CHAPTER 12

Fouling community on the foundations of wind turbines and the surrounding scour protection

Ilse De Mesel, Francis Kerckhof, Bob Rumes, Alain Norro,
Jean-Sébastien Houziaux and Steven Degraer

The introduction of hard substrata in the mainly sandy environment of the Belgian part of the North Sea provides a new habitat to species that could previously not establish in the area. The community is dominated by the amphipod *Jassa herdmani,* the hydroids *Tubularia larynx* and *T. indivisa* and Actiniaria species, of which the plumose anemone *Metridium senile* is the most dominant. Only few species, especially those arriving early in the colonisation process, are able to establish a viable population. The vertical foundations and the complex three-dimensional structure of the scour protection harbour different fouling communities.

INTRODUCTION

With the installation of wind turbines, artificial hard substrata have been introduced in a mainly sandy environment. The foundations and the scour protection provide a new habitat in the Belgian part of the North Sea.

Hard substrata harbour significantly different benthic communities than the surrounding sandy seabed. Artificial hard substrata are known to be quickly colonised by fouling organisms, which are often new to the area (Horn, 1974; Schröder et al., 2006, Kerckhof et al., 2009). This results in increased local species richness. The species composition however generally does not reflect the community of natural hard substrata. Additionally, the artificial reefs may act as stepping stones for non-indigenous species, facilitating their expansion over the North Sea (Chapter 17). On the other hand, some positive effects have been illustrated as well. A number of – economically important – (fish) species have been observed to aggregate around the foundations and scour protection of the wind turbines because they feed on the fouling community (Chapter 14) or find shelter. It is not expected that the introduction of the new fouling species endanger the natural diversity of the sandy sediments. It may alter the soft sediment benthic community in the vicinity of the turbines because of organic enrichment and deposition of epibenthic species and their derivate, but larger scale impacts are not expected (Chapter 13).

In this chapter we describe the colonisation patterns of the macrobenthic fouling community on the foundations and the scour protection of the gravity based foundations on the Thorntonbank and the monopile foundations on the Bligh Bank. On the Thorntonbank, at about 30 km from the coastline, six concrete, gravity based turbines have been installed in spring 2008. The Thorntonbank is situated on the edge between the clear water of the English Channel and the more turbid coastal water (Lacroix et al.,2004). The Bligh Bank, situated 40 km offshore, is influenced exclusively by English Channel water masses. The foundations of these turbines are monopiles. The construction started in autumn 2009. All foundations are surrounded by a scour protection. The aim of our study is to understand the colonisation process and to gain insight in the succession pattern on the artificial hard substrata. The focus of our research is on the subtidal fouling community.

BOX:
Vertical zonation

On the foundations of the wind turbines, a clear vertical zonation in the fouling community has been observed. During the first year of the monitoring, the depth-related patterns of the epifauna were analysed in detail, since then only a more general, visual inspection of the splash zone and intertidal zone are made, while the subtidal zone is continued to be studied in detail (see main text). The marine splash midge *Telmatogeton japonicus* has been dominant in the splash zone since the beginning of the monitoring. The intertidal fringe has evolved from a zone characterised by barnacles and the amphipod *Jassa herdmani,* towards a community dominated by the blue mussel *Mytilus edulis.* The mussels have settled on top of the barnacles. The barnacles extend their range until just above the *Mytilus edulis* zone. This zone is especially well developed on the concrete foundations on the Thorntonbank, where it has a width of about 1 m. Within this zone, some empty patches are present, due to predation and clumps of mussels falling off under pressure of the waves. On the steel surface of the monopiles on the Bligh Bank, the *Mytilus edulis* zone is much narrower and half a meter at most. It is not clear whether this is due to higher predation pressure, lower supply of larvae, or whether other factors are responsible. However, the *'Mytilisation'* of the shallow subtidal as has been reported in other parts of the North Sea, with dense mussel growth down to 10 m (Bouma and Lengkeek, 2012) or deeper (Krone et al., 2013a) was not observed in our study. The intertidal area is the zone with the highest number of non-indigenous species (Chapter 17).The subtidal zone on the foundations is characterised by a *Jassa-Tubularia*-Actiniaria community which is described in detail in this chapter.

Concrete gravity based (upper panel) and steel monopile (lower panel) foundations on the Throntonbank and Bligh Bank, respectively

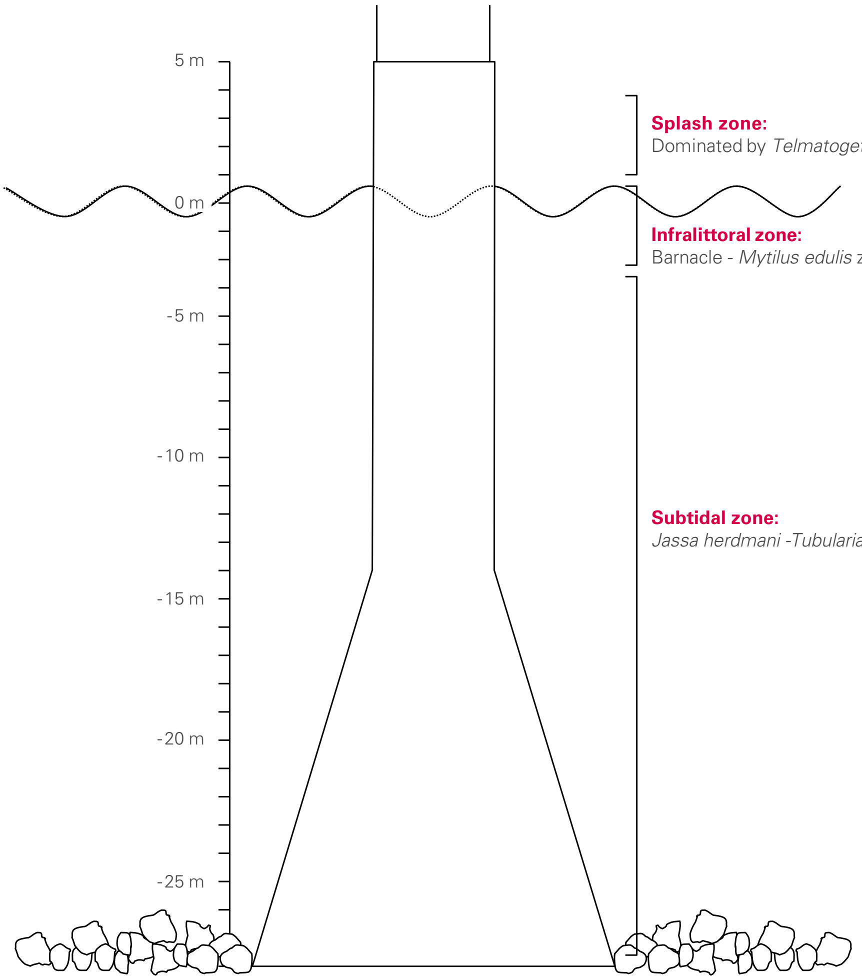


Figure: Schematic representation of the vertical zonation of the fouling community on the foundations of the wind turbines, illustrated with a gravity based foundation.

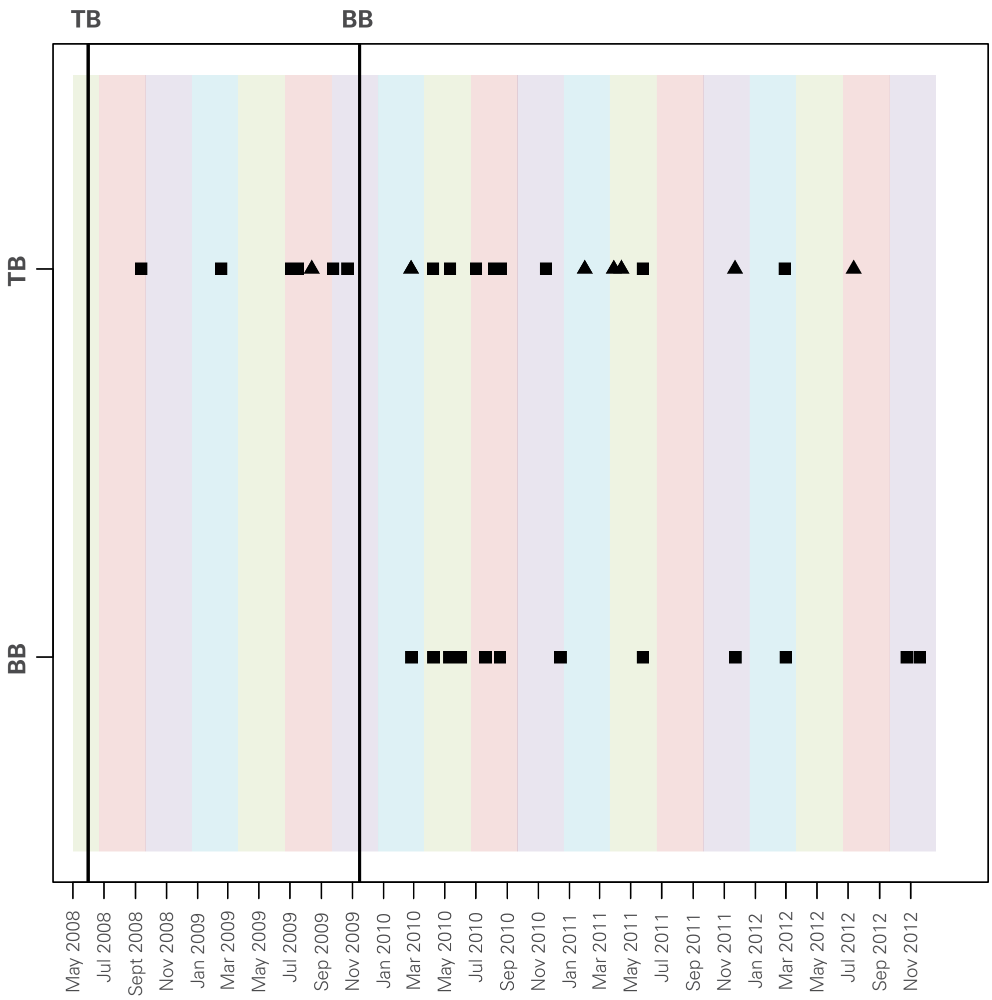
Aequipecten opercularis and a young *Asterias rubens*

RESEARCH STRATEGY

We started collecting samples of the fouling community shortly after the introduction of the first turbines. Initially wind turbines were present only on the Thorntonbank (2008), about one-and-a-half year later the first foundations were installed on the Bligh Bank. At each sampling occasion, one location was sampled in each wind farm. At the Thorntonbank, all samples were collected at the same location, while at the Bligh Bank, three different locations were sampled over time. The results of the first four years of monitoring are presented here.

During the first one to one-and-a-half year, samples were collected on the foundations by scientific scuba divers at different depths. Based on these results, the -15 m zone was identified as being representative for the deeper subtidal community (Kerckhof et al., 2010a). Afterwards, scuba divers scraped, samples of the foundations only at a depth of 15 m. The aim was to sample at least once each season, however due to unfavourable diving conditions, this frequency has not always been obtained (Figure 1). On the Thorntonbank, they also collected stones of the scour protection at a regular basis. In principle, three replicates of each sample were taken. Samples were analysed in the lab in order to investigate patterns in species composition and diversity. Organisms larger than 1 mm were identified to species level when possible or to a higher taxonomic level when the species level could not be obtained. Two components of the community can be distinguished: species that are counted (ind/m^2) and species of which the coverage (% coverage) is determined. Some tube-building organisms, such as the polychaete worm *Pomatoceros triqueter* or the amphipod *Jassa herdmani,* could be quantified in both ways. The coverage of the tubes could be determined or the number of individuals can be counted. In this study, we counted the species when possible. Most species that could not be counted are colonial forms, such as Bryozoa. The patterns observed in the scrapings are compared with those on the scour protection.

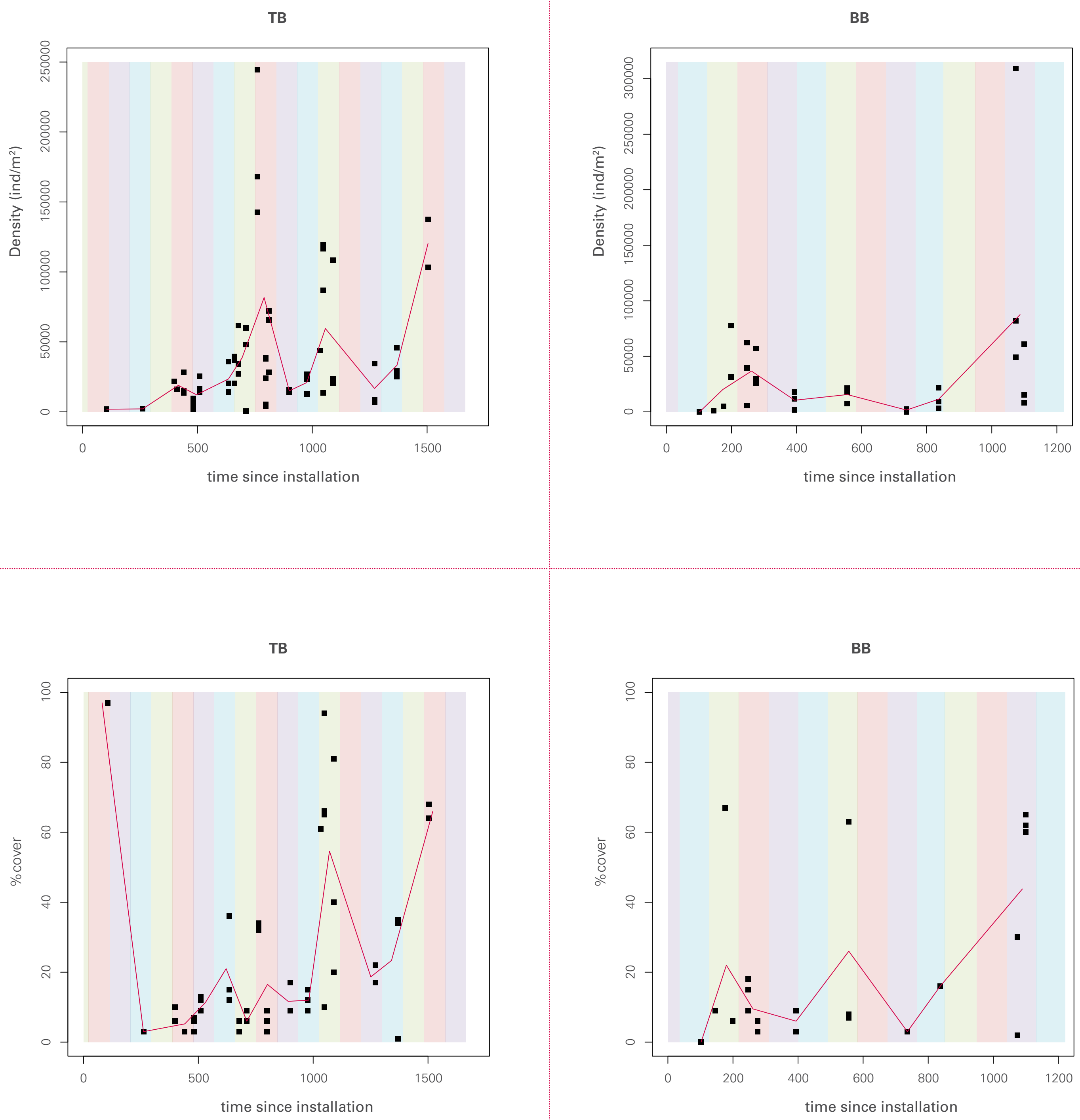
Figure 1. Sampling occasions on the foundations in the wind farm on the Thorntonbank (TB) and Bligh Bank (BB) with the indication of the start of the construction of both wind farms (vertical lines). Squares represent occasions at which only scrape samples on the foundations are collected, triangles represent occasions at which both scrape samples and stones of the scour protection were collected. The background colours represent the seasons (green: spring, red: summer, purple: autumn, blue: winter)



DENSITY AND DIVERSITY

Despite the huge variation between replicates and successive samplings, an increase in densities and coverage over the first two to three years is seen on the foundations of the turbines on the Thorntonbank, after which it more or less stabilises (Figure 2). A seasonal pattern appears, with highest densities (up to 2.5 10^5 ind/m^2, but mostly ranging between 1-1.5 10^5 ind/m^2) and coverage (on average 60-70%) in spring and summer. Although seasonal and long-term dynamics are less clear on the Bligh Bank, similar patterns seem to emerge (Figure 2).

Figure 2. Density (upper panels) and coverage (lower panels) on turbines of the Thorntonbank (left) and Bligh Bank (right). Black dots represent observations in each replicate; the red line connects seasonal averages. The background colours represent the seasons (green: spring, red: summer, purple: autumn, blue: winter). The numbers on the X-axis represent the number of days after installation of the foundations.



The high coverage observed at the first sampling occasion on the foundations of the Thorntonbank (80-100%) was due to an almost complete cover by the hairy sea-mat *Electra pilosa*. This is typically a fast coloniser, that quickly disappears again early in the succession. This dense coverage of *E. pilosa* was not seen on the Bligh Bank, probably because of the timing of the installation of the turbines in autumn, while on the Thorntonbank they were installed in spring. Also, the first sampling on the Bligh Bank was about one month later than on the Thorntonbank, so that the initial heavy colonisation could have been missed. After the heavy colonisation phase *E. pilosa* remained present in almost all samples on the Thorntonbank, but at a much lower density.

The total number of species found on the Thorntonbank (84) is higher than on the Bligh Bank (64). Although these numbers are biased by a lower sampling effort and a shorter sampling period on the latter, the number of species per sample is generally higher on the Thorntonbank as well, where more than 10 species per sample are found in 82% of the samples, but only in 25% of the samples on the Bligh Bank. Although both areas are situated close to each other (about 10 km apart), they are influenced by different water masses. The Thorntonbank is more affected by coastal waters than the further offshore Bligh Bank (Lacroix et al., 2004). The coastal water masses can transport more larvae or other pelagic stages of the fouling community to the foundations than the English Channel water on the Bligh Bank. On the other hand, the foundations on the Thorntonbank are made of concrete, while the foundations that are monitored on the Bligh Bank consist of steel. This might also affect the settling ability of the organisms (Andersson et al., 2009).

DYNAMICS IN THE COMMUNITY

Our results suggest that the species pool that shapes the community on the foundations of the turbines is established in a relatively short time span after their introduction in the marine ecosystem. On the Thorntonbank, out of a total of 84 species found on the foundations during the four years of monitoring, fourteen (17%) were present in more than 75% of the samples after their first appearance. They can be regarded as species that, after settling, have established a viable population. Most of these species (11 out of the 14 species) had arrived during the first year of the succession, two species arrived during the second year. A very similar pattern was seen at the Bligh Bank, where eight out of a total of 64 species found (or 13%) occurred in 75% of the samples after their first observation. Five of these arrived during the first year, and two during the second year.

A community analysis using Multidimensional Scaling (MDS), confirmed the hypothesis that a rather stable species pool was formed early in the colonisation especially on the Thorntonbank. The first year after the turbines have been installed, the samples collected in subsequent sampling events are situated far from each other in the plot, indicating large changes in the community composition (Figure 3). The distance between successive sampling occasions and between samples from different seasons decreases in the MDS plot, implying a decrease in community changes through time. We see mainly seasonal dynamics. Samples collected in summer are very similar to each other, both on the Thorntonbank and the Bligh Bank. The community composition appears to develop largely similar in both sites.

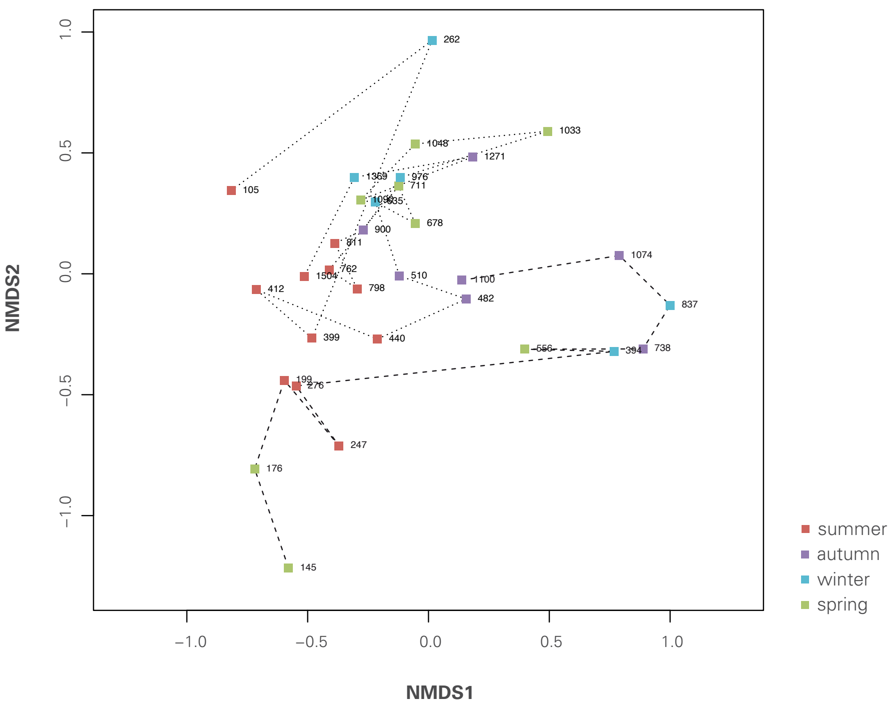


Figure 3. Multidimensional Scaling (MDS) of the communities on the turbines. The analysis was performed on all replicates. The centroids for each sampling occasion were calculated and are represented by the dots shown in the plot. The lines connect the subsequent samplings, the numbers indicate the number of days after the installation of the turbines, the colours represent the seasons. Data were forth root transformed prior to analysis.

COLONISATION, PREDATION AND COMPETITION

Most species that are able to reach new offshore surfaces disperse as planktonic larvae, including many polychaete worms, crabs, barnacles and tunicates (Hiscock et al., 2002). On the other hand, some species do not have such a free living larval stage, for instance the tube-building amphipods *Jassa herdmani,* one of the first species to reach new hard substrata, and *Monocorophium acherusicum*. Juveniles of these species are able to effectively disperse by drifting in the water column (Havermans et al., 2007). The community of *J. herdmani* consists year round of adult and juvenile individuals, without an apparent seasonal pattern allowing them to invade new structures at all times.

Jassa herdmani

Besides the settling of new species, competition and predation are important biological processes in shaping communities. The most conspicuous predators on the foundations are common starfish *Asterias rubens* and sea urchins *Psammechinus miliaris*. Both species prey on a wide range of organisms. Although *A. rubens* shows some preference for bivalves, they also feed on polychaete worms, other echinoderms, barnacles or occasionally other small crustaceans. *Psammechinus miliaris* is an opportunistic predator that feeds on epifaunal species such as hydroids, barnacles, small bivalves, boring sponges or polychaete worms (Hancock, 1957; Lawrence, 1975). Their predation pressure can be that high that large parts of surfaces are cleared of organisms. This was observed on both wind farms by the divers collecting the subtidal samples. This enhances the dynamics within the fouling community as new larvae can settle on the bare substrata. Other predator species are more specific and closely associated with their prey. *Epitonium clathratulum* and *Odostomia turrita* are both small gastropods feeding on respectively the plumose anemone *Metridium* senile and the keelworm *Pomatoceros triqueter* (Robertson, 1963; Høisæter, 1989). Several nudibranch species we observed feed on *Tubularia* spp. and Bryozoa. The impact of these predators on their prey can be high, and might prevent species from dominating the community.

Psammechinus miliaris (above) and *Asterias rubens* (below)

Epitonium clathratulum

Odostomia turrita

The most prevalent means of competition in fouling communities is overgrowth (Osman, 1977). For instance, the dense mass of tubes build by *Jassa herdmani* can smother encrusting species such as Bryozoa or small barnacles. *Tubularia larynx* traps sediment around their basal stolon, smothering other species (Osman, 1977). *Metridium senile,* on the other hand, has the ability to smother newly settled organisms by sliding over them with its pedal disk (Nelson and Craig, 2011).

FEW SPECIES DOMINATE THE COMMUNITY

The communities found on the foundations at both locations were similar to what has been reported for other subtidal artificial hard substrata, at similar depths or deeper, in the southern North Sea (Zintzen et al., 2006; Bouma and Lengkeek, 2012, van Moorsel et al., 1991), and can be described as a *Jassa-Tubularia*-Actiniaria community. The relative abundance of each of the species differs between locations, but their presence is always recorded. On many artificial hard substrata, they often develop towards a climax community consisting of the *Metridium senile* biotope (Conner et al., 2004). This is quite different from natural hard substrata, where a dominance of these species is unusual.

The subtidal community on the foundation of the wind turbines on the Thorntonbank and the Bligh Bank is numerically dominated by the amphipod *Jassa herdmani* and the hydroids *Tubularia indivisa* and *Tubularia larynx*. Both *Tubularia* species have tubular stems with a polyp at the end. *Jassa herdmani* filters fine sediments from the water column to build tubes which can cover large parts of the substratum. It can smother other species and prevent new species from settling. Actiniaria species, are generally not numerically dominant, but because of their size, with diameters of up to 8 or 10 cm, they are conspicuous members of the fouling community.

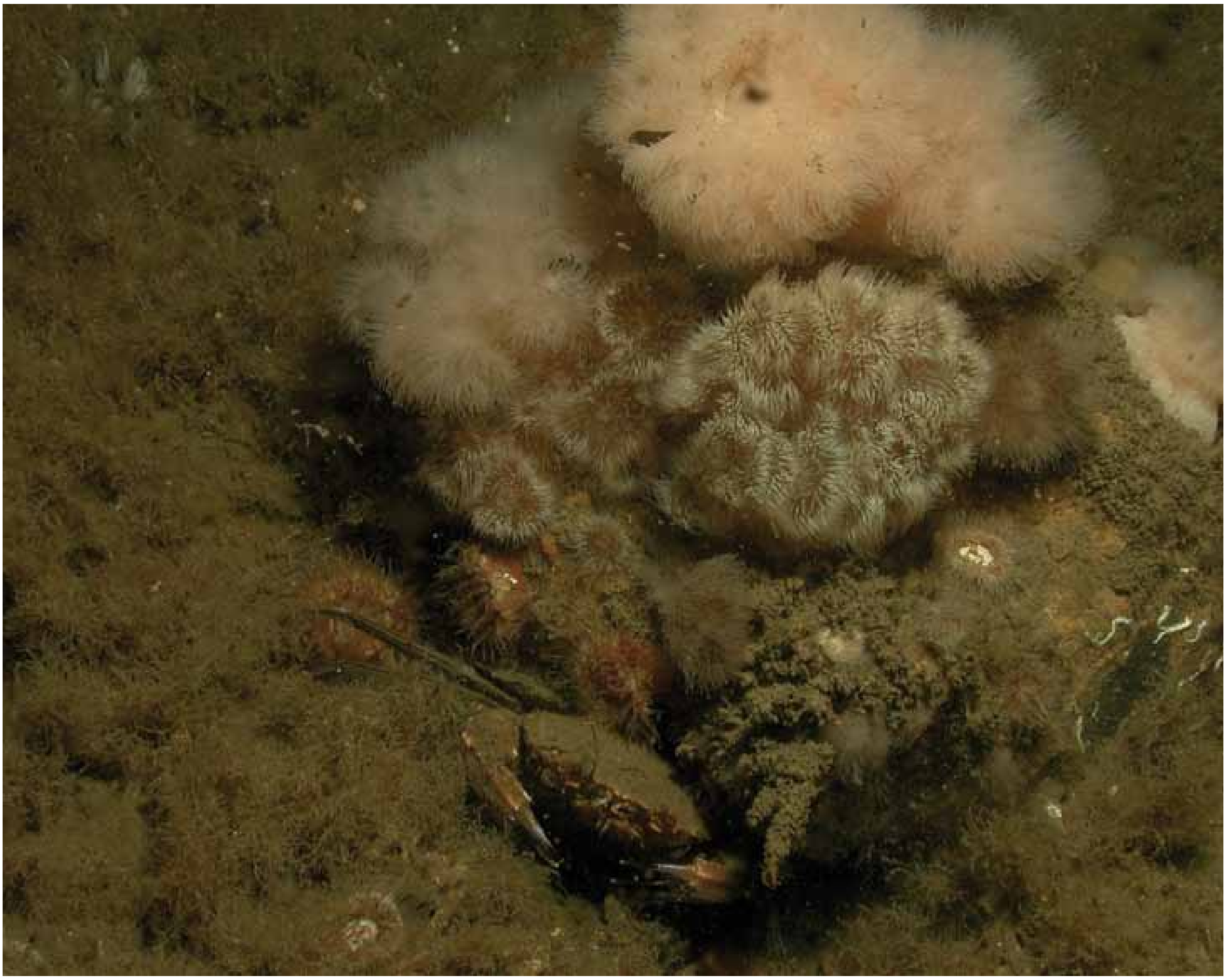
Jassa herdmani

Jassa reached the foundations soon after their installation and reached densities of up to 3 10^5 ind/m^2. *Tubularia larynx* colonised the substrata within one year after construction, and *Tubularia indivisa* followed one (Thorntonbank) or two (Bligh Bank) years later. Both *Tubularia* species show high dynamics in their coverage, both spatially and temporally. It seems that both thrive better on the Thorntonbank than on the Bligh Bank, with maximum coverage of respectively 90% and 60%. By building their stems, *Tubularia* species create a 3-dimensional structure, providing shelter and substrate for other species. In a study on shipwrecks, Zintzen et al. (2008a) found a positive correlation between the biomass of *T. indivisa* and the diversity of other fouling species. We did not detect a similar correlation between the coverage and the number of species.

Within the Actiniaria, *Metridium senile* is the dominant and most characteristic species on artificial hard substrata in the North Sea. This was also the case on the foundations of the wind turbines in the Belgian part of the North Sea. *Metridium senile* was more abundantly found on the Thorntonbank. It has the potential to be a strong structuring force within the fouling community by rapidly colonising new substrata, covering large areas, consuming free-swimming larvae and smothering new recruits (Nelson and Craig, 2011).

Tubularia indivisa

Metridium senile and *Necora puber*

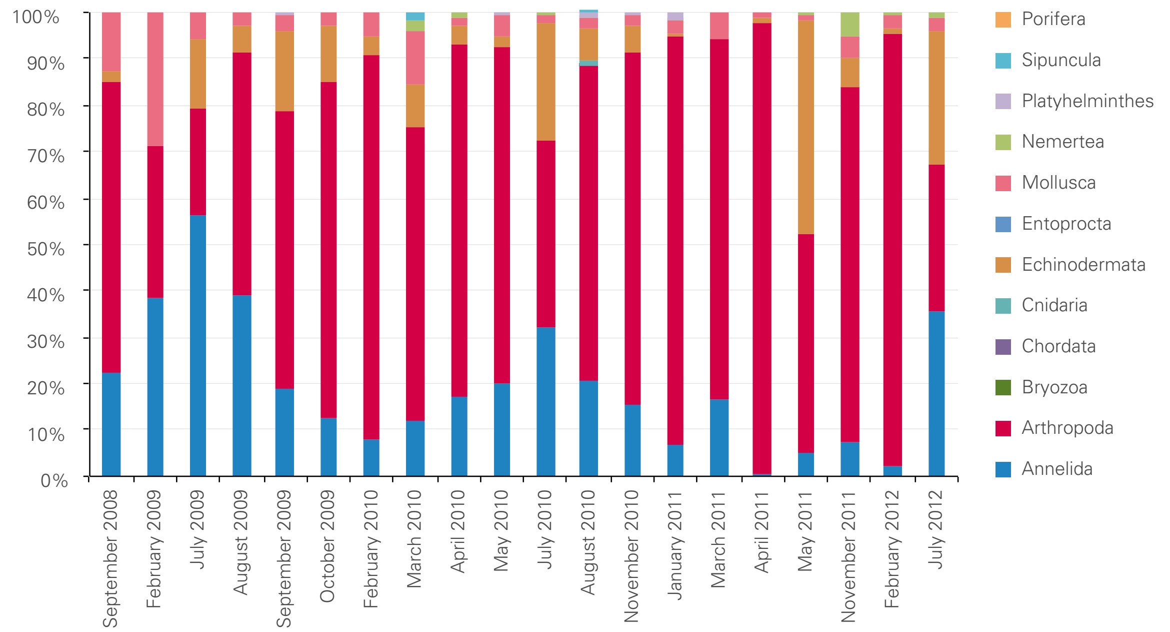


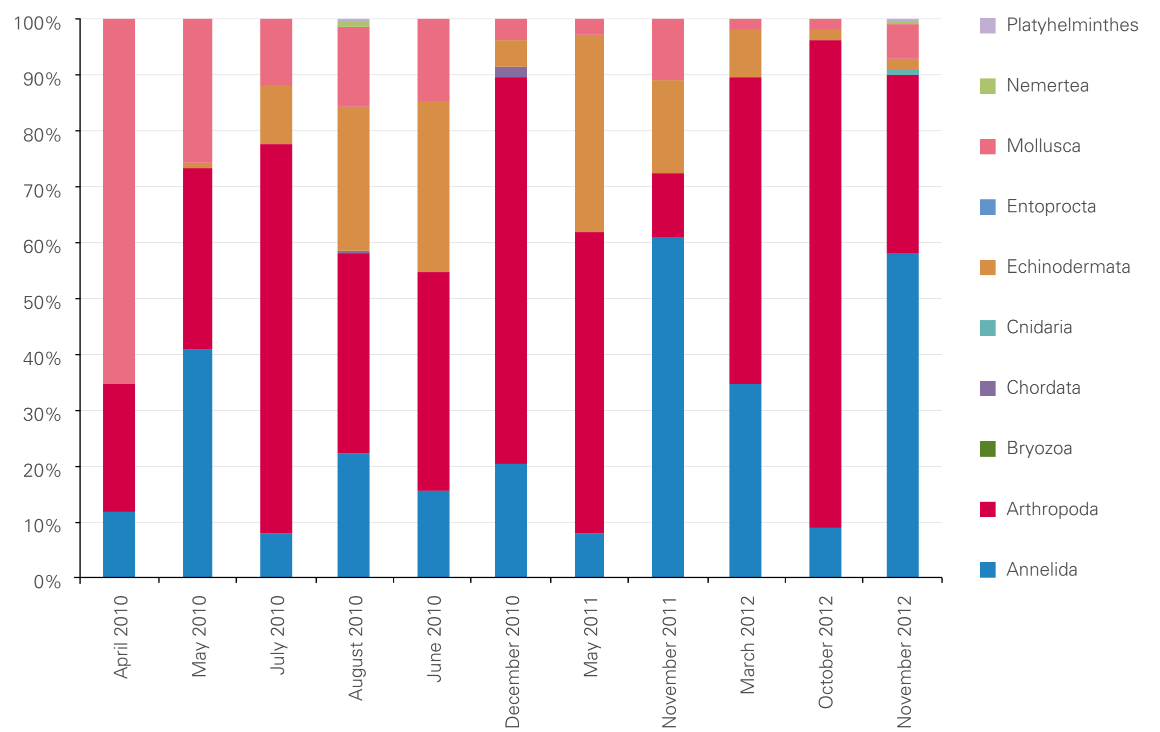
THE SUBDOMINANT SPECIES

The density of the subdominant community – i.e. the community without *J. herdmani,* Actiniaria species and both *Tubularia* species - is higher on the Thorntonbank than on the Bligh Bank, with maxima of respectively up to 2.1 10^4 and 9.0 10^3 ind/m².

The major Phyla in the subdominant part of the community throughout the monitoring are, at both sites Arthropoda and Annelida (mainly Polychaeta) (Figure 4).

Figure 4. Relative composition of the subdominant community (i.e. without *J. herdmani*, *Tubularia* species and Actiniaria species) at the Phylum level at the Thorntonbank (above) and the Bligh Bank (under)





Within the Arthropoda, acorn barnacles such as *Balanus crenatus,* are the first to appear in the subtidal succession series. *Balanus crenatus* is a typical pioneer species that generally, following an initial heavy settlement, quickly decreases in numbers after one or two years (Pyefinch, 1948). In our study, it is predated on mainly by the common starfish *A. rubens* and overgrown by other species.

Balanus crenatus

The long clawed porcelain crab *Pisidia longicornis* and the hairy crab *Pilumnus hirtellus* are two Decapoda that are common inhabitants of hard substratum communities (Ingle, 1980; Zintzen et al., 2008b). They are found on the foundations from the first summer onwards. Remarkably, we found only small individuals of *P. hirtellus* (< 1 cm) on the foundations. They do not seem to attain their maximum length of up to 3 cm in this habitat. On offshore buoys for instance, where the species also often occurs, they grow much larger.

Pisidia longicornus

Pilimnus hirtellus

From the second year onward, the main Arthropoda on the foundations were amphipods. In total, ten different species were identified, half of them restricted to one of the two areas. Three species were found only on the Thorntonbank (*Aora gracilis, Atylus swammerdami, Hyperia galba*), but all of them just at one sampling occasion, and two were found only on the Bligh Bank: *Caprella linearis* was found only once, while *Stenothoe marina* was found at four sampling occasions, but never exceeding 150 ind/m^2. Two other stenothoid species were found in both areas. *Stenothoe valida* is the most abundant, with maximum densities up to 7000 ind/m^2 on the Thorntonbank and 1000 ind/m^2 on the Bligh Bank. *Stenothoe monoculoides* occurred only occasionally, with overall only four samples where more than one specimen was found. Stenothoid species typically occur in close relationship with hydroids (Gili et al., 1995): we indeed found a correlation between the occurrence of *S. valida* and *Tubularia larynx,* which was more clear on the Thorntonbank than on the Bligh Bank.

Stenothoe sp.

On the Thorntonbank, the amphipod *Monocorophium acherusicum* managed to establish a population on the foundation, after *J. herdmani* already reached high densities. This is unexpected, since both species occupy a similar niche. They are both tube-building amphipods filtering fine sediments from the water column to build their tubes. We would expect a strong competition for space and resources.

Monocorophium sp.

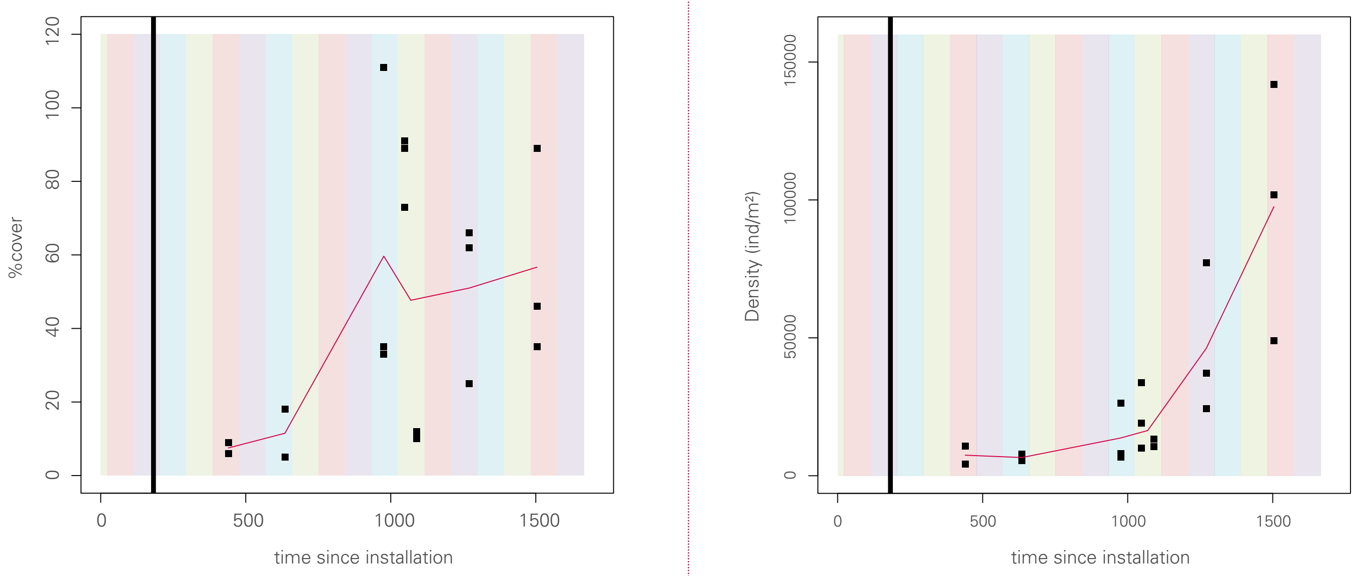
The polychaete worms showed a seasonal trend. *Phyllodoce mucosa, Lanice conchilega, Eunereis longissima* and *Harmothoe extenuate* were mainly found in summer. This results generally in higher polychaete densities (mostly more than 1000 ind/m^2) than in other seasons (generally less than 500 ind/m^2). The last two years of the succession, the keelworm *Pomatoceros triqueter* was the dominant polychaete species on the Bligh Bank, but their densities are highly variable (ranging from 60 to 4000 ind/m^2). *Pomatoceros triqueter* builds calcareous tubes firmly attached to the substratum and is characteristic for communities on both natural and artificial reefs. Its population seemed to be developing well on the foundations of the Thorntonbank in the second year of the succession, with densities up to 700 individual per m^2, but in the last year it did not exceed 100 ind/m^2. Other species thrive better on the Thorntonbank: the greenleaf worm *Eulalia viridis* and *Lepidonotus squamatus* are both observed at almost every sampling occasion on the Thorntonbank while they were only found at the start of the succession on the Bligh Bank.

Pomatoceros triqueter

THE SCOUR PROTECTION

The scour protection was studied on the Thorntonbank. The succession of the fouling community on the scour protection does not entirely develop in parallel with that on the foundations of the wind turbines. The seasonal pattern, as was seen on the foundations, did not appear and the scour protection seems to be colonised more slowly. The density of the countable species is still increasing at the end of the monitoring series, while the coverage seems to have reached its maximum (Figure 5). Total species density was generally higher on the foundations than on the scour protection. This is mainly due to the high number of *J. herdmani* on the foundations. This species was found in lower densities on the scour protection, but the numbers were considerably increasing at the end of the monitoring, with a maximum density of 1.1 10^5 ind/ m^2, while before it did not exceed 1.7 10^4 ind/m^2. When *J. herdmani* was excluded from the analysis, densities were not consistently higher on the foundations than on the scour protection or *vice versa*.

Figure 5. Coverage (%) and density (ind/m2) on the scour protection on the Thorntonbank. Black dots represent observations in each replicate; the red line connects seasonal averages. The background colours represent the seasons (green: spring, red: summer, purple: autumn, blue: winter). The numbers on the X-axis represent the number of days after installation of the foundations. The vertical line represents the approximate time the scour protection was put in place.



Similar to the foundations, species arriving early in the succession are more likely to establish than species arriving later. Out of a total of 80 species, 23 (28.8%) were found in more than 75% of the samples after the first observation. Twelve of these species were observed for the first time at the first sampling occasion, five at the two following samplings. At each sampling occasion, there are generally more species found on the scour protections than in the scrapings, on average respectively 33.8 and 27, and relatively more species are rare (on average 4.1 versus 2.1 species). The three dimensional complexity of the stones might provide a suitable habitat to a larger range of species. Additionally, the dense growth of mainly *J. herdmani* on the foundations can prevent the settlement of certain organisms. However, the sampled surface of the stones of the scour protection is sometimes higher, which can cause some bias as the chance of encountering more (rare) species increases with an increasing sampling surface.

The species composition differs between the foundations and the scour protection. *Monocorophium acherusicum* apparently thrives better on the scour protection than the other tube building amphipod *J. herdmani*, especially early in the colonisation period. Another amphipod that is mainly found on the scour protection is *Phtisica marina*, with maximum densities of 1500 ind/m^2, compared with 400 ind/m^2 on the foundations. During the last monitoring year, *P. marina* was no longer found on the foundations, while it still occurred on the scour protection with densities of up to 200 per ind/m^2. Within the stenothoid species, a spatial segregation occurs: *S. valida* was more numerous on the vertical surface of the foundations, while *S. monoculoides* was almost exclusively found on the scour protection.

The barnacle *Verruca stroemia* colonises the scour protection after *Balanus crenatus* has disappeared. The dense *J. herdmani* turf probably hinders the settlement of *V. stroemia* on the foundations. *Tubularia indivisa* en *T. larynx*, both dominant on the foundations (maximum coverage of 90%), are much less abundant on the scour protection, with a maximum coverage of 15%. Only Actiniaria are equally abundant in both microhabitats.

IN CONCLUSION

Similar colonisation patterns are observed on the Bligh Bank and the Thorntonbank. The subtidal community on the foundations of the wind turbines and scour protection are largely formed during the first two years after the substrata have been introduced in the marine system. Afterwards, several species reach the substratum, but most of them are not able to establish a population or become an important member of the fouling community. Most of the species found are hard substrata species, consequently they are new to the area.

Despite large overall similarities, also some differences in the community composition are found between the wind farms. Some species are restricted to, or develop better in, one area. This can be due to the different water masses that reach the windfarms, and/or the different type of substrata that are available, with concrete foundations on the Thorntonbank and steel monopiles on the Bligh Bank.

The species diversity of the fouling community on the scour protection is higher than on the foundations. This might be due to the higher complexity of the stony scour protection, providing a suitable microhabitat for a wider range of species. Additionally, because *J. herdmani* is less dominant and the stones are not densely covered by their tubes, the settlement of new species might be less hampered than on the foundations. On the other hand, the sampling surface of the stones is sometimes larger, increasing the chance of finding more (rare) species.

There appears to be a spatial segregation, with some species preferring either the scour protection or the foundations. Although both structures are artificial hard substrata, they constitute different habitats. The steep vertical structure of the foundations is unusual in the marine ecosystem, and has no natural counterpart in the North Sea. Because they lack any structural complexity, they can be expected to provide a particular environment. The fouling community we found is typical and similar to what has been described on vertical surfaces of for instance shipwrecks. The stones of the scour protection on the other hand, are more complex with differently orientated surfaces and holes where species can find shelter. This resembles more the natural hard substrata, however the community occupying the scour protection is different.

The long-term continuous monitoring has proven to be valuable in interpreting the patterns on the foundations. Yearly and seasonal variation is high, but the frequent sampling over a four year period, allowed a reliable interpretation of the data.

Hydractinia echinata covering empty *Balanus perforatus*

FURTHER MONITORING

In the future monitoring, we will continue to sample the wind farms that have been studied already for several years, and discussed in this chapter, but also (some of) the new wind farms yet to be built will be included (Chapter 2).

The monitoring program has until now focussed on detailed patterns at species level on and near a number of selected wind turbines. Emphasis in the future will be put on larger scale processes. The time series we collected has resulted in a good understanding of the colonisation and of the dynamics early in the succession. We see a stabilisation of the community development, especially on the foundations. The focus of the research will now move on to studying a larger surface area on the foundations to better understand the spatial heterogeneity. This will be done through the analysis of video and/or photo images. Video images allow qualitative analysis of large surfaces. The advantage of photo images is that the same quadrants can be observed repeatedly in a non-destructive manner, allowing the same area to be studied through time. With the knowledge of the food preferences of some – economically valuable – species, a better assessment of food availability for the higher trophic levels can be made, and a better knowledge of the position of the fouling community in the marine food web could be gained.

Another up-scaling will be done by shifting the focus from few wind turbines to the processes and dynamics along an onshore-offshore gradient. This will allow assessing the influence of environmental variables, such as suspended particulate matter concentration, on the colonisation trajectories and zonation patterns at offshore wind turbines.

For the monitoring of the scour protection, emphasis will be put on the use of the artificial reefs by larger animals, such as crabs and lobsters which can use the stony reef for shelter. Divers reported their presence, but the current sampling techniques do not allow studying their abundance and distribution over the reef. Traps can help analysing the megafauna community composition and their size and sex distribution. Video-based analyses or observations by divers will give better insights in their spatial distribution over the artificial reef.

The biological sampling, by scraping fouling of the foundations and collecting stones of the scour protection, will be continued, but the temporal resolution could be reduced, e.g. samplings once per year rather than once per season. Additionally, biomass will be determined, which will, in combination with the photo-images, allow a better understanding of the food availability for higher trophic levels.

Lobster *Homarus gammarus*