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Note

# First evidence of presence of plastic debris in stomach of large pelagic fish in the Mediterranean Sea

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ABSTRACT

This study focuses, for the first time, on the presence of plastic debris in the stomach contents of large pelagic fish (*Xiphias gladius*, *Thunnus thynnus* and *Thunnus alalunga*) caught in the Mediterranean Sea between 2012 and 2013. Results highlighted the ingestion of plastics in the 18.2% of samples. The plastics ingested were microplastics (<5 mm), mesoplastics (5–25 mm) and macroplastics (>25 mm).

These preliminary results represent an important initial phase in exploring two main ecotoxicological aspects: (a) the assessment of the presence and impact of plastic debris on these large pelagic fish, and (b) the potential effects related to the transfer of contaminants on human health.


## 1. Introduction

The presence of marine debris in the oceans is a growing problem for the marine ecosystem's health (Derraik, 2002) and the monitoring of this issue is, on the Mediterranean scale, one of the objectives of the European Marine Strategy Framework Directive (MFSD) (Galgani et al., 2013a, 2014). A recent study (Eriksen et al., 2014), estimated that 5.25 trillion plastic particles weighing some 269,000 tons are floating on the surface of the sea. More recently (Seltenrich, 2015), plastics in consumer products have become subject to increasing scrutiny regarding their potential effects on human health, through their presence in the food chain.

Several studies highlighted the ubiquitous presence of plastic and other anthropogenic debris in marine habitats as well as its introduction in the marine food web through ingestion by several marine organisms, ranging from zooplankton to apex predators (Fossi et al., 2012, 2014; Cole et al., 2013; Ivar do Sul and Costa, 2014). The impact of debris ingestion by marine fauna is more evident in those areas characterized by convergence currents, where litter is accumulated (Moore et al., 2001); although this phenomenon has larger proportion in some oceanic waters (e.g.: Boerger et al., 2010; Davison and Asch, 2011; Ingraham and Ebbesmeyer, 2001; Choy and Drazen, 2013; Lusher et al., 2013), plastic debris was also found in the guts of Mediterranean organisms such as turtles, teleosts, elasmobranches, cetacean, invertebrates (e.g.: Lazar and Gračan, 2011; Anastasopoulou et al., 2013; Deudero and Alomar, 2014). In the latter area, data on debris ingestion mainly concerns cetaceans and turtles (Deudero and Alomar, 2014), whereas little information is available on fish, largely inferred by stomach content analysis (Deudero, 2001; Massutí et al., 1998; Madurell, 2003; Karakulak et al., 2009). These papers consist in dietary studies reporting also brief lists of debris found in the stomach content. Recently, Anastasopoulou et al. (2013) focuses for the first time on the study of debris ingested by fish (both elasmobranchs and teleosts) inhabiting the deep-waters of the Eastern Ionian Sea.

The present paper investigates, for the first time, the occurrence of plastic debris in the stomach content of three large pelagic fish, which are top predators in the Central Mediterranean Sea: swordfish *Xiphias gladius* Linnaeus 1758, bluefin tuna *Thunnus thynnus* (L. 1758), albacore *Thunnus alalunga* (Bonnaterre, 1788). Considering the hazard associated to the transfer of chemicals from ingested debris to biota, this study provides an important contribution to the knowledge and understanding of plastic occurrence in these

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**Table 1**
Mean values and range of fish length and weight for each predator (SWO = swordfish; BFT = bluefin tuna; ALB = albacore). The number of stomach containing plastics is also reported.

| Species | Number of stomachs examined | Mean fish length ± SD (cm) | Length range (cm) | Mean fish weight ± SD (kg) | W eight range (kg) | Number of stomachs with plastic |
|---|---|---|---|---|---|---|
| SWO | 56 | 145.4 ± 25.4 | 63–206 | 41.2 ± 19.8 | 2.5–109 | 7 |
| BFT | 34 | 156.4 ± 22.1 | 123–201 | 58.7 ± 32.2 | 30–165 | 11 |
| ALB | 31 | 79.0 ± 13.7 | 64–110 | 2.8–16.2 | 2.8–16.2 | 4 |
| Total | 121 | | | | | 22 |

**Table 2**
Frequency of occurrence, color, size of plastic fragments found in the stomach contents of each predator (SWO = swordfish; BFT = bluefin tuna; ALB = albacore).

| Plastic debris | SWO | BFT | ALB |
|---|---|---|---|
| Number | 9 | 16 | 4 |
| Frequency (%) | 12.5 | 32.4 | 12.9 |
| Color | Transparent, white, yellowish, gray | Transparent, white, yellowish, blue, red | Transparent, white, blue |
| Length range (mm) | 3.69–55.40 | 0.63–164.50 | 3.60–58.52 |
| Width range (mm) | 1.51–16.50 | 0.69–60.57 | 2.43–17.95 |
| Thickness range (mm) | 0.02–1.22 | 0.05–5.79 | 0.02–9.58 |
| Weight range (g) | 0.0001–0.0158 | 0.0001–5.5124 | 0.0001–0.4285 |

commercial fish, given also their importance in Mediterranean catches and human consumption.

## 2. Material and methods

A total of 56 swordfish, 36 bluefin tuna and 31 albacore were collected from 2012 to 2013 during an experimental survey in the Central Mediterranean Sea (Eolian Islands, Strait of Messina) by harpoon, hook and lines and drifting longline. Specimens were measured (fork length FL for tunas; lower jaw fork length LJFL for swordfish; centimeters) and weighed (total weight *W* in kg). Stomachs were removed after capture and frozen. In laboratory stomach contents were examined in order to identify plastic debris, which were counted, grouped by color, weighed and measured (length, width, thickness) by the stereomicroscope Zeiss Discovery V.8 coupled with Axiovision digital image processing software. The plastics ingested were categorized as microplastics (<5 mm), mesoplastics (5–25 mm) and macroplastics (>25 mm) following Galgani et al., 2013b. The frequency of plastic debris occurrence (*F*%) in these fish was estimated by the proportion of the individuals examined where plastics were present in the stomach contents.

## 3. Results

Overall, 29 plastic fragments were identified from the stomach content of 22 large pelagic fish (18.2%) and in particular 7 swordfish (12.5%), 11 bluefin tuna (32.4%) and 4 albacore (12.9%) (Table 1). Table 1 reports mean values and range of fish length and weight together with the information on stomach containing plastics.

Plastic fragments had different shapes and color; transparent and white plastic fragments occurred in all top predators, blue particles were found in bluefin tuna and albacore whereas yellowish plastics were observed in swordfish and bluefin tuna stomachs (Table 2).

The plastic debris differed in size in each top predator as reported in Fig. 1. Mesoplastics were more abundant in swordfish stomachs (44.4%) whereas albacore ingested more microplastics (75.0%). In bluefin tuna macroplastics and mesoplastics had the same proportion (31.3%). In Fig. 2 some examples of plastic debris found in the stomach contents are shown.

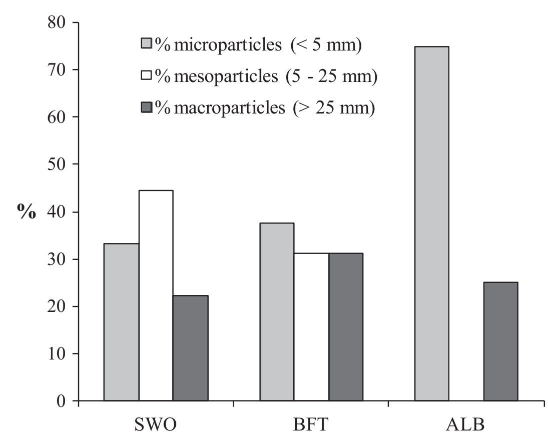


**Fig. 1.** Percentage of size categories of plastic fragments in the stomach contents of each predator (SWO = swordfish; BFT = bluefin tuna; ALB = albacore).

## 4. Discussion

Recent studies (Fossi et al., 2012) reported data on the impact of microplastics on large filter-feeding organisms such as baleen whales or sharks in the Mediterranean sea, which can potentially ingest micro-litter. Until now, no data has been reported on top predators in the same environment. The occurrence of plastic in the stomach contents of the bluefin tuna could be explained by the opportunistic feeding strategy of this species, highlighted in a recent study carried out in the same area (Battaglia et al., 2013). However, plastics were also found in albacore, which is defined as a specialist feeder (Consoli et al., 2008). Plastic particles (ranging from macro- to microplastics) could be ingested during the predation action (primary ingestion), in particular, when the hunts fish small prey aggregated in schools. This kind of feeding behavior may increase the probability of ingesting plastic together with prey for several reasons: (a) tuna often round up and chase prey schools to shallow water where they are more easily caught, but where plastic fragments are more abundant (given their buoyancy); (b) feeding on aggregated prey may increase the ingestion of unwanted particles, as the predator is not focusing on a single large prey, but on several small prey. Secondary ingestion cannot be excluded, since the time of plastic degradation and consequently

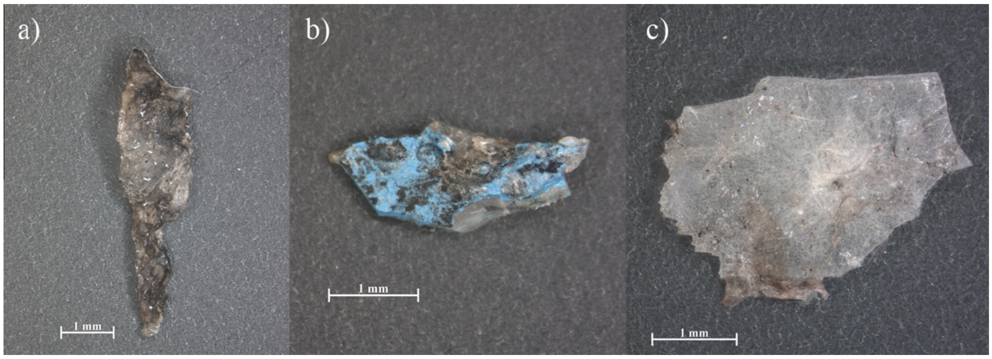


**Fig. 2.** Examples of plastic debris found in the stomach content of swordfish (a), bluefin tuna (b) and albacore (c).

bioaccumulation is quite long and this increases the probability of finding microplastic ingested by prey in the stomach of the predator. The ingestion of microplastics by mesopelagic fish, which represent one of the main food items of *T. thynnus* (Battaglia et al., 2013), have already been reported in the Pacific Ocean (Boerger et al., 2010; Davison and Asch, 2011). The same hypothesis can be formulated for swordfish. In fact, it has been reported in a recent study (Romeo et al., 2009), that some prey, e.g. the bogue *Boops boops*, identified in the stomach of swordfish collected in the Central Mediterranean Sea, have a high percentage of microplastic in the gut (Deudero and Alomar, 2014).

These preliminary results represent an important initial phase in exploring two main ecotoxicological aspects: (a) the assessment of the presence and impact of plastic debris on these large pelagic fish, and (b) the potential effects related to the transfer of contaminants on human health.

One major toxicological aspect of plastic litter in the marine environment and, consequentially, on marine organisms, is enhancing the transport, accumulation, and bioavailability of Persistent, Bioaccumulative and Toxic (PBT) substances, in addition to toxic chemicals that have been added, during the production procedure, to enhance the performance of the plastic (such as phthalates, nonylphenol, bisphenol A, brominated flame retardants). The direct (plastic additives) and indirect (PBT) ecotoxicological effects of micro- and macro-plastic exposure on these large pelagic fish and the potential significance of the impact on human consumption need future extensive investigation.

Results of the study underline the ubiquitous presence of plastic in the Mediterranean marine biota, including the water column where large pelagic fish live and feed. Moreover, the high frequency of micro, meso and macro plastics in the bluefin tuna, represents a further warning signal for a species listed in the IUCN Red List (A2bd ver 3.1, 2014) as "Endangered Species". Potential reproductive alteration has been reported in swordfish and bluefin tuna in the Mediterranean Sea in a previous paper (Fossi et al., 2006). These results show a positive correlation between the level of PBT compounds (PAH, PCB, PBDE, DDT) and alteration on the reproductive system. These levels are biomagnified due to the transfer through the food chain. Moreover, the presence of plastic debris in the diet of this top predator fish could represent an additional source of pollutant, such as PBT compounds and plastic additives, which are suspected endocrine disruptors.

Finally, the implications of these findings for humans who consume large pelagic fish containing microplastics are not yet understood. Government, academic, and independent sources interviewed in a recent article (Seltenrich, 2015) on the topic of seafood safety almost unanimously expressed a mix of skepticism and concern toward the thought of ocean plastics posing a human health risk. Without exception, they also advocated for further research. For this reason, linked to the high consumption of these species in the Mediterranean scale, this topic requires deeper investigation in the future.

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