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Leave no traces – Beached marine litter shelters both invasive and native species

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ABSTRACT

Marine litter has been considered a potential transport vector of non-indigenous species. In this study developed in Tjärnö (Sweden), at the entry of the Baltic Sea, the communities inhabiting coastal litter and natural substrates (N = 5448 macroorganisms) were monitored from eight sites of different ecological conditions. The results showed that litter can support high densities of marine organisms and represent a new habitat in the studied coast. The taxonomic profile of the communities supported by marine litter and hard natural substrate were significantly different. Moreover, opposite to the expectations of reduced diversity in artificial structures, more diverse communities were found on litter. Non-indigenous species were attached mainly to non-plastic artificial materials. From these results it can be concluded that marine litter can significantly alter the biotic composition of coastal ecosystem, representing a shelter for invasive species and diverse natives.

1. Introduction

Over the past decades marine litter has become an ever growing problem to marine and coastal environments around the world, inducing a current threat to the environment. It is defined as “any anthropogenic, manufactured, or processed solid material (regardless of size) discarded, disposed of, or abandoned in the environment, including all materials discarded into the sea, on the shore, or brought indirectly to the sea by rivers, sewage, storm water, waves, or winds” (UNEP, 2016 and NOAA National Centers for Environmental Information, 2013). Like other pollutants, marine litter affects habitats, ecological functions and the health of the organisms in the ecosystems where it accumulates (UNEP, 2016), and its environmental impacts are diverse. There are many kinds of marine litter, which are classified into different categories, such as glass, metal, cardboard, paper and textiles (together they may represent 10–40% of total litter), but the main material is plastic (60–90%; Barnes et al., 2009, 2010; Löhr et al., 2017). Marine litter items can be classified from the type of material and item size under EU regulations using the OSPAR maritime directive (Cheshire et al., 2009).

Plastic and other types of litter break down into smaller parts that can be easily transported by currents and winds over long distances, from the surf zone all the way to remote mid-oceanic gyres and the deep seafloor. This so called “floating debris” or “flotsam” shows the pathway of marine litter, even until the Arctic and Antarctic oceans (Barnes et al., 2009, 2010). Floating velocities can be highly variable due to seasonal variations in wind and current conditions (e.g. Aliani et al., 2003; Thiel et al., 2013; Kiessling et al., 2015), and so the movement of floating debris is highly dependent on the sea state and wind speed; litter objects might mix into the water column by storms or heavy sea. Just as human activities are varied and widespread, so are the sources of litter which can be located directly at sea, on the coast or further inland (Rech et al., 2016; UNEP, 2016; Löhr et al., 2017), from the sea surface until the sea bottom (Engler, 2012).

Eukaryotic microorganisms, seaweeds and invertebrates, are found rafting on floating debris all over the oceans (Barnes, 2002). Marine litter can thus be considered as a transport vector, due to the fact that fauna and flora attached to it can travel hundreds of kilometers. Studies have shown that marine litter doubles the opportunities for biota to travel. Gyres and eddy currents, that can absorb litter from all corners of the globe, aid in the transport of marine litter and carry these “hitchhikers” across the oceans (Barnes, 2002). The properties of floating debris such as size and surface rugosity define the colonization

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Table 1
Characteristics of the sampling sites. Level of exposure to sea (exposure), major substrate type (Substrate) and GPS coordinates of all sample sites. Surface (in cm^2) of each type of hard substrate, as natural rocks (Natural Substrate, NS), glass, ceramic, wood and fabric, metal and plastic (inside and outside the transect as "In" and "Out" respectively). AS: surface of artificial substrate (litter) found in the transects. L: litter surface found out the transects. Biota: number of macroscopic individuals attached to hard natural substrate (NS) or to litter (AS, L) in each site. The ferry station of the line connecting Tjärnö with South Koster island is located between Sites #1 and #8.

					Surface proxy for each type of hard material														
					Glass		Ceramic		Wood & fabric		Metal		Plastic				Biota		
	Exposure	Substrate	GPS coordinates	NS	In	Out	In	Out	In	Out	In	Out	In	Out	L	AS	NS	AS	L
Site 1	Sheltered	Mud	58°52′35.75″N, 11°08′42.44″E	1650	200	400	25	100	0	0	25	100	0	20,000	20,600	250	786	0	365
Site 2	Exposed	Sandy	58°52′29.26″N, 11°08′36.96″E	775	0	100	0	0	0	0	0	0	0	8300	8400	0	71	–	122
Site 3	Sheltered	Sandy	58°52′27.14″N, 11°08′45.50″E	775	0	0	0	800	0	900	0	800	0	2900	5400	0	221	–	379
Site 4	Exposed	Sandy	58°52′40.31″N, 11°08′28.12″E	850	0	0	0	0	0	100	0	0	0	3025	3125	0	200	–	101
Site 5	Exposed	Rocky	58°54′11.74″N, 11°08′49.53″E	3400	0	400	0	0	0	0	100	0	400	5900	6300	500	548	15	350
Site 6	Sheltered	Rocky	58°53′07.14″N, 11°08′20.87″E	2425	0	0	0	75	0	0	0	0	0	17,925	18,000	0	572	–	316
Site 7	Exposed	Sandy	58°52′38.01″N, 11°07′37.62″E	1175	0	0	0	0	0	125	0	0	0	0	125	0	215	–	0
Site 8	Sheltered	Mud	58°52′31.28″N, 11°08′44.11″E	1075	0	0	2600	0	0	0	0	0	0	8225	8225	2600	562	216	116

by marine organisms and the succession of the rafting community, which will affect the characteristics of the substrates (floating stability, buoyancy, degradation). Therefore the specific properties of marine litter are likely to influence colonization and succession processes, and thus the composition of the associated rafting community (Kiessling et al., 2015). Zettler et al. (2013) demonstrated that the "plastispheres" harbor a diverse community, including heterotrophs, autotrophs, predators and symbionts, usually starting with microbial colonization (also called "microbial reefs") and biofilm conformation. Colonization of plastics is triggered by the hydrophobic layer that differs much from the natural substrates; in addition plastics have a longer half-life than any natural substrate, which makes them a longer lasting vector able to transport harmful algae species and persistent organic pollutants over longer distances and time. Organisms that use litter as a habitat and transport vector exhibit differences in the preferred type of material. For example, in the Bay of Biscay, acorn barnacles and polychaetes are more abundant on plastics while goose barnacles seem to prefer foam and other materials (Rech et al., 2018). Another example would be bryozoans preferring plastic over glass for attaching, and acorn barnacles doing the opposite (Li et al., 2015). From such different preferences, knowing the types of litter in a region would allow the assessment of the risks associated with rafting exotic fauna (Rech et al., 2018). This is very important for marine biodiversity conservation.

Non-indigenous species (NIS) of both fauna and flora, can establish themselves in new habitats unlike their own. NIS can disrupt an ecosystem, changing the local and regional biodiversity and, over time, if they resist and adapt, can become invasive (Hellmann et al., 2008). If an aggressive and highly competitive species is introduced, it could harm the local communities and decrease the local biodiversity (Gregory, 2009). Wasson et al. (2005) suggested exotic species would prefer artificial over natural materials because their abundance is higher on human-made structures than in natural substrates. Their study compared soft natural substrates with hard artificial structures, thus the type of biota occurring in each part of the ecosystem was not exactly comparable. In an experimental study in controlled conditions, Tyrrell and Byers (2007) demonstrated that exotic tunicates overgrow native fauna only on artificial substrates like metal and PVC, not when they were attached to natural surfaces like wood and marble. However, the preference of NIS for artificial materials is not clear. Ordóñez et al. (2013) found the colonization capacity of the highly invasive ascidian *Microcosmus squamiger* was the same for hard natural and artificial substrates, in natural conditions. On the other hand, lower species richness of communities inhabiting artificial substrates (Bacchiocchi and Airoldi, 2003) could prevent biotic resistance to invasions that occurs in rich natural communities where all the niches are occupied (e.g. Stachowicz et al., 2002; Miralles et al., 2016). Perhaps NIS occupy artificial surfaces because the natural ones are already covered with native species.

Taking into account the role of marine litter as a vector of rafting NIS, the former could be considered as a reservoir of potential biological invasions. In this study the marine communities present in coastal litter were analyzed and compared it with those inhabiting natural rocks in the same sites. The Kosterhavet Marine National Park in the Skagerrak region on the west coast of Sweden was chosen as the study area. The hydrodynamics and atmospheric conditions cause marine litter to accumulate there and have resulted in one of the highest densities of marine litter within the Northern waters (UNEP, 2009). Artificial (litter) and natural substrates were sampled from eight stations and the attached species and number of individuals analyzed. The goals of this study were firstly, to find out if marine litter carries the same biota as natural hard substrates, and secondly, to know whether there was any correlation between the marine litter and the presence of non-indigenous species.

2. Materials and methods

2.1. Study area

This study was conducted at the Sven Loven Centre for marine research, in the Gothenburg region of Sweden, at Tjärnö bay and on the island of Saltö. This area is located in the border of Kosterhavet National Park, the first marine national park in Sweden. The maritime traffic there is mainly local fisheries and sport sailing, and some ferry activity connecting the islands and mainland. Eight sampling sites were chosen after an observational walk to assess litter accumulation. Sites #1 and #8 flank the station of the ferry that connects Tjärnö with the South Koster island, where the Visitor Centre Kosterhavet is located (https://www.vastsverige.com/en/stromstad/produkter/naturum-kosterhavet/; accessed February 2018). There are no other ferry stations in the study area. Of the eight sites, one (site #5) was chosen outside the bay area as a representative of the surrounding area. Half of the sites had direct exposure to sea currents. The sample sites were all of mixed substrate composition: rocky, sandy, muddy (Table 1) (Fig. 1).

2.2. Litter collection, categorization and assessment

The sampling method involved four 6 m transects, set 3 m apart at each of the eight sites. Tidal conditions meant that 1 m of the 6 m was outside the water at low tide, whereas all 6 m were submerged during high tide. Any marine litter found 1 m on either side of the transect was collected for biotic assessment. To provide a natural and unbiased representation of species data on natural substrate, a quadrat of 1 m^2 was