Impacts of wind farm construction and the importance of piling order for harbour porpoises in the German Exclusive Economic Zone of the North Sea

Scientific note from DCE – Danish Centre for Environment and Energy

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Data sheet

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Introduction

The harbour porpoise (*Phocoena phocoena*) is a small cetacean that inhabits most near-shore northern European waters. Porpoises are known to be sensitive to underwater noise, which can disrupt their natural foraging behaviour (Wisniewska et al. 2018) and cause animals to leave important foraging grounds for extended periods of time (Dähne et al. 2013, 2017; Nabe-Nielsen et al. 2014). This can influence the animals' energetic status to a point where they abandon lactating calves and experience increased risk of death (Nabe-Nielsen et al. 2014), which may ultimately influence the conservation status of the population. As the porpoise is strictly protected in European waters, member states are required to take action to maintain or restore a favourable conservation status of the species (EU 1992), and it is therefore advisable to assess whether noise from anthropogenic activities influence the population. This may be particularly important in the case of construction of offshore wind farms, as the pile-driving noise emitted during construction of wind farms has been observed to influence porpoises up to approximately 20 km from the construction sites (Tougaard et al. 2009; Brandt et al. 2011, 2018; Dähne et al. 2013).

One way to assess whether porpoise populations are influenced by noise from wind farm construction is to use agent-based simulation models (ABMs). In such models the behaviour and fate of the individual animals are simulated explicitly, and the population dynamics emerge from interactions among the individual animals (Grimm and Railsback 2005). It is possible to build ABMs that simulate animal movements, energetics and life-history in realistic landscapes, thus enabling population dynamics to emerge from the same processes as they do in nature (Nabe-Nielsen et al. 2013, 2014; Watkins and Rose 2017). Such process-based models are likely to maintain their predictive power in novel environments (Stillman et al. 2015).

Methods

In this study we used the DEPONS model (Nabe-Nielsen et al. 2018) to assess the impact of wind farm construction noise on harbour porpoises in German waters. The model is a process-based ABM which simulates the movements of individual animals and their change in behaviour and energetics when they are exposed to noise. It includes the exact position and timing of individual pile driving operations. We used version 2.1 of DEPONS, where the porpoises' movements have been carefully calibrated to correspond to that of wild animals in the North Sea (van Beest et al. 2018; Stalder et al. 2020). Simulated animals respond to noise by being scared away to the same extent as observed around a real wind farm (see Nabe-Nielsen et al. 2018 for details), thus facilitating highly realistic simulations of the impacts of wind farm construction. Each simulated porpoise agent corresponds to several real porpoises. New simulated animals entered the population at the point where they became independent of their mothers.

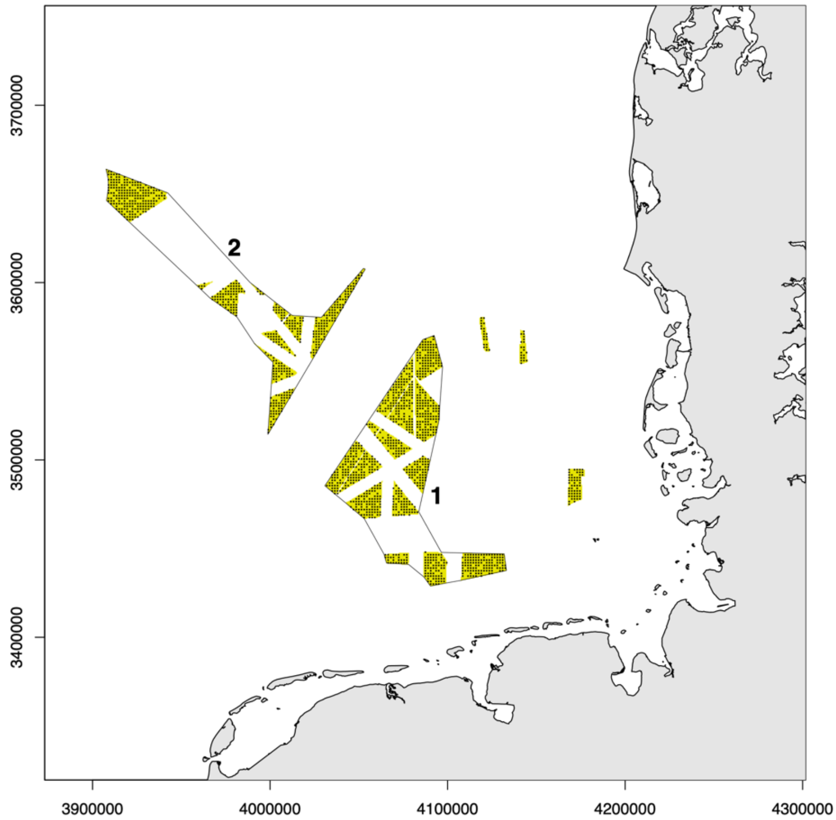

Figure 1. Study area. In the simulations 1650 wind turbines (black dots) are constructed in the period 2021–2040 in German waters. The number of harbour porpoises is counted within two different regions (delimited with black polygons) during this period.

We used two different hypothetical scenarios to study the impact of wind farm construction in German waters. Both scenarios included 1650 wind turbines distributed on a regular 1500 x 1500 m grid (Figure 1). This distance between individual turbines is realistic if we assume a rotor diameter of approximately 220 m. The total capacity of the 1650 turbines is 33 GW if we assume that each turbine has a capacity of 20 MW. The total capacity of the turbines roughly corresponds to the German plan for wind energy development (BSH 2020a) and turbines are placed within the areas set aside for offshore wind development in Germany (BSH 2020b). Both scenarios assume that turbines are built in the same random order, and that the construction of each turbine takes 3.5 hours, followed by a break of 51 hours. Both scenarios included a 10-year burn-in period that was omitted from the analyses, a period of 10 years without wind farm construction, a period of 9.7 years with wind farm construction, and 10 years without wind farm construction. The burn-in period allowed the model to attain a steady-state equilibrium before investigating population dynamics further.

Both scenarios assumed that all turbines are placed on steel monopile foundations, and that pile driving of the foundations emits sound with a source level of 234 dB SEL (sound exposure level) during piling. We modelled sound transmission loss assuming spherical spreading (Urick 1983; Nabe-Nielsen et al. 2018). In one scenario we assumed that porpoises reacted until the sound level dropped below 152.9 dB SEL, which was the case during construction of the Gemini wind farm (see TRACE document on https://github.com/jacobnabe/DEPONS). This caused porpoises to react to the noise up to 11.35 km from the sound source. In the other scenario we assumed that porpoises reacted until the sound level dropped below 146.04 dB SEL, causing them to respond up to 25 km from the sound source.

Results

The number of simulated porpoises fluctuated over the year, with increasing population numbers when new calves became independent of their mothers, followed by gradually decreasing population numbers resulting from competition for food (Figure 2). Population size decreased in the 10-year period before wind farm construction started, suggesting that the population had not entirely stabilized during the burn-in period, but it did not decrease further in the following 9.7 years where porpoises were exposed to noise. That was the case in both the scenarios. The number of porpoises was also nearly the same in the wind farm construction period and in the following noise-free period in both scenarios.

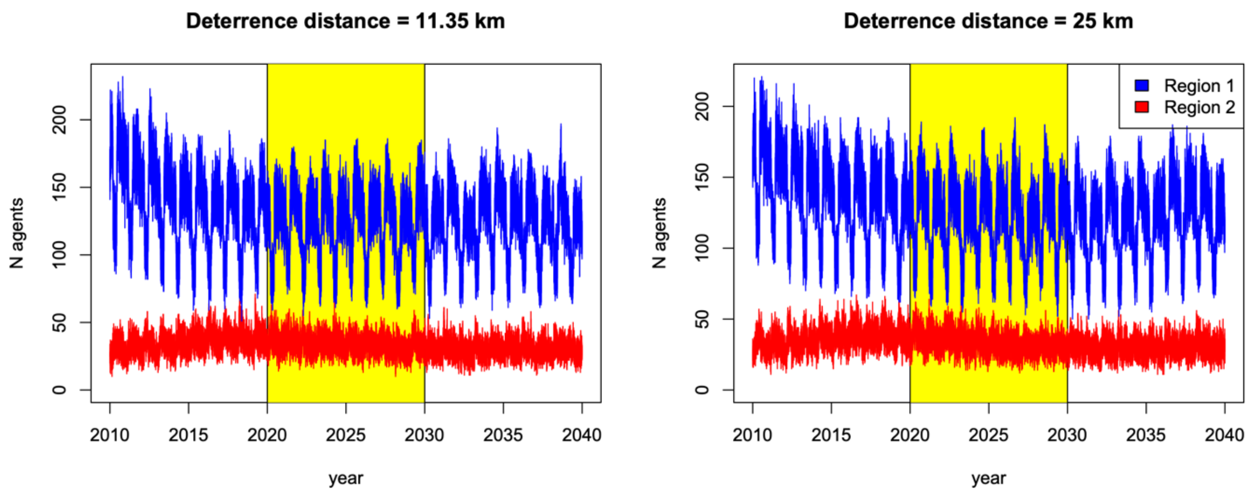

Figure 2. Number of simulated porpoises ('agents') in the two wind farm construction regions shown in Figure 1. Construction takes place in the period 2020–2030 (yellow rectangle). Data from burn-in period not shown.

Discussion

In this study we demonstrate how the effects of wind farm construction on harbour porpoise populations can be assessed using the DEPONS model. There was no apparent effect of wind farm construction on the porpoise population in the studied scenarios, which mirrors the findings of Nabe-Nielsen et al. (2018). In that study, Nabe-Nielsen et al. suggested that the reason for the relatively small impact of wind farm construction was, that porpoises were able to return to the construction sites to continue foraging just a few hours after construction ended. The impact of construction noise on the individuals' energetics and survival was therefore minor. The study by Nabe-Nielsen et al. (2018) also demonstrated that the order of piling was important. In the current study we used a random piling order, which reduces the risk that porpoises are exposed to noise for more than 3.5 hours in the same place. This, in turn, causes the population impacts to be relatively small. The impact is likely to be larger if several piling events take place close to each other, particularly if this prevents porpoises from using valuable foraging areas for several days.

Our results are based on several important assumptions. First of all, the population size in a specific region is very sensitive to the amount of food found there. In the current study this was based on data from Gilles et al. (2016), but in reality certain regions may be more important as foraging grounds than this study suggests, so to ensure that simulation results are realistic for a specific region it would be wise to test the model using food maps based on local studies. Further, several recent studies suggest that porpoises are sensitive to ship and seismic noise (Wisniewska et al. 2018; Sarnocińska et al. 2020), and it will therefore be necessary to simulate the behavioural responses to all the different kinds of disturbances that porpoises are exposed to during wind farm construction to get a complete picture of whether their conservation status is jeopardized.

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