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Artificial hard substrate as a habitat for hard bottom benthic assemblages in the southern part of the Baltic Sea – a preliminary study

by

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Abstract

Benthic species associated with hard substrate are known to form communities characterized by high abundance and biomass. Although the bottom of the Southern Baltic Sea is dominated by soft sediments, such communities find favorable conditions to thrive on artificial substrates of offshore constructions. The aim of this research was to characterize both short-term and long-term benthic communities associated with artificial hard bottom provided by man-made structures in the Southern Baltic Sea. Species composition as well as the abundance and biomass were examined at various sites. An inactive World War II torpedo testing facility in the Gulf of Gdansk served as a site for sampling long-term communities while short-term communities were sampled using settlement panels and PVC cylinders. Panels were deployed at the torpedo testing facility for 127 days. PVC cylinders were deployed for 141-190 days in the Polish Exclusive Economic Zone. Twenty six macrofaunal taxa, including 12 crustaceans, were identified during the research. *Mytilus edulis* and *Amphibalanus improvisus* were the most abundant invertebrates at sampled surfaces. Six non-indigenous species were found. For the first time adult individuals of *Mytilopsis leucophaeata* were found in the Polish Marine Areas indicating that it is possible for this non-indigenous species to reproduce in this region.

Key words: artificial substrates, hard bottom, biofouling, offshore constructions, marine man-made structures

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Introduction

Benthic communities associated with hard substrates in the Baltic Sea are characterized by relatively high species richness (Grzelak, Kukliński 2010). The foundations of such diversity are provided by sessile invertebrates such as barnacles and blue mussels that inhabit hard surfaces in great numbers. Numerous mobile organisms such as amphipods, isopods and polychaetes find shelter and place for foraging among those dense populations of filter feeders (Grzelak, Kukliński 2010). This kind of benthic assemblages is relatively rare in the Polish part of the Baltic Sea since the seabed is dominated by fine sediments and natural hard substrate is present only in few regions (Uścinowicz 2011). Nevertheless, hard bottom communities find favorable conditions at the surfaces provided by numerous man-made structures such as piers, breakwaters and shipwrecks. These habitats are composed of regular horizontal and vertical surfaces that are absent in the natural hard bottom. Some of these vertical surfaces may extend throughout the whole water column which is also an uncommon feature in unchanged environment. As a result, assemblages associated with such constructions may differ significantly from those inhabiting natural hard substrates (Smith, Rule 2001; Zintzen et al. 2006; Zintzen, Massin 2010), although they are often composed of the same species (Myers, Southgate 1980; Kruk-Dowgiałło et al. 2009). The impact of man-made structures in the sea may be considered as positive. Especially in the seas, where the bottom is dominated by fine sediments, such objects may act as biodiversity hotspots since they serve as a suitable habitat for numerous species (Chojnacki 1993; Chojnacki 2000; Zintzen et al. 2006; Zintzen et al. 2008). They may also lead to an enrichment of benthic fauna associated with nearby soft sediments (Coates et al. 2011; Coates et al. 2012). On the contrary, artificial structures are known to be inhabited by non-indigenous species and therefore facilitate a successful colonization of a new environment by such species (Zintzen et al. 2006; Zaiko et al. 2007; Kerckhof et al. 2011). Regardless of their positive or negative influence, man-made structures form a vital element of the marine environment. Their number is growing and so is their significance for marine ecosystems. Previous studies concerning benthic assemblages on artificial substrates in the southern part of the Baltic Sea focused mainly on the fouling processes and ecological succession in the first few years after the deployment of artificial substrate in the water (Ciszewska, Ciszewski 1994; Chojnacki 2000; Dziubińska, Janas 2007; Kruk-Dowgiałło et al. 2009; Dziubińska 2010). Fully developed communities in the region have been poorly studied, considering that a benthic community reaches the climax stage after 2 or even 5-6 years of existence (Chojnacki 2000; Leewis et al. 2000). Also colonization of artificial substrates at depths exceeding 20 meters has never been investigated in the Baltic Sea. The aim of that preliminary study was to describe benthic communities associated with offshore constructions in the southern part of the Baltic Sea. Both long-term and short-term assemblages as well as shallow and deep water communities were investigated in order to observe differences between them.

Materials and methods

Material was collected at six sites in the Polish Marine Areas. Five sampling sites were located in the Polish EEZ at depths varying from 15 to 65 meters. One site (TBD) was located at the inactive World War II torpedo testing facility in the Gulf of Gdańsk (Fig. 1).

The structure is situated over 400 m offshore. The depth around the facility is up to 10 meters. Samples in the Polish EEZ were collected using PVC cylinders. Each cylinder was 11 cm in diameter and 11 cm high, giving the area of 379

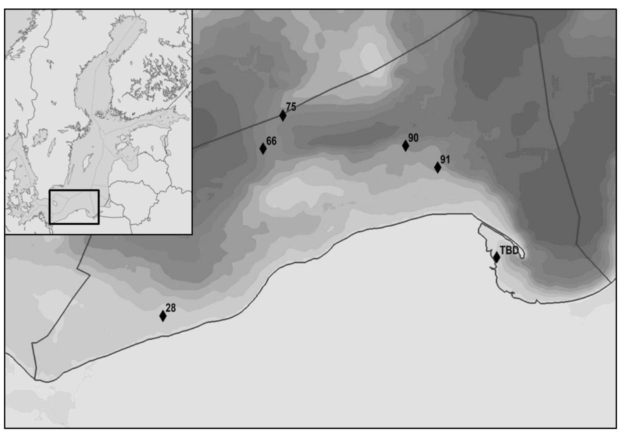

Figure 1

Location of the sampling sites

cm². Surface of each cylinder was roughened in order to facilitate the settlement of sessile invertebrates. Three cylinders were deployed at each site in June and July 2012. They were collected after a certain time of exposure, which varied from nearly five to over six months (Table 1).

Table 1

Information on the time and depth of exposure of cylinders at the sites in the Polish EEZ

Sampling site	Depth (meters)	Date of deployment	Date of collection	Duration of exposure (days)
28	15	5 June 2012	24 October 2012	141
66	65	24 July 2012	19 December 2012	149
75	60	24 July 2012	19 December 2012	149
90	55	26 July 2012	16 January 2013	175
91	45	13 June 2012	19 January 2013	190

Both short-term and long-term communities were sampled at the torpedo testing facility. Samples of short-term communities were collected using settlement panels made of CORREX (corrugated plastic). Each panel consisted of two parts: a 15 cm × 15 cm double-sided vertical panel, which served as the main sampling surface (total surface 450 cm²) and a horizontal panel, which was added to provide better stability. Similarly to the cylinders used at the other sites, the horizontal plates were roughened with sand paper. The total surface of vertical and horizontal parts was 930 cm². Four panels were deployed at the torpedo testing facility at a depth of 5 meters on the 6th of May 2012. They were collected on the 9th of September after 127 days of exposure. Panels were packed underwater in plastic bags by SCUBA divers before retrieving them to prevent the escape of mobile organisms. Those that were able to escape before a panel was put in a bag were noted and identified to the species level. Samples of long-term communities were collected in four replicates by scraping the organisms off the facility's walls at a depth of 5 meters on the 9th of September 2012. Samples were scraped within a 20 × 20 cm (area of 400 cm²) frame into a net (mesh size 200 µm). Mobile organisms, which were able to escape from the sampled area before the material collection, were noted and identified to the species level. All the samples were preserved in 4% formaldehyde. Before further analysis of the short-term community samples, all the organisms were scraped off the experimental substrata in a similar way as the long-term community samples. Vertical and horizontal parts of the panels were split up before scrapping the organisms. Samples from vertical and horizontal plates were kept in separate bottles. Each sample was sieved (mesh size 1 mm) before further analysis. Species were counted and identified to the lowest possible taxonomic level. Samples from vertical and horizontal plates of the panels were analyzed separately. The purpose of each horizontal plate was to maintain the other plate of the panel in the vertical position and the plates were not intended to serve as sampling surfaces. Therefore, sessile organisms were excluded from the analysis of the material scraped off the horizontal plates. On the contrary, mobile organisms could move between horizontal and vertical plates after the panel retrieval. As a result, sessile organisms were investigated only on vertical plates (area of 450 cm² for replicate), while mobile species had to be investigated on the whole panels (930 cm² for replicate). Biomass of each taxon was measured (wet mass). Bivalves were opened to remove an excess of water. Additionally, abundance of each mobile species was measured. Samples collected with PVC cylinders consisted of only sessile species, which may be caused by the fact that cylinders were not packed underwater before retrieval and hence provided the mobile organisms with an opportunity to escape. Therefore, sites TBD and 28 were compared in regard to sessile taxa only.

Results

In total, twenty six faunal taxa, including 12 crustacean species, were identified during the research. Both communities from the site TBD consisted of 19 taxa, 13 of which were present in both short-term and long-term assemblages (Table 2). Among the samples from the Polish EEZ, macrofaunal organisms were observed only in the material from site 28. Cylinders from other sites

Table 2

Taxonomic composition of investigated communities at sites TBD and S28 (L-T – long-term community, S-T – short-term community)

Taxa		Site		
		TBD (L-T)	TBD (S-T)	S28 (S-T)
Porifera	*Halichondria panicea* (Pallas, 1766)	+	-	-
Hydrozoa	*Cordylophora caspia* (Pallas, 1771)	-	+	+
	Gonothyraea loveni (Allman, 1859)	+	-	-
Scyphozoa	*Aurelia aurita* (polipes) (Linnaeus, 1758)	+	-	-
Turbellaria	n.i.	+	-	-
Polychaeta	*Hediste diversicolor* (Müller, 1776)	+	+	-
	Fabricia stellaris (Müller, 1774)	+	-	-
Oligochaeta	n.i.	+	+	-
Crustacea	*Amphibalanus improvisus* (Darwin, 1854)	+	+	+
	Heterotanais oerstedii (Krøyer, 1842)	+	+	-
	Cyathura carinata (Krøyer, 1847)	-	+	-
	Idotea chelipes (Pallas, 1766)	-	+	-
	Jaera spp.	-	+	-
	Apocorophium lacustre (Vanhöffen, 1911)	+	-	-
	Leptocheirus pilosus Zaddach, 1844	+	+	-
	Gammarus oceanicus Segerstråle, 1947	-	+	-
	Gammarus salinus Spooner, 1947	+	+	-
	Gammarus zaddachi Sexton, 1912	-	+	-
	Palaemon elegans Rathke, 1837	+	+	-
	Rhithropanopeus harrisii (Gould, 1841)	+	+	-
Insecta	Chironomidae (larvae)	-	+	-
Bivalvia	*Mytilus edulis* Linnaeus, 1758	+	+	+
	Mytilopsis leucophaeata (Conrad, 1831)	+	-	-
	Cerastoderma glaucum (Bruguière, 1789)	+	+	+
	Mya arenaria Linnaeus, 1758	+	+	+
Bryozoa	*Einchornia crustulenta* (Pallas, 1766)	+	+	+
	Total number of taxa:	19	19	6

were not covered by any organisms or any traces of their presence at any time of exposure.

A cluster analysis showed high similarity (75%) between the investigated communities in regard to taxonomic composition and biomass of sessile fauna. Nevertheless, SIMPROF test revealed a statistically significant difference between the long-term community from the site TBD and both short-term communities from sites TBD and 28 (Fig. 2).

The highest total biomass (4905.7±1841.0 g m^{-2}) was observed in the short-term community from the site TBD. The biomass of the long-term community from the same site was almost four times lower (1300.0±520.9 g m^{-2}) (Fig.3). All of the investigated assemblages were dominated by two sessile species: *Mytilus edulis* and *Amphibalanus improvisus*. The combined biomass of these two species represented over 98% of the total biomass of each sample (Fig. 3).

The highest abundance of mobile organisms (29250±10749 ind. m^{-2}) was observed in the long-term community from the site TBD (Fig. 4). That abundance was six times lower in the short-term community from the same site (4884±2872 ind. m^{-2}). Mobile fauna of both investigated communities was dominated by crustaceans, mainly amphipods. They represented over 70% of the total abundance in each assemblage (Fig. 4). The mobile fauna of the long-term community was significantly dominated by *Leptocheirus pilosus* (73.1%). The second most abundant species was the isopod *Heterotanais oerstedii* (26.0%). The combined abundance of all other taxa came to less than 1% of the total abundance.

L. pilosus dominated also in the short-term community (52.6% of the total abundance). Crustaceans belonging to the genus *Gammarus* were very abundant too. The genus was represented by three species: *G. salinus* (18.9%), *G. zaddachi*

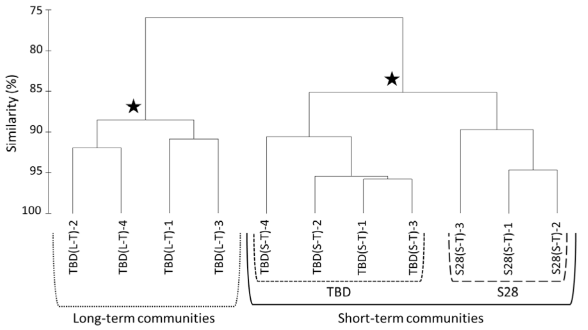

Figure 2

Similarity in species composition and biomass of sessile fauna. - Significant evidence of structure (SIMPROF test, p<0.05)

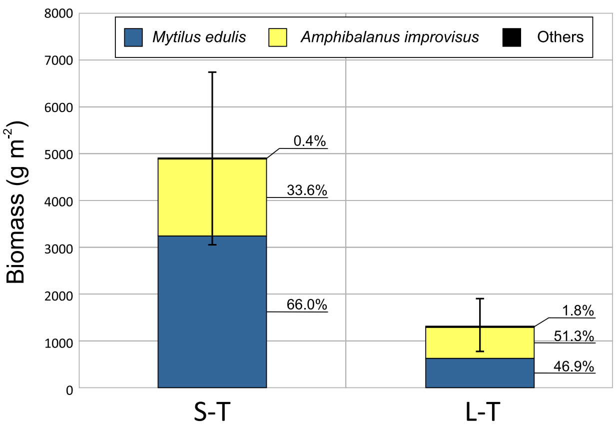

Figure 3

Mean total biomass percentages of species in short-term (S-T) and long-term (L-T) assemblages from site TBD. The others group is composed of species that formed less than 1% of the total biomass.

(5.5%) and *G. oceanicus* (<0.1%), while in the long-term assemblage only *G. salinus* was observed and it represented only 0.002% of the total abundance. *H. oerstedii*, on the contrary, was far less abundant in the short-term community and formed only 6.8% of the mobile macrofauna.

Unlike the total biomass of assemblages, the highest biomass of mobile fauna was observed in long-term community (16.32±11.44 g m^{-2}). It was over 25% higher than in the short-term assemblage (11.83±9.54 g m^{-2}) (Fig. 5). Similarly to abundance, the biomass of the communities was dominated by amphipods. In the long-term community the biomass of *L. pilosus* constituted 88.6% of the total biomass. Remaining 11.4% consisted of the biomass

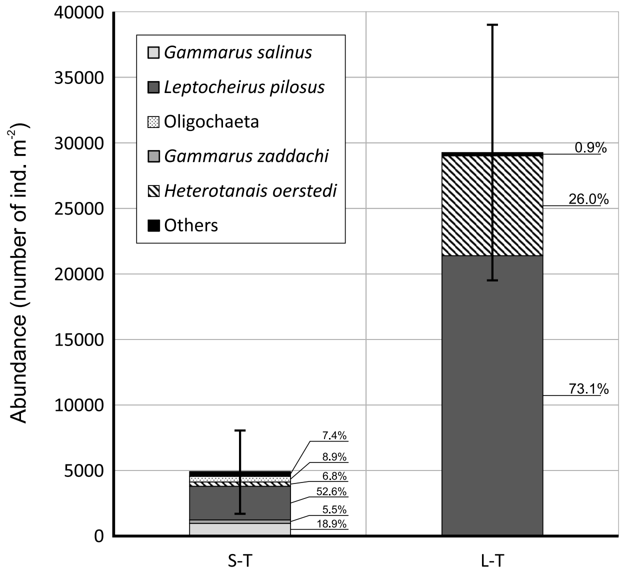

Figure 4

Mean total abundance percentages of mobile species in short-term (S-T) and long-term (L-T) assemblages from site TBD. The others group is composed of species, that formed less than 3% of total abundance.

of seven taxa including 5.4% for Turbellaria. In short-term communities combined biomass of amphipods constituted 59.9% of total biomass. There was a high biomass percentage observed for *Hediste diversicolor* (34.8%)(Fig. 5).

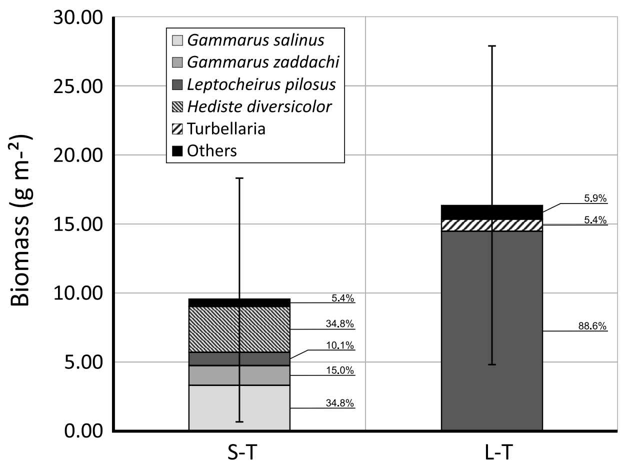

Figure 5

Mean total biomass percentages of mobile species in short-term (S-T) and long-term (L-T) assemblages from site TBD. The others groups were composed of species that represented less than 3% of total biomass.

There were 6 non-indigenous species observed during the research (four in both short-term and long-term communities). Four species were found in the samples: hydrozoan *Cordylophora caspia*, two bivalves *Mytilopsis leucophaeata* and *Mya arenaria* and crustacean *A. improvisus*. Two other crustaceans *Palaemon elegans* and *Rhithropanopeus harrisii* were identified during *de-visu* observations.

Discussion

Benthic assemblages at the site TBD were characterized by high species richness. The total number of taxa (26) was evenly high as in the richest communities of the sandy bottom in the Gulf of Gdańsk (Janas, Kendzierska 2014). That number could have been higher if the samples were collected at several depths instead of one. Dziubińska (2010) conducted a research using settlement plates at 9 depths ranging from 1.5 m to 5.5 m. In total, twenty eight taxa were observed, but 7 of them were absent at a depth of 5 meters. The mean total biomass value of the long-term community from artificial substrates was over 5 times higher than on the natural sandy bottom, whereas the mean biomass of the short-term community was over 20 times higher (Janas, Kendzierska 2014). According to our study, long-term and short-term communities from the site TBD were very similar. Both communities were dominated by the same sessile invertebrate species: *M. edulis* and *A. improvisus,* which are typical of the region (Kruk-Dowgiałło et al. 2008; Chojnacki 2010; Grzelak, Kukliński 2010) but occurred in different proportions. In the short-term community, the biomass percentage of *M. edulis* was two times higher compared to *A. improvisus*, whereas in the long-term community those values were similar. The results obtained for short-term communities resembled those reported by Dziubińska (2010). Communities investigated by the aforementioned author at the same depth and during a similar period of the year were also dominated by those two species, and *M. edulis* was the more abundant species. The overall biomass of the short-term community was over three times higher than in the long-term community. These results follow the reports of Chojnacki (2010) who investigated artificial reefs constructed on the 24th of June 1990 at a depth reaching 9-13 m in the southern Baltic Sea. The author reported a rapid increase in the abundance during the first 145 days after the deployment of the reefs. That increase was followed by a significant drop after 474 days of exposure. The investigated communities differed also in the species composition, abundance and biomass of mobile macrofauna. Contrary to the overall biomass, the abundance and biomass of mobile organisms were much higher in the long-term community that was strongly dominated by two species. They made up a high percentage in the short-term assemblage too, as they probably migrated from nearby abundant populations, but the percentage of other species was significantly higher compared to the fully developed community. It appears that a newly formed habitat attracts a diverse assemblage of mobile organisms during the first several months of exposure. Significant dominance of a few species is established after a longer period of time.

The most unexpected result provided by our research was a lack of the organisms or any other traces of their presence (remains of byssus lines, empty barnacle shells) at the cylinders deployed at depths exceeding 40 meters. Although both *M. edulis* and *A. improvisus* are recorded at such depths in the Baltic Sea (Leppäkoski, Olenin 2000; Wołowicz et al 2006; Węsławski et al 2009), it is possible that sampling sites were affected by water masses from the Bornholm Basin and Słupsk Furrow – deep areas were hypoxia and anoxia were reported in 2012 and 2013 (Hansson et al. 2013, Hansson, Andersson 2014). A deployment of some cylinders in late July may have also led to that result as the most intensive reproductive activity and settling of *A. improvisus* in the Baltic Sea occurred in June and early July, followed by a significant drop in subsequent months (Dziubińska, Janas 2007, Correl et al. 2012). However, cylinders at one deeper site were deployed in the first half of June, only one week after those at the shallow site. Moreover, although periods of the exposure were not favorable for *A. improvisus*, *M. edulis* has been known to reproduce until September (Kautsky 1982, Dziubińska, Janas 2007, Pierścieniak et al. 2010).

The number of non-indigenous species recorded during this study was higher than that reported in the studies of natural hard substrates in the region, where three species were reported (Andrulewicz et al. 2004; Grzelak, Kukliński 2010). It was also higher compared to sandy bottom with and without vegetation cover (Janas, Kendzierska 2014), where three non-indigenous species were reported in most of the sampling sites. In the communities

Table 3

Taxonomic composition of the investigated communities at site TBD (L-T – long-term community, S-T – short-term community) compared to some of the references (Dz. – Dziubińska (2011b) artificial bottom in the Gulf of Gdańsk 4.5 km north of site TBD; K-D – Kruk-Dowgiałło (2008) artificial bottom in the Gulf of Gdańsk; G&K – Grzelak, Kukliński (2010) natural bottom in the Gulf of Gdańsk; A – Andrulewicz (2004) natural bottom in Słupsk Bank

Class	Species / taxa	Present study		References			
		TBD (L-T)	TBD (S-T)	Dz. 2011b	K-D 2009	G&K 2010	A. 2004
Porifera	*Halichondria panicea* (Pallas, 1766)	+	-	-	-	-	-
Hydrozoa	n. i.	+	+	+	+	+	+
Scyphozoa	*Aurelia aurita* (polypes) (Linnaeus, 1758)	+	-	-	-	-	-
Turbellaria	n. i.	+	-	+	-	+	+
Nematoda	n. i.	-	-	+	-	+	+
Polychaeta	*Bylgides sarsii* (Malmgren, 1866)	-	-	-	-	-	+
	Hediste diversicolor (Müller, 1776)	+	+	+	+	+	+
	Fabricia stellaris (Ehrenberg, 1836)	+	-	-	+	+	+
	Pygospio elegans Claparède, 1863	-	-	-	-	+	+
Oligochaeta	n. i.	+	+	+	+	+	+
Hirunidea	*Piscicola geometra* (Linnaeus, 1761)	-	-	-	-	-	+
Arachnoidea	*Hydracarina* sp.	-	-	+	-	-	-
	Lochmannella falcata (Hodge, 1863)	-	-	-	-	-	+
Crustacea	Ostracoda	-	-	+	-	-	-
	Harpacticoida	-	-	+	-	-	-
	Amphibalanus improvisus (Darwin, 1854)	+	+	+	+	+	+
	Cyathura carinata (Krøyer, 1847)	-	+	-	+	+	-
	Heterotanais oerstedii (Krøyer, 1842)	+	+	+	+	+	-
	Idotea balthica (Pallas, 1772)	-	-	-	+	-	+
	Idotea chelipes (Pallas, 1766)	-	+	-	-	+	-
	Jaera spp.	-	+	+	+	-	+
	Saduria entomon (Linnaeus , 1758)	-	-	-	-	-	+
	Calliopius laeviusculus (Krøyer, 1838)	-	-	-	-	-	+
	Caprella mutica Schurin, 1935	-	-	-	-	+	-
	Apocorophium lacustre (Vanhöffen, 1911)	+	-	-	-	+	-
	Corophium multisetosum Stock, 1952	-	-	-	-	+	-
	Crassicorophium crassicorne (Bruzelius, 1859)	-	-	-	+	-	-
	Corophium volutator (Pallas, 1766)	-	-	-	+	-	-
	Leptocheirus pilosus Zaddach, 1844	+	+	-	+	+	-
	Gammarus spp.	+	+	+	+	+	+
	Gammarus locusta (Linnaeus, 1758)	-	-	-	-	+	-
	Gammarus oceanicus Segerstråle, 1947	-	+	-	-	-	+
	Gammarus salinus Spooner, 1947	+	+	-	-	+	+
	Gammarus zaddachi Sexton, 1912	-	+	-	-	+	+
	Mysis mixta Lilljeborg, 1852	-	-	-	-	-	+
	Praunus inermis (Rathke, 1843)	-	-	-	-	-	+
	Palaemon elegans Rathke, 1837	+	+	-	-	-	-
	Rhithropanopeus harrisii (Gould, 1841)	+	+	+	-	-	-
Insecta	Chironomidae (larvae)	-	+	+	+	-	-
Gastropoda	Hydrobidae	-	-	-	-	+	+
	Theodoxus fluviatilis (Linnaeus, 1758)	-	-	+	-	-	+
	Tenelia adspersa (Nordmann, 1845)	-	-	+	-	-	+
Bivalvia	*Mytilus edulis* Linnaeus, 1758	+	+	+	+	+	+
	Mytilopsis leucophaeata (Conrad, 1831)	+	-	+	-	-	-
	Cerastoderma glaucum (Bruguière, 1789)	+	+	+	+	-	-
	Mya arenaria Linnaeus, 1758	+	+	+	-	-	-
	Macoma balthica (Linnaeus, 1758)	-	-	-	-	-	+
Bryozoa	*Einchornia crustulenta* (Pallas, 1766)	+	+	+	+	+	+

associated with sandy bottom, the number of non-indigenous species represented 17% of the total number of taxa, while on the artificial bottom – it represented 26%. The mean biomass percentage of non-native species on sandy bottom reached 10% while on the artificial substrates – 52%, mainly due to very high biomass of one non-native species, i.e. *A. improvisus*. This was consistent with other studies, which reported that artificial structures may facilitate the expansion of non-indigenous species by providing habitats other than those naturally present in the environment (Zintzen et al. 2006; Glasby et al. 2007; Zaiko et al. 2007; Kerckhof et al. 2011). The presence of *M. leucophaeata* is noteworthy. The species was recorded for the first time in the Baltic region in Finland in 2004 (Laine et al. 2006). The first record of that species in the Polish part of the Baltic Sea comes from 2010, when Dziubińska (2011a) found several individuals on experimental panels in the Gulf of Gdańsk. Since all of them were juveniles and no further search for adults was undertaken, the ability of the species to reach the maturity and reproduce in the region remained uncertain. During our research, several adult individuals (shell length 8-13 mm) were found proving that the species is able to settle permanently in the Gulf of Gdańsk. However, there are no other reports of finding *M. leucophaeata* in the Southern Baltic. Therefore, the known range of the species in the region remains limited to the two sites in the Gulf of Gdańsk. Our study is the first attempt at investigating the composition of fully developed benthic assemblages on man-made structures in the Polish part of the Baltic Sea. As mentioned earlier, previous studies of artificial substrata focused on biofouling and young assemblages (Ciszewska, Ciszewski 1994; Dziubińska, Janas 2007; Dziubińska 2010). Fully developed communities in that region were investigated only on natural hard bottom (Andrulewicz 2004; Grzelak, Kukliński 2010). The summarized data on the species composition from these sources and from our study are presented in Table 3. The number of taxa recorded during our study was very close to the reports by other authors. In total, 39 faunal taxa, including 24 crustacean taxa, were recorded in communities associated with artificial substrates by us and other authors. There was a high overlap, i.e. 76%, in the species composition between the short-term community from TBD and assemblages investigated by Dziubińska (2010) at the nearby site using similar sampling methods (experimental panels deployed close to a man-made structure). The overlap was also high when comparing the short-term community from TBD with the short-term assemblages inhabiting underwater breakwaters located in the Gulf of Gdańsk (Kruk-Dowgiałło et al. 2009). The overlap was smaller when comparing long-term and short term communities with the assemblages from Słupsk Bank (47% and 57%, respectively). On the other hand there was a high overlap, i.e. 63%, in the species composition between communities from the natural rocky bottom in the Gulf o Gdańsk (Grzelak, Kukliński 2010) and both assemblages from the site TBD.

Conclussions

The results of our study, combined with previous observations of other authors, confirm that artificial substrata of man-made structures provide favorable habitats for diverse benthic assemblages with a high abundance and biomass but, on the other hand, numerous non-indigenous species were observed. Benthic communities from artificial hard substrata resembled assemblages from natural hard bottom in many ways but, at the same time, they also differed in many other ways. Further research with more extensive sampling will be necessary for better understanding of those assemblages, their biodiversity and functioning.

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