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Changes in fish communities on a small spatial scale, an effect of increased habitat complexity by an offshore wind farm

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ABSTRACT

The number of offshore wind farms (OWF) is increasing to meet the demands for renewable energy. The piles and hard substrate surrounding these piles creates new habitat for species with preference to hard substrates. We studied the impact of this hard substrate on the fish community in a Dutch OWF in the sandy southern North Sea, which had been in operation for five years. Multi-mesh gillnets were placed near the OWF structures on the hard substrate protection revetments and on the sandy bottom in the middle of the farm. The catches indicated attraction of cod, pouting, bullrout and edible and velvet crab, while attraction to the sandy habitat was shown for flatfish and whiting. Further, two species previously not caught in this area, goldsinny wrasse and grey trigger fish, were caught on the hard substrate. In addition a Dual-Frequency Identification Sonar (DIDSON) was used to record transects through the farm to observe individual fish in the water column throughout the farm and very near the OWF structures. High abundances of fish near the structure were observed during some days, while during other days equal distribution of fish in the area was observed. The area around the structures is thus only used temporarily for shelter or feeding. The DIDSON also allowed looking at the aggregation level of the fish. Seasonally the aggregation level differed most likely due to different species occurring in the area. In April, most fish were aggregated in schools, while in summer most observations were individual fish or loose aggregations. The wind farm structures had limited effect on the aggregation level compared to season or weather conditions.

1. Introduction

The number of offshore wind farms (OWFs) is increasing and new farms are planned and expected in the near future to meet the demands for renewable energy (Arapogianni et al., 2013; Lindeboom et al., 2015). The construction of the structures of OWFs in the marine environment has raised concerns about their impact on this environment (Petersen and Malm, 2006; Punt et al., 2009; Bergström et al., 2013, 2014; Bailey et al., 2014; Bergström et al., 2014). The anticipated impact on the environment can be differentiated in two phases: the construction and the operational phase of the OWF. The expected impacts of the construction phase are likely to be more numerous and intense, but these impacts are of a relatively shorter duration and therefore these are considered to be minor (Vaissière et al., 2014). The construction phase impacts are amongst others underwater noise, and vibration of dredging and pile-driving (Bolle et al., 2012, 2016), changes in turbidity, and changes in the amount of resuspended sediment (Bailey et al., 2014; Bergström et al., 2014). In contrast, the impacts of the operational phase are permanent for the life-time of the OWF. The impacts of the operational phase are amongst others underwater noise (Wahlberg and Westerberg, 2005), electro-magnetic fields (Gill, 2005; Petersen and Malm, 2006; Öhman et al., 2007), alterations of the local hydrological (Broström, 2008) and light conditions, and the introduction of new hard substrate: the monopile and the scour-protecting revetments (Wilson and Elliott, 2009).

The hard substrate of the monopile and revetments increases structural heterogeneity in the often sand dominated area and provides a substrate for fouling organisms. The hard substrates form artificial reefs and like natural reefs, these provide shelter for predation or shelter for prevailing currents for macrobenthic and fish species (Langhamer, 2012; Reubens et al., 2014). The fouling organisms and those using the reef alter the local food web (Lindeboom et al., 2011; Krone et al., 2013b; De Mesel et al., 2015; Vandendriessche et al., 2015), as they form a new food source

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previously not found in the open sea. This new food source attracts fish species, thereby forming concentrations of fish (Reubens et al., 2011b, 2013a). In turn, these fish concentrations are expected to lead to an attraction of predatory fish species, marine mammals or birds. However, this expected attraction of fish and other organisms only occurs when the prevailing noise levels and electromagnetic fields are below levels that would discourage or scare them away.

Underwater noise and electromagnetic fields produced by the OWF form a potential risk for fish and other species occurring in the area. The underwater noise might deter individuals, especially incidental sounds like those of adjusting the rotor blades, while electromagnetic fields may distort the orientation capabilities of especially migratory species (Öhman et al., 2007). In addition, the OWF structures can act as stepping stones for non-indigenous species with preference for hard substrate (Degraer et al., 2013). Risks such as these might provide environmental problems which are highly undesirable. To assist in minimizing environmental risks of OWF's, detailed understanding of the potential effects of OWFs on the distribution, behaviour, and ecology of fish species is prerequisite for meaningful predictions. Hence, monitoring and evaluation programs were developed for a number of OWFs constructed in the past decade (e.g. Lindeboom et al., 2011; Bergström et al., 2013; Degraer et al., 2013; Lindeboom et al., 2015; Stenberg et al., 2015).

As part of one of these monitoring and evaluation programs, we studied the local fish community of the first offshore wind farm in the Netherlands (offshore wind farm Egmond aan Zee, OWEZ). This farm was built in 2006 and became fully operational at the beginning of 2007 (Lindeboom et al., 2011). The farm and a surrounding safety zone were closed for all shipping activities including fishing. In the fifth year that the OWF was operational, we used multi-mesh gillnets to sample the benthopelagic fish species on the scour-protection revetments and on the sandy sediment in the centre of the wind farm. We hypothesised to find higher catch rates of, mainly demersal, fish in the vicinity of hard substrate compared to sandy substrate in the open water, in line with the artificial reef effect. Furthermore, we expected to catch fish species preferring the hard substrate otherwise rare or absent on sand. Additionally to the gillnet, we used a Dual-Frequency Identification Sonar (DIDSON) (Moursund et al., 2003) to monitor transects through the wind farm closely encircling the monopiles observing, mainly pelagic, fish in the water column. We expected higher concentrations of these pelagic species near the monopiles. The DIDSON also enabled us to observe schooling behaviour of fish in the water column, e.g. aggregation level: single fish or schools. We expected a change in behaviour near the monopiles, loosening the schooling behaviour as the structures form shelter.

2. Methods

2.1. Study area

This study area was the Dutch Offshore Wind farm Egmond aan Zee (OWEZ). OWEZ is situated on soft-bottom sediments in the North Sea between 10 and 18 km off the Dutch coast in water depths between 17 and 21 m. It consists of 36 Vestas V90 wind turbines, with a total installed capacity of 108 MW, placed on straight steel towers with a diameter of 4.6 m. The wind farm consists of four rows of turbines at a distance of approximately 1 km with a minimum distance of 650 m between the turbines. The total surface area of the wind farm is approximately 40 km^2. The foundation of each turbine consists of a steel monopile pile driven into the sandy sea floor. Scour-protecting revetments were installed around each pile. Each revetment consists of a filter layer of small sized rock and a top layer of heavier rocks, with a diameter of approximately 25 m. The farm and a surrounding safety zone of 500 m are closed to all shipping activities with the exception of vessels for maintenance or research. For safety purposes all fishing is prohibited in the wind farm and the safety zone, however there are plans to open the OWF area for some types of fishing activities in the near future.

2.2. Gillnet

Multi-mesh gillnets with a height of 3.7 m were used to catch the full length range of species expected to occur in the vicinity of the monopiles. The nets were constructed with six different mesh sizes (65, 55, 48.5, 40, 34 and 12 mm half mesh), each mesh size forming a single panel with a width of 6.7 m. A single net was about 80 m in length and consisted of 12 panels, such that each mesh size occurred twice in a single net. The netting material of the panels differed; the 65 and 55 mm were constructed of multi-monofilament, the 12 mm of nylon and the other three mesh sizes of single-monofilament. Eight multi-mesh gillnets were used with randomly ordered panels.

Each sampling event, seven of the eight nets were placed. Four nets were place near a monopile and three were placed on the sandy habitat in the middle of the farm (Fig. 1). The position were the same throughout the whole study period, as due to safety protocols these were the only positions we got permission to fish. All the nets were set in a straight line along with the current, taking account of the dominant current. Setting the nets near the monopiles was done by placing the first anchor outside the scour-protection revetment, then setting the net as close as possible to the monopile, 5–10 m away (measured by a NIKON 550 laser rangefinder), and ending with the second anchor outside the scour-protection revetment again. This way, at maximum only the middle panels of the gillnet were located on the hard substrate of the scour-protection revetment. The outer panels were on the sand close to the hard substrate or on the transition from sand to hard substrate. The nets were left in position for about 24 h. After hauling, per panel all fish and crab were identified to the lowest possible taxonomic level, then counted and total length measured rounded down to the nearest cm.

The gillnets were set in 2011, four times in spring (9, 11, 15 and 18 April), five times in mid-summer (8, 16, 27 June and 11 and 12 July) and four times end of summer (25, 27, 29 September and 1 October). Setting of the nets was limited by the weather conditions, and the fifth placement in mid-summer was done because a part of the nets set on 16 July became entangled due to strong currents.

2.3. DIDSON

A high resolution Dual-Frequency Identification Sonar (DIDSON) uses acoustic lens technology which forms acoustic images that allows observing fish (behaviour) in turbid water (www.soundmetrics.com). Here, the DIDSON was operated from a small boat to allow for a close, but safe approach to the monopiles. The DIDSON was used in the low frequency mode (1.1 MHz, 7–9 frames per second) which is most appropriate considering the average depth of the wind farm of approximately 17–20 m. The orientation of the DIDSON was perpendicular to the seabed floor, as this produces an image parallel to the sea floor covering the whole water column from surface to bottom (Han and Uye, 2009).

The DIDSON field trips were planned to overlap the three periods of the field work with gillnets. The trips were planned on two days in each of the three periods (spring: 14 and 18 April; mid-summer 5 July; late-summer: 24 and 30 September). Unfortunately, the second day in mid-summer failed due to quickly changing weather conditions. Each day, continuous recordings with