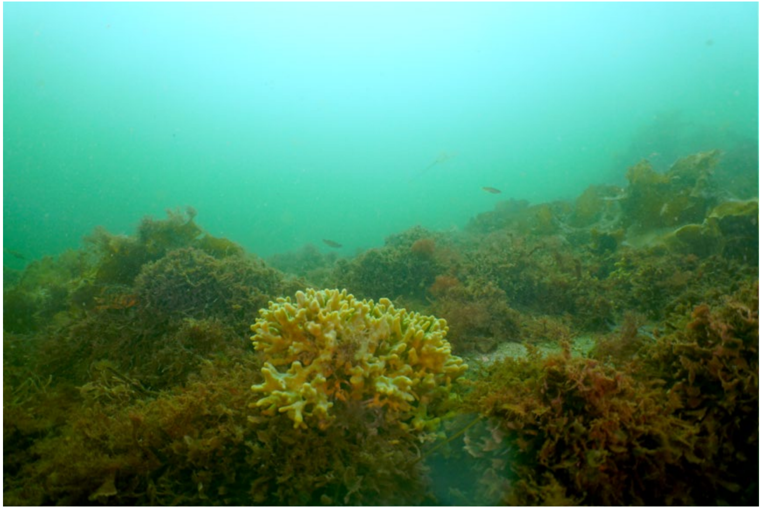
Effects of artificial reefs on marine mammals

Construction and placement of the artificial reef

Scientific note from DCE – Danish Centre for Environment and Energy Date: 07 February 2024 | **07**



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Data sheet

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Content

1 Preface

The Danish Environmental Protection Agency (EPA) contracted the Danish Centre for Environment and Energy (DCE) in December 2023 to assess the impacts on marine mammals, especially porpoises, of the rock placement phase of the restoration of stone reefs. Stone reefs are restored at water depths between 0-15 metres at sites where they have previously been removed, in the inner Danish waters both inside and outside the habitat areas (N2000 sites). The stones for restoration are often in the size range 30-200 cm, with an average of about 65 cm. According to the EPA, the construction period for larger artificial reefs in Danish waters will be up to 4 months with activity on approximately two thirds of these days.

In this report, DCE reviews published information on the potential impact of construction activities and noise from the deployment of stones including the increased ship traffic in connection with the stone deployment. DCE was asked to include the significance of depth, salinity, temperature and other elements in relation to sound propagation.

As part of the assessment, DCE was requested to assess whether marine mammals (especially harbour porpoises) are more sensitive to rock placement during certain parts of the year.

Based on this request, DCE has divided this report into four parts:

1. The sensitivity of harbour porpoises at different times of the year (including a general introduction to impact assessments).

2. The noise propagation of rock placement in relation to harbour porpoises (based on available information).

3. Effects of rock/reef placement on harbour porpoises (our current knowledge from Danish waters).

4. Conclusion.

2 Sensitivity of marine mammals

2.1 Introduction to impact assessments

The overall aim of an impact assessment is to assess the impact significance for certain species in a specific area; however, there are no internationally agreed method or guideline for doing this. Consequently, DCE has reviewed existing methods and based on those, established a method to be used for this assessment. This was, for example, implemented during the assessments of the impact on marine mammals of the Nordstream 2 pipeline (Sveegaard et al. 2017). The assessment was done by combining the sensitivity of marine mammals with the magnitude of the impact (Table 2.1).

Table 2.1. Methodology to evaluate overall significance of an impact.

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

The impact assessment can further be conducted at different scales:

1. Significance of impact at the population level in relation to distribution and abundance.

2. Significance of impact at individual like behavioural disturbance, displacement, injury or death of individual marine mammals. Such impacts may be too small to have an overall impact on the survival and sustainability of the population as a whole, but they may affect local stocks and have ethical implications.

Sensitivity

The sensitivity of marine mammals to any impact is defined by their ability to accommodate the change and their ability to recover, if affected. When assessing the sensitivity of marine mammals in relation to an impact, the following aspects should be included: biology (physiological impact), behaviour, sensitive periods (e.g. migration, feeding, mating, breeding or moulting), protection status (national and international), distribution, abundance and population status (declining/stable/increasing). The assessment methodology of marine mammal sensitivity is summarised in Table 2.2.

Table 2.2. Assessment categories and methodology of sensitivity for marine mammal populations. All cetaceans in Danish and EU waters are internationally and nationally protected. Seals are also protected but in a lower category of the EU's Habitats Directive. However, all marine mammals should be assessed by the same sensitivity categories even if the conservation status differs.

Assessment category	Criteria for assessing the sensitivity for marine mammals
Low	The population is increasing. The impact area does not include nationally or regionally important areas (used for breeding, feeding or migration). Marine mammals only occur in low density. The marine mammal species is not sensitive to the impact, i.e., the species' biology (physiology or behaviour) is not or only temporarily affected by the impact.
Medium	The population is stable or increasing. The impact area includes parts of nationally or regionally important areas (used for breeding, feeding or migration). Marine mammals occur regularly (= medium density). The biology of the marine mammal species is moderately affected by the impact.
High	The population is decreasing and/or the population abundance is low. The impact area includes nationally or regionally important areas (used for breeding, feeding or migration). Marine mammals occur in high densities within the impact area. The marine mammal species is highly sensitive to environmental changes, i.e. their biology (physiology or behavior) is severely affected or damaged by the impact.

Impact magnitude

Impact magnitude of the change is a measure of intensity, direction (direct/indirect), spatial extent and duration of the change caused by the project. The general method for assessing the impact magnitude is summarised in Table 2.3.

Table 2.3. Assessment categories and methodology of impact magnitude for marine mammal populations.

Assessment category	Impact on marine mammals
None or negligible	No detectable impacts on marine mammals.
Low	Impacts are of low intensity. The spatial extent is small and/or the duration is short (hours). Impacts are reversible and do not lead to any permanent change.
Medium	Moderate impacts on marine mammal species. Impact time is from days to weeks. Limited spatial extent. Some impacts may be irreversible.
High	Significant long-lasting (months) or permanent impacts on marine mammals (i.e. high intensity). Large geographical extent. Most impacts are irreversible.

2.2 Sensitivity of harbour porpoises in Danish waters

Harbour porpoises inhabiting Danish waters are part of one of three separate populations with different geographical distribution, abundance and status.

The porpoises in the North Sea, Skagerrak and northern Kattegat constitute the largest population and were relatively stable at around 350,000 individuals (including waters from neighbouring countries) from 1994 to 2022

(Hammond et al. 2017, Gilles et al. 2023). The second population covers the southern part of Kattegat, the Belt Sea, the Sound and the western Baltic Sea. Recent abundance estimates from 2020 and 2022 have shown that this population is declining, and the latest estimate from 2022 is approx. 14,000 individuals. These two populations are categorised as 'Least Concern (LC)' by the IUCN (Hammond et al. 2008b). However, due to the recently documented decline in abundance of the Belt Sea population, this category may no longer be valid, and caution should be taken when assessing anthropogenic impacts on the Belt Sea population.

The third porpoise population, inhabiting the Baltic Proper, was estimated to be only around 500 individuals during the SAMBAH project in 2011-2013 (SAMBAH 2016, Carlén et al. 2018). The Baltic Sea population is categorised as 'Critically endangered' by the IUCN (Hammond et al. 2008b).

The different conservation status of these three populations will affect the assessment of impact of noise. Whereas temporary disturbance of a smaller part of the home range of the larger and stabile North Sea population may not be a problem, similar disturbances of the other two populations could have a negative impact as they are more sensitive (cf. the criteria in Table 2.2).

According to Table 2.2, assessment of sensitivity should also include whether the impacted area includes sites important for breeding, feeding or migration and whether porpoises are present in high, medium or low density. This is naturally specific for each project and should be assessed individually for each project.

Sensitivity across the year

Harbour porpoises are particularly vulnerable in the period when they give birth in May-September, but the calves are dependent on their mother for at least 10 months when they gradually stop nursing and become independent. The mother/calf relation may therefore be vulnerable to disturbance throughout the first year. Even during the first month after leaving their mother, the yearlings may be vulnerable, which has been seen as an elevation in bycatch and strandings of juveniles during spring and early summer (Fiskeri- og Søfartsmuseet 2023). Also, a far majority of the stranded and bycaught porpoises are around the size of weaning (<130 cm), indicating that losing contact with the mother or the time around weaning may increase the risk of mortality in fishing gear.

3 Noise propagation of rock placement

Rock placement or rock dumping is used in several types of marine constructions, such as support bed for pipelines, construction of harbours, scour protection of monopile foundations and restoration of stone/boulder reefs. Installation of subsea rocks will most often take place by using a rock placement vessel with a fall pipe, excavator or a crane.

Noise measurement data indicate that the dominant 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.

Noise from rock dumping is low-frequency and thus partly below the hearing threshold of porpoises. When sound pressure levels are frequency weighted to compensate for the hearing of porpoises, the weighted level of the rock dumping noise (155 dB re 1µPa) is comparable to the weighted level of a 50 m ship sailing 10 knots (151 dB re 1µPa). This can be understood such that the perceived loudness of the noise from the rock dumping is comparable to the loudness of the ship itself when arriving in the area. (Figure 3.1).

The VHF-weighted sound pressure level where porpoises start reacting by fleeing from a noise has been estimated to be 103 dB re 1µPa VHF-weighted (Tougaard 2021a). Assuming a sound propagation that follows 17 $\log_{10}$(distance), the estimated reaction distance for the dumping noise is 1,200 m, while for the ship noise it is around 700 m (Tougaard et al. 2023) The reaction distances may differ somewhat between seasons due to differences in sound propagation conditions, but these changes are so small that they do not affect the overall assessment. More specifically, they affect both the rock dumping noise and the ship noise, which means that the relationship between the two remains the same. In other words, the reaction distance to the rock dumping is expected to be in the same order of magnitude as the reaction distance to the noise from the ship itself (approximately 1200 m versus 700 m).

The impact of underwater noise during the rock dumping is therefore considered a behavioural displacement from the area in a radius of about 1.2 km from the rock dumping for as long as the activity takes place. Thus, according to the methodology (Table 2.3), the impact magnitude of the rock dumping on porpoises is considered negligible during short-term activities (i.e. a few days), while if the activity takes place over a longer period (weeks or month), as expected with the construction of larger artificial reefs, it would be considered as low or medium impact, depending on the specific circumstances.

Noise levels from rock dumping are far below the levels required to cause damage to the hearing of porpoises (Southall et al, 2019; Tougaard 2021b). There is thus no need to consider mitigation to reduce the risk of injury due to noise exposure as this risk is already negligible.

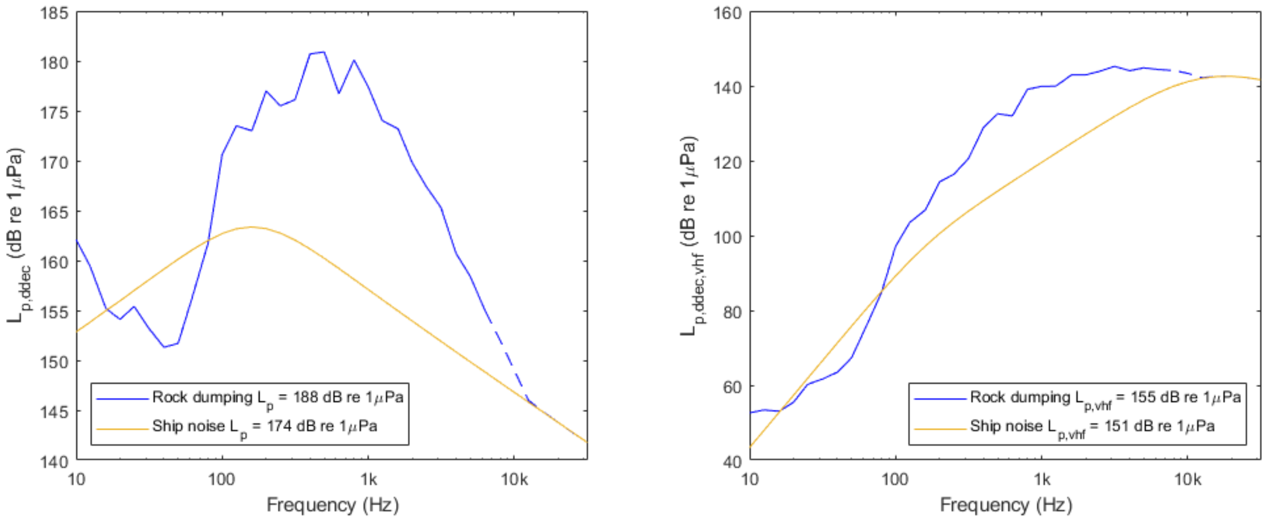

Figure 3.1. Source spectrum of the noise from rock dumping (blue line) and a ship (50 m sand pumping vessel at 10 knots, yellow line). The noise is expressed per decidecade. The left figure shows the unweighted spectrum, and the right figure is weighted with the hearing curve for porpoises (VHF weighting, Southall et al. 2019). The auditory weighting means that the peak of the weighted spectrum corresponds to the part perceived as the loudest by porpoises. Indicated in the legend are also the total sound pressure levels, both unweighted (left) and VHF-weighted (right). Source for rock dumping noise: Hannay et al. 2004, ship noise: MacGillivray & de Jong 2021, Wyatt 2008.

4 Effects of rock/reef placement

There are only few studies estimating the short- and long-term effect of construction stone reefs on harbour porpoises. In the following section, we summarise the two studies that are available from Danish waters (Mikkelsen et al. 2013 and Teilmann et al. in prep.).

A cavernous stony reef is an important habitat type that supports a rich flora and fauna (Ojeda & Dearborn 1989, Andrulewicz et al. 2004). The stable surface of the boulders is essential as anchorage for numerous species of macroalgae and a large variety of sessile animals. In the upper photic zone, the dense algal forests attract numerous species of free-living animals that feed and hide among the complex structures made up of stones and associated algal vegetation. Stony reefs may thus attract top predators such as the harbour porpoise. It has been shown that other structures, such as oil and gas platform foundations, are attractive to harbour porpoises, probably due to the same reasons as for cavernous stony reefs (Clausen et al. 2021)

In summer 2008, the nature restoration project Blue Reef re-established 45,000 m^2 of cavernous stony reef at Læsø Trindel in the northern Kattegat, Denmark (https://naturstyrelsen.dk/ny-natur/life-projekter/natura-2000/life-bluereef-i-kattegat). The aim was to restore the old vertical distribution of the reef to extend between 1.5–18.0 m water depth. To investigate the impact of the re-established reef on harbour porpoises, the acoustic activity of porpoises was monitored by static acoustic data loggers, before, during and after restoration (Mikkelsen et al. 2013). Loggers were placed at the Læsø Trindel reef and at a reference station 10 km away between June and August every year from 2006 to 2012. Results showed that porpoise echolocation activity increased significantly at the Læsø Trindel reef after the reconstruction in 2008 (Figure 4.1). The number of minutes with porpoise recordings (PPM) increased from, on average, 9.5 PPM per day in 2006 to a maximum in 2010 (15.2 PPM per day, 60% increase). An increase in mean encounter duration from 3.0 min in 2006 to 4.7 min in 2010 (57% increase) showed that porpoises not only appeared more often but also stayed longer at Læsø Trindel (Figure 4.2). Furthermore, there was a clear diel pattern in porpoise activity at Læsø Trindel, with significantly higher activity during the night. This pattern became increasingly apparent over the study period. At the reference station, in contrast, most activity took place during the day throughout the study.

The results suggest that these changes reflect a new food source occurring at night on the re-established stony reef, which is exploited by the porpoises. It has been shown that numerous fish species are attracted to such reef habitats and thus provide an increased food supply (Moreno & Jara 1984) and a reduced risk of predation due to the refuge offered by the heterogeneous environment (Demartini & Roberts 1990).

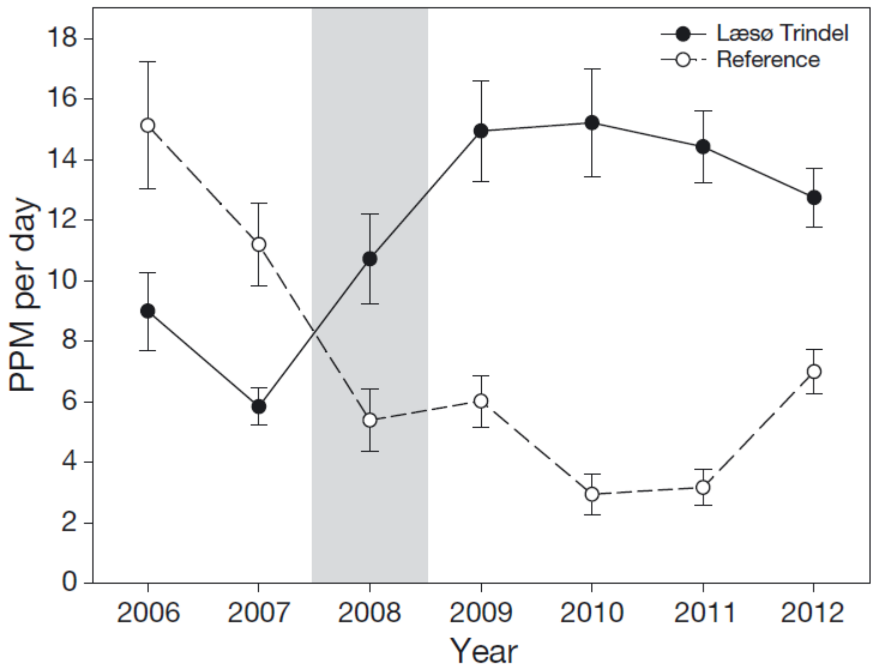

Figure 4.1. PPM (Porpoise Positive Minutes) or number of minutes per day where porpoise echo-location signals were recorded from 2006 to 2012 during the months June to August. The reef construction year is shown with grey shading (from Mikkelsen et al. 2013).

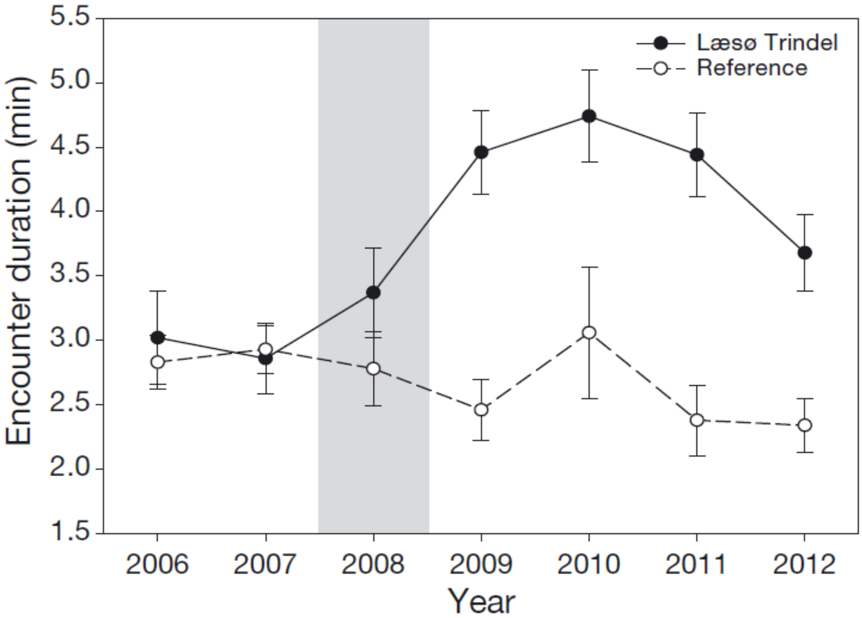

Figure 4.2. Encounter duration or the number of minutes where a porpoise or a group of porpoises was recoded at a time (separated by 10 min silence). Data recorded from 2006 to 2012 during the months June to August. The reef construction year is shown with grey shading (from Mikkelsen et al. 2013).

The conclusion from this study is that during the construction work (June to September), porpoises increased their use of the reef area compared to both years before construction and the reference area. This means that even if the construction work took place at the same time as the acoustic monitoring, a positive effect on porpoise density was seen. The temporal resolution of the acoustic data was not high enough to allow a study of possible reactions of porpoises to the rock dumping events. It is therefore both possible and likely that porpoises reacted negatively to the rock dumping noise locally around the ship – and for a short duration only, but not enough to counteract the overall increase in acoustic activity outside the rock dumping events. The positive effect of the reef increased further after construction ended and was maintained in the subsequent four years.

Another cavernous stony reef was established in Tybrind Vig in January 2023 in Little Belt. This reef was much smaller than Blue Reef, but the acoustic monitoring included more stations. The project is still running under the project "Bælt i Balance" in Naturpark Lillebælt. Preliminary results for two of the monitoring stations near the reef are shown in Figure 4.3.

When comparing January 2022 (no construction) with January 2023 (during rock dumping), the level of porpoise detections is at the same low level in both years. This means that the construction was carried out in the month with the least disturbance of the porpoises. The porpoise activity in the spring months after the construction was very similar to the spring of 2022 when there was no construction work. We therefore conclude that this reef construction was carried out at the time of year with the lowest density and that the effect on the density of porpoises was negligible.

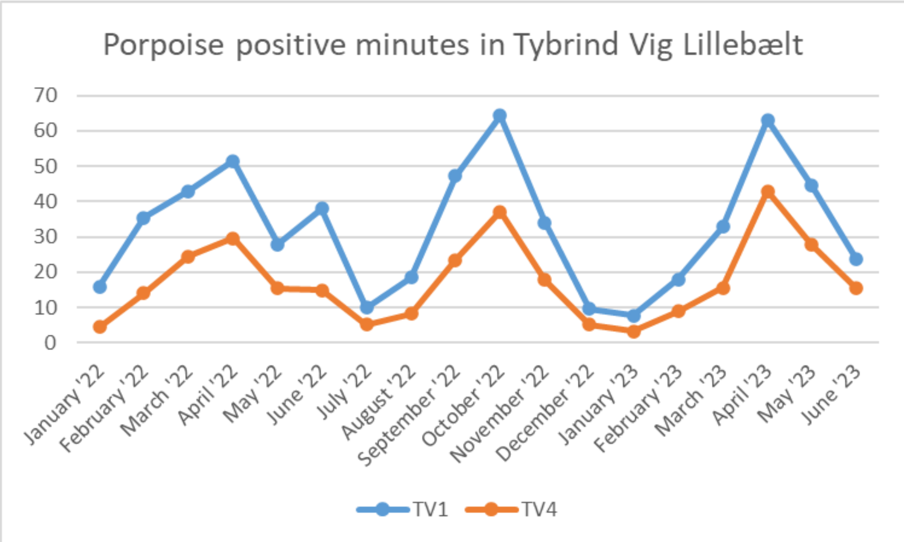

Figure 4.3. PPM (Porpoise Positive Minutes) or number of minutes per day where porpoise echo-location signals were recorded from January 2022 to June 2023. The reef construction was carried out in January 2023. TV1 and TV4 are the two stations on the top of the new reef (Teilmann unpublished data).

5 Conclusion

The assessment of an impact on marine mammals should include an assessment of the animals' sensitivity as well as the impact magnitude to assess the overall impact significance.

Sensitivity

The sensitivity is assessed according to the criteria in Table 2.2. In the case of rock dumping during the establishment of an artificial reef, harbour porpoises will be able to hear the noise from the rock dumping and behavioural disturbance is expected, although the effect will be local and temporary. With our present knowledge, there are no seasons of lesser importance: thus, porpoises are assumed to be equally vulnerable throughout the year. The three populations inhabiting Danish waters have different abundance and conservation status, and this should be included in the assessment of the individual reef restoration projects. Finally, the assessment of sensitivity should also include whether the impacted area is important for breeding, feeding or migration and whether porpoises are present in high, medium or low density. These factors may be highly variable on a relatively small spatial scale and should be assessed individually for each project.

To summarise, the scale of sensitivity for harbour porpoises to rock dumping will range from *Low,* for example in an area with low porpoise density within the large and stable North Sea population range, to *Medium*, for example in high density areas within the declining Belt Sea population range.

Impact magnitude

The criteria for assessment of impact magnitude are shown in Table 2.3. Rock dumping affects a relatively small area (disturbance radius estimated to be 1.2 km). The temporal period affected will last from weeks to months depending on the size of the project. The impact is reversible i.e. animals are expected to return after each the disturbance has ceased. This means that according to the criteria, the impact magnitude is assessed to be between low and medium: the small spatial extent and the reversibility lean towards low, but the length of the disturbance is categorised as medium.

Impact significance

To assess the impact significance of a project, the assessment of sensitivity and impact magnitude should be combined according to Table 2.1. Since the assessment of a specific project depends on project-specific details, such as duration of the project, expected density of porpoises and conservation status of the population, a generally valid assessment of impact significance cannot be made here. However, overall, we conclude that sensitivity and impact magnitude will be assessed as either low or medium. When inserting these assessments into the impact significance table (Table 2.1), it will be the assessment of sensitivity for the individual projects that will determine whether the impact significance is assessed to be minor or medium (since low sensitivity combined with either low or medium impact magnitude always results in a minor impact significance).

Two studies on the effect of construction of stone reefs on harbour porpoises have been conducted in Danish waters. In these, no strong or long-term negative effects were found during after the establishment of the new reefs. In the reef constructed in the Little Belt, this may be due to the reef being established when there were almost no porpoises present in the area due to natural reasons. During the summer, when the Blue Reef project was carried out, there was a clear increase in porpoise activity in the area where the reef was constructed.

Mitigation

If a reef restoration project is assessed to have a medium impact significance, mitigation of the negative effects may be warranted. In general, mitigation of effects of noise can be achieved by three different means: i) reduce the noise produced, ii) reduce the radiation of noise into the environment, iii) reduce the noise received by porpoises. Reduction of the noise produced during rock dumping is difficult as this would require development of new methods and likely involve construction of new ships for this specific purpose. Reduction of the radiated noise can be very efficient as seen in the air bubble curtains used for mitigating pile driving noise. The currently developed bubble curtains require and extra ship, and the extra time required to install and continuously move the air bubble curtain is likely to add significantly more noise to the environment than the noise form the rock dumping itself, thereby being worse than no mitigation. This leaves the third option, to reduce the noise received by porpoises. This can be done effectively by making the construction period as short as possible and to place it, if possible, at a time of the year where there are fewer animals in the area.

As the risk of causing hearing loss in porpoises due to the noise exposure is negligible, the use of deterrent devices (porpoise pingers or seal scarers) to maintain a safety zone around the construction site is not recommended as such a mitigation measure would only add to the disturbance without achieving any additional protection of porpoises.

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