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Corresponding Author: Dr. Pietro Battaglia,

Corresponding Author's Institution: ISPRA

First Author: Pietro Battaglia

Order of Authors: Pietro Battaglia; Pierpaolo Consoli; Giovanni Ammendolia; Michela D'Alessandro; Marzia Bo; Teresa M Vicchio; Cristina Pedà; Mauro Cavallaro; Franco Andaloro; Teresa Romeo

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Suggested Reviewers: Aikaterini Anastasopoulou
Hellenic Centre for Marine Research
kanast@hcmr.gr
Expert in Marine litter for Mediterranean Sea

Monique Mancuso
CNR National Research Council
monique.mancuso@iamc.cnr.it
Expert in marine litter for Mediterranean Sea

Carme Alomar
Instituto Español de Oceanografía, Centro Oceanográfico de Baleares
c.alomar@ba.ieo.es
Expert in Marine Litter

Cristina Panti

University of Siena
panti4@unisi.it
Expert in MArine Litter

Colonization of floats from submerged derelict fishing gears by four protected species of deep-sea corals and barnacles in the Strait of Messina (central Mediterranean Sea)

Pietro Battaglia[1], Pierpaolo Consoli[1], Giovanni Ammendolia[2], Michela D'Alessandro[3], Marzia Bo[4], Teresa Manuela Vicchio[5], Cristina Pedà[3], Mauro Cavallaro[6], Franco Andaloro[1], Teresa Romeo[1,3]

[1]SZN, Stazione Zoologica Anton Dohrn, Villa Pace, via Consolare Pompea (93,51 km), 98167 Messina, Italy

[2]Independent Researcher, Coop. Sicilianella, 98167 Messina, Italy

[3]ISPRA, Institute for Environmental Protection and Research, BIO-CIT, Via dei Mille, 46, 98057, Milazzo (ME), Italy

[4]DISTAV, Department of Earth, Environment and Life Sciences, University of Genoa, Corso Europa 16, 16132 Genova, Italy

[5]Independent Researcher, Via N. Panoramica 1188, Messina, Italy

[6]Department of Veterinary Sciences, University of Messina, Polo Universitario dell'Annunziata, 98168, Messina, Italy

*Corresponding author: Pietro Battaglia, Tel: +39 06 50074064. Email: pietro.battaglia@szn.it; battaglia.pietro@szn.it

ABSTRACT

The distribution of floating litter in marine waters, influenced by currents and wind drag, often determines the dispersal of its encrusting fauna. In the present paper, we observed for the first time the colonization of rafting floats from abandoned, lost or derelict fishing gears (ALDFG) by the four protected deep-sea species: *Errina aspera*, *Desmophyllum pertusum*, *Madrepora oculata* *Pachylasma giganteum*.

Overall, 41 floats, colonized by deep benthic species, were found stranded on the shore of the Sicilian coast of the Strait of Messina, between 2016 and 2019. Species composition, number and occurrence of colonizing organisms were analyzed. On the basis of the species composition (the association between *E. aspera*, *P. giganteum* and *Megabalanus tulipiformis*), the knowledge on their ecology, biogeography, path of local currents, it was possible to define that the area of origin of the most part of these fishing net floats was the Strait of Messina.

Keywords: marine litter; rafting; deep water; macroinvertebrates; encrusting fauna; settling

The oceans' pollution generated by anthropogenic litter has been recognized as a worldwide problem (Bergmann et al., 2015). On average three-quarter of all marine litter consists of plastics, which may affect marine ecosystems by transporting persistent organic pollutants (POPs; Mathalon and Hill, 2014) and alien species (Barnes, 2002), releasing toxic compounds (e.g., additives; Teuten et al., 2009) and entangling several marine species (Consoli et al., 2018), altering benthic communities structure (Katsanevakis et al., 2007). What is more, marine litter impacts on the marine trophic web (Carbery et al., 2018; Nelms et al., 2018) since litter is also ingested by marine organisms (Romeo et al., 2015; Fossi et al., 2018).

Perhaps, one of the problems that has received less attention is the role of floating debris as habitat and dispersal vector for native and non-native species such as alien invasive species (Barnes, 2002; Kiessling et al., 2015; Rech et al., 2016) although at present there is no clear understanding of its global impact (Rech et al., 2016).

Biota can attach several human-made objects, such as glass, wood, metal, paper and persistent plastic items (Kiessling et al., 2015) made up by polypropylene (PP), polyethylene (PE), expanded polystyrene (EPS) and polyvinyl chloride (PVC).

There are several examples of long and medium-distance transport of invertebrates, rafting on anthropogenic litter, such as bivalves, barnacles, gastropods, polychaetes, bryozoans, hydrozoan colonies and anthozoan corals. Few small specimens of the stony coral *Favia fragum* (Esper, 1795) were found attached to a metal gas cylinder that probably crossed the Atlantic Ocean from the USA to the Netherlands (Hoeksema et al., 2012); another invading coral, *Oculina patagonica* de Angelis, 1908, is commonly found on submerged metal objects (Fine et al., 2001); recently a large colony of the scleractinian coral *Astrangia poculata* (Ellis and Solander, 1786) was found on polyurethane substrate at Biville beach Normandy (France) by Hoeksema et al. (2018). The distribution of floating litter and the dispersal of its encrusting fauna is determined by the course of oceanic currents and strongly influenced by wind drag (Hoeksema et al., 2012, 2018; Gutow et al., 2018).

In the present paper, we report for the first time, the evidence of colonization of rafting floats from abandoned, lost or derelict fishing gears (ALDFG) by the following marine protected species: the three deep-water corals *Errina aspera* (Linnaeus, 1767), *Desmophyllum pertusum* (Linnaeus, 1758) and *Madrepora oculata* (Linnaeus, 1758) as well as the deep-sea cirripede crustacean *Pachylasma giganteum* (Philippi, 1836). The finding of these floats stranded on the shore of the Sicilian coast of the Strait of Messina, gave us the opportunity to observe and quantify the colonization by several deep-sea organisms on this anthropogenic litter.

The study area (Strait of Messina) is located in the central Mediterranean Sea (Fig. 1A) and it is considered a hot spot of biodiversity (Spanò and De Domenico, 2017). The Strait of Messina connects the Ionian Sea to the Tyrrhenian Sea and its particular hydrodynamic regime is characterized by the presence of complex physical phenomena producing upwelling currents (Vercelli, 1925; Vercelli and Picotti, 1926; Mosetti, 1988). The depth profile of the Strait decreases from about 1500 m in the Ionian Sea to a minimum value of about 80 m in the narrowest area between Ganzirri and Punta Pezzo (Fig. 1A). These features make possible the presence of very different bottom communities in a relatively small area, with the presence of species unknown in other Mediterranean areas, such as kelp forests (Drew, 1972), *E. aspera* and *P. giganteum* populations (Arnaud and Zibrowius, 1979; Di Geronimo and Fredj, 1987), considered belonging to Mediterranean relict fauna of the Tethys Sea. In particular, the stylasterid deep coral *E. aspera* forms an abundant population on rocky bottoms exposed to the strong currents of the Strait of Messina, occurring at depths between 110 and 230 m, in association with *P. giganteum* and *Megabalanus tulipiformis* (Arnaud and Zibrowius, 1979; Fredj and Giermann, 1982; Di Geronimo and Fredj, 1987; Di Natale and Mangano, 1985; Giacobbe, 2001; Salvati et al., 2010). This hard bottom represented in the past an old fishing ground for artisanal fishermen using pots or trammel nets to target the common spiny lobster *Palinurus elephas* (Potoschi et al., 2004), although today this activity is almost disappeared.

Overall, 41 floats of submerged derelict fishing gears in expanded PVC, colonized by deep benthic species, were found stranded on the shore of the Sicilian coast of the Strait of Messina. They were collected during the sampling activity aimed to assess the phenomenon of mesopelagic fish stranding in the study area (Battaglia et al., 2017), between 2016 and 2019. Floats were observed in laboratory to identify the encrusting fauna. According to Barnes and Milner (2005), each unitary and colonial animal was counted as one recruit. In some cases, the identification of invertebrates at species level was not possible as organisms resulted dried or damaged.

The percentage abundance (%N) and frequency of occurrence (%O) of individuals of each taxon were calculated as follows:

%N = number of individuals of taxa i / total number of individuals * 100

%O = number of floats / total number of floats in which taxa i was found * 100

The mean species richness (S), as average number of taxa found encrusting the floats, was also estimated.

A total of 3014 deep-water organisms were counted on the floats, belonging to 38 taxa of macroinvertebrates (Table 1). The number of colonizing individuals/colonies found on each float varied from 1 to 566 (average = 73.5; standard deviation = 96.6), whereas the species richness (S) ranged between 1 and 17 (average = 5.4; standard deviation = 3.7). Colonizing fauna found on floats belonged to several taxonomic groups: Foraminifera, Porifera, Cnidaria, Anellida, Mollusca, Arthropoda and Bryozoa (Table 1). The most important finding was the presence of several protected species among the encrusting fauna, i.e. the deep-water corals *E. aspera* (Fig. 1B; Fig. 1D), *D. pertusum* (Fig. 1C), and *M. oculata* (Fig. 1G), as well as the deep-sea cirripede crustacean *P. giganteum* (Fig. 1E; Fig. 1F).

The protection level of the recorded species is reported in Table 2, considering the IUCN red list (Red list of Threatened Species of the International Union for the Conservation of Nature and Natural Resources, Otero et al. 2017), CITES (Convention on International Trade of Endangered Species, Washington 1973), SPA/BD Protocol (Protocol concerning the Specially Protected Areas and Biological Diversity in the Mediterranean, Barcelona 1995) and Bern Convention (Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats, Berna 1979).

Table 1 also reports the percentage number (%N) and frequency of occurrence (%O) for each taxon found on floats. At species level, the most abundant organism was the foraminifera *Miniacina miniacea* (%N = 34.07), followed by *Megabalanus tulipiformis* (%N = 19.04), and *P. giganteum* (%N = 5.91), whereas the most frequent species were *M. tulipiformis* (%O = 73.17), *M. miniacea* (%O = 70.73), *Neopycnodonte cochlear* (%O = 46.34) and *P. giganteum* (%O = 36.59). The protected stylasterid *E. aspera* (%N = 3.95; %O = 17.07) was often associated to *M. tulipiformis* and *P. giganteum* (71.43% and 42.86% of cases in which *E. aspera* was found, respectively) in colonized substrata. On the contrary, the other protected species (*D. pertusum* and *M. oculata*) were observed only once. Both *D. pertusum* (Fig. 1C) and *M. oculata* (Fig. 1G) were found associated to *Desmophyllum dianthus*.

On the basis of the species composition, the knowledge on their ecology and biogeography as well as the path of local currents, it was possible to define that the area of origin of the most part of these fishing net floats was the Strait of Messina. Indeed, the association of some organisms (*E. aspera*, *P. giganteum* and *M. tulipiformis*) is typical from deep rocky bottoms of the study area (Arnaud and Zibrowius, 1979; Fredj and Giermann, 1982; Di Geronimo and Fredj 1987; Di Natale and Mangano, 1985; Giacobbe, 2001; Salvati et al., 2010). On the one hand, the upwelling currents of the Strait of Messina, strongly influenced by moon phases, can reach speeds of 500 cm s^{-1} (Mosetti, 1995) and creates the trophic condition for the growth of these protected species. On the other hand, this hydrodynamism produces a continuous and strong frictional stress on the abandoned, lost or derelict fishing gears laying on the bottom and accelerates their degradation. Periodically, this phenomenon can cause the breakage of ropes and nets releasing the fishing floats, which may emerge and strand on the shore, otherwise may sink in deep waters (i.e. when they are heavily colonized) or follow the course of currents. In the last case, floating litter may reach other nearby or far areas contributing to the dispersal of the encrusting fauna and the colonization of new zones. In our study, the observation of colonizing fauna highlighted that coral colonies and barnacles were in most cases alive when they stranded. However, it is very difficult to assess the survival rate of these deepsea species. It is probable that most of them die after such a drastic change of environmental parameters, including light exposure in surface waters, temperature, oxygen concentration, pressure, water circulation. Moreover, according to Kiessling et al. (2015), in order to successfully establish a new population, rafting organisms have to survive the journey and, above all, reproduce upon reaching a potential settling habitat.

With regards to plastic marine debris, although the polymer composition can influence the colonization of micro-organisms (Carson et al., 2013), there is no evidence that it may affect the ability of macrobiota to encrust anthropogenic litter. The examined fishing floats in expanded PVC were colonized by multi-specific communities and the level of colonization was probably mostly depending on the permanence period at sea and on environmental factors.

According to the current knowledge (Lebreton et al., 2012; Maximenko et al., 2012; Kiessling et al., 2015; Fossi et al., 2017), hydrodynamic models are used to understand the main drift trajectories at sea and find the major accumulation zones of floating marine litter. In the Mediterranean context, the Strait of Messina is a convergence region, were upwelling currents and surface fronts may concentrate rafting litter in a relatively narrow area. For this reason, the Strait of Messina could be considered for monitoring purposes on floating and beached litter, and for investigating on ALDGF's colonization and coverage. These actions may provide interesting data for the implementation of the monitoring programme within the Marine Strategy Framework Directive. They may also contribute to the development of specific management measures as well as implement national and regional action plans of the MED POL programme.

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Figure caption

Fig. 1. Study area in the Strait of Messina and examples of macrofauna colonization on rafting floats from abandoned, lost or derelict fishing gear. A) stranding site of rafting floats (in pale blue) and location of hard bottoms (black asterisk) colonized by *Errina aspera* and exploited by local artisanal fisheries to target *Palinurus elephas*; B) colonies of *Errina aspera* together with *Megabalanus tulipiformis* and other benthic organisms; C) *Desmophyllum pertusum* in association with *Desmophyllum dianthus*; D) small colonies of *Errina aspera*; E) colonies of *Pachylasma giganteum* and *Megabalanus tulipiformis*; F) *Pachylasma giganteum* and *Megabalanus tulipiformis* in association with hydrozoa colonies; G) a small colony of *Madrepora oculata* congregated with *Desmophyllum dianthus*.

Tables

Table 1. List of macroinvertebrates encrusting floats of submerged derelict fishing gears found stranded on the Sicilian coast of the Strait of Messina. Percent number (%N) and frequency of occurrence (%O) for each taxon is given.

Phylum / *Class*	**Order**	**Family**	**Genus / Species**	**%N**	**%O**
Arthropoda					
Hexanauplia	Sessilia	Balanidae	*Megabalanus tulipiformis* (Ellis, 1758)	19.04	73.17
		Pachylasmatidae	*Pachylasma giganteum* (Philippi, 1836)	5.91	36.59
		Poecilasmatidae	*Octolasmis* sp.	0.07	2.44
		Pyrgomatidae	*Adna anglica* Sowerby, 1823	0.03	2.44
Cnidaria					
Anthozoa	Alcyonacea	Alcyoniidae	*Alcyonium coralloides* (Pallas, 1766)	0.50	4.88
	Scleractinia	Caryophylliidae	*Coenocyathus cylindricus* Milne Edwards & Haime, 1848	0.10	4.88
			Desmophyllum pertusum (Linnaeus, 1758)	0.03	2.44
			Desmophyllum dianthus (Esper, 1794)	2.32	12.20
			Caryophylliidae ind	0.20	12.20
		Oculinidae	*Madrepora oculata* Linnaeus, 1758	0.03	4.88
	Zoantharia	nd	unidentified	0.03	2.44
Hydrozoa	Anthoathecata	Stylasteridae	*Errina aspera* (Linnaeus, 1767)	3.95	17.07
	Leptothecata	Sertularellidae	*Sertularella* sp.	0.17	9.76
		Sertulariidae	Sertulariidae unid.	0.20	7.32
			Hydrozoa unid.	0.66	41.46
Mollusca					
Gastropoda	Littorinimorpha	Ovulidae	*Pedicularia sicula* Swainson, 1840	0.07	2.44
Bivalvia	Ostreida	Gryphaeidae	*Neopycnodonte cochlear* (Poli, 1795)	4.38	46.34
	Arcida	Noetiidae	*Striarca lactea* (Linnaeus, 1758)	0.03	2.44
Anellida					
Polychaeta	Sabellida	Serpulidae	Serpulidae unid.	19.11	56.10
			Metavermilia multicristata (Philippi 1844)	0.66	9.76
			Vermiliopsis sp.	1.23	14.63
			Filogranula sp.	2.32	7.32
			Filogranula gracilis Langerhans, 1884	0.07	4.88
			Filograna sp.	1.66	4.88
			Semivermilia agglutinata (Mrenzeller, 1893)	0.36	9.76
			Semivermilia sp.	0.07	4.88
			Serpula vermicularis Linnaeus, 1767	0.33	7.32
			Placostegus tridentatus (Fabricius, 1779)	0.13	4.88
Porifera					
Calcarea	Leucosolenida	Sycettidae	*Sycon raphanus* Schmidt 1862	0.10	2.44
Bryozoa					
Gymnolaemata	Cheilostomatida		Cheilostomatida unid.	0.86	21.95
		Celleporidae	*Cellepora* sp	0.63	12.20
			Celleporina sp	0.03	2.44
		Haplopomidae	*Haplopoma* sp.	0.07	2.44
		Cellariidae	*Cellaria salicornoides* Lamouroux 1816	0.07	2.44
		Cribrilinidae	*Puellina cfr gattyae*	0.07	2.44
			Puellina sp.	0.23	2.44
Stenolaemata	Cyclostomatida		Cyclostomatida unid.	0.20	9.76
Foraminifera					
Globothalamea	Rotaliida	Homotrematidae	*Miniacina miniacea* (Pallas, 1766)	34.07	70.73

Table 2. Protection level of deep-sea protected invertebrates colonizing the floats analyzed in this study.

Protected species	***Errina aspera***	***Desmophyllum pertusum***	***Madrepora oculata***	***Pachylasma giganteum***
IUCN red list (Otero et al. 2017)		Endangered (EN)	Endangered (EN)	
CITES: Appendix II lists species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled.	*	*	*	
SPA/BD Protocol: Annex II lists species that are endangered or threatened	*	*	*	*
Bern Convention: Appendix II – Strictly protected fauna species.	*			*

Figure 1

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