BENTHIC COMMUNITIES ON HARD SUBSTRATES WITHIN THE FIRST DUTCH OFFSHORE WIND FARM (OWEZ)

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Five years after the commissioning of the offshore wind farm Egmond aan Zee, the monopiles and the rocks of the scour protection layers were covered by a wide variety of marine organisms. This paper describes the results of qualitative and quantitative assessments carried out in 2008 and 2011. The assessments were based on video footage, pictures and samples collected by divers at three different wind turbines. The ecological relevance of identified taxa is also discussed.

INTRODUCTION

The Offshore Wind farm Egmond aan Zee (OWEZ) (fig. 1) was built between April and September 2006 and has been in operation since January 2007. The turbine monopile foundations and the rocks around the foundations, that serve as scour protection, form a new hard substrate habitat in an environment previously dominated by soft sandy substrates. Over time, these new hard substrates became colonised by a wide variety of benthic organisms. Video footage, pictures and samples collected by divers in 2008 and 2011 were used to describe the new hard substrate benthic communities (both qualitative and quantitative). Bouma & Lengkeek (2012a) provide more detailed information on the methods and results.

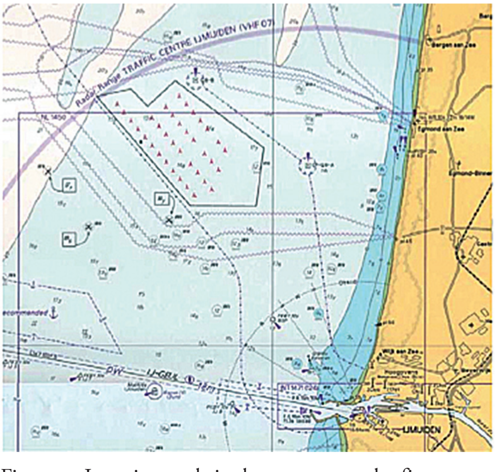

Figure 1. Location and site layout OWEZ, the first Dutch offshore wind farm. Bron NoordzeeWind.
Figuur 1. Locatie en ligging turbines OWEZ, het eerste Nederlandse offshore windmolenpark.
Bron NoordzeeWind.

The results were also presented at the ICES Annual Science Conference in Bergen, Norway in September 2012 (Bouma & Lengkeek 2012b) and the Offshore Wind and Ecology Congress organised by Noordzeewind in Amsterdam in October 2012. This paper provides a summary of the key results and a complete species list of the benthic hard substrate community five years after commissioning of the wind farm.

Monitoring the development of hard substrate communities was part of an extensive evaluation programme, designed by the Dutch Government and executed by the wind farm owner NoordzeeWind, to study economical, technical, ecological and social effects of the construction and operation of the wind farm.

MATERIALS AND METHODS

Video footage, pictures and samples collected by professional divers were used to describe the development of benthic communities on hard substrates of three selected turbines. The first assessments were carried out in February and September 2008 (Bouma & Lengkeek 2009).

Table 1. Species identified on the monopiles and scour protection of three turbines in OWEZ. The edible oyster was identified based on phenological features, but species identification was not validated in the laboratory.
Tabel 1. Aangetroffen soorten op funderingspalen en stenen van de erosie beschermende laag rondom de fundering van drie turbines in OWEZ. De gewone oester werd in het veld geïdentificeerd, maar niet bevestigd op basis van verzameld materiaal.

Species	Monopiles 2008	Monopiles 2011	Scour protection 2008	Scour protection 2011
Algae				
Porphyra spec.		x		
Ulva spec.	x	x		
Anemones				
Actinia equina	x	x		
Actinothoe sphyrodeta		x		
Diadumene cincta	x	x	x	x
Metridium senile	x	x	x	x
Urticina felina		x		
Sagartia spec.	x	x	x	x
Barnacles				
Balanus crenatus	x	x	x	
Megabalanus coccopoma	x	x		
Semibalanus balanoides	x	x	x	
Balanus perforatus		x	x	
Elminius modestus		x		x
Molluscs				
Crepidula fornicata	x	x	x	
Crassostrea gigas	x	x	x	
Ostrea edulis		x		
Mytilus edulis	x	x	x	x
Nassarius reticulates		x		x
Tellimya ferruginosa		x		
Odostomia scalaris		x		
Aeolidia papillosa	x	x		
Crustaceans				
Caprella mutica	x	x	x	x
Stenothoe marina		x		
Monocorophium acherusicum	x	x	x	x
Monocorophium sextonae	x	x	x	x
Jassa herdmani	x	x	x	x
Jassa marmorata	x	x	x	x

Idotea pelagica	x	x	x	
Pilumnus hirtellus	x	x		
Pisidia longicornis	x	x		x
Necora puber	x	x	x	
Cancer pagurus	x	x	x	x
Pinnotheres pisum		x		
Insects				
Telmatogeton japonicus		x		
Echinoderms				
Asterias rubens	x	x	x	x
Ophiotrix fragilis	x			x
Psammechinus miliaris	x	x	x	
Sponges				
Halichondria panicea		x		x
Bryozoans				
Conopeum reticulum	x	x	x	x
Cryptosula pallasiana			x	
Hydroids				
Tubularia larynx	x	x	x	
Tubularia indivisa		x		x
Obelia spec.	x		x	
Obelia dichotoma		x		
Halecium halecinum		x		x
Opercularella lacerata		x		
Polychaetes				
Lepidonotus clava	x	x	x	x
Lepidonotus squamatus		x		x
Harmothoe impar		x		
Nereis pelagica	x	x	x	
Eunereis longissima		x		
Eulalia viridis		x		
Lanice conchilega		x	x	
Spirobranchus triqueter		x	x	
Nemertines				
Lineus longissimus	x	x	x	
Nematodes				
Nematoda		x		

Figure 2. Growth in the intertidal zone of a monopile in OWEZ. Photo Sietse Bouma.
Figuur 2. Aangroei in de getijdenzone van een funderingspaal in OWEZ. Foto Sietse Bouma.

In 2011 these assessments were repeated in the same months, selecting the same turbines and using the same methods (Bouma & Lengkeek 2012a).

Video footage was collected from the entire depth range of the monopiles and from the rocks of the scour protection using a video camera in a hand-held underwater housing. Images were linked to depths by using a depth gauge connected to the underwater housing.

Samples of organisms on the monopiles were collected at five different depths (intertidal zone, 2, 5, 10 and 15 metres of seawater) and at both the northern and southern side of the monopile. At each sample point all organisms within an area of approximately 28 centimetres by 20 centimetres were scraped of the monopile using a putty-knife and collected in a fine-mesh net (mesh size circa 0.25 mm). Samples of organisms on the scour protection layers were taken by collecting several small rocks.

In the laboratory the collected organisms were sorted and species identified and counted. Subsequently, biomass (as ash-free dry weight, AFDW) was determined for the most abundant taxa (dried at 60°C for 60 hours and combusted at 520°C for two hours).

RESULTS

Identified taxa

In 2008 and 2011 a total of 55 taxa were identified on the monopiles (28 in 2008 and 49 in 2011) (table 1). In 2011, 23 new species that were not observed in 2008 were recorded. Three species identified in 2008 were not identified in 2011 and four distinct crustacean species were distinguished that were grouped during the analysis in 2008.

Several non-indigenous species were identified including the titan acorn barnacle *Megabalanus coccopoma*, the acorn barnacle *Balanus perforatus*, the Australasian barnacle *Elminius modestus*, the slipper limpet *Crepidula fornicata*, the Pacific oyster *Crassostrea gigas*, the skeleton shrimp *Caprella mutica*, the small crustacean *Jassa marmorata*, and the marine splash midge *Telmatogeton japonicus*.

Monopiles

The intertidal zone of the monopiles was generally characterised by the presence of a band of green algae, different species of barnacle, oysters and a band of small mussels (fig.2, table 1). In 2011, several larvae of the marine splash midge were also found in this zone. This species was not recorded in 2008. Mussels in the intertidal zone were more

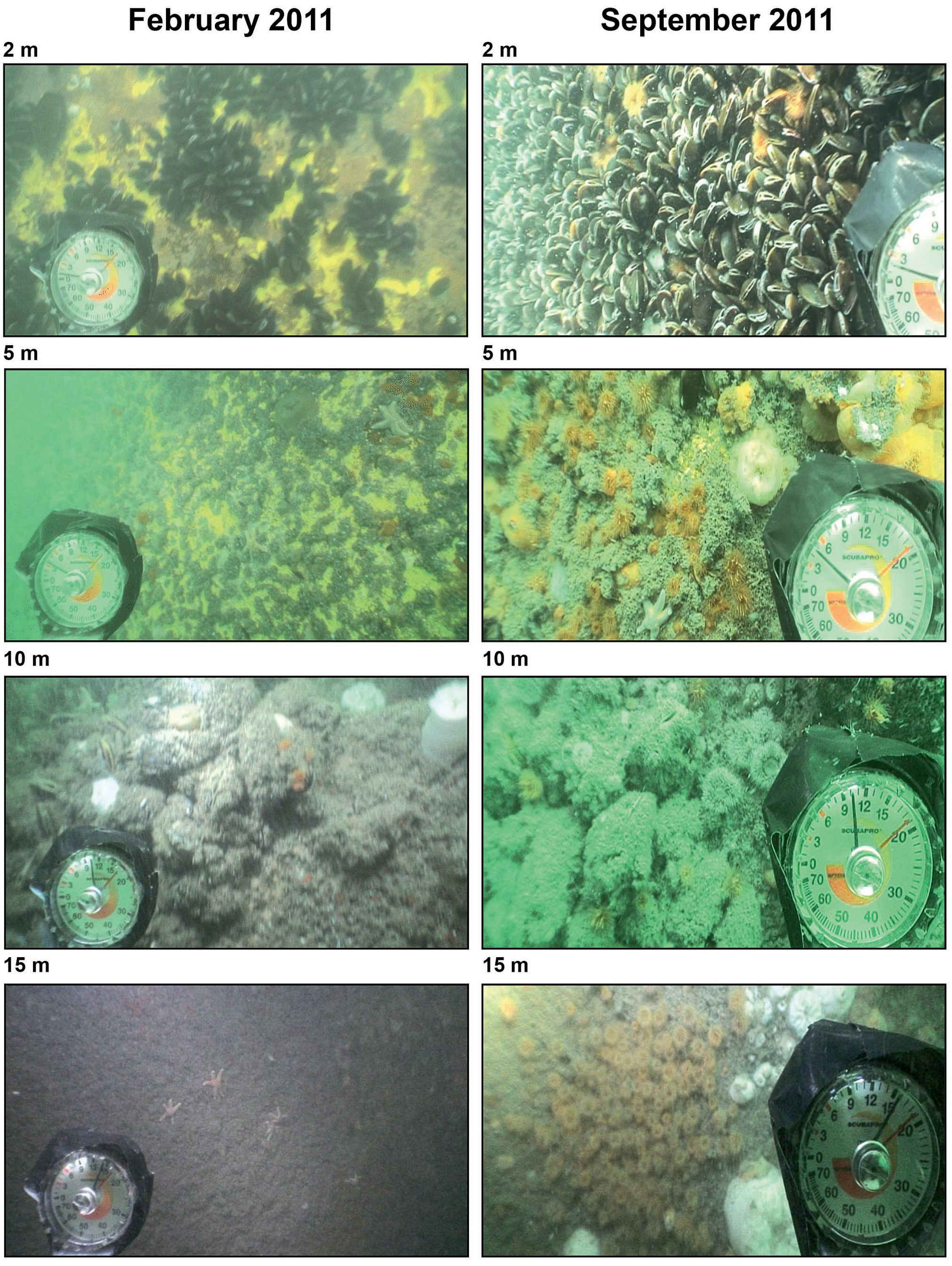

Figure 3. Growth in the subtidal zone of a monopile in OWEZ. Video stills collected by Wals Diving, figure by Bureau Waardenburg.
Figuur 3. Aangroei in de subtidale zone van een funderingspaal in OWEZ. Videofragmenten verzameld door Wals Diving, figuur door Buerau Waardenburg

Figure 4. Rocks of the scour protection layer of a turbine in OWEZ. Video still collected by Wals Diving.
Figuur 4. Stenen van de erosiebeschermde laag rondom de fundering van een turbine in OWEZ. Videofragment door Wals Diving.

abundant in September than in February, possibly because of loss of mussels during winter storms and recolonisation during the summer months.

Organisms in the subtidal zone showed a 'patchy' distribution with strongly varying cover percentages. But generally a thick layer of adult mussels was present from the shallow subtidal zone to circa 10-12 m depth (fig. 3). In 2011 these mussels were more overgrown by other species (mainly by small crustaceans and the orange anemone) than in 2008. Common species associated with these mussels included common starfish, several species of crab and various polychaetes. Edible crabs were often found in open 'patches' between the mussels, especially during the September 2011 survey.

From circa 12 m to the seafloor at circa 15 m depth, the monopiles were fully covered by small crustaceans, anemones (mainly plumose anemones and *Sargartia* sp. anemones) and 'patches' of the ringed tubularia.

In 2011 total densities of hard substrate species on the monopiles reached values up to circa 28,000 individuals per m^2. Most numerous were small crustaceans (circa 22,000 per m^2) anemones (circa 1,000 per m^2), polychaetes (circa 500 per m^2) and common starfish (circa 130 per m^2). A clear increase in total densities occurred between February 2008 and September 2011.

The total biomass of hard substrate species on the monopiles varied between circa 450 (February 2008) and 1,400 g AFDW per m^2 (September 2008). Mussels and anemones contributed most to this biomass (on average circa 83% and 7%).

Scour protection layers

The most dominant species on the rocks of the scour protection layers were plumose anemones, small crustaceans and the encrusting sea mat. Common starfish were also abundant. Less abundant species include other anemone species, various crabs, polychaetes and hydroids. In 2011, eight new species were identified that were not recorded in 2008 including the breadcrumb sponge and eggs of the mollusc *Nassarius reticulus*.

The density of marine life on the rocks of the scour protection layers was high (fig. 4). Densities of anemones were circa 2,500 individuals per m^2 and densities of common starfish circa 180 individuals per m^2. The covering percentages of the sea mat and small crustaceans varied between 60-100% and 30-50% respectively.

DISCUSSION

Small crustaceans, mussels and polychaete worms can form a valuable food source for fish and bird species. A simplified extrapolation showed an availability of circa 7,400 kg AFDW mussels and circa 100 kg AFDW small crustaceans and polychaete worms.

Identifying causal relationships between the presence of these hard substrate species and fish and or birds was beyond the scope of the study. However, a study carried out in the summer of 2010 using DIDSON (Dual Frequency IDentification SONar) techniques showed that fish densities within 15-20 metres of the monopiles were much higher than in other areas of the wind farm (above the rocks of the scour protection on average 37 times higher) (Couperus et al. 2010). Catches with fishing rods identified mackerel *Scomber scombrus*, jack mackerel *Trachurus trachurus* (length between 25-35 cm) and juvenile cod (length 30-55 cm) as the most dominant species in the vicinity of the monopiles, but it was also possible that Clupeiformes were present (Couperus et al. 2010, Hal et al. 2012). Other species that were more abundant on the hard substrates compared to other parts of the wind farm were pouting *Trisopterus luscus*, bull rout *Myoxocephalus scorpius* and dragonets *Callionymus lyra* (Hal et al. 2012).

Another study focusing on the residence time and behaviour of sole and cod in OWEZ showed that juvenile cod stay in the wind farm for prolonged periods of time. 55% of tagged individuals stayed in OWEZ for several weeks or months and 15% during the entire study period of 8-9 months (Winter et al. 2010). Inventories of demersal fish species showed that several demersal fish species, including sole, whiting and striped mullet, have significantly increased in the wind farm and not in reference sites outside the wind farm (Hille Ris Lambers & Hofstede 2009, Lindeboom et al. 2011).

Studies on flight patterns and on distribution of local birds (Krijgsveld et al. 2011, Leopold et al. 2010) showed that cormorants *Phalacrocorax carbo* are attracted to the wind farm, mostly because the turbines provide the resting place that these birds require to dry their feathers. Cormorants foraged for fish on a regular basis in the wind farm, especially during the summer months. Also various species of gull were shown to forage within the wind farm. The most abundant gull species occurring in the area and within the wind farm were lesser black-backed gull *Larus fuscus*, herring gull *Larus argentatus* and common gull *Larus canus,* but also the larger great black-backed gull *Larus marinus* in winter, and the smaller black-headed gull *Larus ridibundus* and kittiwakes *Rissa tridactyla*. Gulls feed on a variety of food, including smaller fish and crustaceans, which were encountered in high densities in the wind farm. Sea ducks, such as scoters that could potentially benefit from the high biomass of the mussels, were seen flying through the wind farm only occasionally (Krijgsveld et al. 2011, Leopold et al. 2010).

The presence of several non-indigenous species indicates that newly introduced hard substrates provide a habitat for both indigenous and non-indigenous species.

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SAMENVATTING

Benthische gemeenschappen op harde substraten van het eerste Nederlandse Offshore Windmolenpark Egmond aan Zee (OWEZ)

Vijf jaar na de inbedrijfstelling van het offshore windmolenpark Egmond aan Zee waren de funderingspalen en de stenen van de erosiebeschermende laag rondom de fundering van de turbines bedekt met een grote verscheidenheid aan mariene organismen. Dit artikel beschrijft de resultaten van kwalitatieve- en kwantitatieve evaluaties uitgevoerd in 2008 en 2011.

De evaluaties waren gebaseerd op video-opnamen, foto's en monsters verzameld door duikers bij drie verschillende turbines. In totaal werden 55 taxa aangetroffen, waaronder diverse niet-inheemse soorten. In de intergetijdenzone kwamen vooral algen, zeepokken, oesters en jonge mosselen voor. In 2011 werden in deze zone ook larven van Japanse dansmuggen gevonden.

De bedekkingen van benthische soorten in de subtidale zone varieerden sterk, maar over het algemeen konden twee gemeenschappen onderscheiden worden:

- Een gemeenschap in de zone van de intergetijdenzone tot circa 10-12 meter diepte die sterk gedomineerd werd door de aanwezigheid van mosselen met daartussen allerlei aanverwante soorten, zoals krabben, zeesterren en polychaete wormen.
- Een gemeenschap in de zone van circa 12 meter diepte tot de zeebodem op 15 meter diepte die gedomineerd werd door verschillende soorten anemonen en kleine kreeftachtigen en in mindere mate hydroïdpoliepen.

De aanwezigheid van deze nieuwe benthische gemeenschappen heeft waarschijnlijk ook effecten op andere soortgroepen zoals vissen en vogels.

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