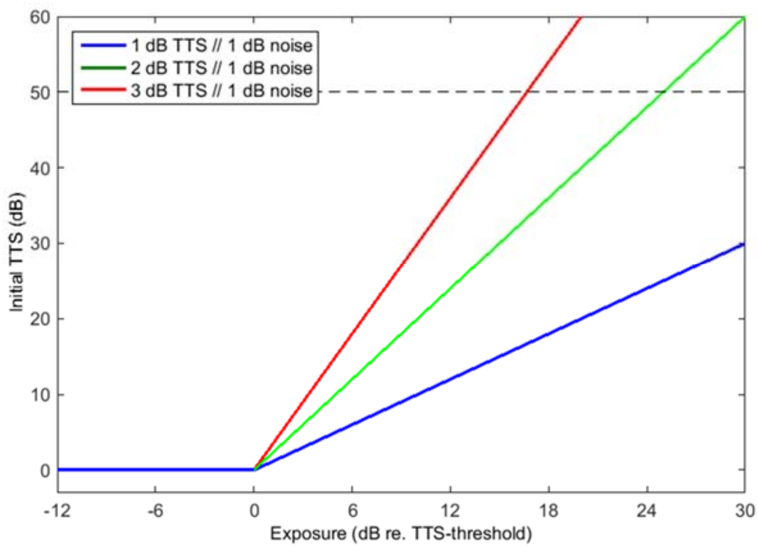

Figure 8 *Schematic illustration of the growth of initial TTS with increasing noise exposure. Three different slopes are indicated. Note that the real curves are not necessarily linear. Broken line indicate threshold for inducing PTS, assumed to be at 50 dB initial TTS. From Skjellerup et al. (2015).*

The long-term effects of various degrees of permanent hearing loss on long-term survival and reproductive success of marine mammals is unknown and it is thus difficult to assess the population effects. As PTS is graded, there is a lower level, where the hearing loss is so small that it is without long-term consequences for the animal, but for very large hearing losses the ability of the animal to carry out its normal range of behaviours will be affected and hence its fitness lowered. As there is very limited experimental evidence on this question and the general relationship between magnitude of exposure and degree of hearing loss, even for humans. Consequently, it is not possible to quantify these relationships in a meaningful way beyond extrapolating thresholds for development of the lovest levels of PTS based on TTS thresholds, as done below. Therefore it must be stressed that there is a considerable uncertainty connected to the assessment of impact of PTS on seals and porpoises.

PTS primarily affects hearing around and slightly above the frequency range of the damaging sound, i.e. low frequencies in case of noise from underwater explosions. mainly decreases hearing of the low frequencies. All Baltic species of seals use underwater calls in the low frequency range (e.g. Bjørgesæter, Ugland, and Bjørge 2004), which means that substantial PTS in this range could reduce communication abilities of affected seals, which again potentially could impact mating behaviour, but the degree of such a potential impact cannot be assessed.

Thresholds for inducing TTS and PTS in seals

No experiments have been performed on harbour seals with single noise impulses. Instead the thresholds derived for harbour porpoises are used, i.e. 164 dB re. 1 $\mu Pa^2 s$ and 179 dB re. 1 $\mu Pa^2 s$ for TTS and PTS, respectively. See (Sveegaard et al. 2017, this report) for a detailed justification of these thresholds.

The sensitivity of seals to TTS is assessed to be **low** on both individual and population level due to the reversible and temporary nature of the impact.

The sensitivity of grey seals in the impact area to PTS is assessed to be **high** on individual level because of the potential detrimental effect and the high likelyhood that an individual will be present near a munition clearance. At a population level, sensitivity is assessed to be **low**, because, despite that the impact may be detrimental to several individuals, the population as a whole is increasing and the population is in good environmental status.

The sensitivity of ringed seals to PTS is assessed to be **high** on individual level, in the same way as for grey seals. At the population level the sensitivity is assessed to be low, because the ringed seals likely to be encountered east of Gotland are likely to be from the Estonian or Bothian populations, which are populations in favourable development (increasing).

Seasonal sensitivity

The most vulnerable periods for seals in the Baltic Sea are primarily during their moulting, breeding and lactation periods. Table 3 below summarises these vulnerable periods over a year per species on the basis of the low, medium, high sensitivity matrix used for this assessment. For more details see baseline report (Teilmann et al. 2017). **The actual sensitivity for a given activity is found as the combination of the sensitivity to the activity itself and the sensitivity related to the period**.

Table 3 *Sensitivities of seals in Swedish waters during the year. Sensitivities are judged without consideration of actual abundance of animals and thus represents the sensitivity of individuals that might be present in the relevant areas at the different times of the year, even if they are encountered only rarely.*

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Harbour seal	Med	Med	Med	Med	High	High	High	High	Med	Med	Med	Med
Grey seal	Med	High	High	Med	High	High	Med	Med	Med	Med	Med	Med
Ringed seal	Med	High	High	High	High	Med	Med	Med	Med	Med	Med	Med

Magnitude of impact from underwater noise

Transmission of underwater noise were modelled in order to estimate impact ranges for the noise and results provided by Rambøll Sweden. There are considerable differences between summer and winter, due to the different hydrographical conditions and hence sound propagating properties. Estimated maximum impact ranges and mean expected impact ranges are given in Table 4. It is evident that the extent of the TTS and PTS impact zones are considerable and extend into the waters around Gotska Sandö.

Effects of the munitions cleareance are either temporary and reversible (TTS) or permanent and irreversible (PTS, by definition). Permanent and irreversible applies only to the individual animal inflicted with PTS and the effect will thus disappear from the population whenever the affected animals eventually die. For the population the effect is thus long-term, but reversible.

For all species in the TTS/avoidance zone (164 dB) the duration is short-term and the impact magnitude is **low**.

Within the PTS zone (179 dB), impact of munition clearance is irreversible and covers a large area, up to 80 km from the NSP2 route, under worst case conditions, i.e. strong halocline and deep water. The duration is long-term, as PTS by definition is permanent. As described above it is unknown to what degree a smaller or larger permanent hearing loss will effect individual animals in terms of impact on their fitness, reproduction and communication, but it is considered unlikely that animals will be subject to hearing losses sufficiently large to affect their survival.

The impact magnitude of PTS is **medium** in all areas and for all marine mammal species on both the individual and the population level, due to the large geographical extent, the irreversible and high intensity of the impact.

Table 4 *Maximum and mean extent of the TTS and PTS zones for explosions, as estimated by Rambøll, and indicated are both maximum and mean values (based on maximum and mean sound pressure, respectively, encountered during construction of Nord Stream).*

Effect	Threshold	Winter Threshold distances		Summer Threshold distances	
	SEL_{CUM} dB re 1µPa²s	Maximum (km)	Average (km)	Maximum (km)	Average (km)
PTS	179 dB	13	8.8	18	11
TTS	164 dB	40	31	84	46

Blast injuries from munition clearance may cause fatal injuries (most notably rupture of lungs and intestines) in the vicinity of the explosion. Depending on the size of the detonation and which threshold is considered most relevant for marine mammals, thie fatal injuries may occur within some hundred meters from the explosion. Applying the thresholds of Yelverton et al. (1973) to the large explosion in Figure 6 provides an estimate of impact range for moderately severe (but survivable) injuries up to 900 m from the explosion at the surface and up to 2.8 km at the bottom and evidently a smaller range for fata injuries (no threshold given by Yelverton et al. 1973). If, instead, the thresholds for fatal injury in human divers derived by Lance et al. (2015) is applied to the large explosion in Figure 6**Error! Reference source not found.**, lethal injuries can be expected out to ranges about 1 km from the blast in the surface and 3 km at the bottom.

The impact magnitude of blast injury is **high** in all areas and for all marine mammal species on both the individual and the population level, due to the irreversible and high intensity of the impact.

Mitigation measures

During during munition clearance in connection to construction of the Nord Stream pipeline mitigation measures were implemented to reduce impact on fish and marine mammals, as described in Rambøll (2017):

"*Several measures were implemented to mitigate and monitor impacts on marine mammals, diving seabirds and fish. Visual observations were performed by marine mammal observers from one hour before the detonation to one hour after the detonation. A sonar survey to identify any fish shoals in the area was carried out by the work boat and a passive acoustic monitor was deployed into the water column to record any vocalisation by marine mammals prior to detonation. In addition to observations, four acoustic deterrents (seal scrammers) were deployed and activated prior to detonation and a small fish scarer charge detonated was before firing the main donor charge to scare away any seals or fish from the area.*"

The typical layout is illustrated in Figure 9.

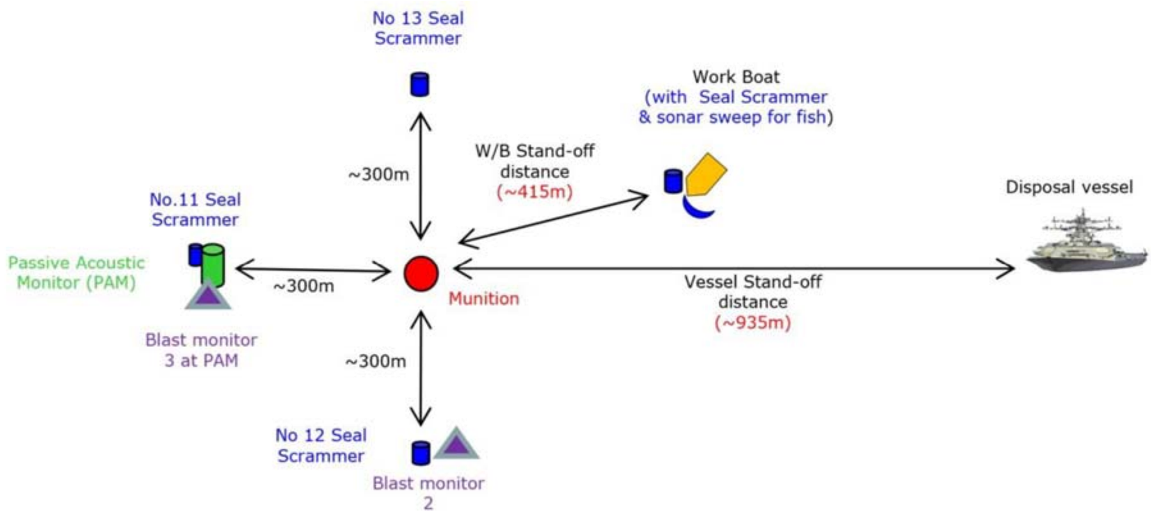

Figure 9 Layout of monitoring and mitigation equipment typically used during munitions clearance for the Nord Stream pipeline. From Rambøll (2017).

The following assessment is made under the assumption that similar mitigation measures will be implemented in case munition clearance in the Swedish Baltic is performed. Of the different measures, the use of seal scarers (scrammers) is likely to have the largest mitigating effect.

Seals react differently to seal scarers than porpoises (Götz and Janik 2014). First of all the response is strongly context dependent. The primary use of seal scarers is to deter seals from aquaculture facilities and fishing gear. Seal scarers have been reported to have very variable ability for deterrence in these situations, ranging from some deterrence to active attraction (so-called “dinner-bell”-effect). See (Königson et al. 2007; Mikkelsen, Hermannsen, and Tougaard 2015) for reviews. When used as a mitigation device for loud underwater noise the context is different and the seals are not rewarded for ignoring the loud sound by a food source (the fishing gear or net pen). There is thus several studies supporting that seals are deterred from the vicinity of seals scarers when used without food reinforcement. The Lofitech device is considered effective in deterring harbour and grey seals out to a distance of at least some hundred meters (Mikkelsen, Hermannsen, and Tougaard 2015). At further distances, out to around 1 km, the seals may not be deterred, but will change their behaviour and spend more time in the surface (Gordon et al. 2015). Using the NSP setup described above, seals would be scared away from the nearest few hundred meters of the seal scarers (which corresponds to an area with a radius of at least 500 m from the blast site, as four seal scarers were used, Figure 9) and alter their behaviour to be more surface active up to around 1300 m from the explosion site.

However, even though seals may only be displaced a few hundred meters from the seal scarer, the fact that several seal scarers are used, each about 300 m from the blast site, and that seals are likely to react to the seal scarer signals at distances up to 1 kilometre away by spending more time in the surface, will provide considerable protection for the seals for up to 1300 m from the explosion.

Assessment of impact of underwater noise

The overall significance of an impact is a combination of sensitivity and impact magnitude.

Grey seals

Grey seals are abundant on haul out sites on, and in the waters around Gotska Sandö. The grey seals in the Baltic are considered to belong to one population. The population is abundant, has been increasing in numbers and is not considered threathened.

The sensitivity to TTS is assessed as low and the impact magnitude is also low. Thus, the overall significance are assessed to be **minor** on both individual as well as population levels since the impacts will be temporary and most likely only affect a small proportion of the population. TTS can occur at considerable distance from the blast site, i.e. well beyond the reach of the seal scarers used for mitigation. This means that the risk of inflicting TTS on marine mammals is largely unaffected by the use of seal scarers.

The sensitivity to PTS is high on the individual level and the impact magnitude is medium. The overall significance is thus assessed to be **moderate**. Deterrence of seals prior to munitions clearance will also have substantial effects on the number of animals likely to suffer permanent hearing loss (PTS) but only in a relative small area compared to both the average and maximum extend of the PTS zones. However, due to the exponential (on average) decrease in sound pressure level with distance from the blast site, the exclusion of seals from the innermost area around the blast site will significantly reduce the number of animals which would acquire severe PTS. On the other hand, as far more animals are likely to be exposed at larger distances, the overall number of animals acquiring PTS will not be reduced very much by the seal scarers. Consequently, the suggested mitigation measure of using seal scarers is considered not to change the assessed significance, which thus remains moderate.

The sensitivity to PTS is low on population level and the impact magnitude is medium. The overall significance is thus assessed to be **minor**.

The sensitivity to blast injuries is considered high on the individual level, since seals will be injured and possibly die. The unmitigated impact magnitude is also high and the overall significance is thus assessed to be major. Mitigation measures, more specifically seal scarers, however, will greatly reduce the risk that marine mammals are very close when the explosion occurs and thus also reduce the risk that they suffer significant blast injury or death due to exposure to the shock wave from the explosion, reducing the significance to **minor**.

Lethal blast injuries can reduce the number of grey seals and hence impact the population. However, the Baltic population of grey seals is abundant and has been increasing over the last decades. The sensitivity to blast injuries is therefore considered low at the population level and the overall significance is thus **minor**.

Ringed seals

Ringed seals can potentially be found everywhere in the northern Baltic, but with higher densities along the eastern parts and in the Bothnian Bay.

The sensitivity of ringed seals to TTS as well as the impact magnitude of TTS is assessed to be low, and the overall significance is thus **minor** on individual as well as population levels since the impact is temporary.

The sensitivity to PTS is high on the individual level and the impact magnitude is medium. However, the expected density of ringed seals in the Swedish part of the Baltic is considered low and the overall significance is thus assessed to be **low**. Deterrence of seals prior to munitions clearance will also have substantial effects on the number of animals likely to suffer permanent hearing loss (PTS) but only in a relative small area compared to both the average and maximum extend of the PTS zones. However, due to the exponential (on average) decrease in sound pressure level with distance from the blast site, the exclusion of seals from the innermost area around the blast site will significantly reduce the number of animals which would acquire severe PTS. On the other hand, as far more animals are likely to be exposed at larger distances, the overall number of animals acquiring PTS will not be reduced very much by the seal scarers.

The sensitivity to PTS is low on population level and the impact magnitude is medium. The overall significance is thus assessed to be **minor**.

Sensitivity to blast injury on the individual level as well as the impact magnitude is assessed as high. The unmitigated impact magnitude is also high and the overall significance is thus assessed to be major. Mitigation measures, more specifically seal scarers, however, will greatly reduce the risk that marine mammals are very close when the explosion occurs and thus also reduce the risk that they suffer significant blast injury or death due to exposure to the shock wave from the explosion, reducing the significance to **minor**.

The sensitivity to blast injury is low on the population level and the impact magnitude is medium. The overall significance is thus assessed to be **minor**.

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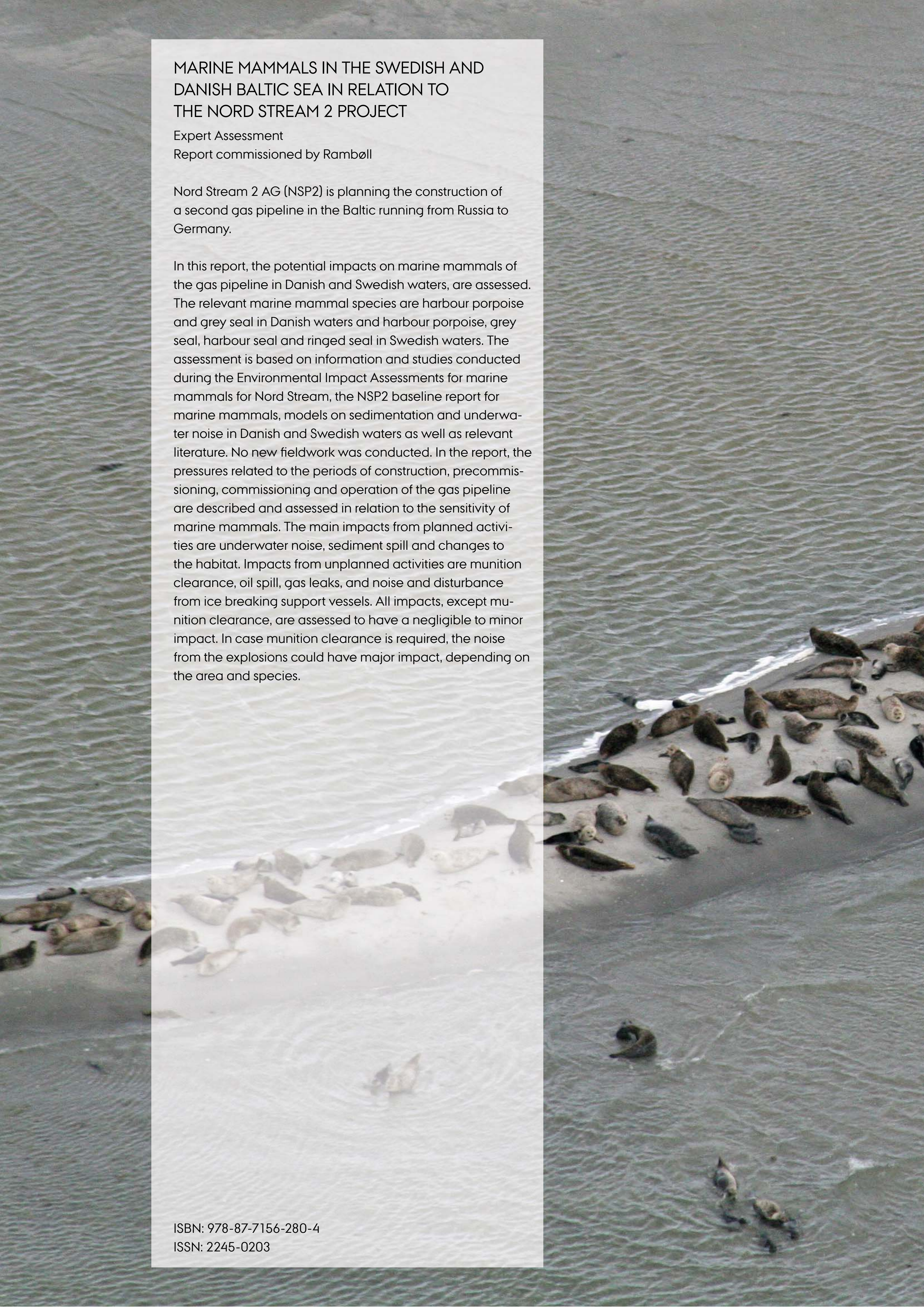

MARINE MAMMALS IN THE SWEDISH AND DANISH BALTIC SEA IN RELATION TO THE NORD STREAM 2 PROJECT

Expert Assessment
Report commissioned by Rambøll

Nord Stream 2 AG (NSP2) is planning the construction of a second gas pipeline in the Baltic running from Russia to Germany.

In this report, the potential impacts on marine mammals of the gas pipeline in Danish and Swedish waters, are assessed. The relevant marine mammal species are harbour porpoise and grey seal in Danish waters and harbour porpoise, grey seal, harbour seal and ringed seal in Swedish waters. The assessment is based on information and studies conducted during the Environmental Impact Assessments for marine mammals for Nord Stream, the NSP2 baseline report for marine mammals, models on sedimentation and underwater noise in Danish and Swedish waters as well as relevant literature. No new fieldwork was conducted. In the report, the pressures related to the periods of construction, precommissioning, commissioning and operation of the gas pipeline are described and assessed in relation to the sensitivity of marine mammals. The main impacts from planned activities are underwater noise, sediment spill and changes to the habitat. Impacts from unplanned activities are munition clearance, oil spill, gas leaks, and noise and disturbance from ice breaking support vessels. All impacts, except munition clearance, are assessed to have a negligible to minor impact. In case munition clearance is required, the noise from the explosions could have major impact, depending on the area and species.

ISBN: 978-87-7156-280-4
ISSN: 2245-0203