CHAPTER 6

ON THE REPLICABILITY OF NATURAL GRAVEL BEDS BY ARTIFICIAL HARD SUBSTRATA IN BELGIAN WATERS

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Abstract

In this contribution, we were particularly interested in qualifying the differences of natural (*e.g.*, gravel beds) versus artificial (*e.g.*, turbine foundations and scour protection) hard substrates. Therefore, we explored the epifauna data based on biological trait composition rather than the species composition of the epifouling communities. Both habitats harbour a rich species diversity and share a number of species. The initial results show that natural hard substrata harbour a much higher number of species and also more unique species than the artificial ones and that there are also some differences in life traits. Therefore, it seems that artificial hard substrata cannot act as alternatives to the loss of natural hard substrata.

1. Introduction

Gravel areas occur scattered in the soft sediment dominated southern North Sea and the Eastern Channel (Veenstra 1969; Cameron & Askew 2011). Several studies demonstrate that gravel areas, such as the Westhinder sandbank area (Belgian waters – Houziaux *et al.* 2008; Haelters *et al.* 2007), the Klaverbank (Dutch waters – Van Moorsel 2003) and the Dover Strait (French waters – Foveau *et al.* 2008), accommodate a unique community of species. These gravel beds are composed of boulders of variable sizes, shell fragments and sand. This high habitat heterogeneity leads to a huge biodiversity.

In addition to natural hard substrata, many artificial hard substrata occur in the North Sea (Zintzen *et al.* 2008; Coolen 2017) such as wrecks and wind farms. The hardening of the coastal zone, due to the increasing construction of harbours, groynes and other structures, is rapidly changing the coastal environment and also further offshore with a proliferation of wind farms and other marine infrastructure in response to the increasing demand of renewable energy, the number of man-made structures increases (*e.g.*, Mineur *et al.* 2012). In the wind farms, both the foundations of the turbines and the erosion protection around the foundations form hard substrata where species can settle. On the other hand, unspoiled natural hard substrata are decreasing due to fisheries pressure and aggregate extraction (Lindeboom *et al.* 1998).

The creation of new habitats increases the habitat diversity, which in turn increases species diversity. Hence, artificial hard substrata too are often considered hot spots of biodiversity (Wolff 1999). However, in coastal regions they often harbour introduced species that occur all over the world (Kerckhof *et al.* 2016; Reise *et al.* 1999).

From the onset of the hardening of the coast, which started in the 16th century (Wolff 1999), many hard substrata species successfully colonised this newly created habitat (*e.g.*, Mineur *et al.* 2012). Through history, shipwrecks further augmented the extent of suitable habitat for many of these hard substrata species (Zintzen & Massin 2010; Lengkeek *et al.* 2013). With the construction of offshore wind farms finally, a new habitat of artificial hard substratum was introduced in a region mostly characterized by sandy sediments, enhancing the habitat heterogeneity and biodiversity of the region (Kerckhof *et al.* 2009; 2010). The effect of the introduction of these hard substrata – the so-called reef effect – is regarded as one of the most important changes of the marine environment caused (Petersen & Malm 2006). These artificial substrata are in general rapidly colonised by fouling organisms (Horn 1974; Connell & Slatyer 1977; Kerckhof *et al.* 2010).

Because fishing activities, including bottom trawling, are prohibited in the Belgian wind farms and due to the intrinsic architectural characters of the wind turbines, the fouling communities on the artificial hard substrata of the scour protection and the piles are not disturbed by human activities. In contrast, natural hard substrata are threatened under the influence of various human activities such as bottom trawling and sand and gravel extractions (Lindeboom *et al.* 1998). The impact of bottom disturbing fisheries has increased significantly over the last 100 years due to technological advances and consequently, long-lived fragile species and erect species have declined or disappeared while scavengers and opportunistic species are favoured (Lindeboom *et al.* 1998). Some parts of the gravel areas in the Westhinder sandbank area are practically more difficult for fishing because they are situated in a trough of sickle-shaped barchan hills (Houziaux *et al.* 2008). Here, in this somewhat sheltered zone, the biodiversity proved to be greater than in the surrounding, more fished zones. These areas can be regarded as relicts and hence important for the possible recovery of the surrounding Habitat Directive Area. Due to their higher biodiversity, they can act as a source from which disturbed areas could be recolonized.

In the royal decree establishing a maritime spatial plan for the Belgian waters (Anonymous 2014; Vandevelde *et al.* 2014), the gravel areas of the Westhinder sandbank area are part of the proposed special area for conservation "Vlaamse Banken - Flemish banks" (Anonymous 2012) (kaart MSP) that, in turn, is part of the ecological network Natura 2000 (Anonymous 1992). In the gravel bed area of the Westhinder sandbank area, two subzones have been designated for improving the seafloor integrity by reducing fisheries with bottom contacting gears, called zone 3 and zone 4 (MSP) In zone 3, no bottom disturbing fisheries are allowed at all while zone 4 experimental fishing techniques are still allowed. Zone 3 is also known as a relict (formerly called "refugium") zone (Houziaux *et al.* 2008) because of its rich epifauna since this zone is less fished than the surroundings due to the presence of barchan dune structures that hamper beam trawling.

Another anthropogenic activity with a potential impact is sand and gravel extraction (Vanaverbeke *et al.* 2007). Since 2011 in an area located 2.5 km from zone 4 of the "Vlaamse Banken", sand and gravel is extracted (Anonymous 2011). The silt that is suspended by the extraction is carried by the flow and can cause clogging of the gills of filter feeders (Vanaverbeke *et al.* 2007), many species of which occur on hard substrate. Also, organisms on the stones can catch the sludge, so that typical hard substrate species can no longer settle (De Mesel *et al.* 2013).

Recently, artificial hard substrata are sometimes put forward as a possible alternative for the loss of natural hard substrata habitat and are even proposed to strengthen biodiversity *e.g.*, plan Zeehond (Van de Lanotte *et al.* 2012). When evaluating whether artificial hard substrata habitat may indeed strengthen and/or even replace natural hard substrata habitat, we first have to investigate the (dis)similarities in species and community composition between both types of hard substrata habitat. In this preliminary exercise, we therefore explored to what extent artificial hard substrata (*i.e.*, turbine foundations and scour protection) are comparable to natural ones (*i.e.*, gravel beds) and if, for example, they in a way contribute to and/or strengthen species and functional (*i.e.*, biological traits) diversity of naturally occurring hard substrata.

2. Material and methods

We selected three data sets on hard substrate fauna available from the same water mass, situated in clear offshore (Channel) waters (M'harzi *et al.* 1998; Lacroix *et al.* 2004). We focused on hard substrata waters influenced by Channel waters because most of the natural hard substrata in Belgian waters are situated in this type of water.

2.1. Artificial hard substrata sample selection

As an example of the artificial substrata, we selected the wind farm located on the Bligh Bank at about 50 km off the Belgian coast (see Brabant *et al.* 2011). This wind farm is furthest situated from the Belgian coast and is entirely located in the English Channel's water flow. The construction started at the end of 2009. The turbines are steel monopile foundations surrounded by a scour protection consisting of natural stones of various sizes (Van Oord Dredging & Marine Contractors 2009). As such, the combined scour protection sites could be regarded as an artificial reef consisting of 107 separate locations, each composed of a single steel foundation pile surrounded by approximately 500 m^2 (~ 840 m^3) of scour protection.

All subtidal samples were collected by scuba divers in 2011. The samples included 9 scrape samples taken on the turbine foundations and 9 stones gathered from the scour protection (Kerckhof *et al.* 2011). On the piles samples, were taken at a depth of 15 m by scraping 3 replicates of the fouling organisms from a sampling surface area of 6.3 dm^2 of turbines BBC2 (May) and BB8 (May and November). Divers collected 3 stones of the scour protection of turbines BBC2 (May) and BB8 (May and November). The scraped material and the stones were collected in plastic bags that were sealed and transported to the laboratory for further processing: sieving over a 1 mm sieve and sorting. The samples were preserved on buffered formalin 10% and further processed in the laboratory.

2.2. Natural hard substrata sample selection

To represent natural hard substrata, we selected two data sets taken in the Westhinder sandbank area, part of the special area for conservation, the "Vlaamse Banken". The first set consisted of 5 samples taken on 3 July 2013 at a depth of around 30 m in zone 3 (the so-called relict zone, *sensu* Houziaux *et al.* 2006). The second was taken in zone 4 in December 2016 and consisted of 13 samples. The samples of the natural hard substrata were taken at a depth of approximately 25 m with a 0.1 m^2 Hamon grab. This device is, contrary to other commonly used grabs such as the Van Veen and Box Corer, especially suitable for use in gravelly sediment although it does not collect large boulders or stones. Once on board, the samples were sieved over a 1 mm sieve and sorted. The largest boulders (with or without growth) were separated from the coarse material, which consisted of coarse sand, shell fragments and gravel. Then the samples were preserved on buffered formalin 10% and further processed in the laboratory. We pooled both data sets of the Westhinder sandbank area because both originated from the same area.

After preservation of the samples, individual organisms were sorted and identified to the lowest taxonomic group possible – mostly species level (further called "species") – using a stereoscopic binocular microscope.

Additionally, to assess the quality of the habitats and as part of the criteria put forward in the Determination of the Good Environmental Status and Establishment of Environmental Targets for the Belgian Marine Waters (Belgische Staat 2012) as required in the framework of the Marine Strategy Framework Directive, we also looked at the presence of large erect species, in particular certain Bryozoans such as *Flustra foliacea*, *Alcyonidium* spp. and sponges such as *Haliclona oculata* and Hydrozoans.

2.3. Data selection

In this study, we took into account both countable macrofaunal (retained by a 1 mm mesh-sized sieve) organisms and uncountable crust forming and erect (bushy) epifaunal species such as Cnidaria, Bryozoa, sponges, etc. To be able to combine both types, we transformed the data to presence/absence.

The samples taken in the Westhinder sandbank area with the Hamon dredge contained both epifaunal species and infaunal species – contrary to the samples of the scour protection that only consisted of stones. Since we were only interested in species associated with hard substrata, we scored them in relation to their affinity with hard surface. Obligate hard substrate species such as forms cemented on a surface (*e.g.*, acorn barnacles, forms attached by threads or knobby structures *e.g.*, mussels) and mobile forms (*e.g.*, snails, sea urchins) or species living in burrows under or in the vicinity of hard substrata such as certain worms received score 3. Infaunal species that do not depend on a solid surface were scored 0. A certain number of free living species is nevertheless associated with hard substrata, as they are dependent on either the substrate itself as shelter or because they are associated with species that are obligate hard substrate species as, for example, Stenothoe or nudibranchs feeding on Tubularia. Moreover, some species, such *as Lanice conchilega* or *Crepidula fornicata*, are capable to live both on hard and on soft substrata. Such species were scored 1 or 2 according to their dominant occurrence. Some species such as *Venerupis corrugata* and *Aequipecten opercularis* start their live attached to hard substrata before moving to an adult free living (Aequipecten) or infaunal (Venerupis) stage. Since we only encountered juvenile stages of these species in our samples we treated them as obligate hard substrate species, score 3.

We extracted a species list for the three habitats and only retained hard-surface species: out of the species pool of all species identified, we eliminated those species – infaunal species – that were not associated to hard surfaces. This yielded a list with genuine hard substratum species and species that are associated with hard substrata during at least part of their life cycle. The dataset contained in total 208 unique species of which 136 were considered hard substrate or hard substrate associated species.

2.4. Biological traits selection

In this exercise, we gathered information for two biological traits: the feeding method and the mobility of the adults. Information was gathered from a variety of published sources. Additionally, information was obtained from online databases *e.g.*, WORMS,

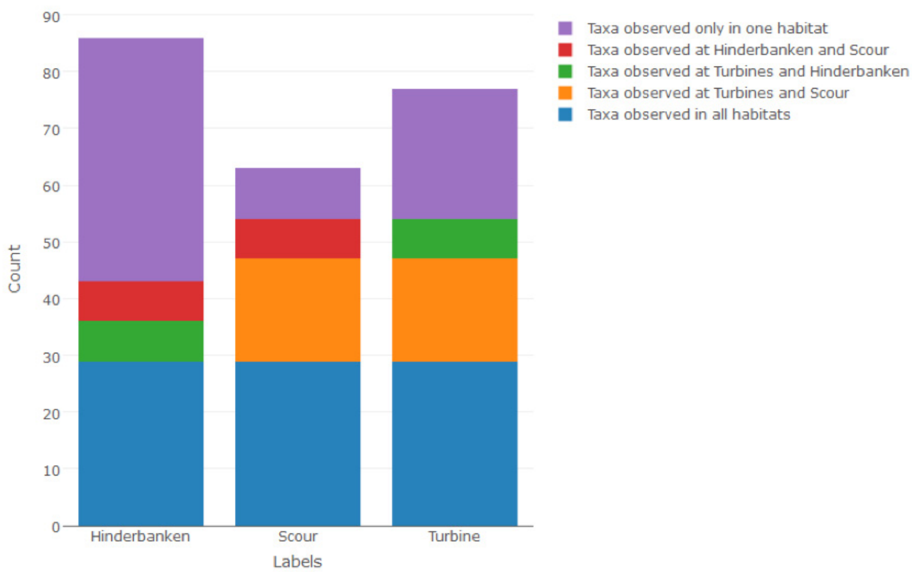

Figure 1. Number of hard substrate species observed per habitat.

BIOTIC or specialized literature. In case the information was not available for a particular species, we looked at other species of the same genus, or family.

We recognized five feeding traits: suspension feeder, deposit feeder, parasite, predator/scavenger and grazer. A "suspension feeder" is an organism that feeds on organic particles filtered out of the water column, a "deposit feeder" feeds on fragmented organic particles deposited onto the bottom. We combined predator and scavenger into one category, as most predators are also to some extent feeding on carrion.

For the mobility trait, we recognized five categories: sessile, hemi sessile, permanently attached, crawler and digger. We used the category hemi sessile for organisms that usually stay on the same spot, but can move to a limited extent in a limited area, such as the amphipod *Jassa herdmani*, the plumose anemone *Metridium senile*, or the mussel *Mytilus edulis*. Sessile was used for organisms living in rigid tubes firmly attached to the substrate or organisms firmly attached to the substrate (*i.e.*, permanently attached), *e.g.*, Cnidaria, sponges. Species belonging to the digger category live and move into the soil. *Venerupis corrugata* and *Aequipecten opercularis* start their lives attached to hard substrata and are treated here as hemi sessile.

2.5. Criteria for the classification of traits

Because some species can belong to more than one category we used the "fuzzy coding" method (Chevenet *et al.* 1994). For each type, a score of zero to three was assigned to each category of traits. Zero means that the species does not belong to that category, three means that the type belongs to that category and one or two means that the species exhibits that property but with lower or higher affinity for that category. If the species belongs to two categories, one or two will be assigned to those categories. For each species, the sum of all categories of one feature is equal to three.

3. Results

3.1. Species richness

The three habitats shared an equal species number (29) (fig. 1). The scour and the turbine of the wind farm habitats shared 17 species, and 7 species were present on both Scour and Hinderbanken and the Westhinder sandbank area shared 7 species with the turbines.

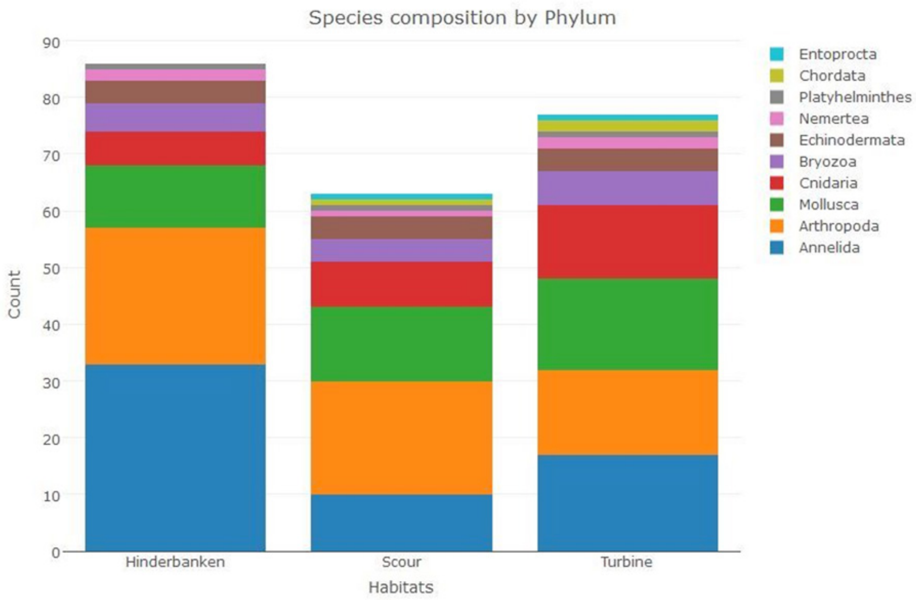

Figure 2. Taxonomic species composition per phylum in the different habitats is presented in.

The Westhinder sandbank area harboured the highest number of unique species. The number of unique species was much lower in the wind farm habitats with 9 on the scour and 23 on the turbines.

3.2. Taxonomic composition

In all three habitats Annelida, Arthropoda and Mollusca were the three most species-rich phyla, followed by Cnidaria and Bryozoa (fig. 2). Cnidaria were relatively more species rich in the Westhinder sandbank area.

The distribution of the feeding classes is similar over the three habitats (fig. 3) with the exception of sessile species of which the number is clearly higher on the turbines than on the other habitats. Crawlers are in the majority in all three habitats while swimmers and diggers are virtually absent.

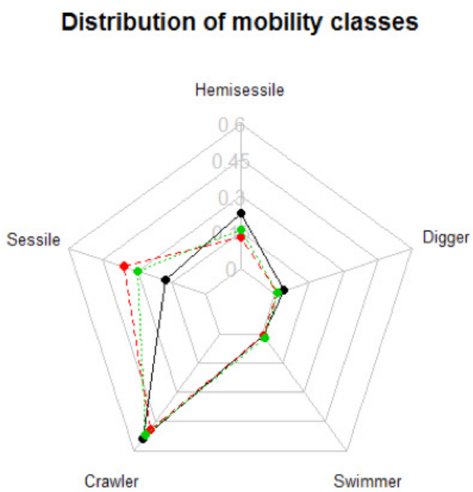

Figure 3. Radar chart of mobility classes indicating the relative composition of mobility classes of the species encountered in the three habitats (red: turbines; black: Westhinder sandbank area; green: scour protection).

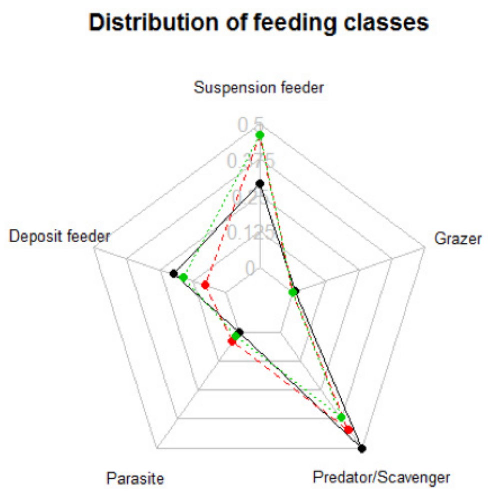

Figure 4. Radar chart of feeding classes indicating the relative composition of feeding classes of the species encountered in the three habitats (red turbines, black Westhinder sandbank area, green scour protection).

Suspension feeders are nearly twice as common on the artificial hard substrata of the piles and scour than on the natural hard substrata while deposit feeders are slightly more numerous on the natural hard substrata of the Westhinder sandbank area than on the wind turbine habitats. The Westhinder sandbank area contained the highest number of predator/scavengers their number was slightly lower the two artificial habitats. Grazers and parasites are virtually absent in all three habitats.

3.3. Number of long-lived and erect species

The number of long-lived and erect species found was very low in all three habitats including the natural gravel beds. Such erect species as the bryozoans *Flustra foliacea*, *Alcyonidium* spp. or the sponge *Haliclona oculata* were not found at all and from *Alcyonium digitatum* only small colonies were present.

4. Discussion

Despite this limitation mentioned above, the natural hard substrata of the Westhinder sandbank area harbour more and unique species than the other two habitats, including the scour protection. However, a rich community can only develop if the habitat is not strongly subjected to natural and/or anthropogenic disturbance. Bulleri *et al.* (2000) suggested that certain man-made structures in the marine environment could act as surrogate rocky shores but further research showed that artificial reefs could not be considered as substitutes for natural habitats in terms of relevant ecological processes (*e.g.*, Bulleri & Chapman 2010).

The species assemblages in the three habitats are characteristic for a hard substrate community and the contribution of dominant phyla to the species list is similar. There is a slight difference in species composition, species numbers, phylum composition and difference in biodiversity between the Westhinder sandbank area and the erosion protection. For example, we observed a higher species richness with many unique spies in the natural hard substrata of the Westhinder sandbank. In reality, the number could be much higher because the preliminary data we used for these exercise clearly have limitations as for example no large stones were collected in the Westhinder sandbank area. However, the data allows to form an idea of a possible difference in species, species, dominant phyla, biodiversity and functional groups. In the future, data of larger stones will be taken into account as we will add data collected with the Gilson dredge, a device aimed to target larger stones and boulders. So it is likely that the species richness will increase even more if more data will be used. The possible underestimation of species richness potential, also holds true for the erosion protection that was in place for only two years. It should be noted however that the scour protection is expected to remain in place only for a period of 20-30 years in accordance with the conditions stipulated in the environmental permit for the construction and exploitation of the wind park (BMM 2007). The number of long-lived and erect species found was zero in all three habitats including the natural gravel beds. This was not expected as in a healthy natural hard substrate community their number should be higher. This could be a consequence of the sampling technique and/or degradation of the environment by *e.g.*, fishing/aggregate extraction. The relict zone is probably still touched by fishing activities despite the zone being less accessible. Both natural hard substrata and the scour protection are situated in a very dynamic environment, influenced by the movements of strong sand waves that sometimes cover the stones completely. It is unclear why deposit feeders and predators/scavengers are more numerous on the natural hard substrata than on the artificial hard substrates.

5. Conclusion

Our results – although preliminary – suggest that artificial hard substrata cannot readily be put forward as an alternative for declining natural substrata. We noted a difference in species numbers, functional groups and a difference in biodiversity between natural and hard substrata. This illustrates the importance of maintaining the Westhinder sandbank area, and thus the Vlaamse Banken, as part of the Natura 2000 network.

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