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Report

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Did the pile driving during the construction of the Offshore Wind Farm Egmond aan Zee, the Netherlands, impact local seabirds?

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Summary

The Dutch consortium "NoordzeeWind" operates the first offshore wind farm in Dutch North Sea waters. The park, consisting of 36 turbines on monopiles, is located NW of IJmuiden harbour, some 8 NM off the Dutch mainland coast. Named after the nearest town ashore, the park is known as "Offshore Windfarm Egmond aan Zee" (OWEZ). Erecting the 36 monopiles was done by pile driving, from a large ship using a hydro-hammer. This technique generates considerable underwater noise levels (see report OWEZ_R_251_Tc_20070327) that might be detrimental for local wildlife. In this study, possible effects on sensitive seabirds are considered. Bird species most likely to be vulnerable to underwater sound are those that forage by diving after fish of shellfish. Diving birds that may occur in relatively high densities at the OWEZ location include auks, and possibly divers and seaduck. Terns, that feed by shallow dives are considered less vulnerable and mostly occur closer to the mainland coast. Several gull species may occur in the area in high densities, but they feed at the surface only, and are considered the least vulnerable. Pile driving took place from 17 April to 28 July 2006. The potentially vulnerable divers, seaduck and auks had largely left the area by the time the pile driving started. Migration commenced early in 2006 and any birds still left in the area by mid-April would have been scared away by the shipping activities long before actual pile driving started. Further mitigation of possible effects on sensitive seabirds included a ramp-up procedure that ensured that full hamming power was only administered after a period of low-energy blows that were unlikely to cause lethal effects on any birds still present. Furthermore, an underwater pinger, aimed at scaring off marine mammals, was put into operation 3-4 hours before pile driving started. Visual observations before and during three pile driving sessions failed to detect any of the seabirds deemed sensitive to pile driving noise in the vicinity of the construction work. Birds that did fly by the construction site (mainly gulls and terns) did not show a noticeable reaction to the activities. It is therefore concluded that effects of underwater noise on seabirds, though potentially detrimental, were negligible during construction of OWEZ. This was due to fortunate timing of the work and to appropriate mitigation measures.

Samenvatting

Het consortium "NoordzeeWind" heeft het eerste Nederlandse windpark op de Noordzee laten bouwen. In dit park verrezen 36 turbines op zogenaamde monopiles, in een concessiegebied, gelegen op circa 8 zeemijlen voor de kust van Egmond aan Zee. De palen werden geplaatst door ze vanaf een groot hei-schip de bodem in de slaan. Dergelijk heiwerk gaat gepaard met hoge geluidsniveaus, met name onderwater (zie rapport OWEZ_R_251_Tc_20070327). Dit geluid is in potentie schadelijk voor onderwaterleven, waaronder zeevogels die duikend voedsel zoeken. In deze studie worden de effecten van het geluid van het heien op de zeevogels die ter plaatse (kunnen) voorkomen onderzocht. De zeevogels die het meest kwetsbaar lijken zijn de alk en de zeekoet, die diep duikend foerageren en -in de winter- in hoge dichtheden in het werkgebied kunnen voorkomen. Zeeduikers en zee-eenden lijken ook kwetsbaar, maar komen in de regel dichter onder de kust voor. Meeuwen, die vooral aan het wateroppervlak hun voedsel zoeken lijken minder kwetsbaar, terwijl ondiep duikende soorten als sterns een tussenpositie zullen innemen. Meeuwen kunnen in hoge dichtheden in het gebied voorkomen maar sterns verblijven in de regel dichter onder de kust, wat hun kwetsbaarheid vermindert. Het heiwerk werd uitgevoerd tussen 17 april en 28 juli 2006. In 2006 kwam de voorjaarstrek vroeg op gang en de meeste zeeduikers, zee-eenden, alken en zeekoeten hadden half april het gebied al verlaten, waardoor er geen schadelijke effecten van het geproduceerde onderwatergeluid meer konden optreden. Daar kwam bij, dat de aanwezigheid van het -zeer grote- heischip en andere werkschepen in het gebied al bij voorbaat verstoringsgevoelige zeevogels op afstand gehouden zullen hebben. Er werd bovendien actieve mitigatie toegepast. Het heien startte bij iedere sessie steeds met een aantal "voorzichtige" klappen en het volle vermogen werd pas later toegepast, waardoor gevoelige dieren de gelegenheid hadden naar een veilige afstand uit te wijken voordat zeer hoge geluidsniveaus bereikt werden. Tenslotte werd een onderwater pinger ingezet die al 3-4 uur voor aanvang van het heien een eigen, afschrikkend bedoeld onderwatergeluid produceerde. Een drietal heisessies werd gevolgd vanaf een klein bootje in de nabijheid van het heischip. Er werden geen kwetsbaar geachte zeevogels nabij het werk gezien en de vogels die wel in de buurt kwamen (meeuwen, sterns) vertoonden geen reactie op het (bovenwater)geluid. De conclusie is daarom, dat er geen significante effecten van het onderwatergeluid van het heien zijn opgetreden, ten opzichte van zeevogels. Een gunstige timing ten opzichte van de winter- en trekseizoenen, en geslaagde mitigatiemaatregelen waren hier debet aan.

Introduction

The Dutch consortium "NoordzeeWind" operates the first offshore wind farm in Dutch North Sea waters. The park, consisting of 36 turbines on monopiles, is located NW of IJmuiden harbour, some 8 NM off the Dutch mainland coast. Named after the nearest town ashore, the park will be known as "Offshore Windfarm Egmond aan Zee" (OWEZ; Figure 1).

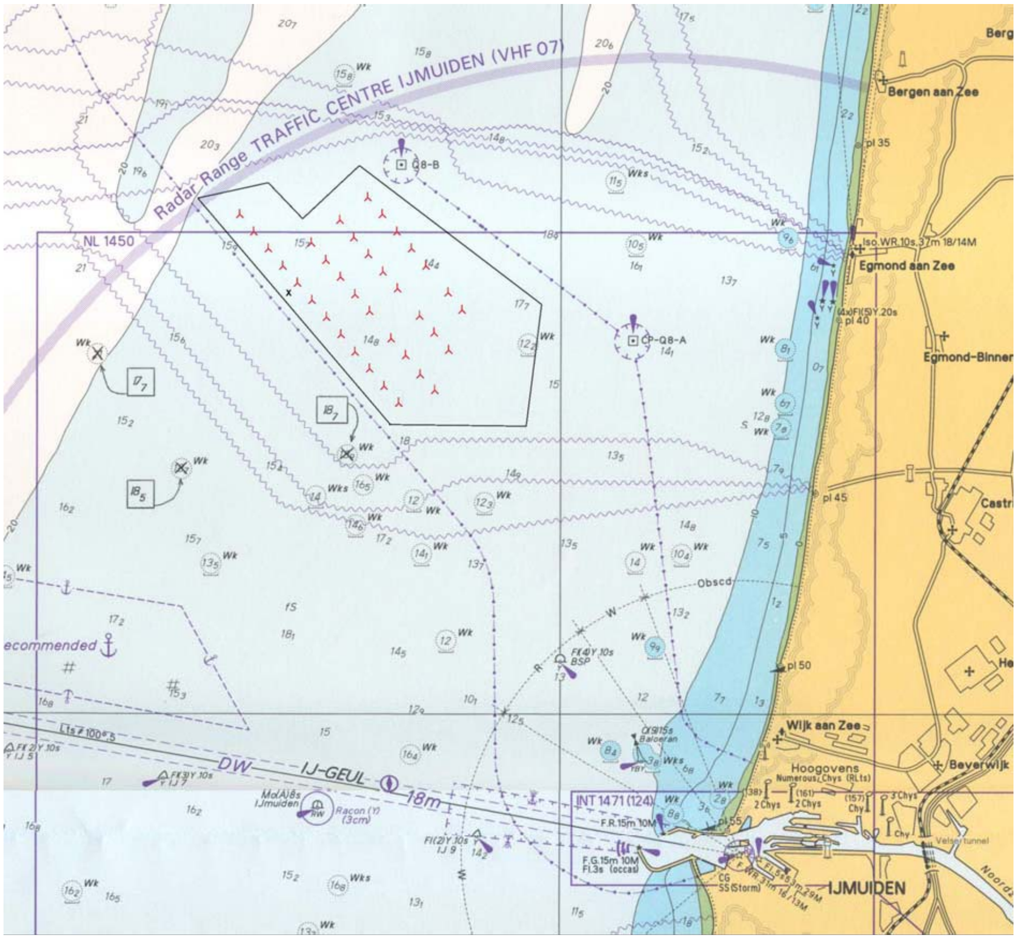


Figure 1. Location of OWEZ (polygon off Egmond aan Zee) with the 36 turbines (image taken from NoordzeeWind 2003).

The construction of this wind farm has taken many months and constituted among others several ship-based site surveys, cardinal buoys around the perimeter of the site, the laying of foundations for the monopiles (rocks being dropped into the sea from a barge), pile driving of the monopiles and attachment of transition pipes for the monopiles and further attachments of the turbines (at 70 m asl) and rotor blades (reaching up to 115 asl, NoordzeeWind 2003), and trenching cables. The ships involved in these tasks and for trafficking workers and equipment to and from the site and performing guard duties will all have impacted local seabirds. These impacts may range from attraction to deterrence from the site and, in a worst case scenario, to the death of some seabirds.

The location of OWEZ is within the Dutch EEZ, but outside any of the proposed NATURA 2000 sites within this area (Lindeboom *et al*. 2005). However, the site may hold rather important concentrations of vulnerable and protected seabirds at certain times of year, particularly during spring migration (April, May) and during winter (November through March; Leopold *et al*. 2004).

A study of the possible detrimental effect of construction work at sea on local seabirds probably is a *novum* in the North Sea. There are several reasons for conducting such a study. OWEZ is the first wind farm in Dutch waters but many more may be built In the near future. OWEZ Is seen as a demonstration and learning project from which lessons should be learnt that should be used to built better (putting less stress on the environment) wind farms In the future. Even though the separate building activities (ship-based site surveys, dropping foundation rocks, pile driving, trenching and construction of above-sea level large steel structures at sea are all rather normal procedure in the North Sea, the fact that this park should be the first of many was seen as a reason for scrutiny. The pile driving in particular was seen as a possible detrimental activity (e.g. Verboom 2005a,b) to sea life (fish, seabirds, marine mammals) in general. This is because the action of the hydro-hammer on the large steel pipes that need to be driven into the seabed might produce underwater sound levels in excess of 200 dB and this would be lethal to vertebrates swimming in the vicinity (within several hundreds of meters). Although pile driving is also used in other at-sea activities, such as offshore oil/gas drilling, the construction of a wind farm with dozens of monopiles is of another order of magnitude than the single piles driven in occasionally for oil/gas platforms.

Although lethal effects of hard underwater noise, such as blasting (including for seismic surveys), or (military) sonar and pile driving are well-known on cetaceans and fish (summaries in: Simmonds *et al*. 2003; Hastings & Popper 2005; ICES 2005; Madsen *et al*. 2006), very little is known about the effects of hard underwater sound on seabirds. In an early review, Turnpenny & Nedwell (1994) state"

"From the limited work on seabirds and seismic surveys (undertaken in Canada), no evidence was found of harm caused by the use of air guns, and even chemical explosives were rarely harmful unless the birds ventured very close to detonation"

In a more recent review, Nedwell *et al*. (2004) even left out the seabirds altogether. In line with this, the guidelines for dealing with detrimental effects of seismic surveys in UK waters (including the North Sea) only consider cetaceans and ignore possible effects on seabirds (JNCC 2004).

The U.S. Department of the Interior (2004) briefly mentioned effects of underwater sound (seismic surveys) briefly In their extensive Environmental Impact Assessment of exploration activities In the Gulf of Mexico:

"Generally, noise produced from activities associated with seismic surveys might impact only those offshore species of birds that spend large quantities of time underwater, either swimming or plunge diving while foraging for food. Offshore birds that may be classified as underwater swimmers include certain waterfowl (some diving ducks) and seabirds (loons and cormorants). Generally, these species are limited to waters of the inner continental shelf. Waterfowl and loons are both seasonal migrants (winter), whereas cormorants are resident species. Plunge diving birds include only certain seabirds (primarily brown pelicans, gannets, and boobies). Gannets are seasonal migrants that may range throughout the Gulf of Mexico. Noise from seismic surveys could adversely affect surface-feeding and diving seabirds near air gun arrays. However, there are no data indicating such impacts exist. Stemp (1985) found no effect of seismic survey activity on the distribution and abundance of seabird populations in arctic Canadian environment. Parsons (in Stemp, 1985) reported that shearwaters with their heads underwater were observed within 30 m of seismic sources (explosives) and did not respond. Because seismic pulses are directed downward and highly attenuated near the surface …, birds feeding on the surface or diving just below it are unlikely to be exposed to sound levels sufficient to cause temporary or permanent hearing impairment. In any case, sound pressure levels would not be sufficient to cause death or life-threatening injury."

Obviously, effects of seismic survey underwater sound cannot directly be compared to effects of pile driving, particularly in shallow waters where sound propagation may be quite different from that in deeper waters generally studied in seismic surveys. Interestingly, however, of the species considered vulnerable that also occur In the Dutch EEZ (seaduck including scoters that are numerous in Dutch nearshore waters), loons (American English for "divers"), cormorants, gannets and shearwaters most are also considered easily disturbed by operating wind farms (Elsam Engineering 2005; Elsam Engineering & Energi E2 2005 in their studies at Horns Reef, Denmark) and shipping traffic Schwemmer *et al*. (2006). Mostly absent from the Gulf of Mexico, but abundantly present in Dutch waters are auks (mainly guillemots and razorbills) and these birds too spend a sizeable amount of time under water and are apparently disturbed by operating wind farms (Elsam Engineering 2005; Elsam Engineering & Energi E2 2005). In summary, although information on seabirds is scanty, diving birds that spend time under water hunting for prey, may be vulnerable to hard underwater sound, such as associated with pile driving.

It was therefore considered useful to study possible effects of pile driving, potentially the most damaging activity during the construction process to seabirds and to concentrate on potentially vulnerable species that might feed in the area. Only birds that venture underwater seemed vulnerable to hard underwater sound, stemming from pile driving. At the construction site, these might include: divers (probably in April/May only), cormorants (spring through autumn), shearwaters (only rarely, during autumn migration) gannet (spring and autumn migration), seaduck (migration periods and winter), and auks (winter). Other birds that may occur in significant numbers at the site include gulls, terns and skuas and any migrating seabirds. However, as these would occur mainly in the air or, when submerged only very briefly so and only very shallow, these birds seems less at risk from underwater sound.

The timing of OWEZ pile driving and seabirds surveys on site

Pile driving was dependent on weather; on the on-shore supply of material and on the skills of the workers onboard the pile driving vessel. Weather was of course only predictable to a certain extent and very low sea states were required. Both the on-shore supply of material and the skill of the crew improved over time as experience was gradually built up. This resulted in a rather irregular spacing of pile driving events, its frequency increasing over time, but with rather large periods with little or no activity due to bad weather spells. The first pile was driven in on 17 April 2006, the last on 28 July 2006 (Table 1). Not all pile driving events were suitable for seabird research as pile driving did not depend on the time of day and could commence both during daylight and darkness. Although radar studies could overcome the problem of conducting observations at night, this possibility was not further pursued (see below) and this made the seabird work dependent on the timing of the pile driving. As the on-site situation needed to be assessed before pile driving started, only events during which pile driving (predictably) started some time around noon were potentially suitable for observations

Assuming that particularly some wintering seabirds would be most susceptible to the loud underwater noise of pile driving, it seemed most important to conduct observations at a time when such birds would still be present in the area of OWEZ at large. This meant that the first few pile driving sessions were deemed most important and that is was expected that mid-summer sessions were unlikely to do much damage. Should pile driving run into autumn, the last sessions would again become more interesting for research.

Date	Start piling	Stop piling	WTG nr.	break
17-04-06	15:00	17:05	13	
30-04-06	20:30	22:55	01	
4-05-06	22:50	0:00	22	***
5-05-06	0:30	0:50	22	***
7-05-06	16:45	17:35	02	
11-05-06	14:45	16:10	03	
14-05-06	20:25	21:50	04	
25-05-06	23:15	0:00	05	***
26-05-06	0:30	3:13	05	***
2-06-06	18:40	19:00	07	***
2-06-06	19:20	20:20	07	***
4-06-06	22:30	23:45	06	
7-06-06	11:15	13:30	08	
9-06-06	7:25	9:00	09	
11-06-06	2:20	4:00	12	
13-06-06	11:35	11:56	10	***
13-06-06	14:50	16:20	10	***
16-06-06	15:20	16:52	11	
18-06-06	4:45	6:05	14	
20-06-06	2:10	3:30	15	
24-06-06	21:34	23:15	16	
27-06-06	22:35	23:15	17	***
28-06-06	0:15	1:00	17	***
29-06-06	12:30	15:30	18	
3-07-06	2:42	3:50	19	
4-07-06	17:17	18:30	20	
6-07-06	17:45	18:55	21	
8-07-06	5:25	6:40	27	
10-07-06	21:00	22:10	28	
12-07-06	4:51	6:10	29	
16-07-06	15:05	16:25	23	
18-07-06	2:45	3:55	25	
19-07-06	7:10	8:05	26	
20-07-06	12:50	13:30	24	
21-07-06	19:30	20:20	30	
22-07-06	20:55	21:30	31	
23-07-06	19:45	20:30	32	
25-07-06	4:00	5:30	33	
26-07-06	10:15	11:45	35	
27-07-06	14:05	15:05	36	
28-07-06	17:55	19:25	34	

Table 1. Dates and times (from, to) of pile driving for OWEZ. Note that technical difficulties caused some pile driving sessions to be interrupted, to be continued and finalised later. These are marked *** in the last column. Dates of pile driving sessions that were used for observations are marked grey.

Methods, personnel and materials

In order to study possible disturbing effects of pile driving on local seabirds, several methods were reviewed before one was chosen. In general, it was considered necessary to make an on-site comparison of seabird density and behaviour before and during pile driving. It was envisaged that pile driving itself would take about two to three hours and that this activity would be preceded by a more lengthy period of bringing the Svanen to the site, anchoring it exactly in position for pile driving and getting ready to start. Although these preliminary activities would also disturb local seabirds, possibly to an extent where no more of these birds would be present at the site (see under "mitigation"), these were not considered potentially lethal to the birds. Rather, moving and anchoring a ship, even an exceptionally large one like the Svanen would not have effects that would be much different from some other offshore activities such as regular shipping traffic, military exercises with ships, sand extractions, maneuvering large objects like tugging offshore drilling platforms, etc. In other words, these activities would probably scare off birds, but not kill them. The research question at hand was whether the underwater noise of pile driving would disturb seabirds significantly; if seabirds would have been scared off the site beforehand by the anchoring maneuvers, the answer to this question would simply be: "no".

Figure 1. The pile driving ship "Svanen" with its superstructure rising over 100 m above sea level.

Two main options seemed open to conduct this study. One way would be to map seabird distribution patterns before and during pile driving in an area around and including the site. This could, in theory be done from three different platforms:

1. ship. Ships are widely used to map seabirds distribution patterns at sea and this platform has also been used to map distributions in and around OWEZ before any building took place (Leopold *et al*. 2004). However, a period of only 2-3 hours of pile driving was considered too short to map an area large enough to collect useful results. Spacing of lines sailed by the research vessels should be sufficiently spaced to prevent disturbing all birds off the site by the activity of this vessel itself, and with only 2-3 hours to go at an average speed of 10 knots (18.5 km/h) this was simply not feasible.

2. aircraft. Using a small high-winged plane is another common technique for mapping seabirds (e.g. Arts & Berrevoets 2005). Although a plane is much faster than a ship, the number of repeated transect lines over the small impact site necessary to collect sufficient data would also disturb sensitive seabirds, before the pile driving would even start. Other than that, there were safety issues to be considered, when flying a plane repeatedly by the tall (circa 100 m above sea level; Figure 1) Svanen.

3. The Svanen itself. From the Svanen, particularly from a high vantage point, a 360° area around the pile driving site could be observed and seabirds mapped using so-called point-transect methodology (Burnham *et al*. 1980). By mapping compass bearing and radial distance to each bird swimming (visibly) around the Svanen, densities could be calculated. Also behaviour could be followed, from before until the onset and beyond of pile driving. This seemed a promising approach at first but it had several drawbacks. First, only a limited area around the pile driving site could be observed and at the expected low seabird densities, it was questionable weather sufficient data could be collected. Second, without the possibility to move away from the pile driving site, any effects at larger distances would be impossible to see. Third, there was the safety issue of exposing observers to the noise of the pile driving, at a position directly above the hydro-hammer. In the end, it was decided that the risks, both of failure and in terms of safety, were too great to further pursue this line of research.

The second option for conducting research was to make the observation from a second ship that could move independently from the Svanen. We considered, that the most notable reaction of seabirds to the onset of pile driving would be to leave the area quickly, that is taking to the air abruptly and flying off. As seabirds can only take off from the water into the wind, these flights would be most easily spotted from a position at the windward site of the Svanen. Optimal distance to the Svanen could not be known beforehand, but this could be varied and by using binoculars, birds the size of guillemots, seaduck or divers could be seen flying off at distances of several kilometers. Hence, birds leaving an area of at least 10 km^2 would probably be noted from a vessel anchored or drifting at some distance from the Svanen. By using a fast boat, the Svanen could be reached rather quickly from our research institutes at Texel, making this a rather flexible approach. Moreover, the transit from Texel to the pile driving site could be used to glean information of the general presence of the critical seabird species in the general area, also at distances well beyond the believed impact zone of pile driving. We therefore rented a small (about 7 m long) but fast (16 knots) vessel, named "Het SOP" that was otherwise used for offshore angling trips (http://www.hetsop.nl/; Figure 2). This vessel was on stand-by during the entire pile driving period and could be used at short notice, i.e. within 12 hours of departure. An impression of the transit route towards a suitable anchoring position relative to the Svanen is given in Figure 3.

Figure 2. The two principal observers at work on the hired research vessel "Het Sop", 17-04-2006. Photo: Rutgert Oosterhuis.

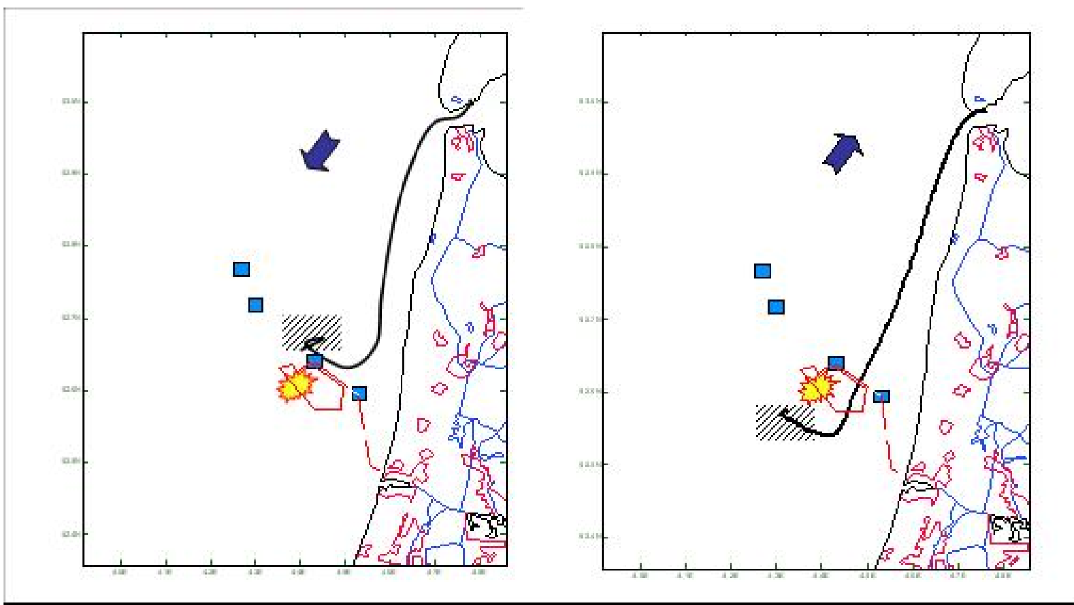


Figure 3. Possible transits (black line) to an anchoring position (hatched area) near the pile driving site (star), at different wind directions, indicated by blue arrow. Offshore gas production platforms in the area are marked (blue blocks) as is a gas pipeline connecting the two nearshore platforms to the mainland (red line); these structures had to be avoided for safety (collision, anchoring) and operational (blocking the view) reasons.

At each observed pile driving session, seabirds were studied by two observers working together, from several hours before the onset of pile driving, until pile driving was at least two hours under way. All birds that could be seen on the water or in the air around the Svanen were noted as such (swimming or flying, with further behavioural notes whenever relevant) in 5-minute periods. In particular, reactions at the onset of pile driving were noted, if noticeable and before- and after onset of pile driving comparisons of seabird numbers and behaviours were made.

Three complete bird sessions were carried out, at 17 April, 7 June and 13 June. Several attempts were undertaken to conduct observations in May as well, but bad weather, poor predictability of timing of pile driving and piles being driven in at night frustrated these. One more trip was started but aborted half way to the anchoring site when it became apparent that the Svanen would start pile driving much later than originally planned. After the two June sessions, further (summer) work was postponed until the last piles, should these be driven in by the end of August or later as only at that point in time would the first guillemots return to the area (wintering divers and seaduck would arrive even later). As the last pile was driven in at 28 July, no more sessions were carried out.

Observers

The principal observers were Kees Camphuysen and Mardik Leopold, the authors of this report. They conducted the observations together on the first observation day. During the second observation day, observations were led by Kees Camphuysen with assistance of the skipper of Het Sop, Rutgert Oosterhuis. During the final observation days, observations were led by Mardik Leopold, aided by Rutgert Oosterhuis.

Seabird migration in spring 2006: an early or late spring?

As it was critically important to know if vulnerable birds were likely to be present at all, concurrent data on seabird migration were reviewed. The passage of seabirds is followed by seawatchers, at several observation posts along the Dutch coast. We examined the (uncorrected) spring migration data on divers, common scoters, little gull and auks (guillemot and razorbill combined) for the seawatching post "Egmond aan Zee" and for two posts a little further north (Hondsbossche Zeewering and Huisduinen) and one to the south (Scheveningen). These data are available at www.trektellen.nl and represent total numbers seen per day, regardless of numbers of hours on watch. Although these are crude data, seasonal patterns should be apparent.

RESULTS

Spring migration in 2006 of divers and auks was mostly over by the time of the first pile driving session (17 April). The seawatching data for the divers (Figure 4) clearly show that their presence was rapidly trailing off by April and that in May and June these birds were only rarely seen.

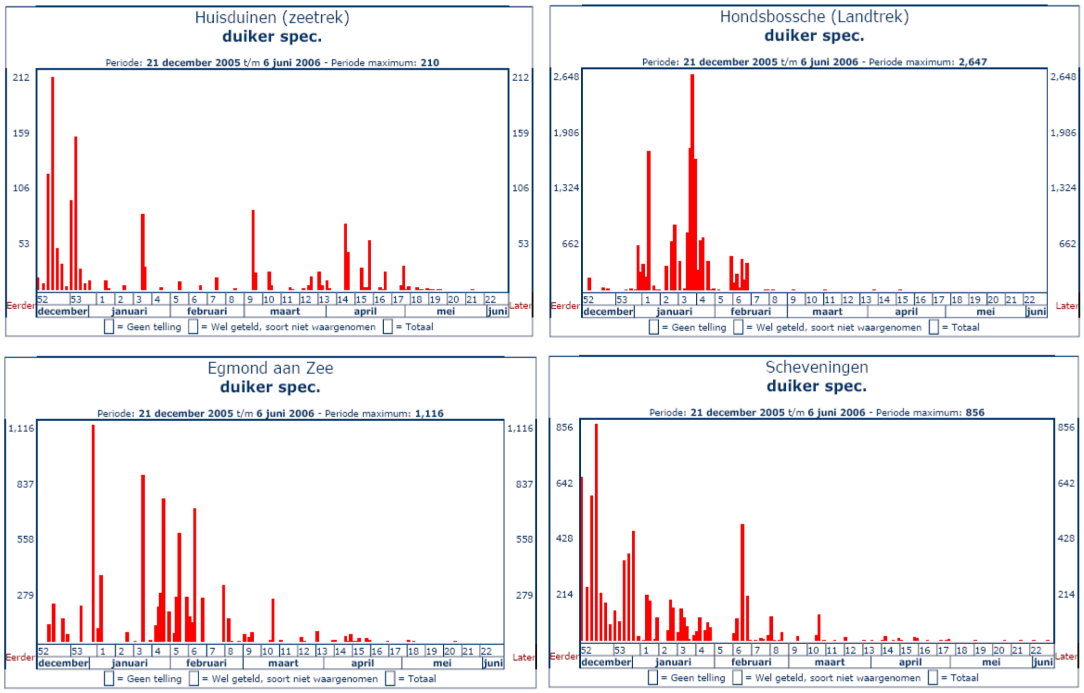


Figure 4. Seasonal pattern of spring migration of red- and black-throated divers (species combined) off the Dutch mainland coast in 2006, as noted by seawatchers. Source: www.trektellen.nl.

Likewise, the auks had largely left the area by the time pile driving commenced (Figure 5), but common scoters were seen flying by throughout May and June, although in lower numbers as compared to March and April (Figure 6). There were, however, no records of large groups of staging common scoters on the water off Egmond this spring (Steve Geelhoed, seawatching post Egmond aan Zee, *pers. comm*.). Staging scoters were only seen in substantial numbers (several thousands) off Huisduinen (*pers. obs*.). Hence, although scoters kept on passing along the Dutch mainland coast throughout the construction phase, this, and only this was exactly what these birds were doing at the time: flying by. Disturbance of such birds would have been light, making them veer temporarily off course, but continuing on their northward migration. In the air, these birds would not be subject to hard underwater sounds.

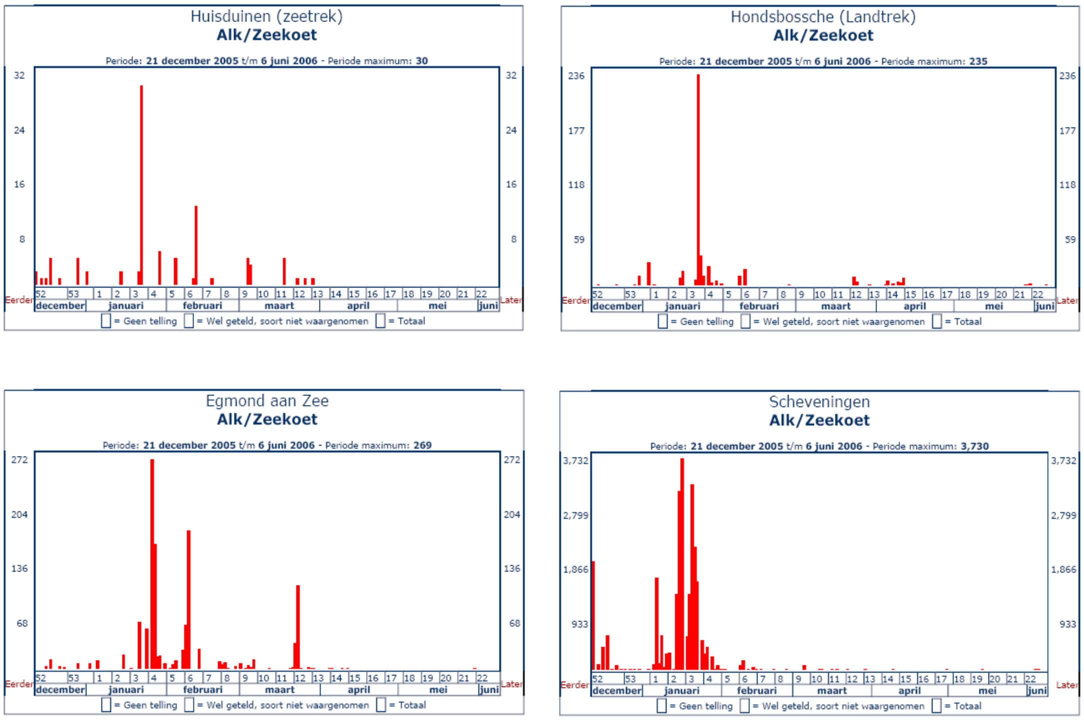


Figure 5. Seasonal pattern of spring migration of auks (guillemots and razorbills combined) off the Dutch mainland coast in 2006, as noted by seawatchers. Source: www.trektellen.nl.

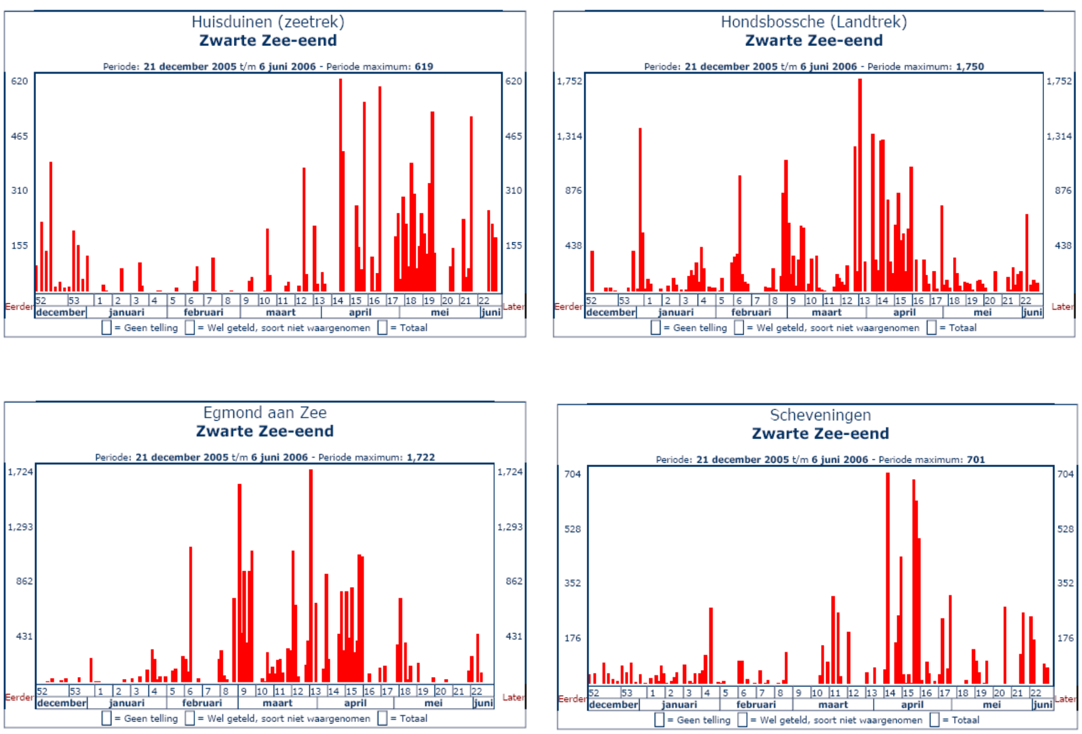


Figure 6. Seasonal pattern of spring migration of common scoters off the Dutch mainland coast in 2006, as noted by seawatchers. Source: www.trektellen.nl.

These seawatching results suggested that there was very little scope for significant effects of pile driving on divers, auks and seaduck, as these birds were either no longer present, or did not stay on the water in the vicinity. It should be noted that the early departure could not be attributed to the presence of the Svanen, as seawatching data tap in to widely spread-out populations of seabirds. Birds seen for instance passing Egmond aan Zee, will have started their migration further south, often tens to hundreds of kilometers. Most will have started their flight from locations (far) beyond possible influence of the Svanen's activities.

Very few (two) divers were seen during our at sea survey of 17 April, and none in June (Figures 7-9). No auks were seen on any of the observation days. Most scoters were seen in the morning of 17 April (Figure 8): a total of 144 birds, in several groups, all flying north to the landward side of OWEZ. The distribution of sighting over the day does not allow for statistical testing for a difference in presence before and during pile driving. Even though all scoters were seen before pile driving started, this may simply be related to time of day as seaduck passage along the Dutch coast normally peaks in the morning hours. None were seen during the pile driving spells, but time periods of similar length without any ducks being seen also occurred before pile driving. These results are therefore inconclusive. All passing scoters were seen at distances of >> 1 km from the Svanen. We did not note any reaction (sudden changes in flying directions) for the two divers or the groups of seaduck: if these reacted at all to the presence of the Svanen, this was not discernable from our position.

The only seabirds that were present at the site, at close range to the Svanen, were gulls (mostly lesser black-backed gulls), terns, cormorants and gannets, in order of decreasing numbers. As the gulls were by far the most numerous group, we restricted our statistical analyses to these birds as the other species were seen in lower numbers, which did not warrant such analyses. Both gulls and terns were found not to respond negatively to operating wind turbines on Horns Reef; the gulls might even have been attractive to the (associated shipping of) that wind farm (Elsam Engineering 2005; Elsam Engineering & Energi E2 2005). The Horns Reef data for gannet suggested that these birds avoided the park but this was based on very little data. Likewise, we only noted very few, distant gannets. The Horns Reef studies did not mention cormorants. Around OWEZ, cormorants did occur (some even roosting on previously placed monopiles) but in very low numbers only.

Figures 7-9 (overleaf). Patterns of seabird presence around the Svanen before and during pile driving on the three observations days in this study: 17 April and 7 and 13 June 2006, respectively. The surroundings of the Svanen were constantly surveyed for birds (swimming or flying) and numbers were summed in 5-minute periods. Below the X-axis different activities are indicated: blank: no visible activity other than the Svanen being at the site (not that the sound of the pinger or any other sounds originating from the Svanen are ignored); yellow blocks indicate associated shipping (arriving/departing vessels ferrying personnel, survey or guard ships nearby, nearby dropping of rocks); orange blocks indicate helicopter traffic around the Svanen and red blocks indicate pile driving. Numbers of birds seen per 5-minute period are separated into different taxonomical groups, indicated by different colors.

In **Figure 9**, the pink "species" blocks indicate numbers of mackerel caught per 5 minutes of angling. Angling, using artificial "feather lures" was done using two fishing rods during the whole observation day; numbers of fish caught were noted per 5-minute period, like the birds were.

Figure 7. Birds (No/5 mins) seen in the vicinity of the Svanen, 17 April 2006

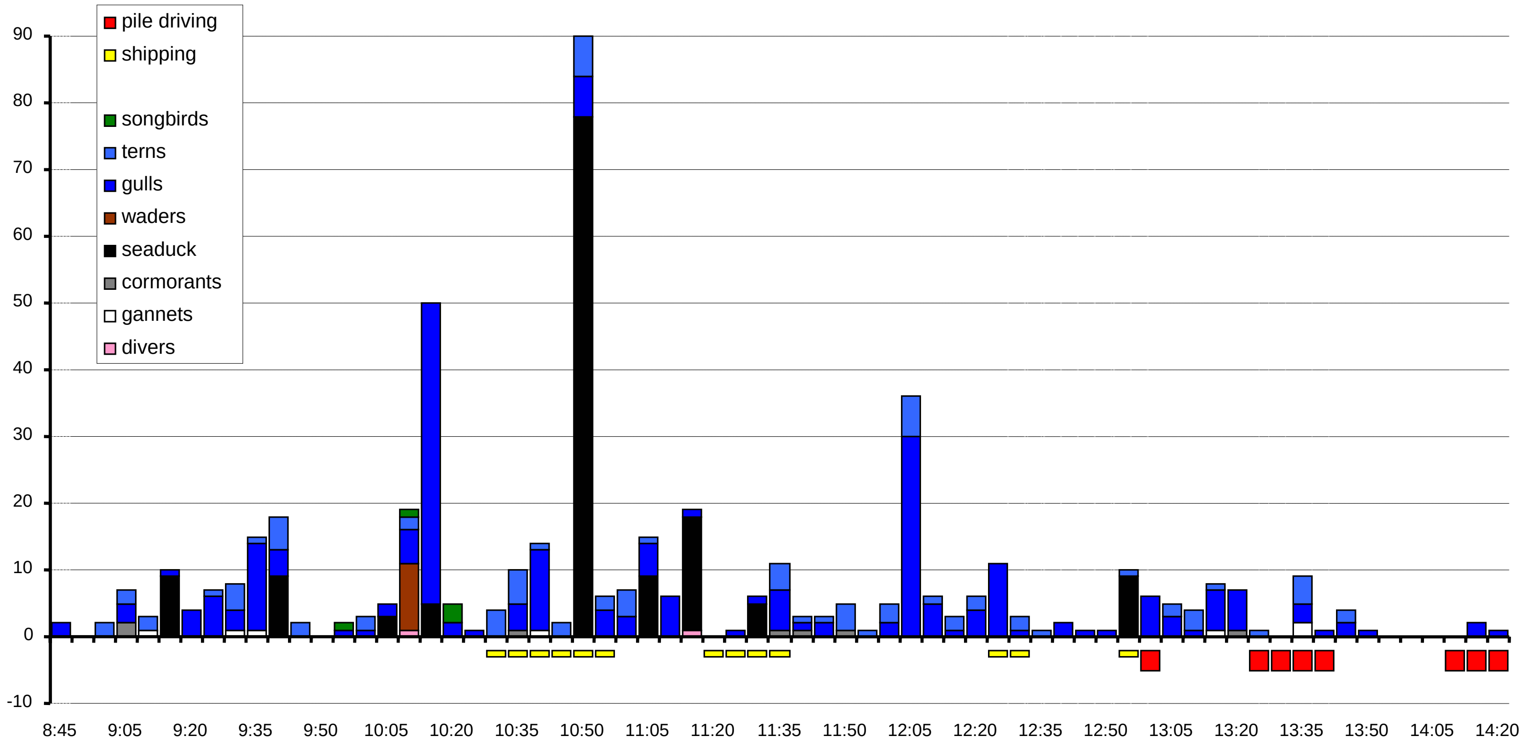


Figure 8. Birds (No/5 mins) seen in the vicinity of the Svanen, 7 June 2006

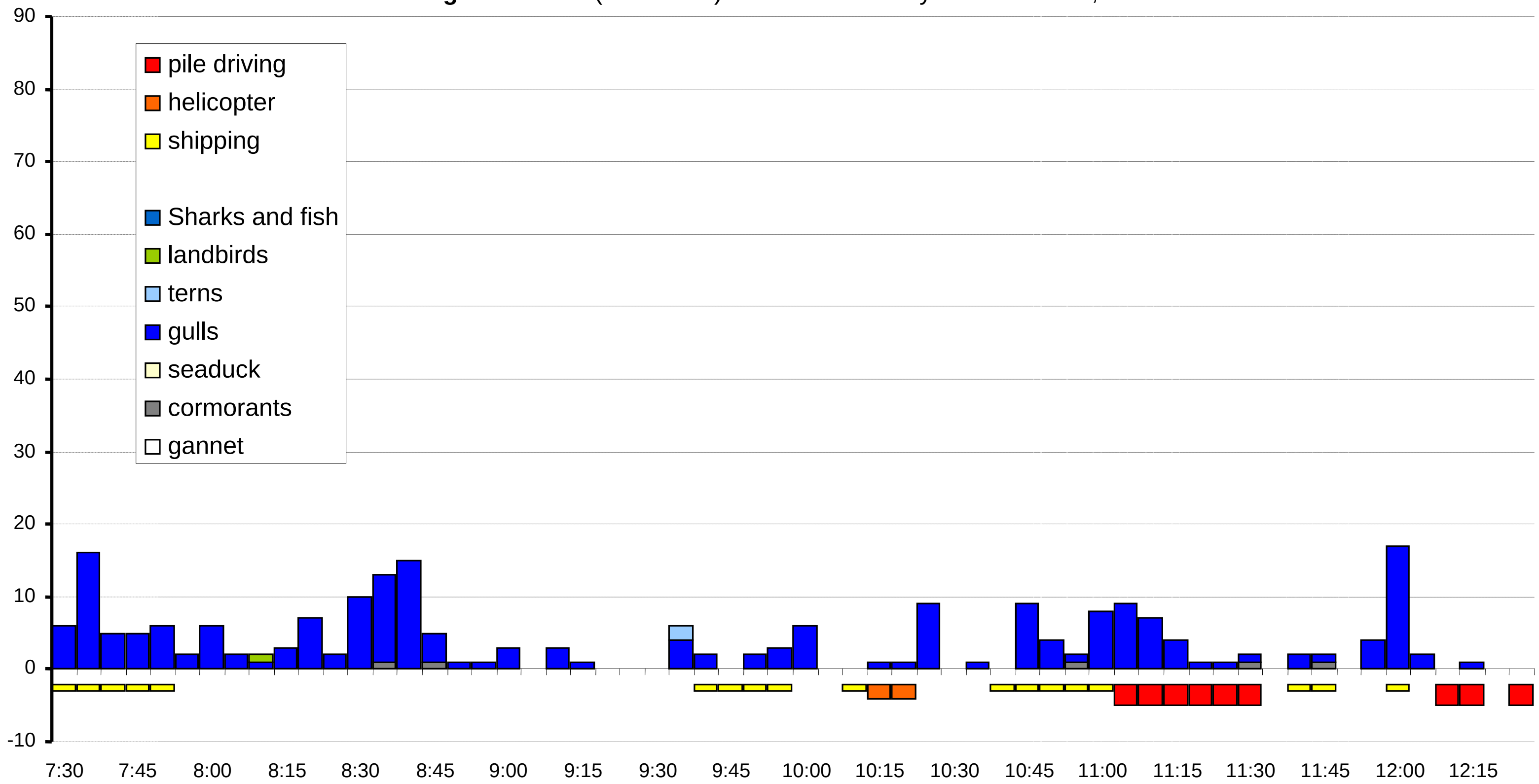
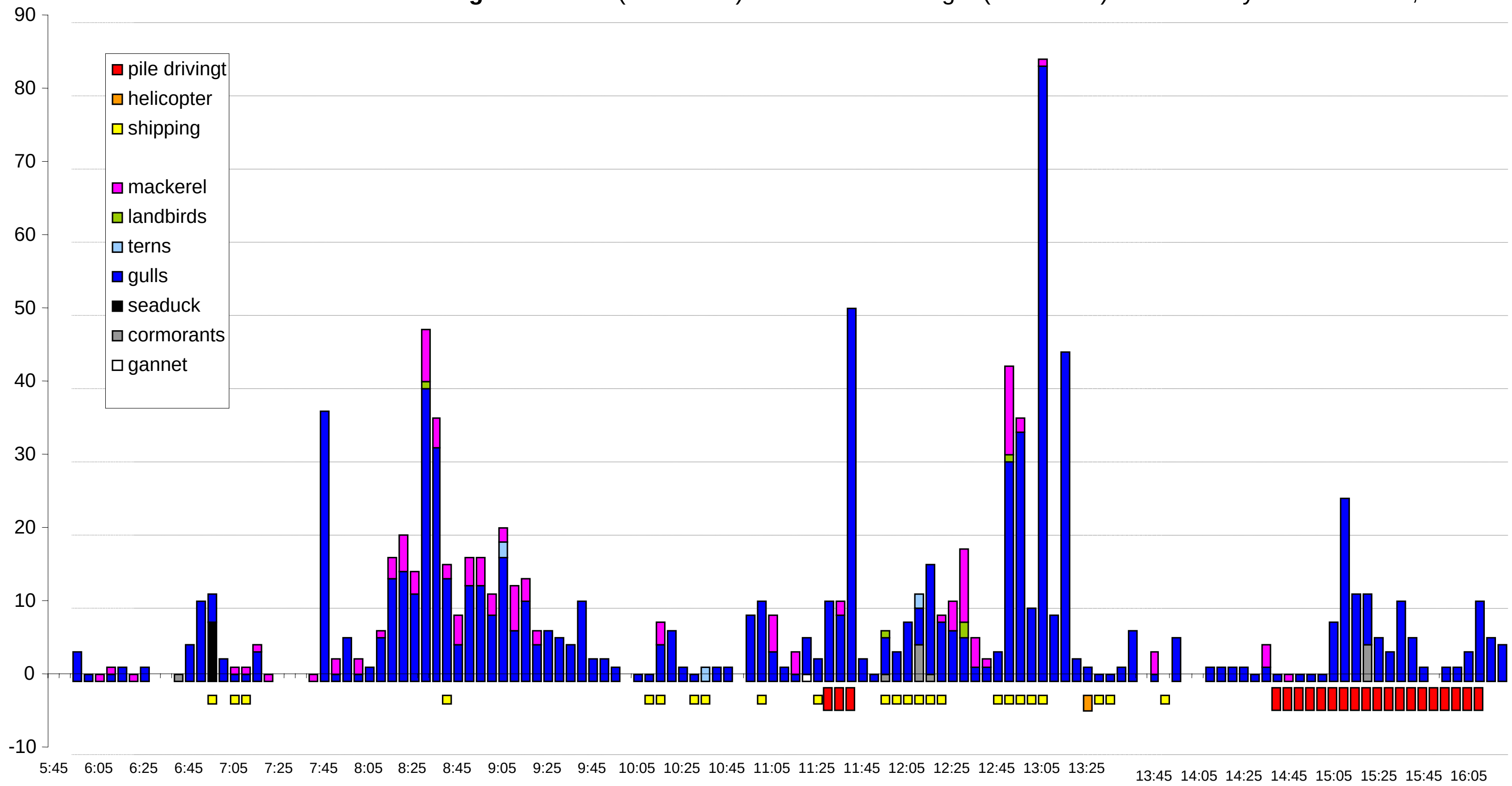


Figure 9. Birds (No/5 mins) seen and fish caught (No/5 mins) in the vicinity of the Svanen, 13 June 2006



The data depicted in Figures 7-9 suggest that bird numbers were relatively high in the morning hours, trailing off later during the day. Only at 7 June numbers of birds were low during the entire day, without this pattern being apparent. Because of this presumed pattern, results have to be regarded cautiously, as pile driving was always observed around noon, i.e. when bird presence might have been trailing off naturally. Statistical tests (G-tests) were used to compare bird presence during these different activities. Considering the gulls, we tested for differences in the numbers of 5 minute periods with and without gulls and the total numbers of gulls per activity category (expected versus observed on the basis of numbers of 5-minute periods in each category). The results of these analyses are given in Tables 2 and 3. No significant results were found on the basis of numbers of records: these were distributed as expected, regardless of activity at or around the Svanen. Significant, but contradicting results were found when the total numbers of gulls are considered. On the first observation day numbers were higher than expected at maximum noise levels (pile driving) while on the last observation day the opposite was found: now numbers were relatively high when there was no shipping or pile driving. On the second day, results did not differ from the expected.

Date		Calm	Shipping/ Helicopter	Pile Driving	Total	G_{adj}	P
17 April	Observed	79	28	10	117	1.20	n.s.
	Expected	80.3	22.7	14.0	117		
07 June	Observed	64	43	16	123	0.22	n.s
	Expected	63.6	41.0	18.5	123		
13 June	Observed	65	23	21	109	0.31	n.s
	Expected	69.0	21.3	18.7	109		

Table 2. Statistics of the numbers of periods with gulls seen (numbers of records) for the three observation days in 2006. The data were grouped into three categories: no noise (“calm”), slight noise (associated shipping or helicopter) and pile driving.

Date		Calm	Shipping/ Helicopter	Pile Driving	Total	G adj	P
17 April	Observed	176	46	13	235	6.22	**P<0.05**.
	Expected	161.3	45.6	28.1	235		
07 June	Observed	98	89	26	213	3.31	n.s
	Expected	110.1	71.0	32.0	213		
13 June	Observed	473	252	169	894	23.09	**P<0.01**
	Expected	565.7	174.6	153.7	894		

Table 3. Statistics of the numbers of gulls seen (numbers of individuals) for the three observation days in 2006.

In contrast, the numbers of mackerel caught differed substantially between pile driving periods and non-pile driving periods (Table 4 and Figure 9). Mackerel were caught throughout the lengthy period before pile driving, regardless of associated shipping. When pile driving started, not a single mackerel was caught and this remained so during the whole first pile driving session and for another half hour afterwards. The first pile driving sessions was only brief and pile driving was interrupted because of technical problems and lunch (at the Svanen). This intermezzo lasted for three hours, during which mackerel resumed taking the bait. As soon as the final pile driving session started, mackerel refrained from taking the bait and not a single fish was caught while pile driving lasted during the next one and a half hours (Figure 9). The G-test cannot deal with such data as no positive records were obtained in the category “pile driving” (division by zero). However, the results may be regarded significant, also considering the two periods without any catches during two separated pile driving sessions, with a recovery period in between.

Date		Calm	Shipping/ Helicopter	Pile Driving	Total	G adj	P
13 June: **events**	Observed	32	8	0	40	**Cannot test**	***.**
	Expected	25.3	7.8	6.9	40		
13 June: **total # caught**	Observed	97	23	0		**Cannot test**	***.**
	Expected	75.9	23.4	20.6			

Table 4. Statistics of the numbers of 5-minute periods with mackerel catches (top) and the total numbers of mackerel caught, at constant fishing effort throughout periods without any additional noise, with additional shipping noise and with pile driving, 13 June 2006.

Discussion and conclusion

The construction work at sea took place in spring and summer of 2006. In terms of spring migration, the year 2006 had an "early spring" in the sense that many birds had left the area when construction commenced. This was shown by seawatching results from several sites along the Dutch mainland coast. The majority of birds that were expected to be sensitive to loud noises that come with construction (particularly pile driving), such as divers, seaduck and auks, had largely left the area at the start of the construction season. Only birds that were expected to be rather insensitive to underwater sound, mainly gulls, remained.

The birds species considered sensitive are all nearshore species, that winter in coastal waters. Although the construction site was just within range of these birds, the highest (winter) densities are always found closer inshore. Densities of divers, seaduck and auks would have been lower than those further Inshore, also in a late spring, at the construction site. Low densities were thus to be expected at the site, in any year, in late spring and autumn.

Constructing an offshore wind farm is a complex building process that would have disturbed any remaining sensitive birds. The presence of a fleet of ships, including the very large Svanen, and the use of pingers before actual pile driving, would probably have driven off any remaining sensitive birds long before pile driving bouts. Therefore, it comes as no surprise that such birds were never present at the site during pile driving. Birds densities would have been very low, if not zero from the start, the additional effects of the pinger and of pile driving therefore remain unknown.

The tentative conclusion of our observations must be that no birds were disturbed, and certainly not physically hurt, by the pile driving. Birds simply were not present near the site, firstly because the area is at the fringe of the normal range of sensitive nearshore species, secondly because most of these birds had already left the general area in this particular year and thirdly, because any remaining, offshore, sensitive birds would have been scared off be the pre-pile driving activities.

This leaves the possibility that some birds were in fact scared off, and were displaced to such distances from the construction site that the observers missed this displacement. Observations from coastal sites, where usually much higher bird numbers are seen than offshore, largely preclude this possibility. Seawatching observations clearly indicated that most sensitive birds had left Dutch mainland coastal waters when construction commenced.

Given the combined effects of construction in a low bird densities area, In a year with early bird departures and added to this "favourable" situation the fact that the Svanen with associated activities was already a very disturbing entity, it is highly unlikely that any sensitive bird remained close enough to the potentially detrimental pile driving activity to get physically hurt. Any bird that is vulnerable to loud underwater noise would therefore, in all likelihood, have been scared off to a safe distance, before it could be hit by the pile driving noise. Finally, pile driving did not suddenly happen at full power, and in the unlikely event that vulnerable birds would have remained in the vicinity of the Svanen right until pile driving started, they would still have had the chance to escape lethal noise levels. There is thus no reason to believe that even a single bird suffered injury, or even major discomfort, from the pile driving sessions.

The only birds seen to be present around the Svanen at the times of (observed) pile driving were gulls (mainly lesser black-backed and herring gulls) and terns (mainly sandwich and common terns). These birds were mainly seen flying by, i.e. in the air where they were not subjected to underwater noise. A very small negative effect was found on gulls on 17 April, with slightly fewer than expected birds present during pile driving, but this was possible a time-of-day effect. In contrast, a much larger positive effect was found on 13 June, with disproportionably large numbers of gulls being present during pile driving and even more during periods with associated shipping. None of this additional shipping

involved fishing vessels and a reason for this gull presence, other than chance, cannot be given. There was thus little, if any effect of pile driving on the presence of gulls.
In contrast there was a marked effect on the behaviour, or presence of mackerel during pile driving, strongly suggesting that there could be, as expected, significant effects of the underwater noise on local (underwater) seabirds. The fact that seabirds were not affected was due to a combination of factors, most importantly the general absence of birds that spend a lot of time diving under water, and the added scaring-off effects that the operation would have had, merely by it taking place.

In future situations, significant effects of pile driving are not to be expected on divers, grebes or seaduck. Future wind farms in Dutch waters will be situated even further offshore and it seems highly unlikely that significant numbers of these birds will ever be found at construction sites in offshore Dutch waters, particularly when the work is carried out in summer. Timing of work (summer) will also save the auks, that winter offshore in large numbers, from being impacted. However, as auks are generally less easily disturbed than divers or seaduck, more care is needed considering this group. Should future pile driving be planned in spring, possible effects on auks should be taken into account.

Mitigation

Mitigation of adverse effects of pile driving is possible and may be achieved by any of six different means, or any combination of these:

1. conducting the activity in an area that holds no or very few sensitive seabirds.

2. conducting the activity in the season when least sensitive birds reside in the area.

3. applying measures to muffle the sound, for instance by using bubble curtains around the monopile. Streams of bubbles of air, applied from the base of the monopile and rising up, mask the sound of the pile driving to some extend, making the activity somewhat less lethal (McIwem 2006).

4. ramping up sound levels, starting pile driving sessions at less than full power. The first blows are probably most devastating to unsuspecting wildlife in the vicinity. Therefore, if such wildlife can be scared off to a safe distance by starting up pile driving sessions using less than full blowing power, lethal effects may be avoided.

5. using scaring devises to move susceptible wildlife off, before the onset of pile driving.

6. interrupting, or not even starting, pile driving if sensitive seabirds or other wildlife were present in the vicinity. This requires the presence of a dedicated observer, with the authority to have the operation stopped or postponed.

Because OWEZ is situated rather far offshore, just outside the nearshore waters where important concentrations of sensitive divers and seaduck overwinter (Leopold *et al*. 2004 and *in prep*.; Lindeboom *et al*. 2005) the first option for mitigation was followed to some extent, as a result as the licensing process for Dutch offshore wind farms. However, in the offshore waters of the Southern Bight of the North Sea, relatively high densities of auks may appear, and these birds should also be considered as vulnerable to underwater sound.

However, the construction phase that was most noisy (the pile driving) mainly took place in summer, when divers, ducks and auks would all be rare or absent in the general area. The main concern was that the onset of this construction phase was still rather early (April) when large numbers of these birds might still be present or passing through the area on their spring migration. As timing of migration might be related to factors such as weather or food availability, year to year variation in the timing of migration could make the difference between high or low presence of vulnerable seabirds in April. This was left to chance by the operators, but as it turned out, the most critical birds had left the area just before pile driving commenced (see below)

Bubble curtains were not deployed during pile driving for OWEZ, but other mitigation measures were taken, both on purpose and by chance. In any case, the presence of the large construction ship at the site, together with several support vessels and sometimes with foundation rocks being sank at another monopile site nearby at the time of pile driving, all contributed to making the site unattractive to seabirds that are sensitive to disturbance and loud noises. All pile driving sessions started at less than full power and the pile would sink into the soil on its own weight first. This was standard operation for practical reasons, but this *modus operandi* would give vulnerable wildlife the chance to move away from the site to distances were the sound levels would no longer be lethal when the full power of the hammer was applied later on. Finally, a dedicated "pinger" was used that generated loud underwater noise, meant to scare off any cetaceans or seals in the vicinity of the construction site. This devise would, in all likelihood, have had a similar effect on sensitive seabirds, if present. It was always put into operation 3-4 hours before pile driving started. There were thus many factors contributing to a situation in which very few, if any vulnerable seabirds would be within lethal distance of the pile driving ship, the "Svanen" (Figure 1), when blows were delivered at full power. There was, however, no dedicated observer present at the Svanen during OWEZ pile driving to monitor any remaining effects.

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Appendix: mammal and bird names mentioned in this report

English	Dutch	scientific name
cetaceans	walvisachtigen	Cetacea
loons (USA)	zeeduikers	Gaviidae
divers	zeeduikers	Gaviidae
shearwaters	pijlstormvogels	Procellariidae
pelicans	pelikanen	Pelecanidae
boobies	jan van genten	Sulidae
scoters	zee-eenden	Anatidae
seaduck	zee-eenden	Anatidae
skuas	jagers	Stercorariidae
gulls	meeuwen	Laridae
terns	sterns	Laridae
auks	alkachtigen	Alcidae
gannet	jan van gent	Morus bassanus
cormorant	aalscholveri	Phalacrocorax carbo
common scoter	zwarte zee-eend	Melanitta nigra
lesser black-backed gull	kleine mantelmeeuw	Larus graellsii
guillemot	zeekoet	Uria aalge
razorbill	alk	Alca torda

Justification

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has been produced with great care. The scientific quality has been peer-reviewed and assessed by or on behalf of the Scientific Board of Wageningen IMARES.

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Senior scientist

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