

Chapter 6

Marine Litter as Habitat and Dispersal Vector

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Abstract Floating anthropogenic litter provides habitat for a diverse community of marine organisms. A total of 387 taxa, including pro- and eukaryotic micro-organisms, seaweeds and invertebrates, have been found rafting on floating litter in all major oceanic regions. Among the invertebrates, species of bryozoans, crustaceans, molluscs and cnidarians are most frequently reported as rafters on marine litter. Micro-organisms are also ubiquitous on marine litter although the composition of the microbial community seems to depend on specific substratum characteristics such as the polymer type of floating plastic items. Sessile suspension feeders are particularly well-adapted to the limited autochthonous food resources on artificial floating substrata and an extended planktonic larval development seems to facilitate colonization of floating litter at sea. Properties of floating litter, such as size and surface rugosity, are crucial for colonization by marine organisms and the subsequent succession of the rafting community. The rafters themselves affect substratum characteristics such as floating stability, buoyancy, and degradation. Under the influence of currents and winds marine litter can transport associated organisms over extensive distances. Because of the great persistence (especially of plastics) and the vast quantities of litter in the world's oceans, rafting dispersal has become more prevalent in the marine environment, potentially facilitating the spread of invasive species.

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Keywords Anthropogenic flotsam · Rafting community · Succession · Biogeography · Biological invasions · Plastic pollution

6.1 Introduction

Litter in the marine environment poses a hazard for a great variety of animals. Various species of marine vertebrates including fish, seabirds, turtles and marine mammals become easily entangled in floating marine litter, resulting in reduced mobility, strangulation and drowning (Derraik 2002; Kühn et al. 2015). Additionally, ingested litter can damage or block intestines, thereby affecting nutrition with often lethal effects (reviewed by Derraik 2002; Kühn et al. 2015). On the seafloor, marine litter can smother the substratum and thus cause hypoxia in benthic organisms (Moore 2008; Gregory 2009). In addition to these immediate hazardous effects on marine biota, marine litter has been suggested to facilitate the spread of non-indigenous species (Lewis et al. 2005). Biological invasions are considered a major threat to coastal ecosystems (Molnar et al. 2008).

Like any other submerged substrata, marine litter provides a habitat for organisms that are able to settle and persist on artificial surfaces. Once colonized by marine biota, litter items floating at the sea surface can facilitate dispersal of the associated rafters at different spatial scales. Previous studies have reported over 1200 taxa that are associated with natural and anthropogenic flotsam (Thiel and Gutow 2005a) and the extreme localities that rafting organisms can reach when transported over large distances by currents and wind (Barnes and Fraser 2003; Barnes and Milner 2005). While floating macroalgae, wood and volcanic pumice have been part of the natural flotsam assemblage of the oceans for millions of years, marine litter adds a new dimension to the dispersal opportunities of potential rafters (Barnes 2002). Marine litter is diverse (e.g. domestic waste, derelict fishing gear, detached buoys), persistent (afloat for longer than many natural substrata-Thiel and Gutow 2005b; Bravo et al. 2011), widespread (Barnes et al. 2009; Eriksen et al. 2014) and abounds in oceanic regions where natural floating substrata, such as macroalgae, occur less frequently (Rothäusler et al. 2012).

Unlike biotic substrata, anthropogenic litter is of no nutritional value to most organisms. Additionally, marine litter items differ from natural substrata in their physical and chemical characteristics such as surface rugosity and floating behavior. Accordingly, rafters need to overcome specific challenges with regard to food acquisition and attachment in order to persist for extended time periods on artificial floating substrata. The specific properties of marine litter are likely to influence colonization and succession processes, and thus the composition of the associated rafting community (Bravo et al. 2011).

In this chapter, we compiled information from peer-reviewed scientific literature on the biota associated with marine floating litter and on characteristics of litter items that affect the composition of the rafting community. Information on the biological traits of species associated with floating marine litter was used to characterize the rafting assemblage's functionally and to identify specific conditions that rafters on floating marine litter have to cope with. Finally, the environmental

implications of litter rafting will be discussed, including the dispersal and invasion potential of non-indigenous species.

6.2 Floating Litter as a Habitat

Marine flotsam can be classified according to its nature (abiotic or biotic) and its origin (natural or anthropogenic). Biotic flotsam comprises macroalgae, animal remains/carcasses, wood and other parts of terrestrial plants such as seeds and leaf litter. Abiotic flotsam of natural origin consists mostly of volcanic pumice and ice. Flotsam of anthropogenic origin includes every kind of discarded material: biotic anthropogenic flotsam consists mainly of manufactured wood, discarded food (e.g. fruits) and oil/tar lumps, but the great majority of anthropogenic flotsam is abiotic and comprises any artificial object at sea.

Floating marine litter consists of consumer and household articles, industrial waste products or objects that had previously served maritime and fishery purposes (Fig. 6.1).

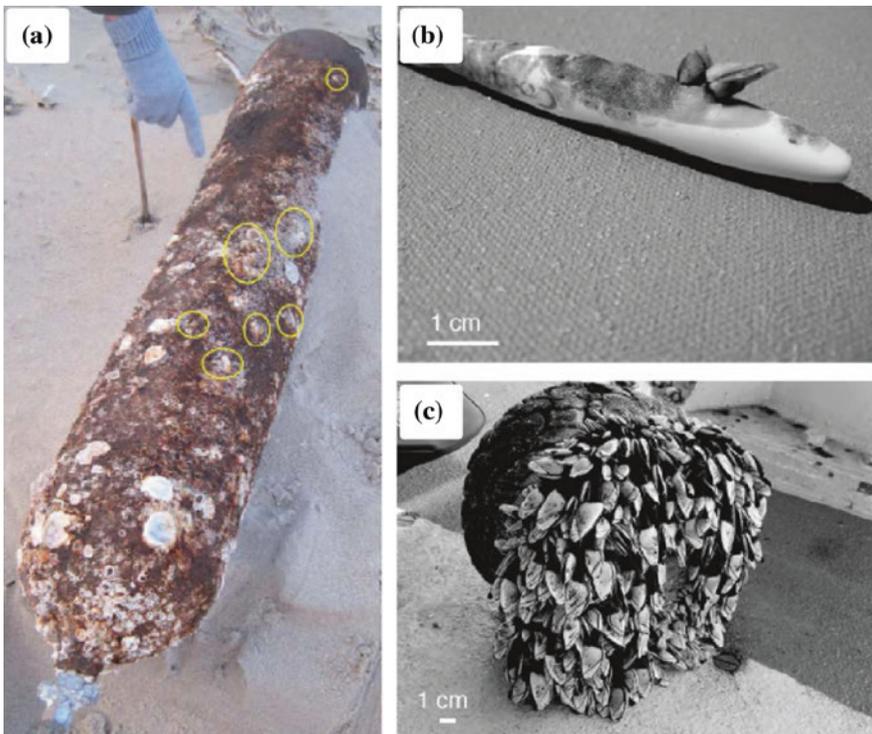


Fig. 6.1 Taxa floating on different marine litter items, **a** the tropical coral *Favia fragum* on a metal cylinder found in The Netherlands (Reprinted with permission from Hoeksema et al. 2012), **b** *Lepas* and a bryozoan colony growing on a toothbrush handle (Reprinted with permission from Goldstein et al. 2014), **c** extensive *Lepas* cover on a floating buoy (Reprinted with permission from Goldstein et al. 2014)

Discarded or lost consumer articles usually start their floating journey in a “clean” state, i.e. free of fouling biota. Floating litter from maritime activities comprises detached buoys, discarded fishing gear and chunks of piers and harbor infrastructure. These objects usually have spent long time periods in the marine environment, and therefore often host an extensive and reproductively active fouling biota, before they become part of marine floating litter, e.g. after detachment from anchorings. For example, Astudillo et al. (2009) found diverse rafting communities in advanced successional stages on lost aquaculture buoys floating off the Chilean coast. Detached buoys might carry with them anchoring lines, which extend into greater depths, thereby offering a habitat less influenced by harsh surface conditions. Highly buoyant items, such as Styrofoam, often have low floating stability and tip over more easily, a process, which suppresses colonization by fouling organisms (Bravo et al. 2011). However, colonization by fouling organisms may stabilize the floating item, equivalent to the “biological keel” of attached organisms on floating pumice described by Bryan et al. (2012). Accordingly, the degree of colonization has substantial impact on the floating behavior of the substratum at sea and therefore on the succession of the rafting community.

The rafting community on litter is described as being similar to but less species rich than that of floating macroalgae (Stevens et al. 1996; Winston et al. 1997; Gregory 2009). Winston et al. (1997) attribute this partly to the higher structural complexity and the soft mechanical properties of macroalgae compared to smooth and hard plastic particles. In contrast, Barnes and Milner (2005) report a significantly higher amount of encrusting organisms on floating wood and plastic compared to floating kelp. Only few studies allow for a comparison of the rafting communities on different marine litter substrata, probably because the vast majority of the floating litter is composed of plastics. Wong et al. (1974) found similar organisms colonizing larger plastic items and tar lumps of the same size. In a colonization experiment, organisms settled rapidly on floating substrata regardless of its type (plastic, Styrofoam or pumice—Bravo et al. 2011). However, in an early stage of colonization fewer species were found on plastic surfaces than on Styrofoam and pumice, indicating that surface rugosity of the substratum facilitates initial colonization of floating objects (Bravo et al. 2011—Fig. 6.2). Similarly, Carson et al. (2013) observed more diatoms, though not bacteria, on rough surfaces.

Only few studies have considered the material differences between types of plastic. Though there is no evidence that the polymer type is relevant for the composition of the rafting macrobiota, it was shown that it influences the composition of micro-organisms: Carson et al. (2013) found significantly more bacteria on polystyrene than on polyethylene and polypropylene, probably because of the surface characteristics of the material. Zettler et al. (2013) found distinct bacterial assemblages on polypropylene and polyethylene with a compositional overlap of less than 50 %.

Biotic flotsam occurs in a wide size range with floating macroalgae and tree trunks often reaching several metres in diameter or length. The majority of abiotic flotsam is generally smaller and rarely reaches a size of 1 m (Thiel and Gutow 2005b). Marine litter of any size, ranging from fragments in the order of millimetres (Gregory 1978; Minchin 1996) to larger items, such as lost buoys (Astudillo et al. 2009) and even refrigerators (Dellinger et al. 1997) are colonized by organisms. Carson et al. (2013) found that a larger surface area of plastic fragments is

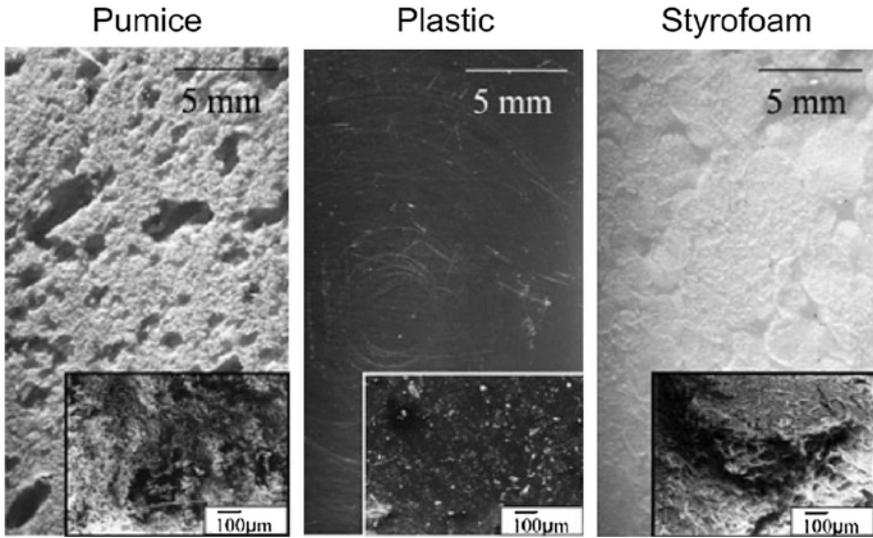
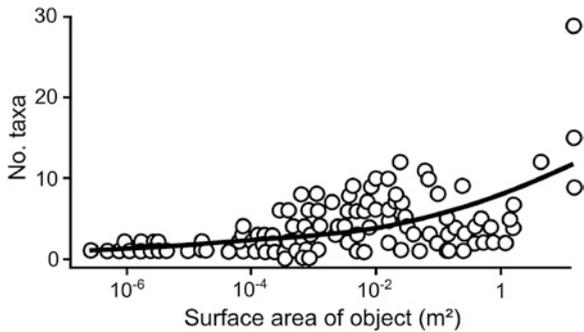


Fig. 6.2 Macro-photographs of the surface of pumice, plastic and Styrofoam, illustrating the different rugosities of the materials (Reprinted with permission from Bravo et al. 2011)

Fig. 6.3 Number of taxa in relation to the surface area of floating litter items (modified after Goldstein et al. 2014)



associated with a higher taxonomic richness, though not necessarily abundance, of microbiota. Similarly, Goldstein et al. (2014) recorded a positive correlation between the surface area of floating litter items in the North Pacific and species richness of the rafting community (Fig. 6.3). Most of these larger litter items consisted of fishing gear, which are more likely to harbor a diverse biota before being discarded or lost than are smaller domestic litter items. Other possible explanations involve stochastic effects (a random distribution of organisms on marine flotsam leads to a higher quantity on larger items), biased sampling efforts (small items sink already when colonized by only few organisms) or other raft characteristics, e.g. stability (Goldstein et al. 2014). A floating experiment conducted by Ye and Andrady (1991) revealed that larger surfaces are more quickly colonized by macrobiota than smaller surfaces. Wong et al. (1974) did not find algae and invertebrates on plastic fragments, which were significantly smaller than floating pumice in the

same region. Lepidid barnacles seem to have species-specific preferences for litter of certain size, and some species (*Lepas pectinata* and *Dosima fascicularis*) associated with smaller litter items develop morphological adaptations, such as a small body size and light-weight valves, that minimize the risk of sinking of colonized flotsam (Whitehead et al. 2011). A size-specific selection of floating substrata has previously been shown for lepidid barnacles rafting on tar pellets (Minchin 1996).

Abiotic and biotic flotsam differ in their expected longevity. The persistence of biotic flotsam, such as floating seaweeds, is clearly limited by physical factors such as temperature and biological processes such as consumption and decomposition (Vandendriessche et al. 2007; Rothäusler et al. 2009). Therefore, the longevity of floating macroalgae is in the range of a few weeks up to six months (Thiel and Gutow 2005b). Floating litter is of no nutritional value for metazoans, and so far only few microorganisms have been shown capable of plastic digestion (Zettler et al. 2013). Accordingly, biological degradation is slow and marine litter, especially plastic, is expected to persist for years or even centuries in the marine environment (Derraik 2002; O’Brine and Thompson 2010). Plastics are particularly persistent at sea because lower temperatures and oxygen levels decelerate decomposition processes (Andrady 2011). Attached biota may protect the raft from degradation through solar radiation (Winston et al. 1997), thereby further extending its lifetime.

Estimating the time a floating item has spent in the marine environment is complicated and at present no reliable method exists. Age estimations for floating litter are inferred from (a) drift trajectories and velocities based on the supposed origin of the items (Ebbesmeyer and Ingraham 1992; Rees and Southward 2009; Hoeksema et al. 2012), (b) the successional stage of the rafting community (Cundell 1974), (c) the size of rafting organisms of known growth rates, e.g. bryozoans or lepidid barnacles (Stevens 1992 cited by Winston et al. 1997; Barnes and Fraser 2003; Tsikhon-Lukanina et al. 2001), or (d) the degradation of the substratum, for example by measuring the tensile extensibility of the material (Andrady 2011). However, all these methods have drawbacks, introducing a high degree of uncertainty to age estimates for floating litter. The sources of litter items are often unknown and floating velocities can be highly variable due to seasonal variations in wind and current conditions. Additionally, the composition and the successional stage of the rafting community may change the floating behavior of a litter item. Biological interactions such as predation and competition may influence the composition and the age structure of a rafting community rendering the size of specific rafting organisms an unreliable predictor of the duration of the floating period. Moreover, unlike floating macroalgae, abiotic flotsam may repeatedly return to the sea even after extended periods on the shore, which likely influences the state of degradation of the raft as well as the composition of the associated biota. Bravo et al. (2011) discussed that degradation of marine litter may either facilitate colonization by producing more rugose surfaces or alternatively impede it by abrasion processes. Overall, degradation and fragmentation of litter items into smaller pieces reduces the size of individual rafts, thereby changing settlement opportunities for species of a certain size range.

Removal of floating litter rafts from the sea surface occurs through stranding, sinking or ingestion by aquatic animals. Sinking of litter rafts mostly occurs because

of high epibiont biomass that increases the weight of a floating object (Barnes et al. 2009; Bravo et al. 2011). Depending on environmental conditions, a critical accumulation of biomass that forces a substratum to sink can develop within 8–10 weeks on smaller household plastic items and plastic bags (Ye and Andrady 1991). Sinking flotsam may facilitate the transport of associated organisms to the seafloor. However, subsequent establishment of rafters in the benthic environment is unlikely, especially in the deep sea. The loss of buoyancy is reversible if epibionts die at greater water depth and fall off their substratum (Ye and Andrady 1991). Consequentially, the item may resurface, initiating a new cycle of colonization. Rafting organisms likely benefit from neutral buoyancy of a litter item because they are less exposed to desiccation and solar radiation on a substratum that barely emerges above the sea surface (Bravo et al. 2011; Carson et al. 2013). Vertical export of litter into deeper waters may be facilitated by wind-driven mixing or eddies (Kukulka et al. 2012).

6.3 Composition of Rafting Assemblages on Floating Litter

6.3.1 Taxonomic Overview

A review of 82 publications revealed a total of 387 marine litter rafting taxa, of which 244 were identified to the species, and 143 to the genus level (for complete species list see Appendix 1). In this review we included publications that report on organisms associated with floating litter in the field as well as experimental studies on the colonization of anthropogenic flotsam. We did not consider the many experimental studies on the succession of fouling communities on rigidly fixed artificial substrata because these items do not display the specific floating behavior, which probably affects the colonization by marine biota. To avoid potential overlaps, taxa identified at genus level were excluded if a species-level identification existed for the same genus. The identification of some micro-organisms was vague despite the use of advanced analytical methods such as electron microscopy and RNA analysis. Most taxa (335) were associated with plastic substrata (domestic waste, plastic fragments or buoys made of plastic), which constitute the large majority of anthropogenic floating litter in the oceans (Galgani et al. 2015). Accordingly, only few taxa (17) were recorded from other floating litter items consisting of metal, glass and paper. For 83 taxa, the floating substrata were of unknown composition or were composed of various materials. The given numbers exceed the total number of 387 taxa because some species have been found on more than just one substratum type. 132 taxa were recorded from items, which previously served maritime purposes (mainly buoys and fishing gear). A large proportion (60 %) of the rafting taxa was sampled in situ, associated with their floating substrata, whereas 35 % of the taxa are only known from beached litter. For 2 %, the ability to raft on floating litter was inferred from floating experiments (Bravo et al. 2011) and the remaining 3 % consist of taxa that could not be reliably identified but were assigned to a certain genus or species by the respective authors.

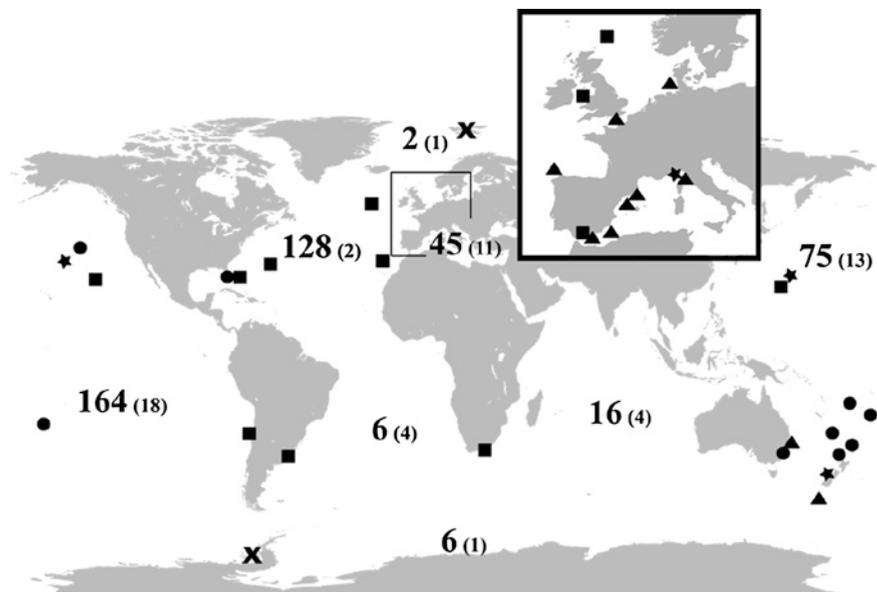
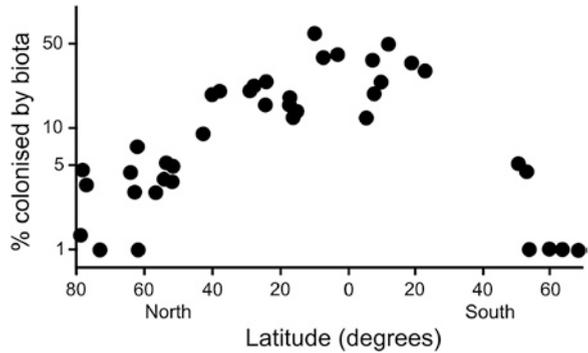


Fig. 6.4 Number of observed rafting taxa on floating marine litter (number of studies in brackets) in major oceanic regions (from *top left* Arctic, North Atlantic, Mediterranean, North Pacific, South Pacific, South Atlantic, Indian Ocean, Southern Ocean). The symbols represent reports of frequently observed rafting species on marine litter: *Circles* = *Jellyella tuberculata*, *squares* = *Lepas anatifera*, *triangles* = *Idotea metallica*, *stars* = *Fiona pinnata*. The two *crosses* represent the northern- and southernmost observations of rafters on marine litter

The highest numbers of rafting taxa on floating litter were found in the Pacific and North Atlantic, which might be explained by the overall high research effort undertaken in these regions (Fig. 6.4). A considerable number of rafters were also found in the Mediterranean while only few taxa were reported from the South Atlantic and from the Indian Ocean. Some rafters have even been found in the Arctic at 79°N (Barnes and Milner 2005) and in Antarctica at approximately 67°S (Barnes and Fraser 2003). The percentage of anthropogenic litter items colonized varied significantly with latitude. Barnes and Milner (2005) found that at low latitudes (0–15°) about 50 % of all beached litter items were colonized by marine biota while at higher latitudes (15–40°) only 25 % of the litter items had attached organisms. This rate decreased further to 5–10 % at 40–60° latitude and beyond 60° colonization of marine litter was rarely observed (Fig. 6.5). This geographic pattern was evident for remote sites as well as for sites close to the continental shore (Barnes 2002). A similar latitudinal decrease of the colonization rate was evident on a smaller spatial scale for the Indian Ocean (Barnes 2004).

Numerous taxa of bacteria, protists and algae (most prominently diatoms and Rhodophyta) form part of the rafting community on marine floating litter (Table 6.1). Four studies examined the microbiota associated with marine microplastics (i.e. plastic particles in the size range of millimetres and a few centimetres—Fortuño et al. 2010; Carson et al. 2013; Zettler et al. 2013; Reisser et al. 2014) and found a total

Fig. 6.5 Proportion of marine litter colonized according to latitude (modified after Barnes and Milner 2005)



of 44 bacteria and 56 Chromista taxa. Micro-organisms seem to be ubiquitous on marine litter as Carson et al. (2013) found microbes on each plastic item sampled in the North Pacific gyre. Plastic litter offers a habitat for various functional microbial groups including autotrophs, symbionts, heterotrophs (including phagotrophs) and predators (Zettler et al. 2013). Harmful micro-organisms were also found on floating litter, including potential human and animal pathogens of the genus *Vibrio* (Zettler et al. 2013), the ciliate *Halofolliculina* sp., which causes skeletal eroding band disease in corals (Goldstein et al. 2014) and the dinoflagellates *Ostreopsis* sp., *Coolia* sp. and *Alexandrium taylori*, known to form harmful algal blooms under favorable conditions (Masó et al. 2003). The composition of the microbial community clearly differs from the surrounding seawater suggesting that plastic litter forms a novel habitat for microbiota (termed ‘microbial reef’ by Zettler et al. 2013). Some organisms found on plastic samples are otherwise strictly associated with open seawater and their presence was probably the result of entanglement (Zettler et al. 2013). Carson et al. (2013) characterized the encountered microbial community in the North Pacific gyre as dominated by rod-shaped bacteria and pennate diatoms, each at densities of roughly 1,000 cells m⁻². Less frequent microbiota on plastic samples comprised coccoid bacteria, centric diatoms, dinoflagellates, coccolithophores, and radiolarians. A surprisingly low morphological diversity among the abundant diatoms was mentioned.

Macroalgae have occasionally been found attached to floating marine litter, among them red (11 taxa), brown (6 taxa) and some green algae (4 taxa). However, rarely was a single taxon encountered more than once. Diatoms (29 taxa), dinoflagellates (5 taxa) and foraminiferans (7 taxa) seem to be more common, although likewise, very few taxa were reported more than once, probably owing to the low number of studies focusing on micro-organisms.

The most common invertebrate groups on marine litter are crustaceans, bryozoans, molluscs and cnidarians (Table 6.1). The composition of taxa retrieved from beached litter tends to be biased towards sessile organisms with hard (calcified) structures such as bryozoans, foraminiferans, tubeworms and barnacles (Stevens et al. 1996; Winston et al. 1997; Gregory 2009). Mobile organisms such as crustaceans and annelids are more frequently observed on rafts collected while afloat (Astudillo et al. 2009; Goldstein et al. 2014). Some taxa have repeatedly been observed associated with floating litter (Fig. 6.4) and thus, may not just be accidental rafters.

Table 6.1 Taxonomic overview of marine litter rafters (for complete taxonomic list see Appendix 1)

Kingdom	Phylum	Class	Order	Number of taxa
Bacteria				44
Chromista				
	Ciliophora			2
	Foraminifera			7
	Myzozoa			
		Dinophyceae		5
	Haptophyta			7
	Ochrophyta			
		Bacillariophyceae		29
		Phaeophyceae		6
Plantae				
	Charophyta			1
	Chlorophyta			3
	Rhodophyta			11
Animalia				
	Porifera			2
	Cnidaria			
		Anthozoa		10
		Hydrozoa		26
	Nemertea			1
	Annelida			
		Polychaeta		27
	Arthropoda			
		Pycnogonida		1
		Insecta		3
		Ostracoda		1
		Maxillopoda		
			Kentrogonida	1
			Lepadiformes	11
			Sessilia	15
		Malacostraca		
			Decapoda	22
			Amphipoda	21
			Isopoda	8
			Tanaidacea	1
	Mollusca			
		Gastropoda		18
		Bivalvia		21
	Echinodermata			3
	Bryozoa			

(continued)

Table 6.1 (continued)

Kingdom	Phylum	Class	Order	Number of taxa
		Gymnolaemata		66
		Stenolaemata		10
	Chordata			
		Ascidiacea		4
Total				387

Stalked barnacles of the genus *Lepas* are by far the most frequently encountered hitchhikers in all major oceanic regions except for the Arctic and Southern Ocean. Seven *Lepas* species have been found rafting on litter, the most frequently observed and widespread being *L. anatifera* and *L. pectinata*. *Lepas* are prominent fouling species and readily colonize a variety of floating objects, a process likely facilitated by their extended planktonic larval stage (Southward 1987).

Isopods of the genus *Idotea* are frequently found on marine litter in the Atlantic, Pacific and Mediterranean. While *I. metallica* and *I. baltica* have repeatedly been reported on floating litter items other species such as *I. emarginata* are less common. *Idotea metallica* is an obligate rafter without benthic populations, and the constant replenishment of an otherwise not self-sustaining population in the North Sea illustrates its conformity with the rafting environment (Gutow and Franke 2001). *Idotea metallica* shows specific adaptations to the rafting life-style such as reduced “locomotive activity and a tight association to the substratum” and low food requirements compared to its congener *I. baltica* (Gutow et al. 2006, 2007). The latter species predominantly colonizes algal rafts, which are rapidly consumed by this voracious herbivore (Gutow 2003; Vandendriessche et al. 2007).

Other frequently encountered crustaceans include the three pelagic species of crab, *Planes major*, *P. marinus* and *P. minutus*, found in the Atlantic, Pacific and Indian Ocean; and five species of the diverse amphipod genus *Caprella*, whose members show morphological adaptations in the form of reduced abdominal appendages enabling them to cling to flotsam (Takeuchi and Sawamoto 1998).

Bryozoans from the closely related genera *Membranipora* and *Jellyella* were found rafting on marine litter in the Atlantic, Pacific, Mediterranean and even in Arctic waters. *Jellyella tuberculata* was the most frequently encountered species in the Atlantic and Pacific and is known to colonize a wide range of substrata including plastic litter and macroalgae (Winston et al. 1997). The species typically occurs at tropical and subtropical latitudes (Gregory 1978), however, sightings on marine litter are reported from all major oceanic regions with the exception of polar seas (Fig. 6.4). The most common gastropod on floating litter, *Fiona pinnata*, was sighted in the Pacific and Mediterranean. According to Willan (1979), *F. pinnata* has a cosmopolitan distribution and commonly inhabits floating wood and macroalgae where it can exploit its *Lepas* prey, growing on the same substratum.

6.3.2 *Biological Traits of Rafting Invertebrates on Floating Litter*

Given the specific habitat conditions on floating marine litter, it can be expected that certain biological traits will predominate among the assemblage of rafting organisms. Of the 215 invertebrate species considered for this analysis, 25 (12 %) have been classified as obligate rafters that live exclusively on floating objects. 165 species (77 %) are facultative rafters that occupy benthic habitats as well. For 25 species (12 %) the available information was not sufficient to determine their raft status.

6.3.2.1 Mobility

Fifty-nine percent of the rafting species on floating litter are fully sessile whereas 5 % of the species can be classified as semi-sessile (with the ability to detach and re-attach). Only 27 % of the reported species are mobile, for the remaining species the information was insufficient. In contrast to these numbers, Astudillo et al. (2009) and Goldstein et al. (2014) found more mobile than sessile taxa on floating litter, indicating that the inclusion of studies from beached litter is likely leading to an underestimation of mobile taxa. Nevertheless, the high proportion of sessile and semi-sessile species highlights the necessity for a firm attachment of rafting species to the often smooth and solid abiotic surfaces of floating litter items. It further illustrates the often low structural complexity of litter items compared to, for example, floating macroalgae which host a much higher proportion of mobile species that can efficiently cling to the often complex algal thalli with numerous branches and highly structured holdfasts (Thiel and Gutow 2005a). Disadvantages for sessile organisms arise when unstable rafts change positions and expose organisms to surface conditions (Bravo et al. 2011), or if the raft sinks or strands (Winston 2012).

6.3.2.2 Feeding Biology

The great majority (72 %) of the rafting taxa on marine floating litter are suspension feeders whereas only 7 % of the species feed as grazers and borers, and 9 % as predators and scavengers (for the remaining 12 % no feeding mode could be identified). The high proportion of suspension feeders on marine litter is not surprising. Abiotic floating substrata are of no nutritional value for associated rafters, making them dependent on food from the surrounding environment. On floating seaweeds, which are consumed by associated herbivores, the proportion of suspension feeders is substantially lower (approx. 40 %) and the proportion of grazers and borers higher (approx. 20 %—Thiel and Gutow 2005a). Rafting suspension feeders benefit from the concentration of their rafts and suspended organic material in surface

fronts generated by the convergence of surface waters, wind-induced Langmuir cells and other surface features (Woodcock 1993; Marmorino et al. 2011). The accumulation of suspended matter and nutrients in these convergence zones apparently fuels diverse rafting communities on floating abiotic substrata, which also encompass primary producers, herbivores, and predators.

6.3.2.3 Reproductive Traits

Forty-eight percent of the rafting invertebrate species on marine floating litter reproduce sexually (of which 42 % are hermaphroditic and 58 % are gonochoric) and 38 % have, at least theoretically, the ability to reproduce both sexually and asexually while for 14 % of the species no information on the reproductive mode is available. Bryozoans, constituting most of the species that are capable of asexual and sexual reproduction, reproduce primarily asexually. This facilitates establishment and rapid local spread. However, encrusting bryozoans seem to reproduce exclusively sexually (Thomsen and Hakansson 1995). Bryozoans also perform “spermcast mating” where sperm is accumulated from the surrounding water and stored prior to fertilization (Bishop and Pemberton 2006), a strategy which appears particularly beneficial for rafting organisms because there may be no (or only few) conspecifics nearby. If bryozoans grow in isolation many have the ability to self-fertilize rather than to rely on neighbouring colonies (Maturio 1991 cited by Winston et al. 1997).

About 9 % of the rafting species on marine litter have benthic larvae or larvae with a short pelagic development of less than two days and 12 % release fully developed individuals. Thirty percent of the species have pelagic larvae with an extended planktonic phase of up to several weeks. For 49 % of the invertebrate species no details on larval biology were available. Winston et al. (1997) suggest that long-lived larvae may be beneficial for settlement on litter floating in the open ocean, although upwelling events and storms may facilitate the colonization of litter items by species with short larval development. Astudillo et al. (2009) found mainly rafters with short larval development or direct development on floating buoys in the south-eastern Pacific, a region under influence of upwelling regimes. Stevens et al. (1996) also reported many bryozoans with short larval development on beached litter in northern New Zealand. Given the long distances floating litter can travel, some stranded items may have been under the influence of upwelling regions as described for the South Taranaki Bight (summarized by Foster and Battaerd 1985), approximately 500 km to the south of the sampled location.

6.3.3 *Other Species Attracted to Marine Litter*

Fishes and other marine vertebrates and invertebrates are known to aggregate around floating objects at sea (for example Hunter and Mitchell 1967; Taquet et al.

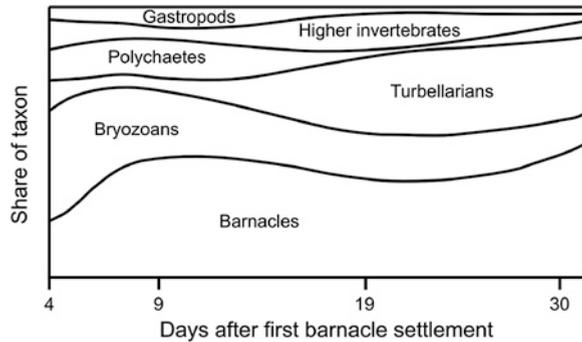
2007). Aliani and Molcard (2003) observed dolphins, sea turtles and fish below larger items (mostly plastics) in the Mediterranean. Fish that aggregate below rafts (of natural or anthropogenic origin) may also become dispersed over long oceanic distances, occasionally even crossing oceanic barriers (Luiz et al. 2012). Possibly, the increasing number of observations of raft-associated fish species near oceanic islands (e.g. Afonso et al. 2013) is due to increasing densities of floating litter in these regions (e.g. Law et al. 2010). It is still not well known why fish aggregate around floating objects, especially because they are rarely observed feeding on organisms living on flotsam (e.g. Ibrahim et al. 1996). On the other hand, fish and shark bite marks in plastic litter might indicate that fishes prey actively on the biota on floating litter (Winston et al. 1997; Carson 2013). A review by Castro et al. (2002) concludes that the reasons why fish aggregate around floating objects, and especially macroalgae assemblages, may be manifold, including serving as a refuge, a source for food, and a meeting point for solitary fish. Seabirds may accidentally ingest litter items if they confuse artificial flotsam such as Styrofoam with food (e.g. van Franeker 1985; Kühn et al. 2015). Some species may also ingest litter while feeding on the organisms growing on small litter items.

6.3.4 Succession of the Rafting Community

The colonization of artificial floating substrata follows a general pattern that has been investigated experimentally in several studies (Ye and Andrady 1991; Artham et al. 2009; Bravo et al. 2011; Lobelle and Cunliffe 2011): first, a biofilm consisting of bacteria and biopolymers develops within hours after submergence. This first phase is primarily controlled by the physico-chemical properties of the substratum (such as rugosity and hydrophobicity) whereas biological processes seem less important at this stage (Artham et al. 2009). The exact development and composition of the biofilm is highly variable, even on similar substrata at the same site (Ye and Andrady 1991) and probably influenced by seasonal (Artham et al. 2009) and other environmental variables (temperature, salinity—Carson et al. 2013). The composition of the initial colonizer assemblage affects the further succession of the fouling community (Ye and Andrady 1991; Bravo et al. 2011), although bryozoans readily colonize clean substrata without a biofilm (Maki et al. 1989; Zardus et al. 2008). In general, invertebrates and macroalgae may colonize submerged substrata within three to four weeks (Ye and Andrady 1991; Bravo et al. 2011). Results from a fouling experiment conducted by Dean and Hurd (1980) suggest that initial colonization of organisms on artificial substrata may facilitate some later arrivals but inhibit others.

The settlement of invertebrates seems to depend mainly on the availability of propagules (larvae and juveniles) in the surrounding environment (Stevens et al. 1992 cited by Winston et al. 1997; Barnes 2002) but less on the distance from the coast (Barnes 2002). Further information on later successional stages of rafting communities on floating litter has been collected from floating and stranded

Fig. 6.6 Succession of a rafting community on floating objects, among them marine litter. The y-axis gives the share of the respective taxa in terms of abundance. Higher invertebrates are mainly represented by amphipods. Modified after Tsikhon-Lukanina et al. (2001)



substrata and from experiments: during an experimental exposure of different plastic items for 13–19 weeks, an initial biofilm with green algae was replaced after seven weeks by hydroid colonies followed by bryozoans and ascidians (Ye and Andrady 1991). Bravo et al. (2011) found a peak in taxonomic richness on abiotic substrata (plastics, Styrofoam and pumice) that had been submerged for eight weeks. The community was initially dominated by diatoms, whereas later successional stages were characterized by hydrozoans (mainly *Obelia* sp.), barnacles (*Austromegabalanus psittacus*) and an ascidian (*Diplosoma* sp.). Tsikhon-Lukanina et al. (2001), studying natural and anthropogenic flotsam in the western North Pacific, recognized a bryozoan-dominated phase with a higher abundance of polychaetes and gastropods, followed by a lepadid barnacle phase with a higher incidence of malacostracan crustaceans, especially amphipods (Fig. 6.6). Turbellarians increased in abundance and biomass throughout the experimental duration. Winston et al. (1997) found no signs of succession on beached litter in Florida and Bermuda, which may have been obscured by the state of desiccated animals. In contrast to the initial biofilm formation, later successional stages are much more controlled by biological processes. For example, the bryozoan *Electra tenella* occurs exclusively on plastic items (floating off the U.S. Atlantic coast), thereby avoiding competition, mainly with *Membranipora tuberculata*, which frequently overgrows *E. tenella* on natural substrata (Winston 1982).

6.4 Floating Litter as Dispersal Vector

Floating litter can facilitate the dispersal of associated organisms when moved across the ocean surface by winds and currents. The efficiency of rafting dispersal depends on the availability and the persistence of floating substrata in the oceans. Already established populations may disperse regionally with the help of marine litter, as was observed by Whitehead et al. (2011) for lepadid barnacles in South Africa, by Serrano et al. (2013) for a Mediterranean population of the coral *Oculina patagonica* and also by Davidson (2012) for the isopod *Sphaeroma*

quoianum, which “manufactures” its own raft by causing fragmentation of Styrofoam/polystyrene dock floats.

Several taxa, including potential invaders, were found on marine litter far beyond their natural dispersal range: stranded barnacles (of the genera *Dosima*, *Lepas* and *Perforatus*) were observed in Ireland and Wales (having spent considerable time rafting in the North Atlantic), though individuals were not found alive (Minchin 1996; Rees and Southward 2009). Studies from the Netherlands report the reef coral *Favia fragum*, also dead and having rafted from the Caribbean (Hoeksema et al. 2012, Fig. 6.1a) and shell parts of the bivalve *Pinctada imbricata* (Cadée 2003). Barnes and Milner (2005) recorded *Austrominius modestus* (as *Elminius modestus*), an exotic invader, on drift plastic on the Shetland Islands (Scotland, UK), although this was not the first record of that barnacle there. By far the biggest piece of long-distance-rafting flotsam is described by Choong and Calder (2013): A 188-ton piece of a former dock, dislodged during a tsunami in Japan in 2011, stranded in Oregon and offered a rafting opportunity for over 100 species, non-native to the U.S. coast. Several other large pieces of tsunami debris of the same origin transported further species to the North Pacific east coast (Calder et al. 2014).

To successfully establish a founding population rafting organisms not only have to survive the journey but be able to reproduce upon reaching a potential habitat. In general, colonial organisms have the highest potential to successfully establish in new habitats as every individual “represents a potential founder population” (Winston 2012). Reproductively active organisms have been observed on numerous occasions, including bryozoans, as far south as Adelaide Island, Antarctica (Barnes and Fraser 2003), and egg-bearing crustaceans in many different regions (e.g. Spivak and Bas 1999; Gutow and Franke 2003; Poore 2012; Cabezas et al. 2013). Resting cysts of dinoflagellates attached to plastic have been observed (Masó et al. 2003) as well as egg masses of gastropods, even though no adult specimens were present (Winston et al. 1997; Bravo et al. 2011). The pelagic insects *Halobates sericeus* (Goldstein et al. 2012) and *H. micans* (Majer et al. 2012) are known to deposit eggs on marine plastics, and the ubiquity of this substratum helps these species to overcome limitations of suitable oviposition sites.

On numerous occasions, rafting taxa have been reported for the very first time on marine litter in a given region (Jara and Jaramillo 1979; Stevens et al. 1996; Winston et al. 1997; Cadée 2003), a mentionable feat considering the stochastic nature of rafting events. Like other floating substrata marine litter is under the influence of winds and currents, but due to high buoyancy some litter items may be pushed along different trajectories than other flotsam, such as mostly submerged macroalgae. However, unlike other potential dispersal vectors for invasive species, especially transport by ship (ballast water and hull fouling), it is not expected that marine litter opens up novel pathways that are not available for other floating substrata (Lewis et al. 2005).

Given the high persistence of marine litter and the enormous abundances in the world’s oceans (Eriksen et al. 2014) it becomes evident that the littering of the oceans with plastics over the past decades has substantially enhanced rafting

opportunities for marine organisms, and it is estimated that floating marine litter doubles or even triples the dispersal of marine organisms (Barnes 2002, however doubted by Lewis et al. 2005). The implications of the increasing amounts of long-lived floating substrata in the oceans are pointed out by Goldstein et al. (2012) who suggest that the populations of the ocean skater *H. sericeus* are no longer limited by the availability of floating objects, used for egg attachment. Similar effects may be responsible for the reported population expansion of other common rafters (e.g. Winston 1982 for *Electra tenella*).

More importantly, floating litter is not only more abundant than natural floating substrata in many parts of the world's oceans, but its abundances are chronically high, throughout all seasons and across years. This continuous presence of large amounts of floating litter contrasts strongly with the highly episodic appearance of pumice rafting opportunities (e.g. Bryan et al. 2012) and few natural rafting opportunities in tropical waters (Rothäusler et al. 2012). It is likely that this change in the temporal and spatial availability of abiotic rafts dramatically affects the dynamics of rafting transport and colonization by associated organisms.

6.5 Summary and Outlook

In an earlier global compilation Thiel and Gutow (2005a) listed 108 invertebrate species that have been found rafting on plastics in the ocean. Since then the list of rafting invertebrates on marine litter (including plastics and other anthropogenic litter) has almost doubled to 215 species. Additionally, some recent studies revealed the ubiquity of micro-organisms on marine litter. Sessile suspension feeders seem to be particularly well adapted to life on solid artificial substrata with specific surface characteristics and limited autochthonous food supply. The colonization of floating litter items is apparently facilitated by larvae with an extended planktonic development. Sexual and asexual reproduction is equally common among rafting species on marine litter with asexual reproduction probably allowing for rapid monopolization, especially of colonial species (e.g. bryozoans) on isolated floating substrata. Physical characteristics of the raft, such as surface rugosity and floating behavior, are crucial for colonization processes and subsequent succession of the rafting invertebrate community. The associated organisms themselves can influence the persistence and stability of their raft indicating complex interaction between the rafting substratum and the associated biota.

Abundant floating marine litter has been suggested to facilitate the spread of invasive species and, in fact, some species have been observed rafting on marine litter beyond their natural distributional limits. Marine litter has probably not opened new rafting routes in the oceans. However, the permanent availability of high densities of persistent floating litter items, especially in regions where natural flotsam occurs in low densities or only episodically, has substantially increased rafting opportunities for species that are able to persist on abiotic flotsam.

Accordingly, the continuous supply of individuals from distant up-current regions probably facilitates the establishment of species in new regions.

Recent studies have not only enhanced our understanding of the role of marine litter as a habitat and dispersal vector for marine biota but also revealed open questions that clearly deserve more research effort. Ocean current models have been used to identify drift trajectories and major accumulation zones of floating marine litter in the Atlantic, Pacific and Indian Ocean (Lebreton et al. 2012; Maximenko et al. 2012), which could be confirmed by field surveys (see for example Law et al. 2010; Goldstein et al. 2013). These models are primarily based on drift trajectories of surface buoys equipped with drogues extending several metres below the sea surface and are thus suitable for identifying broad distributional patterns and large-scale accumulation zones of litter in the oceans. In coastal waters, currents are much more variable and complex and litter objects floating at the sea surface are more strongly influenced by wind than common drifter buoys (e.g. Astudillo et al. 2009). However, our knowledge on how wind and currents influence the floating behavior of different litter items is limited (Neumann et al. 2014). Experimental studies on the floating speed and direction of different categories of floating litter under the influence of variable wind and current conditions would improve our abilities to model floating trajectories of marine litter, predict potential rafting routes, and identify sources of marine floating litter.

Persistence of a litter item in the sea is crucial for its suitability as a habitat and dispersal vector for marine biota. However, the dynamics of degradation of the various litter types under variable marine environmental conditions are poorly understood. Likewise, more research is required to understand how marine biota can accelerate or decelerate degradation processes of marine litter. Investigations on the degradation processes should combine *in situ* monitoring of litter items in the marine environment and biochemical laboratory studies, e.g. on the enzymatic decomposition of plastic polymers.

The degradation of plastics may induce the release of chemicals, some of which are known to affect the health of marine organisms (Rochman 2015). The role of ingested microplastics for the transport of contaminants to marine biota may be limited also because of the rapid gut passage of the small particles (Koelmans 2015). However, the firm attachment of a sessile organism to an artificial surface is permanent and it is yet unknown whether this form of chronic exposure might allow for a slow but continuous transfer of contaminants from plastics to animals via epithelia or with chemically enriched water from the micro-layer on the plastic surface. These studies would require laboratory measurements on the chemical load and the health status of litter rafters, but should also involve organisms collected from litter at sea.

Combined, new and sound information on floating trajectories, raft persistence, and performance of associated organisms will help to estimate the potential of marine litter for the transport of invasive species or entire rafting communities, and therefore add to our understanding of the hazardous character of marine litter beyond the immediate effects of ingestion and entanglement.

Acknowledgments We thank Miriam Goldstein and Emmett Clarkin for valuable comments on an earlier draft of the manuscript. This is publication no. 37793 of the Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung.

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Appendix 1

Table of marine floating litter rafters. Raft substrata: P = Plastic, G = Glass, M = Metal, Pa = Paper, U = Unknown composition of multiple materials. Ocean: Arctic = Arctic Ocean, A(N) = North Atlantic, A(S) = South Atlantic, P(N) = North Pacific, P(S) = South Pacific, Ind = Indian Ocean, Southern = Southern Ocean, Med = Mediterranean. Inference (rafting evidence): fl = floating, in situ, str = collected from stranded items, exp = inferred from floating experiments, spec = speculative because of uncertain identification (only ‘strongest’ rafting evidence is listed fl > str > exp > spec). The taxonomic classification (and taxa names) follows the World Register of Marine Species (WoRMS)

Taxon	Substratum	Region	Inference	Reference
Bacteria				
<i>Acinetobacter</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Albidovulum</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Aleromonas</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Bacteriovorax</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Bdellovibrio</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Blastopirellula</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Devosia</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Erythrobacter</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Filomicrobium</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Fulvivirga</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Haliscomenobacter</i> sp.	P	A(N)	fl	Zettler et al. (2013)

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Taxon	Substratum	Region	Inference	Reference
<i>Hellea</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Henriciella</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Hypomonas</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Iamia</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Idiomarina</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Labrenzia</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Lewinella</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Marinoscillum</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Microscilla</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Muricauda</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Nitratireductor</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Oceaniserpentilla</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Parvularcula lutaonensis</i>	P	A(N)	fl	Zettler et al. (2013)
<i>Parvularcula</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Pelagibacter</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Phormidium</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Phycisphaera</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Plectonema</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Pleurocapsa</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Prochlorococcus</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Pseudoalteromonas</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Pseudomonas</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Psychrobacter</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Rhodovulum</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Rivularia</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Roseovarius</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Rubrimonas</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Rubritalea</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Saprospira</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Synechococcus</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Tenacibaculum</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Thalassobius</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Thiobios</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Vibrio</i> sp.	P	A(N)	fl	Zettler et al. (2013)
Chromista–Ciliophora				
<i>Ephelota</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Halofolliculina</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
Chromista–Foraminifera				
<i>Acervulina</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Cibicides</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Discorbis</i> sp.	P	A(N)	str	Gregory (1983)

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Taxon	Substratum	Region	Inference	Reference
<i>Homotrema rubra</i>	P	P(S)	str	Gregory (1990), Winston et al. (1997)
<i>Planogypsina acervalis</i>	P	A(N)	spec	Winston (2012)
<i>Planulina ornata</i>	P	P(N)	fl	Goldstein et al. (2014)
<i>Rosalina</i> sp.	P	A(N)	str	Winston et al. (1997)
Chromista–Myzozoa–Dinophyceae				
<i>Alexandrium taylori</i>	P	Med	str	Masó et al. (2003)
<i>Alexandrium</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Ceratium macroceros</i>	P	Ind	fl	Reisser et al. (2014)
<i>Ceratium</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Coolia</i> sp.	P	Med	str	Masó et al. (2003)
<i>Ostreopsis</i> sp.	P	Med	str	Masó et al. (2003)
<i>Prorocentrum</i> sp.	P	Med	str	Masó et al. (2003)
Chromista–Haptophyta				
<i>Calcidiscus leptoporus</i>	P	Ind	fl	Reisser et al. (2014)
<i>Calciosolenia</i> sp.	P	Ind	fl	Reisser et al. (2014)
<i>Coccolithus pelagicus</i>	P	Ind	fl	Reisser et al. (2014)
<i>Emiliana huxleyi</i>	P	Ind	fl	Reisser et al. (2014)
<i>Gephyrocapsa oceanica</i>	P	Ind	fl	Reisser et al. (2014)
<i>Umbellosphaera tenuis</i>	P	Ind	fl	Reisser et al. (2014)
<i>Umbilicosphaera hultburtiana</i>	P	Ind	fl	Reisser et al. (2014)
Chromista–Ochrophyta–Bacillariophyceae				
<i>Achnanthes</i> sp.	P	Ind or P(S), Med	fl	Fortuño et al. (2010), Reisser et al. (2014)
<i>Amphora</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Ardissonea</i> sp.	P	P(N)	spec	Carson et al. (2013)
<i>Chaetoceros</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Cocconeis</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Cyclotella meneghiniana</i>	P	A(N)	fl	Carpenter and Smith (1972)
<i>Cylindrotheca</i> sp.	P	Med	fl	Fortuño et al. (2010)
<i>Cymbella</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Diploneis</i> sp.	P	P(N)	spec	Carson et al. (2013)
<i>Fragilaria</i> sp.	P	P(N)	spec	Carson et al. (2013)
<i>Frustulia</i> sp.	P	P(N)	spec	Carson et al. (2013)
<i>Grammatophora</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Haslea</i> sp.	P	P(N), Ind or P(S)	fl	Carson et al. (2013), Reisser et al. (2014)
<i>Licmophora</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Mastogloia angulata</i>	P	A(N)	fl	Carpenter and Smith (1972)

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Taxon	Substratum	Region	Inference	Reference
<i>Mastogloia hulburti</i>	P	A(N)	fl	Carpenter and Smith (1972)
<i>Mastogloia pusilla</i>	P	A(N)	fl	Carpenter and Smith (1972)
<i>Mastogloia</i> sp.	P	P(N), Ind or P(S)	fl	Carson et al. (2013), Reisser et al. (2014)
<i>Microtabella</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Minidiscus trioculatus</i>	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Navicula</i> sp.	P	A(N), Ind or P(S), Med	fl	Fortuño et al. (2010), Zettler et al. (2013), Reisser et al. (2014)
<i>Nitzschia longissima</i>	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Nitzschia</i> sp.	P	A(N), Ind or P(S)	fl	Zettler et al. (2013), Reisser et al. (2014)
<i>Pleurosigma</i> sp.	P	A(N)	fl	Carpenter and Smith (1972)
<i>Protoraphis</i> sp.	P	P(N)	spec	Carson et al. (2013)
<i>Sellaphora</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Stauroneis</i> sp.	P	A(N)	fl	Zettler et al. (2013)
<i>Tabularia</i> sp.	P	Med	fl	Fortuño et al. (2010)
<i>Thalassionema nitzschioides</i>	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Thalassionema</i> sp.	P	P(N), Med	fl	Fortuño et al. (2010), Carson et al. (2013)
<i>Thalassiosira</i> sp.	P	Ind or P(S), Med	fl	Fortuño et al. (2010), Reisser et al. (2014)
Chromista–Ochrophyta–Phaeophyceae				
<i>Cystoseira</i> sp.	P	Med	fl	Aliani and Molcard (2003)
<i>Ectocarpus acutus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Hincksia granulosa</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Petalonia</i> sp.	P	P(S)	exp	Bravo et al. (2011)
<i>Sargassum</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Scytosiphon lomentaria</i>	P	P(S)	fl	Astudillo et al. (2009), Bravo et al. (2011)
Plantae–Charophyta				
<i>Closterium</i> sp.	P	Med	fl	Fortuño et al. (2010)
Plantae–Chlorophyta				
<i>Bryopsis rhizophora</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Codium fragile</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Ulva rigida</i>	P		spec	Morton and Britton (2000a, b)
<i>Ulva</i> sp.	P, U	P(S)	fl	Thiel et al. (2003), Astudillo et al. (2009)

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Taxon	Substratum	Region	Inference	Reference
Plantae–Rhodophyta				
<i>Amphiroa</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Antithamnion densum</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Antithamnion</i> sp.	P	P(S)	exp	Bravo et al. (2011)
<i>Corallina officinalis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Fosliella</i> sp.	P	A(N)	str	Gregory (1983), Winston et al. (1997)
<i>Gelidium</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Hydrolithon farinosum</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Jania</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Lithophyllum</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Mesophyllum</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Polysiphonia mollis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Polysiphonia</i> sp.	P	P(S)	exp	Bravo et al. (2011)
<i>Rhodymenia</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Porifera				
<i>Halichondria panicea</i>	P	P(N)	fl	Goldstein et al. (2014)
<i>Sycon</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
Animalia–Cnidaria–Anthozoa				
<i>Actinia</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Anthopleura dixoniana</i>	P	P(N)	fl	Goldstein et al. (2014)
<i>Anthopleura</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Anthothoe chilensis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Calliactis</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Diadumene lineata</i>	P, U	P(N)	str	Zabin et al. (2004)
<i>Favia fragum</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Metridium</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Oculina patagonica</i>	P, M	Med	str	Fine et al. (2001)
<i>Phyllangia americana</i>	P	A(N)	str	Winston et al. (1997)
<i>Pocillopora</i> sp.	G	P(N)	str	Jokiel (1984)
Animalia–Cnidaria–Hydrozoa				
<i>Aglaophenia latecarinata</i>	P, U	A(N)	str	Calder (1993) (cited by Calder 1995)
<i>Amphisbetia furcata</i>	U	P(S)	str	Calder et al. (2014)
<i>Bougainvillia muscus</i>	U	P(S)	str	Calder et al. (2014)
<i>Clytia gracilis</i>	P	A(N)		Carpenter and Smith (1972)
<i>Clytia gregaria</i>	P	P(N)	fl	Goldstein et al. (2014)
<i>Clytia hemisphaerica</i>	P, U	A(N), Med	fl	Calder (1993) (cited by Calder 1995), Aliani and Molcard (2003)

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Taxon	Substratum	Region	Inference	Reference
<i>Clytia</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Eudendrium</i> sp.	P	Med	fl	Aliani and Molcard (2003)
<i>Eutima japonica</i>	U	P(S)	str	Calder et al. (2014)
<i>Gonothyraea loveni</i>	P	A(N), Med	fl	Carpenter and Smith (1972), Aliani and Molcard (2003)
<i>Halecium</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Halecium tenellum</i>	U	P(S)	str	Calder et al. (2014)
<i>Hydrodendron gracilis</i>	U	P(S)	str	Calder et al. (2014)
<i>Laomedea angulata</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Millepora</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Obelia dichotoma</i>	P, U	A(N) Med	fl	Calder (1993) (cited by Calder 1995), Aliani and Molcard (2003)
<i>Obelia griffini</i>	U	P(S)	str	Calder et al. (2014)
<i>Obelia longissima</i>	U	P(S)	str	Calder et al. (2014)
<i>Obelia</i> sp.	P, U	A(N), P(N), P(S)	fl	Winston et al. (1997), Astudillo et al. (2009), Bravo et al. (2011), Goldstein et al. (2014)
<i>Orthopyxis integra</i>	U	P(S)	str	Calder et al. (2014)
<i>Phialella</i> sp.	U	P(S)	str	Calder et al. (2014)
<i>Plumularia margaretta</i>	P, U	A(N)	str	Calder (1993) (cited by Calder 1995)
<i>Plumularia setacea</i>	P, U	P(N), P(S)	fl	Astudillo et al. (2009), Calder et al. (2014), Goldstein et al. (2014)
<i>Plumularia</i> sp.	P, U	P(S)	str	Bravo et al. (2011), Calder et al. (2014)
<i>Plumularia strictocarpa</i>	P, U	A(N)	str	Calder (1993) (cited by Calder 1995)
<i>Sertularella mutsuensis</i>	U	P(N)	str	Choong and Calder (2013)
<i>Sertularella</i> sp.	U	P(S)	str	Calder et al. (2014)
<i>Sertularia</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Stylactaria</i> sp.	U	P(S)	str	Calder et al. (2014)
<i>Tubularia</i> sp.	P	P(S)	exp	Bravo et al. (2011)
<i>Zanclaea alba</i>	P, U	A(N)	str	Calder (1993) (cited by Calder 1995)
Animalia–Nemertea				
<i>Oerstedia dorsalis</i>	U	P(S)	str	Calder et al. (2014)

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Taxon	Substratum	Region	Inference	Reference
Animalia–Annelida–Polychaeta				
<i>Amaeana</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Amphinome rostrata</i>	P, U	P(N)	fl	Inatsuchi et al. (2010), Goldstein et al. (2014)
<i>Branchiomma</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Circeis spirillum</i>	P	A(N)	str	Winston et al. (1997)
<i>Cirratulus</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Dodecaceria opulens</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Eunice</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Halosydna patagonica</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Halosydna</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Hipponoe gaudichaudi</i>	P	P(N)	fl	Goldstein et al. (2014)
<i>Hydroides dianthus</i>	P	A(N)	str	Winston et al. (1997)
<i>Hydroides elegans</i>	P		str	Winston et al. (1997)
<i>Hydroides sanctaerucis</i>	U		spec	Stafford and Willan (2007)
<i>Hydroides</i> sp.	P	A(N)	str	Gregory (1983), Winston et al. (1997)
<i>Myrianida simplex</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Myrianida</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Nereis falsa</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Nereis grubei</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Nereis</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Odontosyllis</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Paleanotus</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Platynereis australis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Polycirrus</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Romanchella pustulata</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Salmacina</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Spirobranchus polytrema</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Spirobranchus triqueter</i>	P	A(N)	str	Southward et al. (2004)
<i>Spirorbis corrugatus</i>	P	A(N)	str	Winston et al. (1997)
<i>Spirorbis spirorbis</i>	P	A(N)	str	Winston et al. (1997)
<i>Spirorbis</i> sp.	P	A(N), P(N), P(S)	fl	Gregory (1983, 1990), Goldstein et al. (2014)
<i>Steggoa magalaensis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Typosyllis magdalena</i>	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Arthropoda–Pycnogonida				
<i>Phoxichilidium quadridentatum</i>	P	P(N)	fl	Goldstein et al. (2014)

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Taxon	Substratum	Region	Inference	Reference
Animalia–Arthropoda–Insecta				
<i>Halobates micans</i>	P	A(S)	str	Majer et al. (2012)
<i>Halobates sericeus</i>	P	P(N)	fl	Goldstein et al. (2012)
<i>Halobates</i> sp.	P	Ind or P(S)	fl	Reisser et al. (2014)
<i>Halocladius variabilis</i>	P	A(N)	exp	Ingólfsson (1998)
Animalia–Arthropoda–Ostracoda				
<i>Cypris</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Arthropoda–Maxillopoda–Kentrogonida				
<i>Heterosaccus</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
Animalia–Arthropoda–Maxillopoda–Lepadiformes				
<i>Conchoderma auritum</i>	P	A(N)	spec	Gittings et al. (1986)
<i>Conchoderma virgatum</i>	G, U	P(N), P(S)	fl	MacIntyre (1966), Newman (1972)
<i>Dosima fascicularis</i>	P, U	A(N), P(N), Ind	str	Cheng and Lewin (1976), Zevina and Memmi (1981), Minchin (1996), Whitehead et al. (2011)
<i>Dosima</i> sp.	P, G, M, U	Ind	str	Whitehead et al. (2011)
<i>Lepas anatifera</i>	P, M, U	A(N), A(S), P(N), P(S), Ind, Med	fl	Patel (1959), MacIntyre (1966), Green et al. (1994), Minchin (1996), Dellinger et al. (1997), Winston et al. (1997), Spivak and Bas (1999), Barnes and Milner (2005), Astudillo et al. (2009), Whitehead et al. (2011), Cabezas et al. (2013), Goldstein and Goodwin (2013), Goldstein et al. (2014)
<i>Lepas anserifera</i>	P, G, U	P(N), Ind	fl	Newman (1972), Celis et al. (2007), Inatsuchi et al. (2010), Whitehead et al. (2011)
<i>Lepas australis</i>	P	A(S), P(S), Ind	fl	Barnes and Milner (2005), Astudillo et al. (2009), Whitehead et al. (2011)
<i>Lepas hillii</i>	G	P(N)	str	Newman (1972)
<i>Lepas pacifica</i>	P, U	P(N)	fl	Cheng and Lewin (1976), Goldstein and Goodwin (2013), Goldstein et al. (2014)

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Taxon	Substratum	Region	Inference	Reference
<i>Lepas pectinata</i>	P, U	A(N), P(N), P(S),Ind, Med	fl	Minchin (1996), Winston et al. (1997), Tsikhon-Lukanina et al. (2001), Aliani and- Molcard (2003), Wirtz et al. (2006), Astudillo et al. (2009), Bravo et al. (2011), Whitehead et al. (2011), Ryan and Branch (2012)
<i>Lepas testudinata</i>	P, U	Ind	str	Whitehead et al. (2011), Ryan and Branch (2012)
<i>Lepas</i> sp.	P, G, M, U	P(N), P(S), Ind,Med	fl	Woods Hole Oceanographic Institution (1952), Dell (1964), Willan (1979), Holdway and Maddock (1983b), Frazier and Margaritoulis (1990), Gregory (1990), Astudillo et al. (2009), Whitehead et al. (2011), Calder et al. (2014), Goldstein et al. (2014), Reisser et al. (2014)
Animalia–Arthropoda–Maxillopoda–Sessilia				
<i>Amphibalanus amphitrite</i>	P, U	A(N), P(N)	fl	Winston et al. (1997), Stafford and Willan (2007), Goldstein et al. (2014)
<i>Amphibalanus eburneus</i>	P	A(N)	str	Winston et al. (1997)
<i>Austromegabalanus psittacus</i>	P	P(S)	fl	Astudillo et al. (2009), Bravo et al. (2011)
<i>Austrominius modestus</i>	P	A(N), Med	str	Southward et al. (2004), Barnes and Milner (2005)
<i>Balanus flosculus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Balanus laevis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Balanus trigonus</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Balanus</i> sp.	P	P(S)	exp	Bravo et al. (2011)
<i>Chelonibia patula</i>	P	Med	str	Frazier and Margaritoulis (1990)
<i>Chthamalus</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Hesperibalanus fallax</i>	P, U	A(N), Med	str	Kerckhof (1997) (cited by Kerckhof 2002), Southward et al. (2004)

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Taxon	Substratum	Region	Inference	Reference
<i>Megabalanus rosa</i>	P, U	P(N), P(S)	fl	Calder et al. (2014), Goldstein et al. (2014)
<i>Megabalanus tulipiformis</i>	P, U	A(N), Med	str	Southward et al. (2004)
<i>Perforatus perforatus</i>	P	A(N), Med	str	Southward et al. (2004), Rees and Southward (2009)
<i>Semibalanus balanoides</i>	P	Arctic	str	Barnes and Milner (2005)
<i>Semibalanus cariosus</i>	U	P(N)	str	Choong and Calder (2013)
Animalia–Arthropoda–Malacostraca–Decapoda				
<i>Acanthocyclus</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Allopetrolisthes spinifrons</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Cancer setosus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Chorilia</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Halicarcinus planatus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Herbstia</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Hippolyte</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Latreutes antiborealis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Liopetrolisthes mitra</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Lysmata</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Pachycheles</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Palaemon affinis</i>	U	P(N)	fl	Goldstein et al. (2014)
<i>Petrolisthes tuberculatus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Pilumnoides perlatus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Pilumnus</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Pisoides edwardsii</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Plagusia immaculata</i>	P		spec	Donlan and Nelson (2003)
<i>Plagusia</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Planes major</i>	P, U	P(N), P(S)	fl	Chace (1951), Goldstein et al. (2014)
<i>Planes minutus</i>	P, U	A(N), P(N), Ind	fl	Dellinger et al. (1997), Winston et al. (1997), Ryan and Branch (2012), Goldstein et al. (2014)
<i>Planes</i> sp.	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Synalpheus spinifrons</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Taliepus dentatus</i>	P	P(S)	fl	Astudillo et al. (2009)

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Taxon	Substratum	Region	Inference	Reference
Animalia–Arthropoda–Malacostraca–Amphipoda				
<i>Aora</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Calliopius laeviusculus</i>	P	A(N)	exp	Ingólfsson (1998)
<i>Caprella andreae</i>	U	A(S), Med	fl	Spivak and Bas (1999), Cabezas et al. (2013)
<i>Caprella equilibra</i>	P, U	P(S)	fl	Thiel et al. (2003), Astudillo et al. (2009)
<i>Caprella hirsuta</i>	U	Med	fl	Cabezas et al. (2013)
<i>Caprella mutica</i>	U	P(S)	str	Calder et al. (2014)
<i>Caprella scaura</i>	P, U	P(S)	fl	Thiel et al. (2003), Astudillo et al. (2009)
<i>Caprella verrucosa</i>	P, U	P(S)	fl	Thiel et al. (2003), Astudillo et al. (2009)
<i>Caprella</i> sp.	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Deutella venenosa</i>	P, U	P(S)	fl	Thiel et al. (2003), Astudillo et al. (2009)
<i>Dexamine thea</i>	P	A(N)	exp	Ingólfsson (1998)
<i>Elasmopus brasiliensis</i>	U	Med	fl	Cabezas et al. (2013)
<i>Erichthonius</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Gammarus locusta</i>	P, Pa	A(N)	spec	Vandendriessche et al. (2006)
<i>Hyale grimaldii</i>	U	Med	fl	Cabezas et al. (2013)
<i>Jassa cadetta</i>	U	Med	fl	Cabezas et al. (2013)
<i>Jassa marmorata</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Jassa slatteryi</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Jassa</i> sp.	U	A(N)	fl	LeCroy (2007)
<i>Paracaprella pusilla</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Paradexamine pacifica</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Phtisica marina</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Stenothoe</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Arthropoda–Malacostraca–Isopoda				
<i>Sphaeroma quoianum</i>	P	P(N)	fl	Davidson (2008)
<i>Ianiropsis serricaudis</i>	U	P(S)	str	Calder et al. 2014
<i>Idotea balthica</i>	P, Pa, U	A(N), Med	fl	Holdway and Maddock (1983a, b), Franke et al. (1999), Gutow and Franke (2003), Vandendriessche et al. (2006)
<i>Idotea emarginata</i>	U	A(N)	fl	Gutow and Franke (2003)

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Taxon	Substratum	Region	Inference	Reference
<i>Idotea metallica</i>	P, U	A(N), P(S), Med	fl	Holdway and Maddock (1983a, b), Davenport and Rees (1993), Poore and Lew-Ton (1993), Franke et al. (1999), Aliani and Molcard (2003), Gutow and Franke (2003), Abelló et al. (2004), Cabezas et al. (2013)
<i>Idotea</i> sp.	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Sphaeroma terebrans</i>	P	A(N), P(N)	fl	Davidson (2012)
<i>Synidotea innatans</i>	U	P(S)	fl	Poore (2012)
<i>Synidotea marplatensis</i>	P		spec	Masunari et al. (2000) (cited by Loyola-Silva and Melo 2008)
Animalia–Arthropoda–Malacostraca–Tanaidacea				
<i>Zeuxo marmoratus</i>	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Mollusca–Gastropoda				
<i>Berthella</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Crepidula fornicata</i>	P	A(N)	str	Cadée (2003)
<i>Crepidula</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Crucibulum</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Doto uva</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Doto</i> sp.	P	Med	fl	Aliani and Molcard (2003)
<i>Erronea</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Evalea tenuisculpta</i>	P	P(N)	fl	Goldstein et al. (2014)
<i>Fiona pinnata</i>	P, U	P(N), P(S), Med	fl	Willan (1979), Aliani and Molcard (2003), Inatsuchi et al. (2010), Goldstein et al. (2014)
<i>Fissurella cumingi</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Fissurella latimarginata</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Fissurella</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Laevilitorina antarctica</i>	P	Southern	str	Barnes and Fraser (2003)
<i>Litiopa melanostoma</i>	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Mitrella</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Nassarius</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Petalococonchus varians</i>	U	A(S)	str	Breves and Skinner (2014)
<i>Phidiana lottini</i>	P	P(S)	fl	Astudillo et al. (2009)

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Taxon	Substratum	Region	Inference	Reference
<i>Prisogaster</i> sp.	P	P(S)	fl	Astudillo et al. (2009)
<i>Scurria viridula</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Thecacera darwini</i>	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Mollusca–Bivalvia				
<i>Aequipecten opercularis</i>	P	A(N)	str	Cadée (2003)
<i>Anomia ephippium</i>	P	A(N)	str	Southward et al. (2004)
<i>Anomia</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Argopecten purpuratus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Brachidontes granulatus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Chama congregata</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Chama</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Chioneryx grus</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Chlamys</i> sp.	U	P(N)	fl	Goldstein et al. (2014)
<i>Crassostrea gigas</i>	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Crassostrea</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Hiatella arctica</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Isognomon</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Lopha cristagalli</i>	P	P(S)	fl	Gardner (1971) (cited by Gregory 2009), Winston et al. (1997)
<i>Musculus cupreus</i>	U	P(S)	str	Calder et al. (2014)
<i>Mytilus edulis</i>	P, U	A(N)	exp	Ingólfsson (1998), Cardigos et al. (2006)
<i>Mytilus galloprovincialis</i>	P, U	P(N), P(S)	fl	Calder et al. (2014), Goldstein et al. (2014)
<i>Mytilus</i> sp.	P	Med	str	Frazier and Margaritoulis (1990)
<i>Ostrea edulis</i>	P	Med	str	Frazier and Margaritoulis (1990)
<i>Ostrea equestris</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Pinctada imbricata</i>	P	A(N)	str	Ávila et al. (2000) (cited by Cardigos 2006), Cadée (2003)
<i>Pinctada</i> sp.	P, U	A(N), P(N)	fl	Winston et al. (1997), Gregory (2009), Goldstein et al. (2014)
<i>Pteria</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Rocellaria dubia</i>	M	A(N)	str	Hoeksema et al. (2012)
<i>Semimytilus algosus</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Zirfaea</i> sp.	P	P(N)	fl	Goldstein et al. (2014)

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Taxon	Substratum	Region	Inference	Reference
Animalia–Echinodermata				
<i>Arbacia lixula</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Patiria chilensis</i>	P	P(S)	fl	Astudillo et al. (2009)
<i>Tetrapygyus niger</i>	P	P(S)	fl	Astudillo et al. (2009)
Animalia–Bryozoa–Gymnolaemata				
<i>Aetea</i> sp.	P	A(N)	str	Winston et al. (1997)
<i>Aimulosia antarctica</i>	P	Southern	str	Barnes and Fraser (2003)
<i>Aimulosia marsupium</i>	P	P(S)	str	Stevens et al. (1996)
<i>Amphiblestrum contentum</i>	P	P(S)	str	Stevens et al. (1996)
<i>Arachnopusia inchoata</i>	P	Southern	str	Barnes and Fraser (2003)
<i>Arachnopusia unicornis</i>	P	P(S)	str	Stevens et al. (1996)
<i>Beania inermis</i>	P	P(S)	str	Stevens et al. (1996)
<i>Beania plurispinosa</i>	P	P(S)	str	Stevens et al. (1996)
<i>Biflustra arborescens</i>	P		str	Winston et al. (1997)
<i>Biflustra savartii</i>	P	A(N)	str	Key et al. (1996), Winston et al. (1997)
<i>Bitectipora cincta</i>	P	P(S)	str	Stevens et al. (1996)
<i>Bowerbankia gracilis</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Bowerbankia</i> sp.	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Bugula flabellata</i>	P	P(S)	fl	Stevens et al. (1996), Astudillo et al. (2009), Bravo et al. (2011)
<i>Bugula minima</i>	P	A(N)	str	Winston et al. (1997)
<i>Bugula neritina</i>	P, U	A(N), P(S)	fl	Southward et al. (2004), Stafford and Willan (2007), Astudillo et al. (2009), Bravo et al. (2011)
<i>Bugula</i> sp.	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Caberea rostrata</i>	P	P(S)	str	Stevens et al. (1996)
<i>Caberea zelandica</i>	P	P(S)	str	Stevens et al. (1996)
<i>Callopora lineata</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Calloporina angustipora</i>	P	P(S)	str	Stevens et al. (1996)
<i>Calyptotheca immersa</i>	P	P(S)	str	Stevens et al. (1996)
<i>Celleporaria agglutinans</i>	P	P(S)	str	Stevens et al. (1996)
<i>Celleporella cancer</i>	P	P(S)	str	Stevens et al. (1996)

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Taxon	Substratum	Region	Inference	Reference
<i>Celleporella tongima</i>	P	P(S)	str	Stevens et al. (1996)
<i>Celleporina hemiperistomata</i>	P	P(S)	str	Stevens et al. (1996), Winston et al. (1997)
<i>Celleporina</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Chaperia acanthina</i>	P	P(S)	str	Stevens et al. (1996)
<i>Chaperiopsis</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Chiastosella</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Crepidacantha crinispina</i>	P	P(S)	str	Stevens et al. (1996)
<i>Cryptosula pallasiana</i>	P	P(S)	fl	Stevens et al. (1996), Winston et al. (1997), Astudillo et al. (2009)
<i>Electra angulata</i>	P		str	Key et al. (1996), Winston et al. (1997)
<i>Electra posidoniae</i>	P	Med	fl	Aliani and Molcard (2003)
<i>Electra tenella</i>	P	A(N), P(S)	str	Winston 1982, Gordon and Mawatari (1992), Stevens et al. (1996), Winston et al. (1997)
<i>Ellisina antarctica</i>	P	Southern	str	Barnes and Fraser (2003)
<i>Escharoides angela</i>	P	P(S)	str	Stevens et al. (1996)
<i>Escharoides excavata</i>	P	P(S)	str	Stevens et al. (1996)
<i>Eurystomella foraminigera</i>	P	P(S)	str	Stevens et al. (1996)
<i>Exochella armata</i>	P	P(S)	str	Stevens et al. (1996)
<i>Exochella tricuspis</i>	P	P(S)	str	Stevens et al. (1996)
<i>Fenestrulina disjuncta</i>	P	P(S)	str	Stevens et al. (1996)
<i>Fenestrulina rugula</i>	P	Southern	str	Barnes and Fraser (2003)
<i>Foveolaria cyclops</i>	P	P(S)	str	Stevens et al. (1996)
<i>Galeopsis polyporus</i>	P	P(S)	str	Stevens et al. (1996)
<i>Galeopsis porcellanicus</i>	P	P(S)	str	Stevens et al. (1996)
<i>Inversiula fertilis</i>	P	P(S)	str	Stevens et al. (1996)
<i>Jellyella eburnea</i>	P, U	P(N), P(S)	fl	Stevens et al. (1996), Goldstein et al. (2014)
<i>Jellyella tuberculata</i>	P, U	A(N), P(N), P(S)	fl	Gregory (1978, 1990, 2009), Stevens et al. (1996), Winston et al. (1997), Goldstein et al. (2014)
<i>Jellyella</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Macropora grandis</i>	P	P(S)	str	Stevens et al. (1996)

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Taxon	Substratum	Region	Inference	Reference
<i>Membranipora isabelleana</i>	P	P(S)	fl	Astudillo et al. (2009), Bravo et al. (2011)
<i>Membranipora membranacea</i>	P	Arctic, Med	fl	Aliani and Molcard (2003), Barnes and Milner (2005)
<i>Membranipora tenella</i>	P, U	P(N)	fl	Goldstein et al. (2014)
<i>Membranipora</i> sp.	P	A(N), P(N)	fl	Winston et al. (1997), Goldstein et al. (2014)
<i>Micropora brevissima</i>	P	Southern	str	Barnes and Fraser (2003)
<i>Micropora mortenseni</i>	P	P(S)	str	Stevens et al. (1996)
<i>Microporella agonistes</i>	P	P(S)	str	Stevens et al. (1996)
<i>Microporella speculum</i>	P	P(S)	str	Stevens et al. (1996)
<i>Opaeophora lepida</i>	P	P(S)	str	Stevens et al. (1996)
<i>Parasmittina</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Rhynchozoon larreyi</i>	P	P(S)	str	Stevens et al. (1996)
<i>Schizoporella pungens</i>	P	A(N)	str	Winston (2012)
<i>Schizosmittina cinctipora</i>	P	P(S)	str	Stevens et al. (1996)
<i>Schizosmittina</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Smittina torques</i>	P	P(S)	str	Stevens et al. (1996)
<i>Smittoidea maunganuiensis</i>	P	P(S)	str	Stevens et al. (1996)
<i>Smittoidea</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Steginoporella magnifica</i>	P	P(S)	str	Stevens et al. (1996)
<i>Thalamoporella evelinae</i>	P	A(N)	str	Winston et al. (1997)
<i>Tricellaria inopinata</i>	U	P(S)	str	Calder et al. (2014)
<i>Victorella</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Watersipora subtorquata</i>	P, U	P(S)	str	Stevens et al. (1996), Winston et al. (1997), Stafford and Willan (2007)

Animalia–Bryozoa–Stenolaemata

<i>Diastopora</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Disporella sibogae</i>	P	P(S)	str	Stevens et al. (1996)
<i>Disporella</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Eurystrotos ridleyi</i>	P	P(S)	str	Stevens et al. (1996)
<i>Favosipora</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Filicrisia</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Hastingsia</i> sp.	P	P(S)	str	Stevens et al. (1996)

(continued)

(continued)

Taxon	Substratum	Region	Inference	Reference
<i>Lichenopora novaezelandiae</i>	P	P(S)	str	Stevens et al. (1996)
<i>Platonea</i> sp.	P	P(S)	str	Stevens et al. (1996)
<i>Stomatopora</i> sp.	P	P(N)	fl	Goldstein et al. (2014)
<i>Tubulipora</i> sp.	P	P(N), P(S)	fl	Stevens et al. (1996), Goldstein et al. (2014)
Animalia—Chordata—Ascidiacea				
<i>Diplosoma</i> sp.	P	P(S)	fl	Astudillo et al. (2009), Bravo et al. (2011)
<i>Ascidia</i> sp.	U	P(S)	fl	Thiel et al. (2003)
<i>Ciona intestinalis</i>	P	P(S)	fl	Astudillo et al. (2009), Bravo et al. (2011)
<i>Pyura chilensis</i>	P, U	P(S)	fl	Thiel et al. (2003), Astudillo et al. (2009), Bravo et al. (2011)

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