Intended for
Nord Stream 2 AG

Date
September 2017

Document number
W-PE-EIA-PSE-REP-805-DCERESEN-01

Report prepared by: DCE/Institute for Bioscience, Aarhus University

NORD STREAM 2
IMPACT OF THE NSP2 GAS PIPELINE ON HARBOUR PORPOISES WITHIN THE NATURA 2000 SITE “HOBURGS BANK OCH MIDSJÖBANKARNA”

Response to comments made by to Swedish Authorities on the possible impact of Nord Stream 2 on marine mammals in the Swedish Baltic sea

IMPACT OF THE NSP2 GAS PIPELINE ON HARBOUR PORPOISES WITHIN THE NATURA 2000 SITE "HOBURGS BANK OCH MIDSJÖBANKARNA"

Revision **01**
Date **September 2017**

Document ID W-PE-EIA-PSE-REP-805-DCERESEN-01
Reference 1100019533 / PO16-5068

Revision Record:

Revision	Date	Description	Made by	Checked by	Approved by (discipline lead)	Approved by (Project Manager)
01	01.09.2017	Final	Jakob Tougaard, Signe Sveegaard	Susanne Boutrup		

Report prepared by: DCE/Institute for Bioscience, Aarhus University

Note from DCE – Danish Centre for Environment and Energy

Impact of the NSP2 gas pipeline on Harbour porpoises within the Natura 2000 site "Hoburgs Bank och Midsjöbankarna"

Response to comments made by to Swedish Authorities on the possible impact of Nord Stream 2 on marine mammals in the Swedish Baltic sea

Jakob Tougaard
Signe Sveegaard

Aarhus University, Department of Bioscience

Date: 2017.09.01

Quality assurance: Susanne Boutrup (DCE)

1. Background and scope

The Environmental Impact Assessment (EIA) for the gas pipeline Nord Stream 2, proposed for construction in the Baltic Sea, is currently submitted to the national authorities. During this process, a number of questions have been raised by different authorities in Sweden. Some of these relate to possible negative effects of construction and operation of the pipeline on marine mammals. The objective of this memo is to answer these questions in accordance with the latest scientific knowledge on Baltic marine mammals and potential anthropogenic impact on these as well as new calculations of this impact. This memo should not be read in isolation, but be seen as an extension of the EIA and in particular the background reports on marine mammals (Sveegaard *et al.* 2016; Teilmann *et al.* 2017)

The issues raised with respect to the Swedish part of Nord Stream 2 are described in opinion letters given by the Swedish authorities (Gotland, Kalmar and Skåne Counties, and SwAM), dated between June 1st and 5th. Concern is raised with respect to possible impact on harbour porpoises in one existing Natura 2000 site “Sydvästskånes Utsjövatten” and one proposed Natura 2000 site “Hoburgs Bank och Midsjöbankarna”. As “Sydvästskånes Utsjövatten” is located more than 37 nautical miles from the proposed pipeline and thus unlikely to be affected by the pipeline, only the area Hoburgs Bank and Midsjöbankarna will be dealt with here. In the following, it is often referred to simply as “the Natura 2000 site”.

Three different types of impact on harbour porpoises are described in the opinion letters:

- Possible “barrier effect” from noise and vibrations during operation of the pipeline
- Repeated disturbance of the individuals’ natural behavior
- Masking of communication and other sounds by underwater noise

Numbering is used for reference only and is not an indication of priority or otherwise a measure of severity of impact. The letters also indicate problems with increased sediment spill and turbidity. For this we refer to the assessment for marine mammals (Sveegaard *et al.* 2016), as no new scientific knowledge has become available and the conclusions from the EIA are thus still valid.

The possible impacts are discussed in the sections below. The main geographical area of concern is the above-mentioned Natura 2000 site, although much of the discussion below regarding impact are of a general nature.

This assessment is mainly relevant if the schedule of the planned construction activity is performed during the summer period (a worst case period, where harbour porpoises breed and congregate in the Natura 2000 site. However, the currently proposed scheduling of the construction activities within the Natura 2000 area is from late 2018 to early 2019 i.e. outside the breeding season of harbour porpoises.

2. Relevant sections of opinion letters

Below are central excerpts from the opinion letters, relevant for marine mammals.

Länsstyrelsen Skåne:

"Appendix 9 [to the EIA] describes that noise from the pipeline is only audible to marine mammals very close to the pipeline and that the effect is irreversible, long lasting, but local. Although the assessment is that the intensity and magnitude of the sound is low, there is no analysis of whether the pipeline in operation can be expected to have a barrier effect on the movement and distribution of the different species."
(Own translation).

This concern relates to a possible "barrier effect" from noise and vibrations during operation of the pipe line (listed as the first point above) and is discussed in section 4 below.

Länsstyrelsen Gotland

"Noise from the pipe lay work is not considered as the largest challenge when it comes to the risk of permanent or temporary hearing loss. The authority would like to stress the fright effect that occurs at much lower noise levels is a far greater threat to the harbour porpoises, and needs to be taken into consideration. The most trafficked shipping lane lies west of the Natura 2000 area, while the pipe lay simultaneously will be ongoing east of the area, with scheduled pipelay vessel traffic between the banks. Given the cumulative impact of underwater noise, the authority is worried that the pipelay phase, which overlaps with important periods in the life cycle of the harbour porpoise, will disturb them to such an extent that they will avoid large parts of the area. This could in turn have a negative impact on the population level. The authority underlines that the mating season (June-Aug) is a period when the harbour porpoise is particularly sensitive to underwater noise that could mask their communication."
(Translation provided by the County Administrative Board)

Two concerns are raised here: the repeated disturbance of the natural behaviour of porpoises, caused by construction ships (listed as point 2 above), and possible masking of communication and other sounds by underwater noise, also from the ships (listed as point 3 above). These are treated below in sections 5 and 6, respectively.

SwAM

"SwAM considers that the pipelay in the proposed extension of the Natura 2000 area during the harbour porpoises' sensitive period should be avoided. The months that are the most adequate for the pipelay, and post-lay works are Nov through March.
…
SwAM does not consider that the activities are likely to cause physical harm on the individuals [porpoises], but considers that they could disturb their behaviour. Repeated disturbance of the individuals' natural behaviour, such as feeding trials, communication or suckling, could reduce the viability of individuals. Studies have for instance shown that the communication distance between the female and the calf could be negatively impacted by underwater noise. Underwater

noise could mask other noise in the vicinity, which could be of importance to the harbour porpoise to listen to.
...
SwAM considers that even short-term disturbance on a few individuals could harm the entire population in this case, as each individual should be attributed an equal value."
(Translation provided by Nord Stream 2)

The concerns raised here are essentially identical to the issues raised by Länsstyrelsen Gotland and are thus treated below in sections 5 and 6.

Länsstyrelsen Kalmar

"The planned pipeline will stretch through an area between Northern and Southern Midsjöbanken ... considered to be an important gathering area for harbour porpoises, and their most important area for mating.
...
The construction-related works such as pipe lay, trenching and rock placement will cause underwater noise that could impact marine mammals in different ways: they could for instance create physical damage and damage on the auditory system, disturb the animals' behaviour and mask other sounds.
...
Considering the cumulative impacts of underwater noise the authority considers that there is a high risk that harbour porpoise will try to avoid the area where activity is ongoing due to high noise levels. Even if the risk of permanent and temporary hearing impairment is not expected to be very high, the fright effect occurring at very low noise levels should be taken into consideration."
(Translation provided by Nord Stream 2)

Three different concerns are raised here: auditory damage, disturbance and masking. Auditory damage has been dealt with in the EIA and the background report, Sveegaard *et al.* 2016 and is not dealt with further here. Disturbance and masking are discussed below in sections 5 and 6, below.

3. Brief description of the NSP2 project (relevant activities only)

The construction of the NSP2 pipeline within the Natura 2000 site will involve the following planned activities that may potentially have a potential impact on harbour porpoises:

- Increased vessel traffic
- Pipelaying
- Post-lay trenching
- Rock placement

It is important to note, that NSP2 does not expect the need for any munitions clearance within the proposed Natura 2000 area. The project has taken extra measures to minimise the risk of munitions clearance in the area, e.g. via applying for a wide corridor that allows for routing around such objects and via the use of a Dynamically Positioned (DP) lay barge. If munition clearance will be performed in the proposed Natura 2000 area a separate impact assessment will have to be made, as it is not included here.

The currently proposed scheduling of the construction activities within the Natura 2000 site is from late 2018 to early 2019 i.e. outside the breeding season of harbour porpoises and outside the summer period when porpoises congregate in the N2000 site. However, this assessment considers a worst case scenario, where construction is undertaken during summer.

Planned construction activities in Swedish waters will be limited in both its temporal and spatial extent at any specific location. An overview is provided in Figure 1.

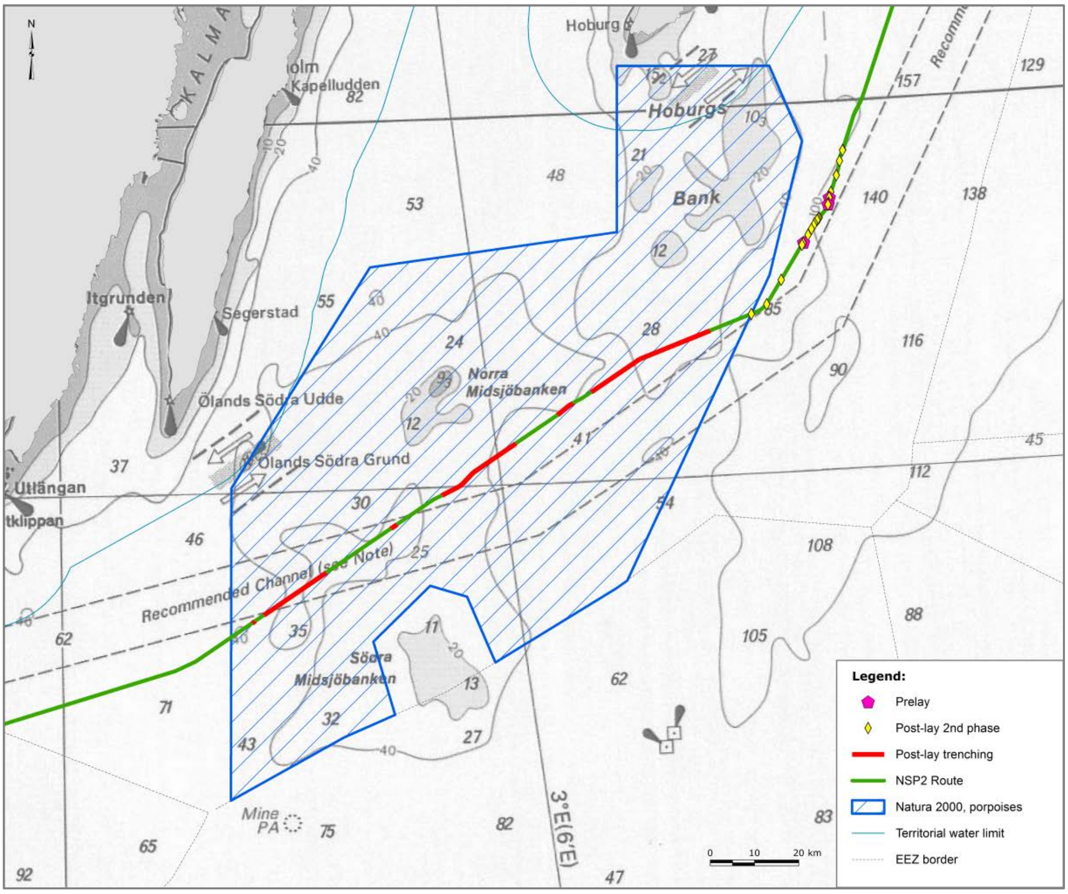

Figure 1 Overview of the planned activities in the Swedish part of the Baltic, along the route of the pipeline. The new extended Natura 2000 site Hoburgs Bank och Midsjöbankarna is indicated.

Vessel traffic

For NSP2, it is planned that an average of four supply vessels per day will sail to the offshore construction site during pipelay (including pipe supply).

During NSP1, pipelay was undertaken with an anchor handling pipelay vessel, and during this period 12 other vessels took part in the operation. NSP2 will use Dynamically Positioned Vessels which will use less involved vessels.

During NSP1 Slite on Gotland and Karlskrona was used as a supply base for pipes. That is not the case for NSP2 where pipes will be supplied mainly from Karlshamn. However, the number of vessels will be about the same. In case rock placement is needed then it will only be one vessel due to the limited amounts needed in or close to the area.

As described above, the vessel traffic during pipelay is comparable or less than the number of vessels used during NSP1 in the area of the new extended Natura 2000 site Hoburgs Bank och Midsjöbankarna and we can thus use the NSP1 AIS data as a conservative estimate of predicted NSP2 vessel traffic. During NSP1 an average of 3.3 vessels per day where used in 2011 and 2012. The number of vessels used did, however, vary across the year with 80% of the vessel traffic being deployed during pipelaying (anchor pipelaying vessel, survey vessels, pipe supply vessel, anchor handling vessels) from January to March (Average of 5.4 vessels per day).

Pipelaying

Pipe-lay is currently planned from late 2018 to early 2019. In the N2000 site Hoburgs bank och Midsjöbankarna, pipe-lay will be conducted on a 24 hour basis, and the pipe-laying vessel will move forward continuously. Pipe-laying is expected to move at a speed of 2.5 km/d (i.e. 56 days per pipeline).

This is shorter than the pipelaying during NSP1, where it took the pipelaying vessel Castoro Sei approx. 64 days per pipe. The disturbance models presented in section 4 thus present a conservative approach, since all 64 days of vessel traffic during the pipe-lay are included.

Post-lay trenching

Trenching (ploughing) is expected to be conducted in the N2000 site. It is currently estimated to be conducted a stretch of 72 km and duration of 10 days, with an average speed of 7 km/d (Figure 1).

Rock placement

Rock placement is not planned in the Natura 2000 site. However the possible requirement at limited locations for spot rock placement cannot be excluded, especially if trenching alone is not sufficient to ensure pipeline stability (as well as for cable crossing supports etc.).

4. Possible barrier effects from pipeline noise

Possible effects of the noise from the operational pipeline were assessed in the background report to the EIA (Sveegaard *et al.* 2016):

"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."***

This assessment is extended and further supported below.

Very few studies are available on noise levels from pipelines in operation, and potential barrier effects from noise have been very poorly documented. In connection with the assessment of the Nord Stream pipeline the radiated noise from the pipe line was modelled (Nord Stream 2009). This was done at four different distances from the compressor station in Russia and results are shown in Figure 2. The noise was quantified in the modelling as radiated noise power. This 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 ρc = 1.5×106 $kgm^{-2}s^{-1}$ this gives a correction factor of 54 dB, which was added to the modelled levels from Nord Stream (Nord Stream 2009) to obtain sound pressure level relative to 1 µPa.

The modelled sound pressure levels can be compared to actual measurements made from a pipeline in operation (Figure 3, Secret Cove, British Columbia, Glaholt *et al*. 2008). This pipeline had a smaller diameter than Nord Stream. Noise levels were measured close to shore and thus also the compressor station. The exact distance to the compressor station is not provided, but is assumed to be in low tens of km.

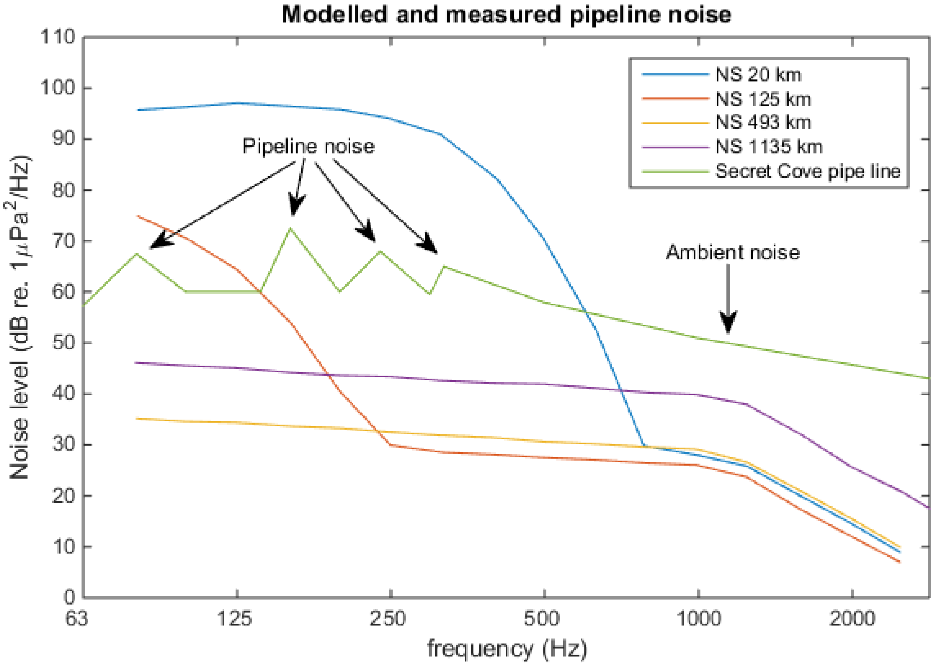

Figure 2 Modelled noise levels 1 m above the Nord Stream pipeline (Nord Stream 2009), at various distances from the compressor station, together with noise levels recorded from an actual pipeline; Secret Cove (Glaholt *et al.* 2008) from **Figure 3** below). As the measurements were made close to the compressor station, they should be compared to the modelled noise at the 20 km point, whereas the more distant positions (493 km and 1135 km) are more indicative of the levels to be expected from the Nord Stream 2 pipeline in the Natura 2000 sites. Note that the pipeline at Secret Cove had no concrete corrosion protection. The presence of such a concrete cladding is estimated to attenuate the noise by at least 15 dB relative to the unclad condition (Glaholt *et al.* 2008).

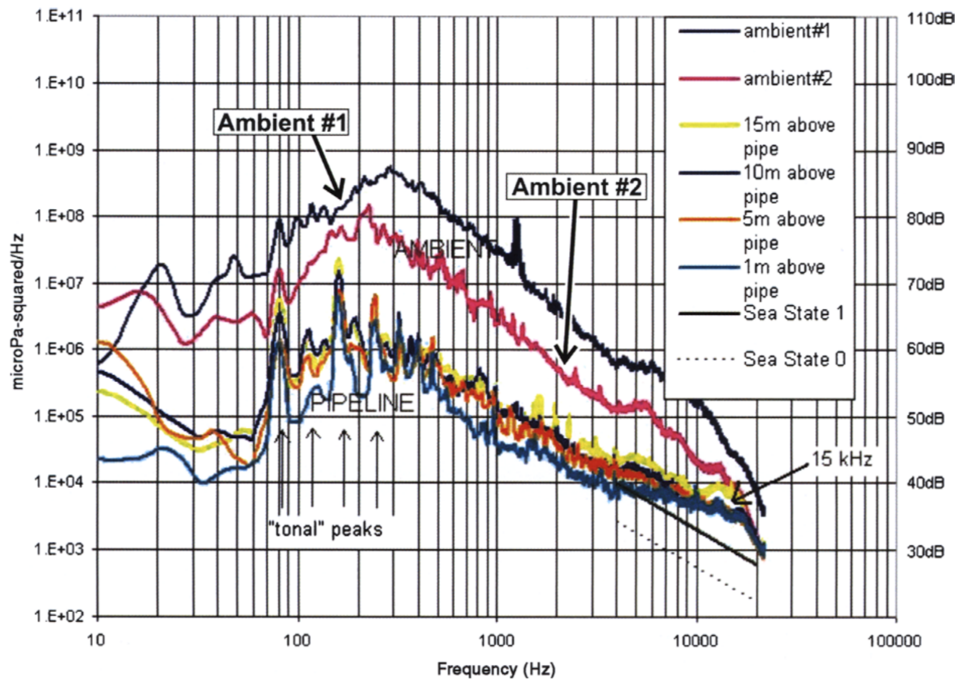

Figure 3 Noise levels as measured and accompanying representations of the high frequency portions of oceanic noise expectations for Sea States 0 and 1. Arrows denote the high (15 kHz) and low frequency "tonal" noise component from Secret Cove pipeline, British Columbia. Measurements were made in shallow waters close to shore and thus close to the compressor station. The pipeline consisted of two closely spaced iron pipes with an outer diameter of 25 cm. Ambient noise measurements recorded further away from the pipeline are also included. From Glaholt *et al.* (2008).

The measured noise from the Secret Cove pipeline is lower than the modelled levels from Nord Stream, even at the 20 km point from the compressor, despite the absence of a concrete corrosion protection around the pipeline, which, according to Glaholt *et al*. (2008), could attenuate the radiated noise by at least 15 dB. The pipe diameter at Secret Cove was considarbly smaller than the Nord Stream pipeline, however.

In any case, the absolute levels of noise are of little concern in relation to impact. It is only when they are compared to ambient noise levels that the possible influence on marine mammals can be assessed. The noise from the pipeline at Secret Cove contained pronounced peaks at low frequencies (highest frequency with a clearly discernable peak was 320 Hz), whereas no noise at higher frequencies could be attributed to the pipeline (Glaholt *et al*. 2008).

One study has looked into the noise from the Nord Stream pipeline in operation. Lindfors *et al.* (2016) analysed recordings of noise levels at three different locations in the Bay of Finland close to the Nord Stream pipeline. Very high levels of shipping noise was recorded at all three stations, so the pipeline noise could not be detected in any of the recordings.

More relevant for the Natura 2000 site Hoburgs Bank och Midsjöbankarna, however, are the noise recordings obtained by FOI (Johansson & Andersson 2012). They recorded ambient noise at several stations in the Midsjö Banks region, some of which were close to the proposed location of the Nord Stream 2 pipeline. Figure 4 shows results of their measurements under conditions where no ships were present within 9 km from the recording station (as assessed by AIS data) and under different wind speeds. Also shown is the average noise spectrum for the station (i.e. including a variable contribution from passing ships) from the baseline period without construction work on the Nord Stream pipeline taking place.

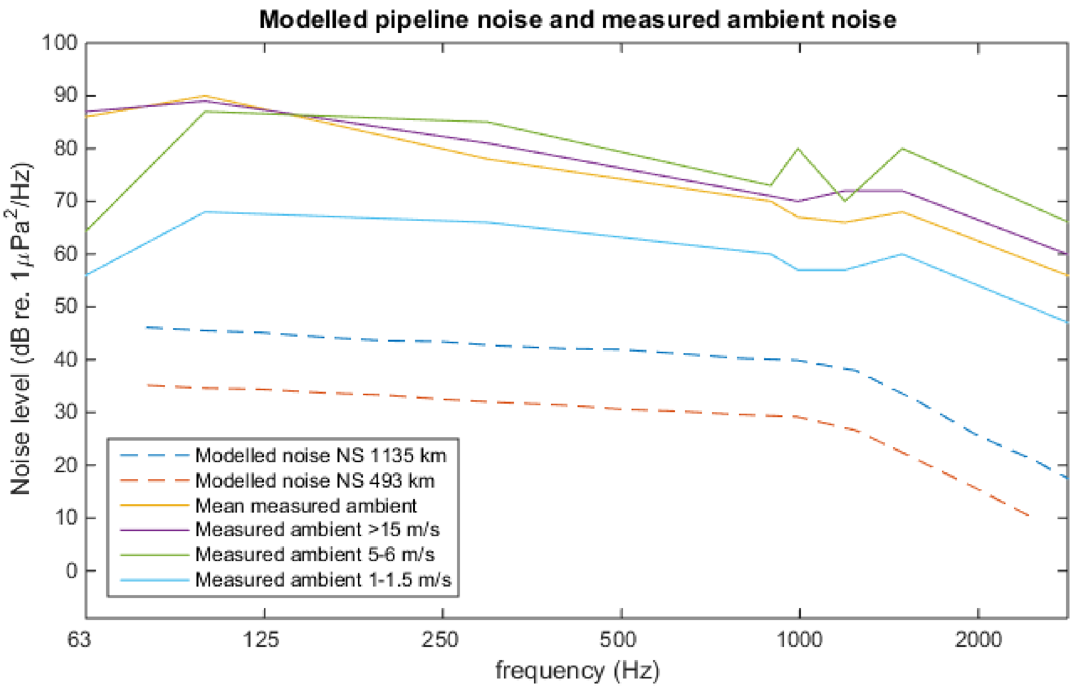

Figure 4 Modelled noise levels 1 m from the Nord Stream pipeline (Nord Stream, 2009) at distances far away from the compressor station, similar to the situation in the Natura 2000 sites (located about 800-900 km from the compressor). Also shown are ambient noise spectra measured under quiet conditions (no ships within 9 km from recorder) and mean ambient noise (including ships), all at station B1, located close to the proposed Nord Stream 2 pipeline (roughly 900 km from the compressor) and inside the Natura 2000 site (Johansson & Andersson 2012).

When these measurements of ambient noise are compared to the modelled levels from Nord Stream (2009) it is clear that the modelled noise is 20 dB or more below ambient noise levels and thus completely inaudible, even under the quietest conditions. This conclusion is further supported by measurements near the Nord Stream pipeline in the Gulf of Finland (Lindfors *et al.* 2016). Measurements at three underwater stations close to the exsisting baseline failed to detect any noise, which could be attributed to the pipeline. Instead the noise was dominated by ships in the nearby shipping lane.

Thus, the potential for the noise from the pipeline in operation to interfere with migration and distribution of harbour porpoises appears extremely low, as the pipeline noise is present only at very low frequencies, likely inaudible to harbour porposes and furthermore very likely to be completely masked by ambient noise, even very close to the pipeline.

5. Behavioural reactions of porpoises to ships – disturbance

Behavioural reactions to noise were assessed in the background report to the EIA (Sveegaard *et al.* 2016):

"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). The intensity and impact magnitude from vessel noise and rock placement is therefore rated* ***low*** *impact magnitude and the overall significance* ***minor****."*

This section elaborates on this assessment and adds support to the conclusion.

The Natura 2000 site Hoburgs Bank och Midsjöbankarna is heavily trafficked by large cargo vessels and passenger ferries. All of these emit underwater noise and are likely to disturb the behaviour of nearby porpoises to a smaller or larger degree (Hermannsen *et al.* 2015). Very little information is available, however, on the behaviour of porpoises in reaction to ship noise. Studies in captivity indicate that porpoises react to the higher frequencies of the noise, above 1 kHz, and at low levels, L_{eq} around 130 dB re. 1 µPa (Dyndo *et al.* 2015). Other studies on noise from various merchant ships in the outer Baltic have shown that there is considerable energy in the noise also at ultrasonic frequencies up to at least 100 kHz, and out to ranges of at least 1 km (Hermannsen *et al.* 2015).

Both could indicate that porpoises could react to ships at considerable distances, maybe several kilometres away. Speaking against very long reaction distances is the fact that some of the most heavily trafficked waters of the western Baltic, such as the Kadet Trench, the Great Belt, the northern Sound and the northern tip of Skagen are also some of the areas where the highest concentrations of porpoises are found (Sveegaard *et al.* 2011).

A recent study conducted on porpoises in the Istanbul Strait showed that porpoises are more likely to change behaviour, for example from surface-feeding or travelling to diving, if vessels are within a 400 m radius of the porpoise. Furthermore vessel speed and distance have a significant effect on the probability of response of the porpoises to the ship (Bas *et al.* 2017). Such changes in behaviour indicate that vessels do disturb the animals at close range, but the study found no overall significant effect of the disturbance on the animals' cumulative (diurnal) behavioural budget (i.e. total amount of time spent on the different types of behaviour). The correlation between swimming speed and the probability of porpoises responding by changing their swimming direction is illustrated in Figure 5. This shows that at any given ship speed there is little probability (<10%) of a behavioural reaction if the boat is more than 400 m away and furthermore that as ship speed increases from slow (<3 knots) to fast (>9 knots), the probability of reaction to the ship 200 m away increases from about 10% to 40%.

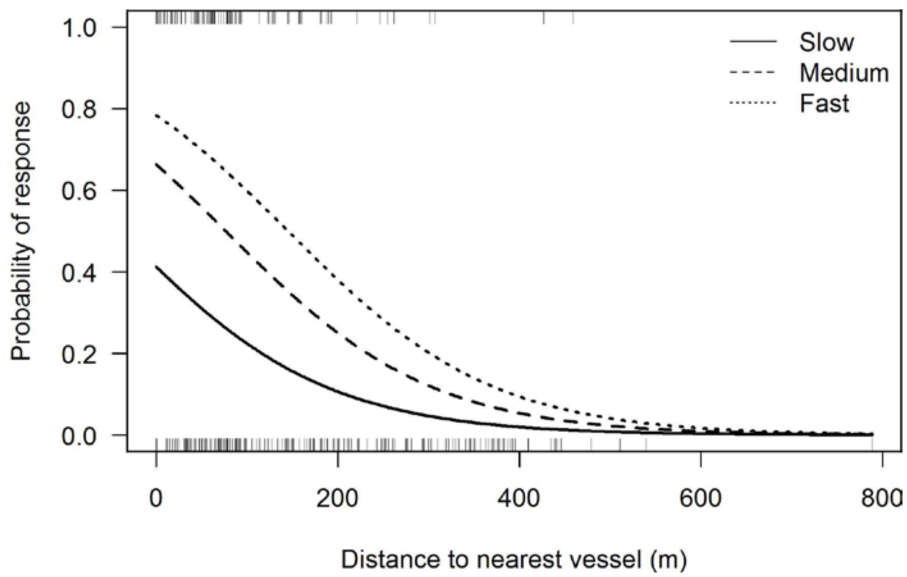

Figure 5 Probability of porpoises responding to a ship by a change in swimming direction as a function of the distance to the nearest vessel for slow (<3 knots, solid line), medium (3-9 knots, dashed line) and fast (>9 knots, dotted line) moving vessels. The lines represent the fitted values of the best fitting generalized linear model. The distribution of distance values for responding and non-responding porpoises are shown by the top and bottom rug plots, respectively. n = 305 (From Bas et al. 2017).

No similar studies are available for Baltic harbour porpoises or even porpoises in the Danish Straits, so it is not known whether the same distances apply to porpoises in the Baltic proper. As a precautionary measure in the modelling in section 4.1-4.2, we have assumed that all porpoises within 200 m of a vessel are disturbed.

5.1 Estimate of current habitat loss caused by shipping

Based on information received from AIS messages transmitted by the vessels and an estimate of the effective disturbance radius of ships, the habitat disturbance can be estimated. The habitat disturbance (HD) is expressed as a ratio between the disturbed area and the total area of the Natura 2000 sites. This ratio can either be expressed as habitat disturbance as a function of time, or as a function of geographical coordinates.

The current level of disturbance is estimated from two representative samples of AIS-records from commercial ships in the Natura 2000 site. Each sample was one week; one from February 2014 and one from July 2014.

The positions of individual ships (632 from February, 644 from July) were converted to Universal Transverse Mercator (UTM) projection, separated into passages through the Natura 2000 site and resampled on a common and regular time scale with one position every 10 minutes. Grid resolution was 50x50 m. For each 10 minute time step the habitat disturbance was calculated as:

HD(t) = disturbed grid cells at time t/total grid cells in Natura2000 site,

where a cell was counted as disturbed if the centre of the cell was closer to a ship than the effective disturbance radius (r_{eff}). Results are shown in Figure 6.

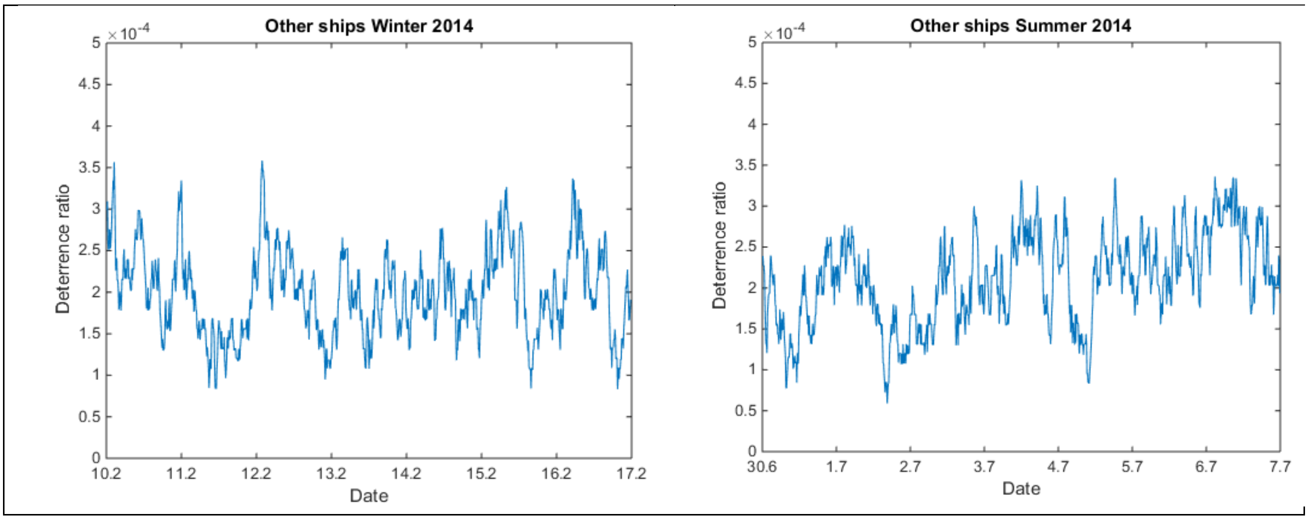

Figure 6 Habitat disturbance factor (HD) estimated from AIS-derived ship traffic during two representative weeks in February and July 2014, respectively. HD expresses the fraction of the total area of the Natura2000 sites which at any given point in time (resolution 10 minutes) is within 200 m of one or more ships and thus considered to be disturbed (for porpoises).

The habitat disturbance fluctuates considerably with time. However, it was never zero or close to zero, which is an indication of the fact that one or more ships are always present inside the Natura 2000 site. Average habitat disturbance of the two randomly selected weeks are very similar, although slightly higher in summer, indicative of a very low seasonal variation in shipping levels across the year. This is in turn probably a reflection of the relatively large ships largely being unaffected by weather and ice further into the Baltic, resulting in very little annual variation in ship traffic.

The spatial habitat disturbance of the grid cell in column *i* and row *j* was calculated as:

HD(i,j) = Number of 10-minute intervals where the cell was disturbed/total number of observation intervals,

where disturbance is defined as for HD(t) above. Results are shown in Figure 7.

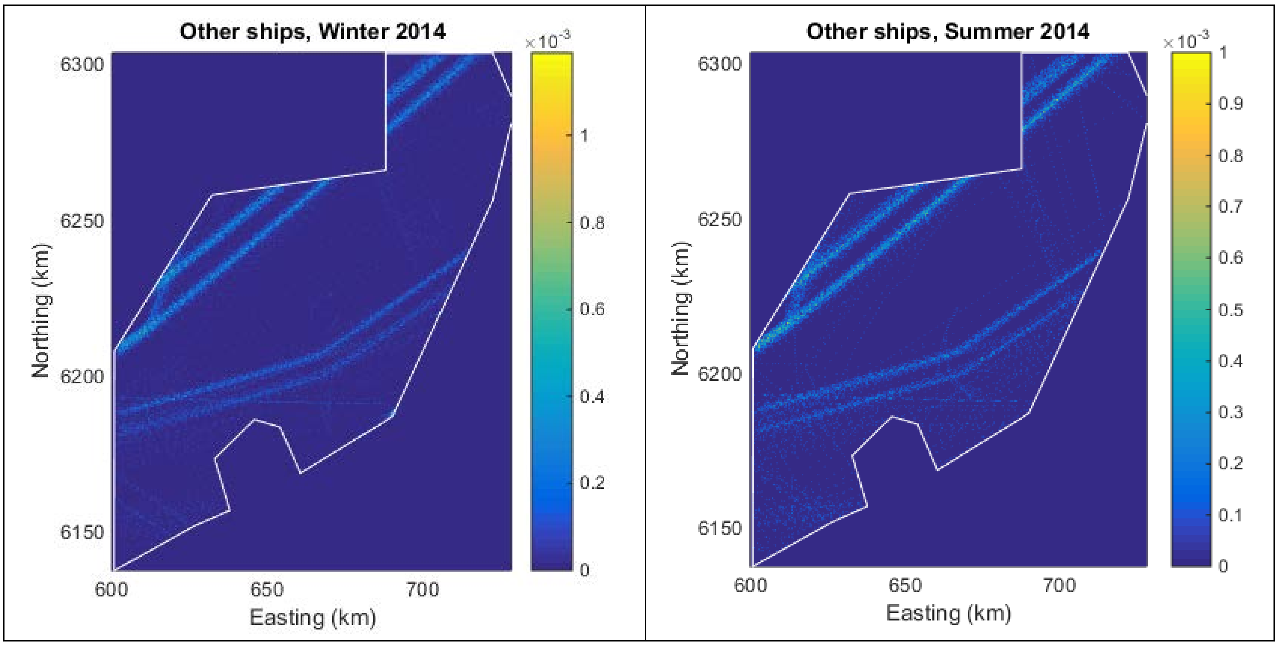

Figure 7 Habitat disturbance factor (HD) estimated from AIS-derived ship traffic during two representative weeks in February and July 2014, respectively. HD in the spatial formulation expresses the fraction of time (out of one week) where each grid cell (50x50 m) was within 200 m of one or more ships and thus considered to be disturbed (for porpoises).

From the two maps, it is evident that the main disturbance occurs in the shipping lanes through the area: the most heavily trafficked main shipping lanes through the north-western part of the area and the less trafficked deep-water route through the central part.

The grand average of the habitat disturbance, HD, is found as the average of either HD(t) or HD(i,j), the two results being identical.

HD can also be estimated in a simpler way, without spatial modelling and simulation, from the following equation:

$$HD = \frac{\pi r_{eff}^2 dN}{tA} \quad \text{Eq. 3}$$

Where r_{eff} is the effective disturbance range; d is the average time it takes for one ship to pass through the area; T is the time interval assessed (one week in this example); N is the total number of ships passing; and A is the total area of the Natura2000 sites.

In both cases HD express the average proportion of the total area in which porpoises are disturbed due to presence of the ships. Estimates of the disturbance are shown in Table 1.

Table 1 Habitat disturbance ratio, which expresses the average fraction of the Natura 2000 site considered unavailable to porpoises due to disturbance from ships. Estimates are given for summer and winter and computed by two different methods: spatial modelling and based on average ship passage time (equation 3).

	Winter	Summer
HD from modelling	0.00020	0.00021
HD from equation 3	0.00024	0.00025

5.2 Cumulative habitat loss caused by the pipelay vessel, support vessel and ploughing vessel

The same computation as above can be repeated for the slow moving construction vessels (including pipelay vessel, support vessels and ploughing vessel), which will provide the incremental (cumulative) impact of the pipeline construction.

Basis for the computation was AIS-information obtained during construction of the Nord Stream pipeline. One pass of the pipe-laying vessel (Castoro Sei) through the Natura 2000 sites was selected. This passage started on 1.1.2012 and lasted 64 days. During this period 12 other vessels took part in the operation. The combined habitat disturbance from the passage of Castoro Sei and support vessels were computed in the same way as for the commercial vessels.

The noise levels around the pipe laying vessels were clearly elevated during construction, as documented by the monitoring program (Johansson & Andersson 2012). Measurements about 1.5 km from the pipeline corridor indicated an elevation in the low frequency range (below 3 kHz) of about 20 dB, compared to the baseline levels. These measurements indicate that the noise generated by the slow moving Castoro Sei was higher than from a slow moving normal ship of the same size, but on the other hand comparable in characteristics and level to the noise of a fast moving (15-20 knots) merchant vessel (Johansson & Andersson 2012). Based on these observations, the reaction distance of porpoises was set at 200 m, similar to the merchant ships modelled above.

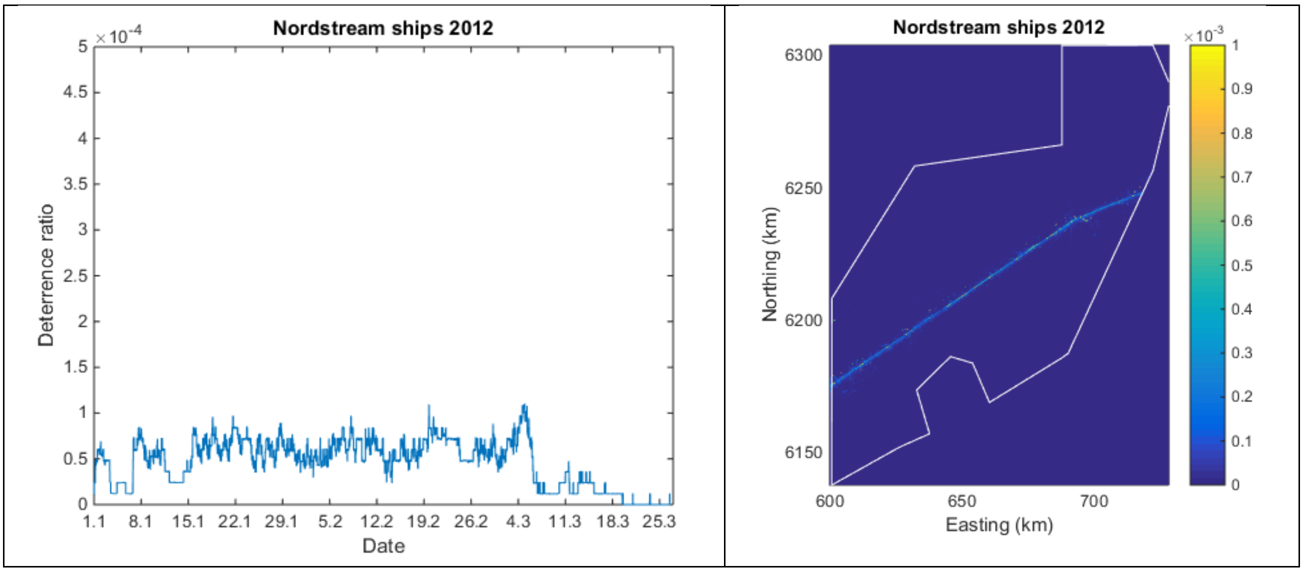

Figure 8 Contribution by the pipelaying vessel and support vessels to the habitat disturbance factor, estimated from actual pipelaying operations during construction of Nord Stream. Scales are identical to scales in **Figure 6** and **Figure 7** and thus directly comparable.

The habitat disturbance is very constant throughout most of the construction period (Figure 8), reflecting the slow, but continuous movement of the pipelaying vessel through the area. Two periods in the beginning show decreases in disturbance, likely due to bad weather and thus stop in construction activities. The decrease in disturbance towards the end of the period is likely a reflection of the support vessels operating in front of the pipelaying vessel begins to move out of the area, together with shorter and shorter commuting routes for the service vessels sailing back and forth between harbours and the pipelaying vessel. From the map it is evident that although there was a very busy traffic to and from the pipelaying area, the main disturbing factor is the slowly moving pipelaying operation itself.

The disturbance estimated from the pipelaying operation can be compared to the predicted disturbance form the shipping routes, computed below (Table 2). As there only is limited overlap in space between the pipeline and the shipping lanes (during the crossing of the deep water shipping lane and when paralleling close to the shipping lane southeast of Hoburgs Bank) the two contributions are simply added in a conservative approach. This could in the worst case give a small overestimation of the cumulative impact, as the Nord Stream ships move into area where other ships are present.

Table 2 Cumulative increase in habitat disturbance, as estimated above, and expressing the mean fraction of the Natura 2000 site considered unavailable to porpoises due to disturbance from the ships.

	Winter	Summer
HD Regular shipping	0.00020	0.00021
HD Nord Stream	0.00005	0.00005
HD total	0.00025	0.00026
Cumulative increase	**25%**	**24%**

The estimated disturbance caused by existing shipping in the area is very low, and does not appear to change much between summer and winter. On average less than 1/1000 of the Natura 2000 site is expected to be disturbed by ships. In relative terms, the construction of the Nord Stream pipeline is estimated to have caused an increase in disturbance of about 25% on top of the disturbance from regular shipping. However, as the absolute levels are very low, the combined disturbance was still low and it is considered unlikely that this increase could have translated into significant detrimental effects on the local population of porpoises.

The disturbance from construction of Nord Stream 2 is expected to be different than the disturbance caused by Nord Stream. The fact that construction will be faster will decrease the overall impact. While the construction is ongoing, the habitat disturbance may be comparable to what was modelled above, but the duration of the impact will be smaller, hence the total impact smaller.
Other types of ships will be used for construction of Nord Stream 2. Most significant will likely be the absence of anchor handling vessels, as ships will use dynamic positioning for construction of Nord Stream 2. This will on one hand reduce the number of vessels, again reducing the disturbance, but on the other hand, the ducted propellers used in dynamic positioning are known to be noisy, although not well studied. All in all, however, the cumulative increase in the disturbance caused by presence of the Nord Stream 2 vessels inside the Natura 2000 site is assessed to likely be similar to, or less than what was caused by construction of Nord Stream.

6. Masking of porpoise sonar and communication by ship noise

Masking of porpoise sounds by ship noise was only touched lightly upon in the background report to the EIA (Sveegaard *et al.* 2016):

"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."

Masking caused by construction noise was thus considered a negligible impact. This assessment is qualified further below.

Loud noise has the capacity to mask the reception of weaker sounds of importance to the porpoises. These sounds can be the animal's own echolocation signals, communication signals from other porpoises, including between mother and calf (Clausen *et al.* 2010); or other sounds that the animals may use to find prey or navigate. From studies in captivity, it is well known that a requirement for masking to occur is that there is an overlap in both time and frequency range between the noise and the sound in question. This means that for masking of sonar and communication sounds to take place, the noise must have substantial energy in the frequency range around 130 kHz, the frequency band used by porpoises in echolocation (Villadsgaard *et al.* 2007), and communication (Clausen *et al.* 2010). Noise from shipping and construction work has a very strong emphasis in the very low frequencies (e.g., McKenna *et al.* 2012; Hermannsen *et al.* 2015), but can contain substantial energy above ambient noise levels also at higher frequencies and thus also in the frequency range of porpoise vocalisations. The higher frequencies do not propagate far from the ship, however, due to the increase in absorption with frequency.

Noise from construction activities were measured during construction of the Nord Stream pipe line (Johansson and Andersson 2012). They conducted measurements on the sea bed approx. 1.5 km from the pipe line traché and recorded noise from both the pipe laying vessel (Castoro Sei) and the subsequent trenching (ploughing). They reported elevated levels during both activities, compared to background levels, as seen in Table 3.

Table 3 Measurements of noise during construction of the Nord Stream pipeline, as measured 1.5 km from the pipeline traché and compared to ambient conditions at the same location. Bandwidth of recordings were 25 Hz – 3 kHz and unit is dB re. 1 µPa. From Johansson and Andersson (2012). L95 and L5 are percentiles, thus indicating the levels exceeded 95% and 5% of the time, respectively.

Noise source	Mean	L95	L5
Ambient	110.9	99.2	116.6
Pipelay	130.5	121.4	134.0
Trenching	126.0	118.7	129.8

The noise levels were clearly elevated during construction, about 20 dB, a little less for trenching than pipelaying. All three indicators, mean and two percentiles, appears equally affected, indicating that the entire noise regime has been elevated by 20 dB.

Unfortunately, the bandwidth of the recordings were limited to 3 kHz, so it is unknown to what degree noise levels were elevated at higher frequencies, most importantly above 100 kHz where the porpoise vocalisations are located. It is likely that energy was present also in this frequency band, thus giving potential for masking.

Measurements at a second measuring station about 25 km from the pipeline showed marginally higher noise levels during construction activities compared to ambient, for the pipelaying possibly partly attributable to the construction activities (Johansson & Andersson 2012).

Although there is potential for masking to occur due to the noise from the construction activities, as noise above ambient and in the relevant frequency range around 130 kHz is likely to be present, it is close to impossible to quantify the level of masking. Likewise it is close to impossible to quantify the level of masking due to the existing shipping through the Natura 2000 site. Any attempt to compare the two would be even more difficult. Although some authors have attempted to quantify the possible level of masking, through indices such as the range reduction factor (Møhl 1980), or otherwise (Clark *et al.* 2010), such quantifications require a much better description of ambient noise and masking noise than what is available and still be based on poorly founded assumptions about the masking itself.

Therefore, instead of a quantitative approach to masking, some common sense considerations are presented. These considerations relate to the likely extent of a zone of masking, the likely reaction from porpoises to the masking and the possible consequences of this masking.

Masking is a natural phenomenon that occurs all the time

Masking occurs every time the ambient noise (natural or man-made) exceeds the hearing threshold in the relevant frequency range. This means that porpoises, just as all other animals with sensitive hearing, may be limited in echolocation range and communication distanced by ambient noise, rather than the absolute sensitivity of their hearing, at least for parts of the time. Some natural phenomena, one good example being rain, can generate very high levels of noise and thus expose animals to high levels of natural masking.

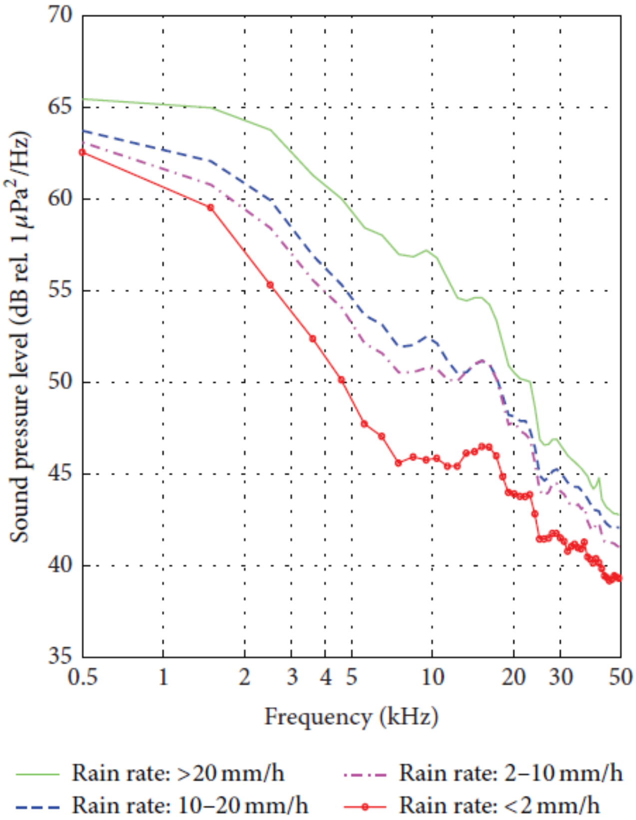

Figure 9. Examples of mean measured noise spectra at different levels of rain in the Mediterranean Sea. The curves show that noise levels can be elevated by 5-10 dB across the entire frequency spectrum during heavy rain. From (Pensieri *et al.* 2015).

Porpoises are likely to respond to masking by behavioural changes

As masking is a naturally occurring phenomenon it is reasonable to assume that porpoises and other animals react to masking in an adaptive way. In particular for a female porpoise with a dependent calf, an appropriate behaviour to noise at levels capable of masking would be to stay closer together, thus compensating for a decrease in maximum communication range. If noise levels increase even further, so as to make communication difficult even at close range, then the adaptive reaction would be for the animals to move away from the noise source.

Porpoises are likely to have evolved appropriate responses to loss of communication

About the worst that could happen to a porpoise calf still dependent of its mother is to become separated from the mother, outside communication range. In theory, and perhaps also in practice, this could occur if at a time when the mother and calf are some distance apart, a sudden noise instantly makes communication impossible. Such a noise could be a nearby ship that suddenly turns on the engine at full power, but it could also be natural events, such as the sudden onset of a heavy rain shower, as illustrated above. The fact that such a masking could occur due to natural sources would suggest that mother and calf have evolved some adaptive behaviour to deal with such a possible separation. Such a behaviour has not been described, but could consist of the calf remaining stationary while emitting so-called distress-signals (Clausen *et al*. 2010), and the mother at the same time searching the area systematically. Thus, by this line of reasoning, it is far from certain that a break of communication between mother and calf due to masking or otherwise necessarily leads to permanent separation of the two (and likely death of the calf).

The above reasoning suggests that porpoises could react in a sensible way to the presence of ship noise, by evading the vicinity of the ship and thereby reduce the masking. In fact, one could speculate whether the evasive reaction observed to ships (**Figure 5**) could be partly explained by such a response. Furthermore, assuming a worst case scenario of permanent separation as a result of a short break of communication between mother and calf likely relies on a significant underestimation of the abilities of the animals to re-locate each other following a separation.

Therefore, considering the nature of the noise from the construction activities and the likely responses of the animals, it is considered unlikely that the construction activities will add to any significant degree to the present level of masking in the area, attributed to the shipping lanes and especially that such an increase in masking would lead to significant impact on individual porpoises.

7. Conclusion

Summing up from the above sections the following is concluded on the three main issues of concern raised by the Swedish Authorities:

Barrier effect by pipeline noise
The noise is almost certainly going to be below ambient noise and thus inaudible to porpoises.

Disturbance of behaviour from pipelaying
In this study, porpoises are conservatively assumed to be completely deterred from ships in a distance of up to 200 m. When using this assumption, the disturbance i.e., the absolute area estimated to be unavailable to porpoises is 0.0002% of the Natura 2000 site caused by regular traffic and an additional 0.00005% caused by the NSP2 vessel traffic during pipelaying. The impact of the pipelaying operation is thus assessed to be insignificant for porpoises.

Masking of communication and echolocation by noise from pipelaying
Pipelaying vessel are likely to significantly elevate ambient noise levels around the ship(s): estimated 20 dB at 1.5 km distance in the frequency range below 3 kHz (from construction of Nord Stream), and likely also at higher frequencies.

There is thus potential for masking of echolocation and communication between porpoises locally around the ship(s).

The affected area is insignificant in relation to the entire Natura 2000 site and the effect of masking is considered to be effectively mitigated by appropriate behaviour of the porpoises (evasion).
Overall impact of masking is therefore considered insignificant.

Consequently, the extended analysis and reviews conducted here supports the conclusions from the original assessment in Sveegaard *et al*. 2016.

As a final note, it is worth to mention that DCE during the preparation of this report have been informed by NSP2 about some project optimisations (mainly an increased pipelay speed, leading to fewer construction days, and a reduced need for seabed stability measures) within the Natura 2000 area. Such changes would naturally further strengthen the conclusions reached in this paper.

8. References

Bas A.A., Christiansen F., Ozturk A.A., Ozturk B. & McIntosh C. (2017) The effects of marine traffic on the behaviour of Black Sea harbour porpoises (Phocoena phocoena relicta) within the Istanbul Strait, Turkey. *PLoS ONE* **12**.

Clark C.W., Ellison W.T., Southall B.L., Hatch L., Van Parijs S.M., Frankel A. & Ponirakis D. (2010) Acoustic masking in marine ecosystems as a function of anthropogenic sound sources. IWC Scientific Committee SC-61 E10. pp. 1-19.

Clausen K.T., Wahlberg M., Beedholm K., DeRuiter S.L. & Madsen P.T. (2010) Click communication in harbour porpoises *Phocoena phocoena*. *Bioacoustics* **20**, 1-28.

Dyndo M., Wiśniewska D.M., Rojano-Doñate L. & Madsen P.T. (2015) Harbour porpoises react to low levels of high frequency vessel noise. *Scientific Reports* **5**, 11083.

Glaholt R., Marko J. & Kiteck P. (2008) Investigations into Gas Pipeline Operational Noise and its Potential to Impact Toothed and Baleen Whales. In: *Environment Concerns in Rights-of-Way Management 8th International Symposium* (pp. 693-709. Elsevier, Amsterdam.

Hermannsen L., Tougaard J., Beedholm K., Nabe-Nielsen J. & Madsen P.T. (2015) Characteristics and Propagation of Airgun Pulses in Shallow Water with Implications for Effects on Small Marine Mammals. *PLoS ONE* **10**, e0133436.

Johansson T. & Andersson M. (2012) Ambient underwater noise levels at Norra Midsjöbanken during construction of the Nord Stream pipeline. Report no FOI-R--3469--SE to Nord Stream AG and Swedish Environmental Agency. FOI, Stockholm.

Lindfors A., Meriläinen T. & Mykkänen J. (2016) Environmental baseline surveys in the Finnish exclusive economic zone. NSP2 Document No: W-PE-EIA-PFI-REP-812-FINBESEN-02. Helsinki.

McKenna M.F., Ross D., Wiggins S.M. & Hildebrand J.A. (2012) Underwater radiated noise from modern commercial ships. *JASA* **131**, 92-103.

Møhl B. (1980) Marine mammals and noise. *Arctic Seas Bulletin* **2**, 1-2.

Nord Stream (2009) Ofshore pipelines through the Baltic Sea. Environmental Impact Assessment for the Danish Section. G-PE-PER-EIA-100-42920000-AA. Copenhagen.

Pensieri S., Bozzano R., Nystuen J.A., Anagnostou E.N., Anagnostou M.N. & Bechini R. (2015) Underwater Acoustic Measurements to Estimate Wind and Rainfall in the Mediterranean Sea. *Advances in Meteorology* **2015**, 1-18.

Sveegaard S., Teilmann J. & Tougaard J. (2016) Marine mammals in the Swedish and Danish Baltic Sea in relation to the Nord Stream 2 project – Environmental Impact Assessment. p. 40, Aarhus University, Frederiksborgvej 399, DK-4000 Roskilde, Denmark.

Sveegaard S., Teilmann J., Tougaard J., Dietz R., Mouritsen H., Desportes G. & Siebert U. (2011) High density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. *MMS* **27**, 230-46.

Teilmann J., Galatius A. & Sveegaard S. (2017) Marine mammals in the Baltic Sea in relation to the Nord Stream 2 project – Baseline report. Roskilde, Denmark.

Villadsgaard A., Wahlberg M. & Tougaard J. (2007) Echolocation signals of free-ranging harbour porpoises, *Phocoena phocoena*. *JEB* **210**, 56-64.