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Amount and distribution of benthic marine litter along Sardinian fishing grounds (CW Mediterranean Sea)

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ABSTRACT

Reports of marine litter pollution first appeared in scientific literature of the early 1970s; yet, more than 40 years later, no rigorous estimates exist of the amount of litter existing in the marine environment. To cope with this global urgency, this study reports the status of marine litter abundance along fishing grounds surrounding the island of Sardinia (CW Mediterranean Sea; FAO Geographical Sub-Area 11) through three years of trawl surveys. A total of 302 hauls, covering a total of 18.4 km^2 of trawled surface were carried out in the framework of the MEDITS campaign, at depths comprised between 0 and 800 m. A total of 918 items were collected and sorted, with the highest concentration observed above 200 m depth. Overall, plastic was the dominant component of litter, followed by glass and metal. Comparing our results with other areas from the Mediterranean basin, Sardinian waters showed a lower impact, possibly as a consequence of multiple factors such as the lower human population density and the low flow of the main rivers, among others. In addition, fishermen behaviour with respect to marine litter was investigated by mean of anonymous questionnaires, emphasizing the necessity to further develop management policies and infrastructures supporting litter disposal.

1. Introduction

Marine litter is a ubiquitous concern worldwide, with always increasing signs that no oceanic region is immune from this threat (Galgani et al., 2013; Pham et al., 2014; Jambeck et al., 2015). Recently, the National Oceanic and Atmospheric Administration (NOAA) has asserted that, annually, the weight of waste dumped into the oceans is three times bigger than the weight of fish caught in the same period (Maes, 2013).

Marine debris can generally be divided into land-based and marine-based items (Eryaşar et al., 2014). Land-based debris comprises all different kinds of anthropic items derived from agricultural, industrial and domestic activities (Stefatos et al., 1999; Galgani et al., 2000; Moore and Allen, 2000; Katsanevakis and Katsarou, 2004; Munari et al., 2015); while marine-based debris consist of marine litter produced by both fishing and recreational boats discharge, together with energy production activities (Dicon and Dixon, 1981, 1983; Horsman, 1982; Ribic et al., 1993; Galil et al., 1995; Hess et al., 1999; Stefatos et al., 1999; Galgani et al., 2000).

Plastic has been observed worldwide as the most present marine debris (Barnes et al., 2009) and is generally assumed, that its amount is constantly growing year by year, besides human population-density growth (Rochman et al., 2013). Some new alarming insights suggest that, by 2025, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase from tens of million tons to hundreds of million tons (Jambeck et al., 2015). In this sense, the Mediterranean Sea is also experiencing an unprecedented trend, with an estimate of >62 million macro-litter items currently floating on its surface (Suaria and Aliani, 2014). It is known that a broad spectrum of marine species is badly affected by the presence of debris (Laist, 1997). In some cases, floating litter causes physiological threat for ingestion due to misidentification (*e.g.* turtles, dolphins, fish and marine birds among the others) (Katsanevakis et al., 2007; Gregory, 2009; CBD 2012; Galgani et al., 2014; Camedda et al., 2014; Guerranti et al., 2016); in other cases, the damage is caused by mechanical abrasion and entangling (*e.g.* from big marine mammals like whales and sperm whales to the deep benthic suspension feeders) (Bo et al., 2014; Angiolillo et al., 2015; Cau et al., 2017a).

Beyond being a severe ecological concern, marine litter also has serious implications from a socio-economical perspective, affecting many sectors: a polluted beach is not only a problem for the local biota, but also an aesthetic and economic damage to nearby human

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communities making a living from tourism (*e.g.*, costs of beach cleaning and waste deposal) (Gregory, 2009; Hall, 2000; UNEP, 2009). Fishing activities are also affected by various categories of debris that could reduce the carrying capacity in trawls or cause damage to the caught and gears (Eryaşar et al., 2014).

The main existing coordinated framework to protect European seas is the Marine Strategy Framework Directive (MSFD) of the European Commission (Directive 2008/56/EC). The main goal of MSFD is to achieve a 'Good Environmental Status' (GES) by 2020, which is evaluated through 11 descriptors, the 10th of which is quantifying the marine litter.

Over the last decade, even because of the MSFD, the number of scientific literature focused on the assessment of marine debris has drastically increased (Galgani et al., 2013; Mifsud et al., 2013; de Lucia et al., 2014; Depledge et al., 2013; Pham et al., 2014; Chen, 2015; Deudero and Alomar, 2015; Neves et al., 2015; Strafella et al., 2015). Nevertheless, nowadays, the quantity and composition of benthic litter in the Mediterranean Sea has only been documented for few and, sometimes, small regions, often with different sampling approaches and devices, which does not allow for a proper comparison among different areas or studies (*e.g.*, Galgani et al., 1996, 2000; Mifsud et al., 2013; Angiolillo et al., 2015; Strafella et al., 2015; Pasquini et al. 2016; Cau et al., 2017b).

This study aims to provide an extensive survey on the impact of marine litter fishing grounds surrounding the island of Sardinia, Central-Western Mediterranean Sea. This area, is particularly relevant because of its geographical location in the heart of the Mediterranean Sea and, in addition, still misses an assessment of benthic litter present on its fishing grounds, while few estimations of human impacts were recently performed through ROV prospection on a limited portion of rocky bottoms hosting deep water corals biodiversity (Angiolillo et al., 2015; Cau et al., 2015, 2017b). Since the MSFD GES Technical Subgroup on Marine Litter (2011) emphasized how trawls provide the most suitable method to estimate the amount of litter along the continental shelf as standardize methodology, this work provides baseline information for further spatio-temporal comparisons, contributing to the development of proper conservation measures. The main goals of the present work are: (i) to assess marine litter status on the seafloor of a wide Central-Western Mediterranean area, in terms of abundance, distribution and composition; (ii) test for differences in litter composition and abundance among geographical areas and bathymetric *strata;* (iii) evaluate fishermen current role and consciousness community with respect to the threat of marine litter and their potential role in the process of seabed cleaning.

2. Material and methods

2.1. Study area

This study was carried out in Sardinian waters (CW Mediterranean Sea), which are identified by FAO's General Fisheries Commission for the Mediterranean (GFCM) as Geographical Sub-Area 11 (GSA 11). This large area comprised among the Algero-Provençal (Western Mediterranean Sea), the Tyrrhenian basin and the Sardinian Channel, is characterized by heterogeneous fishing grounds (Cau et al., 1994, Sabatini et al., 2013). In terms of geomorphology (Palomba and Ulzega, 1984; Ulzega, 1988) and hydrodynamic features (Ribotti et al., 2004; Olita et al., 2011, 2015), the southern and western coasts show a wide continental shelf with a gradual decline ending at ca. 200 m depth, while a much narrow continental shelf (few kilometres from the nearest coastline) characterizes the eastern bottoms. Indeed, the continental shelf and slope along the eastern coast are connected to the peculiar inland orographic structure and to the river basin: the presence of narrow inlets, interspaced by high and steep mountains, correspond to a very narrow continental shelf with irregular bottoms, and to a slope interspaced by very deep canyons (Palmas et al., 2017). The main water masses influencing the continental shelf-slope areas are mainly the Modified Atlantic Water (MAW), formed by the inflow of Atlantic Waters from Gibraltar (advected eastward by the Algerian Current), the Intermediate Levantine Water (ILW) coming from Eastern Mediterranean and only marginally by the deeper waters (TDW, Tyrrhenian Deep Water) (Millot, 1999).

2.2. Data collection

Data was collected during experimental trawl surveys 'Mediterranean International Bottom Trawl Survey' (MEDITS Handbook, 2013; Bertrand et al., 2002), carried out in Sardinian fishing grounds, between 2013 and 2015, covering a bathymetric range comprised between 0 and 800 m.

The main scope of the MEDITS project was to obtain information about demersal resources by monitoring distribution and demography of selected target species important to fisheries (Relini et al., 2008). Moreover, these surveys allowed the estimation of human pressure in terms of presence of litter. For the MEDITS surveys, the vessel was equipped with the GOC73 experimental bottom trawl (Fiorentini et al., 1999) with a cod-end mesh size of 20 mm. The vertical opening was comprised between 2.4 and 2.9 m and a horizontal opening comprised between 10.7 and 19.3 m, data were acquired for each haul trough the Simrad Integrated Trawl Instrumentation (ITI) system.

During the three years, a total of 302 trawl hauls (n = 102, 101 and 99 in 2013, 2014 and 2015, respectively) were carried out. According to the MEDITS protocol, sampling stations remain constant from year to year and have been distributed applying a stratified sampling scheme with random stations within five bathymetric *strata* (A: 0–50 m; B: 51–100 m; C: 101–200 m; D: 201–500 m; E: 501–800 m; Table 1) and 7 geographical zones (Fig. 1) (MEDITS Handbook, 2013). Hauls within 200 m depth lasted 30 min, while hauls between 201 and 800 m lasted 60 min each. The swept surface was calculated using the horizontal opening of the net and the distance trawled for each haul:

$$Surface\ (km^2) = \frac{distance\ (m) * horizontal\ opening\ (m)}{1000000} \quad (1)$$

Distance was obtained from the mean speed of the boat (*i.e.*, 3 knots during trawls) and the time of the haul:

$$Distance\ (m) = speed\ (miles/h) * time\ (h) * 1852 \quad (2)$$

Following MEDITS protocol, once on board, litter items contained in the catch were separated from fish and other natural elements, photographed, counted and weighted (0.01 kg precision) (Fig. 2). Collected items were divided into nine major categories: plastic, rubber, metal, glass, cloths, processed wood, paper and cardboard, other materials, undefined.

The swept area was used to standardise the mean weight and number of items (*i.e.*, kg km^{-2} and number of items km^{-2}, respectively). Since not all investigated stations showed the presence of debris, the frequency of occurrence for each litter category was estimated as the percentage of hauls containing items over the total number of hauls.

Standardized data per km^2 from each station was then used to generate distribution maps of the most important categories of debris with the open-source QGIS (QGIS Development Team, 2016). The main rivers of the island, Tirso and Flumendosa, have been geo-graphically represented, using the layers obtained from the regional open source website (www.sardegnageoportale.it), in order to observe if any trend in debris accumulation near to their mouths was present.

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