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Microplastics pollution after the removal of the Costa Concordia wreck: First evidences from a biomonitoring case study☆

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ABSTRACT

Microplastics (MPs) represent a matter of growing concern for the marine environment. Their ingestion has been documented in several species worldwide, but the impact of specific anthropogenic activities remains largely unexplored. In this study, MPs were characterized in different benthic fish sampled after 2.5 years of huge engineering operations for the parbuckling project on the Costa Concordia wreck at Giglio Island. Fish collected in proximity of the wreck showed a high ingestion of microplastics compared to both fish from a control area and values reported worldwide. Also the elevated percentage of nylon, polypropylene lines and the presence of polystyrene are quite unusual for marine organisms sampled in natural field conditions, thus supporting the possible relationship of ingested microplastics with maritime operations during wreck removal. On the other hand, the use of transplanted mussels revealed a lower frequency of ingested MPs, and did not discriminate differences between the wreck and the control area. Some variations were observed in terms of typology and size of particles between surface- and bottom-caged mussels highlighting the influence of a different distribution of MPs along the water column. In conclusion, this study demonstrated that MPs pollution in the area of Costa Concordia was more evident on benthonic environment than on seawater column, providing novel insights on the possibility of using appropriate sentinel organisms for monitoring specific anthropogenic sources of MPs pollution in the marine environment.

1. Introduction

Microplastic pollution in the oceans is recognized as a worldwide phenomenon with nearly 300.000 tons of debris floating at sea surface, or accumulating on seafloor and shorelines from polar regions to the equator (Cózar et al., 2014; Eriksen et al., 2014).

The presence of microplastics with a grain size lower than 5 mm has been documented in marine organisms from different taxa and trophic levels, spanning from planktonic species, invertebrates, fish up to birds, top predators and cetaceans (Lusher et al., 2013; Fossi et al., 2014; Lima et al., 2014; Van Cauwenberghe et al., 2015; Ryan, 2015; Ryan et al., 2016). Because of their small dimensions, the uptake of microplastics in invertebrates can occur through respiration across gills (Watts et al., 2014) or by feeding activities in detritivores, deposit-, suspension- and filter-feeders (Graham and Thompson, 2009; Avio et al., 2015a). Ingestion of microplastics may depend on a combination of parameters, including size, shape and density, that determine the position of particles in the water column or sediments, and hence their availability for marine organisms (Wright et al., 2013; Avio et al., 2017).

In addition to direct uptake, marine vertebrates can ingest microplastics also through trophic transfer from preys consumption (Lusher et al., 2013). Different typologies of polymers including polyethylene and, to a lower extent, polystyrene, polyamide, polypropylene, polyester, nylon, polyethylene terephthalate, polyurethane have been recently detected in wild-caught and commercial fish species from North Pacific Subtropical and Central Gyres (Davison and Asch, 2011; Boerger et al., 2010), English Channel (Lusher et al., 2013), Portuguese coasts (Neves et al., 2015),

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Indonesia and California (Rochman et al., 2015), Central Mediterranean (Romeo et al., 2015), Central Adriatic (Avio et al., 2015b), North Sea and Baltic Sea (Rummel et al., 2016), Tokyo Bay (Tanaka and Takada, 2016). At now, such field studies were mostly aimed to expand our knowledge on baseline levels of microplastics in wild organisms, with general comparisons between geographical areas, species, biological or ecological characteristics (Lusher et al., 2013; Rochman et al., 2015; Romeo et al., 2015).

Microplastics are now being defined as emerging pollutants and the European Marine Strategy Framework Directive (MSFD, 2008/56/EC) included marine litter and microplastics among the descriptors of the Good Environmental Status. Traditional pollutants are often monitored through the quantitative comparison of tissue levels measured in organisms from different areas or sampling periods. In recent years, International Expert Committees and Organizations (like ICES, GESAMP, UNEP-MEDPOL, JPI Oceans) supported activities to define standardized protocols and enhance scientific knowledge for monitoring microplastics (Galgani et al., 2014; GESAMP, 2015; Lusher et al., 2017). With a few exceptions however, temporal trends or the impact of specific anthropogenic activities are almost unknown for microplastics, partly because the majority of data on MPs ingestion are too recent and results not always fully comparable (Lusher et al., 2017). The possibility to investigate the variations of microplastic pollution in a well-defined case study was offered by the huge maritime operations related to the removal of the 114.000 tons Costa Concordia wreck, sunk at Giglio Island on January 2012. After the emergency phase and removal of fuel, the biggest maritime salvage operation officially began on September 2012 with the parbuckling project, which allowed the re-floating of the wreck finally towed to Genoa harbor in September 2014 (http://www.theparbucklingproject.com, Fig. 1). Overall, these operations required the use of roughly 30.000 tons of steel (equivalent to 4 Eiffel Towers), 21 pylons of more than 1 m diameter drilled for 9 m in the granite sea-bottom of the island to fix 6 artificial platforms, 56 chains for the anchoring system each 58 m long and 26 tons weight, 1.189 cement grout bags for a total volume of 12.000 m^3 and more than 16.000 tons weight. Approximately 30 vessels and craft were used with 500 workers on site, further highlighting the great anthropogenic pressure of such activities on the area.

The National Civil Protection and the Italian Institute for Environmental Protection and Research (ISPRA) coordinated a large monitoring program, which excluded serious contamination events from the wreck or a consistent increase of chemical pollution in this area (Regoli et al., 2014). Nonetheless, considering the massive maritime and underwater operations, it was of interest to evaluate for the first time the possible impact of specific anthropogenic activities on microplastics ingestion in marine organisms. These effects were assessed in different benthic fish species sampled close to the wreck and in a control side of the island in summer 2014, after almost 2.5 years of activities, when refloated ship was towed away. Such comparison was performed on specimens of the same species selected among those ecologically linked to the benthonic environment, with limited spatial movements and thus suitable as bioindicators for the sampling areas. Due to the lack of wild mussel populations on the island, an active Mussel Watch approach was also performed caging these organisms at different depths of water column in both the wreck and in a control site. The combination of the 2 approaches with benthonic fish and caged mussels was expected to provide new insights on the effects of rescue operations on microplastic pollution in the sediment compartment and is seawater column, and the more appropriate use of marine organisms as specific bioindicators of anthropogenic activities at local level.

2. Materials and methods

2.1. Fish sampling

A total of 41 fish representative of different commercial species were sampled from two areas of Giglio island, in the September 2014 during the final operations for removal and towing away the Costa Concordia wreck. Fishing grounds were respectively north of Costa Concordia wreck in proximity of the stern (42°22′04.80″ N, 10°55′16.80″ E), and in a reference site located on the opposite side of island (42°37′06.36″ N, 10°86′81.37″ E), chosen as not influenced by rescue operations (Fig. 1). General hydrodynamic conditions of the 2 sampled areas can be considered as comparable, being the island exposed to currents with a predominant NW-SW direction, linked to the shape and orientation of the island itself (Cutroneo et al., 2016). Such currents, dominated by the cyclonic Tyrrhenian circulation, allow to exclude an anomalous deposition area for microplastics close to the wreck.

Gillnets with mesh of 50 mm were deployed overnight at a depth between 30 and 45 m. Common species collected in the 2 areas included *Scorpaena* sp., *Uranoscopus scaber* and *Phycis phycis* as a typically benthonic fish, and *Spondyliosoma cantharus* as bentho-pelagic species; number and characteristics of analyzed fish are given in Table 1. Gastrointestinal tracts were collected and frozen at −20 °C, until the analyses.

2.2. Mussels sampling

Translocation experiments were carried out in the period August–September 2014, at the end of the parbuckling project during the final wreck removal operations. Native mussels, *M. galloprovincialis* (5.5 ± 0.5 cm shell length), were sampled from the control area of Portonovo (Ancona, Adriatic Sea) at a depth of 8 m, immediately transported to Giglio Island and deployed within 24 h (Regoli et al., 2014). Two caging sites were selected, respectively north of Costa Concordia wreck in the same site used for fish investigation and in a reference site located in front of the Caldane beach, approximately 2 nautical miles south of the wreck (42°20′42.00″ N, 10°55′27.00″ E). To evaluate possible differences along the water column, at each site mussels were caged for 4 weeks at 2 different depths, approximately at 1.5 m from the surface and from the bottom (30–45 m). At the end of translocation periods, for every site and depth, 30 specimens, were dissected and stored at −20 °C for microplastic analyses. General data on analyzed mussels are given in Table 2.

2.3. Extraction methods and polymer characterization

Gastrointestinal tracts of fish and soft tissue of mussels were processed with a recently developed procedure based on trituration of dried samples followed by separation under density gradient and filtration under vacuum, partial digestion in 15% H_2O_2, visual sorting and FT-IR characterization (Avio et al., 2015b). Extracted particles were microscopically observed, photographed, measured at their largest cross section through an ocular micrometer, and categorized according to both size classes (1–5 mm; 0.5–1 mm; 0.1–0.5 mm; <0.1 mm) and shapes (fragments, film, pellet, line). Criteria for shape characterization were the following: fragments were considered the irregular shaped particles, like crystals, powder and flakes, rigid, thick, with sharp crooked edges and irregular shape; pellets were particles with spherical shape, like common resin pellets, spherical microbeads and microspheres; films appeared in irregular shapes, thin and flexible and usually transparent in comparison with fragments; lines or filaments were characterized by regular diameter along the particles and not