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Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: The case studies of the Mediterranean basking shark (*Cetorhinus maximus*) and fin whale (*Balaenoptera physalus*)

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ABSTRACT

The impact of microplastics (plastic fragments smaller than 5 mm) on large filter feeding marine organisms such as baleen whales and sharks are largely unknown. These species potentially are ingesting micro-litter by filter feeding activity. Here we present the case studies of the Mediterranean fin whale (*Balaenoptera physalus*) and basking shark (*Cetorhinus maximus*) exploring the toxicological effects of microplastics in these species measuring the levels of phthalates in both species. The results show higher concentration of MEHP in the muscle of basking shark in comparison to fin whale blubber. These species can be proposed as indicators of microplastics in the pelagic environment in the implementation of Descriptor 8 and 10 of the EU Marine Strategy Framework Directive (MSFD).

1. Introduction

Are the largest filter feeder marine organisms affected by any of the smallest human debris? How can 5 mm plastic debris affect 24 m long marine mammals and 7 m long sharks? In this paper we investigate the invisible war between the Mediterranean fin whale (*Balaenoptera physalus*) and basking shark (*Cetorhinus maximus*) against the smallest marine debris and their potential toxicological effects. Why microplastics may pose a threat to these species?

In 2009, 230 million tons of plastics were produced globally, Europe is the second larger producer of plastic (PlasticsEurope, 2012). According to sea-based sources such as shipping, fishing and transport activities (Derraik, 2002) and land-based sources such as tourism, adjacent industries or river inputs (Browne et al., 2010), plastics are entering our seas and oceans, “posing a complex and multi-dimensional challenge with significant implications for the marine and coastal environment and human activities all over the world” (UNEP, 2009).

For the Mediterranean environment marine litter (including plastic) represents a serious concern (UNEP, 2009; UNEP/MAP, 2011; MSFD, 2011). Three billions of litter items float or cover the sea bottom in the Mediterranean Sea, which 70–80% is plastic waste. The increasing of marine litter is mainly related to waste production in-land with an average amount of municipal solid waste in the EU of 520 kg per person/year and a projected increase to 680 kg per person/year by 2020.

The incidence of debris in the marine environment is cause for concern. It is known to be harmful to marine organisms and to human health (Derraik, 2002; Gregory, 2009; Wright et al., 2013), it represents a hazard to maritime transport, it is aesthetically detrimental, and may also have the potential to transport contaminants (Mato et al., 2001; Teuten et al., 2009). Marine debris, and in particular the accumulation of plastic debris, has been identified as a global problem alongside other key issues such as

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climate change, ocean acidification and loss of biodiversity. Impacts vary depending on the type and size of debris and the organisms affected.

The occurrence of microplastics (MPs – generally defined as fragments less than 5 mm in dimension – NOAA) in the ocean is an emerging world-wide concern. Due to high sorption capacity of plastics for hydrophobic organic chemicals, the adherent chemicals can be transported by MPs traveling long distances (Lee et al., 2013). MPs can serve as carrier of persistent organic pollutants (POPs) in marine ecosystems (Rochman et al., 2013; Koelmans et al., 2013). Small plastic particles in the environment are of particular concern as a wide range of organisms, from plankton to larger vertebrates such as turtles or whales, may ingest them (Wright et al., 2013). In particular, while evidence of macro and microplastic negative effects on marine organism is growing, little scientific investigation has focused on the problem in the Mediterranean. More information is required about plastic and microplastic inputs, spatial and temporal distributions, including transport dynamics, interactions with biota and potential accumulation areas.

Microplastics found in the marine environment are likely to be derived either directly or through the fragmentation of larger items. MPs can be subdivided by usage and origin as: i) Primary, pellets used in the plastics industry, and in certain applications such as abrasives; ii) Secondary, fragments resulting from the degradation and breakdown of larger items.

Microplastics floating over water are transported by ocean currents and are found in regions where water circulation is relatively stationary or on sea shores (Hidalgo-Ruz et al., 2012). A number of heavily produced low density plastics (e.g. polypropylene, polyethylene, and polystyrene) have been identified as the main components of MPs, and these have various shapes and sizes, ranging from a few micrometers to a few millimeters (Hidalgo-Ruz et al., 2012; Martins and Sobral, 2011).

Microplastics are accumulating at the sea surface, especially within the neustonic habitat (Ryan et al., 2009) that included a specifically adapted zooplankton fauna. Basking shark and particularly fin whale, being characterized by a long life span, could be chronically exposed to these persistent contaminants both leaching from microplastic ingestion and degradation and through the food chain.

Recent studies have identified potential effects of plastic particles mainly in invertebrates and fish, including: I) transport of persistent, bioaccumulating and toxic (PBT) substances from plastics; II) leaching of additives such as phthalates from the plastics; III) physical harm (Wright et al., 2013).

However, there is still little monitoring data on the occurrence of microplastics in large marine vertebrates. Until the paper of Fossi et al. (2012), no data were reported on the impacts of microplastics on large filter feeding marine organisms such as baleen whales or sharks. These species potentially undergo to the ingestion of microlitter by filtrating feeding activity.

In this paper we focus on the case study of the two large Mediterranean filter feeders, the fin whale and basking shark.

The basking shark (*C. maximus* Gunnerus, 1765) is a very large, filter-feeding cold-water and migratory pelagic species. It is widely distributed throughout temperate waters but only regularly seen in few favored coastal locations. It may be considered frequently present in the Mediterranean, especially in the North-Western part, mainly in spring (Mancusi et al., 2005). Basking sharks are regular seasonal visitors in coastal waters of Sardinia, where between 2005 and 2012 a total of 111 individuals (including 14 captures) were recorded within "Operazione Squalo Elefante", the first dedicated basking shark research project in the Mediterranean basin (de Sabata and Clò, 2010). The basking shark is one of only three shark species that filter seawater for planktonic prey. It captures zooplankton by forward swimming with an open mouth, so that water passively flows across the gill-raker apparatus. The rates of gastro-intestinal evacuation in basking sharks are unknown; however, filtration rates have been estimated using measurements of swimming speed and mouth gape area. Seawater filtration rate for a 7 m basking shark (mouth gape area ca. 0.4 m^2) swimming at a speed of 0.85 $m\ s^{-1}$ was calculated to be 881 $m^3\ h^{-1}$; if it fed constantly in food patches, a so 5–7 m long basking shark might consume 30.7 kg of zooplankton in a day (Sims, 2008). During this massive filtering activities the basking shark could undergo to the ingestion and degradation of microplastics.

Due to its slow growth rate, lengthy maturation time, long gestation period, probably low fecundity, probable small size of existing populations – some severely depleted by targeted fisheries – the basking shark is classified by the IUCN Red List of Threatened Species as "Endangered" in the North-East Atlantic Ocean and "Vulnerable" in the Mediterranean Sea (Fowler, 2009; Cavanagh and Gibson, 2007). It is listed in all four major International conventions (Bern, CMS, CITES, Barcelona). Every year basking sharks are accidentally caught in small-scale fisheries throughout the Mediterranean region.

The fin whale (*B. physalus*, Linnaeus 1758), one of the largest filter feeders in the world, feeds primarily on planktonic euphausiid species. This baleen whale, the only resident mysticete in the Mediterranean Sea, forms aggregations during the summer on the feeding grounds of the Pelagos Sanctuary Marine Protected Area (MPA). The fin whale is a wide ranging cetacean. It is found in largest water masses of the world, from the Equator to the polar regions, but, in spite of its cosmopolitan distribution, it is classified as "Endangered" by the IUCN Red List of Threatened Species. Fin whale feeding, in general, has been described as the largest biomechanical event that has ever existed on earth (Croll and Tershy, 2002). Fin whales capture food by initially swimming rapidly at a prey school and then decelerating while opening the mouth to gulp vast quantities of water and schooling prey. Fin and blue whales foraging on krill off the coast, concentrate their foraging effort on dense aggregations of krill (150–300 m) in the water column during the day, and near the surface at night (Croll et al., 2005).

With each mouthful, the fin whales can trap approximately 70,000 l of water. Since their feeding activities include surface feeding and, they undergo to the risk of the ingestion of MPs occurring in the sea surface and consequent degradation once ingested by the organism. Seawater filtration daily is 5893 m^3 rate with 913 kg of plankton consumed daily.

One major toxicological aspect of MPs in the marine environment and, consequentially, on filter-feeding organisms, is the influence that microplastics may have on enhancing the transport and bioavailability of PBT persistent, bioaccumulative, and toxic substances. These two large filter feeders species (fin whale and basking shark) could therefore face risks caused by the ingestion and degradation of microplastics.

PBT compounds, such as dichlorodiphenyltrichloroethane (DDT) or polychlorinated biphenyls (PCBs), are of particular concern for human health and the environment. Plastic debris can be a source of PBT chemicals. Some plastic debris can release toxic chemicals that have been added to enhance the performance of the plastic (such as phthalates, nonylphenol, bisphenol A, brominated flame retardants). Plastic debris may also be a sink for toxic chemicals: toxic chemicals from the environment can sorb to the debris and to be released once inside the organism (Engler, 2012; Lithner et al., 2011). Since PBT chemicals, generally, have low solubility in marine water they tend to migrate into water microlayers where they tend to migrate to microdebris or in the sediments also