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Amount, composition, and spatial distribution of floating macro litter along fixed trans-border transects in the Mediterranean basin

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ABSTRACT

Marine litter is a major source of pollution in the Mediterranean basin, but despite legislative requirements, scant information is available for the ongoing assessment of this threat.

Using higher size classes as proxy for litter distribution, this study gave a synoptic estimation of the amount, composition, and distribution of floating macro-litter in the Mediterranean. The average amount of macro-litter was in a range of 2–5 items/km^2, with the highest in the Adriatic basin. Seasonal patterns were present in almost all study areas and were significant in the Ligurian Sea, Sardinian-Balearic basin, and Central Tyrrhenian Sea. Plastic accounted for > 80% of litter in all areas and seasons, with the highest proportion in the Adriatic Sea, Ligurian Sea, and Sicilian-Sardinian Channels; in the Bonifacio Strait, Tyrrhenian Sea, and Sardinian-Balearic basin, litter composition was instead more diverse. Spatial analysis suggested an almost homogeneous distribution of litter without evident regular aggregation zones.

1. Introduction

The term marine litter indicates any solid material which has been manufactured or processed by man and, after its use, has been discarded or disposed and reaches the marine environment (Coe and Rogers, 1997; Galgani et al., 2013a; Veiga et al., 2016). Due to current high plastic consumption patterns, high uses of disposable packaging, consumer behaviour, and illegal dumping into seawater or riversides, the amount of litter in the sea is increasingly becoming an environmental concern.

In the Mediterranean Sea, marine litter is a major threat for living marine organisms. The Mediterranean basin is one of the world's biodiversity hotspots, but it is also one of the most polluted seas worldwide (Barnes et al., 2009; Deudero and Alomar, 2015; Jambeck et al., 2015). Worldwide, over 390 species have been reported ingesting or becoming entangled in debris, such as plastic, monofilament lines, rubber, and aluminium foil (Laist, 1997; Derraik, 2002; Gall and Thompson, 2015). For the marine animals involved, this can lead to the impairment of movements and/or feeding with rebounds on reproductive output, and/or it can cause lacerations, ulcers, and death (Camedda et al., 2014; de Lucia et al., 2014; Derraik, 2002; Laist, 1997). Fishes (Boerger et al., 2010; Davison and Asch, 2011), birds (Ryan, 2008; Van Franeker and Law, 2015), cetaceans (De Stephanis et al., 2013; Gomerčić et al., 2006; Levy et al., 2009; Mazzariol et al., 2011), and marine turtles (Camedda et al., 2014; Campani et al., 2013; Lazar and Gracan, 2011; Matiddi et al., 2017; Schuyler et al., 2014; Tomás et al., 2002) are particularly affected, since it is common to find accidentally-swallowed plastic debris in their digestive tracts. In addition, large floating objects can act as a vector for spreading or introducing pest/alien species in new areas (Barnes, 2002; Aliani and Molcard, 2003; Rech et al., 2016).

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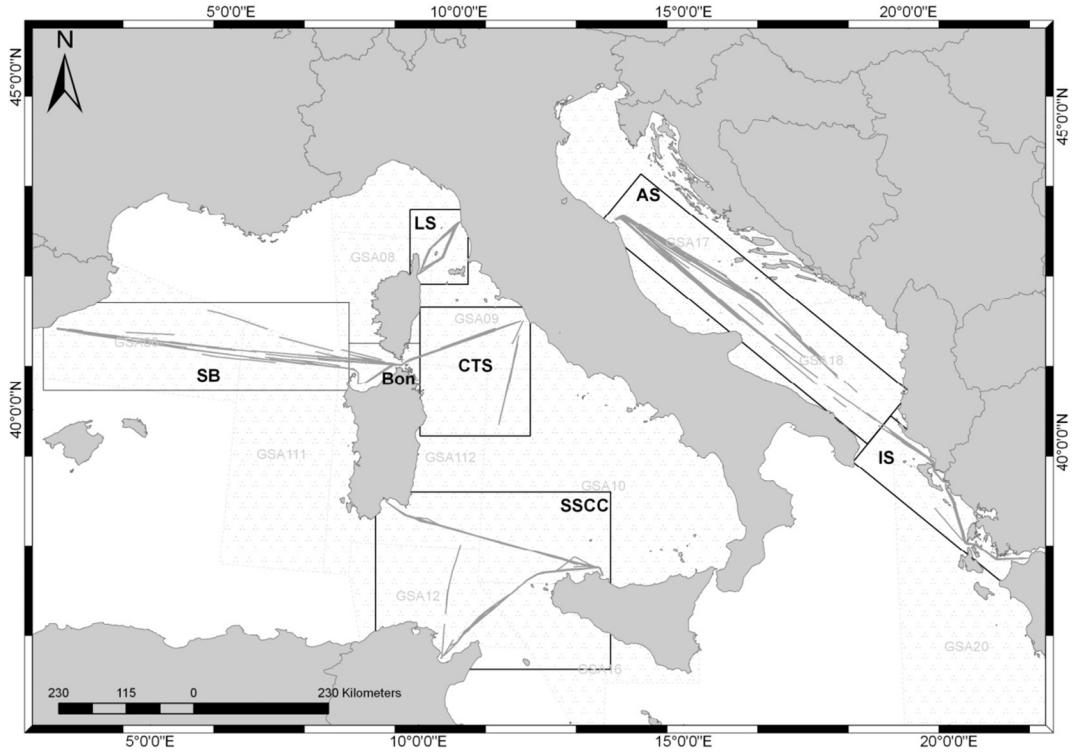

Fig. 1. The Mediterranean Sea basin with the monitored transects (grey lines) included in the seven areas of the study (LS: Ligurian Sea; SB: Sardinian-Balearic basin; Bon: Bonifacio Strait; CTS: Central Tyrrhenian Sea; SSCC: Sicilian-Sardinian Channels; AS: Adriatic Sea; IS: Ionian Sea) within the three MSFD marine subregions: the Western Mediterranean Sea, the Adriatic Sea, the Ionian and Central Mediterranean Sea.

Therefore, marine litter has a significant environmental impact (Galgani et al., 2013a) in spoiling marine ecosystem services, and it can consequently damage all the industries based on the use of marine resources. It also has an important social and economic impact by reducing the aesthetic value of the environment and public use, subsequently creating a reduction in the value of the land, tourism, and the local economy (Barnes et al., 2009; Derraik, 2002; Deudero and Alomar, 2015; Gregory, 2009; Judd et al., 2015).

The role of marine litter in impairing marine life is now widely recognized and regulated by both national and international protocols (e.g. Annex V - MARPOL Convection; Marine Litter Regional Plan - UNEP/MAP Barcelona Convention; Packaging Directive 94/62/EC and successive amending; Plastic carrier bags Directive 2015/720/UE and amending 94/62/EC). In particular in the Habitats Directive, marine litter is considered a main anthropogenic threat (code for pressure/threats H03.03) for many of the marine species listed in the Directive, and the six year report on the conservation status must also include an assessment on pressures (Crosti et al., 2017). The Marine Strategy Framework Directive (MSFD, 2008/56/EC) asks for the good environmental status (GES) of marine waters so that the properties and quantities of marine litter do not cause harm to the coastal and marine environment (descriptor 10); among the others criteria used to assess the achievement of the GES is the evaluation of trends in the amount of floating litter at the surface, including an analysis of its composition, spatial distribution, and where possible, source. All these International agreements, but in particular EU Directives, call on measures for waste reduction, and some of them are, or will soon be, enforced into State legislation (i.e. Italy with specific measures for biodegradable and compostable plastic carrier bags or France with the ban on disposable plastic tableware). As a main consequence, large scale consistent monitoring programs are essential for implementing efficient measures for the ongoing assessment of the environmental status and trends and to support decision-making processes (Cheshire et al., 2009; Galgani et al., 2013a; Ryan et al., 2009). The Monitoring programs are also crucial in increasing our understanding of the multi-level effects of "marine litter" in Mediterranean waters; recently indeed, within the "Integrated Monitoring and Assessment Programme", monitoring programs were shared among the contracting parties of the Barcelona Convection in the context of the Ecosystem Approach (EcAp) and among the EU State members in the context of the MSFD. However, scant information is available from monitoring programs designed to census marine litter and its relationship with the main affected taxa.

Macro litter floating at the surface is considered a pertinent indicator for marine litter monitoring (Di-Méglio and Campana, 2017; Thiel et al., 2003). Floating macro litter is completely included in the marine compartment, and the "timeliness" of this indicator (JRC, 2008) is the shortest since litter only successively submerges and sinks to the sea bottom, is washed ashore, or is fragmented in micro particles. Consequently, even if the mean residence times of litter on the sea surface is still poorly known, floating macro litter at the surface can give indications about what has been more recently discarded from land or sea, the main sources and sinks, and the effects of waste prevention measures (Thiel et al., 2013; Veiga et al., 2016). Since it is responsible for direct harm to marine species, monitoring macro litter can also help identify risky areas and seasons to design appropriate mitigation measures (e.g. Arcangeli et al., 2015; Di-Méglio and Campana, 2017).

Nevertheless, monitoring floating litter is challenging, since the main fraction of litter is often widespread in off-shore areas that are difficult to reach and are presumably subjected to seasonal distributional patterns due to ocean dynamics. The occurrence of floating macro litter has already been investigated around the world using boats or large observation platforms (e.g. Aliani et al., 2003; Day and Shaw, 1987; Di-Méglio and Campana, 2017; Hinojosa and Thiel, 2009; Matsumura and Nasu, 1997; Pyle et al., 2008; Shiomoto and Kameda, 2005; Suaria and Aliani, 2014; Thiel et al., 2003; UNEP-MAP, 2011; Vlachogianni et al., 2016). However, monitoring programs in off shore areas are generally expensive and difficult to run, especially further from summertime. The different approaches adopted to sample the

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