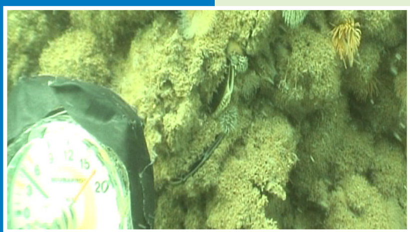
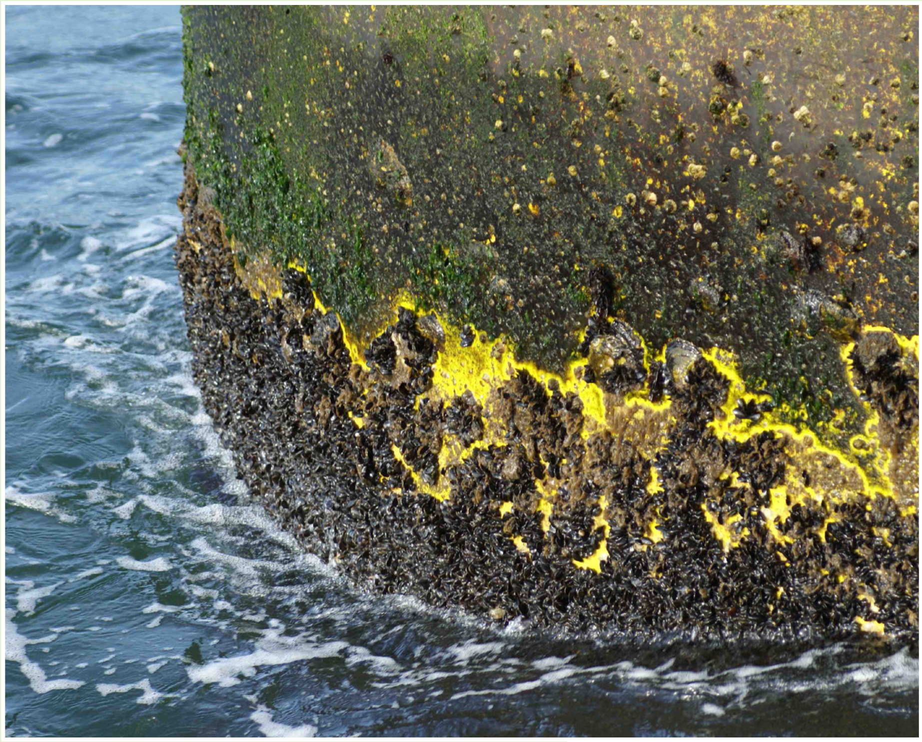
Benthic communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ)

Including results of samples collected in scour holes



S. Bouma
W. Lengkeek

Bureau Waardenburg bv
Consultants for environment & ecology

Benthic communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ)

Including results of samples collected in scour holes

S. Bouma
W. Lengkeek

Bureau Waardenburg bv
Consultants for environment & ecology
P.O. Box 365, 4100 AJ Culemborg The Netherlands
Tel. +31 345 51 27 10, Fax +31 345 51 98 49
E-mail wbb@buwa.nl Website: www.buwa.nl

commissioned by: Noordzeewind

6 February 2012
report nr. OWEZ_R_266_T1_20120206_hard_substrate

Status:	Final report 2012
Noordzeewind reference	OWEZ_R_266_T1_20120206_hard substrate
Bureau Waardenburg report nr.:	11-205
Date of publication:	6 February 2012
Title:	Benthic communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ).
Subtitle:	Including results of samples collected in scour holes
Authors:	Drs. S. Bouma Dr. W. Lengkeek
Number of pages incl. appendices:	80
Project nr:	10-503
Project manager:	Drs. S. Bouma
Name & address client:	Noordzeewind, 2e Havenstraat 5-B, 1976 CE, IJmuiden
Reference client:	Framework Agreement for the provision of MEP services, 30 May 2005
Signed for publication:	Team Manager Aquatic Ecology
	drs. A. Bak
Initials:	ABak

The Quality Management System of Bureau Waardenburg bv has been certified by CERTIKED according to ISO 9001:2000.

Bureau Waardenburg bv
Consultants for environment & ecology
P.O. Box 365, 4100 AJ Culemborg The Netherlands
Tel. +31 345 51 27 10, Fax +31 345 51 98 49
E-mail wbb@buwa.nl Website: www.buwa.nl

Preface

Noordzeewind designed an extensive Monitoring and Evaluation Programme (NSW-MEP) to study effects of the construction of the Offshore Wind farm Egmond aan Zee (OWEZ). The ecological monitoring and evaluation was granted to a consortium consisting of IMARES, Bureau Waardenburg and NIOZ.

As part of this contract Bureau Waardenburg has been commissioned to describe the development of benthic communities on hard substrates (monopiles and scour protection layer) within OWEZ. The first qualitative and quantitative assessments were carried out in February and September 2008, approximately two years after construction of the wind farm. The results are reported in Bouma & Lengkeek (2009). In 2011 these assessments were repeated in the same months, selecting the same three turbines and using the same methods as in 2008. Diving activities were carried out by divers from Wals Diving & Marine Service based in IJmuiden and laboratory analyses and reporting by Bureau Waardenburg in Culemborg. This report presents the results of the 2011 assessments and provides a comparison with the results of 2008.

In addition to the hard substrate assessments, benthic samples were collected in the scour holes that were present at the edge of the scour protection layers of the three turbines, both in February and September 2011. In September 2011 samples were also collected to determine the particle sizes (grain size analysis) of the sediment in the scour holes. The benthic samples and samples for the particle size analyses were treated similarly to the methods used by NIOZ to assess the macrofauna living in or on top of the soft sediments within the wind farm and six reference areas.

The offshore wind farm Egmond aan Zee has a subsidy of the Ministry of Economic Affairs under the CO2 Reduction Scheme of the Netherlands.

Table of contents

Summary

The Offshore Wind farm Egmond aan Zee (OWEZ) was built between April and September 2006 and has been in operation since January 2007. As part of an extensive Monitoring and Evaluation Program (NSW-MEP), Bureau Waardenburg was commissioned to describe the development of benthic communities on hard substrates (monopiles and scour protection layer) within OWEZ. The first qualitative and quantitative assessments were carried out in February and September 2008 and were reported in Bouma & Lengkeek (2009). In 2011 these assessments were repeated in the same months, selecting the same turbines and using the same methods as in 2008. This report presents the results of the 2011 assessments and provides a comparison with the results of 2008.

In February and September 2011 additional information was gathered on the presence of benthic species in scour holes that are present at the edge of the scour protection layers of the turbines. Furthermore, additional samples were collected in September 2011 in order to determine the particle sizes of the sediment in these holes. These results are also included in this report.

For this study three turbines were selected to cover different distances from the shore and different areas within the OWEZ: turbines 7, 13 and 34.

Hard substrate communities
Video footage, pictures and samples collected by commercial divers were used to describe the hard substrate communities on the monopiles and the rocks of the scour protection layers of the selected turbines (both qualitative and quantitative). Samples of 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 using a putty-knife. Samples of organisms present on the rocks of the scour protection layer were taken by collecting several small rocks and bringing these to the surface.

<u>*Monopiles*</u>
Qualitative assessment
In 2008 and 2011 a total of 55 species were identified on the monopiles (28 in 2008 and 49 in 2011). 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.

New species on the monopiles include the foliose red algae *Porphyra spp*., the sandalled anemone, dahlia anemone, the edible oyster, the marine splash midge and the breadcrumb sponge.

The intertidal zones of turbines 7 and 34 were comparable to each other. They were characterised by the presence of a band of green algae, different species of barnacles, several oysters in the upper part of this zone and small mussels in the lower part of this zone. In February 2011, the mussels showed a ‘patchy’ distribution

covering percentages varying from circa 0 to 60%. In September however, this zone was almost entirely covered with small mussels, which reflected the situation in September 2008. The intertidal zone of turbine 13 was relatively bare with a band of green algae and few barnacles and small mussels. On all three turbines larvae of the marine splash midge were identified in the intertidal zone. This species was not found during any of the surveys carried out in 2008.

In September 2008, the shallow subtidal zones (from the intertidal zone to circa 3 m depth) of all three turbines were almost entirely covered by mussels. In February 2011, covering percentages of mussels in this zone were much lower (circa 5-10% for turbines 7 and 34 and 30-70% for turbine 13). Patches without mussels were (partly) covered with (tubes of) small crustaceans (four different species) and anemones (most abundant plumose anemones and the orange anemone *Diadumene cincta*). In September 2011 this depth zone of turbines 7 and 34 was almost fully covered by small (juvenile) mussels (90-100%) similar to the situation in September 2008. Mussels in this depth zone of turbine 13 still showed a ‘patchy’ distribution with covering percentages between 30-100%.

The deeper subtidal zone (from circa 3 to 10-12 m depth) was generally characterised by the presence of a thick layer of large (adult) mussels (covering percentages monopiles 7: 80-100%; 13: 30-100%; 34: 3-6m 10-20%, 6-12m 90-100%). In comparison to the 2008 surveys, these mussels were more overgrown by other species (mainly small crustaceans and the orange anemone *Diadumene cincta*). Edible crabs were often found in open ‘patches’ between the mussels, especially during the September 2011 survey. In between the mussels, polychaetes and crabs were common, and occasionally Pacific oysters and sea urchins were found.

From circa 12 to 15 m depth, the three monopiles were fully covered by (tubes of) small crustaceans, anemones (mainly plumose anemones, but also the orange anemone *Diadumene cincta* and *Sargartia spp*. anemones) and ‘patches’ of the ringed tubularia.

Common starfish were very abundant at all depths, both in February and September 2011. Aquatic sow bugs were very abundant in February 2011, but less abundant in September 2011. Three new species on the monopiles that were seen on video, but not collected in the samples, were the sandalled anemone, the dahlia anemone and the breadcrumb sponge. These species were not identified during the 2008 assessments.

Quantitative assessment

In 2011, total densities of hard substrate species on the monopiles reached values up to 28,000 individuals per m^2. Small crustaceans contributed most to these densities (circa 22,000 individuals per m^2), followed by common mussels (circa 4,000 individuals per m^2), anemones (circa 1,000 individuals per m^2), common starfish (circa 130 individuals per m^2) and polychaetes (circa 500 individuals per m^2). A clear increase occurred over the study period between February 2008 and September 2011.

The total biomass of hard substrate species on the monopiles varied between circa 450 and 1,400 g AFDW[1] per m^2. Mussels contributed most to this biomass (on average 83% of the total biomass) followed by anemones (on average 7% of the total biomass). Biomass values reached its maximum in September 2008 (circa 1,400 g AFDW per m^2).

Scour protection layers
Qualitative assessment
In 2008 and 2011 a total of 35 species have been identified on the scour protection layers (24 in 2008 and 18 in 2011). In 2011, eight new species were recorded compared to 2008, including the breadcrumb sponge (turbine 13) and eggs of the mollusc *Nassarius reticulatus*. A total of 14 species recorded in 2008 were not identified in 2011 and four distinct crustacean species were distinguished that were grouped during the analysis in 2008.

As in September 2008 there were no clear differences between the hard substrate communities on rocks collected from the scour protection layers of the three different turbines. Most dominant were plumose anemones (coverages varying between 50-100%), (tubes of) small crustaceans (100% coverage at places without anemones) and the encrusting sea mat. Common starfish were also very abundant. Less abundant species include other species of anemones (e.g. *Sargartia spp*., and *Diadumene cincta*), crabs (velvet swimming crab and edible crab) and several species of polychaetes and hydroids.

Quantitative assessment
The density of marine life on the scour protection was high. Densities of anemones were circa 2,500 individuals per m^2 and densities of 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. It should be noted that the extrapolation to densities per m^2 are subject to large error margins due to the low number of samples collected and the high variation between the samples. Therefore, these densities should be regarded as indicative only.

Some samples showed different species compositions and densities. In September 2008, one rock was collected with mussel densities reaching 10,000 individuals per m^2. Probably a clump of mussels had fallen of the monopiles and was collected during sampling. In September 2011, one sample contained a large specimen of the breadcrumb sponge with large numbers of the skeleton shrimp (density circa 65,000 per m^2).

Scour holes
Samples in the scour holes were collected in the period around slack tide when tidal currents are relatively low. In this situation organisms and sediment particles in the water column may sink to the seafloor and temporarily accumulate in these holes. In other phases of the tidal cycle tidal currents get stronger and the accumulated

[1] AFDW = Ash Free Dry Weight

material may wash out again. Therefore the results only present the situation in the scour holes during the period around slack tide.

Benthos

The sediment cores collected in the scour holes did not only contain species characteristic for sandy substrates, but also species that are characteristic for hard substrates. It is most likely that these hard substrate species had detached from the monopiles and rocks of the scour protection layers and subsequently accumulated in the scour holes. A total of 55 different species were identified in the samples collected during both the February and the September surveys, including 26 species characteristic for sandy substrates and 29 species characteristic for hard substrates.

Most of the hard substrate species in the scour holes were similar to the species found on the monopiles and/or rocks of the scour protection layers. New hard substrate species found in the sediment cores collected in the scour holes are *Clytia hemisphaerica*, *Ectopleura larynx*, *Abludomelita obtusata*, *Phtisica marina* and *Arenicola defodiens*. It is likely that these species were present on the monopiles and/or the rocks of the scour protection layers as well.

Many species characteristic for sandy sediments were present in the samples as single specimens. Therefore, the limited number of samples only allow for a global assessment of the species composition. It is expected that the actual number of these species in the scour holes is higher. Most endobenthic species identified in the sediment cores were polychaetes. A remarkable find was a specimen of the polychaet *Sthenelais boa*. This species has been reported from OWEZ before, but has not been encountered in the national monitoring programme for benthos in recent years.

Calculated densities, biomass and production values showed large variations both between the different surveys in February and September and between different turbines. Taking into account that the divers were not completely sure that they were actually sampling in the scour holes in February 2011 (due to poor underwater visibility) and that the number of samples was low, no attempts are made to explain these differences.

Grain size

The average median particle size in the scour holes of the three turbines was 243µm and the percentage silt (fraction < 63µm) is 2.5%. The median particle size is comparable data collected during benthic fauna surveys carried out in 2011 by NIOZ at 19 other locations (Bergman *et al.,* in prep.) in the wind farm outside the scour holes (264µm), but the percentage silt was slightly higher than the value found by NIOZ (0.3µm).

Ecological relevance of hard substrate communities

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 is beyond the scope of this study. However, results of various fish studies (Hille Ris Lambers & Hofstede, 2009; Ybema *et al*., 2009; Winter *et al.,* 2010) showed that juvenile cod may stay in the wind farm for prolonged periods of time and that several demersal fish species, including sole, whiting and striped mullet, have significantly increased in OWEZ and not in reference sites outside the wind farm.

Bird studies (Krijgsveld *et al.,* 2011; Leopold *et al.,* 2011; Poot *et al.,* 2011) indicate that cormorants and several species of gulls are attracted to 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.

Comparison with other wind farms and other hard structures in the North Sea

The results of this study are comparable with results of similar studies in the C-power wind farm in Belgium, the Horns Rev offshore wind farm in Denmark. The intertidal zone is dominated by algae and barnacles and the marine splash midge *Telmatogeton japonica* is present. In the upper subtidal zone a hard substrate community dominated by mussels (with associated species such as common starfish) and in the lower subtidal zone, close to the seafloor, a community dominated by anemones (most notable plumose anemones) and small crustaceans. These results are also comparable to growth on other hard structures (with both intertidal and subtidal zones) in the North Sea .

1 Introduction

1.1 Background

Wind energy is one of the most important and promising forms of renewable energy, and a significant increase in the exploitation of wind energy is expected. Offshore wind farms are an attractive alternative to onshore wind turbines, especially in densely populated countries like the Netherlands. Positive effects of offshore wind farms are mainly economically and socially related, but benefit is gained also for mitigating global climate change by increasing the amount of sustainable energy. Negative impacts of offshore wind farms could be effects on the surroundings in terms of visibility, noise emission and potential impacts on nature. In order to increase the supply of renewable energy in the Netherlands, the Dutch government supported the construction of the Netherlands' first offshore wind farm near Egmond aan Zee (OWEZ). OWEZ covers a total area of 30 km^2 and consists of 36 turbines located at distances varying from 10 to 18 kilometres off the coast of Egmond aan Zee.

The project was granted to 'NoordzeeWind' (a consortium of Nuon Duurzame Energie and Shell Wind Energy). The wind farm was built between April and September 2006 and is in operation since January 2007. The project serves as a demonstration project to gain knowledge and experience with the construction and exploitation of large-scale offshore wind farms. To collect this knowledge, an extensive Monitoring and Evaluation Program (NSW-MEP) has been designed in which the economical, technical, ecological and social effects of the OWEZ are gathered. The ecological monitoring and evaluation was granted to a consortium consisting of IMARES, Bureau Waardenburg and NIOZ.

1.2 Description of OWEZ

OWEZ is located at distances varying from 10 to 18 kilometres off the coast of Egmond aan Zee (figure 1). It consists of 36 turbines placed on steel monopiles (diameter 4.6 metres) that rise to 70 metres above sea level. The total height of the turbines including the rotor is 115 metres. The water depth within OWEZ varies between 15 to 20 metres. The wind farm consists of four rows of turbines (at a distance of 1 kilometre) with a minimum distance of 650 metres between the turbines. A 116 metre high meteorological mast (metmast) has been installed, to measure wind speeds at various altitudes, temperature, rainfall and humidity .

Around the base of the monopiles a scour protection layer was installed, with a diameter of approximately 25 metres, which consists of a filter layer of small sized rock and a top layer of heavier rock grading.

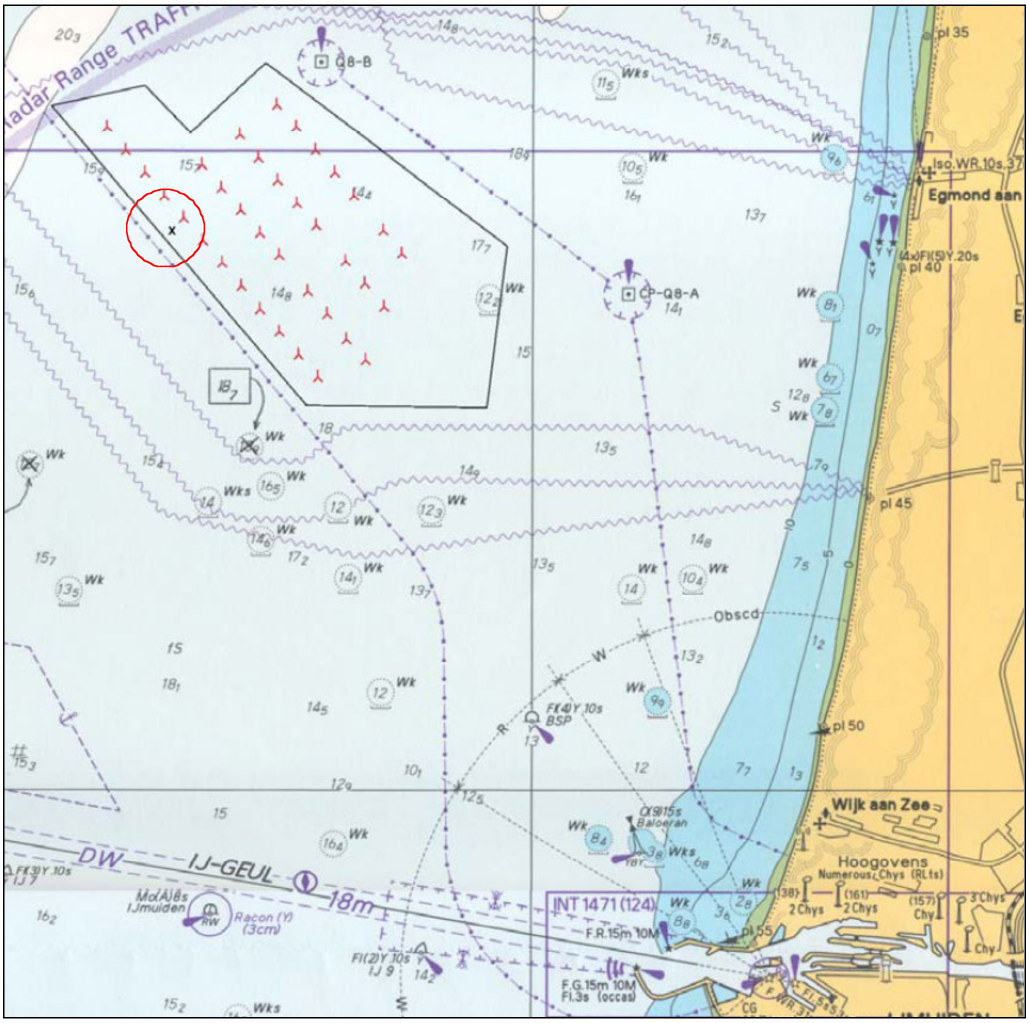


Figure 1. Location and site layout of the OWEZ (source: Noordzeewind 2003a).

1.3 Present study

With the construction of OWEZ, two types of hard substrates (the monopiles of the turbines and rocks around the foundation of the turbines for scour protection) were introduced in an area that previously contained only soft sandy substrate. Over time it is to be expected that these hard substrates will be colonised by a variety of species. Benthic communities will develop that are different from the soft substrate communities previously present at the OWEZ location.

The present study focused on the colonisation and development of benthic communities on hard substrates introduced by the wind farm. Results of assessments carried out in February and September 2011 are described and compared to similar assessments carried out in February and September 2008 (reported in Bouma & Lengkeek, 2009).

In February and September 2011, additional information was gathered on the presence of benthic species in scour holes that are present at the edge of the scour protection layers of the turbines. Furthermore, in order to determine the particle sizes of the sediment in these holes additional samples were collected in September 2011. These results are included in this report.

1.4 Objectives

The main objective of this study was to gain insight in the qualitative (species composition and covering percentages) and quantitative development (numbers and biomasses of species present) of benthic communities on the two types of hard substrates introduced by the construction of OWEZ.

Other objectives were to gather information on benthic species in scour protection holes that are present at the edge of the scour protection layers of the turbines and to determine the particle sizes of the sediment in these holes.

Picture 1. Diver (Wals Diving & Marine Services) preparing for a dive.

2 Materials and methods

Fieldwork was carried out on the 17th and 18th of February 2011 (end of winter situation) and the 24th and 25th of September 2011 (end of summer situation).

The vessel 'Zeeland' was used for transport from IJmuiden Harbour to the wind farm and served as a platform to conduct the research activities. Diving activities were carried out by divers from Wals Diving & Marine Service. Bureau Waardenburg ecologists closely monitored the activities of the divers by means of an underwater CCTV (closed circuit television) and communication system and gave them instructions during the dive.

2.1 Selection of turbines

The colonisation of underwater man-made structures in the marine environment depends on several factors including the availability of larvae (influenced by flow patterns and distance from shore) and environmental conditions (e.g. temperature, salinity, current speed, water depth and light).

In 2008, three turbines were selected to cover different distances from the shore and different areas within the OWEZ: turbines 7, 13 and 34 (figure 2). In 2011, the same three turbines were selected to enable the comparison of results with previous assessments. Since the construction of these turbines no organisms have been removed from the monopiles as part of technical maintenance. This made it possible to monitor the development of hard substrate communities five years after construction of the wind farm.

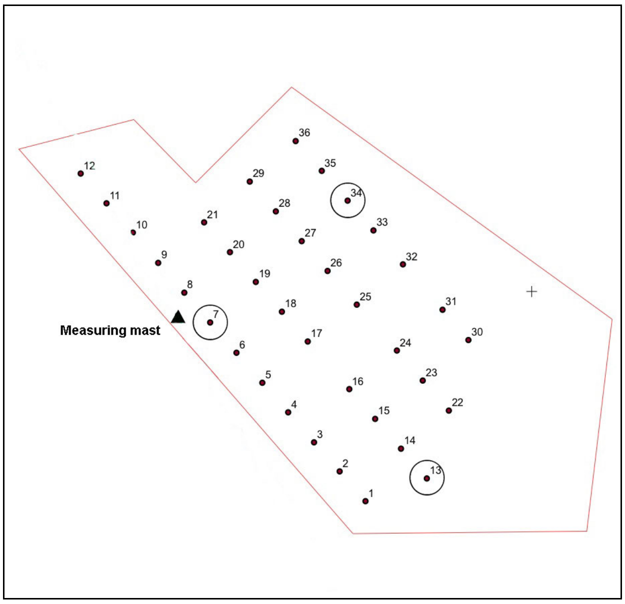


Figure 2. Turbines selected to cover different distances from the shore and different areas within the OWEZ: turbines 7, 13 and 34.

2.2 Development of hard-substrate communities

2.2.1 Fieldwork activities: collection of video-footage and samples

Video-footage and pictures

The monopiles and the scour protection layers of the selected turbines were filmed using a video camera in a handheld underwater housing. The monopiles were filmed from the seafloor to the surface covering the entire depth ranges of the monopiles. The video images were linked to depths by using a depth gauge connected to the housing of the camera. It was difficult for the diver to handle the camera at the surface, because of waves and currents. Therefore pictures from the intertidal zone were taken from the 'Zeeland'.

Sampling

Samples of organisms present on the rocks of the scour protection layer were taken by collecting several small rocks and bringing these to the surface.

Samples of the organisms present on the monopiles were collected at five different depths (intertidal zone, 2, 5, 10 and 15 metres of seawater (= dive depth: see text box)) and at both the northern and southern side of the monopile using a putty-knife. At each sample point all organisms within an area of approximately 28 centimetres by 20 centimetres were scraped of the monopile, collected in a fine-mesh net (mesh size circa 0.25 mm) and brought to the surface. It should be noted that accurate sampling is quite difficult due to the strong currents in the wind farm. Therefore these sample-surface areas contain relatively large error margins.

Sampling in the intertidal zone was carried out from a rigid inflatable boat (RIB).

All samples were taken to the laboratory of Bureau Waardenburg in Culemborg for further analyses (§ 2.2.2).

Dive depth (expressed in metres of seawater) versus water depth (expressed in relation to NAP (Normaal Amsterdams Peil)

Dive activities in the wind farm can only be carried out safely in the time period close to slack tide, when currents are relatively low. In this study two turbines were sampled within a 12-hour time period. This means that one turbine was sampled at the time when the water was close to its highest level, and the second turbine when the water was close to its lowest level. The actual dive depths (expressed in metres of seawater) were corrected to water depth in relation to NAP (Normaal Amsterdams Peil) to determine the effect of tidal differences on the sampling depth. This was done by using the recorded times of sampling at the different dive depths and the actual water levels from two measuring stations in the vicinity of the OWEZ, namely Zuid-Petten and IJmuiden buitenhaven[2]. The results showed a difference in sampling depth varying between 0.4 and 1.4 metres (appendix 1). Taking the 'patchy' distribution of benthic communities on the monopiles into account (organisms occur in depth ranges rather than on specific depths), the effect of tidal differences on the sampling depth is negligible.

Picture 2. Sampling in the intertidal zone.

[2] Actual water levels were retrieved from the Servicedesk of Rijkswaterstaat in time periods of 10 minutes.

2.2.2 Laboratory analyses

In the laboratory the collected organisms were sorted and species and/or higher taxa identified and counted. Subsequently, biomasses (as ash-free dry weights, AFDW) were determined for the most abundant taxa. Biomasses were determined to quantify the high abundance of the most dominant taxa (e.g. mussels) and illustrate their energetic value for higher predators (e.g. birds, fish). Therefore, biomasses were only determined for taxa that occurred in significant quantities.

To determine biomass, samples were dried at 60° for 60 hours and combusted at 520° for two hours. Samples were allowed to cool down for 10 minutes after drying or combusting before they were weighed.

Small crustaceans occurred in high numbers (up to several thousands per sample) and with extremely small body sizes (younger individuals). Within these crustaceans, four species where confirmed: *Monocorophium acherusicum, Monocoropium sextonae, Jassa herdmani* and *Jassa marmorata*. These species where not counted separately in each sample. Instead, a total estimate of numbers of small crustaceans to the nearest 100 is presented. Biomass has been determined on an exact number of 200-400 from four different samples. Mean biomass per individual has been used to calculate small crustacean biomasses for each sample.

2.2.3 Qualitative and quantitative assessments

Using the video footage collected by the divers and results from the laboratory analyses, qualitative (species composition and covering percentages) and quantitative assessments (numbers and biomasses of species present) of the hard substrate communities on the monopiles and the scour protection layers were carried out. The results are compared with results of the assessment carried out in February and September 2008 (Bouma & Lengkeek, 2009).

In the discussion (chapter 4) an indicative extrapolation is also provided for the development of underwater flora and fauna communities on all 36 monopiles within OWEZ. The ecological value of these communities is discussed and results are compared with growth on hard structures in offshore wind farms in the Belgian part of the North Sea and in Denmark (Horns Rev offshore wind farm) and with growth on other hard structures in the North Sea.

2.3 Benthos and particle sizes in scour holes

2.3.1 Fieldwork: sampling

Benthos

Since the realisation of OWEZ, scour holes have developed at the edges of the scour protection. These holes are most pronounced north-northeast of the turbines with a distance of approximately 20-25 m between the deepest location of the hole and the centre of the pile of the turbine. In May 2009, the maximum edge scour varied between 0.8 and 2.2 m with an average value of 1.5 m (Raaijmakers, 2009).

In February and September 2011 additional information was gathered on the presence of benthic species in these scour holes. Starting at the base of the monopile, the divers swam in northeasterly direction to the edge of the scour protection layer searching for the scour holes. In the scour holes three sediment cores were collected using a pitch pipe (Ø 12 cm; depth circa 20 cm; picture 3). These sediment cores were washed through a 1 mm mesh sieve on board of the 'Zeeland' and the residue preserved in a 6% neutralised formaldehyde solution for later analysis in the laboratory (§ 2.3.2).

Note: In February, the divers were not completely sure if they were actually sampling in a scour hole due to the poor underwater visibility. In September the visibility was much better and divers clearly identified the scour holes.

Picture 3. Pitch pipe used to collect sediment for sampling of benthos in the scour holes.

Grain size

In September 2011, eleven small sediment cores (Ø 3 cm; depth circa 10 cm) were collected to determine the particles sizes of the sediment in the scour holes of the three turbines. These cores were frozen and sent to NIOZ for grain size analysis (§ 2.3.2).

2.3.2 Laboratory analyses

Benthos

In the laboratory benthic samples were treated similarly to the methods used by NIOZ to assess the macrofauna living in or on top of the sediments within the wind farm and six reference areas (Daan *et al*., 2009). First, samples were stained with rose bengal [3] and washed over a set of nested sieves, with 1 mm as the smallest mesh size, to get rid of the formaldehyde (picture 4). Then the various sieve fractions were examined and macrobenthos species sorted into major taxonomic groups like Polychaeta, Mollusca, Crustacea and Echinodermata.

Subsequently, species within the major taxonomic groups were identified and their densities, biomass and production values measured and/or calculated. A full description of the methods is provided in appendix 1.

Picture 4. Staining the samples with rose bengal and washing them over a set of nested sieves.

[3] Rose bengal stains proteins present in animals collected alive. In this way bengal rose creates a strong contrast between living and dead material, which facilitates sorting of the samples (Daan *et al.*, 2009).

Grain size analysis

NIOZ carried out the grain size analyses. The sediment samples were freeze-dried for up to 96 hours till dry. Prior to grain-size analysis between 0.5 and 5 grams, depending on the estimated grain size, of homogenized sample was weighed over a 2 mm sieve, in 13 ml PP Autosampler tubes. RO water was added and the sample was shaken vigorously on a vortex mixer for 30 seconds. Median particle size and the percentage silt (fraction < 63 μm) of sediments were determined using a Coulter LS 13 320 particle size analyser and Autosampler. This apparatus measured particle sizes in the range of 0.04–2,000 μm in 126 size classes, using laser diffraction (780 nm) and PIDS (450 nm, 600 nm and 900 nm) technology. The optical module 'Gray' was used for the calculations.

3 Results

3.1 Hard substrates

3.1.1 Qualitative assessment monopiles

Species

Table 1 shows the total number of species identified on the video footage and/or collected samples from the monopiles, both for the assessments carried out in February and September 2011. Species identified during previous assessments in 2008 are included in this table for comparison.

In both 2008 and 2011, a total of 55 species were identified on the monopiles (28 in 2008 and 49 in 2011).

In 2011, 23 new species were identified on the monopiles that were not identified in 2008: the foliose red algae *Porphyra spp.*, the sandalled anemone *Actinothoe sphyrodeta*, the dahlia anemone *Urticina felina*, the acorn barnacle *Balanus perforatus*, the Australasian barnacle *Elminius modestus*, the edible oyster *Ostrea edulis*, the molluscs *Tellimya ferruginosa* and *Odostomia scalaris*, the marine gammarid amphipod *Stenothoe marina*, the pea crab *Pinnotheres pisum*, the marine splash midge *Telmatogeton japonicus*, the breadcrumb sponge *Halichondria panicea*, the hydroids *Tubularia indivisa*, *Obelia dichotoma* and *Halecium halecinum*, *Opercularella lacerata* and the polychaetes *Lepidonotus squamatus, Harmothoe impar*, *Eunereis longissima*, *Eulalia viridis*, *Phyllodoce maculata, Lanice conchilega, Spirobranchus triqueter*.

Three species identified in 2008 were not identified in 2011: the velvet swimming crab (*Necora puber*), the common brittle star (*Ophiotrix fragilis*) and the hydroid *Obelia spp.*).

In 2008, no distinction was made between the crustacean *Jassa herdmani, Jassa marmorata, Monocorophium acherusicum* and *Monocorophium sextonae*. Instead these four species were all grouped under *Jassa spp.*. In 2011, the presence of these four separate species has been confirmed. Not all polychaetes were identified to species level in 2008.

Table 1. Species identified on the monopiles of turbines 7, 13 and 34 during surveys carried out in February and September 2008 and 2011.

		Turbine 7				Turbine 13				Turbine 34			
		2008		2011		2008		2011		2008		2011	
Species	English name	February	September	February	September	February	September	February	September	February	September	February	September
Algae													
Porphyra spp.	foliose red algae								x				
Ulva spp.	sea lettuce	x	x	x	x	x	x	x	x	x	x	x	x
Anemones													
Actinia equina	beadlet anemone				x					x			
Actinothoe sphyrodeta	sandalled anemone				x[1]				x[1]				
Diadumene cincta	orange anemone	x	x	x	x	x	x	x	x	x	x	x	x
Metridium senile	plumose anemone	x	x	x	x	x	x	x	x	x	x	x	x
Urticina felina	dahlia anemone				x[1]				x[1]			x[1]	x[1]
Sagartia spp.		x	x	x	x	x	x	x	x	x	x		
Barnacles													
Balanus crenatus	crenate barnacle	x	x	x	x	x	x	x	x	x	x		x
Megabalanus coccopoma	titan acorn barnacle			x	x	x			x	x			
Semibalanus balanoides	rock barnacle	x	x			x	x	x		x	x	x	x
Balanus perforatus	acorn barnacle			x									
Elminius modestus	Australasian barnacle			x	x			x	x			x	x
Molluscs													
Crepidula fornicata	slipper limpet				x		x	x	x				x
Crassostrea gigas	Pacific oyster	x[1]		x	x				x	x	x	x	x
Ostrea edulis	edible oyster				x								x
Mytilus edulis	common mussel	x	x	x		x	x	x		x	x	x	
Tellimya ferruginosa					x			x					x
Odostomia scalaris								x	x				
Aeolidia papillosa	gray sea slug								x	x	x		x
Crustaceans													
Caprella mutica	skeleton shrimp	x	x	x	x		x	x	x	x	x	x	x
Stenothoe marina	marine gammarid amphipod			x	x			x	x			x	x
*Monocorophium acherusicum / M.sextonae / Jassa herdmani / J.marmorata**		x	x	x	x	x	x	x	x	x	x	x	x
Idotea pelagica	aquatic sowbug		x	x	x		x	x	x	x	x	x	x
Pilumnus hirtellus	hairy crab	x	x	x	x		x	x	x	x	x	x	x
Pisidia longicornis	porcelain crab		x	x	x			x	x	x		x	
Necora puber	velvet swimming crab		x[1]				x			x[1]	x[1]		
Cancer pagurus	edible crab		x[1]	x	x			x	x				x
Pinnotheres pisum	pea crab			x									
Insects													
Telmatogeton japonicus	marine splash midge				x			x	x				x
Echinoderms													
Asterias rubens	common starfish	x	x[1]	x	x	x	x	x	x	x	x	x	x
Ophiothrix fragilis	common brittlestar					x							
Psammechinus miliaris	green sea urchin		x	x	x	x	x		x	x	x		
Sponges													
Halichondria panicea	breadcrumb sponge				x					x			
Bryozoans													
Conopeum reticulum	sea mat (encrusting bryozoan	x	x	x	x	x	x	x	x	x	x		x
Cryptosula pallasiana	orange crust (bryzoan)												
Hydroids													
Tubularia larynx	ringed tubularia	x	x	x	x	x	x	x	x	x	x	x	x
Tubularia indivisa	oaten pipes hydroid			x				x					
Obelia spp.		x				x				x			
Obelia dichotoma	sea threat hydroid				x								
Halecium halecinum	herringbone hydroid							x				x	
Opercularella lacerata								x					
Polychaetes													
Lepidonotus clava	scale worm	x	x	x	x	x	x	x	x	x	x	x	x
Lepidonotus squamatus				x	x			x	x			x	x
Harmothoe impar				x	x			x	x			x	x
Nereis pelagica		x	x	x	x		x	x	x	x	x	x	x
Eunereis longissima				x	x			x	x			x	x
Eulalia viridis	greanleaf worm			x	x			x	x			x	x
Nassarius reticulus					x				x				
Lanice conchilega	sand mason			x	x			x	x				
Spirobranchus triqueter	keelworm				x								
Nemertines													
Lineus longissimus	bootlace worm				x		x		x				x
Nematodes													
Nematoda	nematodes			x	x			x	x			x	x
	Total number of species	17	20	31	38	16	20	33	35	25	20	23	29

[1] Identified on video, not in collected samples

Intertidal zone
Pictures of the intertidal zones of turbines 7, 13 and 34 in February and September 2011 are shown in figure 3.

The hard substrate communities in the intertidal zones of turbines 7 and 34 in February and September 2011 were comparable. The upper part of the intertidal zone of both turbines was characterised by the presence of a band of green algae (mainly *Ulva spp*., but also the red foliose algae *Porphyra* was identified in September on turbine 13) with different species of barnacles (see table 1) and several oysters (mainly *Crassostrea gigas*, but also individuals of the edible oyster *Ostrea edulis* were identified in September on turbines 7 and 34). Covering percentages of green algae in this zone varied between 80-100%, with slightly more algae in September than in February. Covering percentages for barnacles and oysters were estimated at approximately 5%, both in February and September. Below the band of green algae to a water depth of approximately two metres, the intertidal zone of these turbines was dominated by the presence of small mussels (*Mytilus edulis*). These mussels showed a 'patchy' distribution in February, with covering percentages varying from circa 0 to 60%, but in September this zone was almost entirely covered with small mussels (90-100%).

The hard substrate community in the intertidal zone of turbine 13 varied substantially from the other two turbines. The intertidal zone was relatively bare, both in February and September. Green algae dominated the entire intertidal zone with covering percentages varying between 80% and 100%. Only very few barnacles and small mussels were present in the lower part of the intertidal zone.

In February 2011 larvae of the marine splash midge (*Telmatogeton japonica*) were identified in the intertidal zone of turbine 13 (picture 5). In September 2011 this species was also found in the intertidal zone of turbines 13 and 34. This species was not found during the previous surveys carried out in 2008.

Picture 5. Larvae of the marine splash midge Telmatogeton japonica.

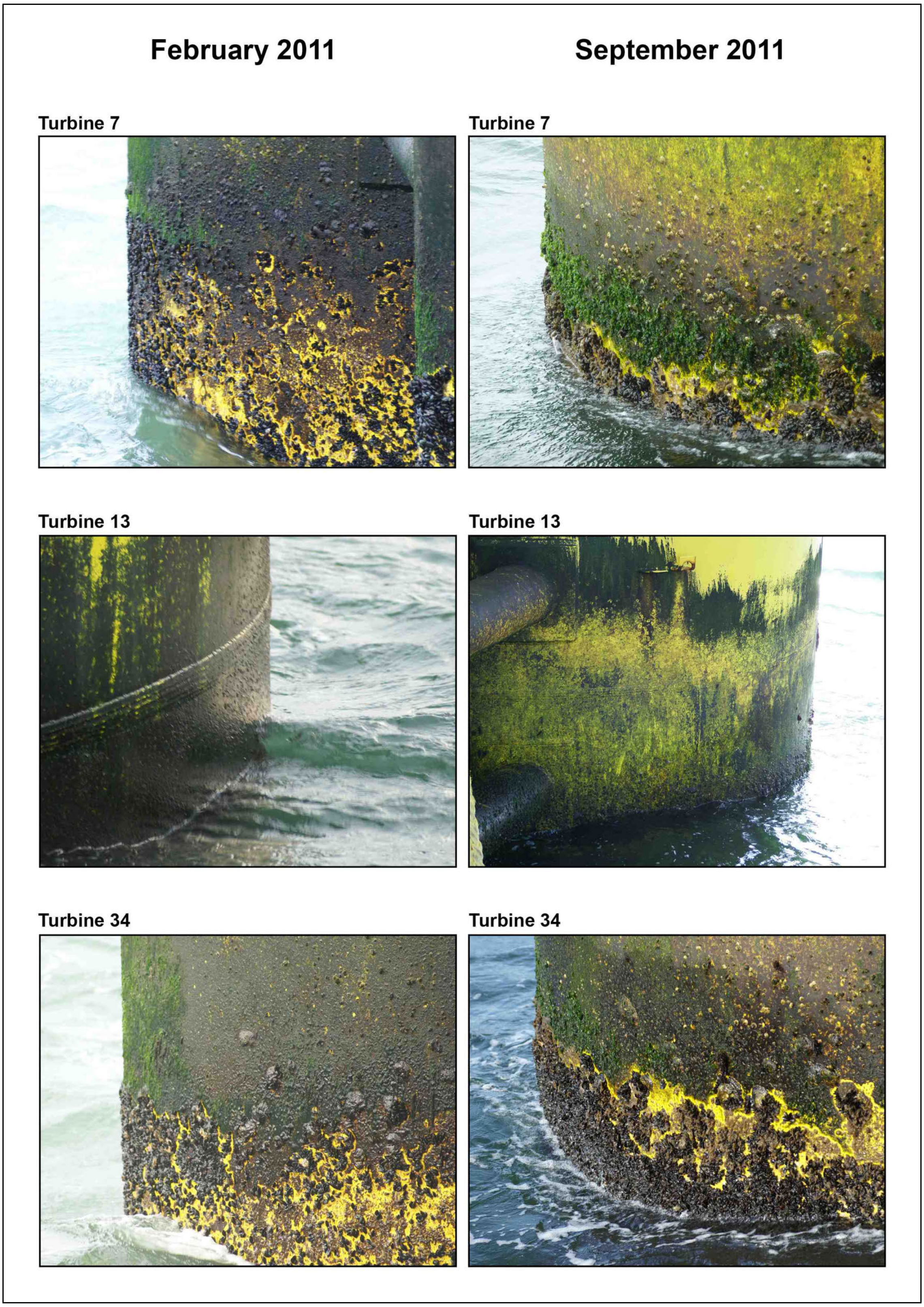


Figure 3. The intertidal zone of turbines 7, 13 and 34 in February and September 2011.

Subtidal zone

A full qualitative description of the hard substrate communities in the subtidal zone is provided in the paragraphs below. In these paragraphs the results of both the February and September surveys are combined. The given water depths are sampling depths and are not corrected to NAP (text box § 2.2.1).

Turbine 7 (figure 4)

In September 2008 the shallow subtidal zone to circa 3 m depth was almost fully covered by mussels (90-100%). In February 2011 small crustaceans (four different species, table 1) were most dominant in this zone (covering percentages varying between 40% and 60%) and covering percentages of mussels were much lower (5-10%). Anemones (mainly the plumose anemone *Metridium senile*; coverage <5%), common starfish (coverage <5%) and aquatic sow bugs were also common in this depth zone in February 2011. In September 2011 this zone was almost fully covered by small (juvenile) mussels (90-100%) similar to the situation in September 2008. Anemones and common starfish were still very common, but aquatic sow bugs were less abundant.

From circa 3 to 6 m depth, the monopile was covered by large (adult) mussels. Covering percentages were generally between 80% and 100% (both in February 2011 and September 2011), but at some places clumps of mussels have fallen of the monopile resulting in 'patches' of small crustaceans and anemones (most abundant the orange anemone *Diadumene cincta*). In September 2011 edible crabs were often found in these open patches. In comparison to the 2008 surveys, these mussels were more overgrown by other species (mainly small crustaceans and the orange anemone *Diadumene cincta*). In between the mussels polychaetes (several species) and crabs (most notable *Cancer pagarus*) were common and occasionally Pacific oysters and sea urchins were found.

During both surveys in February and September 2011 the zone from 6 to 12 m depth was totally covered (90-100%) by a thick layer of large (adult) mussels. These mussels were fully overgrown by small crustaceans and anemones (different species), but also small patches of the ringed tubularia were identified. In between the mussels many other species were identified similar to the species found in the 3 to 6 m depth zone.

From 12 m to the seafloor at circa 15 m depth the monopile was fully covered by tubes of small crustaceans (coverage between 80 and 100%) and anemones (mainly plumose anemones (0-20%), but also the orange anemone *Diadumene cincta* and *Sargartia spp*. anemones (both species <5%). Common starfish also occurred in this depth zone, but were less abundant than in the other depth zones.

Three species that were seen on video, but not collected in the samples were the sandalled anemone, the dahlia anemone and the breadcrumb sponge (picture 6). These species were not identified during the 2008 assessments.

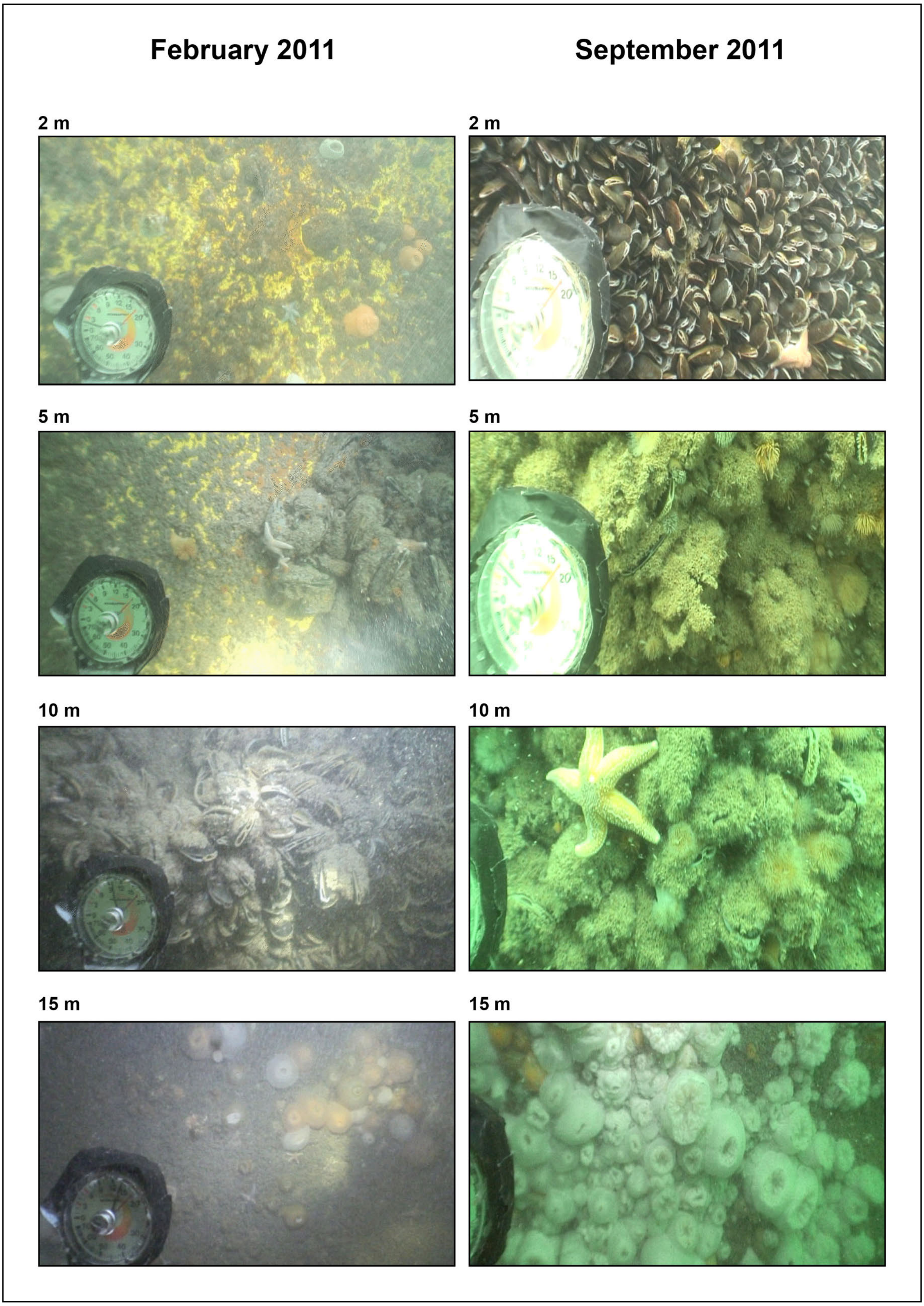


Figure 4. *Underwater growth on the monopile of turbine 7 at different depths in February and September 2011.*

Turbine 13 (figure 5)

In September 2008 mussels occurred to depths of 6 m. The subtidal zone to 5 m depth was fully covered by mussels (100%). In February and September 2011 mussels occurred to depths of 10 m, but showed a ‘patchy’ distribution with covering percentages varying between 30% and 70% in February 2011 and between 30% and 100% in September 2011 (with highest percentages in depth zones to circa 6-7 m depth). The slightly higher percentages in September 2011 can be explained by recolonisation of bare patches by small (juvenile) mussels, mainly in the depth zone from the surface to 2 m depth. Patches without mussels were (partly) colonised by small crustaceans (four different species, table 1), but also by several species of anemones (most notable the orange anemone *Diadumene cincta*) and small patches of the ringed tubularia. In between the mussels many other species were found mainly polychaetes and crabs (most notable *Cancer pagarus*, especially in September 2011).

From circa 6-7 m depth to the seafloor at 17 m depth the hard substrate community was dominated by small crustaceans, anemones (most notable the orange anemone *Diadumene cincta* and the plumose anemone) and patches of the ringed tubularia. In February 2011 covering percentages of these species with small crustaceans and orange anemones being most dominant in the depth zone from 6-7 m to 13 m (covering percentages respectively between 40-80% and 5-10 %) and ringed tubularia and small crustaceans being most dominant at depths between 13 and 17 m (covering percentages respectively between 40-60% and 20-40%). In September 2011 patches of ringed tubularia were less common and the monopile from 10-15 m depth was fully covered and dominated by small crustaceans and the orange anemone *Diadumene cincta* (and some plumose anemones).

Common starfish were very abundant at all depths, both in February and September 2011. Aquatic sow bugs were very abundant in February 2011, but less abundant in September 2011.

The sandalled anemone and the dahlia anemone, two species that were not found during the 2008 assessments (picture 6), were also identified on the video footage of the monopile of turbine 13, but were not collected in the samples.

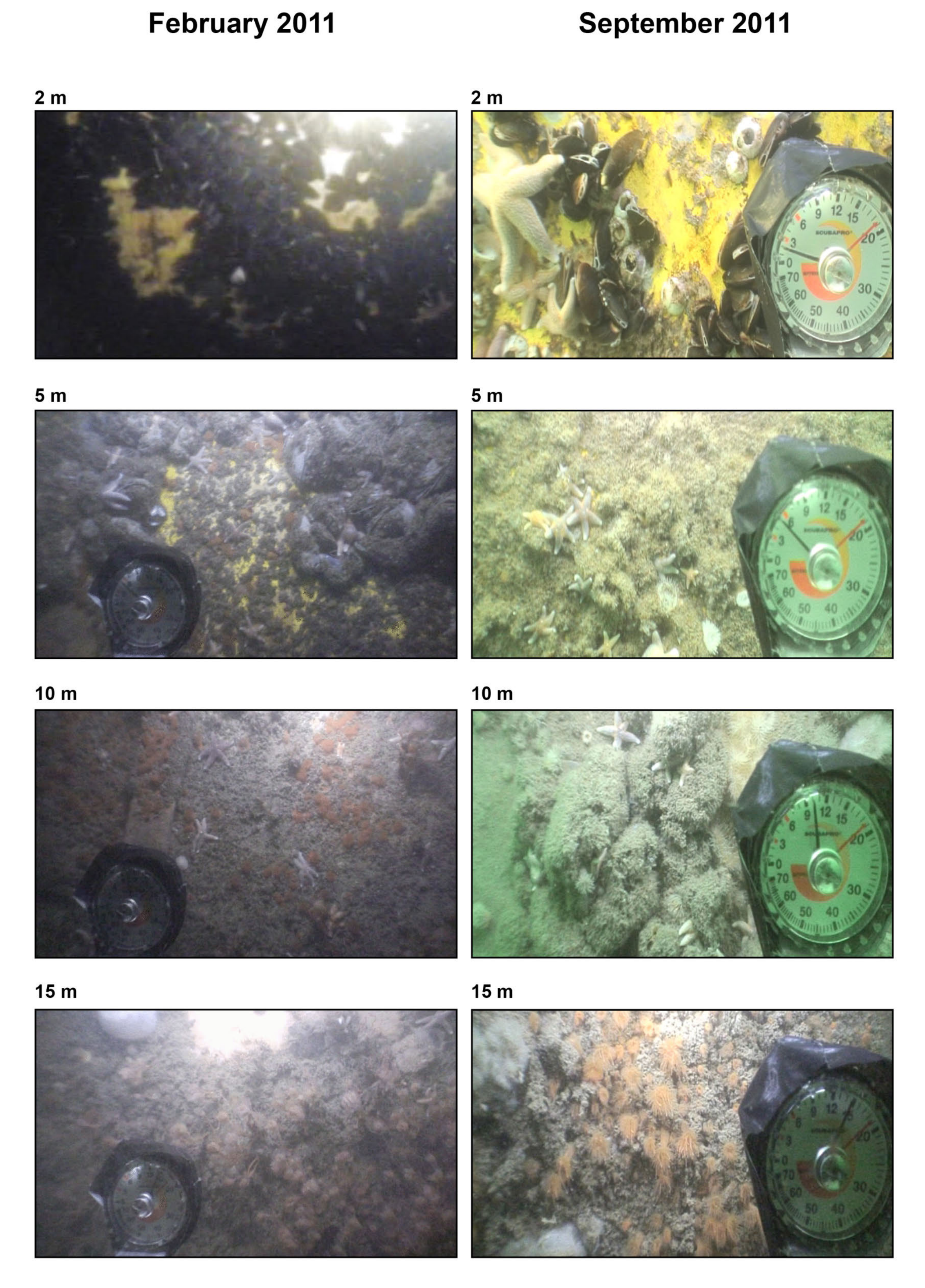


Figure 5. *Underwater growth on the monopile of turbine 13 at different depths in February and September 2011.*

Turbine 34 (figure 6)
The shallow subtidal zone to circa 3 m depth was comparable the turbine 7. This zone was only partly covered by mussels in February 2011 (circa 5%), but in September 2011 this zone was fully covered by small (juvenile) mussels (100%) similar to the situation in September 2008. Patches without mussels in February 2011 were bare (30-40%) or covered by small crustaceans (four species, table 1; 55-65%) and plumose anemones (<5%).

The depth zone from 3 to 6 m was different from turbine 7. This zone of the monopile of turbine 34 was not dominated by large mussels, but by small crustaceans and the orange anemone *Diadumene cincta*, both in February 2011 and September 2011. Covering percentages of these species varied from respectively circa 70% (February) and 50% (September) for small crustaceans and 10% (February) and 50% (September) for the orange anemone *Diadumene cincta*. Also common at these depths were plumose anemones (<5% coverage) and common starfish.

The depth zone from 6 to 12 m was comparable again with turbine 7. The monopile was almost fully covered (90-100%) by a thick layer of large (adult) mussels that were overgrown by small crustaceans and anemones (most notable the orange anemone *Diadumene cincta* and plumose anemones; coverage both species circa 5%). At some places clumps of mussels have fallen of the monopile resulting in 'patches' of small crustaceans and anemones. In September 2011 edible crabs were often found in these open patches. In between the mussels polychaetes (several species) and crabs (different species) were common and occasionally a Pacific oyster was found.

From 12 m to the seafloor at circa 15 m depth the monopile was fully covered by tubes of small crustaceans (coverage 80-100%), anemones (mainly plumose anemones (0-20%), but also the orange anemone *Diadumene cincta* and *Sargartia spp*. anemones (<5%)) and small patches of the ringed tubularia (<5%).

Common starfish were highly abundant at all depths, both in February and September 2011. Aquatic sow bugs were very abundant in February 2011, but less abundant in September 2011.

Two species that were seen on video, but not collected in the samples were the dahlia anemone and the breadcrumb sponge (picture 6). These species were not identified during the 2008 assessments.

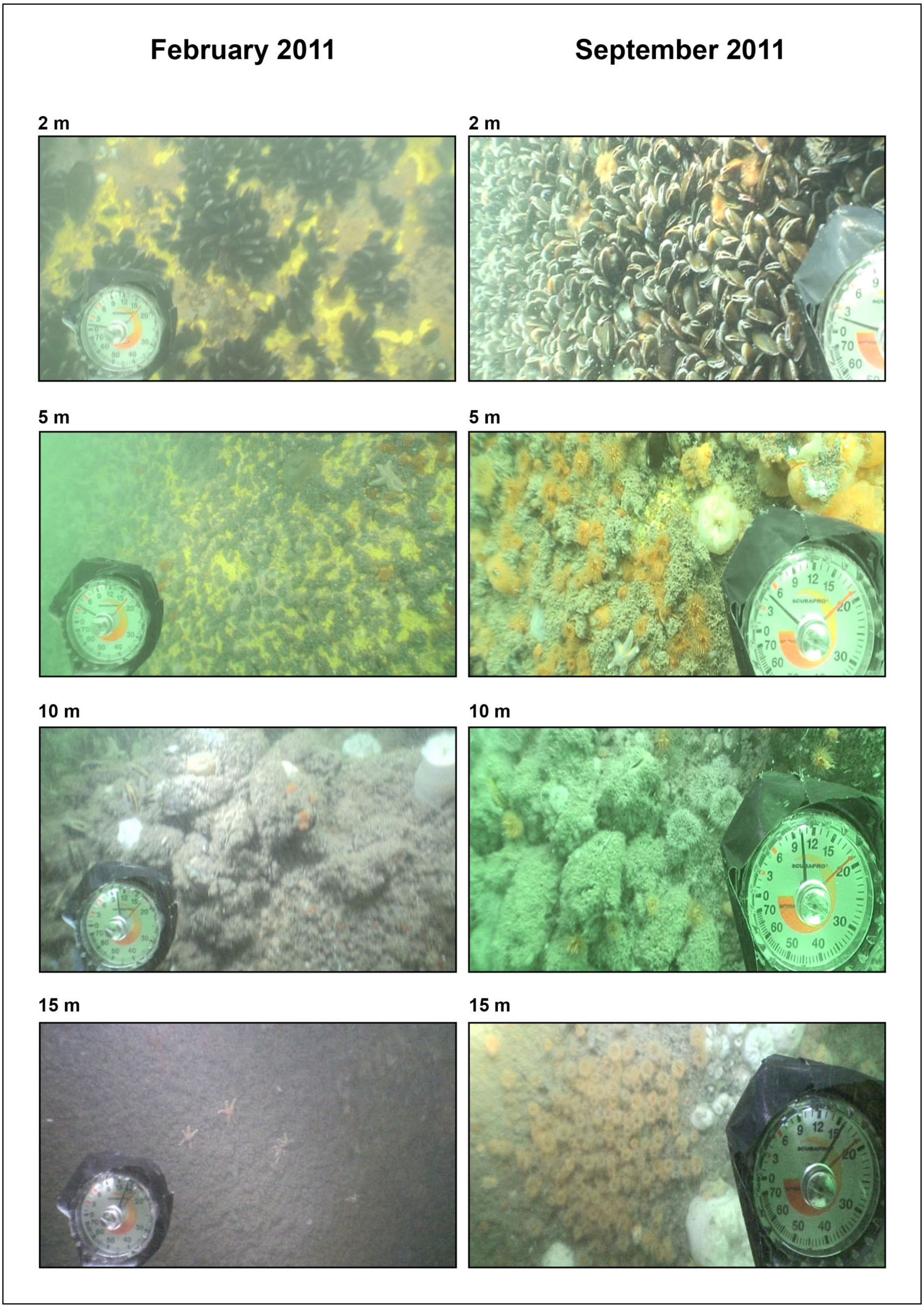


Figure 6. *Underwater growth on the monopile of turbine 34 at different depths in February and September 2011.*

Picture 6. Two species identified on video of the monopiles, not collected in the samples: left the dahlia anemone (Urticina felina) and right the breadcrumb sponge (Halichondria panicea).

3.1.2 Quantitative assessment monopiles

In appendix 4 the densities and biomasses of the dominant species in the collected samples are presented for all four surveys in both 2008 and 2011. The following paragraph presents the development of the most dominant species of the hard substrate community in the period 2008-2011.

The presented data only provide an indication of actual quantities, because:
- Most importantly, covering percentages on the monopiles (also within the same depth) and on the scour protection layer show substantial variation (visible on collected footage). As a result, substantial variation also exists between samples;
- Sample collection along the monopiles was not always accurate due to harsh working conditions (e.g. strong currents and wave action).

Density and biomass of all taxa combined

Marine organisms within the hard substrate communities on the monopiles reached extreme densities, up to almost 28,000 individuals per m^2 in September 2011 (figure 7). Small crustaceans (*Monocorophium acherusicum, Monocorophium sextonae, Jassa herdmani* and *Jassa marmorata*) contributed most to these densities with circa 22,000 individuals per m^2 (figure 11), followed by common mussels (circa 4,000 individuals per m^2; figure 9), anemones ((*Actinia equina, Actinothoe sphyrodeta, Diadumene cincta, Metridium senile, Urticina felina and Sagartia spp.* combined; circa 1,000 individuals per m^2; figure 12), common starfish (circa 130 individuals per m^2; figure 13) and polychaetes (up to 500 individuals per m^2). A clear increase in density occurred over the study period between February 2008 and September 2011 (figure 7).

Sea urchins (*Psammechinus miliaris*) were one of the dominant species in the 2008 surveys, with densities reaching circa 7 and 20 individuals per m^2 in February and September 2008 respectively. In 2011 these densities were much lower, namely 0-1 individuals per m^2 (appendix 4).

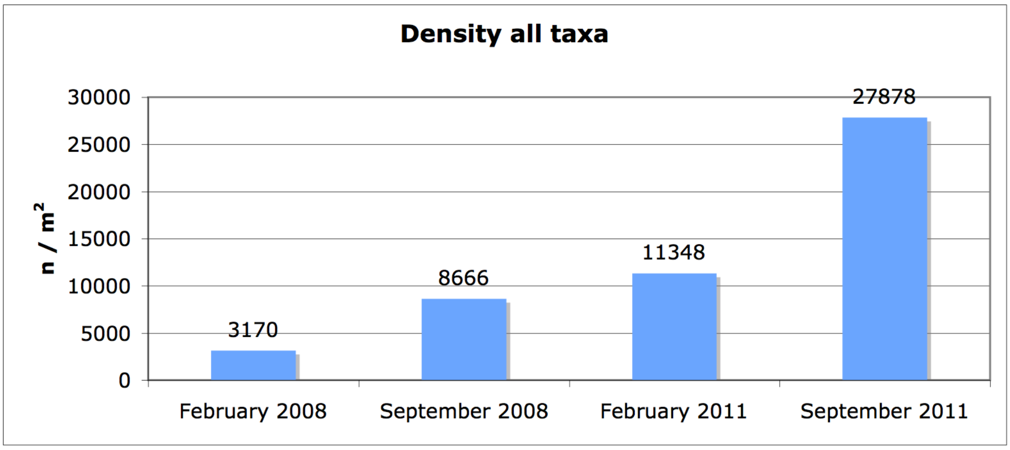


Figure 7. Average densities (numbers per m^2) of collected marine organisms for all taxa combined on the monopiles in OWEZ.

Biomass of all taxa combined varied between circa 450 g AFDW in February 2008 and 1,400 g AFDW per m^2 in September 2008. Biomass values reached its maximum in September 2008 (circa 1,400 g AFDW per m^2) (figure 8). Biomass values expressed in wet weights (approximately 10 times higher than AFDW) varied between circa 8 and 14 kg per m^2 in 2011. The common mussel contributed most to the total biomass (on average 83% of the total biomass) followed by anemones (on average 7 % of the total biomass).

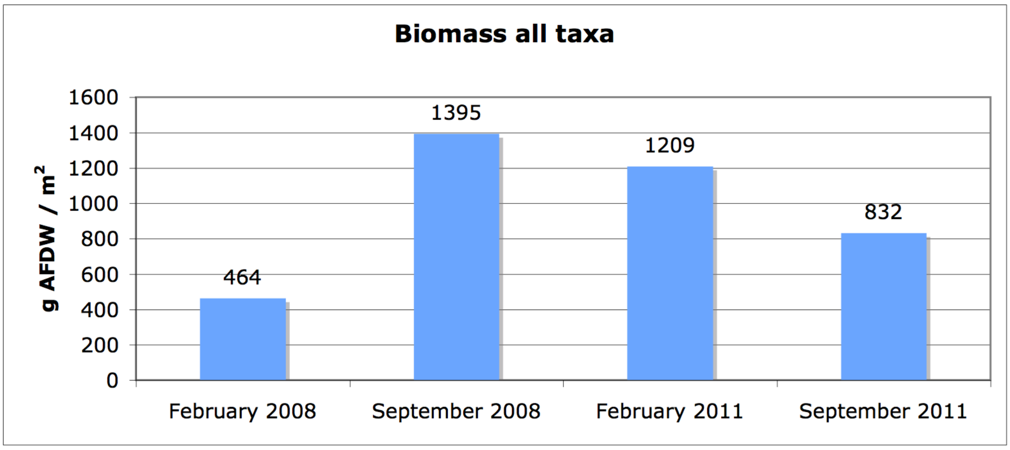


Figure 8. Average biomass (g AFDW / m^2) of collected marine organisms for all taxa combined on the monopiles in OWEZ.

Density and biomass of the common mussel (*Mytilus edulis*)
Average densities of mussels were 1,600 per m^2 in February 2011 and 4,200 per m^2 in September 2011 (figure 9). Only densities of small crustaceans were higher in February and September 2011 (circa 8,500 per m^2 and 22,000 per m^2).

Average biomasses of mussels were circa 900 g AFDW per m^2 in February 2011 and 700 g AFDW per m^2 in September 2011 (circa 7-9 kilograms of wet weight per m^2), making this species most dominant in terms of biomass.

Densities and biomasses of mussels in February and September 2011 were lower than in September 2008, but higher than in February 2008 (figure 9). In both years, densities were higher in September than in February, which can be explained by loss of mussels in the winter period due to storms and recolonisation by young mussels in the summer period. In 2008, biomasses of mussels were higher in September than in February, but in 2011 biomasses in February and September were comparable (figure 10). (The (small) difference between the February 2011 and September 2011 surveys may be an effect of natural variation and limitations in sampling accuracy).

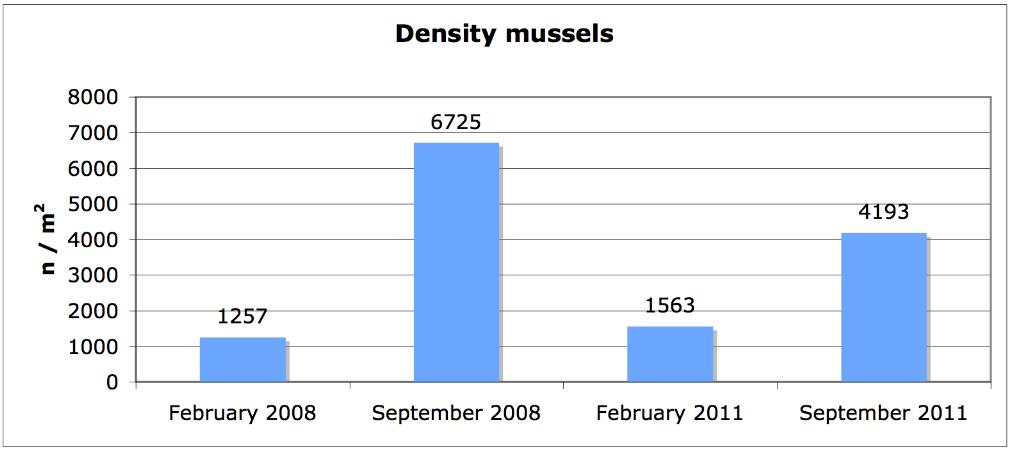


Figure 9. Average densities (numbers per m^2) of the common mussel (Mytilus edulis) in the collected samples on the monopiles in OWEZ.

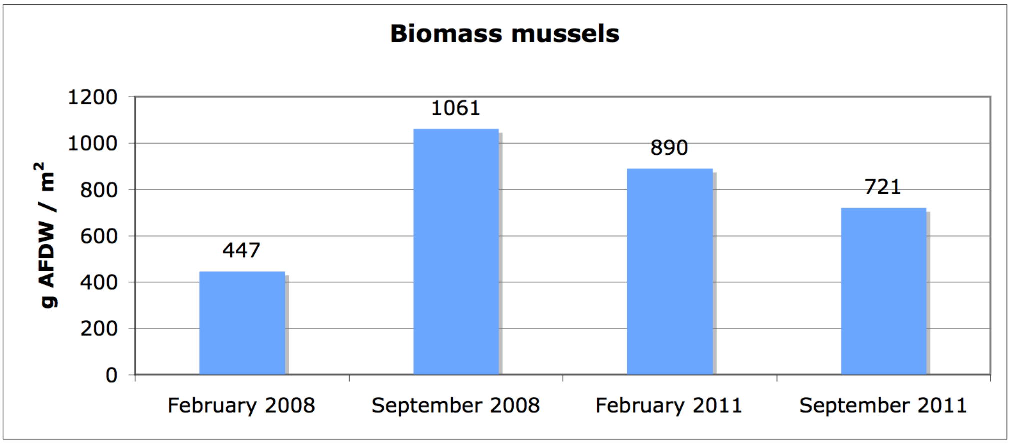


Figure 10. Average biomass (g AFDW per m^2) of common mussel (Mytilus edulis) in the collected samples on the monopiles in OWEZ.

Density small crustaceans

Small crustaceans of the species *Monocorophium acherusicum, Monocorophium sextonae, Jassa herdmani and Jassa marmorata* occured in high densities on the monopiles, and their density showed a strong increase between February 2008 and

September 2011. In September 2011, they were the most dominant organisms in the collected samples with densities reaching over 22,000 per m^2 (figure 11). They occurred on the bare substrate, but also on other organisms such as mussels. They reached body sizes up to more than 1 cm, but generally they were very small and their combined biomass did not reach more than circa 10.0 g AFDW per m^2 (Appendix 4).

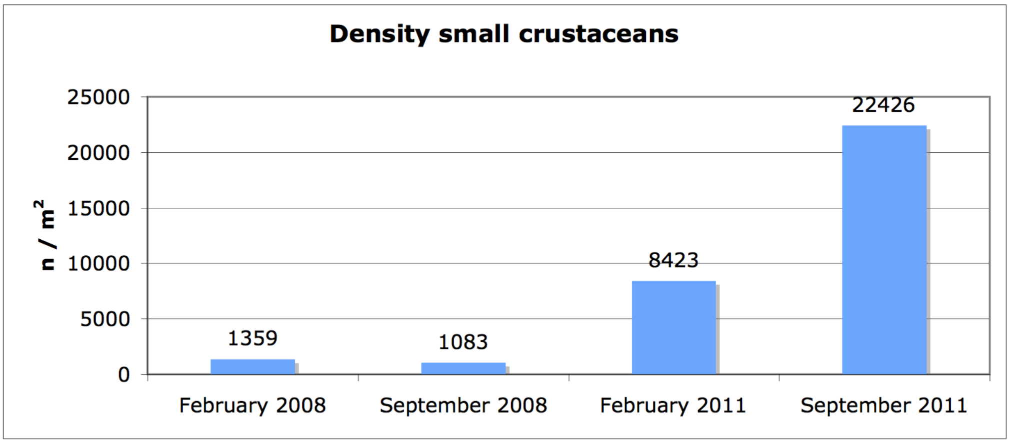


Figure 11. Average densities (numbers per m^2) of small crustaceans (*Monocorophium acherusicum, Monocorophium sextonae, Jassa herdmani* and *Jassa marmorata* combined) in the collected samples on the monopiles in OWEZ.

Densities of anemones and common starfish

Average densities of anemones were circa 1,000 per m^2 in February 2011 and circa 800 per m^2 in September 2011 (figure 12). Only densities of small crustaceans and mussels were higher (respectively circa 22,00 per m^2 and circa 4,000 per m^2; figure 11 and figure 9).

Average biomasses of anemones were approximately 50 g AFDW per m^2 in February 2011 and 75 g AFDW per m^2 in September 2011, making this species the second most dominant in terms of biomass.

In both February and September 2011, densities of anemones were higher than in 2008.

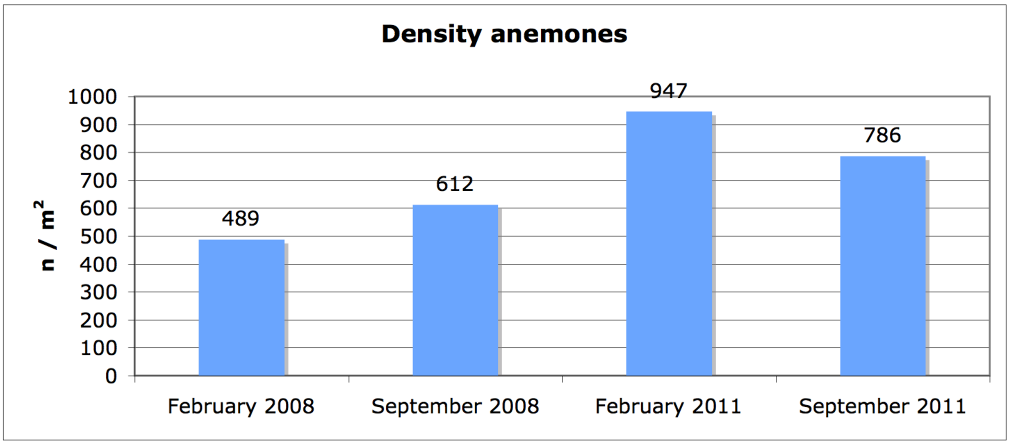


Figure 12. Average densities (numbers per m^2) of anemones in the collected samples (Actinia equina, Actinothoe sphyrodeta, Diadumene cincta, Metridium senile, Urticina felina and Sagartia spp. combined) on the monopiles in OWEZ.

Average densities of common starfish (*Asterias rubens*) were circa 100 per m^2 in February 2011 and circa 130 per m^2 in September 2011 (figure 13). Only densities of small crustaceans, mussels and anemones were higher (respectively circa 22,000 per m^2, circa 4,000 per m^2 and circa 800 per m^2; figures 11, 9 and 12).

In both February and September 2011 densities of common starfish were significantly higher than in 2008.

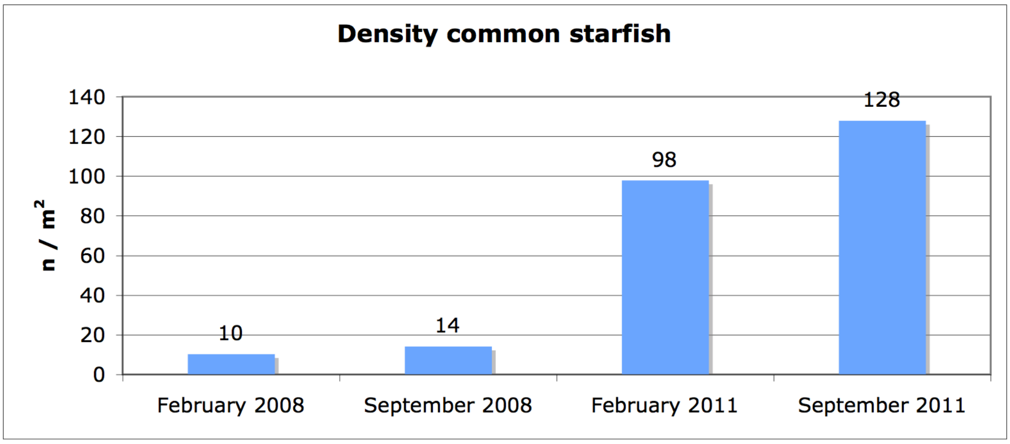


Figure 13. Average densities (numbers per m^2) of the common starfish (Asterias rubens) in the collected samples on the monopiles in OWEZ.

3.1.3 Qualitative assessment scour protection layer

<u>Species</u>

Table 3 shows the total number of species identified on the video footage and/or collected samples from the scour protection layers, both for the assessments carried out in February 2011 and September 2011. Species identified during previous assessments in 2008 are included in this table for comparison.

In 2008 and 2011 a total of 35 species were identified on the scour protection layers (24 in 2008 and 18 in 2011).

In 2011, eight new species were identified on the monopiles that were not identified in 2008: the Australasian barnacle (*Elminius modestus*), the porcelain crab (*Pisidia longicornis*), the common brittle star (*Ophiotrix fragilis*), the breadcrumb sponge (*Halichondria panicea*), the hydroids *Tubularia indivisa* and *Halecium halecinum* and the polychaetes *Lepidonotus squamatus* and *Nassarius reticulates.*

A total of 14 species identified in 2008 were not identified in 2011: the crenate barnacle *Balanus crenatus*, the rock barnacle *Semibalanus balanoides*, the slipper limpet *Crepidula fornicata*, the aquatic sowbug *Idothea pelagica*, the velvet swimming crab *Necora puber*, the edible crab *Cancer pagarus*, the green sea urchin *Psammechinus miliaris*, the orange crust *Cryptosula pallasiana*, the hydroids *Tubularia larynx* and *Obelia spp*., the polychaetes *Nereis pelagica*, *Lanice conchilega* and *Spirobranchus triqueter* and the bootlace worm *Lineus longissimus*.

In 2008, no distinction was made between the crustacean *Jassa herdmani, Jassa marmorata, Monocorophium acherusicum* and *Monocorophium sextonae*. Instead these four species were all grouped under *Jassa spp*.. The presence of these four species has been confirmed in the scour holes (§ 3.2.1). Therefore, it might be expected that these four species were present on the scour protection layers as well.

Table 3. Species identified on the scour protection layers of turbines 7, 13 and 34 during surveys carried out in February and September 2008 and 2011.

		Turbine 7				Turbine 13				Turbine 34			
		2008		2011		2008		2011		2008		2011	
Species	English name	February	September	February	September	February	September	February	September	February	September	February	September
Algae													
Porphyra spp.	foliose red algae												
Ulva spp.	sea lettuce												
Anemones													
Actinia equina	beadlet anemone												
Actinothoe sphyrodeta	sandalled anemone												
Diadumene cincta	orange anemone	x	x		x		x	x		x	x		
Metridium senile	plumose anemone	x	x	x	x	x	x	x	x	x	x	x	x
Urticina felina	dahlia anemone												
Sagartia spp.		x	x	x	x	x	x			x	x		x
Barnacles													
Balanus crenatus	crenate barnacle	x	x										
Megabalanus coccopoma	titan acorn barnacle												
Semibalanus balanoides	rock barnacle						x						
Balanus perforatus	acorn barnacle												
Elminius modestus	Australasian barnacle							x					
Molluscs													
Crepidula fornicata	slipper limpet									x			
Crassostrea gigas	Pacific oyster	x								x	x		x
Ostrea edulis	edible oyster												
Mytilus edulis	common mussel	x[1]	x	x[1]	x[1]		x[1]	x[1]	x[1]			x[1]	x[1]
Tellimya ferruginosa													
Odostomia scalaris													
Aeolidia papillosa	gray sea slug												
Crustaceans													
Caprella mutica	skeleton shrimp		x				x	x			x		
Stenothoe marina	marine gammarid amphipod												
*Monocorophium acherusicum / M.sextonae / Jassa herdmani / J.marmorata**		x	x	x[1]	x	x	x	x	x[1]	x	x	x	x
Idotea pelagica	aquatic sowbug		x				x						
Pilumnus hirtellus	hairy crab												
Pisidia longicornis	porcelain crab				x				x				x
Necora puber	velvet swimming crab						x[1]				x[1]		
Cancer pagurus	edible crab						x[1]				x[1]		
Pinnotheres pisum	pea crab												
Insects													
Telmatogeton japonicus	marine splash midge												
Echinoderms													
Asterias rubens	common starfish	x[1]	x[1]	x	x	x[1]	x[1]	x	x[1]	x	x[1]	x[1]	x
Ophiotrix fragilis	common brittlestar				x				x				x
Psammechinus miliaris	green sea urchin		x										
Sponges													
Halichondria panicea	breadcrumb sponge							x	x				
Bryozoans													
Conopeum reticulum	sea mat (encrusting bryozoan)	x	x	x	x	x	x	x		x	x	x	x
Cryptosula pallasiana	orange crust (bryzoan)	x								x			
Hydroids													
Tubularia larynx	ringed tubularia	x					x			x			
Tubularia indivisa	oaten pipes hydroid							x					
Obelia spp.		x				x				x	x[1]		
Obelia dichotoma	sea threat hydroid												
Halecium halecinum	herringbone hydroid			x									
Opercularella lacerata													
Polycheates													
Lepidonotus clava	scale worm		x	x			x				x		
Lepidonotus squamatus								x					
Harmothoe impar													
Nereis pelagica			x				x						
Eunereis longissima													
Eulalia viridis	greanleaf worm												
Nassarius reticulus				x									x
Lanice conchilega	sand mason	x											
Spirobranchus triqueter	keelworm									x			
Nemertines													
Lineus longissimus	bootlace worm		x										
Nematodes													
Nematoda	nematodes												
	Total number of species	13	14	8	8	6	15	10	6	12	12	4	9

[1] Identified on video, not in collected samples

Covering percentages
Video stills of the rocks of the scour protection layers collected in September 2011 are shown in figure 14 (turbine 7), figure 15 (turbine 13) and figure 16 (turbine 34). The quality of the pictures taken in February 2011 was poor due to the limited underwater visibility. Therefore these pictures are not included.

Like in September 2008, there were no clear differences between the hard substrate communities on rocks collected from the scour protection layers of the three different turbines. Most dominant were plumose anemones (coverages varying between 50-100%), (tubes of) small crustaceans (100% coverage at places without anemones) and the encrusting sea mat *Conopeum reticulum*. Common starfish were also very abundant. Less abundant species include other species of anemones (e.g. *Sargartia spp*., and the orange anemone *Diadumene cincta*), crabs (velvet swimming crab and edible crab) and several species of polychaetes and hydroids (table 3).

Two new species identified on the scour protection layers were the breadcrumb sponge (turbine 13) and eggs of the mollusc *Nassarius reticulates* (turbine 7).

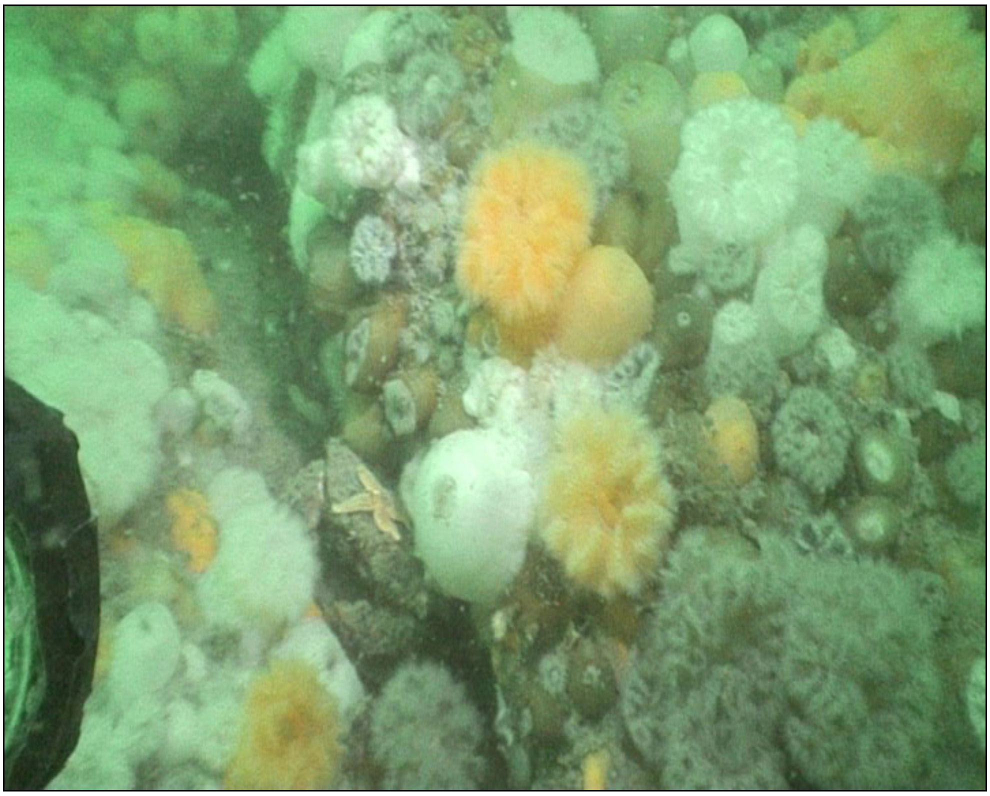


Figure 14. Video still of the scour protection layer of turbine 7 (taken 25th of September 2011).

Figure 15. *Video still of the scour protection layer of turbine 13 (taken 24th of September 2011).*

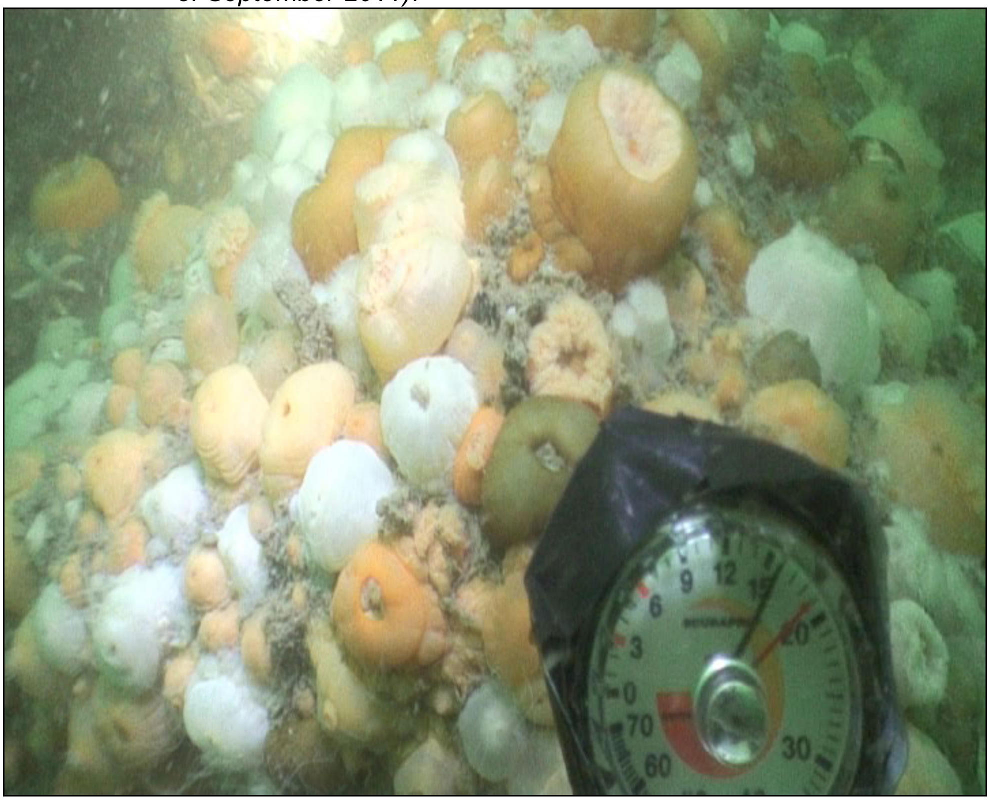


Figure 16. *Video still of the scour protection layer of turbine 34 (taken 24th of September 2011).*

3.1.4 Quantitative assessment scour protection layer

Quantitative information about the most abundant species found on the rocks of the scour protection layer of turbines 7, 13 and 34 is presented in Appendix 5. Generally, the most abundant species in the scour protection samples were anemones (mostly *Metridium senile,* but also *Diadumene cincta* and *Sargartia spp*.), starfish (both *Asterias rubens* and *Ophiothrix spp*.), the sea mat (*Conopeum reticulum)* and small crustaceans (*Monocorophium acherusicum, Monocorophium sextonae, Jassa herdmani* and *Jassa marmorata*). No clear differences could be identified in the dominance of species between the surveys carried out in 2008 and 2011.

In the following paragraphs densities per m^2 are presented. These densities are calculated using the number of species in the sample and the sampling area. It should be noted that the extrapolation to densities per m^2 are subject to large error margins due to the low number of samples collected and the high variation between the samples. Therefore, the densities should be regarded as indicative only.

Densities of marine organisms on the scour protection are high. Anemones (all species combined) reach densities of circa 2,500 individuals per m^2, approximately 2.5 times higher than on the monopiles, where they reach densities of circa 1,000 per m^2. Starfish (both species combined) reached densities of circa 180 individuals per m^2. The covering percentages of the sea mat and small crustaceans (all species combined) varied between respectively 60-100% and 30-50%.

Some samples showed different species compositions and densities. In September 2008 one rock was collected, where a large quantity of mussels had fallen from the monopile on the scour protection. The mussel density was circa 10,000 individuals per m^2. In September 2011, one sample contained a large specimen of the breadcrumb sponge *Halichondria panicea*. On this sponge, a large number of *Caprella cf. mutica* were identified reaching a density of circa 65,000 per m^2.

3.2 Scour holes

The results of samples taken in the scour holes are presented in the following paragraphs. It should be noted that these samples are collected in the period around slack tide, when currents are relatively low (necessary for a safe diving operation, see text box § 2.2.1). In this situation organisms and sediment particles in the water column may sink to the seafloor and temporarily accumulate in these holes. In other phases of the tidal cycle tidal currents get stronger and the accumulated material may wash out again. Therefore, the results present only the situation in the scour holes during the period around slack tide.

3.2.1 Benthos

<u>Species</u>

The sediment cores collected in the scour holes did not only contain species characteristic for sandy substrates, but also species that are characteristic for hard substrates. It is likely, that these hard substrate species have detached from the monopiles and rocks of the scour protection layers and subsequently have accumulated in the scour holes. A total of 55 different species were identified in the samples collected during both the February and the September surveys, 26 species characteristic for sandy substrates (table 4) and 29 species characteristic for hard substrates (table 5).

Hard substrates

Most of the hard substrate species listed in table 4 were similar to the species found on the monopiles (see table 1) and/or rocks of the scour protection layers (see table 3). New hard substrate species found in the sediment cores collected in the scour holes are *Clytia hemisphaerica*, *Ectopleura larynx*, *Abludomelita obtusata*, *Phtisica marina* and *Arenicola defodiens*. It is likely that these species are present on the monopiles and/or the rocks of the scour protection layers as well. More species were found in February (24 species) than in September (12 species), which was mainly caused by the high number of species (22 species) found in the samples taken in the scour hole of turbine 13.

Table 4. Species characteristic for hard substrates identified in sediment cores taken in scour holes of turbines 7, 13 and 34.

Taxonomic group	Taxon/*species*	Turbine 7		Turbine 13		Turbine 34		Total	
		February	September	February	September	February	September	February	September
Bryozoans	*Conopeum reticulum*		x		x	x		x	x
	Electra pilosa			x	x			x	x
Cnidaria	Campanulariidae	x	x	x	x	x	x	x	x
	Clytia hemisphaerica			x	x			x	x
	Ectopleura larynx	x		x				x	
	Tubularia indivisa			x				x	
	Thenaria	x	x	x	x			x	x
Crustacea	*Abludomelita obtusata*	x		x				x	
	Caprella cf. mutica								
	Idotea pelagica	x		x				x	x
	Jassa herdmani	x	x	x	x	x	x	x	x
	Jassa marmorata		x	x	x			x	x
	Monocorophium acherusicum	x		x			x	x	x
	Monocorophium sextonae	x		x				x	
	Stenothoe marina	x	x	x		x		x	x
	Phtisica marina			x				x	
	Pinnotheres pisum					x		x	
Echinodermata	*Asterias rubens*	x	x	x				x	x
Insects	*Telmatogeton japonicus*				x				
Molluscs	*Mytilus edulis*			x				x	
	Nassarius reticulatus (egg capsules)		x	x	x			x	x
	Nudibranchia			x				x	
Polychaetes	*Arenicola defodiens*			x				x	
	Eulalia viridis	x		x				x	
	Harmothoe impar			x				x	
	Nereis pelagica			x				x	
	Number of species	11	8	22	9	5	3	24	12

can also be found in sandy substrates
new species in September

Sandy substrates

The number of species found in February (19 species) and September (23 species) was comparable and no differences could be detected between turbines.

Many endobenthic species (species living in the sediment) were present in the samples as single specimens. Therefore, the limited number of samples only allow for a global assessment of the species composition. It is expected that the actual number of these species in the scour holes is higher. Most endobenthic species identified in the sediment cores were polychaetes.

A remarkable find was a specimen of the polychaet *Sthenelais boa*. This species has been reported for OWEZ before (Jarvis *et al.,* 2004), but has not been encountered in the national monitoring programme for benthos in recent years. The polychaet *Cossura longocirrata* was also identified and although the identity could not be confirmed with certainty it is unlikely to be confuses with other species of polychaetes.

Table 5. Species characteristic for sandy substrates identified in sediment cores taken in scour holes of turbines 7, 13 and 34.

Taxonomic group	Taxon/*species*	Turbine 7		Turbine 13		Turbine 34		Total	
		February	September	February	September	February	September	February	September
Crustacea	*Bathyporeia elegans*					x		x	
	Diastylis bradyi						x		x
	Leucothoe incisa		x						x
	Orchomenella nana			x				x	
	Pariambus typicus						x		x
	Philocheras trispinosus						x		x
	Urothoe brevicornis	x				x		x	
	Urothoe poseidonis	x		x			x	x	x
Molluscs	Bivalven				x				x
	Ensis directus						x		x
	Tellina fabula						x		x
	Tellimya ferruginosa	x						x	
Nematoda	Nematoda		x	x	x	x	x	x	x
Nemertea	Nemertea	x	x	x	x		x	x	x
Nemertea	*Nemertea rodeband*	x	x		x	x	x	x	x
Phoronida	Phoronida	x					x	x	x
Polychaetes	*Capitella capitata*		x	x	x			x	x
	Cossura longocirrata					x		x	
	Eteone longa	x	x	x	x	x	x	x	x
	Eunereis longissima		x	x	x		x	x	x
	Eumida sanguina		x						x
	Lanice conchilega	x	x	x		x	x	x	x
	Malmgrenia darbouxi	x	x	x	x	x	x	x	x
	Nephtys cirrosa	x				x		x	
	Notomastus latericeus				x				x
	Phyllodoce mucosa	x	x	x				x	x
	Poecilochaetus serpens		x				x		x
	Scoloplos armiger	x	x			x		x	x
	Spio decoratus		x		x				x
	Sthenelais boa			x				x	
	Number of species	12	14	10	10	10	15	19	23

new species in September

<u>Densities, biomass and production values</u>

In table 6 the total density of all species combined and measured or calculated biomass and production values are presented for samples collected in the scour holes.

This table shows great differences both between the different surveys in February and September and the different turbines. Taking into account that the divers were not completely sure, whether they were actually sampling in the scour holes in February 2011 (due to poor underwater visibility) and that the number of samples was low, no attempts are made to explain these differences.

Table 6. Densities, biomass and production values of organisms collected in the scour holes of turbines 7, 13 and 34.

		Turbine 7		Turbine 13		Turbine 34	
		February	September	February	September	February	September
Sandy substrate species							
density	n / m^2	4,303	442	54,908	766	147	442
biomass	g AFDW / m^2	13.0	13.6	112.8	2.4	0.4	0.4
production	g AFDW/ m^2 / year	11.9	6.8	111.9	2.2	0.6	0.6
Hard substrate species							
density	n / m^2	2,800	1,798	1,562	648	472	1,798
biomass	g AFDW / m^2	44.3	17.1	5.7	0.3	1.4	14.8
production	g AFDW/ m^2 / year	68.0	24.5	8.1	0.5	2.4	21.6

3.2.2 Grain size

In table 7 the median particle size and the percentage silt (fraction < 63 μm) in the scour holes of turbines 7, 13 and 34 (10 cm depth) is presented and compared with data collected during benthic fauna surveys carried out in 2011 by NIOZ at 19 other locations (Bergman *et al.,* in prep.) within the wind farm.

Table 7. Median particle size and percentage silt (fraction < 63 μm) in the scour holes of turbines 7, 13 and 34 (10 cm depth) and 19 other locations within the wind farm (Bergman et al., in prep).

Location	Median particle size (μm)	Fraction < 63 μm (%)
Scour hole turbine 7 (n=3)	247	2.4
Scour hole turbine 13 (n=4)	232	3.4
Scour hole turbine 34 (n=4)	249	1.8
Average scour holes (n=11)	**243**	**2.5**

4 Discussion

4.1 Methods: lessons learnt

Monitoring hard substrate communities on monopiles and scour protection layers of offshore wind turbines is still relatively new. Lessons learnt in this study include:

- Dive operations for these assessments can only be carried out in the period around slack tide. In OWEZ this gives a maximum dive time of circa 1.5 hours per slack tide period to collect the video footage and the samples. The effort in this study was the maximum achievable within two days and was only possible, because there were no setbacks.
- It is difficult for divers to sample the intertidal zone accurately because of waves and currents. In this study sampling in the intertidal zone was carried out from a rigid inflatable boat (RIB), but this can only be done safely when sea conditions are calm.
- The combination of underwater video and sampling by divers proved to be an effective method for studying the benthic hard substrate communities. The video footage and the samples complement each other and are both necessary for an accurate assessment of hard substrate communities. Organisms that occur in low densities are easily missed in the samples (e.g. in this study the sandalled anemone, the dahlia anemone and the breadcrumb sponge) and very small organisms (such as the various crustacean species) are impossible to identify on the video footage. Furthermore, sampling is not always accurate in the challenging working conditions of the North Sea, and video footage provides useful complement to quantify relative abundance of organisms.

4.2 Hard substrates

4.2.1 Ecological relevance of identified hard substrate communities

Food source for fish- and bird species

Small crustaceans and polychaete worms can provide a valuable food source for fish species such as the North Sea cod (*Gadus morhua*) and pouting (*Trisopterus lucus*). The North Sea cod is an important commercial species that showed a strong decline in the North Sea as a result of over-fishing. Pouting is commercially less interesting, but can be a food source for birds such as cormorants (*Phalacrocorax carbo*).

Mussels can be eaten by bird species such as common eider (*Somateria mollisima*) and common scoter (*Melanitta nigra*).

In this paragraph a simplified extrapolation is carried out to determine the total numbers and biomasses of small crustaceans, polychaete worms and mussels to determine the ecological relevance of the hard substrate communities identified on the monopiles.

First the total underwater surface area of hard substrates provided by the 37 monopiles of OWEZ was estimated as follows:

- Calculation of the surface area of the monopile of one turbine:
  The diameter of the monopile is 4.5 m on average and the length of the underwater area of the monopile, which is similar to the depth in the wind farm, on average circa 18 m. The surface area was calculated using the formula $2*\pi*r*h=2*3.14*2.25*18 = 254{,}34\ m^2$.
- Calculation of the total surface area of hard substrates in OWEZ:
  37 monopiles * 254.34 m^2 = 9,410.58 m^2.

Then the average density and biomasses of common mussels, small crustaceans and polychaete worms per turbine were calculated using data collected in February and September 2011 (Appendix 4) and extrapolated to provide the total numbers and biomasses for the entire wind farm. The results are presented in table 8. It should be noted that the results contain large error margins, because of limitations with data collection, the strong variation between growth on different turbines and the simplified method to carry out the extrapolation.

This table indicates a total average biomass for mussels of 7,500 kg AFDW, for small crustaceans of 45 kg AFDW and for polychaete worms of 35 kg AFDW. The estimated food availability provided by these groups for fish and bird species is more than 7,500 kg AFDW.

Table 8. Estimated total numbers and biomasses of common mussels, small crustaceans and polychaete worms on the 37 monopiles (36 turbines and the metmast) in OWEZ in February and September 2011.

Species	Average density on turbines 7,13 and 34 (number per m^2)	Average biomass on turbines 7,13 and 34 (g AFDW per m^2)	Total number in the OWEZ (million)	Total biomass in the OWEZ (kg AFDW)
February 2011				
Common mussel	1,563	889	14.7	8,366
Small crustaceans	8,423	2.9	79.3	27.3
Polychaete worms	179	2.4	1.7	22.6
September 2011				
Common mussel	4,193	720.9	39.5	6,784
Small crustaceans	22,426	6.5	211	61.2
Polychaete worms	255	4.8	2.4	45.2

Causal relationships between the presence of the new hard substrate communities and fish and bird species cannot be demonstrated at present, but results of bird and fish monitoring programmes show the following results:

<u>Fish monitoring (Imares)</u>
Multiple monitoring programs focussed on the impact of OWEZ on the fish community:

1. Demersal fish monitoring (Hille Ris Lambers & Hofstede, 2009; van Hal *et al*., in prep);
2. Pelagic fish monitoring (Ybema *et al*., 2009; van Hal *et al*., in prep);
3. Behavioural study on sole and cod to determine residence times in OWEZ (Winter *et al*., 2010);
4. Static gear monitoring near the monopiles (van Hal *et al*., in prep);
5. DIDSON observations near the monopiles (Couperus *et al*,. 2010; van Hal *et al*., in prep).

The behavioural study (Winter *et al*., 2010) demonstrated that 55% juvenile cod stayed in OWEZ for several weeks or months, and that 15% stayed in OWEZ for the entire study period (8-9 months). Juvenile cod stay in the wind farm for prolonged periods of time and the authors of this study conclude, that OWEZ may serve as a refuge for young cod. A similar study has been carried out in a Belgian offshore wind farm (Reubens *et al.*, 2011). They also concluded that cod stayed in the wind farm for prolonged periods of time. No such positive effect was shown for sole, but no negative effects (avoidance behaviour) were shown either.

Both pelagic and demersal fish monitoring studies, studying the fish community in the wind farm but not near the monopiles, found large natural variation between sampling years on both reference sites and in OWEZ, making it hard to distinguish effects of the wind farm. However, some demersal fish species have increased significantly in OWEZ and not in reference sites in the T1: sole (*Solea solea*), whiting (*Merlangius merlangus*) (Hille Ris Lambers & Hofstede, 2009; Lindeboom *et al*., 2011). Only one species decreased significantly in the wind farm in the T1: the lesser weever (*Echiichthys vipera*). More species, such as for instance cod, have increased in the wind farm, but this was not significantly different from the reference sites, amongst others because of high natural variation. For cod it is shown in the static gear monitoring, that they occur in higher numbers near the monopiles than elsewhere in OWEZ (van Hal *et al.*, inprep).

For pelagic fish, some changes were expected too, but natural variation was dominant and no differences between OWEZ and reference sites or between pre- and post OWEZ construction could be demonstrated (Lindeboom *et al*., 2011).
The DIDSON observations, however, showed increased abundances of fish, up to 35 times as much, near the monopiles in summer (Couperus *et al*., 2010). This could not be confirmed for other seasons (van *Hal et al.,* in prep).

<u>Bird monitoring (Bureau Waardenburg)</u>
Three studies focus on the impact of OWEZ on the bird community:

1. Fluxes, flight altitude and behaviour of flying birds in and around OWEZ (Krijgsveld *et al.* 2011);
2. Local birds in and around OWEZ (Leopold *et al.* 2011);
3. Cumulative effects of OWEZ on seabirds (Poot *et al.* 2011).

The studies on flight patterns and on distribution of local birds (Krijgsveld *et al.,* 2011 and Leopold *et al.,* 2011) show 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 gulls 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, herring gull and common gull (*Larus fuscus, L. argentatus* and *L. canus* respectively), but also the larger great black-backed gull (*Larus marinus*) in winter, and the smaller black-headed gulls and kittiwakes (*Larus ridibundus* and *Rissa tridactyla* respectively). Gulls feed on a variety of food, including smaller fish and crustaceans, which were encountered in high densities in the wind farm.

Pelagic seabirds such as gannets, divers, sea ducks and alcids all showed high levels of avoidance around the wind farm, and these species will not directly benefit from any increase in food abundance within the wind farm. Sea ducks such as common scoters (*Melanitta nigra)*, that could potentially benefit from the increasing levels of bivalves, were seen flying through the wind farm only occasionally, and only once a pair of common eiders (*Somateria mollissima)* was seen foraging within the wind farm (Krijgsveld *et al.,* 2011, Leopold *et al.,* 2011). The behaviour of these species may change when food becomes more abundant and when the birds become accustomed to the wind farm, as was shown by Petersen & Fox (2007) for the Danish Horns Rev wind farm. The increase of both common scoter and common eider within this wind farm could be a reflection of increasing food availability as a result of establishment of new hard substrate communities on the monopiles and rocks of the scour protection layer, but no conclusive explanation could be provided.

Gannets (*Morus bassanus*), which feed on pelagic fish, showed increasing numbers in the wind farm between 2007 and 2009, but this increase was not statistically significant (Krijgsveld *et al.* 2011). Gradual accustomisation of the species to the turbines may not be ruled out, especially when combined with increasing food abundance.

Increase of biodiversity

Before the wind farm was built the area contained only sandy substrates with characteristic soft substrate communities. The introduction of hard substrates in the form of monopiles and scour protection layers has facilitated the establishment of hard substrate communities with characteristic hard substrate species that were not present before realisation of the wind farm. At least 55 hard substrate species have been identified on hard substrates within OWEZ. It can be concluded that the local biodiversity in the wind farm, expressed in the number of species present, has increased.

Non-indigenous species

Several non-indigenous species have been identified in the 2008 and 2011 assessments 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*, the hairy crab (*Pilumnus hirtellus*) and the marine splash midge (*Telmatogeton japonicus*).

A comparison of the 2008 and 2011 surveys shows the following similarities and differences in the occurrence of non-indigenous species:

- The skeleton shrimp and *Jassa marmorata* were the most abundant non-indigenous species both in 2008 and 2011. No differences in the abundances of these species were found between surveys;
- Barnacles were most numerous in the intertidal zone and the shallow subtidal zone. The Australasian barnacle was only found in 2011, but in general no clear differences between the abundances of non-indigenous barnacles in 2008 and 2011 were found;
- Pacific oysters were more abundant and larger in 2011 than they were in 2008;
- The hairy crab was common both in 2008 and 2011. This species was found on all monopiles in all surveys except for the survey carried out at turbine 13 in February 2008;
- The slipper limpet occurred in low numbers both in 2008 and 2011;
- The marine splash midge was only found in 2011, not in 2008.

4.2.2 Comparison with other wind farms

Many reports have been written since the 2008 surveys, but it is beyond the scope of this project to provide a complete review. Here results are compared with the C-Power wind farm in Belgium and the Horns Rev offshore wind farm in Denmark. C-Power was chosen, because this wind farm is the closest to OWEZ in the North Sea and the monopiles are similar to the ones in OWEZ. Horns Rev was chosen, because the monopiles and scour protection are very similar to OWEZ.

C-Power wind farm (Belgium)(Kerckhof *et al.*, 2010)

In late spring 2008, the first six concrete foundations of the C-Power wind farm were installed at the Thornton Bank, approximately 30 km off the Belgian coast. Each turbine foundation consists of a base slab, a truncated conical portion, a cylindrical portion and a platform. The conical portion rises 14 m above the seafloor and has an outside diameter that varies from 14 m at the seafloor to 6.5 m at the top. During eight sampling campaigns between February 2009 and February 2010 scuba divers collected 23 subtidal samples and four intertidal samples on the foundation of one selected turbine (each time the same turbine) at depths ranging from 4 to 25 m. Samples were collected using the same methods as those used in OWEZ (scraping with a putty-knife from an area of 25 cm x 25 cm).

The results of both studies are comparable:

- In the Belgian wind farm a total of 75 taxa (most species) has been identified during eight sampling campaigns, in OWEZ a total of 55 taxa (most species) during four sampling campaigns. It is expected that the number of species in OWEZ would have been higher if more sampling campaigns were carried out.
- One of the most numerous species in the Belgian wind farm was *Jassa herdmani* with densities of circa 200,000 individuals per m^2 in July 2009. In OWEZ this species was grouped together with other small crustaceans. Small crustaceans were also the most numerous species in OWEZ, with maximum densities circa a factor ten lower than observed in the Belgian wind farm (circa 22,000 individuals per m^2).
- In the Belgian wind farm three different vertical zones were distinguished: an intertidal-splash zone, a transitional barnacle-*Jassa* zone and an extensive subtidal zone. Strong seasonal variations existed in community structures with the most notable difference that a conspicuous belt of was established in the transitional barnacle-*Jassa* zone in the summer period. This variation was noted in the OWEZ as well. In February the shallow subtidal zone was only partly covered by mussels and in September almost entirely.
- Large algae were rare both in the Belgian wind farm and in OWEZ.
- The nine non-indigenous species mentioned in § 4.1.1. have been identified in both wind farms.

Horns Rev offshore wind farm (Denmark) (Leonhard & Pedersen, 2005)

The Horns Rev offshore wind farm in Denmark consisting of 80 turbines was constructed between March and August 2002 and is located approximately 14-20 km offshore where water depths vary between 6 and 14 m. The monopiles of the turbines (diameter 4 m) and the scour protection layer (consisting of one layer of large rocks and one layer of smaller rocks; diameter of 27 m) are very similar to the monopiles and scour protection layers used in OWEZ. Therefore, results of surveys of hard substrate communities in the Horns Rev wind farm carried out in September 2003 and March and September 2004 provide a good comparison for data collected in OWEZ. The authors are not aware of any more recent monitoring programmes carried out in this wind farm.

In the Horns Rev offshore wind farm substantial differences were found between surveys carried out in 2003 and 2004. Differences in spatial and temporal distribution of species and communities indicate the process of ecological succession. Growth on the monopiles of the turbines in this offshore wind farm was described as follows (summarised from Leonhard & Pedersen*,* 2005):

- In the splash zone an almost monoculture population of the marine splash midge *Telmatogeton japonicus* is present. This population increased significantly between 2003 and 2004.
- A total of 11 taxa of seaweeds were registered on the monopiles and rocks of the scour protections, but in general the vegetation was very scarce. The brown algae *Petalonia fascia*, *Petalonia zosterifolia* and the red algae *Callithamnion corymbosum* seemed to be typical for the monopiles to approximately 4 m depth, whereas different species of the green algae *Ulva spp*. seemed to be typical for the scour protections (with a highest covering percentage of approximately 20% in September 2004).
- In the sublitoral on the monopiles just beneath the surface, dense aggregations of either spat or larger individuals of the common mussel *Mytilus edulis* (in March 2004 on average circa 1,700 individuals per m^2) with associated species like the crenate barnacle *Balanus crenatus* and common starfish *Asterias rubens*.
- In the lower zone the plumose anemone *Metridium senile*, *Sargartia spp*. anemones and the crustacean *Jassa marmorata* were very abundant (*Jassa marmorata* was dominant in terms of both numbers (in March 2004 on average circa 168,000 individuals per m^2) and biomass (in March 2004 on average circa 374 g wet weight per m^2)) at all turbines sites and on both the monopiles and the scour protection rocks. Less abundant, but common species in the lower zone were the keelworm *Pomatoceros triqueter* and the hydroid *Tubularia indivisa*.
- In 2004, 14 new epifaunal species were recorded that were not present in 2003. Notable species included the bristle worm *Sabellaria* (presumably *Sabellaria spinnulosa*) and the white weed *Sertularia cupressina*, which in the Wadden Sea are regarded as threatened or red list species.
- Compared to 2003 a considerable higher abundance of juvenile crabs were found on the monopiles and larger individuals were often observed in caves and crevices among stones of the scour protection in 2004.

The hard substrate communities in OWEZ are comparable to those identified in the Horns Rev wind farm. In the intertidal zone the marine splash midge *Telmatogeton japonica* is present, in the upper subtidal zone a hard substrate community dominated by mussels (with associated species such as common starfish) and in the lower subtidal zone close to the seafloor a community dominated by anemones (most abundant plumose anemones) and small crustaceans.

A difference between both wind farms is the presence of 11 taxa of seaweeds in the Horns Rev offshore wind farm. In OWEZ only a band of green algae and Porphyra have been identified so far. The keel worm *Pomatoceros triqueter* and the bristle worm *Sabellaria spinnulosa,* present in the Horns Rev wind farm, have so far not been identified on the hard substrates within OWEZ **.**

4.2.3 Comparison with growth on other hard structures in the North Sea

Based on information from several surveys carried out to describe growth on offshore structures in the North Sea (e.g. surveys of growth on steel platforms in the central and northern North Sea published by Forteath *et al*. (1982) and information on fouling communities in the Moray Firth published by Picken (1986). Hiscock *et al.* (2002) provide an illustration of the types of colonisation likely to occur in the region of wind turbine towers (see figure 17).

Intertidal
Predominantly barnacles and ephemeral algae including: the barnacles *Semibalanus balanoides* and *Elminius modestus*, sea lettuce *Ulva lactuca*, gut weed *Enteromorpha intestinalis*, and laver *Porphyra* spp.

Kelp zone c+.1-2 m
Kelps, foliose red seaweeds, barnacles, encrusting sea mats. Mussels sometimes dominant below kelps. Foliose algae (including *Palmaria palmata* and *Polysiphonia* spp. especially) may extend deeper

Shallow subtidal c+. 2m-6m Two alternative are illustrated:

1. (Left-side of illustration.) Plumose and other anemones, sponges, possibly hydroids. Large individuals of the plumose anemone *Metridium senile*, with groups of sagartia anemones *Sagartia elegans* and patches of hydroids, *Tubularia larynx* and sponges, *Halichondria panicea.* Occasional red seaweeds especially filamentous species.

2. (Right-side of illustration.) Dominated by mussels, *Mytilus edulis* with scattered elements of the above and starfish (*Asterias rubens*) predators.

Main column to scoured area.
Likely to be dominated by plumose anemones *Metridium senile*, sagartia anemones *Sagartia elegans*, soft corals *Alcyonium digitatum*, hydroid sea firs including *Obelia* spp., *Kirchenpauria pinnata*, *Tubularia indivisa*, sponges such as *Amphilectus fucorum* and solitary sea squirts *Ascidiella* spp. Patches of feather stars *(Antedon bifida)* may be present as well as areas of the colonial sea squirt *Diplosoma listerianum* and the sponge *Polycarpa spp.* Scoured area are dominated by keeled tubeworms, *Pomatoceros triqueter*, and barnacles *Balanus crenatus*,with encrusting bryozoan sea mats near the top of the zone. May be dominated by ross worm *Sabellaria spinulosa.* Large amounts of bare substratum likely to be present.

Base of structure Two alternatives are illustrated:
1. (Left-side of illustration.) No or few mussels on structure above and anti- scour in the form of small boulders installed. Boulders colonised by same species as scoured structure although sheltered intertices may attract solitary sea squirts and other species. Reef species such as wrasse, *Labrus bergylta*, wreck fish *Trisopterus luscus,* lobster *Homarus gammarus*, crab *Cancer pagurus*, and conger *Conger conger* attracted.

2. (Right-side of illustration.) Mussels dominant on structure above and no anti-scour. Live and dead mussels accumulate at base. Possibly peacock worms *Sabella pavonina* present. Scavengers such as crabs and flat fish attracted.

Figure 17. Source: Hiscock et al. (2002): Stylized drawing of zonal communities likely on structures placed in waters deeper than 15 m where scour is limited to the lowest part of the column. Sketches of species are not to scale.

When the observed growth on the hard structures within OWEZ is compared with this figure, than the following differences and similarities can be distinguished:

Intertidal zone
In 2008 the intertidal zone of the monopiles was relatively bare. In February 2008 no large algae were present and in September 2008 only a small band of green algae (*Ulva spp*.) with some barnacles. In 2011 a band of green algae (*Ulva spp*.) was present in the upper intertidal zone of all three observed turbines and also the foliose red algae Porphyra, mentioned by Hiscock *et al*. (2002), was identified in the intertidal zone of one turbine. Five different species of barnacles were identified in the intertidal zone including the three species mentioned by Hiscock.

Neither in 2008 or 2011 were kelp zones identified on the monopiles within OWEZ.

Hiscock *et al.* (2002) did not mention the marine splash midge *Telmatogeton japonicus*. This species was not identified in 2008, but was present in the intertidal zone of all three turbines in 2011. This species is also common in other offshore wind farms in the Belgian part of the North Sea and in the Horns Rev offshore wind farm in Denmark (§ 4.2.1).

Shallow subtidal zone
The shallow subtidal zone of turbines 7, 13 and 34 are all dominated by the presence of mussels with associated species such as common starfish, which is comparable to alternative 2 in figure 17. In OWEZ, however, this zone generally extends to a depth of approximately 10-12 m instead of the 6 m mentioned by Hiscock *et al.* (2002). In places where clumps of large (adult) mussels have fallen of the monopiles in OWEZ bare patches were often occupied by edible crabs *Cancer pagarus*, a species not mentioned for this part of the monopile in figure 17.

Several species mentioned for the main column in figure 17 are also found on the monopiles within OWEZ including the plumose anemone *Metridium senile*, *Sargartia spp.* anemones, the orange anemone *Diadumene cincta*, patches of *Tubularia indivisa* and *Obelia spp*. No ascidians, soft corals, sea squirts and/or feather stars have been identified in OWEZ so far.

'Large amounts of bare patches' in the main column to the scour area (see figure 17) are not present in OWEZ. The area of the monopiles in depth ranges below the mussels to the seafloor (approximately 12 to 15 m depth in OWEZ) are generally fully covered by (tubes of) small crustaceans (*Monocorophium acherusicum, Monocorophium sextonae, Jassa herdmani* and *Jassa marmorata*) and various species of anemones (mainly plumose anemones *Metridium senile* and the orange anemone *Diadumene cincta)*.

Clumps of mussels are found at the base of the turbines in between the rocks of the scour protection layers. The encrusting sea mat *Conopeum reticulum* is present on the rocks, but plumose anemones and small crustaceans are by far the most dominant species. The breadcrumb sponge *Halichondria panicea* was identified on the monopile near the seafloor and on rocks of the scour protection layers in 2011. Edible crabs *Cancer pagarus* were especially common during the survey carried out in September 2008. No lobsters *Homarus gammarus* have been identified within OWEZ so far.

4.3 Scour holes

4.3.1 Benthos

It is not possible to directly compare densities, biomass and production values of identified benthic species in the scour holes with similar data collected by NIOZ at other locations within the wind farm (Bergman *et al.,* in prep), because:

- Samples were collected using different sampling devices (pitch pipe in this study versus a boxcorer and triple-D dredge in the NIOZ study);
- Sampling took place during different phases of the tide (present study around slack tide, NIOZ study various tidal phases). The tidal phase is expected to have a strong effect on the presence of organisms in the scour holes;

It can be concluded however, that the species composition within the scour holes differs from the species composition in other areas within the wind farm. In the scour holes a mixture of species characteristic for sandy substrates and species characteristic for hard substrates (fallen of the monopiles and/or scour protection layers) has been identified. In other areas within the wind farm only species characteristic for sandy substrates are present.

4.3.2 Grain size

The average median particle size in the scour holes of the three turbines was 243µm and the percentage silt (fraction < 63µm) is 2.5%. The median particle size is comparable data collected during benthic fauna surveys carried out in 2011 by NIOZ at 19 other locations (Bergman *et al.,* in prep.) in the wind farm outside the scour holes (264µm), but the percentage silt was slightly higher than the value found by NIOZ (0.3%).

5 Conclusions

5.1 Hard substrates

- Since the construction of OWEZ, no organisms have been removed from the monopiles of turbines 7, 13 and 34 as part of technical maintenance. It was therefore possible to monitor the development of hard substrate communities over a period of five years after construction.
- In 2008 and 2011, a total of 55 species were identified on the monopiles and 35 species on the scour protection layers.
- The upper part of the intertidal zone of the monopiles was generally characterised by the presence of a band of green algae, different species of barnacles and several oysters; the lower part was domminated by small mussels.
- In February, mussels were less abundant in the intertidal zone and the shallow subtidal zone compared to September. This seasonal variation was also observed in the C-Power wind farm in Belgium. A possible explanation is loss of mussels during winter storms and recolonisation during the summer months.
- Hard substrate communities in the subtidal zone of the monopiles show a ‘patchy’ distribution (resulting in large variations between samples), but generally the subtidal zone is characterised by the presence of a thick layer of large adult mussels overgrown by small crustaceans and anemones. In between the mussels, polychaetes and starfish are common and occasionally Pacific oysters and sea urchins are found.
- The total density of all organisms combined was circa 28,000 individuals per m^2. Densities are dominated by 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).
- The total biomass of all organisms combined was circa 800-1,400 g AFDW per m^2. Biomasses are dominated by mussels (circa 83% of total biomass) and anemones (circa 7% of total biomass).
- Most dominant species on the scour protection layers were plumose anemones (coverage varying between 50-100%), (tubes of) small crustaceans (100% coverage at places without anemones) and the encrusting sea mat. Common starfish were also abundant.
- Densities of marine organisms on the scour protection layers are high. Densities of anemones were circa 2,500 individuals per m^2 and densities of starfish circa 180 individuals per m^2. The covering percentages of the sea mat and small crustaceans varied between respectively 60-100% and 30-50%.
- The hard substrate communities can form a valuable food source for fish and birds and increase the biodiversity in the area where OWEZ is built.

5.2 Scour holes

- A mixture of species characteristic for sandy substrates (26 species) and species characteristic for hard substrates (29 species) is present in the scour holes. It is likely that the hard substrate species have detached from the monopiles and rocks of the scour protection layers and subsequently have accumulated in the scour holes.
- Most endobenthic species identified in the sediment cores were polychaetes.
- Calculated densities, biomass and production values of organisms in the scour holes showed large variations.
- The average median particle size in the scour holes was 243µm and the percentage silt (fraction < 63µm) is 2.5%. The median particle size is comparable data collected during benthic fauna surveys carried out in 2011 in the wind farm (264µm), but the percentage silt was slightly higher than the value found by NIOZ (0.3%).

5.3 Recommendations for future studies

For future work it is recommended:

- To maintain the current daily monitoring effort, because dive operations in OWEZ can only be carried out safely in the period of circa 1.5 hours around slack tide;
- To sample the intertidal zone from a rigid inflatable boat (RIB) and not by diving. It is too difficult for divers to accurately sample this zone because of waves and currents;
- To carry out future assessments of hard substrate communities in the OWEZ using identical methods as described in this report. The combination of video footage and sampling by divers proved to be an effective method and are both necessary to accurately monitor the hard substrate community development.

6 Literature

Bouma S., & Lengkeek W., 2009. Development of underwater flora- and fauna communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ). Report OWEZ_R_266_T1_20090126.

Bouma S., & Lengkeek W., 2008. Development of underwater flora- and fauna communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ). Progress report, May 2008.

Couperus, B., E. Winter, O. van Keeken, T. van Kooten, S. Tribuhl & D. Burggraaf, 2010. Use of high resolution sonar for near_turbine fish observations (DIDSON) – We@Sea 2007_002. IJmuiden, IMARES.

Daan R., Mulder M & Bergman M.J.N., 2009. Impact of windfarm OWEZ on the local macrobenthos community. Report OWEZ_R_261_T1_20091216.

Forteath G.N.R., Picken G.B., Ralph R. & Willimas J., 1982. Marine growth studies on the North Sea oil platform Montrose Alpha. Marien Ecology Progress Series,8:61-68.

Hille Ris Lambers, R. & R. ter Hofstede, 2009. Refugium Effects of the MEP-NSW Windpark on Fish: Progress Report 2007. Imares IJmuiden.

Hiscock K., Tyler-Walters H., & Jones H., 2002. High level environmental screening study for offshore wind farm developments – marine habitats and species project. Report from the Marine Biological Association to the Department of Trade and Industry & Renewable Energy Programme (AEE Technology, Environment Contract: W/35/00632/00/00).

Jarvis, S., J. Allen, N. Proctor, A. Crossfield, O. Dawes, A. Leighton, L. McNeill & W. Musk 2004. North Sea Wind Farms: NSW. Lot 1 Benthic Fauna. Final Report. Rep. ZBB607.2-F-2004. Institute of Estuarine and Coastal Studies (IECS), University of Hull, U.K.

Kerckhof, F., Rumes, B., Norro, A., Jacques, T.G. & Degraer, S., 2010. Seasonal variation and vertical zonation of the marine biofouling on a concrete offshore windmill foundation on the Thornton Bank (southern North Sea). pp. 53-68. In: Degraer, 2010. Offshore wind farms in the Belgian part of the North Sea. Early environmental impact assessment and spatio-temporal variability.

Krijgsveld, K.L., R.C. Fijn, M Japink, P.W. van Horssen, C. Heunks, M.P. Collier, M.J.M. Poot, D. Beuker & S. Dirksen, 2011. Effect Studies Offshore Wind Farm Egmond aan Zee. Flux, flight altitude and behaviour of flying birds. Bureau Waardenburg report 10-219, Bureau Waardenburg, Culemborg, NoordzeeWind report OWEZ_R_231_T1_20111114_flux&flight.

Lindeboom, H. J., H. J. Kouwenhoven, M. J. N. Bergman, S. Bouma, S. Brasseur, R. Daan, R. C. Fijn, D. de Haan, S. Dirksen, R. van Hal, R. Hille Ris Lambers, R. ter Hofstede, K. L. Krijgsveld, M. Leopold, and M. Scheidat, 2011. Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environmental Research Letters 6:035101.

Leonhard S.B. & Pedersen J., 2005. Hard bottom substrate monitoring Horns Rev offshore wind farm. Annual status report 2004. Elsam Engineering, May 2005.

Leopold, M.F., C.J. Camphuysen, H. Verdaat, E.M. Dijkman, H.W.G. Meesters, G.M. Aarts, M. Poot & R. Fijn, 2010. Local Birds in and around the Offshore Wind Park Egmond aan Zee (OWEZ) (T-0 & T-1). Report C034/10 IMARES, IJmuiden, NoordzeeWind report OWEZ_R_221_T1_OWEZ_R_221_T1_20110915_Local_ birds.

NoordzeeWind (2003a) Wbr/Wm vergunningaanvraag – Near Shore Windpark (PWA/EMA consent application – Near Shore Wind farm), submitted to Ministry of Public Works, Transport and Water Management, March 2003.

Peterson & Fox, 2007. Changes in bird habitat utilisation around the Horns Rev 1 offshore wind farm, with particular emphasis on the Common Scoter. Commissioned by Vattenfall A/S.

Picken G.B., 1986. Moray Firth fouling communities. Proceedings of the Royal Society of Edinburgh B. 91:213-220.

Poot, M.J.M., M.P. Collier, P.W. van Horssen, R. Lensink & S. Dirksen, 2011. Effect studies Offshore Wind Egmond aan Zee: Cumulative effects on seabirds. A modelling approach to estimate effects on population levels in seabirds. Bureau Waardenburg report 11-026, Bureau Waardenburg. Culemborg, NoordzeeWind report OWEZ_R_212_20111021_Cumulative_Effects.

Raaijmakers T., 2009 Evaluation of performance of scour and edge scour development. Offshore Windpark Egmond aan Zee. Deltares refrence 1200160-002-HYE-0001.

Reubens, J., Degraer, S. & Vincx, M., (2011). Spatial and temporal movements of cod (*Gadus morhua*) in a wind farm in the Belgian part of the North Sea using acoustic telemetry, a VPS study. pp. 39-46.

Winter, H.V., G. Aarts & O.A. van Keeken, 2010. Residence time and behaviour of sole and cod in the Offshore Wind farm Egmond aan Zee (OWEZ). Rapport nr. OWEZ_R_265_T1_20100916 / Imares C038/10, Imares, IJmuiden.

Ybema, M.S., G. Dominik & R. Hille Ris Lambers, 2009. OWEZ – pelagic fish, progress report and progression after T1. Interim report pelagic fish. Imares IJmuiden.

Appendix 1 Correction of sampling depth to NAP

February 2011

18-feb	Recorded time of sampling turbine 7	Actual water level Zuid Petten	Actual water level Buitenhaven Ijmuiden	Average water level	Sampling depth related to NAP
Intertidal zone	13.14	-106	-80	-93	-0,93
2 msw	13.12	-106	-81	-94	-2,94
5 msw	13.04	-105	-85	-95	-5,95
10 msw	12.56	-105	-90	-98	-10,98
15 msw	12.50	-106	-93	-100	-16

17-feb	Recorded time of sampling turbine 13	Actual water level Zuid Petten	Actual water level Buitenhaven Ijmuiden	Average water level	Sampling depth related to NAP
Intertidal zone	19.07	50	11	31	0,31
2 msw	19.04	51	12	32	-1,68
5 msw	18.54	52	15	34	-4,66
10 msw	18.45	55	18	37	-9,63
15 msw	18.39	57	21	39	-14,61

17-feb	Recorded time of sampling turbine 34	Actual water level Zuid Petten	Actual water level Buitenhaven Ijmuiden	Average water level	Sampling depth related to NAP
Intertidal zone	no sample	no sample	no sample	no sample	no sample
2 msw	13.00	-65	-17	-41	-2,41
5 msw	12.50	-70	-28	-49	-5,49
10 msw	12.44	-72	-32	-52	-10,52
15 msw	12.37	-75	-37	-56	-15,56

September 2011

25-sep	Recorded time of sampling turbine 7	Actual water level Zuid Petten	Actual water level Buitenhaven Ijmuiden	Average water level	Sampling depth related to NAP
Intertidal zone	12.45	-29	28	-1	-0,01
2 msw	12.31	-45	4	-21	-2,21
5 msw	12.24	-50	-5	-28	-5,28
10 msw	12.15	-58	-18	-38	-10,38
15 msw	12.08	-62	-24	-43	-15,43

24-sep	Recorded time of sampling turbine 13	Actual water level Zuid Petten	Actual water level Buitenhaven Ijmuiden	Average water level	Sampling depth related to NAP
Intertidal zone	13.00	50	69	60	0,6
2 msw	17.58	7	-21	-7	-1,07
5 msw	17.51	10	-20	-5	-5,05
10 msw	17.46	11	-20	-5	-10,05
15 msw	17.39	13	-17	-2	-15,02

24-sep	Recorded time of sampling turbine 34	Actual water level Zuid Petten	Actual water level Buitenhaven Ijmuiden	Average water level	Sampling depth related to NAP
Intertidal zone	12.30	25	60	42,5	0,43
2 msw	12.12	1	47	24	-1,76
5 msw	12.05	-3	43	20	-4,8
10 msw	11.53	-16	28	6	-9,94
15 msw	11.45	-24	22	-1	-15,01

Appendix 2 Assessment benthic communities in scour holes

Samples were analysed according to procedures as applied on previous benthic samples of OWEZ by IECS, Hull (Jarvis *et al.,* 2004) and NIOZ, Texel (Daan *et al*., 2009).

Identification of species

Polychaetes were identified using Hartmann-Schröder 1996. For *Eulalia viridis* also Bonse *et al.* (1996) was consulted. *Malmgrenia darbouxi* was identified using Pettibone (1993) and a recent key of Barnich (2011). *Arenicola defodiens* was identified with Luttikhuizen & Dekker (2009). For *Spio* species, the recent key of Bick *et al.* (2010) was used.

For the identification of crustaceans, several books and keys were used. Amphipods were identified with Lincoln (1979), except for *Jassa* species, which were identified with Stock (1993). For *Bathyporei*a, d'Udekem d'Acoz (2004) was consulted. Caprellids were identified with Stock (1955). The cumacean *Diastylis bradyi* was identified with a recent key of Shalla (2010). The shrimp *Philocheras* was identified with Smaldon *et al.* (1993). The isopod *Idotea pelagica* was identified with Holthuis (1956), Kerckhof (1994) and Huwae & Rappé (2003).

Amphipods of the genus *Stenothoe* were identified as *S. marina*. Although the gnatopods of these amphipods were more similar to *S. monoculoides*, this was considered a juvenile characteristic. The identification of *Stenothoe* as *S. marina* is partly based on the presence of two pairs of dorsolateral spines on the telson (in *S. monoculoides* these spines are lacking).

Counts/densities

In each sample, numbers of specimens per species were counted. In the spring sample 13-1, the number of amphipods was very high (total >1600). A remaining part of the sample, containing only small *Jassa spp*. and *Monocorophium spp*., was counted only partially (25%) and the result was added to the respective species. As calculated densities per m^2 are based on small surface areas, they should be treated with caution. This is also the case with biomass and production.

Biomass values

Biomass values were calculated as ash-free dry weight (AFDW) per species or taxon identified. The AFDW values of the different taxa were determined according to the methods used in the North Sea MWTL programme (also used for OWEZ T0 data, Jarvis *et al.,* 2004 and OWEZ T1 Daan *et al.*, 2009).

Blotted wet weights (WW) were determined with a balance (Denver instrument APX-203) with an accuracy of 1 mg.

Ash-free dry weights (AFDW) were determined using conversion factors supplied by NIOZ. For most species, this was either 13.2% or 22 % of WW.

In a few cases, the list of NIOZ did not contain conversion values. Nematodes were given the same conversion factor as Nemertea (= Nemertini), viz. 22%. The marine splash midge *Telmatogeton japonicus* was given the same conversion factor as

Polychaeta, viz. 13.2%. In a few remaining cases, a conversion was taken from Ricciardi & Bourget (1998) as indicated in table 1.

Table 1. Conversion AFDW/WW (%). NIOZ: values supplied by NIOZ. R&B '98; values in Ricciadi & Bourget (1998). The latter values were used in case NIOZ did not contain ratios.

	NIOZ	R&B '98
Polychaeta errantia (*Eteone, Eulalia, Eumida, Eunereis, Nephtys, Nereis, Harmothoe, Malmgrenia, Notomastus, Phyllodoce, Poecilochaetus, Spio, Sthenelais*)	13,2	17,1
Polychaeta sedentaria (*Arenicola, Capitella, Cossura, Lanice, Scoloplos*)	13,2	15,0
Nematoda: value as Nemertea		
Actiniaria (Thenaria)	22	14,3
Nemertea (Nemertini)	22	20,0
Phoronida	13,2	
Amphipoda & Cumacea	0,3 mg/ind	16,0 & 7,6
Decapoda (*Pinnotheres* and *Philocheras*)		16,5
Isopoda (*Idotea*)		14,2
Opisthobranchia		0,25*68,6
Asteroidea (*Asterias*)		11,2

In the bivalves *Ensis directus*, *Tellina fabula*, *Tellimya ferruginosa*, AFDW was determined based on a conversion of shell length by means of W=a*Lb (W=AFDW in g and L=length in mm, a and b are species-specific coefficients). For *Mytilus edulis*, the other bivalve in the samples, the NIOZ list did not provide coefficient values. Therefore, an AFDW/WW ratio of 4.6% from Ricciardi & Bourget (1998) was used.

Except for amphipods and cumaceans (see below) individual AFDW was calculated by dividing AFDW/sample by the number of individuals in the sample.

Amphipod and cumacean biomass was determined assuming an individual AFDW of 0.3 mg. Daan *et al.* (2009) indicated they used values of 0.2 to 0.5 mg for small crustaceans, refering to Holtmann & Groenewold (1994) and unpublished reports of Duineveld and Holtmann. These authors used such values in the analysis of macrobenthos from the MILZON BENTHOS project in the southern North Sea between 1991 and 1993. These estimated individual weights were based on previous analyses of the AFDW of small crustaceans. Notwithstanding the range of 0.2 to 0.5 mg mentioned, for small as well as larger amphipods, Daan & Mulder (2006) as well as Daan *et al.* (2009) always use individual wet weights of 0.3 mg. Consequently, this procedure was followed in this study as well. Additionally, in this case, blotted wet weights of amphipods were also measured. Such weights may be used as an additional indication of biomass, for example in comparisons of the different amphipod species.

In colonial Hydrozoa and Bryozoa, measurement of biomass was often impossible due to the thorough connection of colonies with their substrates. Moreover, they were frequently mutilated by predators or otherwise damaged. Therefore, calculation of individual AFDW was not only impossible but also irrelevant. Except for nudibranch gastropods, the importance of these animals as food item is dubious. However, some hydroids, such as *Tubularia* and *Ectopleura*, may be important as substrate for free-living as well as domiculous amphipods.

Production values

An indication of production was calculated based on total and individual biomass, according to the method described in Daan *et al.* (2009). This implicates that the instantaneous biomass of the collection date was used instead of an average value for annual biomass. For Polychaeta, Crustacea and Mollusca, taxon-specific coefficients (a, b_1 and b_2) were used. For the remaining taxa, 'Total' coefficients were used. Coefficients were derived from Brey (1990).

References

Barnich, R. 2011. Key to Northeast *Malmgrenia* species (revised 01/2011). Follow-up of Barnich, R. 2010. Identification of scale worms in British and Irish waters. Senckenberg Forschungsinstitute und Naturmuseum Frankfurt.

Bick, A., K. Otte & K. Meißner 2010. A contribution to the taxonomy of Spio (Spionidae, Polychaeta, Annelida) occurring in the North and Baltic Seas, with a key to species recorded in this area. Mar. Biodiv. 40 (3) 161-180.

Bonse, S., H. Schmidt, D. Eibye-Jaconsen & W. Westheide 1996. *Eulalia viridis* (Polychaeta: Phyllodocidae) is a complex of two species in northern Europe: Results from biochemical and morphological analyses. Cah. Biol. Mar. 37: 33-48.

Brey, T. 1990. Estimating productivity of macrobenthic invertebrates from biomass and mean individual weight. Meeresforsch. 32, 329-343.

d'Udekem d'Acoz, C. 2004. The genus Bathyporeia Lindström, 1855 in western Europe (Crustacea, Amphipoda, Pontoporeiidae). Zoologische Verhandelingen, Leiden, 348: 3-162.

Daan, R. & M. Mulder 2006. The macrobenthic fauna in the Dutch sector of the North Sea in 2005 and a comparison with previous data. NIOZ-rapport 2006-3, Texel.

Daan, R., M. Mulder & M.J.N. Bergman 2009. Impact of wind farm OWEZ on the local macrobenthos community. rep. OWEZ_R_261_T1_20091216.

Hartmann-Schröder, G. 1996. Annelida, Borstenwurmer, Polychaeta. Die Tierwelt Deutschlands 58, G. Fischer Verlag, pp. 645.

Holthuis, L.B. 1956. Fauna van Nederland afl. 16 Isopoda en Tanaidacea (K V). Sythoff, Leiden.

Holtmann, S.E. & A. Groenewold 1994. Distribution of the zoobenthos on the Dutch continental shelf: the western Frisian Front, Brown Bank and Broad Fourteens (1992/1993). Milzon benthos II, NIOZ rapp. 1994-1, NIOO-CEMO rapp. & versl. 1994-1.

Huwae, P. & G. Rappé 2003. Waterpissebedden, een determinatietabel voor de zoet-, brak- en zoutwaterpissebedden van Nederland en België. Wetensch. meded. KNNV 118, Utrecht.

Jarvis, S., J. Allen, N. Proctor, A. Crossfield, O. Dawes, A. Leighton, L. McNeill & W. Musk 2004. North Sea Wind Farms: NSW. Lot 1 Benthic Fauna. Final Report. Rep.

ZBB607.2-F-2004. Institute of Estuarine and Coastal Studies (IECS), University of Hull, U.K.

Kerckhof, F. 1994. Opmerkingen bij de excursie van 30 april 1994. De Strandvlo 14 (3) 107-112.

Lincoln, R.J. 1979. British Marine Amphipoda: Gammaridea. British Museum (Natural History) London.

Luttikhuizen, P.C. & R. Dekker 2009. Pseudo-cryptic species *Arenicola defodiens* and A. marina (Polychaeta: Arenicolidae) in Wadden Sea, North Sea and Skagerrak: Morphological and molecular variation . Journal of Sea Research 67: 17-23.

Pettibone, M.H. 1993. Scaled Polychaetes (Polynoidae) associated with Ophiuroids and Other invertebrates and review of species referred to *Malmgrenia McIntosh* and Replaced by *Malmgreniella Hartman*, with descriptions of new taxa. Smithsonian Contr. to Zoology # 538 p 1-92.

Ricciardi, A. & E. Bourget 1998. Weight-to-weight conversion factors for marine benthic macroinvertebrates. Mar. Ecol. Prog. Ser. 163: 245-251.

Shalla, S. 2010. Identification guide to British shallow water cumaceans. NMBAQC workshop 2010.

Smaldon, G., L.B. Holthuis & C.H.J.M. Fransen 1993. Coastal shrimps and prawns. Synopses of the British Fauna (N S) No. 15, Field Studies Council, Shrewsbury.

Stock, J.H. 1955. Nederlandse spookkreeftjes. SWG Tabel no. 14, KNNV & NJN.

Stock, J.H. 1993. De Marmerkreeftjes (Amphipoda: geslacht *Jassa*) van Nederland. Het Zeepaard 53 (1) 10-15.

Verduin, E.C., D. Tempelman & G.W.N.M. van Moorsel 2011. The macrobenthic fauna monitoring in the Dutch sector of the North Sea, MWTL 2009, and a comparison with previous data. Grontmij (rep. nr 290843) & Ecosub.

Appendix 3 Results benthos in scour holes

Turbine 7

February 2011

Species characteristic for hard substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Cnidaria	Campanulariidae (fragments)	0	1,7	0,0
	Ectopleura larynx (1 fragment)	0	0,1	0,0
	Thenaria	29	2,3	1,6
Crustacea	*Abludomelita obtusata*	59	0,0	0,1
	Jassa herdmani	3183	1,0	4,3
	Monocorophium acherusicum	413	0,1	0,5
	Monocorophium sextonae	177	0,1	0,2
	Stenothoe marina	265	0	0
Echinodermata	*Asterias rubens*	59	7,7	4,6
Polychaetes	*Eulalia viridis*	118	0,1	0,1
	Total	**4303**	**13,0**	**11,9**

Species chracteristic for sandy substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Crustacea	*Urothoe brevicornis*	29	0,0	0,0
	Urothoe poseidonis	295	0,1	0,4
Molluscs	*Tellimya ferruginosa*	59	0,1	0,1
Nemertea	*Nemertea rodeband*	59	0,7	0,8
	Nemertea (fragments)	0	0,0	0,0
Phoronida	Phoronida	354	0,1	0,0
Polychaetes	*Eteone longa*	29	0,0	0,0
	Lanice conchilega	1032	42,0	64,1
	Malmgrenia darbouxi	472	0,6	1,2
	Nephtys cirrosa	59	0,1	0,2
	Phyllodoce mucosa	383	0,6	1,3
	Scoloplos armiger	29	0,0	0,0
	Total	**2800**	**44,3**	**68,0**

September 2011

Species characteristic for hard substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Bryzoans	*Conopeum reticulum (encrusting species)*	0	0,0	0,0
Cnidaria	Campanulariidae (fragments)	0	0,3	0,0
	Thenaria	88	12,5	5,7
Crustacea	*Idotea pelagica*	59	0,1	0,1
	Jassa herdmani	206	0,1	0,3
	Jassa marmorata	29	0,0	0,0
	Stenothoe marina	29	0,0	0,0
Echinodermata	*Asterias rubens*	29	0,6	0,6
Molluscs	*Nassarius reticulatus (egg capsules)*	0	0,0	0,0
	Total	**442**	**13,6**	**6,8**

Species chracteristic for sandy substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Crustacea	*Leucothoe incisa*	29	0,0	0,0
Nematoda	Nematoda	59	0,0	0,0
Nemertea	*Nemertea rodeband*	118	0,5	0,6
	Nemertea	118	0,0	0,1
Polychaetes	*Capitella capitata*	29	0,0	0,0
	Eteone longa	147	0,0	0,0
	Eumida sanguina	118	0,0	0,0
	Eunereis longissima	29	0,0	0,0
	Lanice conchilega	206	15,2	21,0
	Malmgrenia darbouxi	147	0,5	0,9
	Phyllodoce mucosa	707	0,9	1,8
	Poecilochaetus serpens	59	0,0	0,0
	Scoloplos armiger	29	0,0	0,0
	Spio decoratus	59	0,0	0,0
	Total	**1798**	**17,1**	**24,5**

Turbine 13

February 2011

Species characteristic for hard substrates

Group	*Species*/taxon	density n / m^2	biomass g AFDW / m^2	production g AFDW/ m^2 / year
Bryozoans	*Electra pilosa (encrusting species)*	0	0,0	0,0
Cnidaria	Campanulariidae (fragments)	0	0,2	0,0
	Clytia hemisphaerica (colony)	0	0,0	0,0
	Ectopleura larynx (gragments, juveniles)	0	5,7	0,0
	Thenaria	2152	25,1	29,5
	Tubularia indivisa (fragments, juveniles)	0	56,8	0,0
Crustacea	*Abludomelita obtusata*	29	0,0	0,0
	Idotea pelagica	118	0,6	1,0
	Jassa herdmani	25494	7,6	36,6
	Jassa marmorata	2623	0,8	3,6
	Monocorophium acherusicum	7015	2,1	9,8
	Monocorophium sextonae	9638	2,9	13,6
	Phtisica marina	29	0,0	0,0
	Stenothoe marina	7368	2,2	10,3
Echinodermata	*Asterias rubens*	118	7,7	5,5
Molluscs	*Mytilus edulis*	88	0,1	0,2
	Nassarius reticulatus (egg capsules)	0	0,0	0,0
	Nudibranchia	29	0,0	0,0
Polychaetes	*Arenicola defodiens*	29	0,0	0,0
	Eulalia viridis	29	0,0	0,0
	Harmothoe impar	118	0,9	1,6
	Nereis pelagica	29	0,0	0,0
	Total	**54908**	**112,8**	**111,9**

Species chracteristic for sandy substrates

Group	Species/taxon	density n / m^2	biomass g AFDW / m^2	production g AFDW/ m^2 / year
Crustacea	*Urothoe poseidonis*	118	0,0	0,1
Nematoda	Nematoda	1149	0,0	0,1
Nemertea	Nemertea	29	0,0	0,0
Polychaetes	*Capitella capitata*	29	0,0	0,0
	Eteone longa	29	0,0	0,0
	Eunereis longissima	59	0,8	1,2
	Lanice conchilega	29	3,4	4,4
	Malmgrenia darbouxi	29	0,0	0,1
	Orchomenella nana	29	0,0	0,0
	Phyllodoce mucosa	29	0,1	0,1
	Sthenelais boa	29	1,4	1,9
	Total	**1562**	**5,7**	**8,1**

September 2011

Species characteristic for hard substrates

Group	*Species*/taxon	density n / m^2	biomass g AFDW / m^2	production g AFDW/ m^2 / year
Bryozoans	*Conopeum reticulum*	0	0,0	0,0
	Electra pilosa (encrusting species)	0	0,0	0,0
Cnidaria	*Clytia hemisphaerica (colony)*	0	0,1	0,0
	Thenaria	59	1,7	1,3
Crustacea	Campanulariidae (fragments)	0	0,4	0,0
	Caprella linearis	29	0,0	0,0
	Jassa herdmani	472	0,1	0,6
	Jassa marmorata	177	0,1	0,2
Insects	*Telmatoggeton japonicus*	29	0,0	0,0
Molluscs	*Nassarius reticulatus (egg capsules)*	0	0,0	0,0
	Total	**766**	**2,4**	**2,2**

Species chracteristic for sandy substrates

Group	Species/taxon	density n / m^2	biomass g AFDW / m^2	production g AFDW/ m^2 / year
Molluscs	Bivalven	29	0,0	0,0
Nematoda	Nematoda	88	0,0	0,0
Nemertea	Nemertea	147	0,0	0,0
	Nemertea rodeband	118	0,2	0,4
Polychaetes	*Capitella capitata*	29	0,0	0,0
	Eteone longa	88	0,0	0,0
	Eunereis longissima	59	0,0	0,0
	Malmgrenia darbouxi (one fragment)	0	0,0	0,0
	Notomastus latericeus	59	0,0	0,0
	Spio decoratus	29	0,0	0,0
	Total	**648**	**0,3**	**0,5**

Turbine 34

February 2011

Species characteristic for hard substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Bryzoans	*Conopeum reticulum (encrusting species)*	0	0,0	0,0
Cnidaria	Campanulariidae (fragments)	0	0,0	0,0
Crustacea	*Jassa herdmani*	88	0,0	0,1
	Pinnotheres pisum	29	0,3	0,4
	Stenothoe marina	29	0,0	0,0
	Total	**147**	**0,4**	**0,6**

Species chracteristic for sandy substrates

Group	Species/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Crustacea	*Bathyporeia elegans*	59	0,0	0,1
	Urothoe brevicornis	29	0,0	0,0
Nematoda	Nematoda	59	0,0	0,0
Nemertea	*Nemertea rodeband*	29	0,0	0,1
Polychaetes	*Cossura longocirrata*	29	0,0	0,0
	Eteone longa	59	0,0	0,0
	Lanice conchilega	59	1,1	1,7
	Malmgrenia darbouxi	29	0,1	0,1
	Nephtys cirrosa	88	0,2	0,4
	Scoloplos armiger	29	0,0	0,0
	Total	**472**	**1,4**	**2,4**

September 2011

Species characteristic for hard substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Cnidaria	Campanulariidae (fragments)	0	0,2	0,0
Crustacea	*Jassa herdmani*	413	0,1	0,5
	Monocorophium acherusicum	29	0,0	0,0
	Total	**442**	**0,4**	**0,6**

Species chracteristic for sandy substrates

Group	*Species*/taxon	density n / m²	biomass g AFDW / m²	production g AFDW/ m² / year
Crustacea	*Diastylis bradyi*	29	0,0	0,0
	Pariambus typicus	59	0,0	0,1
	Philocheras trispinosus	29	0,0	0,0
	Urothoe poseidonis	354	0,1	0,5
Molluscs	*Ensis directus*	29	0,0	0,0
	Tellina fabula	59	1,2	1,0
Nematoda	Nematoda	88	0,0	0,0
Nemertea	*Nemertea rodeband*	177	0,7	1,1
	Nemertea	118	0,3	0,6
Phoronida	Phoronida	29	0,0	0,0
Polychaetes	*Eteone longa*	206	0,0	0,0
	Eunereis longissima	29	0,0	0,0
	Lanice conchilega	265	11,9	17,4
	Malmgrenia darbouxi	206	0,3	0,6
	Poecilochaetus serpens	118	0,1	0,3
	Total	**1798**	**14,8**	**21,6**

Appendix 4 Monopiles: Densities and biomass of the dominant taxa

February 2008

Turbine 7			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				0	0,00	402	14,04	1054	182,96	1857	222,65	828	104,92
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			2304	73,25	71	2,69	27	-	9	-	603	37,97
		2,5-5 cm			4679	1044,14	821	239,28	0	0,00	0	0,00	1375	320,85
		>5 cm			0	0,00	268	156,06	0	0,00	0	0,00	67	39,02
		total			6982	1117,39	1161	398,03	27	-	0	-	2042	505,14
Crustaceans														
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata					0	0,00	1116	0,36	295	0,10	0	0,00	353	0,11
Echinoderms														
Asterias rubens	common starfish				0	0,00	9	82,91	0	0,00	0	0,00	2	20,73
Psammechinus miliaris	green sea urchin				0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia				0	0,00	0	0,00	9	-	9	-	4	0,00
Obelia spp.					0	0,00	0	0,00	54	-	0	0,00	13	0,00
Polychaetes	polychaete worms				0	0,00	54	1,53	0	0,00	27	0,23	20	0,44

Turbine 13			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				9	-	36	12,62	411	38,57	446	81,01	225	44,07
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			277	10,71	0	0,00	18	-	0	0,00	74	3,57
		2,5-5 cm			214	74,24	0	0,00	0	0,00	0	0,00	54	18,56
		>5 cm			0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
		total			491	84,96	0	0,00	18	-	0	0,00	127	28,32
Crustaceans														
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata					179	0,06	8929	2,88	3571	1,15	1607	0,52	3571	1,15
Echinoderms														
Asterias rubens	common starfish				0	0,00	0	0,00	9	-	0	0,00	2	0,00
Psammechinus miliaris	green sea urchin				0	0,00	27	35,20	18	27,13	0	0,00	11	15,58
Hydroids														
Tubularia larynx	ringed tubularia				0	0,00	0	0,00	9	-	36	1,93	11	0,64
Obelia spp.					0	0,00	0	0,00	36	-	9	-	11	0,00
Polychaetes	polychaete worms				0	0,00	0	0,00	18	0,35	0	0,00	4	0,09

Turbine 34			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				71	3,12	63	2,40	438	10,70	1080	40,96	413	14,29
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			536	33,74	232	15,47	214	12,37	27	-	252	20,53
		2,5-5 cm			1580	568,01	1241	351,07	786	253,46	0	0,00	902	293,14
		>5 cm			375	330,27	1071	634,21	339	223,96	0	0,00	446	297,11
		total			2491	932,02	2545	1000,75	1339	489,79	27	-	1600	807,52
Crustaceans														
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata					89	0,03	89	0,03	89	0,03	348	0,11	154	0,05
Echinoderms														
Asterias rubens	common starfish				0	0,00	36	310,25	18	280,53	54	9,38	27	150,04
Psammechinus miliaris	green sea urchin				0	0,00	27	25,06	18	1,85	0	0,00	11	6,73
Hydroids														
Tubularia larynx	ringed tubularia				0	0,00	0	0,00	0	0,00	9	-	2	0,00
Obelia spp.					0	0,00	0	0,00	0	0,00	9	-	2	0,00
Polychaetes	polychaete worms				63	4,54	71	4,09	107	2,08	45	0,37	71	2,77

- Biomass not determined (§2.2.2)

September 2008

Turbine 7			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				1402	26,94	634	27,63	223	17,61	196	18,96	614	22,78
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			3946	203,31	5634	568,52	6143	282,37	4625	193,98	5087	385,92
		2,5-5 cm			2518	1040,62	295	568,75	2679	668,42	5143	1107,86	2658	846,41
		>5 cm			152	208,85	348	707,14	205	336,91	500	867,84	301	530,19
		total			6616	1452,78	6277	1844,41	9027	1287,70	10268	2169,68	8047	1099,06
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**					1800	0,58	900	0,29	0	0,00	0	0,00	675	0,22
Echinoderms														
Asterias rubens	common starfish				9	-	9	63,72	27	6,59	18	-	16	35,16
Psammechinus miliaris	green sea urchin				0	0,00	0	0,00	18	1,34	36	-	54	0,45
Hydroids														
Tubularia larynx	ringed tubularia				p	-	0	0,00	p	-	0	0,00		-
Obelia spp.					0	0,00	0	0,00	p	-	0	0,00		-
Polychaetes	polychaete worms				491	5,55	179	2,79	196	1,84	179	2,59	261	3,19

Turbine 13			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				295	15,92	259	188,91	98	82,69	152	47,04	201	106,21
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			3902	226,12	3652	148,08	2027	96,11	3643	171,96	3306	160,57
		2,5-5 cm			4179	1417,78	5080	779,19	1580	201,08	813	221,83	2913	654,97
		>5 cm			518	617,78	0	0,00	0	0,00	295	-	203	205,93
		total			8598	2261,67	8732	927,27	3607	297,19	4750	393,79	6422	969,98
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**					0	0,00	0	0,00	1800	0,58	900	0,29	675	0,22
Echinoderms														
Asterias rubens	common starfish				18	27,38	9	11,89	27	32,63	27	75,27	20	36,79
Psammechinus miliaris	green sea urchin				9	-	0	0,00	9	23,46	9	32,62	7	18,69
Hydroids														
Tubularia larynx	ringed tubularia				p	-	0	0,00	p	-	p	-	-	-
Obelia spp.					0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Polychaetes	polychaete worms				250	4,08	9	-	116	1,08	125	0,44	125	1,87

Turbine 34			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				223	22,44	705	68,35	2188	38,63	973	87,05	1022	54,12
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			4170	214,73	5411	197,88	6616	196,03	268	1,79	4116	152,60
		2,5-5 cm			2821	689,88	2027	524,66	0	0,00	0	0,00	1212	303,63
		>5 cm			429	722,04	1027	1860,50	54	47,54	0	0,00	377	657,52
		total			7420	1626,64	8464	2583,04	6670	243,57	268	1,79	5705	1113,76
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**					0	0,00	0	0,00	1800	0,58	5800	1,87	1900	0,61
Echinoderms														
Asterias rubens	common starfish				9	-	18	11,15	0	0,00	0	0,00	7	3,72
Psammechinus miliaris	green sea urchin				0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia				0	0,00	0	0,00	p	-	0	0,00	-	-
Obelia spp.					0	0,00	0	0,00	p	-	0	0,00	-	-
Polychaetes	polychaete worms				116	7,21	473	7,48	259	1,67	143	0,83	248	4,30

- Biomass not determined (§2.2.2)
P = present but numbers could not be estimated

February 2011

Turbine 7			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones		0	0,00	0	0,00	652	19,12	679	9,55	732	536,42	413	113,02
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm	4911	309,88	89	2,01	1286	80,63	0	0,00	0	0,00	1257	78,50
		2,5-5 cm	643	106,43	0	0,00	607	366,74	89	38,05	0	0,00	268	102,24
		>5 cm	18	15,55	0	0,00	920	2226,91	804	4212,07	0	0,00	348	1290,91
		total	5571	431,86	89	2,01	2813	2674,29	893	4250,13	0	0,00	1873	1471,66
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**			5357	1,73	12054	3,88	16071	5,19	2232	0,72	0	0,00	7143	2,31
Echinoderms														
Asterias rubens	common starfish		0	0,00	63	10,33	214	94,16	0	0,00	0	0,00	55	20,90
Psammechinus miliaris	green sea urchin		0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia		0	0,00	P	-	P	-	P	-	P	-	p	-
Obelia spp.			0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	-
Polychaetes	polychaete worms		0	0,00	9	-	723	14,13	0	0,00	27	-	151,79	*

Turbine 13			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones		0	0,00	0	0,00	1330	19,59	3348	31,97	875	18,96	1388	23,51
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm	0	0,00	6152	822,28	1750	77,37	161	1,65	0	0,00	2016	299,88
		2,5-5 cm	71	8,63	491	82,15	1143	457,97	9	21,39	0	0,00	411	140,38
		>5 cm	18	57,41	0	0,00	554	1254,04	0	0,00	0	0,00	554	1254,04
		total	89	66,04	6643	904,46	3446	1785,71	170	23,04	0	0,00	2565	896,73
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**			0	0,00	179	0,05	3125	1,01	7589	2,45	12054	3,88	5737	1,65
Echinoderms														
Asterias rubens	common starfish		36	1,66	36	8,75	330	43,61	152	7,38	196	20,22	179	0,00
Psammechinus miliaris	green sea urchin		0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia		0	0,00	0	0,00	p	0,00	p	-	p	79,92	p	26,64
Obelia spp.			0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Polychaetes	polychaete worms		0	0,00	71	-	911	11,47	259	0,98	98	-	335	4,15

Turbine 34			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				813	14,74	1679	48,22	875	8,42	795	2,58	1040	18,49
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			63	1,11	223	6,05	170	10,81	0	0,00	114	5,99
		2,5-5 cm			0	0,00	116	51,90	107	58,57	0	0,00	56	27,62
		>5 cm			0	0,00	54	90,26	277	682,29	0	0,00	83	193,14
		total			63	1,11	393	148,21	554	751,70	0	0,00	252	300,34
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**					10714	3,46	16071	5,19	17411	5,62	5357	1,73	12388	4,75
Echinoderms														
Asterias rubens	common starfish				0	0,00	98	39,28	54	24,38	89	9,01	60	18,17
Psammechinus miliaris	green sea urchin				0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia				P	-	0	0,00	0	0,00	p	-	P	-
Obelia spp.					0	0,00	0	0,00	P	-	0	0,00	P	-
Polychaetes	polychaete worms				0	0,00	0	0,00	71	-	125	2,13	49	0,71

- Biomass not determined (§2.2.2)
P = present but numbers could not be estimated

September 2011

Turbine 7			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones		0	0,00	304	21,35	911	50,58	1411	42,10	982	319,73	721	86,75
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm	8473	318,37	5134	44,72	2616	82,62	286	16,84	161	1,23	3334	92,76
		2,5-5 cm	777	76,07	0	0,00	848	387,06	143	69,15	9	9,54	355	108,36
		>5 cm	0	0,00	0	0,00	375	801,04	786	1604,67	45	133,88	241	507,92
		total	9250	394,44	5134	44,72	3839	1270,71	1214	1690,66	214	144,65	3930	709,04
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**			3571	1,15	22321	7,20	57143	18,43	25000	8,06	14286	4,61	24464	7,89
Echinoderms														
Asterias rubens	common starfish		0	0,00	0	0,00	366	32,54	71	34,84	0	0,00	88	13,48
Psammechinus miliaris	green sea urchin		0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia		0	0,00	P	14,21	0	0,71	p	6,36	0	0,00	p	4,25
Obelia spp.			0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Polychaetes	polychaete worms		0	0,00	250	2,52	411	14,30	313	5,05	27	-	200	5,47

Turbine 13			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones				45	0,79	277	42,69	2000	44,85	1143	112,04	866	50,09
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm			14982	362,46	250	4,53	1973	58,38	1009	41,25	4554	116,66
		2,5-5 cm			643	104,04	134	27,92	839	526,42	759	313,88	594	243,06
		>5 cm			0	0,00	36	63,21	402	809,74	714	1426,43	288	574,85
		total			15625	466,52	420	95,66	3214	1394,54	2482	1781,55	5435	934,57
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**					5357	1,73	0	0,00	49107	7,20	89286	3,23	35938	9,44
Echinoderms														
Asterias rubens	common starfish				223	105,79	214	15,15	143	11,13	196	11,04	194	35,78
Psammechinus miliaris	green sea urchin				0	0,00	9	21,04	0	0,00	0	0,00	2	5,26
Hydroids														
Tubularia larynx	ringed tubularia				0	0,00	0	15,90	0	0,40	0	0,00	0	4,08
Obelia spp.					0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Polychaetes	polychaete worms				116	5,47	348	2,18	920	10,81	545	12,43	482	7,72

Turbine 34			Splash zone		2m		5m		10m		15m		**Average**	
Species / group	English name		numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	numbers	AFDW (g)	**numbers**	**AFDW (g)**
Anemones	anemones		0	0,00	696	77,25	857	91,93	1500	52,54	804	224,95	771	89,33
Molluscs														
Mytilus edulis	common mussel	0-2,5 cm	0	0,00	6866	136,98	3982	83,12	384	18,23	0	0,00	2246	47,67
		2,5-5 cm	1277	30,23	3429	843,62	268	103,87	554	299,72	0	0,00	1105	255,49
		>5 cm	54	14,45	0	0,00	9	24,10	580	1086,07	0	0,00	129	224,92
		total	0	0,00	10295	980,60	4259	211,08	1518	1404,03	0	0,00	3214	519,14
Crustaceans														
*Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata**			0	0,00	14286	4,61	17857	5,76	0	0,00	2232	0,72	6875	2,22
Echinoderms														
Asterias rubens	common starfish		0	0,00	321	13,51	170	17,41	27	0,96	0	0,00	104	6,38
Psammechinus miliaris	green sea urchin		0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Hydroids														
Tubularia larynx	ringed tubularia		0	0,00	0	5,68	0	0,00	0	0,00	0	0,00	0	1,14
Obelia spp.			0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
Polychaetes	polychaete worms		0	0,00	45	0,07	0	0,00	375	6,24	0	0,00	84	1,26

- Biomass not determined (§2.2.2)
P = present but numbers could not be estimated

Appendix 5 Scour protection: Densities and biomass of the dominant taxa

February 2008 scour protection

Turbine 7: 10 small rocks collected; total area circa 0,09 m^2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Diadumene cincta and Metridium seni	anemones	633	37,04
Tubularia larynx	ringed tubularia	1%	*
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		0-70%	*
Sessilia	barnacles	33	0,96
Bryozoans			
Conopeum reticulum	sea mat	0-60%	*

Turbine 13: 3 small rocks collected; total area circa 0,06 m^2			
Species	English name	number per m2/ covering percentage	g AFDW /m2
Cnidarians			
Diadumene cincta, Sagartia sp. and Metridium senile	anemones	300	22,95
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		0-15%	*
Bryozoans			
Conopeum reticulum	sea mat	1-25%	*

Turbine 34: 2 small rocks collected; total area circa 0,0625 m^2			
Species	English name	number per m2/ covering percentage	g AFDW /m2
Cnidarians			
Diadumene cincta, Sagartia sp. and Metridium senile	anemones	1008	46,50
Molluscs			
Crepidula fornicata	slipper limpet	16	4,45
Echinoderms			
Asterias rubens	common starfish	16	4,22
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		15-40%	*
Bryozoans			
Conopeum reticulum	sea mat	30-50%	*

* Biomass not determined (see § 2.2.2)

September 2008 scour protection

Turbine 7: 10 small rocks collected; total area circa 0,018 m2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Metridium senile	anemones	1000	928,56
Tubularia larynx	ringed tubularia	<1%	*
Molluscs			
Mytilus edulis	mussel < 2,5cm	3167	143,44
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/		5%	*
Bryozoans			
Conopeum reticulum	sea mat	60%	*

Turbine 13: 3 small rocks collected; total area circa 0,02 m2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Diadumene cincta, Sagartia sp. and Metridium senile	anemones	2500	185,65
Molluscs			
Mytilus edulis	mussel > 5cm	150	401,8
	mussel 2,5-5cm	10200	2554,25
	mussel < 2,5	9350	593,85
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/		10%	*
Bryozoans			
Conopeum reticulum	sea mat	80%	*

Turbine 34: 2 small rocks collected; total area circa 0,0472 m2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Sagartia sp. and Metridium senile	anemones	403	103,37
Molluscs			
Mytilus edulis	mussel < 2,5cm	64	0,74
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/		50%	*
Bryozoans			
Conopeum reticulum	sea mat	80%	*

* Biomass not determined (see § 2.2.2)

February 2011 scour protection

Turbine 7: 6 small rocks collected; total area circa 0,04 m^2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Sagartia spp. and *Metridium senile*	anemones	375	153,40
Halecium halecium	herring-bone hydroid	1-5%	*
Tubularia larynx	ringed tubularia	<1%	*
Echinoderms			
Asterias rubens	common starfish	100	22,75
Bryozoans			
Conopeum reticulum	sea mat	50%	*

Turbine 13: 3 small rocks collected; total area circa 0,05 m^2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Diadumene cincta and Metridium seni	anemones	380	120,88
Tubularia indivisa	oaten pipes hydroid	<1%	*
Echinoderms			
Asterias rubens	common starfish	20	1,62
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		50%	*
Bryozoans			
Conopeum reticulum	sea mat	60%	*
Poriferans			
Prosuberites epiphytum		30%	*

Turbine 34: 3 small rocks collected; total area circa 0,05 m^2			
Species	English name	number per m2/ covering percentage	g AFDW / m2
Cnidarians			
Metridium senile	plumose anemone	60	9,54
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		30%	*
Bryozoans			
Conopeum reticulum	sea mat	70%	*

* Biomass not determined (see § 2.2.2)

September 2011 scour protection

Turbine 7: 4 small rocks collected; total area circa 0,04 m^2			
Species	English name	number per m2/ covering percentage	g AFDW /m2
Cnidarians			
Diadumene cincta, Sagartia sp. and Metridium senile	anemones	1725	634,03
Echinoderms			
Asterias rubens	common starfish	75	11,88
Ophiothrix spp.	common brittlestar	25	1,13
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		30%	*
Bryozoans			
Conopeum reticulum	sea mat	80%	*

Turbine 13: One large sponge collected from scour protection: total area circa 0,038 m^2			
Species	English name	number per m2/ covering percentage	g AFDW /m2
Cnidarians			
Metridium senile	plumose anemone	26	14,34
Echinoderms			
Ophiothrix spp.	common brittlestar	184	14,18
Crustaceans			
Caprella spp.	skeleton shrimp	65789	16,53
Poriferans			
Halichondria panicea	breadcrumb sponge	100%	301,89

Turbine 34: 3 small rocks collected; total area circa 0,05 m^2			
Species	English name	number per m2/ covering percentage	g AFDW /m2
Cnidarians			
Diadumene cincta and Sagartia sp.	anemones	680	367,42
Echinoderms			
Asterias rubens	common starfish	140	2,46
Crustaceans			
Monocorophium acherusicum/ M.sextonae/ Jassa herdmani/ J.marmorata		40%	*
Bryozoans			
Conopeum reticulum	sea mat	60%	*

* Biomass not determined (see § 2.2.2)

Bureau Waardenburg bv
Consultants for environment & ecology

P.O. Box 365
4100 AJ Culemborg The Netherlands
Tel +31 345 512 710
Fax + 31 345 519 849
E-mail: info@buwa.nl
Website: www.buwa.nl