MARINE MAMMALS IN RELATION TO THE ALTERNATIVE ROUTE NORTH OF BORNHOLM NORD STREAM 2 PROJECT

Baseline and assessment report

Scientific Report from DCE – Danish Centre for Environment and Energy No. 289 2018

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Data sheet

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Abstract: An underwater pipeline, Nord Stream 2, is proposed to be constructed in Danish waters, along a route from the central Baltic, north around Bornholm and making landfall on the coast of Mecklenburg-Vorpommern, Germany. This report describes baseline data for abundance and sensitivity of marine mammals in the area: harbour porpoises, harbour seals and grey seals, as well as an assessment of likely impact by construction and operation of the pipeline on these species. Possible impacts include resuspension of sediment during construction and underwater noise from construction ships and pipeline. Underwater noise from clearing of world war 2 ammunition on the seabed, should this need arise, has potential for significant impact on marine mammals unless properly mitigated. All other impacts are considered to have either negligible or minor (insignificant) effects on the populations of marine mammals in the area, including the critically endangered population of harbour porpoises in the Baltic proper

Keywords: Nord Stream 2, harbour porpoises, harbour seals, grey seals, resuspension of sediment, underwater noise

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1 Introduction

This report concerns potential impact on marine mammals from a proposed alternative route for the Nord Stream 2 pipeline through the Danish exclusive economic zone (EEZ) north of Bornholm (Figure 1-1). This route is referred to as “the northern route” in the following text. The part of the northern route that goes through German waters is covered elsewhere and thus not included in this assessment. Originally, Nord Stream 2 AG proposed to place the NSP2 pipeline along the already existing NSP pipeline from 2009 in a corridor south of Bornholm and through Danish territorial waters. This route is referred to as “the ES route” in the following text. A baseline report (Teilmann et al., 2017) and an assessment report (Sveegaard et al., 2017) regarding marine mammals were published previously for the ES route. This report constitutes a supplement to these reports and is divided into two: a baseline part and an assessment part.

The relevant resident marine mammal species in the area of the northern route are harbour porpoise (*Phocoena phocoena*), harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*). The aim of the baseline part is to describe the biology, distribution, abundance and legal protection of each species. The aim of the assessment part is to assess the magnitude of impact from construction and operation of the pipeline on the local populations of the three species. The report is based on existing data and literature.

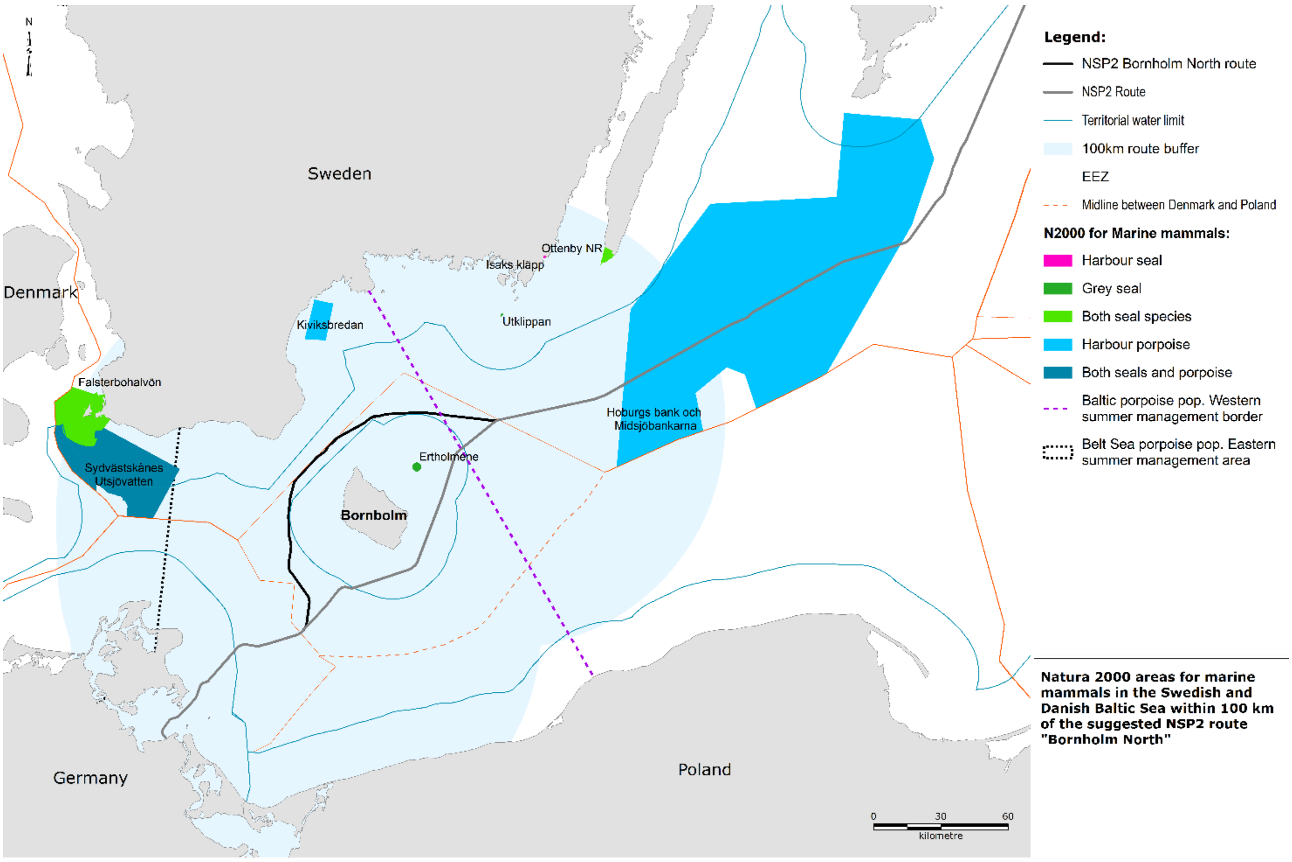


Figure 1-1. Map of the proposed NSP2 pipeline corridors north of Bornholm through the Danish EEZ. There are two alternative corridors connecting into the German EEZ, west and east around Adler Grund, respectively. N2000 areas for marine mammals are indicated as well as a 100 km buffer zone around the route. The summer management borders for the Belt Sea population of porpoises (from the black line and westward) and the Baltic harbour porpoise summer population (from the purple line and eastward) are indicated. Shaded light blue area indicates the 100 km buffer zone from the northern route.

2 Harbour porpoise (*Phocoena phocoena*)

2.1 Population structure

Studies on morphometric skull differences (Galatius et al., 2012) and genetics (Wiemann et al., 2010; Lah et al., 2016) have aimed to elucidate the population structure between the Belt Sea and Baltic Sea porpoise populations. Both studies found that three populations (or subpopulations) may exist in this area, namely 1) in the Baltic Proper, 2) in the western Baltic, the Belt Sea and the southern Kattegat (hencefort called the Belt Sea population) and 3) in Skagerrak and the North Sea. These studies were however not able to determine exact borders between the populations, perhaps due to some overlap in distribution between them. These overlaps located in so-called transition zones were examined further by re-examining the genetics and including data from satellite tracked porpoises (Sveegaard et al., 2011) and passive acoustic monitoring (subset of data from SAMBAH 2016 (see below and sambah.org)) to determine the best possible management area for the Belt Sea population (Sveegaard et al. 201a). It was found that during the summer period (May-Sept) a clear decreasing gradient in porpoise density occurs east of 13.5^0 E, indicating that only few porpoises from the more abundant Belt Sea population cross this line (Figure 1-1, Figure 2-1).

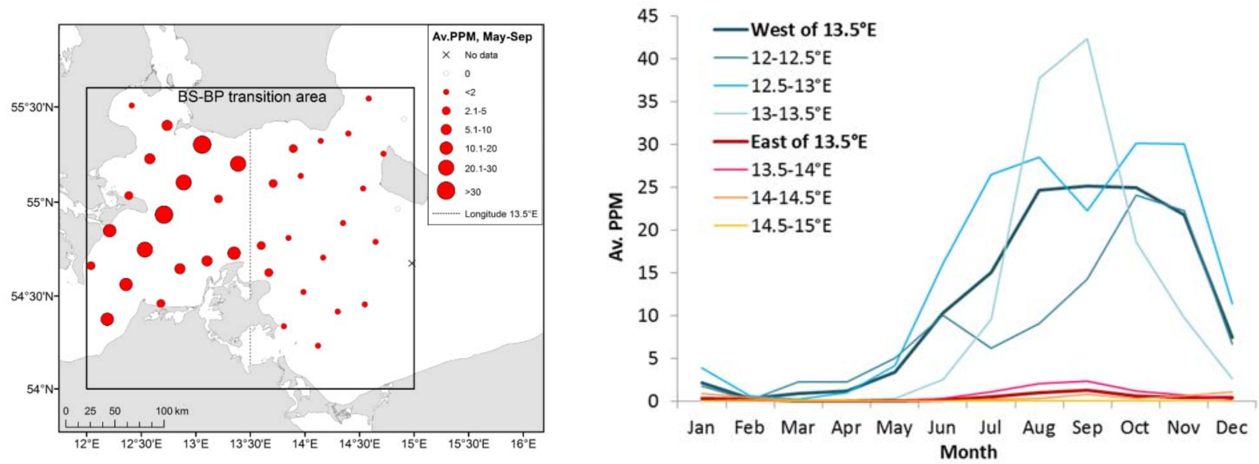


Figure 2-1. Left panel: map of the transition zone between the Belt Sea and Baltic Sea populations, with SAMBAH acoustic stations shown with red dots. Right panel: Showing the average number of minutes with porpoise detections per day. Each line shows the monthly variation in half degree longitude increments over the area shown in the left panel (From Sveegaard et al. 2015a).

The border at 13.5^0 E is, however, not the best management border for the porpoise population in the Baltic Proper. Based on acoustic detections at 304 passive acoustic monitoring (PAM) stations deployed across the Baltic covering all Baltic EU countries from Finland to Denmark for two years (2011-2013), the SAMBAH project concluded that the most parsimoneous management border during summer (May-Sept) was a straight line from Listerlandet peninsula in Sweden to Jarosławiec in Poland (Fig. 1-1, (SAMBAH, 2016). During winter, no clear management border could be determined since the animals were more dispersed more widely and especially towards the southwest compared to summer. The distribution during the summer period is of high importance to the population structure since both calving and mating occur in this season.

The management border of the Belt Sea population is supported by satellite tracking of 94 porpoises during the years 1997-2015, incidentally live caught in pound nets, and equipped with satellite transmitters. Individual animals were tracked for up to 522 days. All animals were caught in Danish waters within the proposed management area for the Belt Sea population (Kattegat, Belt Seas or Western Baltic) (Sveegaard et al., 2015a). Of the 94 porpoises 12 (13%) moved into the 100 km buffer zone of the NSP2 North Borholm route and only 6 (6%) moved east of 13.5^0 E and into the Baltic Proper. These porpoises moved both north and south of Bornholm and swam as far east as 16.5^0 E (towards the sourthern tip of Öland).

The NSP2 Bornholm North route crosses the Baltic population management border and the majority of the route it located in the transition zone between the two porpoise populations. Individuals from both populations are thus likely to be encountered in the area.

2.2 Distribution and abundance

The harbour porpoise is the smallest but also the most numerous cetacean in Europe. It is widely but unevenly distributed throughout European waters. The distribution is presumably linked to the distribution of prey (e.g. Sveegaard et al., 2012), which in turn is linked to parameters such as hydrography and bathymetry (Gilles et al., 2011).

It has not been documented that porpoises have specific migration patterns in the Baltic area. However, studies have identified a trend in acoustic detections in the southern Baltic Sea, suggesting that porpoises may follow a generalized westerly movement in fall / winter and back again in spring moving through the waters around the NSP2 northern route (Gallus et al., 2012; Benke et al., 2014).

2.2.1 Harbour porpoises in the Baltic Proper

Until the first half of the 20th century, the harbour porpoise was widely distributed in the Baltic Sea, but a dramatic decline has been observed during the past 50-100 years. Until recently, little was known about the distribution and status in the Baltic Proper (Skora et al., 1988; Andersen et al., 2001; Koschinski, 2002). The severe decline of the harbour porpoise population in the Baltic Proper makes it the smallest population of harbour porpoises in the world (ASCOBANS, 2002) and it is now listed as “critically endangered” by the International Union for Conservation of Nature (IUCN). Two visual surveys (albeit with low resolution in coverage) of population size in the Baltic Proper have been conducted and estimated 599 (95% CI 200-3300) animals in 1995 (Hiby and Lovell, 1996) and 93 (95% CI 10-460) in 2002 (Berggren et al., 2004), respectively. In 2016, the SAMBAH project using extensive static acoustic monitoring (see above) estimated the remaining number of porpoises in the Baltic Proper to be app. 500 (95% CI 80-1,100) (SAMBAH, 2016).

The porpoise detections from the SAMBAH project were analysed as Porpoise Positive Seconds per day (PPS) and split into two seasons (Figure 2-2 and Figure 2-3). In the summer period, the data were further divided into the two population groups (i.e. east and west of the estimated population border). During the breeding period in summer, porpoises in the Baltic Proper concentrate around the shallow Midsjö Banks south of Gotland and Öland (Figure 2-2). There is a clear drop in density from this area in all directions, confirming the isolation of this population.

During winter the porpoises are more widespread and were detected as far north as the southwestern Finnish waters (Figure 2-3). Furthermore, porpoises were detected on the majority of stations on and near the northern route although most porpoises were detected in the southwestern part near Adler Grund and along the Swedish border.

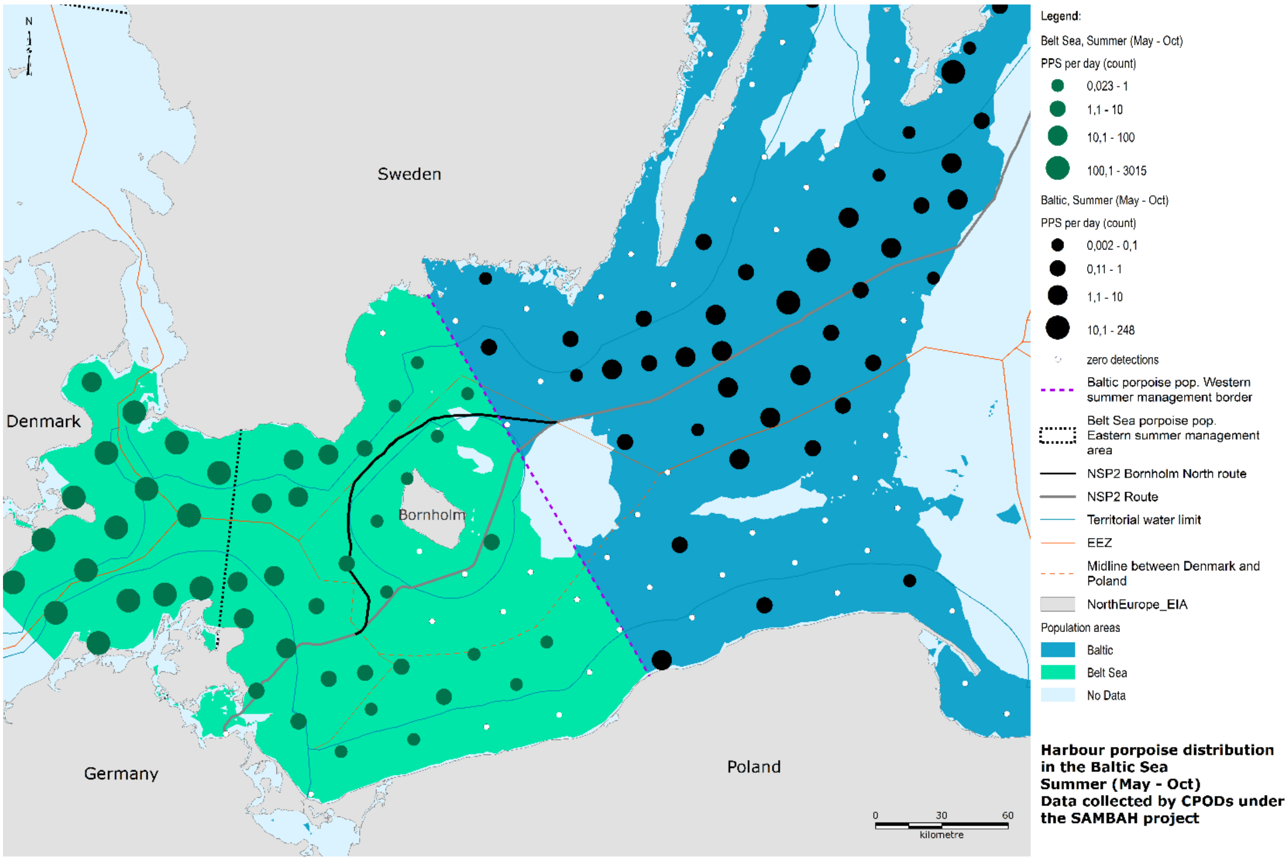


Figure 2-2. Summer distribution of porpoise detections in the western Baltic Sea (Data from the SAMBAH project). Each acoustic station is shown with a dot. If porpoises were detected, the dot is filled and scaled in size to the relative density of 'porpoise positive seconds per day'. If no porpoise was detected, the station is shown as a white dot. Green indicates the area primarily inhabited by the Belt Sea population extending east into the Inner Danish waters (not shown on map) and blue is believed to contain the breeding distribution of the remaining Baltic Proper porpoise population.The two populations overlap and the separation line thus represents the most parsimonious separation. Note that the density represented by the size of the dots in the green and blue areas are not comparable.

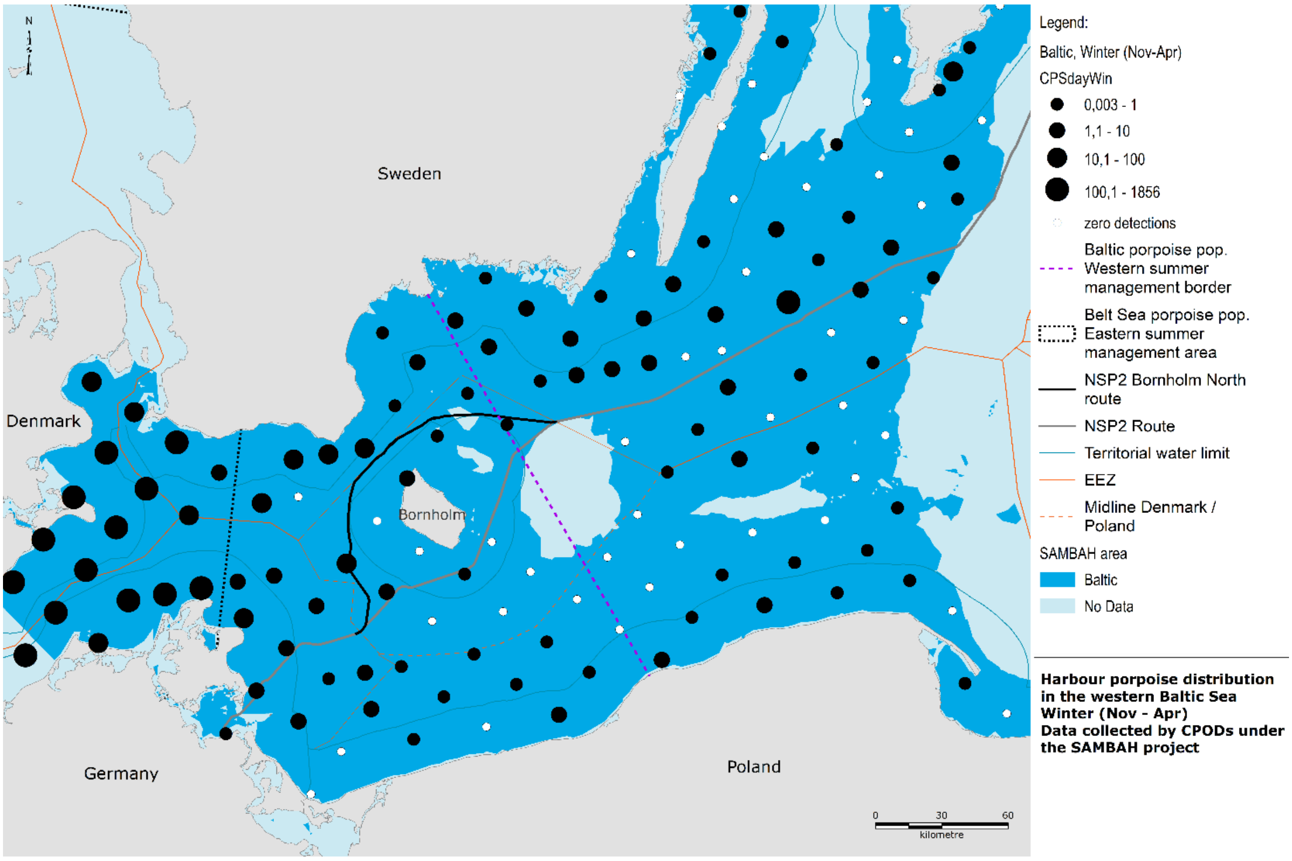


Figure 2-3. Winter distribution of porpoise detections in the western Baltic Sea (Data from the SAMBAH project). Each acoustic station is shown with a dot. If porpoises were detected the dot is black and scaled in size to the relative density of 'porpoise positive seconds per day'. If no porpoise was detected, the station is shown with a white open circle. The dark blue area is believed to contain a mixture of the Baltic Proper porpoise population and the Belt Sea porpoise population. Light blue parts were not surveyed and no data is thus available.

Predictions of probability of occurrence of harbour porpoises were modelled for each month during the SAMBAH project (Figure 2-4). Results resemble the results of the actual detections (Figure 2-2 and Figure 2-3) and show that during the summer season, high probability of detection occurred on and around the offshore banks south of Gotland and east of Öland. The aggregation of animals in this area is most obvious during May–August, i.e. the reproduction period. This is also the period when the separation from the cluster in the southwestern area between Denmark, Germany and Sweden is most clear. During the winter season, especially during January–March, animals were more spread out, and intermediate probabilities of detection occurred along the coasts of Poland and the Baltic states, and also in Finnish and northern Swedish waters.

In the area of the northern route, the distribution of probability of detection confirms the distribution observed in the raw porpoise detections above: in the Danish EEZ, the majority of porpoises are found in the area west of Bornholm and on most stations there are more detections in the winter than during summer.

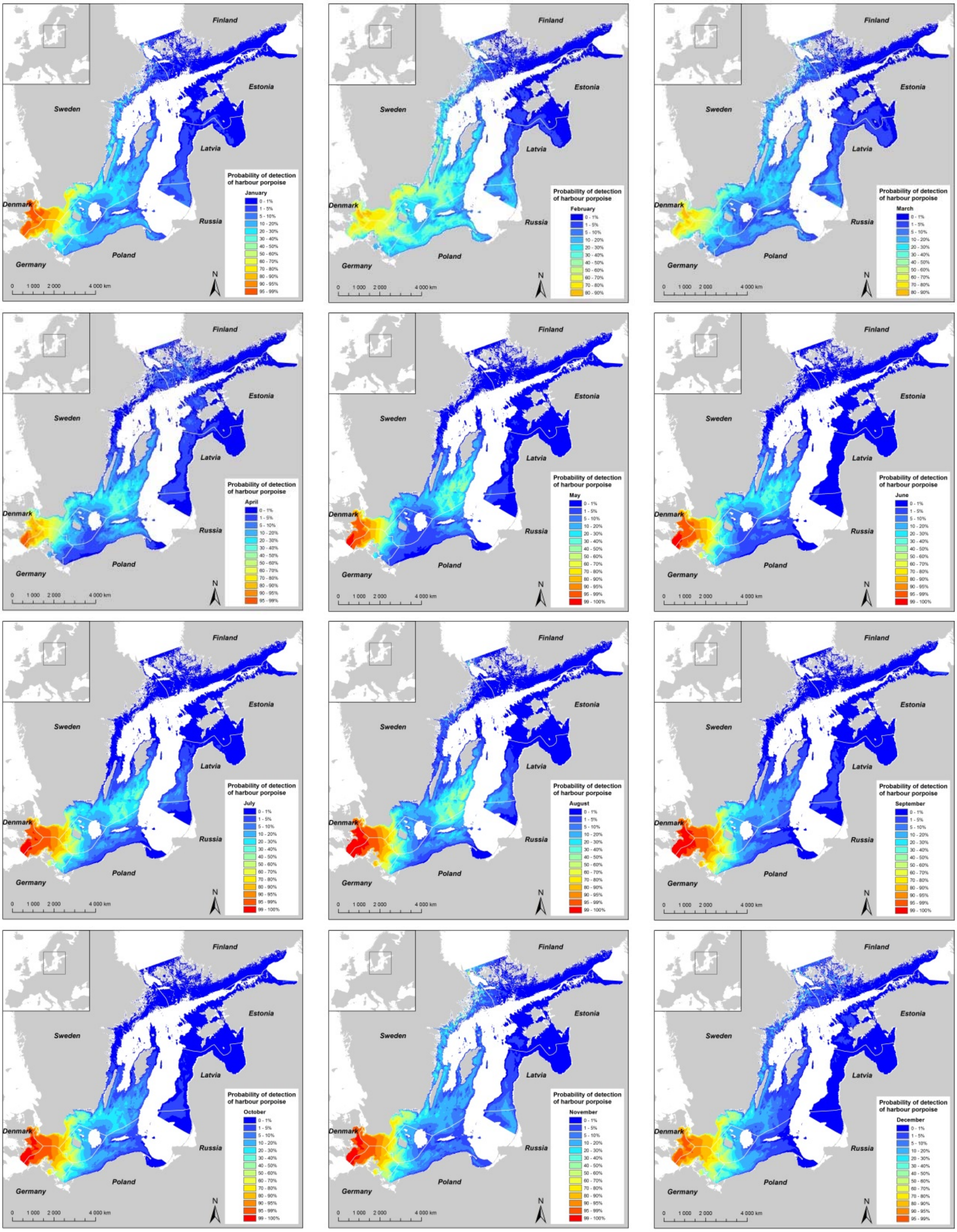


Figure 2-4. Predicted probability of detection of porpoises in the study area, for each month Jan-Dec (From SAMBAH 2016). Red represents the highest probablilty of detecting a porpoise and blue the lowest.

2.2.2 Harbour porpoises in the Belt Sea

The Belt Sea holds high densities of porpoises especially in the Sound, Great Belt, Little Belt and Fehmarn Belt. Based on ship surveys in 1994, 2005 and 2012, the number of porpoises residing in this area was estimated to be 27,923 (95% CI: 11,916 - 65,432, 1994), 10,614 (95% CI: 6,218 - 18,117, 2005) and 18,495 animals (95% CI: 10,892 - 31,406, 2012), respectively (Sveegaard et al., 2013). Sveegaard et al. (2015a) analysed existing data on distribution, genetics and morphology of the Belt Sea population and defined the best possible eastern management delimitation during summer to be at 13.5˚E (Figure 1-1, 2-1). This is approx. 45 km east of the northern route area. This separation does not mean that individuals from the Belt Sea population cannot be found in the northern route area, but rather that these waters are relatively unimportant to the Belt Sea Population.

2.3 Reproduction

In the Baltic, harbour porpoises have a maximum length of 1.8 m and a maximum weight of up to 90 kg. They are relatively short-lived compared to other toothed whales, with a maximum recorded lifetime in the wild of 23 years (confirmed by dentinal growth layer groups (Lockyer and Kinze, 2003)).

The breeding period of Baltic harbour porpoises begins in mid-June and ends in late August. Ovulation and conception typically take place in late July and early August (Sørensen and Kinze, 1994). The gestation time is approx. 11 months and females can thus give birth to a single calf in early summer. The calf begins suckling immediately after parturition and accompanies its mother until March the following year and possibly longer. As females often give birth every year, the suckling period will usually end after 12 months at the latest. Females can conceive when they are 3 or 4 years old (Kinze et al. 2003). Changes in food resources may influence the reproduction of porpoises.

For the Belt Sea population, no specific reproduction areas have been identified, but calves seem to be sighted throughout the population range. Areas of high porpoise density may therefore also be considered important for reproduction (Hammond et al., 1995; Kinze et al., 2003). For the Baltic Proper population, the SAMBAH project identified relatively high porpoise presence during summer in Swedish waters on the Midsjö Bank and Hoburgs Bank south of Gotland (See **Figure 2-6** in section on Natura 2000 sites), which may be areas important for reproduction and calving.

2.4 Diving behaviour

The diving behaviour of harbour porpoises has been studied in Danish and adjacent waters by use of satellite linked dive recorders on 14 harbour porpoises (Teilmann et al., 2007). The average number of dives per hour was 29 during April-August and 43 during October-November. This may indicate a shift in available prey or an increased energy comsumption due to the colder water. Daily maximum dive depth corresponds to the depth of the Belt Seas and Kattegat where depth generally does not exceed 50 m. Maximum dive depth recorded was 132 m for animals moving north into Skagerrak. Maximum dive durations were frequently recorded in the range 10-15 min. The diel pattern shows that harbour porpoises dive continuously during day and night but with peak activity during daylight hours. On average they spend 55% of their time in the upper 2 meters of the water column during April-August. Generally, adult animals make fewer but longer dives while younger animals make more dives of shorter duration (Teilmann et al., 2007).

2.5 Feeding

The average daily food intake per adult harbour porpoise is approx. 1.75 kg consisting mainly of fishes of up to 20-25cm in length with a preference for fatty fishes like mature herring and sprat (Börjesson and Berggren, 2003). Different species of codfish, gobies and sandeel are also important prey items.

Between 1985 and 1990, the stomach contents of 21 harbour porpoises from the southern part of the Belt Seas and the western part of the Baltic Sea were studied. Herring made up 36% while cod made up 41% and eelpout 10% of the fish weight eaten (Börjesson and Berggren, 2003). Besides these, the most important species were mackerel, saithe, plaice, flounder, black goby, sandeel and garfish. In the same area, Lockyer and Kinze (2003) found eelpout, eel, sandeel, garfish, gobies, cod, whiting, herring, anchovies and flatfishes in porpoise stomachs. In conclusion, the harbour porpoise is an opportunistic feeder, and the diet varies both spatially and temporally. In a tagging study, Wisniewska (Wisniewska et al., 2016; Wisniewska et al., 2018a) found that harbour porpoises on average made 125 (juvenile) and 79 (adults) feeding attemts on small fish (3-10 cm) every hour with a 90% success rate.

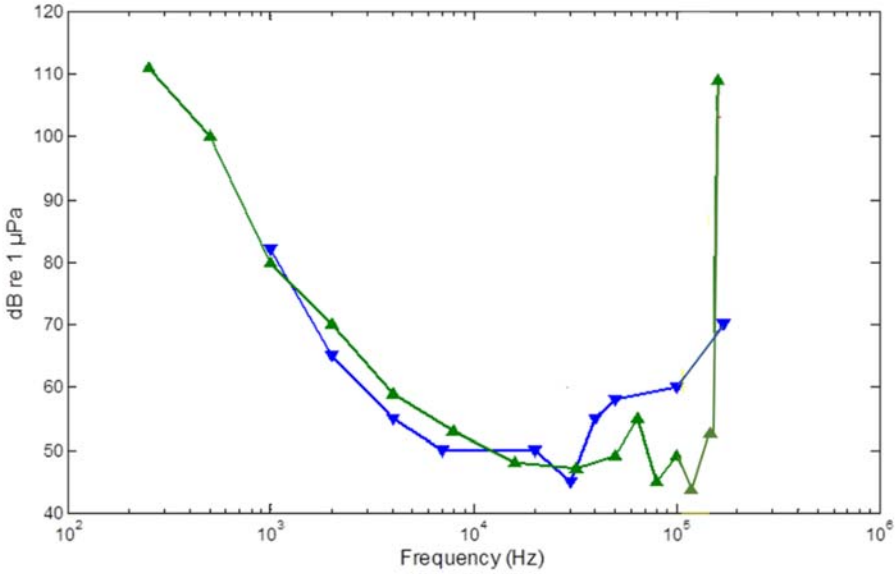
2.6 Echolocation and hearing

Porpoises, like all toothed whales (odontocetes), have good underwater hearing and use sound actively for navigation and prey capture (echolocation). Harbour porpoises produce short ultrasonic clicks (130 kHz peak frequency, 50-100 µs duration (Møhl and Andersen, 1973; Teilmann et al., 2002; Kyhn et al., 2013); and are able to orient and find prey in complete darkness. Data from porpoises tagged with acoustic data loggers indicate that they use their echolocation almost continuously (Akamatsu et al., 2007; Linnenschmidt et al., 2013; Wisniewska et al., 2016).

Hearing is the key sensory modality for harbour porpoises for most aspects of their life. A few studies have investigated other senses, such as the anatomy and chemistry of the eye (Peichl et al., 2001), but regarding functionality hearing is the only sense that has been investigated to any great extent.

Harbour porpoise hearing is very sensitive and covers a broad frequency range (Figure 2-5 (Andersen, 1970; Kastelein et al., 2002; Kastelein et al., 2010). Best hearing is in the frequency range above approx. 10 kHz up to around 160 kHz.

Figure 2-5. Audiograms for harbour porpoises modified from Kastelein et al. (2010) (green) and Andersen (1970) (blue). The audiogram shows the hearing threshold, i.e. the minimum audible level as a function of frequency. Best sensitivity (lowest threshold) is in the range 10-160 kHz (the best sensitivity).



2.7 Vision

Cetaceans have good vision, although especially toothed whales have small eyes relative to their body size, compared to other mammals. The eyes appear to be completely adapted to underwater vision under low light conditions. Under most conditions, the vision of porpoises is restricted by the turbidity of the water and their visual range in Danish waters is unlikely to be more than some tens of meters. Harbour porpoises, like other cetaceans, are functionally colourblind (Peichl et al., 2001).

2.8 Other senses

Toothed whales have no sense of smell, but taste may play a role, not only in relation to tasting prey, but also in terms of collecting information about the surrounding water.

A magnetic sense, that is the ability to determine the direction of the earth's magnetic field, has only been demonstrated convincingly in a few vertebrates (primarily birds) and this ability is very difficult to explore experimentally (Wiltschko and Wiltschko, 1996). It has thus not been shown that any marine mammal has a compass sense, but it cannot be ruled out either.

Until fairly recently it was believed that no marine mammals had electroreceptive abilities, but it has been conclusively demonstrated that the hairless vibrissal crypts on the rostrum of the Guiana dolphin serve as electroreceptors with a sensory detection threshold for weak electric fields of 4.6 μV cm^{-1} (Czech-Damal et al., 2011). This threshold is comparable to the sensitivity of the electroreceptors in other electroreceptive animals. Neither the anatomical structures (ampullary organs), nor the electrorecptive capabilities have been shown in other odontocetes. It is thus not believed that porpoises have this capability, but it has not been thoroughly investigated.

2.9 Disturbances

Harbour porpoises are vulnerable to anthropogenic disturbances and threats. The most severe threat is likely to be incidental bycatch and subsequent drowning in set nets. However, no data on the magnitude of bycatch in the Baltic Sea are available. Another likely major threat to porpoises, particularly in the Baltic proper is contaminants (heavy metals and organochlorines), followed by anthropogenic noise from various sources, prey depletion due to overfishing, habitat destruction and pollution. Disturbances will be elaborated on in the NSP2 assessment report for marine mammals.

2.10 Protection

A number of international treaties, agreements and legislations have been enacted in order to protect harbour porpoises. In European waters, the species has been listed in annex II and IV of the Habitats Directive (European Commission, 1992), annex II of the Bern Convention, annex II of the Bonn Convention and annex II of the Washington Convention. Furthermore, the harbour porpoise is covered by the terms of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), a regional agreement under the Bonn Convention and HELCOM (The Helsinki Commission; protection of the marine environment of the Baltic Sea). The Baltic population of harbor porpoises is listed as 'Critically endangered' by the World Conservation Union while the regional assessment for the harbour porpoise in Europe (which included the Belt Sea population) is listed as "Vulnerable" (IUCN red list, Hammond et al., 2016).

Harbour porpoises are listed under annex IV of the Habitats Directive, which implies that "*Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV (a) in their natural range, prohibiting: ... (b) Deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration ...*" (article 12).

The ASCOBANS agreement covers all small toothed whales and thus also porpoises. It states that member states are obligated to "*Work towards ...(c) the effective regulation, to reduce the impact on the animals of activities which seriously affect their food resources, and (d) the prevention of other significant disturbance, especially of an acoustic nature*" (Annex to Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (www.ascobans.org)). Furthermore, as an extension of the ASCOBANS agreement, the member states have signed the "Recovery plan for porpoises in the Baltic Sea (Jastarnia plan)", (ASCOBANS, 2002), which highlights the highly threatened status of the harbour porpoise population of the Baltic Proper. The aim of the recovery plan is to re-establish the porpoise population in the Baltic to min. 80% of its carrying capacity. Although the recommendations of the plan are focused on measures to reduce incidental bycatch in fisheries, the serious situation that the population currently faces is reflected in the recommendations: "*In other words, analysis indicated that recovery towards the interim goal of 80% of carrying capacity could only be achieved if the bycatch in this part of the Baltic were reduced to two or fewer porpoises per year*".

2.11 Natura 2000 sites in the Western Baltic near the NSP2 pipeline route

Harbour porpoises are not listed as part of the selection criteria for any Danish Natura 2000 site in the Baltic Proper (Figure 2-6). There are currently three designated Natura 2000 areas in the Swedish Baltic with harbour porpoises listed as part of the selection criteria, namely Sydvästskånes Utsjövatten (48 km from northern route), Kiviksbredan (36 km) and Hoburgs Bank and Midsjöbankerne (54 km) (Figure 2-6). All three areas are within the 100 km buffer of the northern route.

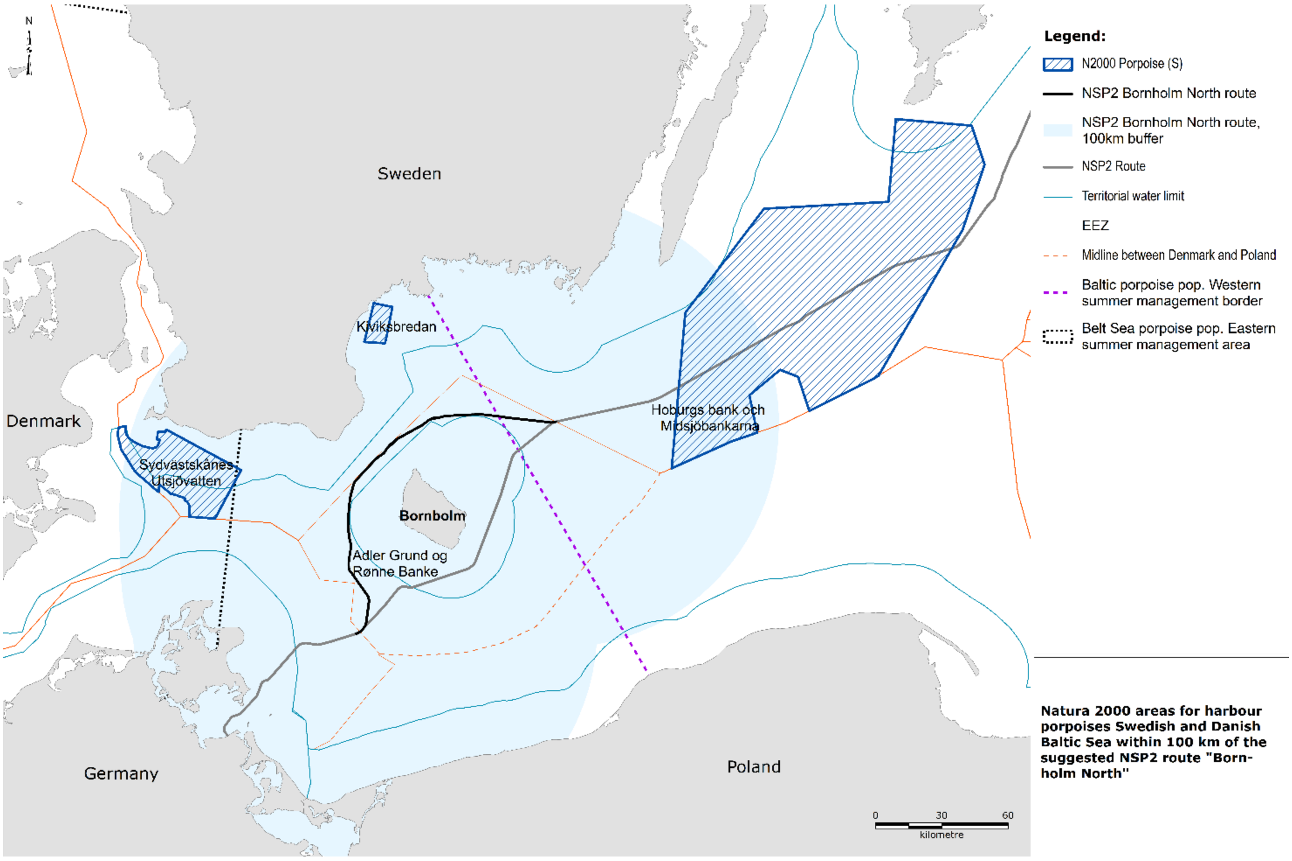


Figure 2-6. Map displaying the 3 designated Natura 2000 sites (N2000) for harbour porpoises in the Swedish Baltic. Only Swedish and Danish N2000 sites within 100 km of the northern route area shown. The summer population management borders for the Belt Sea population (from the black line and westward) and the Baltic harbour porpoise summer population (from the purple line and eastward) are indicated. Shaded blue area indicate the 100 km buffer zone from the northern route.

3 Harbour seal (*Phoca vitulina*)

3.1 Population structure

Based on molecular data and satellite telemetry, the harbour seals in the Baltic region have been split into three management units or sub-populations, among which there is at least partial reproductive isolation: 1) Kalmarsund (between Øland and the Swedish mainland), 2) the southwestern Baltic (along the southern Danish and Swedish coasts) and 3) Kattegat (Goodman, 1998; Härkönen et al., 2006; Olsen et al., 2014). Tagging studies have shown limited movements of harbour seals (e.g. Dietz et al., 2015) and no or limited exchange between colonies separated by more than app. 100 km. The northern route is located in the gap between the Kalmarsund population and the southwestern Baltic population.

3.2 Distribution and abundance

Harbour seals are found in temperate and arctic waters of the Northern Hemisphere. The harbour seals of southern Scandinavia (Skagerrak, Kattegat, western Baltic, and the Limfjord) have probably been present in low numbers since the end of the last glaciation, however, they were assumably not abundant until a few centuries ago. Once established, the harbour seals became subject to intense hunting; first due to the value of the skin and blubber and later because of the threat they constituted to commercial fisheries. During the 1920s the population was at its lowest. Following protection in the Baltic region in the 1960-70s the populations have recovered at a high rate. More recently this continued recovery was interrupted by two severe morbillivirus epidemics in 1988 and 2002 reduced most populations by app. 50% on both occasions (Härkönen et al., 2006).

Haul-out sites (also called colonies) are land localities occupied by seals during periods of mating, giving birth, moulting and resting. Haul-out sites for harbour seals are well known and do not change between years. Annual counts are made on the haul-out sites during the moult in August in Denmark and Sweden. In the Baltic Sea, harbour seals are only found in Kalmarsund between Øland and the mainland of Sweden and in the southwestern Baltic concentrated around the Rødsand sand bar (7 km west of Gedser in Denmark), Aunø Fjord in South Sjælland and Falsterbo and Saltholm in the Sound.

3.3 Harbour seals in the southwestern Baltic Sea

In the Baltic, harbour seals are mainly found in Danish, Swedish and German waters although occasional visits to other areas may occur. There are 2 haul-out sites located within 100 km of the northern route, namely at Falsterbo and at Kalmarsund, south of Öland (Figure 3-1).

The Kalmarsund population comprises around 1,000 individuals (HELCOM, 2015) and the southwestern Baltic population around 1,500 individuals (Sveegaard et al., 2015b). Under the most recent assessment of biodiversity under HELCOM, the Kalmarsund population falls below the threshold for 'Good Status', based on the low abundance, while the growth rate of the stock is satisfactory. The southwestern population falls below the threshold based on a positive growth rate lower than the threshold (HELCOM 2017).

The knowledge on abundance and density of seals is extensive with respect to the locations of the haul-out sites, but very limited when it comes to their use of the surrounding waters, especially in the Kalmarsund region. In the western part of the Baltic, 10 harbour seals have been tagged with GPS transmitters at Falsterbo, Sweden, in 2012 (Figure 3-1). GPS tracking of seals can provide detailed information on the movement of individual seals. The recieved positions (displayed in Figure 3-1) show that the majority of seal positions are at least 70 km away from the northern route and that the closest positions are approximately 24 km away. The sample size of 10 is, however, relatively small it cannot be concluded that seals will not enter the northern route area.

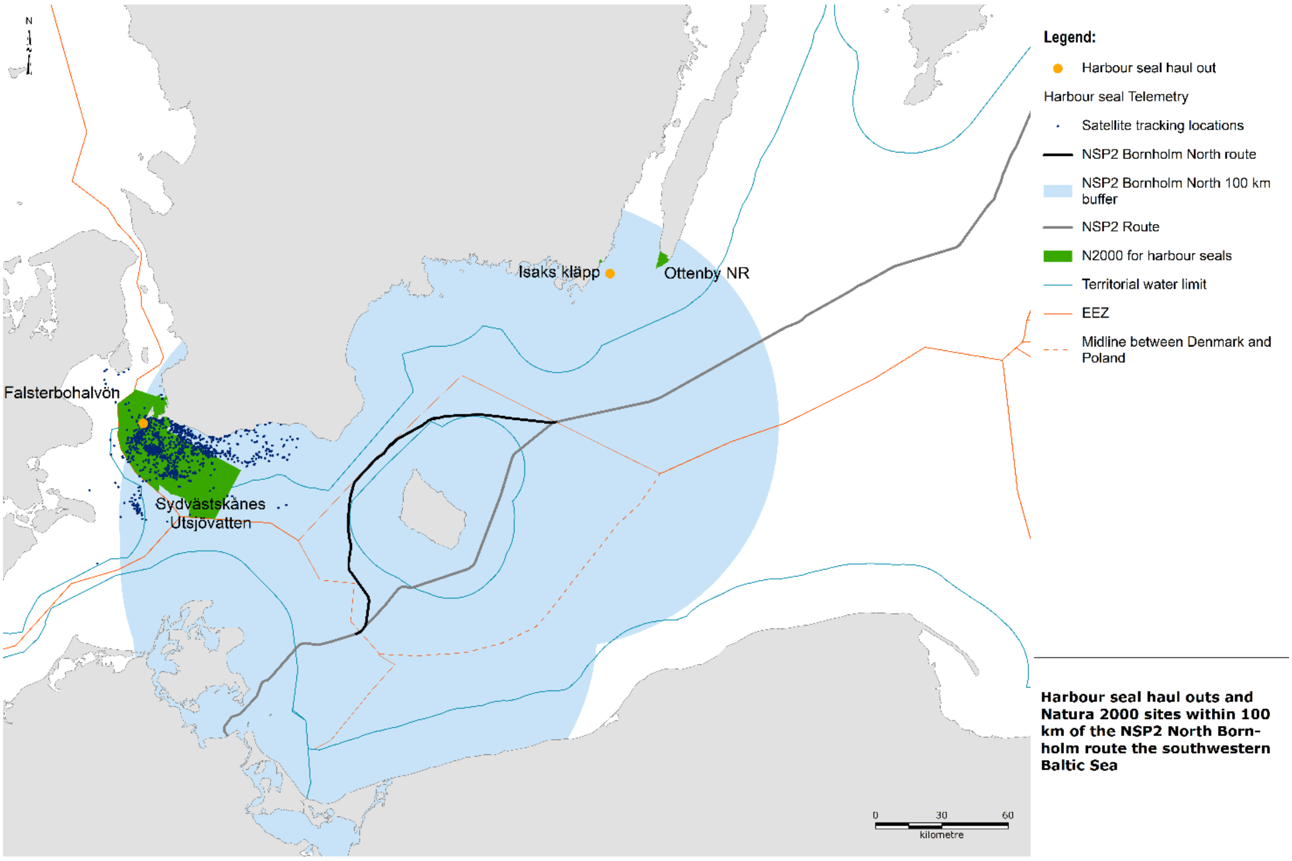


Figure 3-1. Map of haul-out sites (colonies) in the southwestern Baltic used by harbour seals for resting, breeding and moulting. Only sites within the 100 km buffer zone (blue area) from the northern route are included. Dark blue dots indicate positions of 10 satellite tagged seals at Falsterbo (2012). Data source: Aarhus University.

3.4 Behaviour and reproduction

The harbour seal is a relatively small seal with an adult weight of app. 70-100 kg (Teilmann and Galatius 2018). Adult females give birth once a year on land in May and June, with a gestation period of 11 months. The pup suckles for about three to four weeks after which it is left to fend for itself. Harbour seal pups shed their embryonic fur (lanugo) before birth and are thus born with the adult fur. In contrast to most other true seals, the pups are able to swim and dive for longer periods immediately after birth. In case the mother and pup are disturbed on land they will flee together into the water, but as they depend on getting back on land again for suckling, disturbances in the breeding season in May-July can severely affect pup survival. Mating occurs immediately after the end of suckling and takes place in the water. Little is known of the exact circumstances surrounding the mating. Several studies from Norway, Scotland and California have suggested that males perform an underwater display, which includes vocalisations (Bjørgesæter et al., 2004) and that females seek out the displaying males and decide whether to mate or not (Hanggi and Schusterman, 1994; Boness et al., 2006). Moulting occurs in August where seals spend more time on land to develop the new fur. The moult depends on a good blood perfusion to the outer layers of the skin. In order to reduce heat loss from the body, this increased perfusion therefore mainly occurs on land, preferably with dry fur. Thus, also adult seals are vulnerable to disturbances during the summer months.

At sea, harbour seals hunt alone or in small groups. Depending on individuals and the area harbour seals stay within 25-100 km from shore, but individuals are occasionally found more than 100 km offshore (Tougaard et al., 2008). They primarily dwell on the same undisturbed islets and sandy beaches year-round but may occasionally be seen resting on scattered stones along the shores. Adult harbour seals do not migrate, but they are capable of travelling considerable distances. Localised movements are common whilst searching for food, and short-distance movements may also be associated with seasonal availability of prey and with breeding.

Harbour seals generally forage in areas shallower than 100 m (Tollit et al., 1998; Lesage et al., 1999; Eguchi and Harvey, 2005), but have been demonstrated to dive to depths exceeding 400 m (Gjertz et al., 2001). In the south-western Baltic, water depths do not exceed 50 m, and harbour seals tagged in this area regularly dived to the bottom (Dietz et al. 2015). Harbour seals from the Kalmarsund population may potentially forage in deeper waters in the vicinity of their haulouts, but this has not been investigated. Thus, harbour seals may potentially be present at all depths within their range in the areas surrounding the NSP2 route.

3.5 Feeding

Harbour seals are opportunistic predators. They feed mainly on benthic fish but can catch and eat all bony fish species in the area showing a high adaptability to changes in prey availability. The diet of seals varies across their distribution. In the southwestern Baltic Sea, 21 fish species have been detected. Lesser sand eel, black goby and Atlantic cod were found in the highest quantities, making up 44.5%, 15.1% and 11.5% of the otoliths, respectively (Andersen et al., 2007). In Kalmarsund, only 5 prey species were detected with European eel being the most important prey (41.7%), followed by Atlantic cod (16.7%), European flounder (16.7%) and European whitefish (16.7%) (Söderberg, 1975). In addition, garfish have been found in the diet, but as the head is not eaten, the otoliths are lacking and the importance of this species is therefore difficult to estimate.

3.6 Hearing

Seals have ears well adapted to an aquatic life. These adaptations include a cavernous tissue in the middle ear which allows for balancing the increased pressure on the eardrum when the animal dives (Møhl, 1967) and also a separate bone conduction pathway for sound to the middle ear in water. The audiogram of harbour seals shows good underwater hearing in the range from a few hundred Hz to approx. 50 kHz (**Figure 3-2**, left).

The critical bandwidth of harbour seal hearing increases with frequency, at least in the range 2.5 kHz to 30 kHz where it has been measured (Figure 3-2, right) and is comparable to the general pattern in the few marine mammals studied, i.e. about 1/3 octave or smaller in the range of best hearing and broader at the very low frequencies. The critical bandwidth is (among other) a measure of the sensitivity to masking by noise. Noise which falls within the critical bandwidth around a given tone stimulus of constant frequency is able to mask the tone (i.e. make it more difficult to hear the tone) whereas noise that falls outside the critical bandwidth has little or no effect on the detection of the tone. Small critical bandwidths thus indicate lower sensitivity to noise interference, whereas broader critical bands indicate higher sensitivity to noise. Critical bands have not been measured in grey seals or ringed seals, but it is reasonable to expect that they are comparable to what is seen in harbour seals.

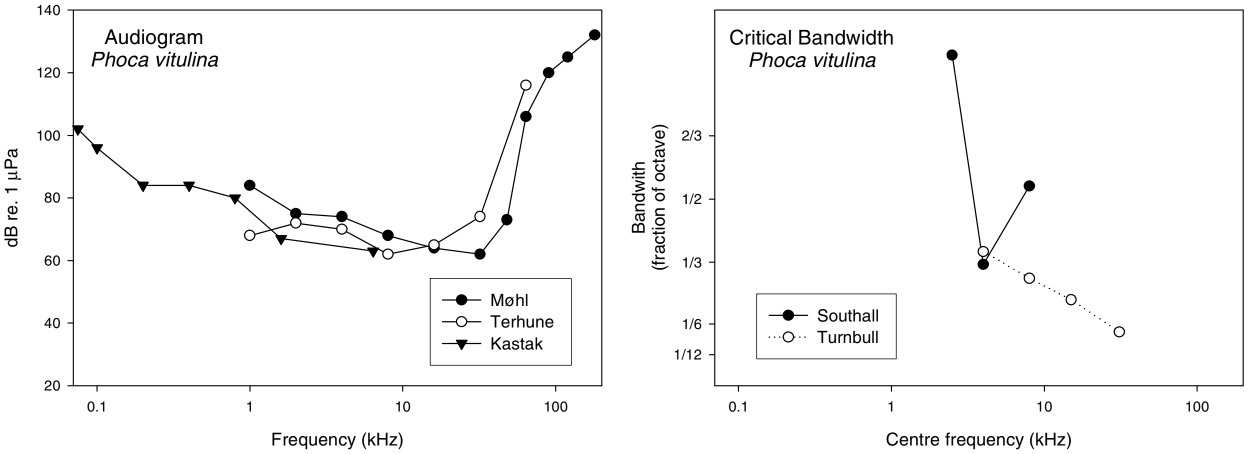


Figure 3-2. Left: audiograms of three harbour seals, showing threshold of hearing under quiet conditions at frequencies in the range from 80 Hz to 150 kHz. Data from (Møhl, 1968; Terhune and Turnbull, 1995; Kastak and Schusterman, 1998). Right: critical bandwidth of harbour seals, expressed as fraction of an octave. Data from Southall et al. (2001) and Turnbull and Terhune (1990).

3.7 Vision

Seals have good vision, both in air and water, with variation from species to species in terms of the degree to which the eyes are adapted to water. The lens is adapted to underwater vision and focusing in air is believed to be possible due to the slit-formed pupil (when contracted), which results in a large depth of focus (Fobes and Smock, 1981; Hanke et al., 2009). As all other pinnipeds (and cetaceans) the harbour seal is considered to be functionally colour blind (Peichl et al., 2001).

The sensitivity of the eyes is high, enhanced by the presence of a *tapetum lucidum* behind the retina and seals are probably able to orient visually even at great depth (Levenson and Schusterman, 1999). As for porpoises, the visual range of seals is most likely limited by the available light and / or the turbidity of the water under most, if not all circumstances in Danish waters.

3.8 Touch/vibration

Seals have very well developed whiskers (vibrissae) and the follicles are highly vascularised and surrounded by a large number of attached sensory nerves (Dykes, 1975). Behavioural experiments have shown that the whiskers of seals are extraordinarily sensitive to particle movement in the water

(Denhardt et al., 1998) and it is quite possible that seals can detect the vortices and eddies left behind in the wake of a swimming fish, even several minutes after the fish has passed (Denhardt et al., 2001) and in that way find and capture prey, even in complete darkness.

The whiskers thus play as large a role as the eyes, if not larger, in terms of locating prey. This is especially true at great depth, at night and when visibility is low.

3.9 Electro- and magnetoreception

There is no evidence of electroreception or the ability to detect magnetic fields in seals. However, as for porpoises, the possibility of magnetoreception should not be dismissed.

3.10 Disturbance

Harbour seals on land react to boats by moving into the water when a boat is 50-500 m from a haul-out. The disturbance distance depends on the area and the type of boat (Henry and Hammill, 2001). In some areas, the seals habituate to regular traffic and seem to develop tolerance to noise (Andersen et al., 2012; Andersen et al., 2014). During construction and operation of a large wind farm near Rødsand in Denmark the effect on hauled out seals was investigated. Only pile driving of sheet piles at one of the wind turbine foundations about 4 km from the haul out site caused measurable effect of the seals on land (Edrén et al., 2010).

Harbour seals are also sensitive to underwater noise, although to a much lesser degree than porpoises (Mikkelsen et al., 2017).

3.11 Protection

Harbour seals are protected under the EU Habitats Directive, the Convention for the Protection of Migratory Species (Bonn Convention) as well as protected under national legislation. Harbour seals are listed as 'Least concern' by the World Conservation Union (Lowry, 2016). However, the International Union for Conservation of Nature (IUCN) expresses concern for the Kalmar Sound population (IUCN, 2007). The harbour seal is listed on the EU Habitats Directive annex II, which means that they should be protected by the designation of special areas of conservation. For seals, these areas are primarily placed in connection with important haul outs on land.

3.12 Natura 2000 sites in the Baltic near the northern route

Four Natura 2000 sites for harbour seal are located within 100 km of the northern route, namely Falsterbohalvön (83 km away), Sydvästshånes Utsjövatten (48 km), Isaks Kläpp (75 km) and Ottenby NR (83 km) (see Figure 3-1 and Table 3-1). There are no Natura 2000 sites for harbour seals in Danish waters within 100 km of the NSP2 pipeline route.

Table 3-1. Natura 2000 sites in the Swedish Baltic waters with harbour seal (*Phoca vitulina*) listed as part of the selection criteria. Area size, percentage of area that is marine, population status (according to the Habitats Directive), population size as well as approx. swimming distance to NSP2 pipeline route (km) (Source: http://natura2000.eea.europa.eu/#).

Site	Site name	Area (km^2)	Marine %	Population status	Pop. Size min-max	Approx. swimming distance to North Bornholm NSP2 pipeline (km)
SE0330108	Ottenby NR	2391.4	40	C	10-40	83
SE0410113	Isaks kläpp	124.7	97	C	50-50	75
Ö284	Sydvästskånes Utsjövatten	1151.28	100	(not assessed yet)	(not assessed yet)	48
SE0430095	Falsterbohalvön	42342.2	97	C	60-60	83

4 Grey seal (*Halichoerus grypus*)

4.1 Population structure

There are at least three separate populations of grey seal in the world. One of them is the Baltic grey seal, which is found in the Baltic Proper, in the Bothnian Sea and in the Gulf of Finland. This population is currently recolonising the southern Baltic (Fietz et al., 2016). The other two populations live in the Northeast and Northwest Atlantic. The grey seal is by far the most abundant seal species in the Baltic (Figures 4.1 and 4.2).

Graves et al. (2008) and Fietz et al. (2016) found clear genetic differentiation between the Baltic and North Sea grey seals. Also some differentiation was found between the three main breeding areas in the Bothnian Bay, Gulf of Riga and northern Baltic Proper, suggesting limited genetic exchange.

4.2 General distribution and abundance

The grey seal is only found in the North Atlantic. In the Northeast Atlantic, grey seals are centered around the British Isles, ranging from Iceland, eastward along the coast of France, and north along the Norwegian coast and the Kola Peninsula. The Northwest Atlantic population is found from the northeastern United States to Cape Chidley at the northern tip of Labrador (60° N), with the largest concentration around Sable Island, off the Nova Scotia coast. The Baltic Sea population shows the highest density in the central Baltic area, bounded by Sweden, Finland and Estonia (NAMMCO, 2007).

4.2.1 Grey seals in the southwestern Baltic Sea

The grey seal is currently the most abundant seal species in the Baltic. Around 1900, the grey seal population had a size of 80-100,000 individuals while in the 1970s it was down to about 4,000 because of hunting and pollution (Harding and Härkonen, 1999). Abundance based on photo-identification in 2000 yielded an abundance estimate of 15,600 individuals while an aerial survey in 2004 found 17,640 grey seals on land (Hiby et al., 2006). With an annual population increase of 7.9% and correction for seals in the water, which are not counted during the surveys, it is believed that the total population in the Baltic in 2014 was above 40,000, based on 32,200 seals counted on land (HELCOM, 2015). Under the most recent assessment of biodiversity under HELCOM, the Baltic grey seal population falls below the threshold for 'Good Status', based on inadequate reproductive and nutritional status, while the abundance and population growth rate are above the evaluation thresholds (HELCOM 2017).

The Baltic grey seals are distributed from the northernmost part of the Bothnian Bay to the southwestern Baltic. Generally, during the breeding period, the seals dwell on drift ice in the Gulf of Riga, the Gulf of Finland, the Northern Baltic Proper and the Bothnian Bay or on rocks in the north-western Baltic.

The area near the northern route holds one major grey seal haul-out at Ertholmene and several further away on the Swedish coast (Figure 4-1). The colony at Ertholmene is at present the largest of the Danish grey seal colonies and up to 600 grey seals have been counted here. In the Danish part of the

Baltic, the number of grey seals has increased considerably over the last decade (Figure 4-2).

Satellite tracking of grey seals has shown that this species moves over long distances in the Baltic Sea and most tagged grey seals from the southern Baltic Sea have moved far into the Baltic Proper (Dietz et al. 2015). A tagged female from Rødsand in the Danish Baltic was observed with a pup in Estonia and observed back at Rødsand a month later. This indicates seasonal migrations that are closely related with the requirements for feeding and site fidelity for breeding area, where grey seals travelled up to 380 km from the tagging site (Dietz et al. 2015). Typically, however, they feed more locally, foraging just offshore and adopting a regular pattern of travelling between local feeding sites and preferred haul-outs (Sjöberg and Ball, 2000; Oksanen et al., 2014).

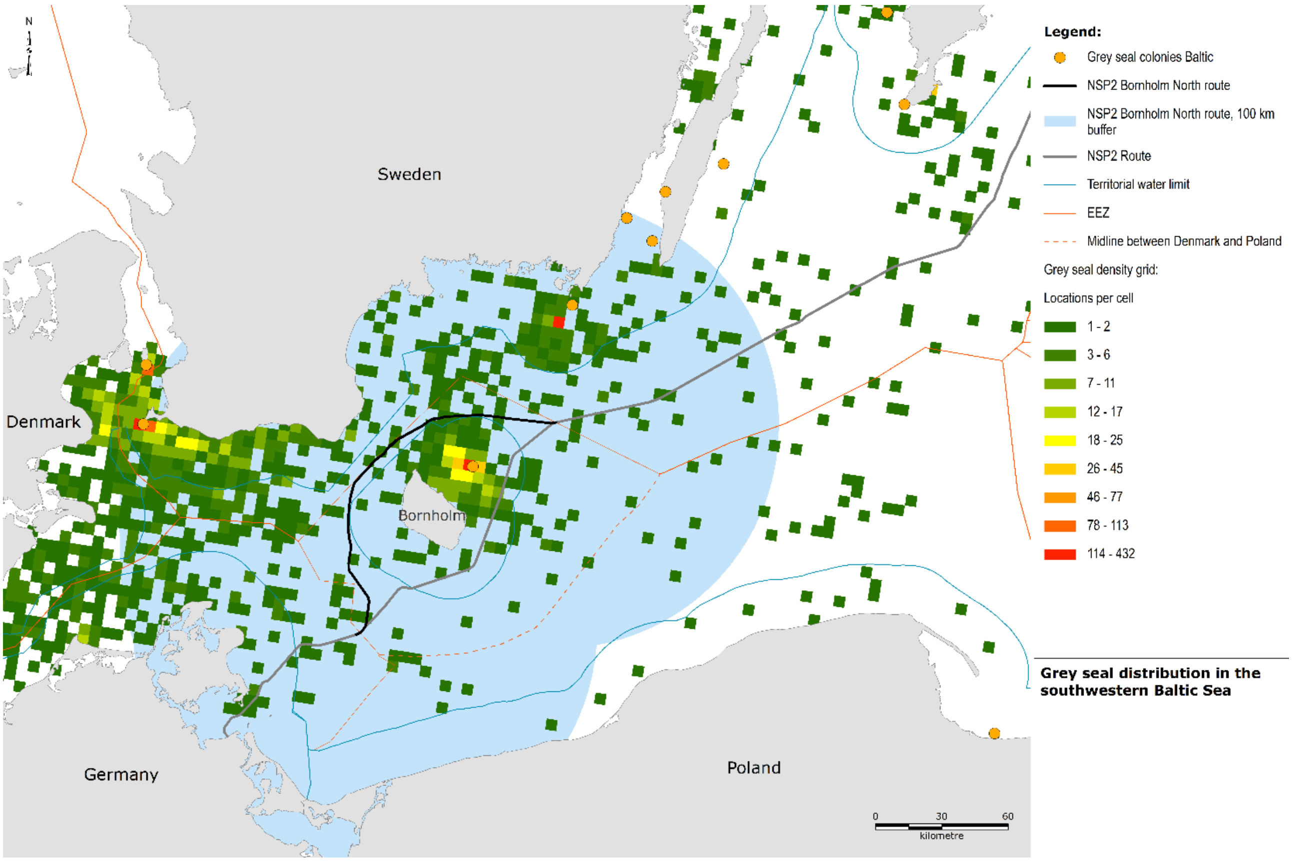


Figure 4-1. Map of haul-out sites (colonies) used by grey seals for resting, breeding and moulting and density grid from satellite tracking of seals.Grey seal density grids are displayed as number of locations from GPS tracked grey seals per grid cell. Data source: HELCOM BALSAM Seal Database. Note that the distribution grid does not show the distribution of the whole population and is biased by the haulout sites where relatively more positions are received from land. Thus, it can only be used as an informative overview of grey seals in Baltic. Shaded blue area indicate the 100 km buffer zone from the northern route.

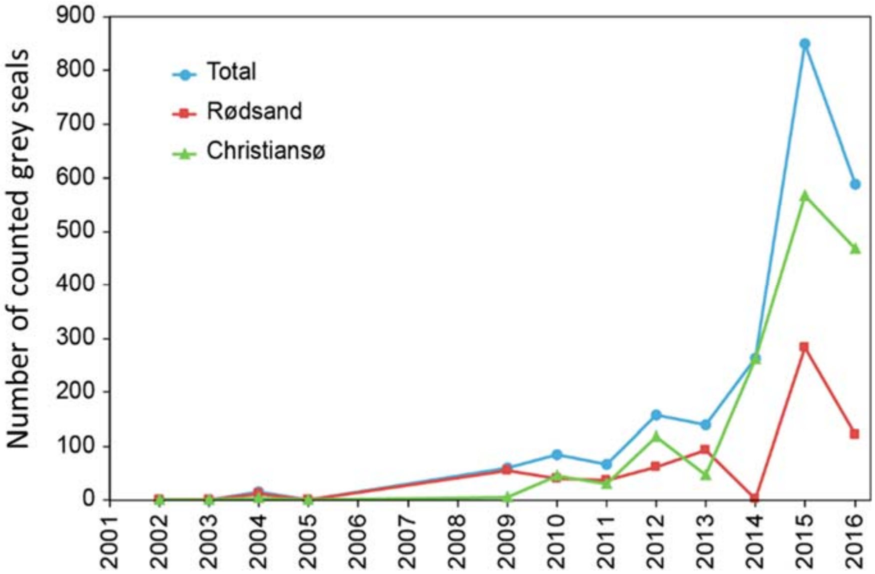


Figure 4-2. Number of grey seals counted during their moulting period (May-June) in the Danish part of the Baltic Sea 2002-2016 (from Hansen, 2018).

4.3 Behaviour and reproduction

Grey seals feed in open and coastal waters and breed in a variety of habitats where disturbance is minimal, such as rocky shores, sandbars, sea ice and islands. In the Baltic, birth takes place on pack ice in February and March or sometimes even in April depending on the ice-conditions. Some grey seals, however, also pup at uninhabited islets, most notably in Estonia and in the Stockholm Archipelago as well as a few seals in Denmark (Rødsand sand bar). Males follow the female closely after she has given birth waiting to mate as soon as nursing has ended.

Grey seals are gregarious and gather for breeding, moulting and hauling out. They primarily haul out in coastal areas - in winter also on drift ice close to open water and during summer preferably on uninhabited islands, outer islets and rocks. During the moulting period, they dwell on rocks and islets and sometimes on the last drift ice in the Bothnian Bay. Grey seals often share their haulouts with the harbour seal in areas where both species live. This is e.g. the case at Falsterbo and Rødsand, some of the southernmost localities for grey seals in the Baltic Sea.

Although dives exceeding 400 m have been recorded, most diving is at depths shallower than 120 m, with males tending to dive somewhat deeper (Beck et al., 2003). In the North Sea, grey seals have been observed to alternate long foraging trips with local, repeated trips and forage at depths between 50 and 90 m (McConnell et al., 1999). In a study of seals tagged in the southwestern Baltic, dive depths were mostly shallower than 30 m, although some dives deeper than 50 m were recorded (Dietz et al. 2015). Only slight seasonal variations in dive patterns were oberserved. Thus, harbour seals may potentially be present at all depths within their range in the areas surrounding the NSP2 route.

4.4 Feeding

Grey seals dive alone or in small groups and feed on many species of fish. In most of the Baltic Sea, herring seems to be the main prey. In samples collected at Gotland, 9 fish species were identified from one study of 41 samples. 530 otoliths were recovered with the most abundant prey items being Atlantic herring, sprat and Atlantic cod, which made up 32.6%, 31.3% and 24.5% of otoliths, respectively. In the Swedish central Baltic Sea, 32 fish species have been identified as prey. Atlantic herring was most abundant (70.4% of recovered otoliths), followed by sprat (9.4%). In the Baltic Proper, sprat, common whitefish, freshwater cyprinids, gobies and flounder are also important while a series of other species, covering most fish species living in the Baltic, contribute in lower amounts (Lundström et al., 2007).

4.5 Sensory physiology

The senses of grey seals have not been studied to any significant level of detail. As the two species are closely related and not dramatically different in size, physiology and anatomy, harbour seal data are considered reasonable proxies for grey seal sensory capabilities.

4.6 Disturbance

Grey seal populations can be disturbed by tourism, commercial fishing and mining activities, although little is known about responses to human presence, underwater noise and airborne noise. The grey seal populations in the Baltic Sea are vulnerable to the effects of disturbance by ice-breaking activities, with a possible impact on breeding success. In the 1970s and 1980s female grey seals in the Baltic showed reproductive abnormalities and highly reduced fecundity with around 50% of females being sterile. These conditions were associated with high levels of organochlorines (Helle et al., 1976) Bredhul et al. 2008). In recent years, birth rates have been much higher, and fluctuations have been ascribed to variations in prey availability, particularly of herring, rather than effects of pollution (Kauhala et al., 2016).

4.7 Protection

4.7.1 Protection in EU waters

The grey seal is a protected species listed in Appendix II and Appendix V of the EC Habitats Directive and Appendix III of the Bern Convention. The Baltic grey seal population is listed as 'Least concern' by the World Conservation Union (Härkönen, 2016). A limited number of grey seals are hunted under quotas in Finland (Finnish Ministry of Agriculture and Forestry, 2007) and Sweden (Havs- och Vattenmyndigheten, 2012). The actual number of shot seals have always been far below the quota, the highest number shot in Sweden in any one year was 132 in 2008, in Finland it was 632 in 2009 (Finnish Ministry of Agriculture and Forestry, 2007; HELCOM, 2014). Estonia and Denmark have opened small quotas to protect fisheries (Naturstyrelsen (2014), http://news.err.ee/v/environment/e9a79e47-7cea-40e6-975d-2be201b91822).

4.7.2 Natura 2000 sites in the Baltic near the NSP2 pipeline route

Grey seals are listed as part of the selection criteria in one Danish and four Swedish Natura 2000 site within 100 km of the northern route (Table 4-1, Fig. 4-3). The nearest area is Ertholmene, which is 16 km away.

Table 4-1. Natura 2000 sites in the Swedish Baltic waters with grey seal (*Halichoerus grypus*) listed as part of the selection criteria. Area size, percentage of area that are marine, population status (according to the Habitats Directive), population size as well as approx. swimming distance to NSP2 pipeline route (km) (Source: http://natura2000.eea.europa.eu/#).

Site	Site name	Area (ha)	Marine %	Population status	Pop. Size (min-max)	Approx. swimming distance to NSP2 pipeline route (km)
DK007X079	Ertholmene	1256	100	C	no data	16
SE0330108	Ottenby NR	2391.4	40	C	10-40	52
SE0410040	Utklippan	117.6	990	C	no data	45
Ö284	Sydvästshånes Utsjövatten	1151.28	100	(not assessed yet)	(not assessed yet)	48
SE0430095	Falsterbohalvön	42342.2	97	C	60-60	83

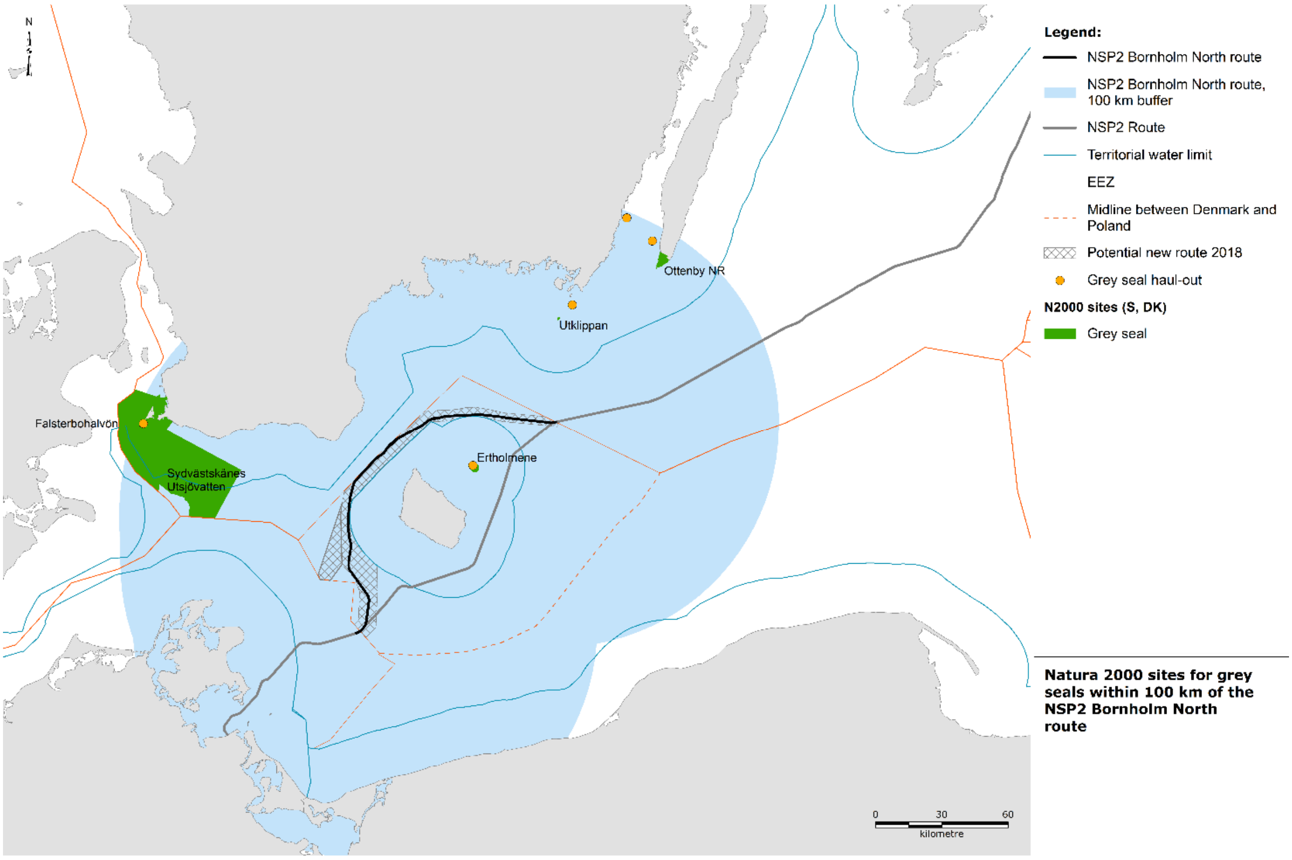


Figure 4-3. Map of Swedish and Danish Natura 2000 sites (marked in green) within a 100 km buffer zone (marked in blue) from the northern route with grey seal listed as part of the selection criteria. Haul-out sites are indicated with orange dots.

5 Critical periods for marine mammals in the Baltic Sea

The most vulnerable periods for seals in the southwestern Baltic Sea are primarily during their moulting, breeding and lactation periods. Harbour porpoises are also vulnerable in the breeding period, but the calves may be vulnerable throughout the first year and especially in the first period after leaving their mother (Table 5-1).

Table 5-1. Critical periods for harbour porpoise, harbour seal and grey seal in Danish waters.

Species	Breeding and lactation period	Moulting period
Harbour porpoise	All year (nursing persists throughout the following year)	-
Harbour seal	May – July	August
Grey seal	February – March/April	May - June

6 Introduction to Assessment

The central question in the context of the NSP2 project and marine mammals answered in this report is whether the construction and operation of the pipeline will have an impact (positive or negative) on the individual animals as well as on the populations (i.e. on abundance and distribution). Whether such an 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. 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.

Assessment methodology follows the methods described in the overall EIA for the Nord Stream 2 project (Rambøll, 2017). Only direct and negative impacts are considered. For each identified impact on each of the relevant species, the spatial extent, duration, and intensity of the impact is assessed (see Table).

Table 2. Categories used in assessment. Adapted from (Rambøll, 2017).

Spatial extent	
Local	Affecting the pipeline route corridor and/or the immediate vicinity of the pipelines/construction site (<5 km).
Regional	Affecting an area between 5-20 km from the pipeline route corridor.
National	Affecting an area >20 km outside the pipeline route corridor, but restricted to country waters (TW/EEZ).
Transboundary	Impacts that are experienced outside the Danish EEZ/TW as a result of activities within the Danish EEZ/TW.
Duration of impact	
Temporary	impacts predicted to be of very short duration and/or intermittent/occasional in nature and will cease within days of completion of the activity
Short-term	impacts that are predicted to be of short duration and will cease within a few years (≤3 years) of completion of the activity, either as a result of mitigation/reinstatement measures or natural recovery
Long-term	impacts that are predicted to continue over an extended period (>3 years)
Intensity of impact	
Low	No significant impact on the individuals/populations concerned.
Medium	Some impact on the individuals/populations concerned, but not likely to affect population conservation status
High	Significant impact on individuals/populations concerned, likely to affect vital rates and/or population conservation status

The main pressures on marine mammals during construction of the gas pipeline are assumed to be underwater noise from construction activities, and sediment spill from seabed intervention activities. In addition, the general changes to the habitat are assesed, as well as impact from unplanned activities, i.e. activities only relevant in case of unforeseen events such as oil spills or discovery of unexploded ordance. A thorough review of other potential impacts during construction, pre-commissioning, commissioning and operation may be found in Sveegaard *et al.* (2017) and are summarized in section 12.

7 Sensitivity of marine mammals

The assessment of sensitivity is largely unchanged from the assessment of the ES route (Sveegaard et al., 2017) and thus not included in complete form. The only exception is the assessment of sensitivity to underwater noise, which have been updated as new information has become available since completion of the ES route assessment.

The main source of potential impact on marine mammals is underwater noise. Assessment of impact from underwater noise is developing rapidly these years, due to a wealth of new experimental data appearing in the primary literature. This means that there is a continuous development in guidelines and discrepancies are common between guidelines from different countries and agencies. The assessment below is largely based on recommendations from the Danish Energy Authority (Tougaard, 2016) (Conservation)(Conservation)and guidance from the US National Marine Fisheries Service (National Marine Fisheries Service, 2016).

7.1 Thresholds for hearing loss in marine mammals

As stated above, the guidance on impact of noise is rapidly developing and this is particularly true with respect to noise induced temporary and permanent threshold shifts (TTS and PTS). It is thus prudent to revisit the thresholds used in the assement of the ES route (Sveegaard et al., 2017, largely based on recommendations of Tougaard, 2016). The most important development has been the revised guidance by the US National Marine Fisheries Service on assessing effects of noise (National Marine Fisheries Service, 2016). Although strictly only intended to be applicable to navy activities (i.e. sonars and underwater explosions), the review and synthesis can safely be generalised with respect to TTS and PTS thresholds. The main change in recommendations is the introduction of auditory frequency weighting resembling the inverted audiogram. Such a weighting was considered in the previous assessment, but dismissed for practical reasons and because the derived thresholds were considered to be precautionary in any case.

Two types of impact are considered for Nord Stream 2: underwater explosions and rock placement (generic for ship noise and other construction-related noise); two types of effects are considered: TTS and PTS; and three species are relevant to the Danish EEZ: Harbour porpoise, harbour seal and grey seal. As there are no data available on grey seals to justify separate thresholds, both species will be treated under one. All in all this yields eight different thresholds. These are shown in Table 7-1 and justified in the text below.

Table 7-1. Thresholds for eliciting TTS and PTS in marine mammals relevant to NS2.

	Explosions		**Rock placement**	
Receptor	**TTS**	**PTS**	**TTS**	**PTS**
Harbour porpoise	164 dB re. 1 uPa^2s	179 dB re. 1 uPa^2s	188 dB re. 1 uPa^2s	203 dB re. 1 uPa^2s
Seals	181 dB re. 1 uPa^2s	196 dB re. 1 uPa^2s	188 dB re. 1 uPa^2s	200 dB re. 1 uPa^2s

7.1.1 Harbour porpoises – explosions

Unchanged from Sveegaard et al. (2017) as there is no new data available relevant to these thresholds.

7.1.2 Seals – explosions

No experimental data were available for the previous assessment (Sveegaard et al., 2017), but recently results from exposure to air gun pulses in ringed seals (*Pusa hispida*) and spotted seals (*Phoca largha*) are available (Reichmuth et al., 2016). Both species are close relatives to the harbour and grey seal. In this experiment, the two seal species were exposed to single air gun pulses up to a level of 181 dB re. 1 μPa^2s, corresponding to 207 dB re. 1 µPa peak-to-peak without developing TTS. This level is thus used as a minimum (precautionary) threshold for TTS for seals, and is an elevation from the 164 dB re. 1 μPa^2s used by Sveegaard et al. (2017).

In line with recommendations of Southall et al. (2007) the PTS threshold is derived by adding 15 dB to the SEL threshold and 6 dB to the peak pressure threshold.

7.1.3 Harbour porpoises – rock placement

No new experimental data is available and the thresholds are unchanged. The threshold used previously, 188 dB re. 1 μPa^2s, was derived by Finneran (2015) and is essentially equal to the experimental threshold at 1.5 kHz (191 dB re. 1 uPa2s Kastelein et al., 2014). By using this threshold, it is implicitly assumed that the peak energy of the rock dump noise is at 1.5 kHz, much higher than the actual peak at 63 Hz. TTS thresholds for frequencies below 1.5 kHz have not been measured, but are likely to be considerably higher than at 1.5 kHz, due to the poorer hearing of porpoises at low frequencies. Using 188 dB re. 1 μPa^2s is thus precautionary and everything else being equal, this leads to overestimation of impact ranges.

PTS threshold is unchanged at TTS threshold plus 15 dB, equal to 203 dB re. 1 μPa^2s.

7.1.4 Seals – rock placement

Same applies to seals, where no new data is available and the TTS and PTS thresholds are maintained from (Sveegaard et al., 2017).

8 Modelling of impacts

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 extent of noise from rock placement and the extent 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 near the northern route.

8.1 Underwater noise during planned construction and operation activities

Transmission of underwater noise was modelled in order to estimate impact ranges for the noise. In line with previous assessments of NSP2, rock placement was assumed to be the loudest regular activity and was used as a worst case situation covering all other noises from the pipelaying vessel and support vessels. The only exception is noise from underwater explosions from munition clearance. Such munition clearances are not expected to take place in the Danish EEZ, but as they cannot be ruled out, they are treated as unplanned events. Details on noise propagation modelling are given in (Rambøll, 2018a).

8.1.1 Hearing loss from construction noise

Rock placement means that the pipeline remains on top of the seabed but is covered with (or supported by) a layer of rocks. 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 (Nedwell and Edwards, 2004; Wyatt, 2008).

Maximum extent of the TTS-zone is listed in Table 8-1 and illustrated on the map in Figure 8-1.

Sound exposure levels are insuficcient to induce permanent hearing loss (PTS) in seals and porpoises.

Table 8-1. Maximum extent of the TTS and PTS zones for rock placement at the Danish positions RP1-RP3.

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

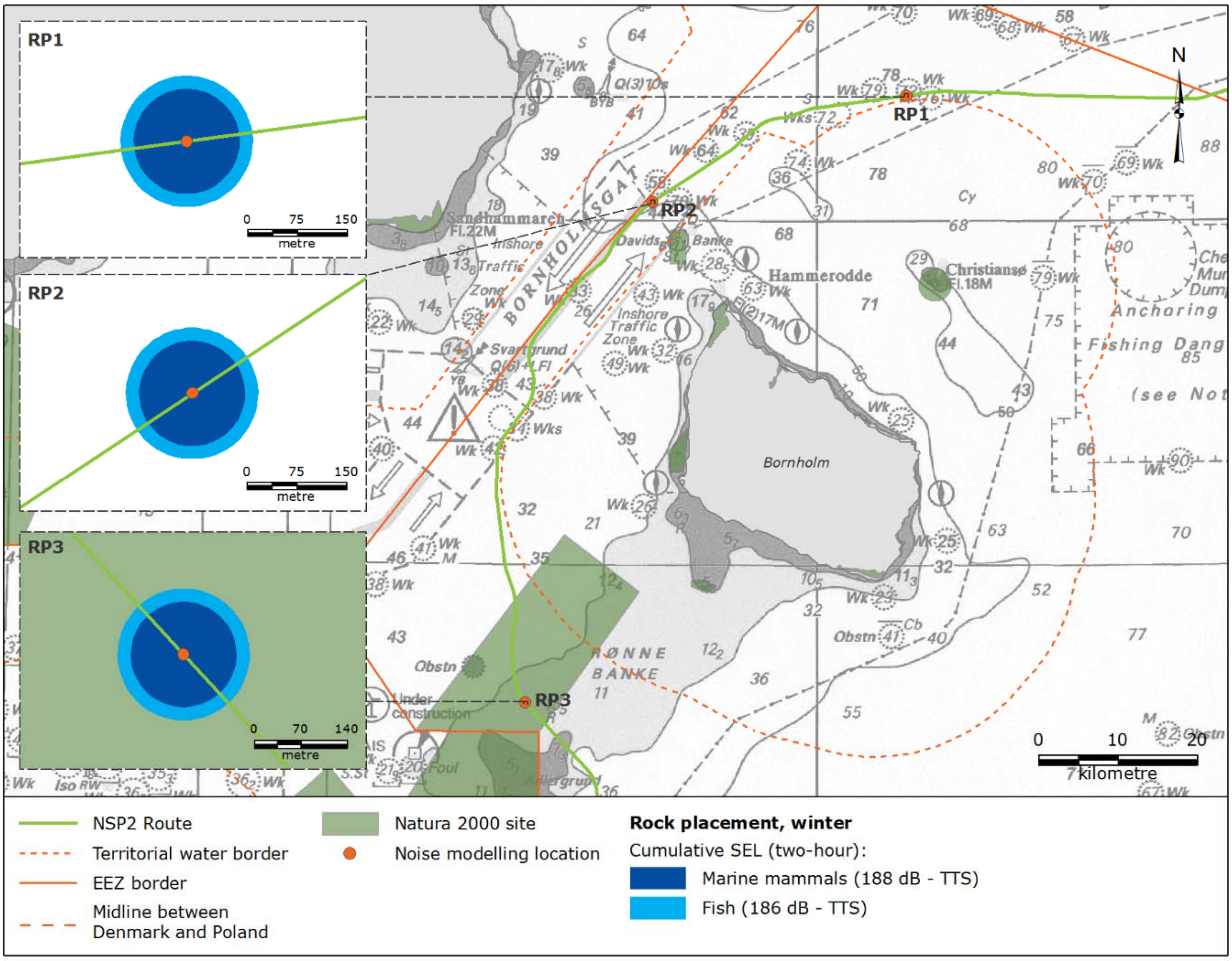


Figure 8-1. Modelled extent of impact ranges of noise from rock placement for seals and porpoises (light blue), as well as fish (deep blue). Note that the spatial extent of the zones are very small and thus have been enlarged in the left panel (Rambøll, 2018a).

8.1.2 Behavioural reactions to construction noise

Noise from construction activities could potentially disturb and displace seals and especially harbour porpoises from the waters around the pipelaying vessel. Bornholm's Gat, however, is heavily trafficked by large cargo vessels and passenger ferries (roughly 55,000 ships passed in 2016, according to the Danish Maritime Authorities). 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., 2014). In addition, studies where sound recorders as well as motion detectors (accelerometers) have been placed on free-swimming porpoises have shown short-term (minutes), but nevertheless severe reactions of individual porpoises to ships (Wisniewska et al., 2018b).

These studies indicate that porpoises could react to ships at considerable distances, possibly several kilometres away. An arguments 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 (diel) 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 8-2. 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%.

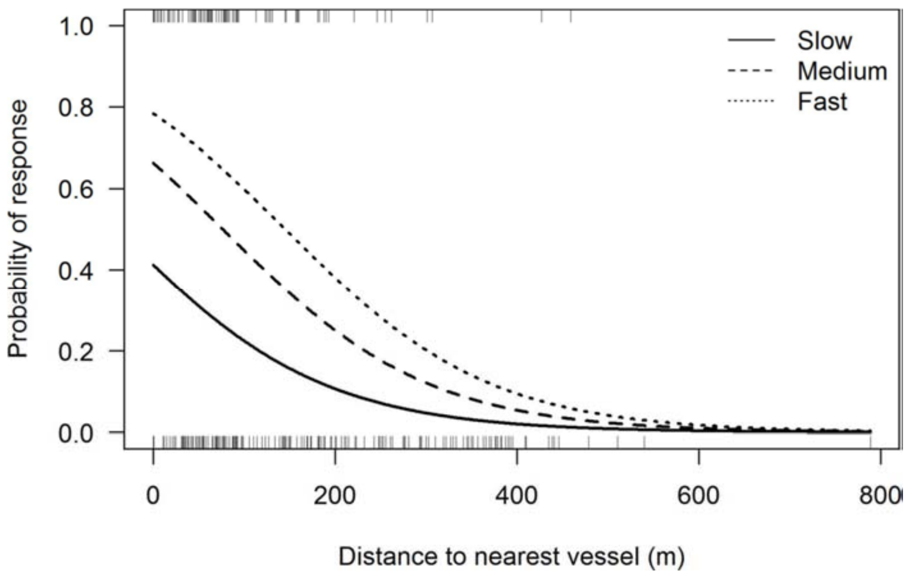


Figure 8-2. Probability of porpoises responding to a ship by a change in swimming direction as a function of the distance to the nearest vessel for slow (<3 knots, solid line), medium (3-9 knots, dashed line) and fast (>9 knots, dotted line) moving vessels. The lines represent the fitted values of the 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. Nevertheless, based on these results, a precautionary threshold for reaction of 200 m was assumed and applied to a modelling of the additional disturbance / displacement caused by construction of the Nord Stream pipeline through the proposed swedish Natura 2000 site Hoburgs Bank och Midsjöbankarna. The results cannot be transferred directly to the northern route through Bornholms Gat, but given that the amount of existing ship traffic is comparable or even larger than through the Natura 2000 site, the results may provide an indication of the possible impact.

Based on information received from AIS messages transmitted by the vessels and an estimate of the effective disturbance radius of ships (precautiously set to 200m), the habitat disturbance was estimated. The habitat disturbance (HD) is expressed as a ratio between the disturbed area and the total area of the Natura 2000 sites.

The current level of disturbance was 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, [Eq. 1]

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 8-3.

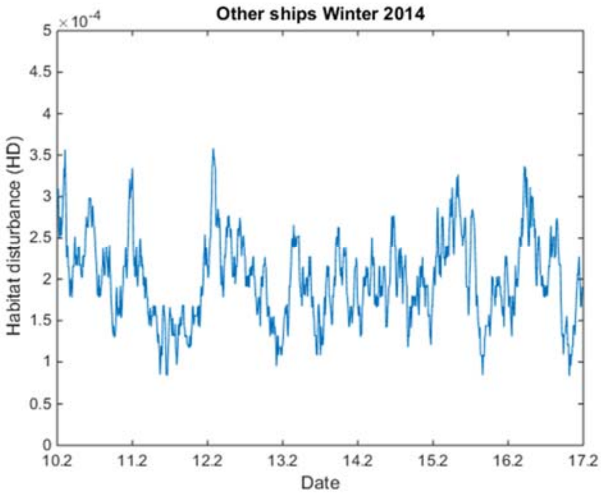


Figure 8-3. Habitat disturbance factor (HD) estimated from AIS-derived ship traffic during two representative weeks in February and July 2014, respectively. HD expresses the fraction of the total area of the Natura2000 sites which at any given point in time (resolution 10 minutes) is within 200 m of 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 reflects 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. This is probably reflecting the fact that relatively large ships are more or less 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* (easting) and row *j* (northing) was calculated as:

HD(i,j) = Number of 10-minute intervals where the cell was disturbed/total number of observation intervals, [Eq. 2]

where disturbance is defined as for HD(t) above. Results are shown in Figure 8-4.

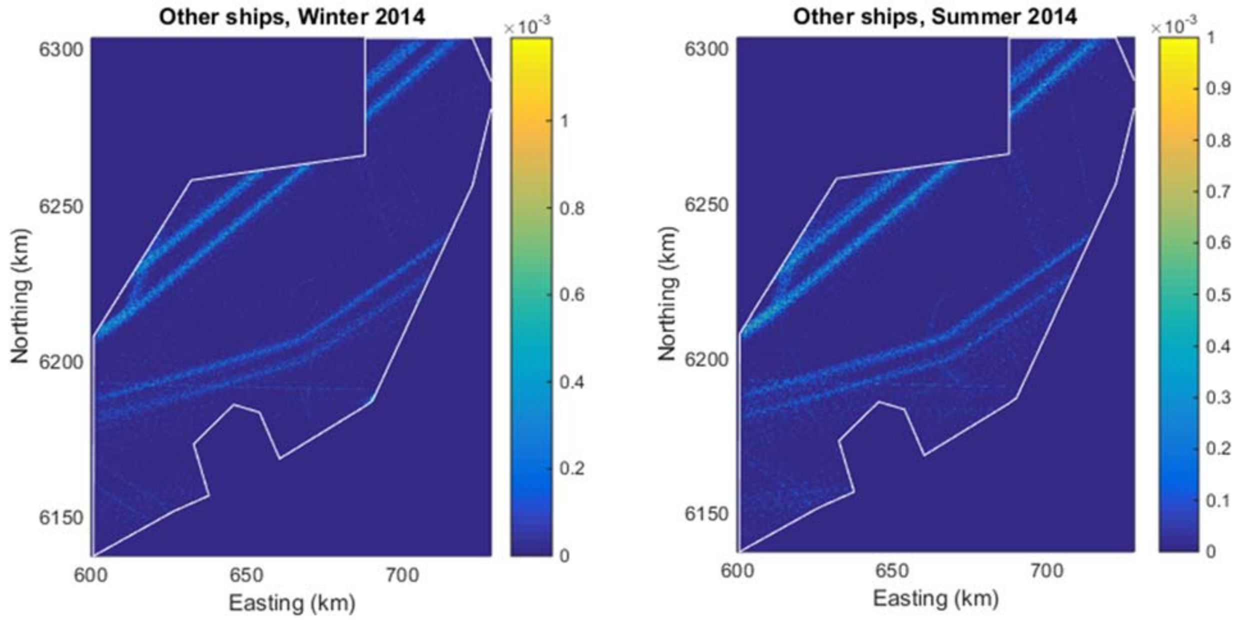


Figure 8-4. Habitat disturbance factor (HD) estimated from AIS-derived ship traffic during two representative weeks in February and July 2014, respectively. HD in the spatial formulation expresses the fraction of time (out of one week) where each grid cell (50x50 m) was within 200 m of one or more ships and thus considered to be disturbed (for porpoises).The white polygon indicate the Natura2000 area. Surroundinga to the Natura2000 area can be seen on **Figure 2-1**.

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:

$$\boldsymbol{HD} = \frac{\pi r_{eff}^2 dN}{tA} \qquad \textbf{[Eq. 3]}$$

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 expresses 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 8-2.

Table 8-2. 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

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 and 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 and Andersson, 2012). Based on these observations, the reaction distance of porpoises was set at 200 m, similar to the merchant ships modelled above.

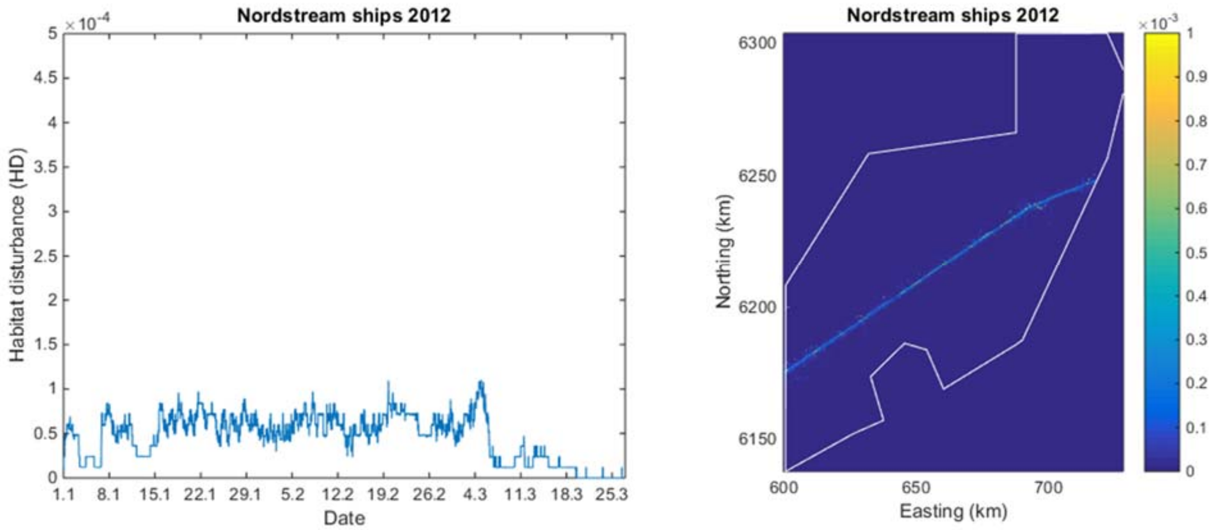


Figure 8-5. Contribution by the pipelaying vessel and support vessels to the habitat disturbance factor, estimated from actual pipelaying operations during construction of Nord Stream. Scales are identical to scales in Figure 8-3 and Figure 8-4 and thus directly comparable.

The habitat disturbance is very constant throughout most of the NSP construction period (Figure 8-5), 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 interruption of 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 still shorter commutes 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 above (Table 8-3). As there is only limited overlap between the pipeline trache and the shipping lanes, the two contributions are simply added in a conservative approach. In the worst case, this could give a small overestimation of the cumulative impact, as the Nord Stream ships move into an area where other ships are present.

Table 8-3. 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, far 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 from the disturbance caused by Nord Stream and the construction activities along the northern route may differ from what was used during construction of Nord Stream. The scenario in the central Baltic during construction of Nord Stream thus cannot be directly transferred to the northern route during construction of Nord Stream 2, but can still serve as an indication of the level of additional disturbance caused by pileline construction in areas with high shipping activity.

8.1.3 Masking of porpoise sonar and communication by ship noise

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 pipeline (Johansson and Andersson 2012). They conducted measurements on the sea bed approx. 1.5 km from the pipe line alignment 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 8-4.

Table 8-4. Measurements of noise during construction of the Nord Stream pipeline, as measured 1.5 km from the pipeline alignment 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 eceedence levels, 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, appear 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 and 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. 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 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 distance 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 8-6).

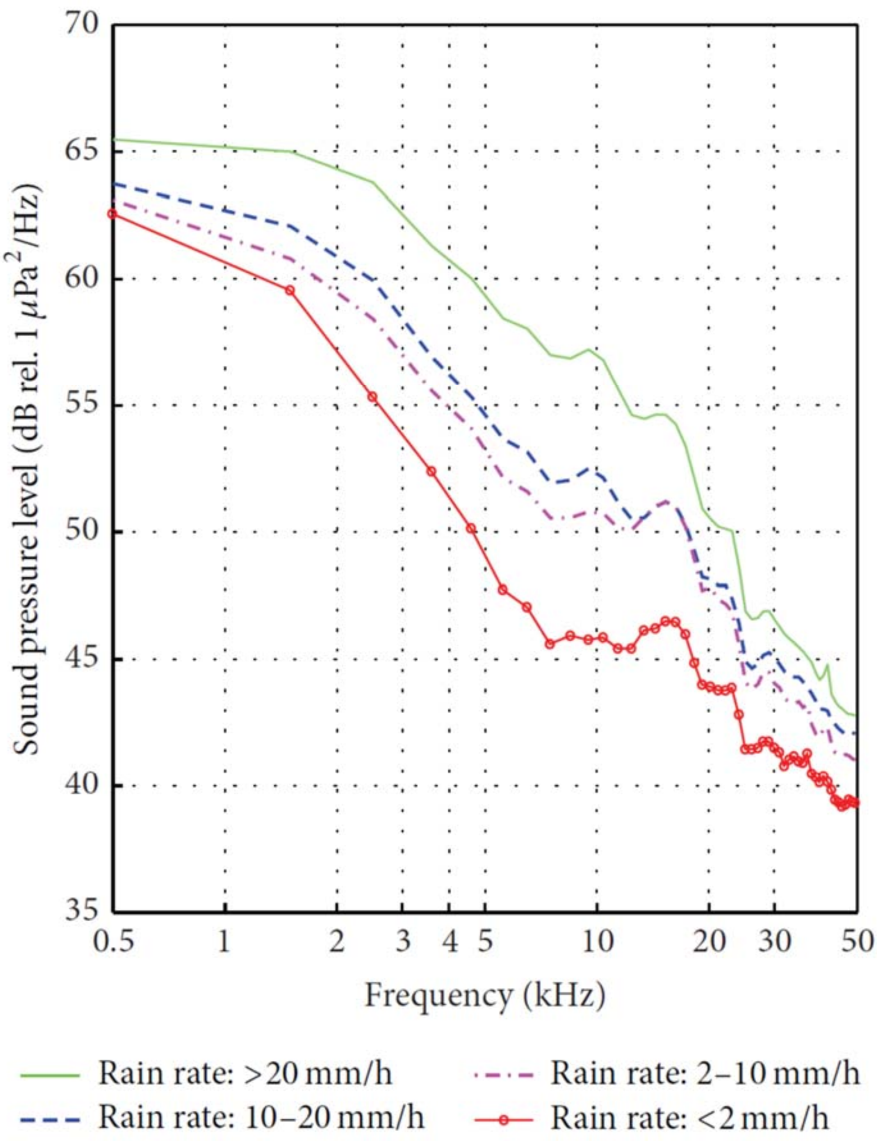


Figure 8-6. Examples of mean measured noise spectra at different levels of rain in the Mediterranean Sea. The curves show that noise levels can be elevated by 5-10 dB across the entire frequency spectrum during heavy rain. From Pensieri et al. (2015).

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, making communication difficult even at close range, then the adaptive reaction would be for the animals to move away from the noise source.

The worst scenario 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 thus reducing the masking. In fact, one could speculate whether the evasive reaction observed to ships (Bas et al., 2017) could be partly explained by such a response. In conclusion, 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.

8.1.4 Behavioural reactions in seals

Comparatively little is known about the effects of ship noise and noise from rock dumping on seals. However, they are generally considered more tolerant towards underwater noise than porpoises (Blackwell et al., 2004; Mikkelsen et al., 2017). Furthermore, the conservation status of the concerned populations are favourable (stable or increasing population size) and the level of protection lower than for porpoises (harbour seal and grey seal are not included in Annex 4 of the Habitats directive). For these reasons seals are not assessed in depth, because impact on seals is considered likely to be smaller than impact on porpoises under all conditions, which means that taking adequate precautions during construction and operation to protect porpoises from impact will automatically provide adequate protection from impact on seals.

8.2 Noise during pre-commissioning and 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.

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 (Nord Stream, 2009).

None of the activities during the precommisioning and commissioning phases are assessed to have a significant impact on marine mammals in Danish waters and are thus not further discussed although they are included in the summary tables in Chapter 12.

8.2.1 Noise from operating pipeline

Gas that flows through the pipeline will generate low levels of noise at low frequencies. Very few studies are available on noise levels from pipelines in operation, and potential effects from noise on marine mammals 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 8-7. 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:

$$I = \frac{p^2}{\rho c} \qquad \textbf{[Eq. 4]}$$

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}:

$$\boldsymbol{L_{eq} = 10\log_{10}(p^2) = L_w + 10\log_{10}\left(\frac{\rho c}{2\pi}\right)} \qquad \textbf{[Eq. 5]}$$

Assuming $\rho c = 1.5\times106\ kgm^{-2}s^{-1}$ 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 8-7, 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.

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 considerably 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 were recorded at all three stations, so the pipeline noise could not be detected in any of the recordings.

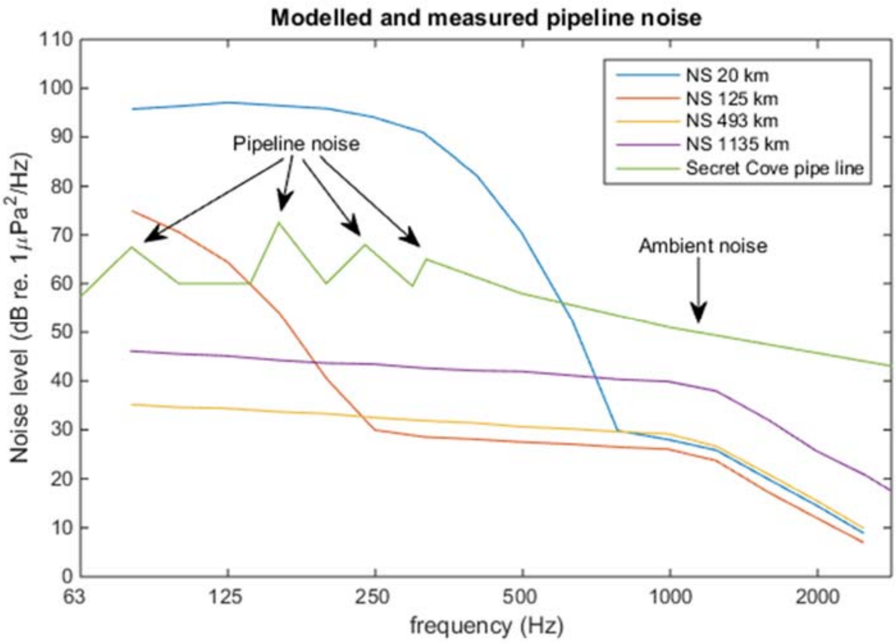


Figure 8-7. Modelled noise levels 1 m above the Nord Stream pipeline (Nord Stream, 2009), at various distances from the compressor station, together with noise levels recorded from an actual pipeline; Secret Cove (Glaholt et al., 2008), green line, taken from **Figure 8-8** below). As the measurements 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 Danish waters. 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).

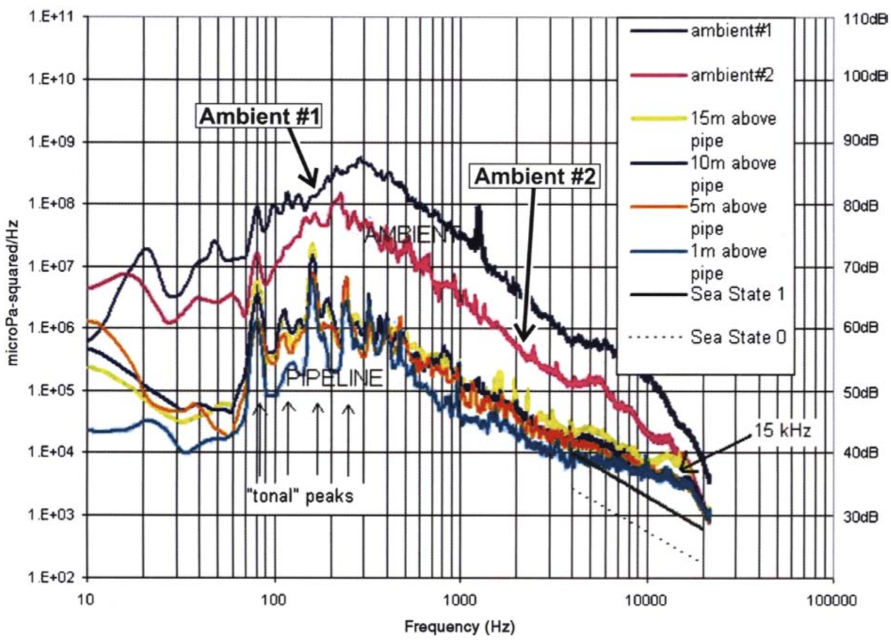


Figure 8-8. Noise levels as measured and accompanying representations of the high frequency portions of oceanic noise expectations for Sea States 0 and 1. Arrows denote the high (15 kHz) and low frequency "tonal" noise component from Secret Cove pipeline, British Columbia. Measurements were made in shallow 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).

Perhaps more relevant for the Danish waters, however, are the noise recordings obtained by FOI (Johansson and 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 8-9 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.

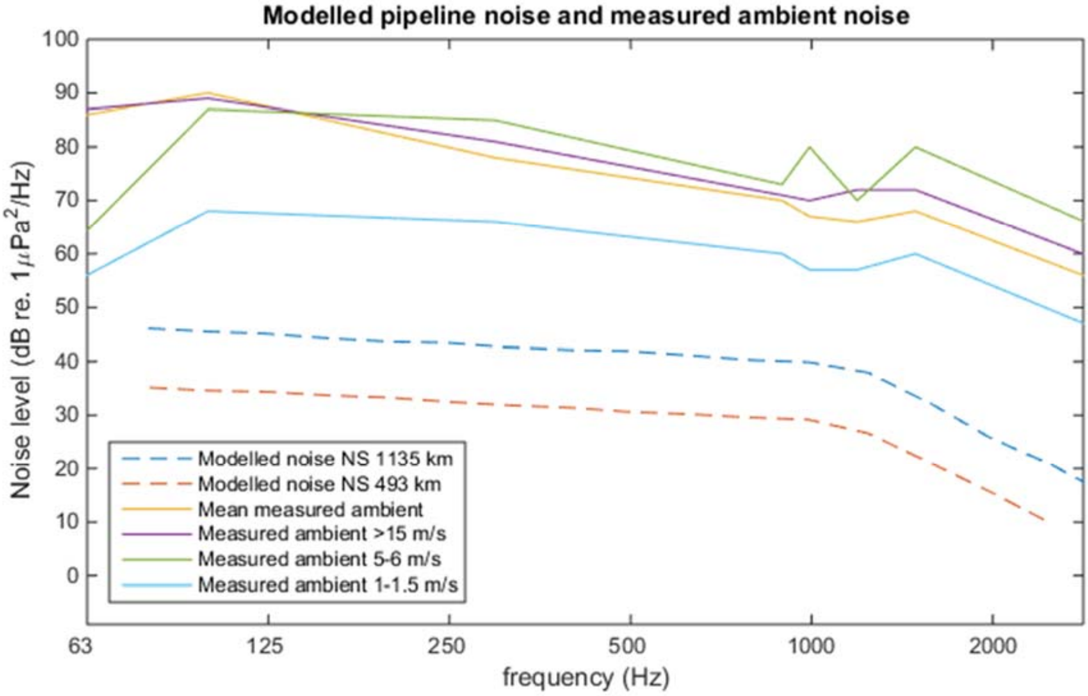


Figure 8-9. Modelled noise levels 1 m from the Nord Stream pipeline (Nord Stream, 2009) at distances far away from the compressor station in Russia, similar to the situation in the Danish waters. Also shown are ambient noise spectra measured under quiet conditions (no ships within 9 km from recorder) 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 at the Midsjö Banks (Johansson and 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 most quiet 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.

8.3 Sediment spill during planned construction and operation activities

The magnitude of the sediment spill for Danish waters was performed by Rambøll. The results from the document "Nord Stream 2 – Environmental Impact Assessment, Denmark" (Rambøll, 2018b) are inserted in summary here:

> Modelling of the release of sediment has been undertaken for planned intervention works in the shipping lane (rock placement and post-lay trenching), at the crossing of NSP (rock placement), and across Rønne Banke (rock placement and post-lay trenching).

Three scenarios have been modelled based on typical hydrodynamic conditions (winter, summer, normal), and the “Winter” condition is regarded as the most conservative.

Modelling results show that release of suspended sediment will occur near the intervention works, and that increased concentrations of sediment are generally local and short-term. The following is concluded based on the modelling:

- For the crossing of NSP (rock placement), modelling results show that increased concentrations of suspended sediment (>2 mg/l) will occur up to 22 hours in an area of 1.2 km2, with concentrations at a distance of 1 km up to ~7 mg/l;

- For the shipping lane (rock placement and post-lay trenching), modelling results show that increased concentrations of suspended sediment (>2 mg/l) will occur up to 25 hours in an area of approximately 81 km^2, with concentrations of up to ~23 mg/l at a distance of 1 km from the intervention works;

- For the intervention works across Rønne Banke (rock placement and post-lay trenching), an area of 1.5 km^2 may be experience SSC >15 mg/l for up to 2 hours.

Modelling results also show that sedimentation is generally local and of low intensity. Sedimentation of 200 g/m^2 corresponds to a fine sand sediment layer of less than 1 mm. Modelling results show that an area of 0.26 km2 will experience >200 g/m^2 of deposited sediment in the shipping lane (postlay trenching and rock placement), while there will be no exceedance of >200 g/m^2 of deposited sediment associated with at crossing with NSP (rock placement) or associated with intervention works at Rønne Banke (rock placement and post-lay trenching). At Rønne Banke, an area of 0.2 km^2 may experience sedimentation above 200 g/m^2.

Due to the location of the pipeline and the extent of the sediment plumes, the scale of sediment spill is thus national, the duration is temporary and the impact is reversible.

8.4 Underwater noise from unplanned events

8.4.1 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).

From Figure 8-10 and Figure 8-11 as well as Table 8-5 it can be seen that the potential impact zones for explosions are of considerable size, especially for porpoises.

Table 8-5. Munition clearance 370 kg munition (maximum) distances to the assessment level limit thresholds given in section above. Calculations have been made for two separate points, MCN1 and MCN2, located at kilometer points KP37 and KP113, respetively. See map in **Figure 8-10**.

			MCN1(KP 37) Summer, max Threshold distances, max	**MCN1(KP 37) Winter, max Threshold distances, max**	**MCN2(KP 113) Summer, max Threshold distances, max**	**MCN2(KP 113) Summer, max Threshold distances, max**
Seals	PTS	196 dB	3400 meters	3500 meters	3500 meters	3550 meters
	TTS	181 dB	8700 meters	8800 meters	7950 meters	7350 meters
Porpoises	PTS	179 dB	9400 meters	9900 meters	8700 meters	8050 meters
	TTS	164 dB	19700 meters	19800 meters	22800 meters	22900 meters

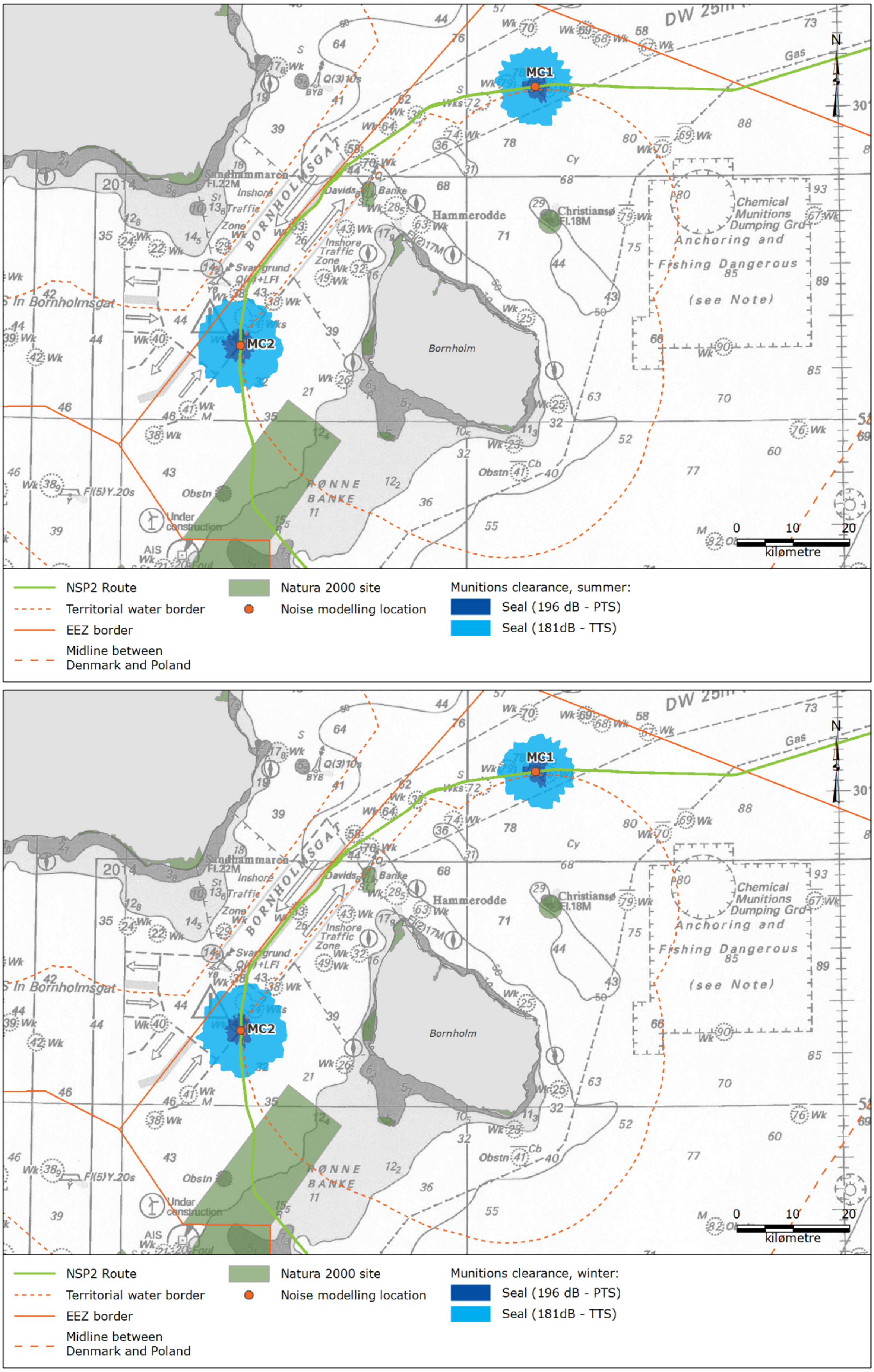


Figure 8-10. Impact zones for TTS and PTS for seals for a worst case munition clearance (complete detonation of 370 kg TNT at a depth of 45 m) for summer (top panel) and winter (lower panel). From Rambøll (2018a).

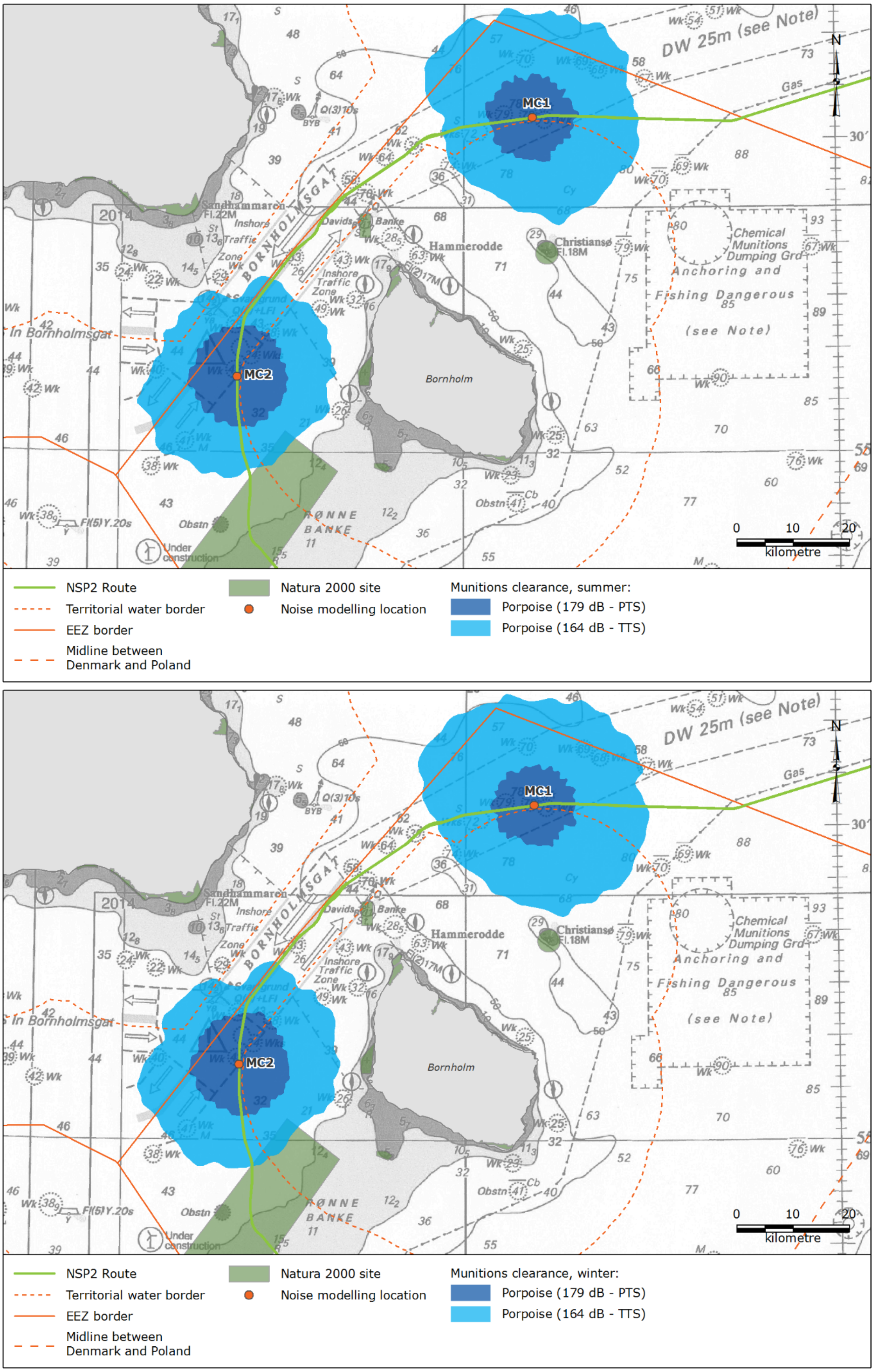


Figure 8-11. Impact zones for TTS and PTS for porpoises for a worst case munition clearance (complete detination of 370 kg TNT at a depth of 45 m) for summer (top panel) and winter (lower panel). From (Rambøll, 2018a).

Blast trauma

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 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 8-6.

Table 8-6. *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 and 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 latter's 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 most transferable to marine mammals.

Figure 8-12 shows an example of estimation of a blast injury zone around a 370 kg mine detonated at 45 m depth, illustrating that the blast injury zone can extend many kilometers out from the blast site.

Animals closer to the bottom are more severely affected than animals closer to the surface and thus the extent of the impact zone differs with depth of the animals. The number of affected animals N_{total}, can be estimated from the density of animals per volume of water, within each of *n* depth layers, each spanning *d* meters vertically.

$$N_{total} = \sum_n D_i d\pi r_i^2 \qquad \textbf{Eq. 1}$$

[1] Note that this unit is different from thFigure 8.**Error! Main Document Only.**. e 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.

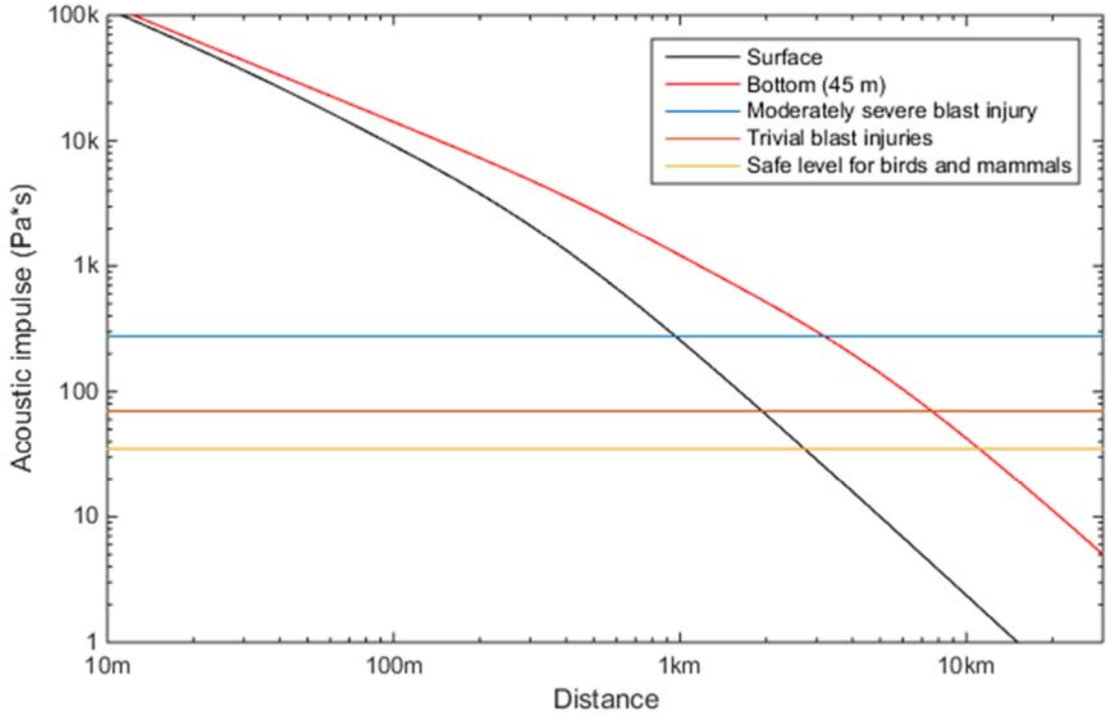


Figure 8-12. *Example of estimated acoustic impulse with range for a detonation of 370 kg explosives (TNT) at the bottom at a depth of 45 m. Black line is for animals at the surface, red line close to the bottom. Three horizontal lines indicate the injury thresholds defined by Yelverton et al. (1973). This is considered a worst case scenario for the northern route through Danish waters, assuming a complete detonation of the munition 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).*

Where D_i is the volume density of animals and r_i is the extent of the impact zone, both in depth layer i. If we assume animals to be evenly distributed with depth, then N_{total} is given as

$$N_{total} = \pi \frac{D}{n} \sum_n r_i^2 \qquad \textbf{Eq. 2}$$

Where D is the more conventional density of animals expressed as animals per square kilometer of sea surface. By rearrangement we can define the equivalent radius of the impact zone, r_{eq}

$$r_{eq} = \sqrt{\frac{1}{n} \sum_n r_i^2} \Leftrightarrow N_{total} = D\pi r_{eq}^2 \qquad \textbf{Eq. 3}$$

This equivalent radius expresses the radius of an area where impact is constant with depth and the same number of animals is affected by the noise as in the more realistic scenario with increasing impact with depth. For the example shown in figure 5.2 the equivalent radius is 5 km. The majority of the actual detonations are likely to be considerably smaller than 370 kg (Rambøll, 2016), and the blast injury zone is thus considered to be within the PTS-zone. The two types of impact are however assessed seperately.

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.

A marine mammal exposed to moderately severe blast injuries will recover on its own, and no long term effects are expected. It is however possible that the injuries will decrease the fitness for a period of time or even cause reproduction failure (miscarriages) for a season. Consequently the impact of moderately severe injuries may have an affect on very small threathened populations such as the Baltic harbour porpoise.

9 Assessment of impact in the construction phase

9.1 Underwater noise

9.1.1 TTS/PTS from rock placement

Even with very precautionary assumptions regarding impact of noise from rock placement the levels are very low, incapable of inflicting damage to hearing in either seals or porpoises (section 8.1.1). The impact is thus strictly **local, temporary, reversible** and of **low intensity** (PTS very unlikely). The magnitude is thus **low** and the significance of the impact is assessed as **negligible** for all species of marine mammals.

9.1.2 Behavioural reactions to construction 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 the noisiest activity 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. Reaction distances to ship noise are not known for neither seals, nor porpoises, but assumed to be some hundred meters or less (see section 8.1.2). The duration is thus **temporary, reversible** 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 and is likely to be several times larger than the potential impact of the construction vessels, even under worst case assumptions. Although the scenario modelled from construction of Nord Stream in the central Baltic (section 8.1.2) cannot be transferred directly to the northern route of Nord Stream2, it can nevertheless serve as an indication of scale. The absolute level of disturbance caused by construction of Nord Stream was very low, likely insignificant. The relative increase in disturbance caused by the construction activities adding to the commercial ship traffic was measureable (about 25% increase). The ship traffic along the northern route is higher and more concentrated than in the central Baltic and the construction activities will overlap with the shipping in large parts of the trache. This means that the exsisting disturbance from ships is likely higher than in the central Baltic and thus that the cumulative impact caused by the pipeline construction will be smaller. The intensity and impact magnitude from vessel noise and rock placement is therefore rated **low** and the overall significance **minor**. This applies to both seals and harbour porpoises.

9.1.3 Masking from construction noise

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. In particular, it is assessed unlikely that an increase in masking due to construction activities would lead to significant impact on individual harbour porpoises (section 8.1.3). This is because masking is only likely to occur very close to the ships (within a few hundred meters at most) and as the porpoises are likely to vacate this area around the ships anyway, the likelihood that any porpoises will actually experience masking is very low.

Masking of seal communication is very poorly studied, but as communication seems to take place predominantly, perhaps even exclusively, near haul-out and breeding sites on the coast, the likelihood that seal communication will be impeded by masking from the pipeline construction is considered virtually absent. Masking from construction noise is thus considered **temporary**, **reversible** and **local**; Intensity and magnitude are **low**, thus overall significance is **minor**.

9.2 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.

9.2.1 Visual impairment

Since the harbour porpoise uses 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 or at a population level.

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

9.2.2 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 present 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 **minor** overall significance.

9.2.3 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 sensitivity also is **low**, the overall significance is **minor**.

9.2.4 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). Furthermore, it has been assessed that impacts on fish and fish stocks and bioaccumulation of contaminants in fish species will be of negligible importance (Rambøll, 2018b).

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**.

9.3 Unplanned events

9.3.1 Noise from munition clearance

For the individual animals (seals and harbour porpoises) the impact from unmitigated explosions could be **irreversible** and **long-term** (permanent injury or ultimately death) and the scale is **transboundary**, as impact may extend into Swedish waters. This means that or the individual seal or harbour porpoise, the intensity and magnitude is **high** and the significance **major**. Mitigation measures, in the form of visual observers and in particular deployment of acoustic deterrence devices prior to the explosion, as was employed during munition clearing in connection to construction of the Nord Stream pipeline, will greatly reduce the risk that animals are present close to the explosion and thus reduce the likelihood of severe injury and death due to the explosion.

The probability of harbour seals being present close to a possible munition clearance is very low, as the northern route is located far from harbour seal haul-out sites. This, in combination with the favourable development of harbour seal populations in the area, leads to an overall assessment of intensity and magnitude at the level of the population as low and hence significance as **minor** (given abovementioned mitigation measures are implemented).

The probability of grey seals being present close to a possible munition clearance is considerably higher than for harbour seals, as haul-out sites are closer (Utklippan and Christiansø) and grey seals generally move further offshore than harbour seals. However, as the population development of grey seals in the Baltic (including the area around Bornholm) has been very good over an extended period of time, the overall intensity and magnitude of impact from munition clearance at the level of the population is low and hence significance **minor** (given abovementioned mitigation measures are implemented).

The probability of harbour porpoises being present close to a munition clearance along the northern route is low, given that the overall density of porpoises in the area is low. Most of the porpoises encountered in along the northern route are likely to belong to the Belt Seas population, which appears to be in a favourable conservation status. Overall significance of impact on this population from munition clearance, given that the above mentioned mitigation measures are implemented, is **minor**. There is a small probability that porpoises belonging to the critically endangered population from the Baltic proper are ancountered along the northern route in case of a munition clearance. The status of this population as critically endangered means that essentially every single animal counts and that injury or death to a single individual could have population level consequences. However, given the very low probability that a porpoise from this population will be within impact range from a munition clearance and the further reduction in impact by properly implemented mitigation measures leads to an overall assessment of impact at the population level as **minor**.

9.3.2 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. 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**.

10 Assessment of impact in the operation phase

10.1 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 both seals and harbour porpoises very close to the pipeline and only close to the compressor station (placed in Russia) (section 8.2.1). Under all conditions the noise from the pipeline in the Danish EEZ is expected to be below the ambient noise. The impact is **irreversible** and **long-term**, but **local**. The intensity and magnitude is **low** and the overall significance of this impact in Danish waters is thus considered **negligible**.

10.2 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 8-3**) and any disturbance from these ships will be local and temporary, as neither seals, nor harbour porpoises are expected to react to the ships unless within a few hundred meters (section 8.1.2).

The intensity and magnitude is **low** and the overall significance of this source of disturbance is thus considered **minor**.

10.3 Changes in the habitat

The physical presence of the pipeline alters the existing habitat and consequently the flora and fauna inhabiting the area. During the construction phase, all benthic flora and fauna will be eliminated, but during 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 be negligible (Rambøll, 2018b). 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.**

10.4 Unplanned events

10.4.1 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 is assessed to be **low**, the overall *significance* of gas release is assessed to be **minor**.

11 Assessment of impact in Natura 2000 areas

11.1 Natura 2000 sites

This assessment has focused on Natura 2000 sites designated for marine mammals within 100 km of the proposed northern NSP2 route. This concerns three Swedish Natura 2000 sites designated for harbour porpoises seal (the nearest is 36 km away), four Natura 2000 sites designated for harbour seal (the nearest is 48 km away) and one Danish and four Swedish areas for grey seals (the nearest area is Ertholmene, which is 16 km away).

11.1.1 Construction phase

All Natura 2000 sites are relatively far away from the nothern route when comparing with the extent of the potential impacts from the construction and is is asessed that all impacts with be negligible to minor. Impact is thus **not significant**.

11.1.2 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 within 100 km of the northern route. As outlined above in Chapter 10, 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).

11.2 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.

12 Summary tables of Assessment

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

12.1 Harbour porpoise

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

*Low = Belt Sea population impact. High = Baltic population both individuals and population.

12.2 Harbour seal

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

*The impact is assessed on population level. Individual animals may be affected, but with the proposed mitigation this impact will be Minor to Moderate.

12.3 Grey seal

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

*The impact is assessed on population level. Individual animals may be affected, but with the proposed mitigation and the low likelyhood of harbour seals being near the norther route during the explosions, this impact will also be Minor.

13 References

Akamatsu, T., Teilmann, J., Miller, L.A., Tougaard, J., Dietz, R., Wang, D., Wang, K., Siebert, U., Naito, Y., 2007. Comparison of echolocation behaviour between coastal and riverine porpoises. Deep-Sea Research Part Ii-Topical Studies in Oceanography 54, 290-297.

Andersen, L.W., Ruzzante, D.E., Walton, M., Berggren, P., Bjørge, A., lockyer, C., 2001. Conservation genetics of harbour porpoises, *Phocoena phocoena*,in eastern and central North Atlantic. Conservation Genetics 2, 309-324.

Andersen, S., 1970. Auditory sensitivity of the Harbour Porpoise *Phocoena phocoena*. Investigations on Cetacea 2, 255-258.

Andersen, S.M., Teilmann, J., Dietz, R., Schmidt, N.M., Miller, L.A., 2012. Behavioural responses of harbour seals to human-induced disturbances. Aquatic Conservation: Marine and Freshwater Ecosystems 22, 113-121.

Andersen, S.M., Teilmann, J., Dietz, R., Schmidt, N.M., Miller, L.A., 2014. Disturbance-induced responses of VHF and satellite tagged harbour seals. Aquatic Conservation: Marine and Freshwater Ecosystems 24, 712-723.

Andersen, S.M., Teilmann, J., Harders, P.B., Hansen, E.H., Hjøllund, D., 2007. Diet of harbour seals and great cormorants in Limfjord, Denmark: Interspecific competition and interaction with fishery. ICES Journal of Marine Science 64, 1235-1245.

ASCOBANS, 2002. Recovery Plan for Baltic Harbour Porpoises (Jastarnia Plan), ASCOBANS secretariat, Bonn, Germany.

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.

Beck, C.A., Bowen, W.D., McMillan, J.I., Iverson, S.J., 2003. Sex differences in the diving behaviour of a size-dimorphic capital breeder: the grey seal. Anim. Behav. 66, 777-789.

Benke, H., Brager, S., Dahne, M., Gallus, A., Hansen, S., Honnef, C.G., Jabbusch, M., Koblitz, J.C., Krugel, K., Liebschner, A., Narberhaus, I., Verfuss, U.K., 2014. Baltic Sea harbour porpoise populations: status and conservation needs derived from recent survey results. Mar Ecol Prog Ser 495, 275-290.

Berggren, P., Hiby, L., Lovell, P., Scheidat, M., 2004. Abundance of harbour porpoises in the Baltic Sea from aerial surveys conducted in summer 2002. Paper SC/56/SM7 submitted to the Scientific Committee of the International Whaling Commission. Available from www.iwcoffice.org., p. 16.

Bjørgesæter, A., Ugland, K.I., Bjørge, A., 2004. Geographic variation and acoustic structure of the underwater vocalization of harbor seal *(Phoca vitulina)* in Norway, Sweden and Scotland. J. Acoust. Soc. Am. 116, 2459-2468.

Blackwell, S.B., Lawson, J.W., Williams, M.T., 2004. Tolerance by ringed seals (*Phoca hispida*) to impact pipe-driving and construction sounds at an oil production island. J. Acoust. Soc. Am. 115, 2346-2357.

Boness, D.J., Bowen, W.D., Buhleier, B.M., Marshall, G.J., 2006. Mating tactics and mating system of an aquatic-mating pinniped: the harbor seal, *Phoca vitulina*. Behav. Ecol. Sociobiol. 61, 119-130.

Börjesson, P., Berggren, P., 2003. Diet of harbour porpoises in the Kattegat and Skagerrak Seas: Accounting for individual variation and sample size. Mar. Mamm. Sci. 19, 38-58.

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.

Conservation, D.o., DOC guidelines on seismic surveys.

Czech-Damal, N.U., Liebschner, A., Miersch, L., Klauer, G., Hanke, F.D., Marshall, C.D., Denhardt, G., Hanke, W., 2011. Electroreception in the Guiana dolphin (*Sotalia guianensis*). Proceedings of the Royal Society of London Series B-Biological Sciences 279, 663-668.

Denhardt, G., Mauck, B., Bleckmann, H., 1998. Seal whiskers detect water movements. Nature 394, 235-236.

Denhardt, G., Mauck, B., Hanke, W., Bleckmann, H., 2001. Hydrodynamic trail-following in harbor seals (*Phoca vitulina*). Science 293, 102-104.

Dietz, R., Galatius, A., Mikkelsen, L., Nabe-Nielsen, J., Riget, F., Schack, H.B., Skov, H., Sveegaard, S., Teilmann, J., Thomsen, F., 2015. Marine mammals - Investigations and preparation of environmental impact assessment for Kriegers Flak Offshore Wind Farm, Energinet.dk, p. 208.

Dykes, R., 1975. Afferent fibers from mystacial Vibrissae of cats and seals. Journal of Neurophysiology 38, 650-662.

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.

Edrén, S.M.E., Andersen, S.M., Teilmann, J., Carstensen, J., Harders, P.B., Dietz, R., Miller, L.A., 2010. The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. Mar. Mamm. Sci. 26, 614-634.

Eguchi, T., Harvey, J., 2005. Diving behavior of the pacific harbor seal (*Phoca vitulina richardii*) in Monterey Bay, California Mar. Mamm. Sci. 21, 283-295.

European Commission, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Fietz, K., Galatius, A., Frie, A.K., Teilmann, J., Dietz, R., Klimova, A., Jensen, L.F., Graves, J.A., Hall, A., McConnell, B.J., Hoffman, J., Gilbert, M.T.P., Olsen, M.T., 2016. Shift of grey seal subspecies boundaries in response to climate, culling and conservation. Mol. Ecol. 25, 4097-4112.

Finneran, J.J., 2015. Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. J. Acoust. Soc. Am. 138, 1702-1726.

Finnish Ministry of Agriculture and Forestry, 2007. Management Plan for the Finnish Seal Populations in the Baltic Sea. http://mmm.fi/documents/1410837/1721042/4b_Hylkeen_enkku_nettiin.pdf/aeb2abf7-d6f0-422e-8a6a-94ba8403df31, Helsinki.

Fobes, J.L., Smock, C.C., 1981. Sensory capacities of marine mammals. Psychol.Bull. 89(2), 288-307.

Galatius, A., Kinze, C.C., Teilmann, J., 2012. Population structure of harbour porpoises in the Baltic region: evidence of separation based on geometric morphometric comparisons. JMBA 92, 1669-1676.

Gallus, A., Dähne, M., Verfuß, U.K., Bräger, S., Adler, S., Siebert, U., Benke, H., 2012. Use of static passive acoustic monitoring to assess the status of the ‘Critically Endangered’ Baltic harbour porpoise in German waters. Endangered Species Research 18, 265-278.

Gilles, A., Adler, S., Kaschner, K., Scheidat, M., Siebert, U., 2011. Modelling harbour porpoise seasonal density as a function of the German Bight environment: implications for management. Endangered Species Research 14, 157-169.

Gjertz, I., Lydersen, C., Wiig, Ø., 2001. Distribution and diving of harbour seals (*Phoca vitulina*) in Svalbard. Polar Biology 24, 209-214.

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

Goodman, S.J., 1998. Patterns of extensive genetic differentiation and variation among European harbor seals (*Phoca vitulina vitulina*) revealed using microsatellite DNA polymorphisms. Mol. Biol. Evol. 15, 104-118.

Graves, J.A., Helyar, A., Biuw, M., Jüssi, M., Jüssi, I., Karlsson, O., 2008. Microsatellite and mtDNA analysis of the population structure of grey seals (Halichoerus grypus) from three breeding areas in the Baltic Sea. Conservation Genetics 10, 59-68.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K.A., Karczmarski, L., Kasuya, T., Perrin, W., Scott, M.D., Wang, J.Y., Wells, R.S., Wilson, B., 2016. *Phocoena phocoena* (Baltic Sea subpopulation). The IUCN Red List of Threatened Species 2016: e.T17031A98831650. Downloaded on 08 November 2016.

Hammond, P.S., Benke, H., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jørgensen, M.-P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F., Øien, N., 1995. Distribution and abundance of the harbour porpoise and other small cetaceans in the North Sea and adjacent waters. Final report Life 92-2/UK/027., p. 240.

Hanggi, E.B., Schusterman, R.J., 1994. Underwater acoustic displays and individual variation in male harbour seals, *Phoca vitulina*. Anim. Behav. 48, 1275-1283.

Hanke, F.D., Hanke, W., Scholtyssek, C., Denhardt, G., 2009. Basic mechanisms in pinniped vision. Exp.Brain res. 199, 299-311.

Hansen, J.W.r., 2018. Marine områder 2016. NOVANA. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 140 s. - Videnskabelig rapport fra DCE - Nationalt Center for Miljø og Energi nr. 253
http://dce2.au.dk/pub/SR253.pdf.

Harding, K., Härkonen, T., 1999. Development in the Baltic grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) populations during the 20th century. Ambio 28, 619-627.

Havs- och Vattenmyndigheten, 2012. Nationell förvaltningsplan för gråsäl (Halichoerus grypus) i Östersjön.¬http://www.rktl.fi/www/uploads/pdf/Hylkeet/forvaltningsplan_grasal_sverige_2012.pdf.

HELCOM, 2014. Registered mortality of seals, HELCOM secretariat, Helsinki.

HELCOM, 2015. Core indicator report - Population trends and abundance of seals, HELCOM secretariat, Helsinki.

Helle, E., Olsson, M., Jensen, S., 1976. PCB levels correlated with pathological changes in seal uteri. Ambio 5, 261-263.

Henry, E., Hammill, M.O., 2001. Impact of small boats on the haulout activity of harbour seals (Phoca vitulina) in Métis Bay, St Lawrence Estuary, Québec, Canada. Aquat. Mamm. 27, 140-148.

Hermannsen, L., Beedholm, K., Tougaard, J., Madsen, P.T., 2014. High frequency components of ship noise in shallow water: implications for harbor porpoises (*Phocoena phocoena*). J. Acoust. Soc. Am. 136, 1640-1653.

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.

Hiby, L., Lovell, P., 1996. Baltic/North Sea aerial surveys - final report, p. 11.

Hiby, L., Lundberg, T., Karlsson, O., Watkins, J., Jüssi, M., Jüsi, J., Helander, B., 2006. Estimates of the size of the Balic grey seal population based on photo-identification data. NAMMCO Scientific Publications 6, 163-176.

Härkönen, T., 2016. *Halichoerus grypus* (Baltic Sea subpopulation). The IUCN Red List of Threatened Species 2016: e.T74491261A74491289. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T74491261A74491289.en. Downloaded on 08 November 2016.

Härkönen, T., Dietz, R., Reijnders, P., Teilmann, J., Harding, K.C., Hall, A., Brasseur, S., Siebert, U., Goodman, S.J., Jepson, P.D., Rasmussen, T.D., Thompson, P., 2006. A review of the 1988 and 2002 phocine distemper virus epidemics in European harbour seals. Diseases of Aquatic Organisms 68, 115-130.

IUCN, 2007. *Phoca vitulina* (Common Seal, Harbor Seal, Harbour Seal). http://www.iucnredlist.org/details/17013/1.

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.

Kastak, D., Schusterman, R.J., 1998. Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology. J. Acoust. Soc. Am. 103, 2216-2228.

Kastelein, R.A., Bunskoek, P., Hagedoorn, M., Au, W.W.L., Haan, D.d., 2002. Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrow-band frequency modulated signals. J.Acoust.Soc.Am. 112, 334-344.

Kastelein, R.A., Hoek, L., de Jong, C.A.F., Wensveen, P.J., 2010. The effect of signal duration on the underwater detection thresholds of a harbor porpoise (*Phocoena phocoena*) for single frequency-modulated tonal signals between 0.25 and 160 kHz. J. Acoust. Soc. Am. 128, 3211-3222.

Kastelein, R.A., Hoek, L., Gransier, R., Rambags, M., Clayes, N., 2014. Effect of level, duration, and inter-pulse interval of 1-2kHz sonar signal exposures on harbor porpoise hearing. J. Acoust. Soc. Am. 136, 412-422.

Kauhala, K., Ahola, M.P., Isomursu, M., Raitaniemi, J., 2016. The impact of food resources, reproductive rate and hunting pressure on the Baltic grey seal population in the Finnish sea area. Annales Zoologica Fennici 53, 296-309.

Kinze, C.C., Jensen, T., Skov, R., 2003. Fokus på hvaler i Danmark 2000-2002, In: Tougaard, S. (Ed.), Biological Papers No. 2, Esbjerg, Denmark.

Koschinski, S., 2002. Current knowledge on harbour porpoises (*Phocoena phocoena*) in the Baltic Sea. Ophelia 55, 167-197.

Kyhn, L.A., Tougaard, J., Beedholm, K., Jensen, F.H., Ashe, E., Williams, R., Madsen, P.T., 2013. Clicking in a Killer Whale Habitat: Narrow-Band, High-Frequency Biosonar Clicks of Harbour Porpoise (*Phocoena phocoena*) and Dall's Porpoise (*Phocoenoides dalli*). PlosOne 8, e63763.

Lah, L., Trense, D., Benke, H., Berggren, P., Gunnlaugsson, T., Lockyer, C., Ozturk, A., Ozturk, B., Pawliczka, I., Roos, A., Siebert, U., Skora, K., Vikingsson, G., Tiedemann, R., 2016. Spatially Explicit Analysis of Genome-Wide SNPs Detects Subtle Population Structure in a Mobile Marine Mammal, the Harbor Porpoise. PLoS One 11, e0162792.

Lance, R.M., Capehart, B., Kadro, O., Bass, C.R., 2015. Human injury criteria for underwater blasts. PLoS One 10, e0143485.

Lesage, V., Hammill, M.O., Kovacs, K.M., 1999. Functional classification of harbor seal (*Phoca vitulina*) dives using depth profiles, swimming velocity, and an index of foraging success. Can. J. Zool. 77, 74-87.

Levenson, D.H., Schusterman, R.J., 1999. Dark adaptation and visual sensitivity in shallow and deep-diving pinnipeds. Mar. Mamm. Sci. 15, 1303-1313.

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.

Linnenschmidt, M., Teilmann, J., Akamatsu, T., Dietz, R., Miller, L.A., 2013. Biosonar, dive, and foraging activity of satellite tracked harbor porpoises (Phocoena phocoena). Mar. Mamm. Sci. 29, E77-E97.

Lockyer, C., Kinze, C.C., 2003. Status and lift history of harbour porpoise (*Phocoena phocoena*) in Danish waters. NAMMCO Scientific Publications 5, 143-176.

Lowry, L.F., 2016. *Phoca vitulina*. The IUCN Red List of Threatened Species 2016: e.T17013A45229114. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T17013A45229114.en. Downloaded 8 November 2016.

Lundström, K., Hjerne, O., Alexandersson, K., Karlsson, O., 2007. Estimation of grey seal (*Halichoerus grypus*) diet composition in the Baltic Sea. NAMMCO Scientific Publications 6, 177-196.

McConnell, B.J., Fedak, M.A., Lovell, P., Hammond, P.S., 1999. Movements and foraging areas of grey seals in the North Sea. J.Appl.Ecol. 36, 573-590.

McKenna, M.F., Ross, D., Wiggins, S.M., Hildebrand, J.A., 2012. Underwater radiated noise from modern commercial ships. J. Acoust. Soc. Am. 131, 92-103.

Mikkelsen, L., Hermannsen, L., Beedholm, K., Madsen, P.T., Tougaard, J., 2017. Simulated seal scarer sounds scare porpoises, but not seals: species-specific responses to 12 kHz deterrence sounds. R Soc Open Sci 4, 170286.

Møhl, B., 1967. Seal Ears. Science 157, 99.

Møhl, B., 1968. Auditory sensitivity of the common seal in air and water. J.Aud.Res 8, 27-38.

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

Møhl, B., Andersen, S., 1973. Echolocation: high-frequency component in the click of the harbour porpoise (*Phocoena ph. L.*). J. Acoust. Soc. Am. 54, 1368-1372.

NAMMCO, 2007. Grey seals in the North Atlantic and the Baltic. Edited by: Tore Haug, Mike Hammill and Droplaug Ólafsdóttir. NAMMCO Scientific Publications 6, 227.

National Marine Fisheries Service, 2016. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing underwater acoustic thresholds for onset of permanent and temporary threshold shifts. NOAA Technical Memorandum NMFS-OPR-55, Silver Spring, MD, p. 178.

Naturstyrelsen, 2014. Forslag om midlertidig ordning til regulering af gråsæl. J.nr. NST-303-00130.¬http://naturstyrelsen.dk/media/nst/9498479/notat_om_regulering_af_gr_s_l.pdf.

Nedwell, J., Edwards, B., 2004. A review of measurements of underwater man-made noise carried out by Subacoustech Ltd, 1993 – 2003. Subacoustech Report ref: 534R0109.

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

Oksanen, S.M., Ahola, M.P., Lehtonen, E., Kunnasranta, M., 2014. Using movement data of Baltic grey seals to examine foraging-site fidelity: implications for seal-fishery conflict mitigation. Mar. Ecol. Prog. Ser. 507, 297-308.

Olsen, M.T., Andersen, L.W., Dietz, R., Teilmann, J., Harkonen, T., Siegismund, H.R., 2014. Integrating genetic data and population viability analyses for the identification of harbour seal (*Phoca vitulina*) populations and management units. Mol. Ecol. 23, 815-831.

Peichl, L., Behrmann, G., Kröger, R.H.H., 2001. For whales and seals the ocean is not blue: a visual pigment loss in marine mammals. European Journal of Neuroscience 13, 1520-1528.

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.

Rambøll, 2016. W-PE-EIA-PFI-REP-805-030600EN Underwater noise modelling Finland, Copenhagen.

Rambøll, 2017. Nord Stream 2 environmental impact assessment, Denmark. Document no. W-PE-EIA-PDK-REP-805-010100en.

Rambøll, 2018a. Nord stream 2 underwater noise modelling, denmark northern route. Report W-PE-EIA-PDK-REP-805-RN1600EN-01 Copenhagen.

Rambøll, 2018b. Report W-PE-EIA-PDK-REP-805-RN0100EN-05 for Nord Stream 2, p. 497.

Reichmuth, C., Ghoul, A., Sills, J.M., Rouse, A., Southall, B.L., 2016. Low-frequency temporary threshold shift not observed in spotted or ringed seals exposed to single air gun impulses. J Acoust Soc Am 140, 2646.

Roberts, D.A., 2012. Causes and ecological effects of resuspended contaminated sediments (RCS) in marine environments. Environment International 40, 230-243.

SAMBAH, 2016. Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise (SAMBAH). Final report under the LIFE+ project LIFE08 NAT/S/000261. Kolmårdens Djurpark AB, SE-618 92 Kolmården, Sweden. 81pp.

Sjöberg, M., Ball, J.P., 2000. Grey seal, *Halichoerus grypus*, habitat selection around haulout sites in the Baltic Sea: bathymetry or central-place foraging? Can. J. Zool. 78, 1661-1667.

Skora, K.E., Pawliczka, I., Klinowska, M., 1988. Observations of the harbour porpoise (*Phocoena phocoena*) on the Polish Baltic coast. Aquat. Mamm. 14, 113-119.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J., Gentry, R., Green, C.R., Kastak, C.R., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., Tyack, P.L., 2007. Marine mammal noise exposure criteria. Aquat. Mamm. 33, 411-521.

Southall, B.L., Schusterman, R.J., Kastak, D., 2001. Masking in three pinnipeds: underwater, low-frequency critical ratios. J. Acoust. Soc. Am. 108, 1322-1326.

Sveegaard, S., Andreassen, H., Mouritsen, K.N., Jeppesen, J.P., Teilmann, J., Kinze, C.C., 2012. Correlation between the seasonal distribution of harbour porpoises and their prey in the Sound, Baltic Sea. Marine Biology.

Sveegaard, S., Galatius, A., Dietz, R., Kyhn, L., Koblitz, J.C., Amundin, M., Nabe-Nielsen, J., Sinding, M.-H.S., Andersen, L.W., Teilmann, J., 2015a. Defining management units for cetaceans by combining genetics, morphology, acoustics and satellite tracking. Global Ecology and Conservation 3, 839-850.

Sveegaard, S., Galatius, A., Teilmann, J., 2015b. Havpattedyr - sæler og marsvin. Marine områder 2014: NOVANA. red. Jens Würgler Hansen. Aarhus Universitet DCE - Nationalt Center for Miljø og Energi 2015. Videnskabelig rapport fra DCE - Nationalt Center for Miljø og Energi, Nr. 167. pp 86-97.

Sveegaard, S., Teilmann, J., Galatius, A., 2013. Abundance survey of harbour porpoises in Kattegat, Belt Seas and the Western Baltic, July 2012. Note from DCE - Danish Centre for Environment and Energy, p. 11.

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.

Sveegaard, S., Teilmann, J., Tougaard, J., Dietz, R., Mouritsen, K.N., Desportes, G., Siebert, U., 2011. High-density areas for harbor porpoises (Phocoena phocoena) identified by satellite tracking. Mar. Mamm. Sci. 27, 230-246.

Söderberg, S., 1975. Feeding habits and commercial damage of seals in the Baltic. Proceedings from the Symposium on the seal in the Baltic, 66-78.

Sørensen, T.B., Kinze, C.C., 1994. Reproduction and reproductive seasonality in Danish harbour porpoises, *Phocoena phocoena*. Ophelia 39, 159-176.

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.

Teilmann, J., Larsen, F., Desportes, G., 2007. Time allocation and diving behaviour of harbour porpoises (*Phocoena phocoena*) in Danish and adjacent waters. J.Cet.Res.Managem. 9, 201-210.

Teilmann, J., Miller, L.A., Kirketerp, T., Kastelein, R., Madsen, P.T., Nielsen, B.K., Au, W.W.L., 2002. Characteristics of echolocation signals used by a harbour porpoise (*Phocoena phocoena*) in a target detection experiment. Aquat. Mamm. 28, 275-284.

Terhune, J.M., Turnbull, S.D., 1995. Variation in the psychometric functions and hearing thresholds of a harbour seal, in: Kastelein, R.A., Thomas, J.A., Nachtigall, P.E. (Eds.), Sensory systems of aquatic mammals, De Spil, Woerden, Netherlands, pp. 81-93.

Todd, V.L.G., Todd, I.B., Gardiner, J.C., Morrin, E.C.N., MacPherson, N.A., DiMarzio, N.A., Thomsen, F., 2015. A review of impacts of marine dredging activities on marine mammals. ICES Journal of Marine Science 72, 328-340.

Tollit, D.J., Black, A.D., Thompson, P.M., Mackay, A., Corpe, H.M., Wilson, B., Van Parijs, S.M., Grellier, K., Parlane, S., 1998. Variations in harbour seal *Phoca vitulina* diet and dive-depths in relation to foraging habitat. J. Zool. 244, 209-222.

Tougaard, J., 2016. Input to revision of guidelines regarding underwater noise from oil and gas activities - effects on marine mammals and mitigation measures.

Tougaard, J., Teilmann, J., Tougaard, S., 2008. Harbour seal spatial distribution estimated from Argos satellite telemetry - overcoming positioning errors. Endangered Species Research 4, 113-122.

Turnbull, S.D., Terhune, J.M., 1990. White noise and pure tone masking of pure tone thresholds of a harbor seal listening in air and under water. Can.J.Zool. 68, 2090-2097.

Urick, R.J., 1983. Principles of underwater sound. 3rd. ed. McGraw-Hill, New York.

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

Weiffen, M., Möller, B., Mauck, B., Dehnhardt, G., 2006. Effect of water turbidity on the visual acuity of harbor seals (Phoca vitulina). Vision Res 46, 1777-1783.

Wiemann, A., Andersen, L., Berggren, P., Siebert, U., Benke, H., Teilmann, J., Lockyer, C., Pawliczka, I., Skora, K., Roos, A., Lyrholm, T., Paulus, K., Ketmaier, V., Tiedemann, R., 2010. Mitochondrial Control Region and microsatellite analyses on harbour porpoise (Phocoena phocoena) unravel population differentiation in the Baltic Sea and adjacent waters. Conserv Genet 11, 195-211.

Wiltschko, R., Wiltschko, W., 1996. Magnetorception: Why is conditioning so seldom succesful? Naturwissenschaften 83, 241-247.

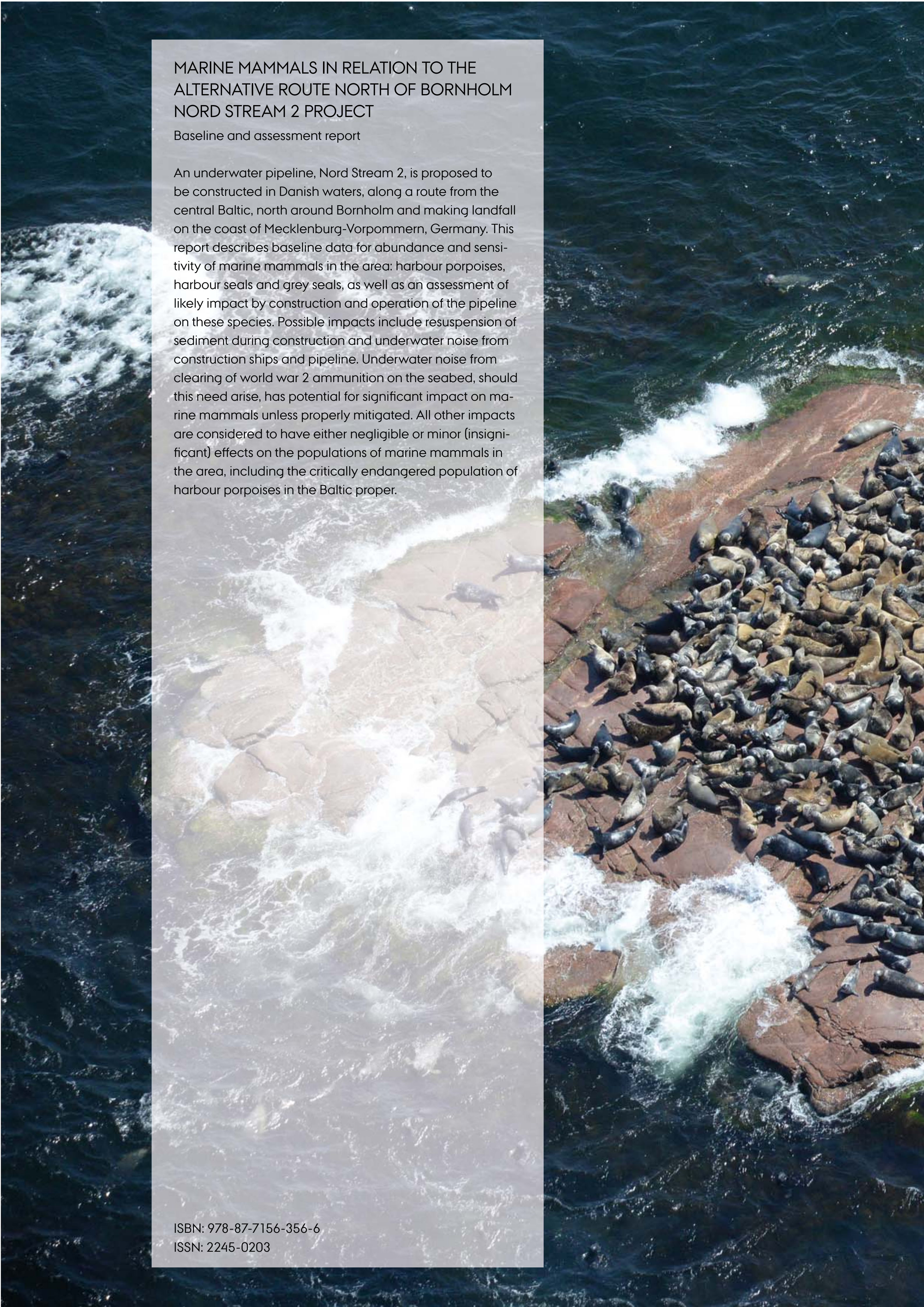
Wisniewska, D.M., Johnson, M., Teilmann, J., Rojano-Donate, L., Shearer, J., Sveegaard, S., Miller, L.A., Siebert, U., Madsen, P.T., 2016. Ultra-High Foraging Rates of Harbor Porpoises Make Them Vulnerable to Anthropogenic Disturbance. Curr Biol 26, 1441-1446.

Wisniewska, D.M., Johnson, M., Teilmann, J., Rojano-Doñate, L., Shearer, J., Sveegaard, S., Miller, L.A., Siebert, U., Madsen, P.T., 2018a. Response to "Resilience of harbor porpoises to anthropogenic disturbance: Must they really feed continuously?". Mar. Mamm. Sci. 34, 265-270.

Wisniewska, D.M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., Madsen, P.T., 2018b. High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). Proc R Soc B 285.

Wyatt, R., 2008. Review of existing data on underwater sounds produced by the oil and gas industry. Report to joint industry programme on sound and marine life, Great Torrington.

Yelverton, J.T., Richmond, D.R., Fletcher, E.R., Jones, R.K., 1973. Safe distances from underwater explosions for mammals and birds, Albuquerque, New Mexico.



MARINE MAMMALS IN RELATION TO THE ALTERNATIVE ROUTE NORTH OF BORNHOLM NORD STREAM 2 PROJECT

Baseline and assessment report

An underwater pipeline, Nord Stream 2, is proposed to be constructed in Danish waters, along a route from the central Baltic, north around Bornholm and making landfall on the coast of Mecklenburg-Vorpommern, Germany. This report describes baseline data for abundance and sensitivity of marine mammals in the area: harbour porpoises, harbour seals and grey seals, as well as an assessment of likely impact by construction and operation of the pipeline on these species. Possible impacts include resuspension of sediment during construction and underwater noise from construction ships and pipeline. Underwater noise from clearing of world war 2 ammunition on the seabed, should this need arise, has potential for significant impact on marine mammals unless properly mitigated. All other impacts are considered to have either negligible or minor (insignificant) effects on the populations of marine mammals in the area, including the critically endangered population of harbour porpoises in the Baltic proper.

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