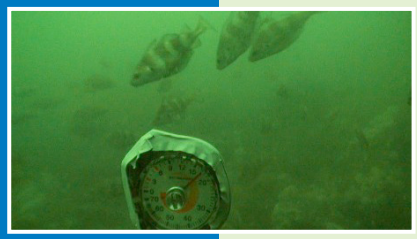
Development of underwater flora- and fauna communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ)



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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 Royal NIOZ.

As part of this contract Bureau Waardenburg was commissioned to describe the colonisation of hard substrates within the OWEZ. For this purpose, a qualitative assessment (species composition and covering percentages) and quantitative assessment (numbers and biomasses of species present) at three different turbines in February 2008 (end of winter situation) and September 2008 (end of summer situation) was carried out. Results of the assessment carried out in February are reported in Bouma & Lengkeek (2008). This report presents the results of February and September and includes a comparison of both assessments.

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. The authors thank Wals Diving & Marine Services for preparing the operational procedures and carrying out the diving activities, and Noordzeewind for their valuable assistance to complete the formal procedures to work in the OWEZ. Furthermore, we thank Pieter-Bas Broeckx for his help with the laboratory analysis and Renée Lefeber for producing some of the figures in this report.

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Summary

The Offshore Wind farm Egmond aan Zee (OWEZ) was built between April and August 2006 and is in operation since January 2007. An extensive Monitoring and Evaluation Program (NSW-MEP) has been designed in which the economical, technical, ecological and social effects of the OWEZ are studied. This report presents an ecological study on the development of marine flora and fauna communities on the new hard substrates introduced by the wind farm: the monopiles and the rocks of the scour-protection layer. Three turbines were selected to cover different areas of the OWEZ: turbines 7, 13 and 34. These turbines were visited in February and September 2008.

Using video footage and samples collected by divers, qualitative (species composition and covering percentages) and quantitative assessments (numbers and biomasses of species present) of the communities that have colonised the hard substrates of turbines 7, 13 and 34 were carried out. Results were compared with growth on hard structures of the turbines in the Horns Rev offshore wind farm in Denmark and with growth on other hard structures in the North Sea.

In February 2008, a total of 30 different species were identified on the video footage and/or collected samples from turbines 7, 13 and 34. In September 2008 three additional species were identified, a species of green algae, the pullet carpet shell (*Venerupis senegalensis*) and the Northsea crab (*Cancer pagurus*) resulting in a total of 33 species. Fish species were not included in this number, but fish species seen during the surveys in February and September 2008 included schools of pouting (*Trisopterus lucus*), longspined bullhead (*Taurulus bubalis*) and Northsea cod (*Gadus morhua*).

In February 2008 and September 2008 two clear zones consisting of two hard substrate communities could be distinguished on the monopiles of turbines 7, 13 and 34:

- An upper zone consisting of a community dominated by the common mussel (*Mytilus edulis*) and associated species like barnacles (*Balanus crenatus* and *Balanus balanoides*), the common starfish (*Asterias rubens*), several species of worms and crabs and the encrusting sea mat (*Conopeum reticulum)*. Covering percentages of mussels within the first few metres from the surface varied between 80-100%. Bare patches in between the mussels were colonised by anemones (mainly *Metridium senile* and *Sargartia spp*.) and (tubes of) the small crustacean *Jassa spp*.
- A deeper zone dominated by a community consisting of (tubes of) *Jassa spp*., several species of anemones (*Metridium senile*, *Sargartia spp*. and *Diadumene cincta*) and patches of the ringed tubularia *Tubularia larynx*. Green sea urchins (*Psammechinus miliaris*) and common starfish (*Asterias rubens*) were also present in this zone, but occurred in low numbers. This community occupied the entire surface of the monopiles (covering percentage 100%) from the zone below the mussels to the sea floor.

Covering percentages of the most dominant species of these communities varied between turbines and different depths. Other less common species identified on the

monopiles include the Japanese oyster (*Crassostrea gigas)*, Titan acorn barnacle (*Megabalanus coccopoma*), skeleton shrimp (*Caprella linearis),* hairy crab (*Pilimnus hortellus),* common brittlestar (*Ophiotrix fragilis),* aquatic sowbug (*Idotea balthica),* porcelain crab (*Pisidia longicornis*), velvet swimming crab (*Necora puber*) and Northsea crab (*Cancer pagurus*).

Two main differences between the assessment carried out in February 2008 and the assessment carried out in September 2008 were recognised:

1. The abundance of mussels increased. Coverage of mussels has become denser in September and bare patches still present in February were colonised.
2. The hard substrate community dominated by mussels expanded to greater depths in September 2008, especially on the monopiles of turbines 7 and 13.

The most dominant species on the rocks of the scour-protection layer of turbines 7, 13 and 34 are the sea mat *Conopeum reticulum*, the plumose anemone *Metridium senile*, *Sargartia spp*. anemones, (tubes of) the crustacean *Jassa spp*. and the ringed tubularia *Tubularia larynx*. Clumps of mussels (fallen of the monopile) between the rocks attract the common starfish *Asterias rubens.* Other notable less abundant species include the Japanese oyster (*Crassostrea gigas*), slipper limpet (*Crepidula fornicata*), barnacles (*Semibalanus balanoides* and *Balanus crenatus*), the hydroid *Obelia spp*. and orange crust (*Cryptosula pallasiana*).

In February 2008 the rocks collected at turbines 7 and 34 were almost fully overgrown, but rocks collected at turbine 13 (figure 8) were relatively bare. This was also expressed in the total number of species found on the rocks around the base of the three turbines (12 species at turbines 7 and 34 and 5 species at turbine 13 (see table 1).

In September 2008 growth on the rocks collected at turbines 7, 13 and 34 was comparable (respectively 14, 17 and 11 species). Different from the February 2008 survey was the presence of large schools of pouting around the base of the three turbines and the presence of the Northsea crab (*Cancer pagurus*) between the rocks.

The new hard substrate communities provide a valuable food source for fish species like the North Sea cod (*Gadus morhua*) and pouting (*Trisopterus lucus*). In September 2008 schools of pouting were present at the bases of turbines 7, 13 and 34. The North Sea cod is an important commercial species that showed a strong decline as a result of over-fishing. If the new hard substrate communities do attract North Sea cod to the OWEZ and if they reside within the park where fishing is prohibited, the OWEZ could contribute to the recovery of this species.

Within the Danish offshore Horns Rev wind farm a significant increase in the abundance of Common scoter (*Melanitta nigra*) was observed between 1999 and 2006, and the Common eider (*Somateria mollisima*) was also a numerous species within this wind farm. This increase of both species within this wind farm could be a reflection of changes in the availability of food as a result of establishment of new hard substrate communities on the monopiles and rocks of the scour-protection layer, but

no conclusive explanation was provided by the researchers. Bird observations carried out by Bureau Waardenburg and IMARES in the OWEZ wind farm since mid 2007 show that cormorants are foraging for fish in the wind farm on a regular basis, especially during the summer months. Other bird species that forage on fish or molluscs are only seen in the wind farm occasionally. For instance, divers are seen incidentally near or in the wind farm, and recently a pair of common eiders was seen foraging (for molluscs) within the wind farm (Karen Krijgsveld personal comments).

Causal relationships between the presence of the new hard substrate communities and fish and/or birds within OWEZ cannot be demonstrated at the moment. Monitoring the effects on birds and fish is still work in progress and further research into the development of the hard substrate communities will also be carried out in 2011. A recommendation for future work is to carry out an analysis to study effects of offshore wind farms on the entire North Sea ecosystem integrating results of separate monitoring and evaluation programmes.

A comparison of the results obtained in the OWEZ with results from the Horns Rev wind farm, indicates that the growth on the hard structures of the turbines in the two wind farms is comparable. Notable differences are: 1) a more distinct presence of an algal zone in Horns Rev, 2) the presence of an almost monoculture population of the giant midge *Telmatogeton japonicus* in the splash zone in Horns Rev and 3) the much higher abundance of *Jassa spp*. in Horns Rev.

The observed growth on the hard structures of the OWEZ also seems comparable to growth on other similar hard structures (e.g. steel platforms) 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 wind-energy exploitation is predicted. 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). The 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 August 2006 and is in operation since January 2007. The project serves as a demonstration project to build up 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. This report presents an ecological study on the development of marine flora and fauna communities on the new hard substrates introduced by the wind farm.

1.2 Description of the OWEZ

The 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) arising 70 metres above sea level. With rotor the total height of the turbines is 115 metres. The water depth within the OWEZ varies between 15 to 20 metres. The wind farm consists of four rows of turbines (at a distance of approximately 1 kilometre) with a minimum distance of 650 metres between the turbines. A 116-metre meteorological mast has been installed, to measure wind speeds at various levels, temperature, rainfall and humidity (measuring mast).

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

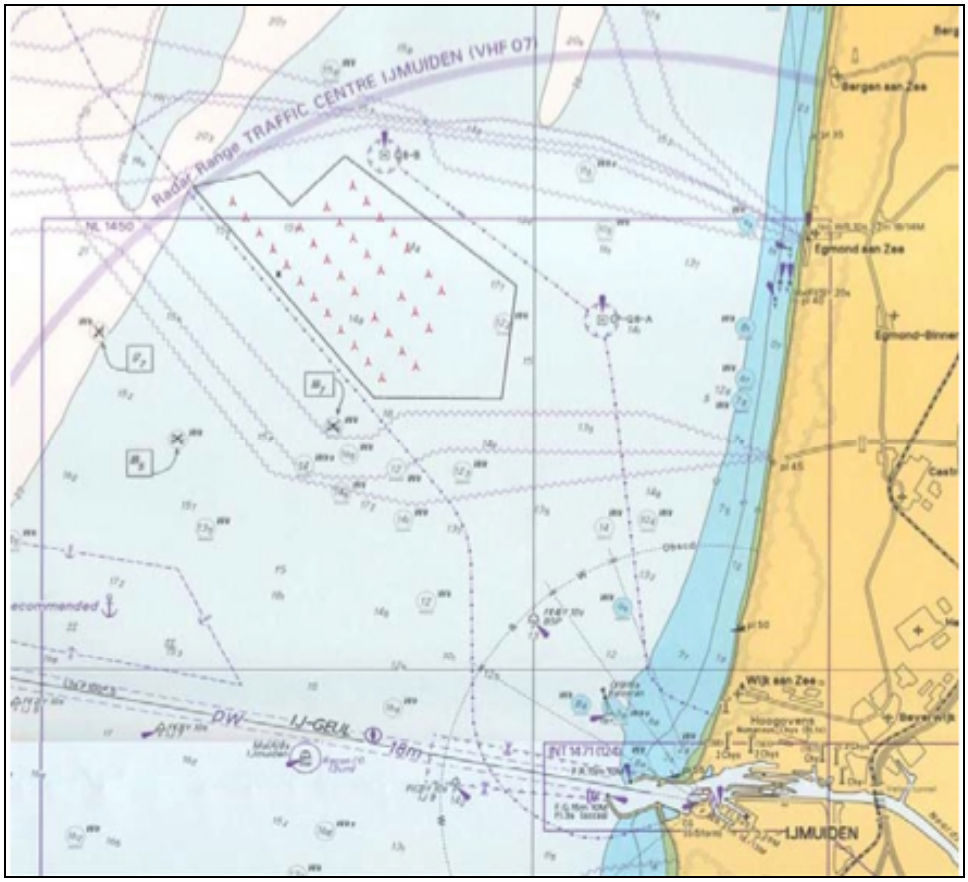

Figure 1 Location and site layout of the OWEZ (source: Noordzeewind 2003a).

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 these hard substrates will be colonised by a variety of sessile species including seaweeds, barnacles, mussels, oysters, anemones, sponges, hydroids, bryozoans and tubeworms. Subsequently these sessile species will attract mobile species like small crustaceans, sea urchins, starfish, crabs and fish. Hard substrate communities will develop that are different from the soft substrate communities previously present at the OWEZ location.

This project was carried out on behalf of NoordzeeWind, through a sub contract with Imares. Bureau Waardenburg was commissioned to describe the colonisation of the two types of hard substrates within the OWEZ by carrying out a qualitative assessment (species composition and covering percentages) and quantitative assessment (numbers and biomasses of species present) at three different turbines in February 2008 (end of winter situation) and September 2008 (end of summer situation). Results of the assessment carried out in February are reported in Bouma & Lengkeek (2008). This report presents the results of February and September and includes a comparison of both assessments.

1.4 Objective

The aim of this study is to gain insight in the qualitative (species composition and covering percentages) and quantitative development (numbers and biomasses of species present) of hard substrate communities on the two types of hard substrates present in the OWEZ.

1.5 Parallel studies

The new developing hard substrate communities may not only have an ecological impact on the existing ecosystem, but could also have an effect on the technical performance of the turbines. Monitoring the colonisation of hard substrates is therefore included in both the ecological and the technical monitoring programmes of the OWEZ. The design of both programmes is different (see table 1) because of different research aims, but data from both programmes complement each other.

Table 1 Colonisation of hard substrates present in the OWEZ: comparison of the technical and ecological monitoring programmes

	Technical Programme	Ecological programme
Researchers	KEMA	Bureau Waardenburg
Research aim	To determine the extent of marine growth on turbine support structures (monopile, access arrangement, J-tubes and cable exits, anodes and the seabed) and if possible link the extent of marine growth to the technical performance of the turbines.	To gain insight in the qualitative (species composition and covering percentages) and quantitative development (numbers and biomasses of species present) of hard substrate communities on the two types of hard substrates present in the OWEZ.
Turbine selection	Turbines were selected that are equipped with instruments that measure the performance of the turbines (turbines 7, 8 and the measuring mast).	Turbines were selected to cover different areas of the OWEZ where colonisation could be different (turbines 7, 13 and 34) (see also §2.2 turbine selection).
Methods	Video images and samples collected by means of a Remotely Operated Vehicle (ROV).	Video images and samples collected by divers.

2 Materials and methods

For transport from IJmuiden Harbour to the wind farm and to conduct research (diving) activities, the vessels 'Pollux' and 'Zeeland' were used in February and September respectively. Diving activities were carried out by divers from Wals Diving & Marine Service based in IJmuiden. By means of an underwater CCTV (closed circuit television) and communication system, Bureau Waardenburg employees were able to instruct the divers and follow their activities. Laboratory analyses and assessments (qualitative and quantitative) were conducted by Bureau Waardenburg in Culemborg.

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 incidence of light). Based on this information it may be possible that colonisation of the monopiles and the rocks of the scour protection is different for different areas of the OWEZ and that colonisation may vary between seasons.

In February 2008 three turbines were selected to cover different areas of the OWEZ where colonisation could be different as a result of various factors described above: turbines 7, 13 and 34 (see figure 2). Turbine 7 was also selected to be able to compare results from the ecological monitoring programme with results from the technical monitoring programme carried out by KEMA (see table 1). In September 2008 the same three turbines were visited.

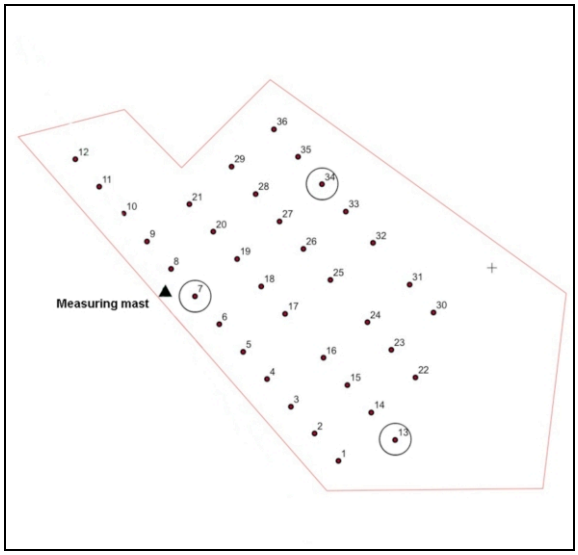

Figure 2 *Turbines selected to cover different areas of the OWEZ: turbines 7, 13 and 34.*

2.2 Collection of video footage and samples

Video footage of the monopiles and the scour-protection layers of turbines 7, 13 and 34 were collected using a SONY video camera in an Amphibico underwater housing. Monopiles were filmed from both the northern and southern side and from the surface to the seafloor. Rocks of the scour-protection layer were filmed at different sides of the monopile and at different distances from the base of the monopile.

Samples of organisms present on the monopiles were collected at four different depths (2, 5, 10 and 15 metres) 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 x 20 centimetres were scraped of the monopile, collected in a fine-maze net (mesh size circa 0,25 mm) and brought to the surface. The sample-surface areas contain fairly large error margins because the rough conditions for diving in the wind farm (i.e. strong current) make accurate sampling difficult. At the surface each sample was stored separately and preserved in a cool box. Samples of organisms present on the rocks of the scour-protection layer were taken through the collection of several small rocks and bringing these to the surface. All samples were taken to the laboratory of Bureau Waardenburg in Culemborg for further analyses.

2.3 Laboratory analyses

In the laboratory the collected organisms were sorted and species and/or higher taxa identified and counted. Individuals of *Jassa sp*. can occur in relatively high numbers and with extremely small body sizes (younger individuals). Numbers of *Jassa sp.* where generally estimated, not counted, because a detailed count of all individuals would not contribute significantly to our analysis of the hard substrate communities.

Subsequently, biomasses (as ash-free dry weights, AFDW) were determined for the most abundant taxa. Biomasses where determined to quantify the high abundance of the most dominant taxa (e.g. mussels) and illustrate their energetic value for predating animals (e.g. birds, fish). Therefore, biomasses where only determined for taxa that occurred in significant quantities. Biomass for *Jassa sp*. was generally not determined, however we determined the biomass for 100 specimens on one occasion so numbers can be translated to biomasses if needed. 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.

2.4 Qualitative and quantitative assessments

Using the video footage collected by 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 that have colonised the hard substrates of turbines 7, 13 and 34 were carried out. The results were compared with results of the assessment carried out in February 2008 (Bouma & Lengkeek, 2008).

In the discussion an indicative extrapolation is provided for the development of underwater flora and fauna communities on hard substrates of all turbines of the OWEZ. The ecological value of these communities is discussed and results are compared with growth on hard structures of the turbines in the Horns Rev offshore wind farm in Denmark and with growth on other hard structures in the North Sea.

3 Results

3.1 Qualitative assessment: species composition and covering percentages

Species composition

Table 1 (and figure 3) shows the total number of species identified on the video footage and/or collected samples from turbines 7,13 and 34 both for the assessment carried out in February 2008 and the assessment carried out in September 2008.

A total of 30 different species were identified on the video footage and/or collected samples (table 1 and figure 3) from turbines 7, 13 and 34 in February 2008. In September 2008 three additional species were identified, a species of green algae (*Ulva spp*. and/ or *Enteromorpha spp*.), the pullet carpet shell (*Venerupis senegalensis*) and the Northsea crab (*Cancer pagurus*) resulting in a total of 33 species. Fish species are not included in table 1, but fish species seen during the surveys in February and September include schools of pouting (*Trisopterus lucus*), longspined bullhead (*Taurulus bubalis*) and Northsea cod (*Gadus morhua*).

In February 2008 the number of species on the monopiles of the three different turbines varied. The number of species found on the monopile of turbine 34 (24 species) was considerably higher than the number of species found on the monopiles of turbine 7 (18 species) and turbine 13 (15 species). In September 2008 the number of species found on the monopiles was the same for the each of three turbines (21 species).

The number of species found on the rocks of the scour-protection layers of the three turbines was generally lower than the number of species found on the monopiles. In February 2008 the lowest number of species was found on the rocks around the base of turbine 13 (5 species). The number of species on the rocks around the base of turbines 7 and 34 was in February exact the same (12 species). In September 2008 the number of species identified on the rocks collected at turbines 7, 13 and 34 were respectively 14, 17 and 11 species.

Table 1 Species identified on either the video footage and/or collected samples from turbines 7, 13 and 34 in February and September 2008.

Species	English name	Turbine 7				Turbine 13				Turbine 34			
		Monopile		Scour-protection		Monopile		Scour-protection		Monopile		Scour-protection	
		February	September	February	September	February	September	February	September	February	September	February	September
Green algae			x				x						
Anemones (Cnidaria)													
Actinia equina	red beadlet anemone									x			
Diadumene cincta	orange anemone	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
Sargatia spp.		x	x	x	x	x	x	x	x	x	x	x	x
Barnacles (Crustacea)													
Balanus crenatus	crenate barnacle	x	x	x	x	x	x			x	x		
Megabalanus coccopoma	titan acorn barnacle					x				x			
Semibalanus balanoides	rock barnacle	x	x			x	x		x	x	x		
Molluscs													
Crepidula fornicata	slipper limpet						x					x	
Crassostrea gigas	Japanese oyster	x[1]		x						x	x	x	x
Mytilus edulis	common mussel	x	x	x[1]	x	x	x		x[1]	x	x		
Aeolidiella glauca	(marine nudibranch)	x								x	x		
Venerupis senegalensis	pullet carpet shell						x				x		
Crustacea													
Caprella linearis	skeleton shrimp	x	x		x		x		x	x	x		x
Corophium volutator	mud shrimp	x	x		x		x		x		x		
Idotea balthica	aquatic sowbug		x		x		x		x	x	x		
Jassa spp.		x	x	x	x	x	x	x	x	x	x	x	x
Pilumnus hirtellus	hairy crab	x	x				x			x	x		
Pisidia longicornis	porcelain crab		x							x			
Necora puber	velvet swimming crab						x		x[1]	x[1]	x[1]		x[1]
Cancer pagurus	Northsea crab		x[1]						x[1]				x[1]
Echinodermata													
Asterias rubens	common starfish	x	x[1]	x[1]		x	x		x[1]	x	x	x	
Ophiotrix fragilis	common brittlestar					x							
Psammechinus miliaris	green sea urchin		x		x	x	x			x	x		
Bryozoa													
Conopeum reticulum	sea mat (encrusting bryozoan)	x	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		x	x		x	x	x	x	
Obelia spp.		x		x		x		x		x		x	x[1]
Worms													
Lepidonotus clava	scale worm	x	x		x	x	x		x	x	x		x
Nereis spp.			x		x		x		x	x	x		
Annelida (multiple species)		x	x		x		x		x	x	x		
Pomatoceros triqueter	keelworm											x	
	Total number of species	18	21	12	14	15	21	5	17	24	21	12	11

x[1] Identified on video, not in collected samples.

Figure 3 Pictures of species identified on hard structures of turbines 7, 13 and 34 (not for all identified species a high quality picture was available).

Covering percentages

Monopiles

In February 2008 a clear zonation (i.e. the distribution of organisms in different zones) existed in the hard substrate communities of monopiles 7, 13 and 34. The hard substrate communities comprised:

- An upper zone consisting of a community dominated by the common mussel (*Mytilus edulis*) and associated species like barnacles (*Balanus crenatus* and *Balanus balanoides*), the common starfish (*Asterias rubens*), several species of worms and crabs and the encrusting sea mat (*Conopeum reticulum)*. Covering percentages of mussels within the first few metres from the surface varied between 80-100%. Bare patches in between the mussels were colonised by anemones (mainly *Metridium senile* and *Sargartia spp*.) and (tubes of) the small crustacean *Jassa spp*.
- A deeper zone dominated by a community consisting of (tubes of) *Jassa spp*., several species of anemones (mainly *Metridium senile* and *Sargartia spp*.; and less abundant *Diadumene cincta*) and patches of the ringed tubularia *Tubularia larynx*. Green sea urchins (*Psammechinus miliaris*) and common starfish (*Asterias rubens*) were also present in this zone, but did occur in low numbers. This community occupied the entire surface of the monopiles (covering percentage 100%) from the zone below the mussels to the sea floor.

Covering percentages of the most dominant species of these communities varied between turbines and different depths.

In September 2008 two different zones in the hard substrate communities could still be distinguished on the monopiles of the three turbines, but two main differences with the February 2008 assessment were recognised:

1. The abundance of mussels increased. Coverage of mussels has become denser in September and bare patches still present in February were colonised.
2. The mussel-dominated zone has expanded to greater depths, especially on the monopiles of turbines 7 and 13.

A full qualitative description of the underwater growth on the monopiles of turbines 7, 13 and 34 at different depths in September 2008 including a comparison with the results of the February assessment is provided in the paragraphs below. Pictures of the underwater growth on the different turbines in respectively February and September 2008 are shown in figure 4 (turbine 7), figure 5 (turbine 13) and figure 6 (turbine 34). Depth ranges presented with the pictures illustrate the zonation and differences in the zonation between February and September 2008.

Turbine 7

In February 2008 the hard substrate community dominated by mussels and associated species occurred to approximately 6 m depth. Covering percentages of mussels in the zone from the surface to approximately 6 m depth varied between 80-100% and only a few bare patches colonised by (tubes of) *Jassa spp.* and anemones were present. At 6-7 m depth mussels became scarcer and the second hard substrate community dominated by (tubes of) *Jassa spp*., anemones and patches of the orange anemone *Diadumene cincta* and the ringed tubularia *Tubularia larynx* takes over. Tubes of *Jassa spp*. were most dominant (covering percentages between 40-80%) followed by the plumose anemone *Metridium senile* (covering percentages between 5-30%) and *Sargartia spp*. anemones (covering percentages between 5-25%). The orange anemone *Diadumene cincta* and the ringed tubularia *Tubularia larynx* were also common, but occurred in patches (covering percentages less than 5%). Other less common species identified on the monopile of turbine 7 included the Japanese oyster (*Crassostrea gigas)*, the skeleton shrimp (*Caprella linearis)* and the hairy crab *Pilimnus hortellus.*

In September 2008 the intertidal area to approximately 0,5 m depth was colonised by green algae (*Ulva spp*. and/or *Enteromorpha spp*.). Below 0,5 m depth the hard substrate community dominated by mussels and associated species has expanded to approximately 10 m depth. Growth of mussels has become more dense and the bare patches in between the mussels present in February 2008 are now colonised by mussels (covering percentage 100% to 10 m depth). In between the mussels plumose anemones, *Sargartia spp*. anemones and patches of the orange anemone *Diadumene cincta* are common and some starfish are present. At 10-14 m depth mussels become scarcer and the community dominated by plumose anemones (covering percentages between 30-40%), *Jassa spp*. (covering percentages between 40% and 60%) and patches of the orange anemone *Diadumene cincta* (covering percentages between 5-10%) is recognised. This community is dominant from approximately 12-13 m depth to the seafloor (circa 17 m depth), but patches of mussels still occur to depths of 15 m. Six new species were identified on the monopile of turbine 7: green algae, the aquatic sowbug (*Idotea balthica*), the porcelain crab (*Pisidia longicornis*), the velvet swimming crab (*Necora puber*) (common at all depths), the Northsea crab (*Cancer pagurus*) (one individual seen on video at 15 m depth) and the green sea urchin (*Psammechinus miliaris*).

Turbine 13

In February 2008 mussels colonised the monopile to a depth of approximately 3 m. Covering percentages varied between 60-80% and the bare patches in between were partly colonised by (tubes of) *Jassa spp.* and anemones. Below 3 m mussels disappeared and the second hard substrate community dominated by (tubes of) *Jassa spp*., anemones and patches of the orange anemone *Diadumene cincta* and the ringed tubularia *Tubularia larynx* occurred. Tubes of *Jassa spp*. were most abundant (more than on the monopile of turbine 7) and covered areas of about 60-90%. At 10 m depth the plumose anemone *Metridium senile* was very common and covered areas up to 30-40%. Covering percentages of *Sargartia spp*. anemones were between 5 and 20%. The orange anemone *Diadumene cincta* and the ringed tubularia *Tubularia*

larynx were common, but occurred in patches (covering percentages less than 5%). Different from the monopile of turbine 7 was the notable presence of green sea urchins (*Psammechinus miliaris*) and common starfish (*Asterias rubens*) especially in the zone below the mussels to the sea floor. Another less common species identified on the monopile of turbine 13 were the common brittlestar (*Ophiotrix fragilis)*.

In September 2008 the intertidal area was colonised by green algae. Below the surface the hard substrate community dominated by mussels and associated species has expanded to approximately 6 m depth. Growth of mussels has become denser and the bare patches in between the mussels present in February 2008 are now colonised by mussels (covering percentage 100% to 5 m depth). Green sea urchins are present in between the mussels, but anemones are relatively sparse, which is different from the monopile of turbine 7. At 5-6 m depth mussels become scarcer and the community dominated by *Jassa spp*. (covering percentages between 60-90%), plumose anemones (covering percentages between 5-50% increasing with depth), patches of the orange anemone *Diadumene cincta* (covering percentage 0-5%) and patches of the encrusting sea mat (covering percentages 0-5%) is present. This community is dominant from approximately 6 m depth to the seafloor (circa 17 m depth), but patches of mussels still occur to depths of 8-9 m. Green sea urchins and starfish are abundant on the monopile, especially below 5 m depth, which is different from the monopile of turbine 7. Eight new species were identified on the monopile of turbine 13: green algae, the slipper limpet (*Crepidula fornicata*), the skeleton shrimp (*Caprella linearis*), the mud shrimp (*Corophium volutator*), the aquatic sowbug (*Idotea balthica*), the hairy crab (*Pilumnus hirtellus*), the velvet swimming crab (*Necora puber*), *Nereis spp.* and Annelida.

Turbine 34

In February 2008 growth on the monopile of turbine 34 was more developed than growth on the monopiles of turbines 7 and 13. A thick layer of mussels (circa 10-15 cm) was present from the surface to approximately 10 m depth with hardly any bare patches in between (covering percentages to 6 m depth were between 80-100% and at 10 m depth (40-70%). Below 10 m mussels became scarcer, but they were still present at all depths to the sea floor; this in contrast to mussels on the monopiles of turbines 7 and 13. The second hard substrate community was dominant below 10 m depth and also seemed more developed (growth more dense) than on the monopiles of turbines 7 and 13. Covering percentages of the most common anemones *Metridium senile* (20-30%), *Sargartia spp*. (5-20%) and *Diadumene cincta* (0-5%) and the ringed tubularia *Tubularia larynx* (0-5%) were comparable to the covering percentages of these species on the other monopiles. Other less common species identified on the monopile of turbine 34 were the marine nudibranch *Aeolidiella glauca*, the Japanese oyster (*Crassostrea gigas)*, the skeleton shrimp (*Caprella linearis*), the aquatic sowbug (*Idotea balthica*), the hairy crab (*Pilumnus hirtellus*), the porcelain crab (*Pisidia longicornis*) and the velvet swimming crab (*Necora puber*).

In September 2008 the growth of mussels has become denser and growth of other species in between the mussels, like plumose anemones, *Sargartia spp*. anemones and different bryozoans and hydroids, seems to be more abundant. The zone with mussels

has expanded to approximately 11 m depth with a covering percentage of 100% to 10 m depth. From 10-12 m depth mussels become scarcer and from 12 m to the seafloor (at 16 m depth) a community dominated by *Jasssa spp*. (covering percentages 50-60%), plumose anemones (covering percentages 10-30%), the orange anemone *Diadumene cincta* (covering percentage 10-30%) and *Sargartia spp*. anemones (covering percentages 5-10%) dominates. Especially the orange anemone *Diadumene cincta* seems more abundant on the monopile of turbine 34 than on the monopiles of turbines 7 and 13. Starfish and velvet swimming crabs are abundant at all depths, green sea urchins are less common. No new species were identified on the monopile of turbine 34.

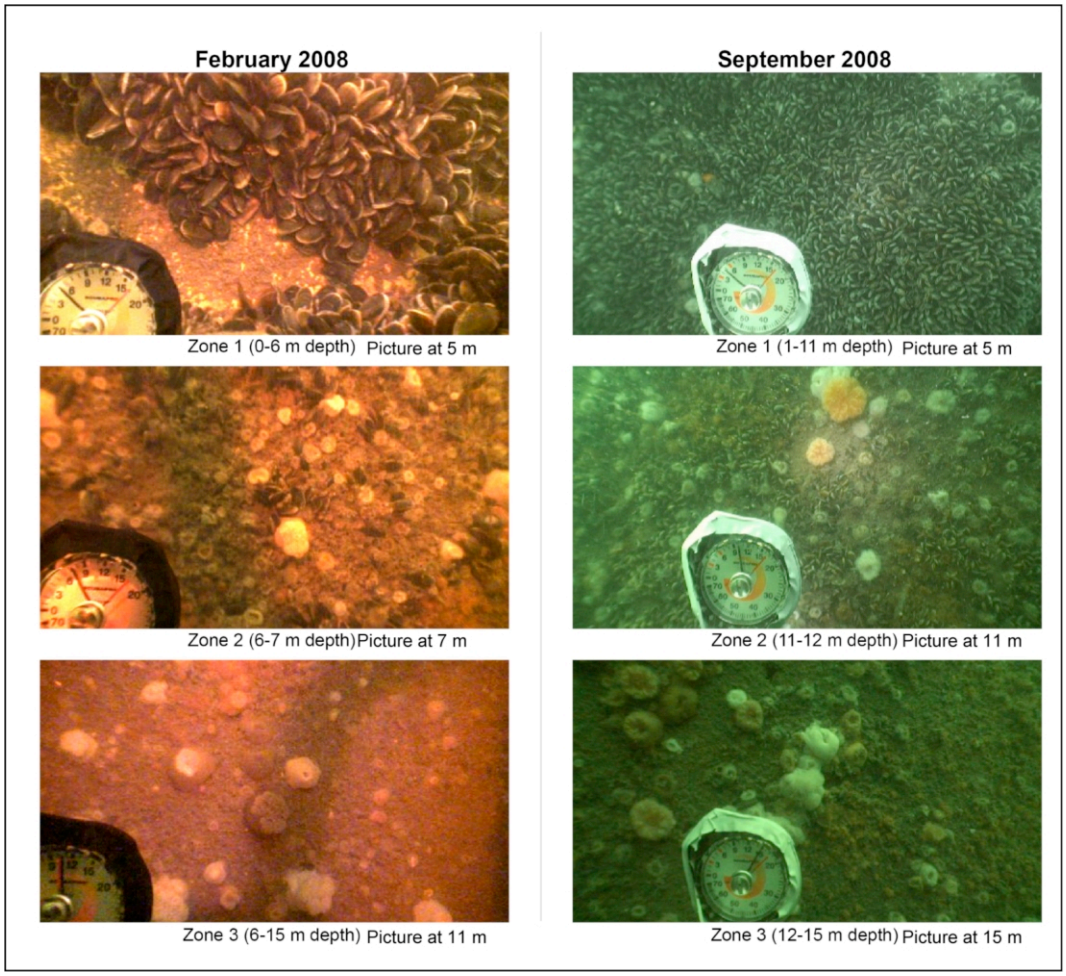

Figure 4 *Underwater growth on the monopile of turbine 7 at different depths in February and September 2008. The different depth ranges presented indicate the differences in zonation between February and March 2008.*

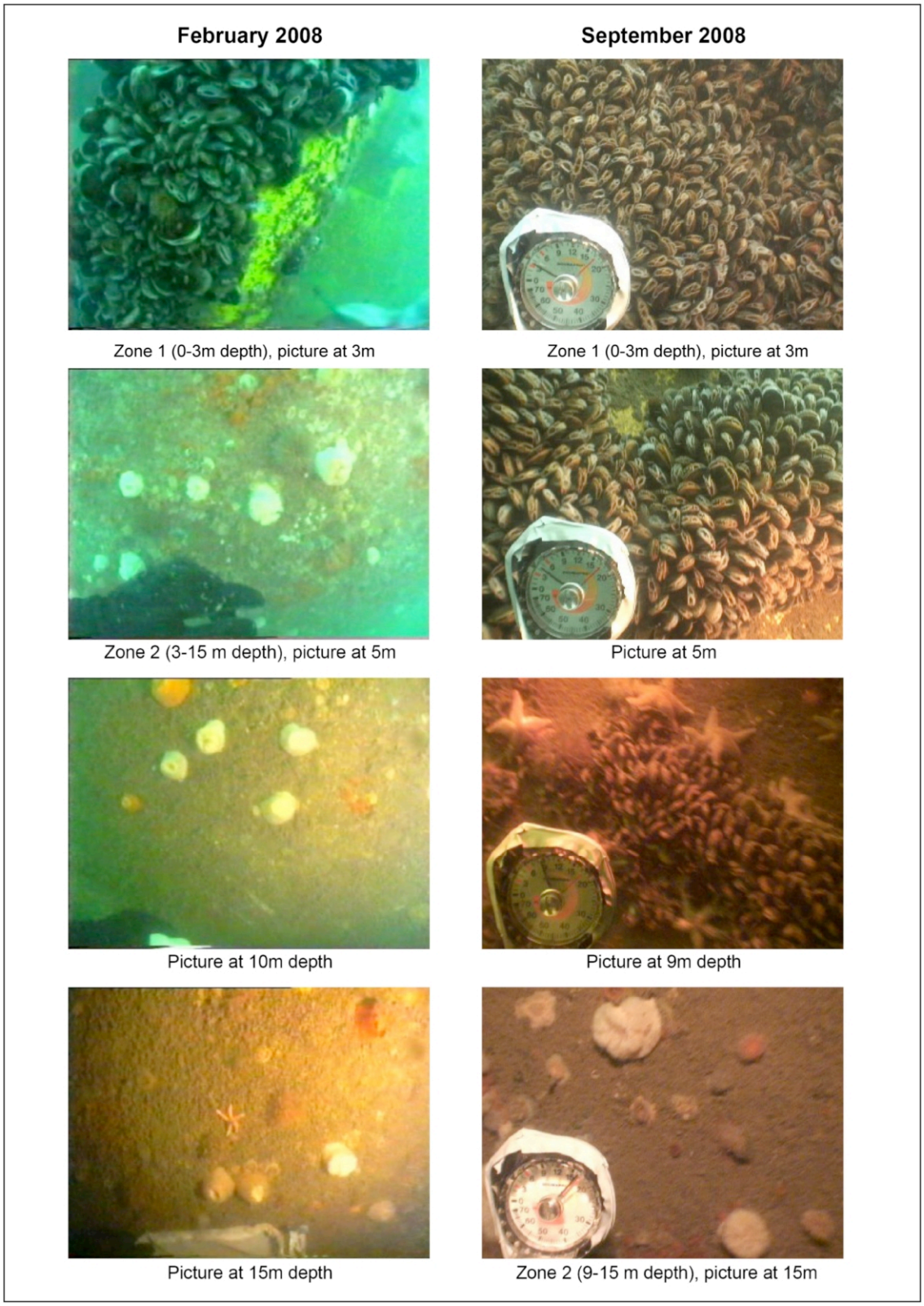

Figure 5 *Underwater growth on the monopile of turbine 13 at different depths in February and September 2008. The different depth ranges presented indicate the differences in zonation between February and March 2008.*

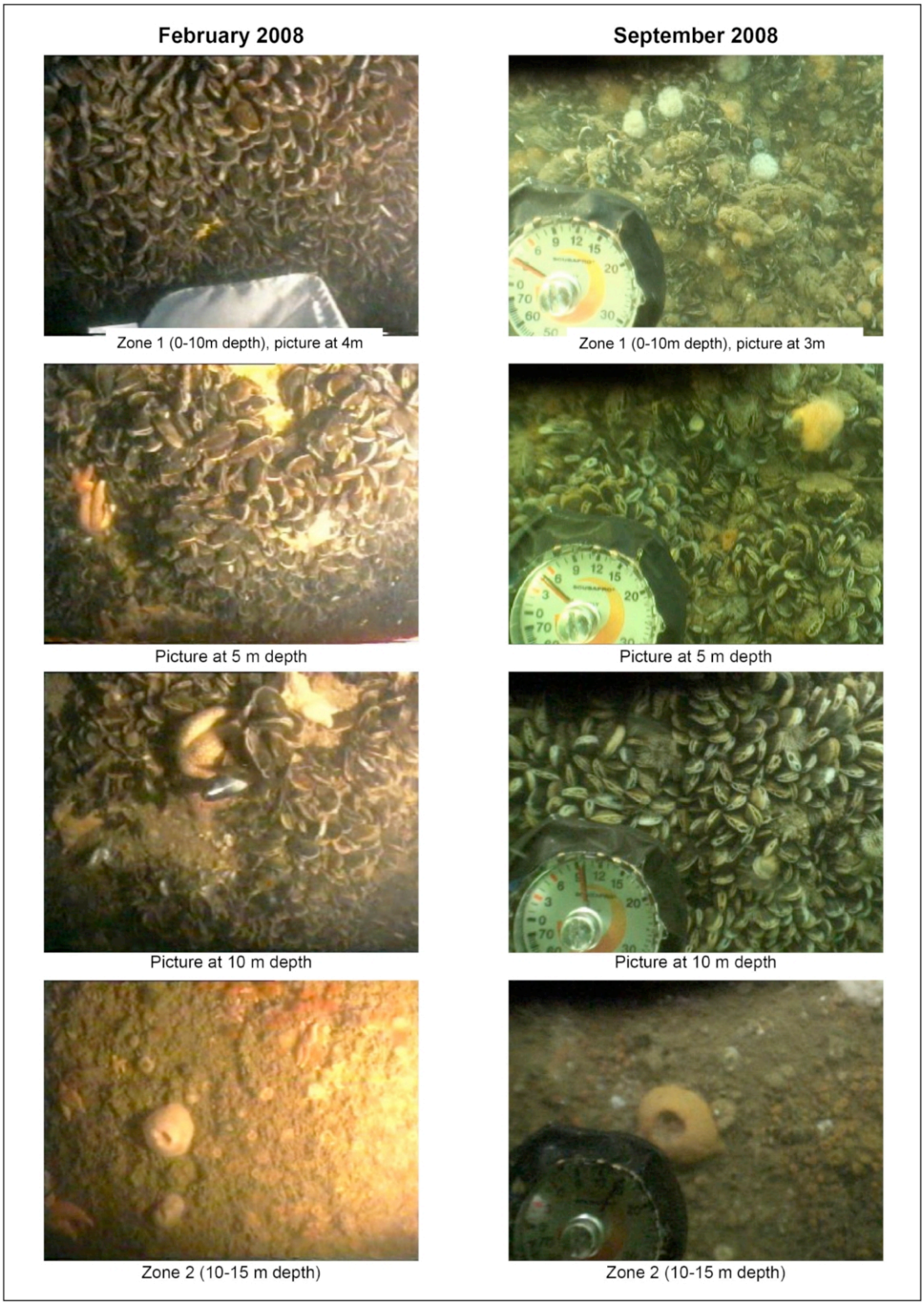

Figure 6 *Underwater growth on the monopile of turbine 34 at different depths in February and September 2008.*

Scour protection rocks

The most dominant species on the rocks of the scour-protection layer of turbines 7, 13 and 34 are the sea mat *Conopeum reticulum*, the plumose anemone *Metridium*

senile, *Sargartia spp*. anemones, (tubes of) the crustacean *Jassa spp*. and the ringed tubularia *Tubularia larynx*. Clumps of mussels (fallen of the monopile) between the rocks attract the common starfish *Asterias rubens.* Other notable less abundant species include the Japanese oyster (*Crassostrea gigas*), slipper limpet (*Crepidula fornicata*), barnacles (*Semibalanus balanoides* and *Balanus crenatus*), the hydroid *Obelia spp*. and orange crust (*Cryptosula pallasiana*). A full list of species found on the rocks of the scour-protection layer is found in table 1.

In February 2008 the rocks collected at turbines 7 and 34 were almost fully overgrown, but rocks collected at turbine 13 (figure 8) were relatively bare. This was also expressed in the total number of species found on the rocks around the base of the three turbines (12 species at turbines 7 and 34 and 5 species at turbine 13 (see table 1). At this stage, it is not clear what caused this difference between the turbines in February 2008.

In September 2008 growth on the rocks collected around the bases of turbines 7, 13 and 34 was very comparable to each other (respectively 14, 17 and 11 species). Different from the February survey was the presence of large schools of pouting around the base of the three turbines and the presence of the Northsea crab (*Cancer pagurus*) between the rocks. Video stills of the rocks of the scour protection layers are shown in figure 7 (turbine 7), figure 8 (turbine 13) and figure 9 (turbine 34).

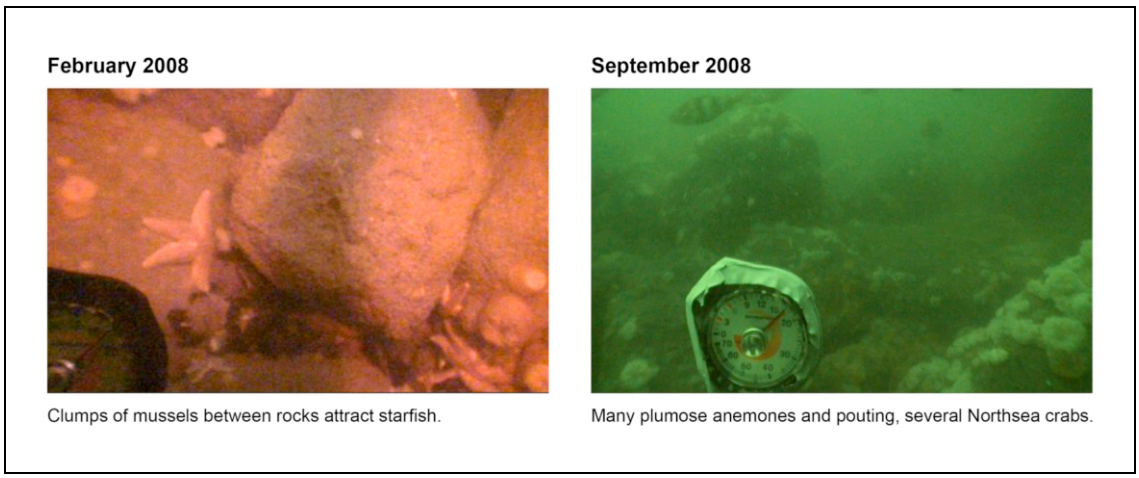

Figure 7 *Underwater growth on rocks of the scour-protection layer of turbine 7 in February and September 2008, depth is 18m.*

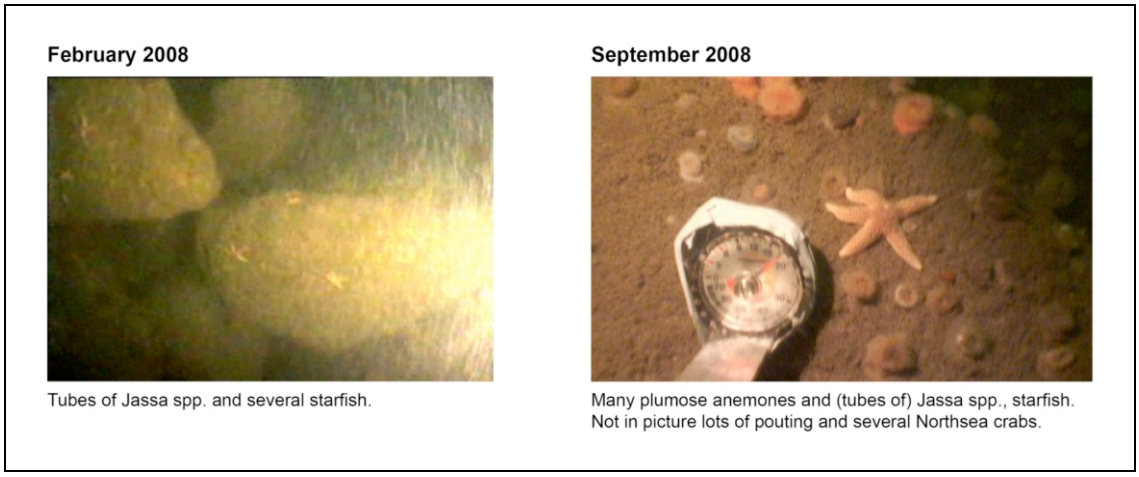

Figure 8 *Underwater growth on rocks of the scour-protection layer of turbine 13 in February and September 2008, depth is 18m.*

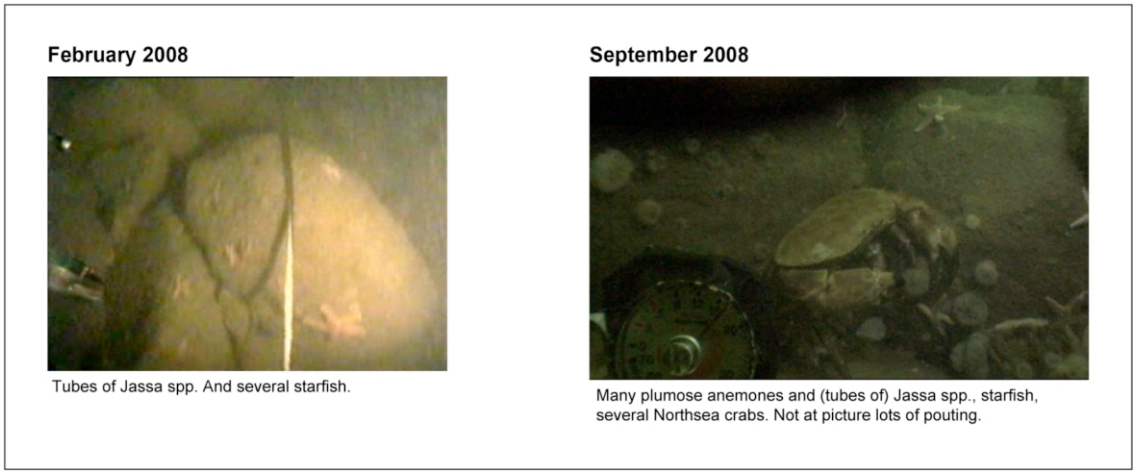

Figure 9 *Underwater growth on rocks of the scour-protection layer of turbine 34 in February and September 2008, depth is 17m.*

3.2 Quantitative assessment: numbers and biomasses of species present

In this paragraph the numbers and biomasses of species present in the collected samples of turbines 7, 13 and 34 in September 2008 are presented. In addition, a comparison is made with data collected in February 2008 (Bouma & Lengkeek, 2008).

The data presented only provide an indication of actual quantities because:

- sample collection along the monopiles was not always accurate due to hard working conditions (e.g. strong currents and wave action);
- only relatively small rocks of the scour-protection layer could be collected by the divers;
- covering percentages on the monopiles within the same depth and on different rocks of the scour-protection layer show substantial variation.

For comparison all numbers and biomasses are expressed as numbers and/or biomasses per m^2 substrate. Raw data for the numbers and biomasses of species collected along the monopiles of turbines 7, 13 and 34 are provided in appendix 1.

Monopiles
Table a and b in appendix 2 show the numbers and biomasses of the most abundant species in samples collected at different depths (2, 5, 10 and 15 m depth) along the monopiles of turbines 7, 13 and 34 in February and September.

The most abundant organism on the monopiles, in numbers and in biomass is the common mussel (*Mytilus edulis*). The abundance of mussels was still variable in February (table a, appendix 2), with a very low abundance on turbine 13, but in September large quantities of mussels occurred on each monopile (table b, appendix 2). The overall number and biomass of mussels significantly increased between February and September, now reaching up to 8047 individuals per squared meter, with a biomass of 1100 g AFDW / m^2. Numbers of mussels increased in each separate size class (table a and b, appendix 2), indicating that the total quantity of mussels increased through both individual growth and recruitment.

Other highly abundant organisms on the monopiles are anemones, *Jassa spp*., common starfish, green sea urchins and various species of worms (Annelidae) (table a and b, appendix 2). In February relatively large numbers of the ringed tubilaria occurred in the samples, a species that was relatively rare in September. Anemones occurred up to 1022 individuals per squared metre, worms up to 261, starfish up to 27, sea urchins up to 54 and *Jassa spp*. occur up to several thousand individuals per squared metre. Quantities of anemones, *Jassa spp*., starfish and sea urchins are highly variable between samples, but show no clear pattern of in- or decrease in the period between February to September. The worms, however, have increased substantially, both in numbers and in biomass (table a and b, appendix 2).

In February, total biomass of marine growth differed substantially between monopiles, with turbine 34 reaching nearly 1000 grams AFDW per squared metre, whilst turbine 13 only contained 88 g AFDW. In September this difference largely disappeared, with each turbine containing ca 1100 g AFDW biomass of marine growth per m^2.

Rocks of the 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 table a and b, appendix 3. The abundance of species is variable among the scour protection samples. In February most abundant taxa were anemones, sea mat (*Conopeum reticulum*), *Jassa spp*. and the ringed tubilaria (*Tubularia larynx*) (table a, appendix 3). Anemones and sea mat were still abundant on the scour protection in September, but ringed tubilaria and *Jassa spp*. were rare (table b, appendix 3). Common mussels were more abundant on the scour protection in September.

4 Discussion

4.1 Ecological relevance of present species

From the surface to approximately 10 m depth growth on the monopiles is dominated by the presence of large quantities of common mussels (*Mytilus edulis*) with associated species like the common starfish (*Asterias rubens*), the small crustacean *Jassa spp*., several species of worms and crabs. Below circa 10m depth a second hard substrate community is distinguished. This community is dominated by *Jassa spp*., anemones (mainly *Sargartia spp*. and *Metridium senile*) and patches of the ringed tubularia (*Tubularia larynx*). Green sea urchins (*Psammechinus miliaris*) and the common starfish (*Asterias rubens*) are also present, but do occur in low numbers. Both hard substrate communities provide a valuable food source for fish species like the North Sea cod (*Gadus morhua*) and pouting (*Trisopterus lucus*). In September 2008 schools of pouting were present at the base of all three turbines visited. The North Sea cod is an important commercial species that showed a strong decline as a result of over-fishing. If the new hard substrate communities do attract North Sea cod to the OWEZ and if they reside within the park where fishing is prohibited, the OWEZ could contribute to the recovery of this species. In February 2007 IMARES started a research trying to determine movements of North Sea cod within the OWEZ. Pouting is commercially less important.

Within the Danish offshore Horns Rev wind farm a significant increase in the abundance of Common scoter (*Melanitta nigra*) was observed between 1999 and 2006, and the Common eider (*Somateria mollisima*) was also a numerous species within this wind farm (Petersen & Fox, 2007). This increase of both species 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 was provided in Petersen & Fox (2007). Bird observations carried out by Bureau Waardenburg and IMARES in the OWEZ wind farm since mid 2007 show that cormorants are foraging for fish in the wind farm on a regular basis, especially during the summer months. Other bird species that forage on fish or molluscs are only seen in the wind farm occasionally. For instance, divers are seen incidentally near or in the wind farm, and recently a pair of common eiders was seen foraging (for molluscs) within the wind farm (Karen Krijgsveld personal comments).

Causal relationships between the presence of the new hard substrate communities and fish and/or birds within OWEZ cannot be demonstrated at the moment. Monitoring the effects on birds and fish is still work in progress and further research into the development of the hard substrate communities will also be carried out in 2011. A recommendation for future work is to carry out an analysis to study effects of offshore wind farms on the entire North Sea ecosystem integrating results of separate monitoring and evaluation programmes.

Many of the species encountered are characteristic for hard substrates that were not present in the area before the OWEZ was constructed. Before the OWEZ was built the area contained only soft sandy substrates with characteristic soft substrate communities. The introduction of hard substrates has created a more diverse ecosystem.

Exotic species found in the samples include the Japanese oyster (*Crassostrea gigas*) and the Titan acorn barnacle (*Megabalanus coccopoma*). The Japanese oyster was found in February and September 2008 on both the monopile and rocks of the scour-protection layer of turbine 7 and turbine 34. The Titan acorn barnacle was only found in samples collected in February from the monopiles of turbines 13 and 34.

4.2 Extrapolation to all turbines of OWEZ

A simplified extrapolation is carried out to provide an indication of the total numbers and biomass of the two most dominant species in the OWEZ: common mussels and *Jassa spp*. This extrapolation is also carried out for worms, because this group can be an important food source for fish. Mussels are mainly found on the monopiles and numbers and biomasses of *Jassa spp*. and worms were only determined from samples collected along the monopiles. Therefore the extrapolation was only carried out for the hard substrate provided by the monopiles of the 36 turbines in the OWEZ.

First the total underwater surface area of hard substrates provided by the 36 monopiles of the 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 $2* *r*h=2*3,14*2,25*18 = 254,34$ m^2.
- Calculation of the total surface area of hard substrates in the OWEZ:
  36 monopiles * 254,34 m^2 = 9.156,24 m^2.

Then the average numbers and biomasses of common mussels, *Jassa spp*. and worms per turbine were calculated using data collected from turbines 7, 13 and 34 in February and September 2008 (see §3.2) and extrapolated to provide numbers and biomasses for the entire wind farm. The results are presented in table 5. 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 (see §3.2) and the simplified method to carry out the extrapolation.

Table 5. Estimated total numbers and biomasses (in kg AFDW) of common mussels, Jassa spp. and worms on the monopiles of the 36 turbines in the OWEZ in February and September 2008

Species	Average number on turbines 7,13 and 34 (number per m^2)	Average biomass on turbines 7,13 and 34 (g afdw/m^2)	Total number in the OWEZ (million)	Total biomass in the OWEZ (kg afdw)
February 2008				
Common mussel	1256	447	11,5	4093
Jassa spp.	1359	0,9	12,4	8,0
Worms	32	1,1	0,2	10,1
September 2008				
Common mussel	6725	1257	61,6	11510
Jassa spp.	1083	Not determined	10,0	Not determined
Worms	211	3,12	1,9	28,5

4.3 Comparison with growth on hard structures of the turbines in the Horns Rev offshore wind farm

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 the 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 the OWEZ.

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 *et al.,* 2005):

- In the splash zone an almost monoculture population of the giant 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 1.664 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 168.413 individuals per m^2) and biomass (in March 2004 on average 374.105 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 marine growth in OWEZ is comparable to the growth in the Horns Rev wind farm. Common mussels in Horns Rev in September 2004 reached over 4000 individuals per m^2; in OWEZ in September 2008 common mussels reached over 8000 individuals per m^2. On both locations, the communities also contained *Jassa spp*., *Caprella linearis*, *Balanus spp*., *Asterias rubens* and several anemone species.

The three main differences between OWEZ and Horns REV are: 1) the near absence of an algal / vegetation zone in OWEZ. In Horns Rev, a green/ brown coating of algae was distinctly present in the splash zone, and several species of seaweed close beneath the surface. In OWEZ, the only present vegetation is a small band of green algae in the intertidal zone to approximately 0,5 m depth, and this does not occur on each monopile. 2) The presence of an almost monoculture population of the giant midge *Telmatogeton japonicus* in the splash zone of Horns Rev. This species is not present in OWEZ. 3) *Jassa spp*. is an abundant taxon in OWEZ but occurs in even much higher quantities in Horns Rev.

4.4 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 colonization likely to occur in the region of wind turbine towers (see figure 10).

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 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 10 *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 the OWEZ in February and September 2008 is compared to this figure the following differences and similarities can be distinguished:

- The intertidal zone of the monopiles of the turbines within OWEZ are relatively bare. In February 2008 no large algae were present at all; in September 2008 a small band of green algae was present in the intertidal zone of turbines 7 and 13 together with some barnacles.
- A kelp zone (1-2 m depth) is not present on the monopiles of the turbines within the OWEZ.
- The shallow subtidal zones (2-6 m depth) of turbines 7, 13 and 34 are very comparable to figure 10. At turbines 7, 13 and 34 this zone is mainly dominated by common mussels (*Mytilus edulis*) (alternative 2).
- The main column to scoured area of turbines 7, 13 and 34 are also comparable to figure 10. The most dominant species are the plumose anemone (*Metridium*

senile), *Sargartia spp.* anemones and the orange anemone *Diadumene cincta* with patches of the ringed tubularia (*Tubularia larynx*) and *Obelia spp*. No sponges, ascidians, soft corals, sea squirts and/or feather stars were present.

- Growth on the scour protection rocks around the base of turbines 7, 13 and 34 is comparable to figure 10. Rocks are overgrown by the encrusting sea mat (*Conopeum reticulum*) and are colonised by species similar to the species found on the main column (e.g. *Metridium senile*, *Sargartia spp.,* and *Tubularia larynx*). No lobsters (*Homarus gammarus*) and/or Northsea crabs (*Cancer pagarus*) were seen during the survey carried out in February, but Northsea crabs were common during the survey carried out in September 2008.

5 Literature

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Appendix 1 Numbers and biomasses (AFDW / 2 samples) of most dominant species in the collected at different depths along the monopiles of turbines 7, 13 and 34 in a) February 2008 and b) September 2008.

a)

Turbine 7: Numbers and biomasses of most dominant species collected from the monopiles. At 2 m depth samples one sample was collected on the northern side within
At 5m, 10m and 15m depth samples were collected from both the northern and southern side within an total area of 2*0,56=0,112m2 and results summarised.

Turbine 7			2m		5m		10m		15m	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)
Anemones (Cnidaria	Anemones		0	0	45	1,57	118	20,49	208	24,94
Molluscs										
Mytilus edulis	Common mussel	0,2-5 cm	129	4,10	8	0,30	3	*	1	*
		2,5-5 cm	262	58,47	92	26,80	0		0	
		>5 cm	0	0	30	17,48	0		0	
		total	391	62,57	130	44,58	3	-	0	-
Crustacea										
Jassa spp.			0	0	circa 125	*	circa 33	*	0	0
Echinodermata										
Asterias rubens	Common starfish		0	0	1	9,29	0	0	0	0
Psammechinus miliar	Green sea urchin		0	0	0	0	0	0	0	0
Hydroids										
Tubularia larynx	Ringed tubularia		0	0	0	0	1	*	1	*
Obelia spp.			0	0	0	0	6	*	0	0
Worms	Worms		0	0	6	0,171	0	0	3	0,026

Turbine 13: Numbers and biomasses of most dominant species collected from the monopiles. At all depths samples were collected from both the northern and southern s
within an total area of 2*0,56=0,112m2 and results summarised.

Turbine 13			2m		5m		10m		15m	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)
Anemones (Cnidaria	Anemones		1	*	4	1,41	46	4,32	50	9,07
Molluscs										
Mytilus edulis	Common mussel	0,2-5 cm	31	1,20	0	0	2	*	0	0
		2,5-5 cm	24	8,32	0	0	0		0	0
		>5 cm	0	0	0	0	0		0	0
		total	55	9,52	0	0	2	-	0	0
Crustacea										
Jassa spp.			20	*	circa 1000	*	circa 400	*	circa 180	*
Echinodermata										
Asterias rubens	Common starfish		0	0	0	0	1	*	0	0
Psammechinus miliar	Green sea urchin		0	0	3	3,94	2	3,04	0	0
Hydroids										
Tubularia larynx	Ringed tubularia		0	0	0	0	1	*	4	0,216
Obelia spp.			0	0	0	0	4	*	1	*
Worms	Worms		0	0	0	0	2	0,039	0	0

Turbine 34: Numbers and biomasses of most dominant species collected from the monopiles. At all depths samples were collected from both the northern and southern s
within an total area of 2*0,56=0,112m2 and results summarised.

Turbine 34			2m		5m		10m		15m	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)
Anemones (Cnidaria	Anemones		8	0,35	7	0,27	49	1,20	121	4,59
Molluscs										
Mytilus edulis	Common mussel	0,2-5 cm	60	3,78	26	1,73	24	1,39	3	*
		2,5-5 cm	177	63,62	139	39,32	88	28,39	0	
		>5 cm	42	36,99	120	71,03	38	25,08	0	
		total	279	104,39	285	112	150	54,86	3	-
Crustacea										
Jassa spp.			circa 10	*	circa 10	*	circa 10	*	circa 39	*
Echinodermata										
Asterias rubens	Common starfish		0	0	4	34,75	2	31,42	6	1,05
Psammechinus miliar	Green sea urchin		0	0	3	2,81	2	0,21	0	0
Hydroids										
Tubularia larynx	Ringed tubularia		0	0	0	0	0	0	1	*
Obelia spp.			0	0	0	0	0	0	1	*
Worms	Worms		7	0,508	8	0,458	12	0,233	5	0,041

* Biomass not determined (see § 2.3)

b)

Turbine 7: Numbers and biomasses of most dominant species collected from the monopiles. ;
At 2m, 5m, and 10m depth samples were collected from both the northern and southern side within an total area of 2*0,056=0,112m2. At 15 m depth 1 sample of 0,05

Turbine 7			2m		5m		10m		15m	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)
Anemones (Cnidaria	Anemones		157	3,017	71	3,094	25	1,972	11	1,062
						0				
Molluscs						0				
Mytilus edulis	Common mussel	0,2-5 cm	442	22,771	631	63,674	688	31,625	259	10,863
		2,5-5 cm	282	116,549	33	63,7	300	74,863	288	62,04
		>5 cm	17	23,391	39	79,2	23	37,734	28	48,599
		total	741	162,711	703	206,574	1011	144,222	575	121,502
Crustacea										
Jassa spp.			200		100					
Echinodermata										
Asterias rubens	Common starfish		1	*	1	7,137	3	0,738	1	*
Psammechinus miliar	Green sea urchin						2	0,15	2	*
Hydroids										
Tubularia larynx	Ringed tubularia		p	*			p	*		
Obelia spp.							p	*		
Worms	Worms		55	0,622	20	0,312	22	0,206	10	0,145

Turbine 13: Numbers and biomasses of most dominant species collected from the monopiles. At all depths samples were collected from both the northern and southern within an total area of 2*0,56=0,112m2.

Turbine 13			2m		5m		10m		15m	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)
Anemones (Cnidaria	Anemones		33	1,783	29	21,158	11	9,261	17	5,268
Molluscs										
Mytilus edulis	Common mussel	0,2-5 cm	437	25,325	409	16,585	227	10,764	408	19,26
		2,5-5 cm	468	158,791	569	87,269	177	22,521	91	24,845
		>5 cm	58	69,191					33	
		total	963	253,307	978	103,854	404	33,285	532	44,105
Crustacea										
Jassa spp.							200	*	100	*
Echinodermata										
Asterias rubens	Common starfish		2	3,066	1	1,332	3	3,655	3	8,43
Psammechinus miliar	Green sea urchin		1	*			1	2,627	1	3,653
Hydroids										
Tubularia larynx	Ringed tubularia		p	*			p	*	p	*
Obelia spp.										
Worms	Worms		28	0,457	1	*	13	0,121	14	0,049

Turbine 34: Numbers and biomasses of most dominant species collected from the monopiles. At all depths samples were collected from both the northern and southern s
within an total area of 2*0,56=0,112m2.

Turbine 34			2m		5m		10m		15m	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)
Anemones (Cnidaria	Anemones		25	2,513	79	7,655	245	4,326	109	9,75
Molluscs										
Mytilus edulis	Common mussel	0,2-5 cm	467	24,05	606	22,162	741	21,955	30	0,2
		2,5-5 cm	316	77,266	227	58,762				
		>5 cm	48	80,868	115	208,376	6	5,325		
		total	831	182,184	948	289,3	747	27,28	30	0,2
Crustacea										
Jassa spp.							200	*	650	2,795
Echinodermata										
Asterias rubens	Common starfish		1	*	2	1,249				
Psammechinus miliar	Green sea urchin									
Hydroids										
Tubularia larynx	Ringed tubularia						p			
Obelia spp.							p			
Worms	Worms		13	0,808	53	0,838	29	0,187	16	0,093

* Biomass not determined (see § 2.3)

Appendix 2 Numbers and biomasses (in g AFDW / m²) of the most abundant species on the monopiles of turbines 7, 13 and 34 at 2, 5, 10 and 15 m depth in a) February 2008 and b) September 2008.

a)

Turbine 7			2m		5m		10m		15m		average per m² for all depths	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	**numbers**	**biomass (g afdw)**
Anemones (Cnidaria)	Anemones		0	0	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		**1375**	**320,85**
		>5 cm	0	0	268	156,06	0		0		**67**	**39,02**
		total	6982	1117,39	1161	398,03	27	-	0	-	**2042**	**505,14**
Crustacea												
Jassa spp.			0	0	1116	*	295	*	0	0	**353**	*
Echinodermata												
Asterias rubens	Common starfish		0	0	9	82,91	0	0	0	0	**2**	**20,73**
Psammechinus miliaris	Green sea urchin		0	0	0	0	0	0	0	0	**0**	**0**
Hydroids												
Tubularia larynx	Ringed tubularia		0	0	0	0	9	*	9	*	**4**	**0**
Obelia spp.			0	0	0	0	54	*	0	0	**13**	**0**
Worms	Worms		0	0	54	1,53	0	0	27	0,23	**20**	**0,44**

Turbine 13			2m		5m		10m		15m		average per m² for all depths	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	**numbers**	**biomass (g afdw)**
Anemones (Cnidaria)	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	18	*	0	0	**74**	**3,57**
		2,5-5 cm	214	74,24	0	0	0		0	0	**54**	**18,56**
		>5 cm	0	0	0	0	0		0	0	**0**	**0**
		total	491	84,96	0	0	18	-	0	0	**127**	**28,32**
Crustacea												
Jassa spp.			179	*	8929	*	3571	*	1607	*	**3571**	*
Echinodermata												
Asterias rubens	Common starfish		0	0	0	0	9	*	0	0	**2**	**0**
Psammechinus miliaris	Green sea urchin		0	0	27	35,20	18	27,13	0	0	**11**	**16**
Hydroids												
Tubularia larynx	Ringed tubularia		0	0	0	0	9	*	36	1,93	**11**	**1**
Obelia spp.			0	0	0	0	36	*	9	*	**11**	**0**
Worms	Worms		0	0	0	0	18	0,35	0	0	**4**	**0,09**

Turbine 34			2m		5m		10m		15m		average per m² for all depths	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	**numbers**	**biomass (g afdw)**
Anemones (Cnidaria)	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		**902**	**293,14**
		>5 cm	375	330,27	1071	634,21	339	223,96	0		**446**	**297,11**
		total	2491	932,02	2545	1000,75	1339	489,79	27	-	**1600**	**807,52**
Crustacea												
Jassa spp.			89	*	89	*	89	*	348	*	**154**	*
Echinodermata												
Asterias rubens	Common starfish		0	0	36	310,25	18	280,53	54	9,38	**27**	**150,04**
Psammechinus miliaris	Green sea urchin		0	0	27	25,06	18	1,85	0	0	**11**	**6,73**
Hydroids												
Tubularia larynx	Ringed tubularia		0	0	0	0	0	0	9	*	**2**	**0**
Obelia spp.			0	0	0	0	0	0	9	*	**2**	**0**
Worms	Worms		63	4,54	71	4,09	107	2,08	45	0,37	**71**	**2,77**

* Biomass not determined (see § 2.3)

b)

Turbine 7			2m		5m		10m		15m		average per m² for all depths	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	**numbers**	**biomass (g afdw)**
Anemones (Cnidaria)	Anemones		1401,79	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**
Crustacea												
Jassa spp. (1)			1800		900						**675**	*
Echinodermata												
Asterias rubens	Common starfish		8,92857	*	9	63,72	27	6,59	18	*	**16**	**35,16**
Psammechinus miliaris	Green sea urchin						18	1,34	36	*	**54**	**0,45**
Hydroids												
Tubularia larynx	Ringed tubularia		p	*			p	*				
Obelia spp.							p	*				
Worms	Worms		491,071	5,55	179	2,79	196	1,84	179	2,59	**261**	**3,19**

Turbine 13			2m		5m		10m		15m		average per m² for all depths	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	**numbers**	**biomass (g afdw)**
Anemones (Cnidaria)	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					295		**203**	**618**
		total	8598	2261,67	8732	927,27	3607	297,19	4750	393,79	**6422**	**969,98**
Crustacea												
Jassa spp. (1)							1800		900		**675**	*
Echinodermata												
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	*			9	23,46	9	32,62	**7**	**18,69**
Hydroids												
Tubularia larynx	Ringed tubularia		p	*			p	*	p	*		
Obelia spp.												
Worms	Worms		250	4,08	9	*	116	1,08	125	0,44	**125**	**1,87**

Turbine 34			2m		5m		10m		15m		average per m² for all depths	
Species / group	English name		numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	numbers	biomass (g afdw)	**numbers**	**biomass (g afdw)**
Anemones (Cnidaria)	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					**1212**	**303,63**
		>5 cm	429	722,04	1027	1860,50	54	47,54			**377**	**657,52**
		total	7420	1626,64	8464	2583,04	6670	243,57	268	1,79	**5705**	**1113,76**
Crustacea												
Jassa spp. (1)							1800		5800	24,96	**1900**	*
Echinodermata												
Asterias rubens	Common starfish		9	*	18	11,15					**7**	**3,72**
Psammechinus miliaris	Green sea urchin										**0**	**0,00**
Hydroids												
Tubularia larynx	Ringed tubularia						p	*				
Obelia spp.							p	*				
Worms	Worms		116	7,21	473	7,48	259	1,67	143	0,83	**248**	**4,30**

* Biomass not determined (see § 2.3)

Appendix 3 Quantitative information about the most dominant species found on the rocks of the scour-protection layer of turbines 7, 13 and 34 in a) February 2008 and b) September 2008.

a)

Turbine 7: 10 small rocks collected; total area circa 0,09 m^2			
Species	English name	number	biomass (g afdw)
Anemones (Cnidaria)		57	3,334
Barnacles		3	0,086
Species	English name	covering percentage	
Crustacea			
Jassa spp.		0-70%	*
Bryozoa			
Conopeum reticulum	sea mat	0-60%	*
Hydroids			
Tubularia larynx	ringed tubularia	1%	*

Turbine 13: 3 small rocks collected; total area circa 0,06 m^2			
Species	English name	number	biomass (g afdw)
Anemones (Cnidaria)		18	1,377
Species	English name	covering percentage	
Crustacea			
Jassa spp.		0-15%	*
Bryozoa			
Conopeum reticulum	sea mat	1-25%	*

Turbine 34: 2 small rocks collected; total area circa 0,0625 m^2			
Species	English name	number	biomass (g afdw)
Anemones (Cnidaria)		63	2,906
Molluscs			
Crepidula fornicata	slipper limpet	1	0,278
Echinodermata			
Asterias rubens	common starfish	1	0,264
Species	English name	covering percentage	
Crustacea			
Jassa spp.		15-40%	*
Bryozoa			
Conopeum reticulum	sea mat	30-50%	*

* Biomass not determined (see § 2.3)

b)

Turbine 7: 10 small rocks collected; total area circa 0,018 m^2			
Species	English name	number	biomass (g afdw)
Anemones (Cnidaria)		18	16,71
Molluscs			
Mytilus edulis	mussel < 2,5cm	57	2,58
Species	English name	covering percentage	
Crustacea			
Jassa spp.		**	*
Bryozoa			
Conopeum reticulum	sea mat	**	*
Hydroids			
Tubularia larynx	ringed tubularia	**	*

Turbine 13: 3 small rocks collected; total area circa 0,02 m^2			
Species	English name	number	biomass (g afdw)
Anemones (Cnidaria)		50	3,71
Molluscs			
Mytilus edulis	mussel > 5cm	3	8,04
	mussel 2,5-5cm	204	51,09
	mussel < 2,5	187	11,88
Species	English name	covering percentage	
Crustacea			
Jassa spp.		**	*
Bryozoa			
Conopeum reticulum	sea mat	**	*

Turbine 34: 2 small rocks collected; total area circa 0,0472 m^2			
Species	English name	number	biomass (g afdw)
Anemones (Cnidaria)		19	4,88
Molluscs			
Mytilus edulis	mussel < 2,5cm	3	0,04
Species	English name	covering percentage	
Crustacea			
Jassa spp.		**	*
Bryozoa			
Conopeum reticulum	sea mat	**	*

* Biomass not determined (see § 2.3)
** Covering percentage not determined because samples were frozen prior to analysis

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