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Distribution and assessment of marine debris in the deep Tyrrhenian Sea (NW Mediterranean Sea, Italy)

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ABSTRACT

Marine debris is a recognized global ecological concern. Little is known about the extent of the problem in the Mediterranean Sea regarding litter distribution and its influence on deep rocky habitats. A quantitative assessment of debris present in the deep seafloor (30–300 m depth) was carried out in 26 areas off the coast of three Italian regions in the Tyrrhenian Sea, using a Remotely Operated Vehicle (ROV). The dominant type of debris (89%) was represented by fishing gears, mainly lines, while plastic objects were recorded only occasionally. Abundant quantities of gears were found on rocky banks in Sicily and Campania (0.09–0.12 debris m^{-2}), proving intense fishing activity. Fifty-four percent of the recorded debris directly impacted benthic organisms, primarily gorgonians, followed by black corals and sponges. This work provides a first insight on the impact of marine debris in Mediterranean deep ecosystems and a valuable baseline for future comparisons.

1. Introduction

In the past, deep-sea ecosystems were among the least studied and explored marine regions of the world, due to logistical difficulties in sampling deeper waters (Menza et al., 2008; Danovaro et al., 2010; Ramirez-Llodra et al., 2011). Recently, thanks to the availability of several technical devices (mainly Remote Operating Vehicles – ROVs), the interest of the marine scientific community has increasingly focused on these particular environments, which support high levels of habitat diversity, species longevity and provide a wealth of resources (Buhl-Mortensen et al., 2010; Ramirez-Llodra et al., 2011; Fabri et al., 2014).

The Mediterranean Sea, intensely studied over the past centuries, is considered a marine biodiversity hotspot, characterized by high levels of endemism (Bianchi and Morri, 2000). Most of the investigations carried out in this basin were conducted above 50 m depth. Only in recent times, several studies have focused on deeper assemblages characterized by a great variety and abundance of habitat-forming taxa, such as sponges and corals, providing high biomasses and structural complexity (e.g. Aguiliar et al., 2009; Bo et al., 2009; 2012a,b; Freiwald et al., 2009; Bongiorni et al., 2010; Cerrano et al., 2010; Salvati et al., 2010; Gori et al., 2011; Fabri et al., 2014).

A common assumption is that deep sea areas are less impacted by anthropogenic disturbances (e.g., trawling, human litter, pollution, mining, oil drilling) (Hinderstein et al., 2010), whereas recent research has shown that this environment is more subjected to and affected by human and natural impacts than previously thought (Davies et al., 2007; Jones et al., 2007; Bongaerts et al., 2010).

The Mediterranean Sea is located among some of the most densely populated and highly industrialized regions of the world and it is affected by intense shipping activity. The pollution of this sea has been recognized internationally as a serious problem (Galil et al.,

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1995), raising concerns regarding threats to the conservation of the rich Mediterranean biodiversity (Coll et al., 2010).

Among the sources of marine pollution, litter is an ecological and social concern and an increasing issue worldwide (Galil et al., 1995; Galgani et al., 2000; Bauer et al., 2008; UNEP, 2009). Marine debris is defined as a solid or persistent material of human origin either discarded or abandoned in the marine and coastal environment (National Academy of Sciences, 1975). It represents a significant and persistent threat to wildlife due to its low biodegradability and its potential to be ingested by or to entangle marine organisms (Laist, 1987, 1997; Bavestrello et al., 1997; Yoshikawa and Asoh, 2004; Lee et al., 2006; Bo et al., 2014). Moreover, it can serve as means of transport and habitat for alien species, altering the natural community composition (Katsanevakis et al., 2007)

Since the 1970s, several studies have faced the problem of debris in marine environments (Galgani et al., 1996; Matsuoka et al., 2005; Katsanevakis et al., 2007; Spengler and Costa, 2008; UNEP, 2009; Keller et al., 2010). In particular, beach and floating litter has been recognized as an important social problem due to its esthetic impact and its influence on public health (Hess et al., 1999; UNEP, 2009). Whereas, little information is available regarding the composition and distribution of submerged marine debris and its influence on the benthic organisms (Galgani et al., 2000; Spengler and Costa, 2008; Watters et al., 2010; Miyake et al., 2011). Once settled on the seabed, marine debris alters the habitat by providing a previously absent hard substrate that organisms can eventually cover. Moreover, the debris covering the sediment prevents gas exchange and interferes with life on the seabed (UNEP, 2009). Finally, lost fishing gears, such as lines and nets, and anchors may cause direct physical damage to benthic organisms (Donohue et al., 2001; Yoshikawa and Asoh, 2004; Bauer et al., 2008; Heifetz et al., 2009; Bo et al., 2013, 2014), since abrasive actions cause the progressive removal of tissues from sessile organisms (Bavestrello et al., 1997).

Various methods have been employed to quantify marine debris on the sea floor and the ones currently used in deep sea environments include: bottom trawlers, sonar, submersibles and ROVs (Spengler and Costa, 2008). In particular, submersibles and ROVs have been used to investigate benthic litter on the continental slope and the abyssal plain (Galgani et al., 1996, 2000; Freese, 2001; Fosså et al., 2002; Heifetz et al., 2009; Watters et al., 2010; Miyake et al., 2011; Mordecai et al., 2011; Bergmann and Klages, 2012; Fabri et al., 2014). Visual data, in form of videos and pictures, have been demonstrated to be useful in obtaining quantitative data on deep-sea litter; even if debris cannot be directly inspected and measured (Spengler and Costa, 2008; Watters et al., 2010). The most important feature of these methods is that they can be effectively applied to all sea bottom types, including complex rocky habitats, where some debris (especially fishing gears) may be found in abundance (Watters et al., 2010). Moreover, these methods do not cause any impact on the explored environments; whereas the bottom trawling gear method can affect the seafloor (Gage et al., 2005).

In the last decade, there has been an increased interest from the scientific communities on how commercial fisheries and the presence of debris have affected the sea bottom. However, the majority of studies have investigated the impact of mobile gears, such as trawls and dredges, on soft bottom community structure (e.g. Kaiser et al., 2000; Freese, 2001; Koslow et al., 2001; Cryer et al., 2002; Fosså et al., 2002; Maynou and Cartes, 2011; Mangano et al., 2013) or the effect of ghost fishing (e.g. Matsuoka et al., 2005; Ayaz et al., 2006; Baeta et al., 2009). While, the impact of lost fishing gears on sessile organisms are less documented (Bavestrello et al., 1997; Eno et al., 2001; Freese, 2001; Chiappone et al., 2002, 2005; Asoh et al., 2004; Yoshikawa and Asoh, 2004; Heifetz et al., 2009; Bo et al., 2013, 2014), and little research has been focused on the impact of debris on rocky environments (e.g. Watters et al., 2010; Mordecai et al., 2011; Fabri et al., 2014).

Although, the Mediterranean basin is considered a particularly sensitive ecosystem (Bianchi and Morri, 2000; Coll et al., 2010), at present little is known about the extent of litter, especially in rocky areas deeper than 100 m (Galgani et al., 1996, 2000; Orejas et al., 2009; Madurell et al., 2012; Watremez, 2012; Bo et al., 2013, 2014; Fabri et al., 2014).

The aim of this study is to draw a baseline quantitative picture, by means of ROV, on the marine debris in three Italian regions (Tyrrhenian Sea, NW Mediterranean). This work attempts to evaluate, through a large number of observations, the occurrence and abundance of different types of debris and their potential impacts on benthic fauna. The study has been carried out in a marine area where there is a high level of tourism, commercial fishing and coastal urban population with respect to other areas of the Mediterranean basin.

2. Material and methods

2.1. Study areas

The data on marine debris were collected during three different surveys financed respectively by the Italian Ministry for Environment, Land and Sea (MATTM) and by Sardinian Regional Council aimed to explore rocky coral assemblages and to study red coral (*Corallium rubrum*) deep-dwelling populations. The cruises were carried out on-board the R/V *Astrea* of ISPRA along the south Tyrrhenian coast (NW Mediterranean Sea, Italy), respectively in June-July 2010 in Campania and September–October 2011 in Sicily and Sardinia (Fig. 1).

Along the north coast of Campania six areas were explored (Fig. 1A), located in the Gulf of Naples and in the Sorrentine Peninsula. The Gulf of Naples is a SW oriented coastal embayment with an average depth of 170 m and a continental shelf with variable width ranging between 2.5 and 10–15 km offshore (Ribera d'Alcalà et al., 2004). The seafloor is characterized by a rough morphology, influencing hydrological features of the gulf, characterized by both oligotrophic and eutrophic systems and exhibiting a strong seasonal variability. The outer part of the Gulf of Naples is more directly influenced by offshore Tyrrhenian oligotrophic waters (Cianelli et al., 2011), that when move inside the gulf, creates a basin-scale cyclonic gyre transporting offshore the land runoff. On the contrary, when the Tyrrhenian current moves southeastward, the inner part remains separated forming anticyclonic gyres (De Maio et al., 1985; Cianelli et al., 2011). This condition prevents the renovation of the coastal waters, thus favoring stagnation and consequently pollution and high sedimentation rate (De Maio et al., 1985; Cianelli et al., 2011). The Gulf of Naples is among the most densely inhabited Italian areas and it is heavily influenced by the land runoff. Along its coasts approximately 30 ports and more than 300 maritime constructions are located (Uttieri et al., 2011). The intense anthropic pressures determine a strong impact on the marine ecosystem and its waters present hydrographic and biological properties reflecting anthropic stress (Ribera d'Alcalà et al., 1989; Zingone et al., 2010).

In Sardinia, eleven areas located in the southern part of the island (Fig. 1B), and distributed through the Sardinia Channel and the Tyrrhenian Sea were explored. The seafloor morphology is different from the south eastern coast westwards; on the western side, a wide shelf area characterized by volcanic outcrops extends from the San Pietro Island to the Gulf of Cagliari, while a smaller shelf area (2 km of extension on average) with several canyon heads occurs along the south eastern shelf margin (Sulli, 2000;