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Prevention of the ecological effects of offshore windfarms in licensing and spatial planning - an overview

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Summary
This report gives an overview of the possibilities of preventing adverse ecological effects of offshore windfarms at the Dutch Continental Shelf by means of suggested measures in windfarm licences. It also suggests a generic approach or assessing adverse ecological effects of offshore windfarms in spatial planning by setting up a procedure for sensitivity mapping of marine natural values.

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1 Introduction

In 2008, Deltares wrote a report called “Development of a framework for Appropriate Assessments or English offshore windfarms” (Prins et al. 2008) as a basis or guideline for the Appropriate Assessments for nineteen initiatives for offshore windfarms (OWFs) on the Dutch continental shelf (DCS). This report is further referred to as the "Framework".

This Framework gave an overall description of the possible negative ecological effects of the construction and operation of OWFs on natural values protected by the European Bird and Habitat Directives and gave guidelines for the quantitative methods for estimating these effects in the project-specific Appropriate Assessments (AAs).

Within the legal context of the European Bird and Habitat Directives (BHD), and based on the Framework, the project-specific Appropriate Assessments zoomed in on three major ecological effects of OWFs, namely:

1. Possible collisions of birds, both from breeding colonies and during the migration seasons during the operational period of the OWFs.
2. Mortality of fish larvae by underwater sound during piling of the OWF monopile foundations and the effects of reduced fish densities on the food availability for birds and marine mammals.
3. Loss of habitat (quality and quantity) of marine mammals due to underwater sound during piling of the OWF foundations and during their operational period.

After completion of the AAs, a process was started to fill the knowledge gaps about the possible negative environmental effects of the construction and operation of OWFs[1]. The first part of this was the establishment of an overarching plan for researching the ecological effects of offshore windfarms. This so-called Masterplan (MP) described the whole of the cause-effect relationships, a comparison with existing knowledge, and the derivation and ranking of research ideas and concrete proposals (Boon et al. 2010). These proposals were then further prioritized, after which funding was found for a first series of research. The first series of research proposals ("shortlist") has been carried out in 2010 and 2011, and is currently completed. The results of this shortlist research have been published in separate reports.

The shortlist research, and the research that is carried out in recent years in the two already existing offshore windfarms *Offshore Windpark Egmond aan Zee* (OWEZ) and *Prinses Amalia Windpark* (PAWP), has increased the knowledge with regard to ecological effects substantially. The increase in knowledge and the next steps needed to further this knowledge have been described in a separate document (Boon 2012).

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[1] *Although the negative ecological impacts of the removal of OWFs is an important aspect of their whole life-cycle, this has not yet been an explicit subject of research. Since there is no experience yet with the decommissioning of OWFs, the effects of removal are thought to be more or less equal to those of construction.. The removal phase and its possible negative ecological effects will not be mentioned in this report; wherever construction is mentioned, removal may be assumed as well.*

To facilitate the use of this updated knowledge, Rijkswaterstaat asked Deltares for a description of the implications of the results from the aforementioned investigations on:

1. The restrictive conditions for the constructions of OWFs as have been described in the permits for OWFs.
2. The spatial planning of OWFs.

Preventing and mitigating the negative ecological effects of the construction, and operation of OWFs can be subdivided into the following aspects:

- Temporal considerations: what is the best period in the year for the construction of OWFs? Also, during the operation of OWFs, temporal measures can be considered: shutting down the OWF during periods of migrating birds passing by the OWF.
- What are the technical possibilities that, apart from the spatial and temporal planning aspects, may contribute to mitigating any negative environmental effect?
- Spatial considerations: what is the best location for planning OWFs with respect to possible environmental effects on marine life? This is treated in chapter 4.

Technically, the first two aspects fall under “prevention”, and only the last aspect is “mitigation”. Mitigation is the term that covers all measures that can be applied to reduce negative environmental effects during the construction or presence of OWFs. At the moment, the licenses restrict the construction of OWFs to the second half of a year; this prevents the occurrence of significant negative effects of piling on marine organisms.

It should be mentioned that the results of the “shortlist” program contribute to the first two aspects only: prevention of environmental effects by planning the construction in time, and by choosing the locations that affect marine life in the least. Construction interacts with both the spatial and temporal aspects; there might be locations and time periods that give less negative effects on marine life. The operational phase relates to the spatial aspect; once the OWF is in place, there is no temporal component to preventing the ecological impacts, apart from shutting down the OWF, although strictly this should be seen as a mitigative measure and not a preventive measure. Technical measures apply on all phases of construction and operation, and may broaden the window in time and space for the planning of these phases.

This report will not treat the technical measures of mitigating the negative ecological effects of the construction and operation of OWFs. Such technical measures, such as changing the configuration of OWFs (affecting bird impact), using under water screens for dampening underwater sounds due to piling, different piling techniques (affecting mammal and fish impact), etc. have been and are subject of some studies (see e.g. Nedwell & Howell 2004, Nehls et al. 2007, Drewitt & Langston 2008). There is even a UNESCO initiative (*The International Quiet Ocean Experiment*), which started last year. However, until now, results on the effects of these technical measures are inconclusive. Therefore, no advice can be given on generic and effective technical measures that mitigate the negative ecological effects of construction and operation of OWFs.

Below, the possibilities for prevention are discussed, subdivided by the cause-effect relationships per planning phase.

It should be stressed that this report only gives a first overview of what possible implications exist for the prevention of ecological effects in policy and licensing based on the recent advancements of ecological cause-effect relationships. A next step would involve a more detailed study on both temporal and spatial aspects of preventing ecological effects of the construction and operation of OWFs. However, to set up such a follow up, additional data and choices are required, which involves a more in-depth discussion with policy makers and researchers. This was not possible within the time frame of this study, Moreover, the effectiveness of doing such a study will be improved by integrating the results of this study with the results from the shortlist studies and the possibilities for the next research round (Boon 2012) and with the currently ongoing study on the methodological update of the Framework (Boon et al. 2012).

2 Current preventive measures in OWF policy

At this moment, two types of limitations are applied on the construction and presence of OWFs. First, for the second round of OWFs locations are chosen through an exclusion policy (e.g. not in clearways, defence areas, etc.) as described in the Nota Ruimte, IBN 2015 and the 'Beleidsregels inzake toepassing Wet beheer rijkswaterstaatswerken op installaties in de exclusieve economische zone'. Second, licenses for the second round OWFs contain two sets of temporal limitations, both for the effects of underwater sound due to piling. One concerns the effects on larval and juvenile fish that may serve as staple food for birds and marine mammals, the other one relates to the effects on marine mammals directly.

2.1 Spatial limitations for OWFs

The latest policy for marine spatial planning with regard to OWFs has been written down in the National Water Plan (NWP, 2010). In this NWP, 4 areas have been assigned for the further development of offshore wind energy until 2020. Two of these areas have already been assigned, two other areas are called “search areas”. This means that on top of the two already assigned areas, additional space needs to be found for OWFs, because it is not certain that the two assigned areas will supply enough space for the establishment of a total of 6000 MW of OWFs. These four areas are:
Assigned:
1. Borssele (344 km^2)
2. IJmuiden-Ver (1170 km^2)

Search areas:
3. Hollandse Kust
4. Wadden-Noord

Below, figure 1 shows these areas, 1 and 2 in dark purple, 3 and 4 in light purple, next to various marine N2000-areas (dotted areas) and inshore and relevant coastal N2000-areas (green).

Currently, no OWFs are planned in the assigned area Borssele, three OWFs are planned in the assigned area IJmuiden-Ver, six OWFs are planned in the searching area Hollandse Kust, two OWFs are planned in the area Wadden-Noord. One OWF is planned in the area between IJmuiden-Ver and Hollandse Kust. Of the two already existing OWFs, there is one situated in the Hollandse Kust (*Prinses Amalia*), and one more nearshore.(OWEZ). The two OWFs planned in the area Wadden-Noord have received additional funding from the Ministry of Economic Affairs (now called Ministry of Economic affairs, Agriculture and Innovation) and are planned to be built (GEMINI, the former BARD farms). Also OWF Q10 received additional funding and is planned for construction. The OWFs that did not receive additional funding from the Dutch government have license to be built, but without funding, construction is currently not profitable.

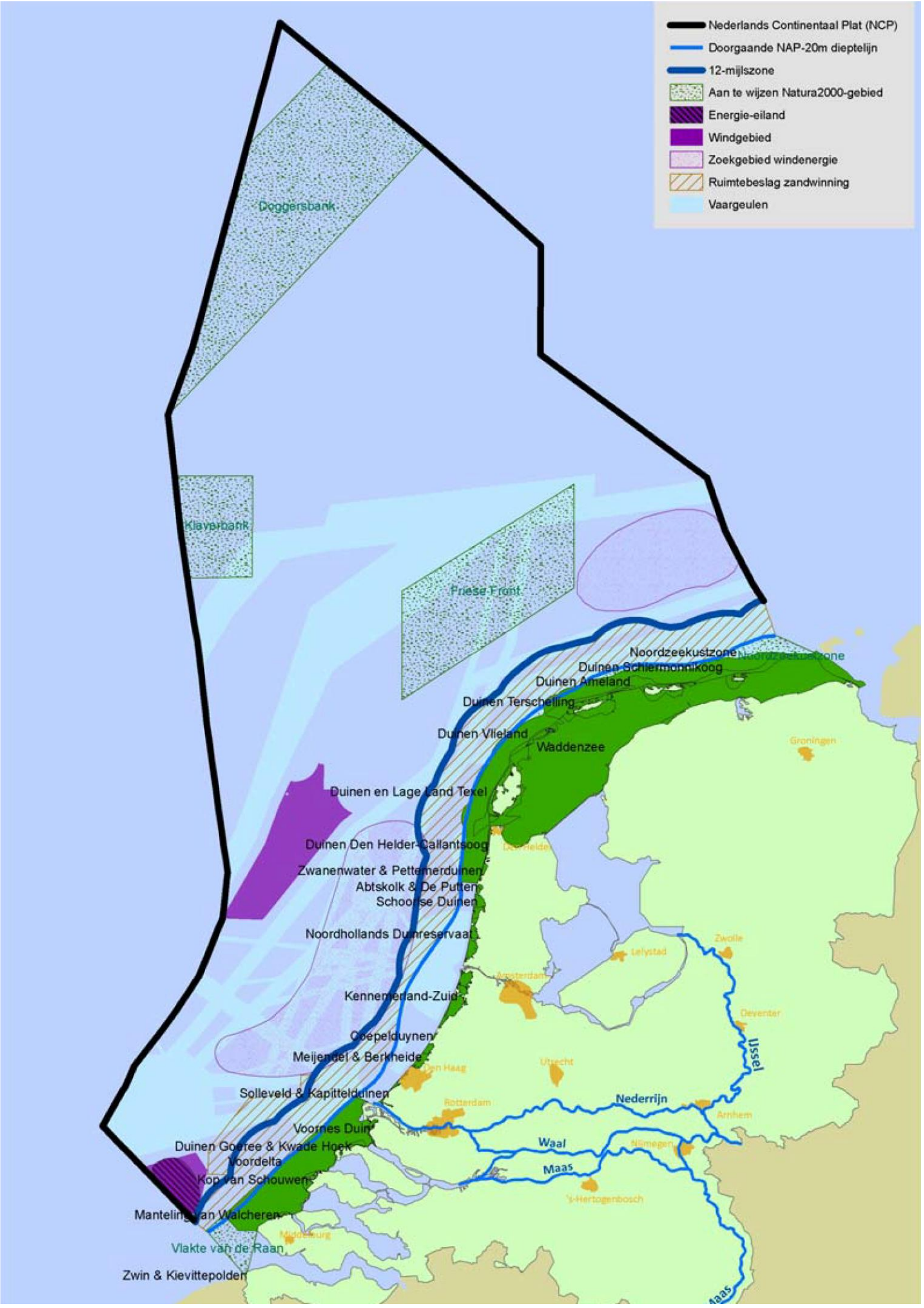

Figure 2.1: Assigned (dark purple) and search areas (light purple) for OWFs in the Dutch part of the North Sea. The dotted areas are marine Natura2000 areas (not yet assigned), the green areas are inshore and coastal Natura2000 areas (assigned).

2.2 Temporal limitations for OWFs

The restrictive conditions in the licences currently in force relate to preventive measures regarding the period in which construction of the offshore windfarms is allowed to take place. These conditions are mentioned in the definitive decision for licensing under the Wet Beheer Rijkswaterstaatswerken (Management of State waters Act). These conditions restrict the period in which piling of the foundation of windfarms may take place from 1 July until 31 December.
This period from 1 January until 1 July is excluded to prevent an unacceptable level of mortality of fish larvae, which are transported to near-coastal areas where they, grown to juveniles, serve as staple food for many sea birds and marine mammal species. This exclusion period also ensures the unhampered migration of pregnant females of the harbour seal from the Voordelta to the eastern Wadden Sea where they give birth to their pups.

Furthermore, in order to prevent cumulative effects of the construction of OWFs on the loss of habitat for marine mammals, it is not allowed to build more than 1 one OWF at a time during this period.

3 Knowledge advancements relevant for preventive measures

3.1 Temporal preventive measures: construction of offshore windfarms

The currently most disconcerting environmental impacts of piling are those caused by sound waves emanating from the piling, creating loss of hearing, of habitat, of fitness, and of foraging and migration possibilities, or causing injuries and even death of marine mammals and fish. Temporal restrictions were set regarding the effects on larval fish and migrating harbour seals.

3.1.1 Impacts of piling on larval fish

The licensing of the second round OWFs in The Netherlands, based on the available knowledge at that moment (2009), included restrictions on the period of piling to prevent the largest effects on fish larvae. Piling was not allowed in the first 6 months of the year, since it was expected that in that period, the fish larvae that were most important as staple food for marine mammals and birds were present in high concentrations at the DCS (Dutch Continental Shelf).Two studies were undertaken to shed more light on the matter of fish mortality due to high impulse sound levels and on the presence of fish larvae in the southern North Sea: one pilot experiment on the mortality of sole fish larvae due to high impulse sound (Bolle et al. 2011), and a year-round survey on the presence and density of larval fish on the wider DCS (Van Damme *et al.* 2011)

From the pilot experiment on fish mortality due to sound pressure waves and particle velocity (Bolle et al. 2011), it became clear that for sole larvae mortality due to impulse sound was not significantly higher at any sound level than without it, at an α error of 5%. As a result, worst-case scenarios were assumed possible with 100% mortality over the first 400 m, and 14% over 400 m to 1000 m distance.
This is a much lower effect range and mortality rate than assumed in the earlier second round environmental impact assessment (100% mortality over 1000 m), and according to Bolle et al. (2011) this leads to a 50% reduction of larval mortality due to piling around the construction site of the OWF. Whether this leads to a proportional increase of larval supply to N2000 areas depends on other factors such as transport and distance from spawning areas and N2000 sites. Moreover, this was only a pilot experiment on sole larvae, a species that is of some importance to seals, but other species such as herring, sprat and sand eel are of higher importance as staple food for harbour porpoises and birds. Additional experiments are planned to show what the lethal effect level is of piling sound on these species.

The survey on fish larvae (Van Damme et al. 2011) showed that for those species deemed important as staple food (clupeids, sand eels, flatfish, gadoids) the first half of the year is the most important periods with the highest densities. Also in July and August reduced, but still noticeable densities of fish larvae can be found. The spatial distribution is not even over the DCS; coastal areas are of higher importance than offshore areas. The model that has been used for distribution of the eggs and larvae in the appropriate assessment for the second round OWFs needs to be validated with these data to check if the results still hold. However, from the data available it can be concluded that the Southern Bight indeed contains the highest larval concentrations of the abovementioned species in the first half of the year, reduced but noticeable densities occur in July and August and significantly lower concentrations can be found in the remainder of the year.

Herring larvae were found in high numbers on our coast from February to April, especially in their early stage, but metamorphosing larvae only in low numbers, and mostly north of the Wadden islands. Plaice eggs and larvae were found in high numbers in the eastern Southern Bight, from January to March mostly. Metamorphosing larvae were found mostly north and northwest of the Wadden islands in April. Sole was found in the whole of the Southern Bight from April to July, but somewhat confined to coastal areas. The model runs for these species used somewhat different spawning periods: for plaice the model simulates the period 15 January - 1 June, for sole the period 1 March - 1 July, and for herring 1 January – 1 June.

So, from the pilot experiment (Bolle et al. 2011) it seems that mortality due to piling on sole larvae is less than previously assumed. The period in which the most relevant species' larvae are present extends beyond the first half of the year, but the highest concentrations indeed appear in the first half of the year (Van Damme et al 2011).

What does this mean for the assumptions made so far in the Appropriate Assessments and the licensing procedures?

Based on the available data and the theoretical considerations, it is not possible to extrapolate the effects on sole to other species. Other species such as herring are hearing specialists and may show a different sensitivity to underwater sound than sole. Furthermore, the theoretical considerations for adult fish may not apply to larval or juvenile fish.

Therefore, only for sole it seems correct that a smaller effect distance can be assumed for mortality due to a series of underwater piling events. As explained in Bolle et al. (2011), this will lead to a ca. 50% decrease in larval mortality in the direct vicinity of the piling site. Whether this leads to a proportionally lower overall mortality and thus a lower decrease in the supply of juvenile (staple) fish to N2000 sites (such as calculated in Prins et al. 2008, and the Appropriate Assessments) cannot be said at this moment. It is likely that the supply of juvenile sole to N2000 areas due to this correction will be better than previously assumed. However, sole as a species was never that much impacted due to piling, since its spawning areas are coastal and piling was not foreseen to be near the coast.

For other species than sole, no change in assumptions on mortality from the Appropriate Assessments is justified.

The restrictive period for piling, based on the assumption that most species' larvae are present in the water in the first half of the year, seems justified based on the data from the surveys (Van Dam et al. 2011). Many species have eggs and larvae extending into the second half of the year as well. The amount of eggs and larvae seems are lower in July and August and minimal in the remainder of the year. Any effect of piling on the survival of larvae and juveniles of these species will be less in the second half of the year.

In conclusion, there seems to be little room for changing the assumed effects of pile driving on larval/juvenile fish mortality, and little need for changing the restricted period for piling. The possible effect of mortality on larvae present in the Dutch part of the North Sea outside the first half of the year cannot be assessed in the context of this report. Additional studies and choices on modelling parameters need to be done to take this a step further.

3.1.2 Effects of OWF piling and presence on marine mammals

In the appropriate assessments for these windfarms, no 'significant' effects were expected, based on assumptions about avoidance behaviour in relation to the effects of piling on seals and porpoises. In the licenses for the second round OWFs, there were temporal restrictions included to prevent effects on larval fish. As a side effect, this also created a time window for pregnant harbour seals migrating from the Voordelta to the eastern Wadden Sea to give birth.

In the shortlist research series, four experiments were carried out to better assess the effects of impulse sound on causing TTS(Temporal Threshold Shift)[2] in porpoises and seals. The results of these studies are described in Kastelein et al. (2011). The implications of the results for the effects of piling and the presence of OWFs on marine mammals is discussed in Boon et al. (2012). The results from this discussion are the following:

Avoidance data on harbour porpoise due to piling in the field show variable reactions, with a maximum observed avoidance reaction at ca. 20 km (Lucke 2010, Brandt et al. 2011). Other studies show comparable or smaller avoidance distances during piling (e.g. Carstensen et al. 2006). It has to be stressed that effects can be expressed differently. In a recent publication by Brandt et al. (2011), reactions of porpoises to piling of Horns Rev II were measured with T-PODs. They measured a decrease in porpoise acoustic activity. A 100% decrease lasted for 24 to 72 hours at a distance of 2.6 km. This period gradually decreased with increasing distance and a no-effect level was detectable to a mean distance of 17.8 km. As a maximum effect (worst-case) scenario, an avoidance distance of 20 kilometres seems appropriate. This is an increase in avoidance distance compared to what was used in the earlier AAs for the second-round OWFs (12 km).

Larger problems exist for assessing the avoidance distances for seals. The data on the behaviour of tagged common seals before, during and after piling (Brasseur et al. 2012) did not show any convincing differences in seal behaviour between these periods. In the study referred to above by Lucke (2010), where the avoidance distance for porpoises due to was piling was estimated at ca. 20 kms, seals could be observed within this range during piling, so at an even smaller distance than 20 kms. It was not mentioned whether the seals were swimming with their heads below or above water. Seals may avoid underwater noise by emerging their ears from the water, during which they will not be able (or willing) to forage under water.
Kastelein et al. (2011) suggest that, based on their experimental findings, seals may not be more sensitive to underwater sound from piling than porpoises. In combination with the observations from Lucke (2010), there seems a basis for adapting the avoidance distance for harbour seals from 80 kms to 20 kms. Moreover, the empirical basis on which the 80 kms as avoidance distance for harbour seals were calculated in 2008 (Kastelein et al 2008) was quite small. Nevertheless, so is the empirical basis for assuming the 20 kms as a better alternative avoidance distance. So, this leads to a Catch 22 situation. Based on a worst-case approach, the current advice would be to maintain the avoidance distance of 80 kms, and to stress that additional field observations and experimental work is needed to elucidate this controversy.

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[2] The TTS is a shift in the threshold for hearing sound, which, at low sound pressure values, is essentially a protection mechanism to the sensory organs of the ear. It creates a temporary increase in the lowest sound level to become audible in the organism. A comparison is the human loss of sensitivity for high frequencies due to listening too often to too loud music. Usually, TTS itself creates no damage and the functioning of the ear recovers fully. When prolonged or repeated, TTS can be become a permanent threshold shift (PTS).

It needs to be emphasised that as more and more OWFs are build in the (southern) North Sea, the chances of an accumulation of effects will grow. Some level of accumulation has been considered in the second-round OWF EIAs and AAs, but this was not based on actually existing OWFs; nor were any foreign OWFs considered. It is not possible to set up some concrete guideline on how to sum up the effects of OWFs on marine mammals. Much depends on the timing of construction, the location, the size and the configuration of the OWFs. However, when planning an OWF, and writing the EIA and AA, the level of cumulative effects to be considered needs to be discussed with the proper authorities (“bevoegd gezag”).

Given the above, there hardly seems to be room for reconsidering the issue in revised or new licenses.

This means that next to the possible loss of the corridor along the Holland coast for pregnant seals, the underwater sound effects also relate to the possible loss of habitat for seals and porpoises for foraging, mating, resting etc. In the AAs, a one-time loss of such areas was considered not to give a significant effect, based on the avoidance of the areas with underwater sound due to piling above a certain threshold. This was assumed irrespective of the importance of the area for the mammal species for foraging, mating, resting, etc.

A spatial analysis of the distribution data of the harbour porpoise (and the harbour seal and grey seal) is needed to find out what room there is for spatial OWF planning regarding high natural values for seals and porpoises. This subject can not be treated within the context of specific OWFs, but needs to be further studied regarding the generic spatial planning of OWFs on the DCS.

4 Possibilities for spatial planning of offshore windfarms

In this chapter, the negative ecological effects of the construction and operation of OWFs will be discussed in a spatial context; The discussion will revolve around the variables that determine the spatial differences in negative effects and the possibilities of spatial management of the placement of OWFs on the Dutch continental shelf. Lastly, the requirements will be given for a further analysis of spatial management of OWFs.

4.1 Spatial implications of offshore windfarm construction

4.1.1 Fish larvae

Currently, the possible effects of underwater noise due to piling that are considered most serious are those on fish larvae, due to their role as staple food for marine birds and mammals protected under the Bird and Habitat Directive (within Natura2000 areas). In neither the Environmental Impact Assessments, nor the Appropriate Assessments, the effects of underwater noise due to construction piling have been estimated to have significant effects on fish populations.

According to the modelling exercises in the second round Appropriate Assessments (e.g. Arends et al. 2008) and a comparison of the effects of the various different OWFs in the second round, piling causes the strongest reduction in available staple food in two cases:

1. when the OWF is located relatively close to a spawning area
2. when the OWF is located relatively close to a Natura2000 area.

Although a further analysis needs to be done to confirm this, these observations are quite logical. In the first case, larval concentrations are highest, not diluted by dispersion, and thus a relatively high proportion of larvae is affected. In the latter case, the larvae affected are mainly those that would have been available as staple food for the marine birds and mammals.

Thus, as a precautionary approach to minimize the effects of the construction of OWFs on fish larvae, locations are best sought away from N2000 areas and from spawning areas of relevant fish species.

The models used for assessing the effects of piling on larval supply to the Dutch N2000 areas did not perform well for the area north of the Wadden Sea. There was no information included on spawning areas for fish around the Dogger Bank, and any effect on N2000 in the German and Danish North Sea waters was solely based on effects on fish spawning in the Southern Bight. A new model set up to include this information is preferred to assess effects of piling on N2000 areas in the countries bordering the Dutch continental shelf.

Also, other species than herring, sole and plaice might need to be considered in the modelling exercise, and the information gathered during the egg and larval survey in 2010 and 2011 might be relevant in validating distribution and transport of eggs and larvae towards the N2000 sites.

Additionally, more knowledge is needed on effect distances, especially regarding physical injuries or TTS-like effects. Avoidance is less relevant for larvae and juveniles, since they are not very mobile, and cannot escape negative effects.

4.1.2 Marine mammals

Marine mammals are highly mobile species, and detailed knowledge on their movements and effects distances is needed to search for those areas that cause minimal negative effects. Such a study can be carried out as explained for birds in paragraph 4.3, using sensitivity mapping.

Harbour seal
Harbour seal hotspots are the Wadden Sea, its outer delta and the Voordelta. Furthermore, migration occurs between the Wadden Sea and the Voordelta and between other continental coastal areas in France, Belgium, Germany, Denmark and also the UK (Brasseur et al. 2008). There are some indications that there are hotspots for foraging, but these need to be confirmed. It is important to get a better view on both the importance of the southern North Sea areas for the seals, and of the specific vulnerable periods in the life of the seals in combination with the uses of specific “hotspot” areas. In general, it can be assumed that harbour seals forage out to 100 kilometres from the coast, although densities appear to drop sharply after ca. 50 km. (Brasseur et al. 2008). Highest concentrations are found off the coasts of the Voordelta and of course the Wadden Sea.

Grey seal
Less information is available for the grey seal. Assumed is that they forage further away from the coast than the harbour seal. There are no indications for foraging hotspots, but that might be due to lack of data or due to high individual variation in foraging strategies. It is known they perform more regular migrations between the UK and the Netherlands than the harbour seal. Based on telemetry data, their distribution in the North Sea appears mainly northwest of the Wadden Sea (Brasseur et al. 2008), but this picture is strongly influenced by the low number of tagged individuals. They also reside in the Voordelta area and along the Holland coast.

To minimize the effects of underwater noise due to piling of OWFs, and following the discussion in paragraph 3.1.2, the placement of OWFs should be at a minimal distance of 50 km from the outer deltas of the Wadden Sea and from the Voordelta[3]. Even then it is possible that foraging seals are disturbed by the underwater noise from piling. Operational noise is assumed only to disturb at very small distances (< 1 km), and seems not likely to cause significant loss of habitat, although data are too scarce to give any solid conclusions.

Harbour porpoise
Harbour porpoises live throughout the whole of the North Sea, and the last decade their distribution appears to have moved southwards, likely due to a spatial shift in preferred prey species (Camphuysen & Siemensma 2011). They are regularly sighted at the Dutch coasts during wintertime, and also regularly strand on the beaches throughout the Netherlands, but with an emphasis in the northwest of Holland and the Wadden islands. Likely as a result of increased densities, their strandings seem to increase the last decade as well.

[3] *This means a distance from the coast of these N2000 areas of ca. 80 kms. If avoidance distances for harbour seals appear to be smaller than 80 kms, then this distance from the outer deltas can be accordingly smaller. Please note that this applies on any single OWF being constructed. When more OWFs are to be built in the same time, additional criteria need to be developed to prevent cumulative effects.*

They migrate through the southern North Sea, moving along the Dutch shores in wintertime and early spring, and moving northwards during spring and summertime. They move into German waters in the spring and summer, and leave the area in autumn. In German waters, hotspots (areas with relatively high densities) have been established at the Borkumer Reef, and at the outer Sylter Reef. Camphuysen & Siemensma (2011) report that mother-calf pairs appear to be present there in relatively high numbers. In Dutch waters, the Borkumer Reef area showed relatively high densities of porpoises in July 2010, but not in the remainder of the survey period (Geelhoed et al. 2011). No mother-calf pairs were found in the area of Borkumer Reef in this survey; these were found most importantly in the Southern Bight. The latest DCS-wide porpoise survey (Geelhoed et al. 2011) confirmed the distributional pattern described above, with highest densities in winter/spring and lowest densities in autumn. Short favourable periods and locations may enhance food availability and thus cause temporary porpoise clusters. In the southwest area (Delta), a small resident population appears to have established.
According to Camphuysen & Siemensma (2011), the lack of consistent clusters does not exclude the existence of important areas that would require additional spatial protection. However, to date there is no clue to the relationship between the porpoises and their habitats, or the reason why certain areas would be more important than others, and how such areas are of importance to the fitness of the (southern) North Sea porpoise population. As such, it is not possible to exclude certain areas from human activities with the purpose of protecting porpoises, at least in the Dutch part of the North Sea.

Camphuysen & Siemensma (2011) propose certain measures to prevent significant negative effects of OWF piling on harbour porpoise, which are listed below:

1. *Avoid pile-driving and use alternative foundation methods available. Taking precedence over alternative foundation methods causing less impact on the marine environment should be part of the permit system and should be a balancing factor against extra costs of alternative foundation,*
2. *When pile-driving, only in daylight hours and under good sighting conditions to detect porpoises.*
3. *Only permit pile-driving in seasons of low porpoise abundance to limit the number of animals exposed. Such a restriction should be based on latest insights in seasonal distribution.*
4. *A pre-piling search 30 minutes prior to the start of piling should be undertaken by skilled marine mammal observers. Piling should not begin, if porpoises (or other marine mammals) are detected within the mitigation zone [to be defined but no less than 500 metres based on the UK piling protocol] or until 20 minutes after the last detection.*
5. *When pile-driving, mitigation measures such as acoustic deterrents or a ramp-up procedure should be properly used to alert porpoises and other marine mammals. First, note that acoustic deterrents might cause adverse effects as well when to close to the animals. It is not guaranteed that using deterrents or a ramp-up scheme do deter porpoises, and if so, note that animals are disturbed from their natural behaviour.*
6. *Technical measures proven to reduce the sound emission during construction works should be used whenever possible.*

None of these measures include permanent spatial regulations, as the knowledge level to do so is still quite low.

4.2 Spatial implications of offshore windfarm operation

4.2.1 Effects on migrating birds – collisions and barrier effect

In the licensing procedure, no restrictions were included with regard to possible collisions of migrating birds with OWFs. The appropriate assessments for the second round OWFs did not calculate any effects that were likely to be significant, also when an (unrealistic) worst-case scenario was considered[4]. The barrier effect, i.e. flying around or over an OWF as to avoid collision has never been assessed as being a serious issue. In the environmental impact assessments and the appropriate assessments, it was calculated that the detour the birds have to make to avoid a single large OWF was negligible compared to the whole migration distance. However, the cumulative impact of OWF on migrating birds is considered to become an issue when tens of GW of OWFs will be installed.

In the "shortlist" program, the surveys that were carried out did not focus on the migration of birds between the UK and the Netherlands, or on any other migration across the North Sea. Already in the Terms of Reference for the surveys it was mentioned that the surveys should be aimed at sea (going) birds. Therefore, in the short term, no preventive spatial measures are foreseen to reduce an impact a migratory birds.

This is an issue that will need to be addressed in a next phase of the research, and becomes relevant in a foreseeable future where tens of OWFs are to be built in the southern North Sea. Obviously, regarding the international character of migratory birds, such research would be most effective in an internationally coordinated effort.

4.2.2 Effects on seabirds – collisions and habitat loss

In the licensing procedure, no restrictions were included with regard to possible collisions of seabirds with OWFs. The appropriate assessments for the second round OWFs did not calculate any effects that were likely to be significant. However, the cumulative impact of OWFs on seabirds is considered to become an issue when tens of GW of OWFs will be installed. This was one of the reasons why a DCS-wide survey for birds received a high priority in the Masterplan (Boon et al. 2010).

In the surveys that were carried for the “shortlist” program, observations were collected on seasonal bird abundance, spatial bird distributions, bird behaviour and flying heights (Van Bemmelen et al. 2011, Poot et al. 2011). These data clearly showed the aggregations of seagoing birds, Poot et al. (2011) gave a synopsis of the aerial surveys (paragraph 5.1), from which it is clear that both search areas for OWFs coincide with several species of seabirds, notably northern fulmar, great skuas, kittiwakes, little gulls, larger gulls, guillemots, razorbills and terns. It is also clear that some species show a more widespread distribution over the areas, while other show relatively strong aggregations within the search areas. Such patterns, when consistent (e.g. linked to specific frontal areas) can be quite relevant for optimizing spatial planning of OWFs within the search areas[5].

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[4] This scenario consisted of a spring and autumn migration of the whole UK population of birds between the UK and The Netherlands passing through an OWF of 450 MW. This is a rather unrealistic scenario, since the population in known to migrate over a much wider area than the width of the assumed 450 MW windfarm.

[5] The spatial effects of OWFs encompass a gradient from effects at the micro level (configuration of OWFs at the level of spacing, height, rotor diameter) to effects at the macro level (distribution of OWFs over the DCS). In this chapter, only the macro level is treated. However, data that play a role in describing the spatial sensitivity of birds to OWFs do include those at the micro level: flying height of birds, avoidance behaviour of birds, etc.

Poot et al. (2011) conclude that it is not known to what extent these spatial patterns are consistent, i.e. representative for other years. On the other hand, from the comparison of the aerial “shortlist” surveys in 2010 and 2011 with the MWTL surveys from 2010 (paragraph 4.3 in Poot et al. 2011), it is clear that for some species, the MWTL surveys show a high degree of similarity, although due to the low numbers of comparable surveys, no firm conclusions can be drawn. Additional analyses are needed to give more detail about the consistency between the 2010 MWTL distributions and other MWTL years from which some conclusions can be drawn about the consistency of the aerial “shortlist” distributions.

Van Bemmelen et al. (2011) have given preliminary windfarm sensitivity indices to the seabird species observed from the “shortlist” ship-based surveys. From this, species such as divers, ducks and terns appear relatively sensitive to windfarms. From their study and from Poot et al (2011), these species appear present in relatively low numbers within the OWF search areas. This is exemplified in the Windfarm sensitivity map (see paragraph 4.3), where the sensitivity indices for the bird species have been combined with their distribution from the ship-based survey. This shows relatively high sensitivity areas in the near-coastal areas, around the Frisian Front, around the Cleaver Bank, parts of the Dogger Bank and the southern part of the Southern Bight (opposite of the southwestern Delta). On the other hand, recent research in and around the existing Dutch OWFs *OWEZ* and *PAWP* (Leopold et al. 2011) have indicated that avoidance is probably substantially less: <100 % inside the windfarm perimeter and zero or near zero outside the windfarms. In addition, the level of avoidance appears to be correlated to the turbine type installed. More studies are underway and in the near future, more avoidance data will be available, allowing for a meta-analysis of disturbance for a range of species and windfarms. In future AAs, additional calculations are needed to adjust the parameters used in the second-round AAs.

These analyses, when giving consistent results and added with additional distribution maps over various years will lead to a spatial sensitivity map for seabirds, that can be used in the spatial planning of future OWFs. The use of such maps is likely to aid in preventing large negative ecological effects on collisions and loss of habitat.

4.2.3 Effects on colony birds – the lesser black-backed gull

An important issue in the latest (second) round of licensing of OWFs was the estimated mortality of the lesser black-backed gull from Dutch coastal breeding colonies. Many aspects in the collision models were quite sure to be different from the assumptions, such as the spatial use of feeding habitats, but the specific situation was unknown. Hence, assumptions were made that led to the refusal of two OWF licences.

In the “shortlist” program, several studies were carried out that focused on the most important unknown or hardly known aspects of breeding gull behaviour: flying distances, flying height, spatial use of feeding grounds etc. The results were quite revealing, and showed that most of the assumptions need a strong adjustment (Camphuysen 2011, Gyimesi et al. 2011).

Based on the new data from the studies on the lesser black-backed gull, a new collision model can be set up, after which a recalculation of collision fatalities is possible. From what we know on the spatial use of the foraging areas by the gulls, this will lead to spatial differences in sensitivity to collision and habitat loss. Such results are obviously of great use in planning future OWFs.

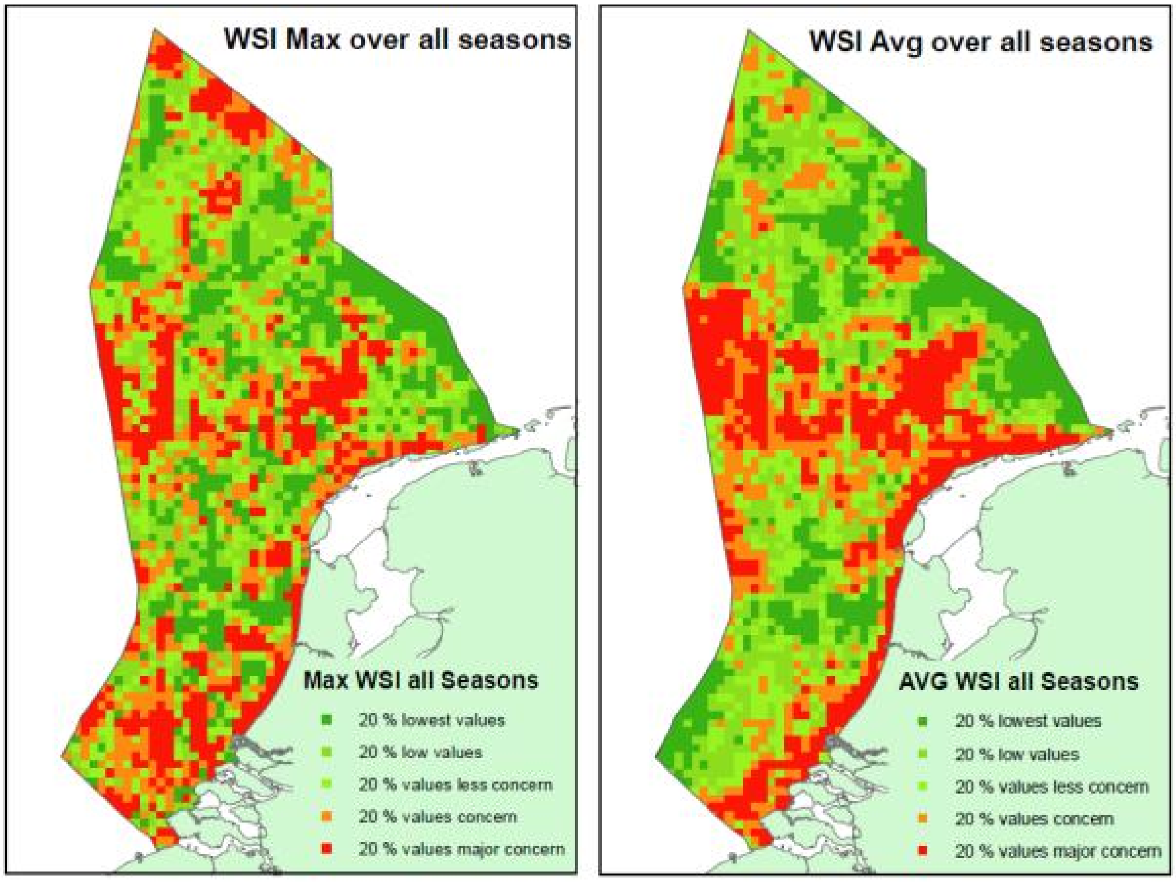
4.3 Cumulative effects and spatial planning

It is important that in future impact assessments, the cumulative effects of OWFs from countries bordering the DCS will be taken into account. Such an approach will be most effective when developed in cooperation with these surrounding countries.

It is advised to do this based on spatial considerations of the possible ecological effects as discussed in this report. The rationale for a spatial approach is that it can be used in a generic sense, as opposed to a project-specific approach, where the possible effects of each OWF plan or project need to be assessed by itself and in accumulation with (possible) other OWFs. It can also be combined with other spatial planning such as needed for fisheries, shipping and oil and gas exploration/exploitation. In combining the spatial distribution of birds at sea with their relative sensitivity to avoiding OWFs, a spatial OWF sensitivity map for seabirds can be constructed.

To make such sensitivity maps, it is necessary to understand:

1. Where do we find natural value “hotspots”. This means where do we find high natural values of marine birds and mammals, and other highly valued organisms and habitats. Such hotspots may be dynamic, such as is the case with porpoises. Parts of the organisms’ lifecycle (e.g. specific feeding, resting, mating and calving grounds) may be crucial for their fitness, so spatial weighting is likely to be important
2. What spatial ecological processes (i.e. relating to the concept of connectivity) can be altered due to the cumulative construction or presence of OWFs. Windfarms may influence the recolonization processes of benthic organisms, be stepping stones for invasive species, or the production of local fish communities.
3. What are the quantitative cause-and-effect relationships between the construction/operation of OWFs and the values and processes under 1 and 2. To what spatial extent do OWFs exert their influence on organisms and processes, and how do these add up when modelled spatially. An example would be the effect of the presence of various OWFs along the migration route of bird species: collisions cause additional mortality, avoidance cause reduction of fitness.



Taken from Leopold & Dijkman (2010). The left panel represents the maximum WSI over six bimonthly periods, the right panel shows the average over these six maps. Note the dominance of the coastal zone, the Frisian Front, the Cleaver Bank and surroundings, (parts of) the Dogger Bank and the Southern Bight. WSI is the summation of the multiplication of bird densities and SSIs.

An international scientific effort could start with comparing data and cumulative models from the Netherlands with those from Belgium, the UK, Germany and Denmark to create sensitivity maps for marine birds and mammals. An example of such a map, based on seabird distribution data until 2009, is given in the figure above. When a species sensitivity index (SSI) is combined with is sensitivity to OWFs, and all SSI are summed spatially, a Windfarm Sensitivity Index (WSI) can be calculated.

Migration routes need to be studied for birds crossing the southern North Sea north-south along the coastlines, but also crossing the North Sea east-west from Denmark to the UK (going over Dogger Bank), and from the Netherlands to the UK.

Modelling exercises are needed to get more insight into movements and distributions of seals and porpoises, and their relationships with habitat and prey species. Avoidance of underwater noise by marine mammals needs to be further investigated. Possible avoidance reactions and loss of habitat due to hearing impediment needs to be modelled spatially in combination with dynamic bio-energetic budgets to assess severity of habitat loss at population fitness level.

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