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Loggerhead sea turtles (*Caretta caretta*): A target species for monitoring litter ingested by marine organisms in the Mediterranean Sea☆

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ABSTRACT

Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Ingestion of marine litter can have lethal and sub-lethal effects on wildlife that accidentally ingests it, and sea turtles are particularly susceptible to this threat. The European Commission drafted the 2008/56/EC Marine Strategy Framework Directive with the aim to achieve a Good Environmental Status (GES), and the loggerhead sea turtle (*Caretta caretta*, Linnaeus 1758) was selected for monitoring the amount and composition of litter ingested by marine animals. An analogous decision has been made under the UNEP/MAP Barcelona Convention for the protection of the Mediterranean Sea, following the Ecosystem Approach. This work provides for the first time, two possible scenarios for the Marine Strategy Framework Directive GES, both related to "*Trends in the amount and composition of litter ingested by marine animals*" in the Mediterranean Sea. The study validates the use of the loggerhead turtle as target indicator for monitoring the impact of litter on marine biota and calls for immediate use of this protocol throughout the Mediterranean basin and European Region. Both GES scenarios are relevant worldwide, where sea turtles and marine litter are present, for measuring the impact of ingested plastics and developing policy strategies to reduce it. In the period between 2011 and 2014, 150 loggerhead sea turtles, found dead, were collected from the Italian Coast, West Mediterranean Sea Sub-Region. The presence of marine litter was investigated using a standardized protocol for necropsies and lab analysis. The collected items were subdivided into 4 main categories, namely, IND-Industrial plastic, USE-User plastic, RUB-Non plastic rubbish, POL-Pollutants and 14 sub-categories, to detect local diversity. Eighty-five percent of the individuals considered (n = 120) were found to have ingested an average of 1.3 ± 0.2 g of litter (dry mass) or 16 ± 3 items.

1. Introduction

1.1. Marine litter in the environment

Marine litter includes all items that have been made or used by

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people and are directly or indirectly discarded in the sea. It includes those items transported from inland areas to the sea via rivers, drainage or through sewage systems, and those transported by the wind. These are materials of various origins, usages and composition, where plastics usually represent the main component (Galgani et al., 2013; MSFD TS-ML, 2011).

Waste pollution is a hazard for the entire marine ecosystem. Marine litter may harm marine animals in different ways: many species are entangled by macro litter, while other species can ingest smaller items accidentally (Laist, 1987; Schuyler et al., 2014a,b). In certain cases, ingestion occurs because marine species are unable to discriminate marine litter, while in other cases they confuse items with prey (Barnes et al., 2009; Derraik, 2002; Mrosovsky, 1981; Schuyler et al., 2014b). According to the recent works of Kühn et al. (2015, 2016), more than 500 animals are threatened by litter, including planktonic organisms (de Lucia et al., 2014; Fossi et al., 2012), sea bird species (Spear et al., 1995; van Franeker et al., 2011), fishes (Boerger et al., 2010; Lusher et al., 2013), marine mammals (de Stephanis et al., 2013; Baulch and Perry, 2014) and all species of sea turtles listed as globally vulnerable or endangered (IUCN, 2013; Schuyler et al., 2014a). Generally, the effects of ingested plastics range from direct mortality to gastrointestinal blockage, lacerations, reduced feeding and absorption of toxic compounds (Bjorndal et al., 1994; Bjorndal, 1997; Bugoni et al., 2001; Kühn et al., 2015).

Sea turtles have been used for many years as pollution bio-indicators (Foti et al., 2009; Keller et al., 2006). Generally considered as a flagship species, sea turtles are able to attract the attention of different social groups and increase awareness of bad habits that affect marine environments (Frazier, 2005).

According to the opinions of 35 specialists from 13 nations involved in sea turtle biology and conservation, sea turtles have been studied more than most marine fauna. Nevertheless, management actions and their evaluation are often hindered by the lack of data on turtle biology, human interactions, population status and threats (Hamann et al., 2010). In particular, their recommendations highlight the need to evaluate the impact of plastics and other marine litter. Marine litter is a global threat for biodiversity and internationally standardized methods are essential for regular monitoring of litter.

It has been estimated that more than 62 million waste items are floating in the Mediterranean (Suaria and Aliani, 2014; Suaria et al., 2016). The majority of this litter originates from land sources but it can also arrive in the Mediterranean Sea from the Atlantic Ocean, floating via the Strait of Gibraltar (Galgani et al., 2013; MSFD TS-ML, 2011). The problem of marine litter in the Mediterranean has been considered by different studies on beach litter (Gabrielides et al., 1991; Golik and Gertner, 1992), accumulation on the sea floor (Galgani et al., 1995, 2000), and floating litter (Aliani et al., 2003). In a recent work aimed to identify the accumulation zones of floating litter in the world's oceans, using numerical models (Lebreton et al., 2012), the Mediterranean Sea was found to have one of the highest concentrations of marine litter in the world.

1.2. Policy strategy

In 2008, the European Commission adopted the Marine Strategy Framework Directive (European Commission, 2008/56/EC) whose objective is to achieve Good Environmental Status (GES) by 2020, considering 11 qualitative Descriptors. Marine litter is Descriptor 10 of the Directive and GES is reached when the "*properties and quantities of marine litter do not cause harm to the coastal and marine environment*" (European Commission, 2008/56/EC; Galgani et al., 2010). One of the "Indicators" to be monitored is known as: "*Trends in the amount and composition of litter ingested by marine animals*". In 2010, following the Commission Decision on criteria and methodological standards on GES of marine waters (European Commission, 2010/477/EU), the Directorate-General for the Environment (DG ENV) established a Technical Subgroup on Marine Litter (TSG-ML) to address gaps and further develop Descriptor 10. For many years, the Northern Fulmar (*Fulmarus glacialis*, Linnaeus, 1761), has been used as a target indicator for litter ingestion by biota in the Northern part of the European Sea. The OSPAR system of Ecological Quality Objectives (EcoQO) notes that: "There should be less than 10% of Northern Fulmars having 0.1 g or more plastic in the stomach in samples of 50–100 beached fulmars from each of 5 different regions of the North Sea over a period of at least 5 years" (van Franeker, 2004; van Franeker et al., 2011). In 2011, DG ENV asked for further development of the indicator and the methods implemented in the North Sea, and adaptation to other regions. This involved the identification of additional marine species to be used as indicators in Mediterranean EU countries.

Expert researchers of the TSG-ML elaborated a number of basic requirements for biota, which can be considered for the purposes of monitoring and selecting target species (MSFD-TS, 2013), such as:

- "***Sample availability***: *Samples of a monitoring species should be available with adequate numbers of individuals over a wider span of time and space.*"

The loggerhead sea turtle (*Caretta caretta*, Linnaeus, 1758) is adopted worldwide as a bio-indicator of environmental conditions such as pollution (Foti et al., 2009; Keller et al., 2006). The loggerhead is the most abundant chelonian in the Mediterranean (Casale and Margaritoulis, 2010; Margaritoulis et al., 2003). Many injured or dead specimens are available because of the network of sea turtle Rescue Centres established in the Mediterranean (Ullmann and Stachowitsch, 2015; RAC-SPA, 2004), and the large number of accidental captures in fishing gears along the Italian coasts (Cambiè, 2011; Casale et al., 2013; de Lucia et al., 2011).

- "***Regular plastic consumption***: *Frequency of occurrence and amounts of plastic found in stomachs should be high enough to allow detection of trends over time and geographical patterns.*"

Loggerheads may ingest plastic bags mistaken for jellyfishes (Fukuoka et al., 2016; Mrosovsky, 1981; Mrosovsky et al., 2009; Plotkin et al., 1993) when they feed in neritic and pelagic habitats. The regular occurrence of solid waste in the stomach contents is documented worldwide (Bjorndal et al., 1994; Hamann et al., 2010. Hoarau et al., 2014; Lazar and Gracan, 2011; Santos et al., 2016) and along the Mediterranean coast (Bentivegna et al., 2013; Camedda et al., 2013, 2014; 2015; Campani et al., 2013; Casale et al., 2008, 2016; de Lucia et al., 2012; Matiddi et al., 2015; Travaglini et al., 2013; Tomás et al., 2002).

- "***Marine feeding habits***: *stomach contents should only reflect the marine environment. For example, many gulls ingest litter, but partially feed on land including rubbish dumps.*"

Loggerhead sea turtles feed exclusively at sea although they frequent different and disparate areas during their life, inhabiting both oceanic and neritic zones. In general, adults/sub-adults use the sea bottom and the water column as feeding compartment, while early juveniles prefer the sea surface; for these reasons, they are likely to ingest waste in different habitats during their life (Bjorndal, 1997; Casale et al., 2008; Lazar et al., 2010).

Each of the above requirements supports the use of the loggerhead sea turtle as an assessment and monitoring tool for litter ingested by marine organisms. After some considerations and a