



First data on plastic ingestion by blue sharks (*Prionace glauca*) from the Ligurian Sea (North-Western Mediterranean Sea)

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(Article begins on next page)

1 **Title:**

2 **First data on plastic ingestion by blue sharks (*Prionace glauca*) from the Ligurian**
3 **Sea (North-Western Mediterranean Sea)**

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10 **Abstract:** Plastic pollution in the oceans represents a risk for the marine environment and biota.
11 Few studies have focused so far on plastic ingestion by sharks in the Mediterranean Sea. The aim
12 of this paper was to determine for the first time the ingestion of plastic litter by blue sharks
13 (*Prionace glauca*), an opportunistic and widespread species in Mediterranean Sea, caught in the
14 Pelagos Sanctuary SPAMI (North-Western Mediterranean Sea). The analysis of the ingested debris
15 in the stomach contents was performed following the MSFD Descriptor 10 standard protocol
16 developed for sea turtles and implemented with FT-IR spectroscopy technique. The results showed
17 that the 25.26% of samples ingested plastic debris of wide scale of sizes from microplastics (<5
18 mm) to macroplastics (> 25 mm). The FT-IR analysis showed that ingested plastic debris, mainly
19 transparent sheetlike items, were composed by polyethylene. Considering that in the
20 Mediterranean Sea Blue shark is categorized as “Critically Endangered” by IUCN List and, besides,
21 given that this species is a top predator of the pelagic habitat, the high amount of plastic litter
22 found in this research contributes to highlight the real impact of plastic debris both on the marine
23 environmental in a protected area and also on a species with an important ecological role in the
24 food web.

25 **Keywords:**

26 Marine litter
27 Plastic ingestion
28 Mediterranean Sea
29 Blue sharks

30 **1 Introduction**

31 Plastic pollution is present in all the oceans and seas of the world, including the Mediterranean
32 Sea, which is considered one of the most impacted areas by marine litter in the world, with an
33 average concentration calculated at 0.243 items /m² (Cózar et al., 2015). Plastic waste can cause
34 physical damages to marine organisms like entanglement and smothering; moreover, plastic
35 ingestion can induce lacerations and ulcerating wounds in the digestive tract, leading to general
36 debilitation (Gregory, 2009; Kühn et al., 2015). Plastics ingestion is the most commonly studied

37 phenomenon, since it could lead to more serious consequences, including changes in satiety and
38 hunger, decrease of the power and capacity of predation, energy disturbance, impairment of
39 reproduction, endocrine disruption, as well as more specific effects such as oxidative stress,
40 dysfunctions in immune defences and neurotransmission, genotoxicity and, as extreme
41 consequences, drowning and death (Avio et al., 2015; Coe and Rogers, 1997; Gregory, 1978;
42 Hjelmeland et al., 1998; Jackson, G.D. et al., 2000; Net et al., 2015; Rochman et al., 2014; Wright et
43 al., 2013).

44 Neutrally buoyant plastic items are the most suitable to be ingested (Outi Setälä et al., 2015), both
45 intentionally and accidentally (Cliff et al., 2002; Laist, 1997). Moreover, plastic debris can be eaten
46 either directly from the water column (primary ingestion), or indirectly (secondary ingestion) from
47 plastic-contaminated food, also in large pelagic species (Romeo et al., 2015). The potential
48 deleterious effects of ingestion underline the urgency to evaluate the impact of plastics on the
49 whole marine food web and the related consequences for end consumers (Galloway, 2015; Koch
50 and Calafat, 2009; UNEP, 2011), especially in hot spot area of plastic pollution such as the
51 Mediterranean Sea.

52 Although plastic ingestion by marine organisms has been investigated in several Mediterranean
53 species (Deudero and Alomar, 2015; Fossi et al., 2018), only few data are available on cartilaginous
54 fish from the Mediterranean Sea; these are mainly focused on demersal species such as *Galeus*
55 *melastomus* (Alomar and Deudero, 2017; Carrassón et al., 1992; Cartes et al., 2016; Deudero and
56 Alomar, 2015; Madurell, 2003), *Centroscymnus coelolepis* (Carrassón et al., 1992; Cartes et al.,
57 2016), *Etmopterus spinax* (Aikaterini Anastasopoulou et al., 2013; Cartes et al., 2016; Deudero and
58 Alomar, 2015; Madurell, 2003). Due to their role as apex predators and their wide distribution,
59 sharks could be exposed to plastic ingestion and to other environmental contaminants, through
60 the food web with bioaccumulation and biomagnification processes (Alves et al., 2016; Serrano et
61 al., 2000; Strid et al., 2007). Therefore, they are considered as sentinel organisms for marine
62 pollution biomonitoring studies (Alves et al., 2016; Marcovecchio et al., 1991; Vas, 1991).

63 The blue shark (*Prionace glauca*) is one of the most wide ranging shark in the Mediterranean Sea
64 (Garibaldi and Orsi Relini, 2000) and worldwide (Stevens, 2009). It is an oceanic and pelagic
65 species with a highly migratory behaviour, for reproductive and feeding purposes; it is also able of
66 huge vertical movements, from the surface to over 600 m depth (Camhi et al., 2008; Campana et
67 al., 2011; Garibaldi and Orsi Relini, 2000; Rondinini et al., 2013; Sims et al., 2016). Blue sharks have
68 an opportunistic feeding strategy (Camhi et al., 2008; Carvalho et al., 2011; Garibaldi and Orsi

69 Relini, 2000) with a non specific diet (Cortés, 1997; Lopez et al., 2010; Vanadia et al., 2004), and
70 are commonly considered "sea shelters" playing a key role in the Mediterranean food web. Most
71 of their preys are pelagic, but bottom fishes and floating elements are also present in their diet
72 (Camhi et al., 2008; Garibaldi and Orsi Relini, 2000). The IUCN Red List assessed the blue shark
73 globally conservation status as "Near Threatened" (Stevens, 2009) however, in the Mediterranean
74 basin, whose population is separated and independent from the North Atlantic one (Kohler et al.,
75 2002; Leone et al., 2017; Megalofonou et al., 2009), is categorized as "Critically Endangered" (Sims
76 et al., 2016). In this area, blue shark is one of the most incidental by-catch species of the long line
77 fisheries targeting swordfish ofalbacore and bluefin tuna (Camhi et al., 2008; De la Serna et al.,
78 2002; Garibaldi, 2015; Garibaldi and Orsi Relini, 2000; Megalofonou et al., 2005a, 2005b). The
79 Mediterranean population was estimated to face a 90% decline over 30 years and it is increasingly
80 closer to overfishing (Sims et al., 2016). Although the presence of various types of debris (metals,
81 plastic) in *P. glauca* stomachs has been occasionally detected, both in the Mediterranean Sea
82 (Garibaldi and Orsi Relini, 2000) and worldwide (McCord and Campana, 2003; Teodoro Vaske
83 Júnior et al., 2009) scale, no specific analysis and detailed data were carried out.

84 Thus, the aim of this work was to investigate, for the first time, plastic ingestion in samples of blue
85 sharks from the North Western Mediterranean (Ligurian Sea), in the Specially Protected Area of
86 Mediterranean Importance (SPAMI), Pelagos Sanctuary. To achieve this goal standardized
87 protocols, developed for the analysis of other marine species, were applied to analyze the
88 stomach contents in order to quantify and characterize the litter ingested.

89 **2 Materials and methods**

90 **2.1 Study area and sampling**

91 From 1999 to 2015 a total of 139 blue sharks (*P. glauca*) were sampled in the Western Ligurian
92 Sea, in an offshore area in front of the coast of Sanremo, Imperia and Nice (Fig. 1). This area is part
93 of the Pelagos Sanctuary, a Specially Protected Area of Mediterranean Importance (SPAMI)
94 established in the North-Western Mediterranean Sea for the conservation of cetaceans.



95

96 **Figure 1. Sampling area**

97 The blue sharks were caught by longlines, deployed both at surface during the night and to a
 98 maximum depth of 600 m during the day. Samples were taken directly on board of fishing vessels
 99 or at landing , where total length measurement (TL in cm), total weight (TW in g) and sex data
 100 were recorded. Specimens were grouped into two size classes on the basis of their total length :
 101 TL ≤120 cm and TL >120 cm.

102 According to Megalofonou et al. (2009), below the threshold of 120 cm samples were considered
 103 juveniles () whereas over this value adults (TL >120 cm) (Tab. 1).

104

105 **Table 1. Specimens of *P. glauca* sampled subdivided by size class: juveniles (TL≤120 cm) and adults (TL >120 cm).**

106

		Juveniles		Adults	
		Male	Female	Male	Female
n° of specimens		29	31	27	52
Total length (cm)	<i>Min</i>	52	66	121	122
	<i>Max</i>	115	115	262	199
	<i>Mean ± S.D.</i>	90.94 ± 39.58	94.95 ± 40.05	157.4 ± 39.81	157.78 ± 39.83

107

108 During the necropsy, the stomach of blue sharks were isolated, by means of clamps, to prevent
 109 spillage of the contents and removed. The stomachs section was opened and the contents

110 collected. The contents were inspected for the presence of any tar, oil, and preserved in 70%
111 alcohol before the subsequent laboratory analysis. The liquid portion, mucus and digested
112 unidentifiable matter were removed by washing the contents through a 1 mm metal sieve with
113 pre-filtered water. The remaining portion was placed in a petri dish and examined under the
114 microscope. Marine litter items were identified from other ingested material, isolated and placed
115 in closed glass jars, for subsequent counts and characterization.

116 **2.2 Marine litter count and characterization**

117 Marine litter was separated from other ingested residue and categorized according to the “Litter
118 in Biota” protocol included in the “Monitoring Guidance for Marine Litter in European Seas”
119 (MSFD Technical Subgroup on Marine Litter, 2013) following the “Guidance of monitoring of
120 Marine Litter in European Seas” protocol developed for sea birds and sea turtles. All items were
121 identified through direct visual sorting of the stomach content using the microscope (Wild
122 Herrtbrugc M5A), isolated and dried at room temperature. The dried items were counted,
123 weighed (Mettler AE 260 DeltaRenge) and scanned with a printer-scanner (Canon MP280).
124 Different measurements (length (cm), width (cm) and area (cm²)) of each item were obtained
125 processing the scanned images with ImageJ program. Items were also classified based on their
126 colors. All plastic items were analyzed by Fourier transform infrared (FT-IR) spectroscopy
127 technique (Agilent Cary 630 spectrophotometer) to identify the plastics polymer composition
128 (Hummel, 2002). For each plastic fragment found, depending on its heterogeneity (including
129 degradation status and fouling presence), three measurements were carried out. Only spectra
130 matching more than 80% with reference polymers present in libraries (Agilent Polymer Handheld
131 ATR Library, Agilent Elastomer Oring and Seal Handheld ATR Library and Agilent ATR General
132 Library) were accepted (Fossi et al., 2017; Lusher et al., 2013). In order to avoid the risk of
133 contamination, stringent laboratory and sampling procedures were carried out to ensure the
134 quality of the results.

135 **3 Results**

136 **3.1 Stomach content of plastic items**

137 Of all the 139 blue shark stomachs examined, 44 (31.4 %) were found completely empty, due to
138 the fact that some specimens could vomit up food during capture (Stevens, 1973). As a
139 consequence, in order to determine the frequency of marine litter in gastric contents, only full
140 contents (95) were considered (Tab.2).

141

142 **Table 2. Number of specimens of blue sharks analyzed, number of full stomachs and frequency of occurrence of**
143 **marine litter in the stomach contents of juveniles (TL≤120 cm) and adults (TL >120 cm).**

	Juveniles			Adults			All
	M	F	Tot.	M	F	Tot.	
n° individuals analyzed	29	31	60	27	52	79	139
Full stomachs	17	26	43	17	35	52	95
Frequency of full stomachs with marine litter (%)	41.18%	30.77%	34.88%	17.65%	17.14%	17.31%	25.26%

144

145 Overall, 109 items of marine litter were found, amounting to a total weigh of 6.14 g; the majority
146 (107 items) were represented by user plastic items and only 2 debris were categorized as rubbish.

147 In 24 out 95 specimens analyzed, the presence of plastic litter was recorded (25.26%) with a range
148 from 1 to 30 items per sample. The total mass of plastics ingested was 3.37 g (range: 0.0001-0.977
149 g), with a total area of 30693.61 cm² (range: 0.019-27.65 cm²).

150 Analyzing the presence/absence of marine litter in different size classes, juvenile blue sharks
151 seems more likely to ingest marine litter than adults showing higher percentage of occurrence
152 (Table 2). The greater quantity of plastics was found into the stomach of juveniles (65 items),
153 amounting to a total weight of 2.836 g (range: 0.0001-0.977 g) and total area of 30615cm² (range
154 0.23-27644.99 cm²). Adults ingested 42 plastic pieces, with a total weight 0.5302 g (range: 0.0001-
155 0.5718 g) and a total area 7860.18 mm² (range 0.01871-18.907 cm²). In addition, no relevant
156 differences were observed between sex (Table 2).

157 **3.2 Characteristics of total plastic items**

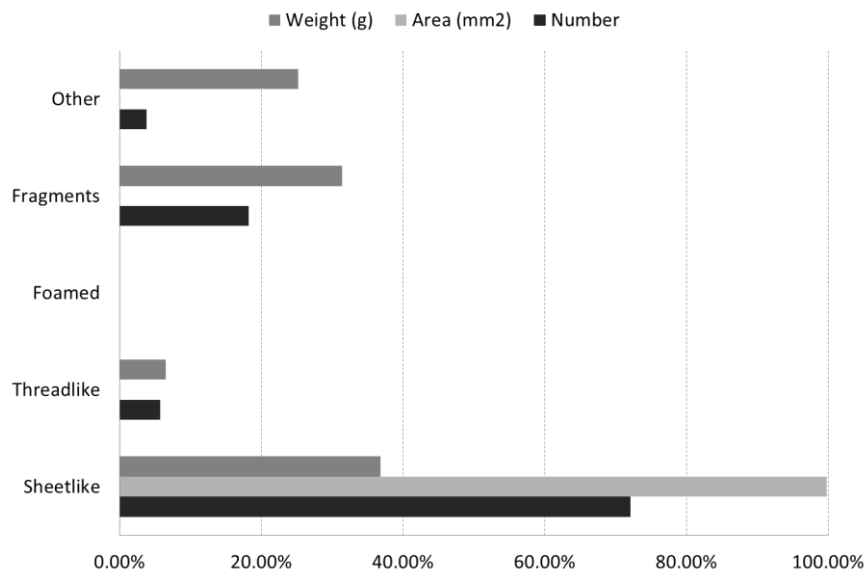
158

159 Ingested plastic items were classified based on their shape: sheetlike, threadlike, fragments,
160 foamed and other typologies (other). The majority of plastic items were sheetlike (72.38%),
161 followed by fragments (18.10%), threadlike (5.71%), others (3.81%). No plastic foams were
162 detected.

163 Total sheetlike items not only had greater external area, but also accounted for the highest
164 weight; the area of threadlike, fragments and other was irrelevant (<1%) (Fig.2).

165

166

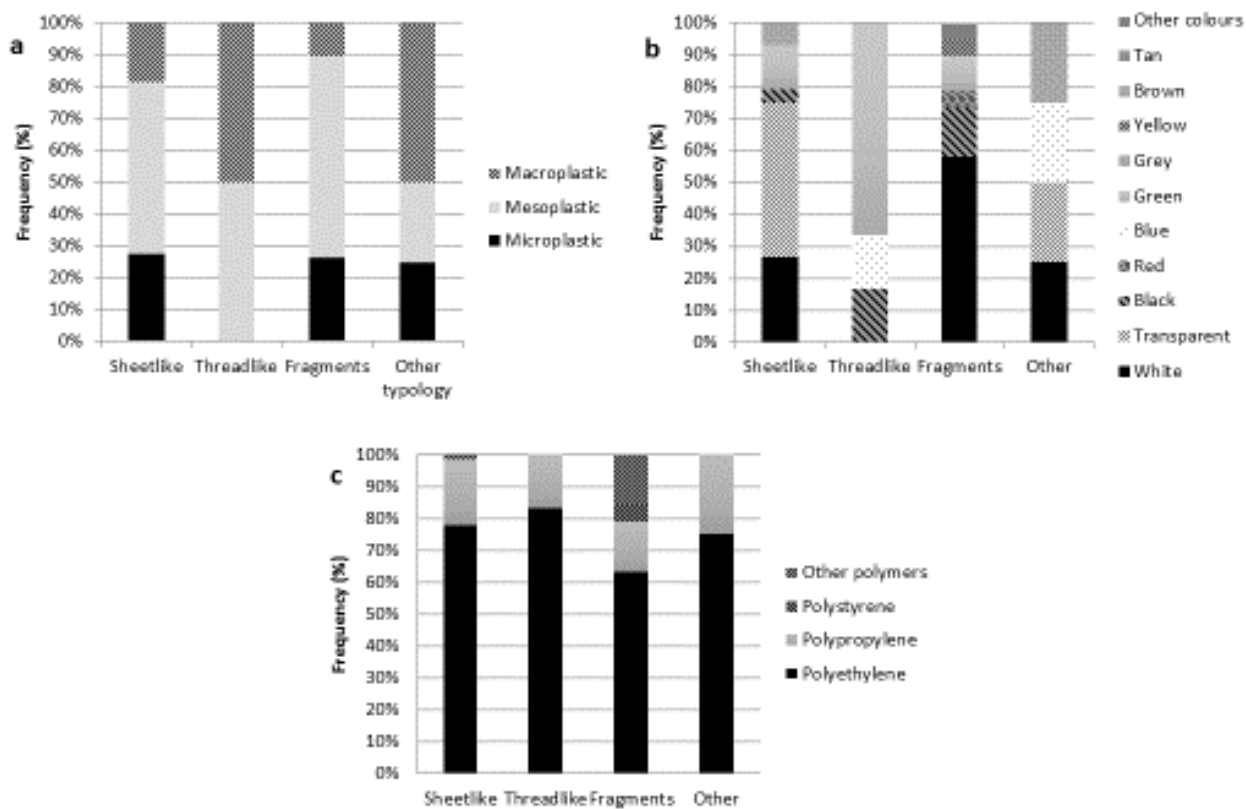


167

168 **Figure 2. Weight, area and number of different user plastics categories found in the in gastric contents of blue**
 169 **sharks.**

170 Items were also grouped in three size classes following (Galvani et al., 2013b): microplastics
 171 (<5mm), mesoplastics (5-25 mm), macroplastics (>25 mm). All size classes were present in
 172 sheetlike, fragments and other typologies of plastic. More than 50% of plastic pieces belong to
 173 mesoplastics, followed by microplastics (25.71%) and macroplastics (20%). Mesoplastics and
 174 macroplastics were present in all category of plastic; in particular mesoplastics accounted for
 175 39.05% and 11.43% of sheetlike and fragments, respectively; the threadlike type was composed of
 176 the same quantity of mesoplastics and macroplastics (Fig.3a). A similar proportion of microplastics
 177 was present in sheetlike, fragments and other, whereas they were absent in the threadlike type.

178



179
 180 **Figure 3. Categories of plastics (sheetlike, threadlike, fragments and other) in relation to a) sizes (macroplastic:>25**
 181 **mm, mesoplastic: 5-25 mm, microplastic:<5 mm) b) colors and c) type of polymers.**

182 Sheetlike plastics showed all colors, except red, which is present just in fragment category, and
 183 blue, present in threadlike and other categories. However sheetlike fragments were represented
 184 mainly by transparent and white pieces (47.37 and 28.95%, respectively); fragments were mostly
 185 white, black and green. Threadlike pieces were composed of 4 green pieces, one blue and one
 186 black. Other class was composed of white, transparent, blue and grey colors in the same
 187 proportion (Fig.3b).

188 With regards to the polymer type, FT-IR analysis revealed that the majority of plastic pieces
 189 (75.2%) were made of polyethylene (PE), both low density and high density followed by of
 190 Polypropylene (PP) (19.1%), and a small proportion of polystyrene (PS) (1.90%) and other
 191 polymers (3.8%).

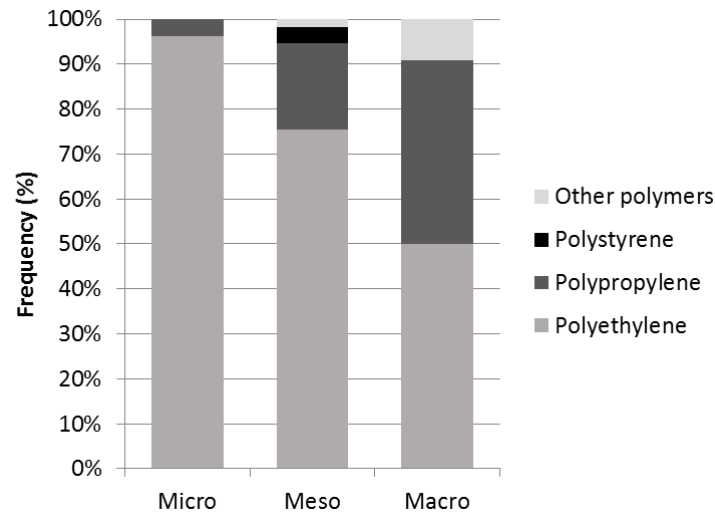
192 PE and PP were present in all plastic items independent of shape (Fig. 3c).

193 On the contrary, other polymers were present only in 4 fragments made of Polyacrylate polyester,
 194 Ethylene propylene diene, Polyester and Polyvinyl chloride (PVC).

195 With regards to the relationship between the polymer type and plastic item size, PE and PP
 196 represented the main polymers in all size classes, in particular in Mesoplastics. PS and other
 197 polymers were much less represented and only in meso- and macroplastics, respectively (Fig. 10).

198 All types of polymers were present in mesoplastics, with 41% represented by PE.

199



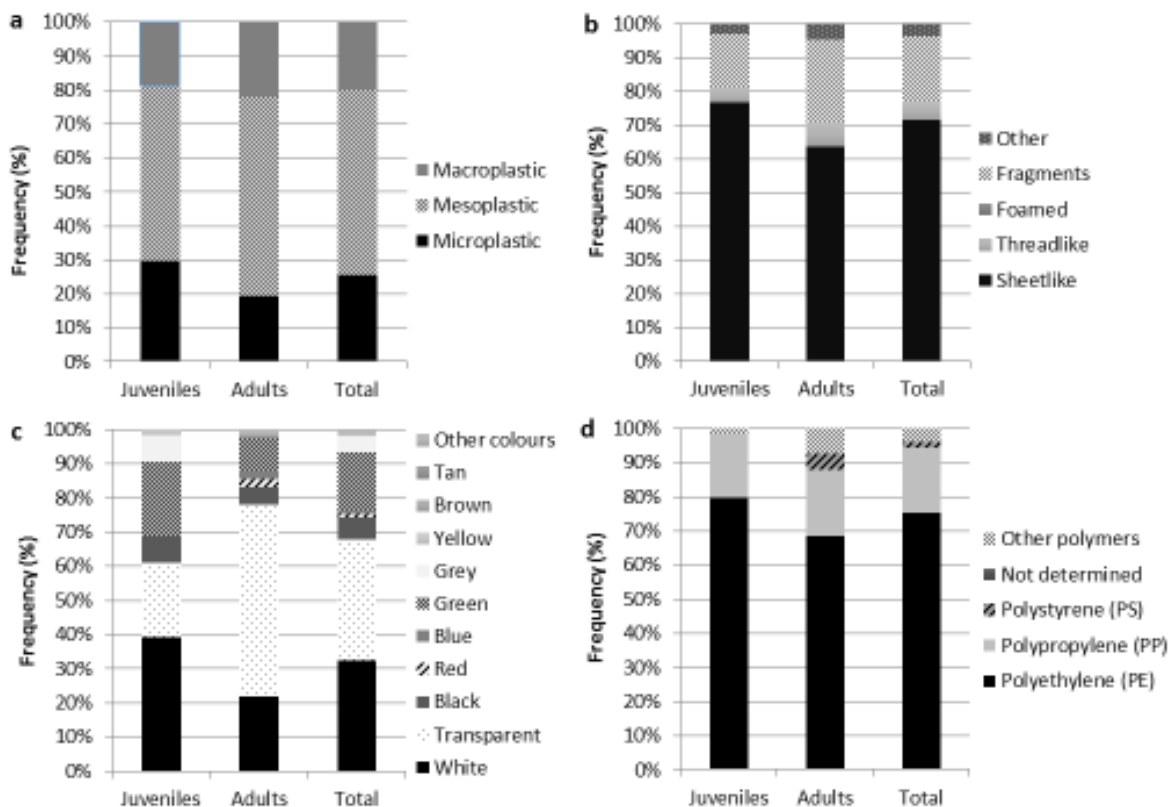
200

201 Figure 4. Frequency of plastic polymers in relation to size.

202

203 3.3 Characteristics of plastic in different sizeclasses

204 Mesoplastics represented the majority of plastic ingested in both juveniles and adults. The
205 percentage of microplastics was higher in juveniles than in adults (Fig.5a).



206

207

208 **Figure 5. Analysis of plastic ingested by the different sizeclasses, juveniles (n=43) and adults (n=52) in relation to a)**
 209 **size, b) shape, c) color and d) type of polymer**

210 With regards to size, in both classes the most widespread typology was sheetlike, 54.69% and
 211 60.98%, respectively in juveniles and adults (Fig.5b). Transparent and white were the most
 212 common colors in adults (56.15%) and in juveniles (39.1%) respectively (Fig. 5c).

213 In juveniles, transparent and green are present with the same percentage (21.9%) and together
 214 constitute quite 45% of plastics (Fig. 5c). Adults showed more differences among color categories:
 215 white (22%) and green (9.8%) are the most signified colors after transparent (Fig. 5c).

216 Both in juveniles and in adults PE was the most abundant polymer (79.69% in juveniles, 68.29% in
 217 adults), followed by PP, however present in much smaller quantities than PE in both classes
 218 (<20%) (Fig.5d).

219

220 **4 Discussions and conclusions**

221 This paper represent the first study on occurrence and characterization of marine plastic litter in
 222 stomachs of blue sharks in the Mediterranean Sea and worldwide scale, given that data available
 223 so far regarding marine litter ingestion these species came from feeding ecology studies.

224 It is difficult to compare among different studies on amounts, types of ingested debris because
 225 the methods used for marine litter quantification and characterization are not standardized (Fossi
 226 et al., 2018), however comparing the occurrence of plastic ingested by sharks species sampled in
 227 different areas of Mediterranean Sea, with data obtaining in the present study (Tab. 3), *P. glauca*
 228 shows high occurrence of plastic items (25% of specimens with full stomachs), second only to
 229 *Squalus acanthias*, caught in the Adriatic Sea where the authors isolated, from 9 specimens,
 230 plastics particles smaller than 1 mm (Avio et al., 2015).

231 **Table 3. Comparison of plastic occurrence in different species of shark caught in the Mediterranean Sea. The specific**
 232 **areas of sampling are: AS (Adriatic Sea), IS (Ionian Sea), Eastern Mediterranean Sea (EMS), CMS (central**
 233 **Mediterranean Sea), WMS (Western Mediterranean Sea), Aegian-Levantine Sea (ALS) and the habitat (demersal**
 234 **and pelagic)**

Order	Species	GSA	Study area	Habitat	N° of stomaches analyzed	Plastic occurrence (%)	Bibliography
Carcharhiniformes	<i>Prionace glauca</i> (Linnaeus, 1758)	GSA09	WMS	Pelagic	95	25.3%	Present study
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque,	GSA20	IS, CMS	Demersal	741	3.2%	Anastasopoulou et al. 2013

	1810)							
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque, 1810)	Eastern Mediteranean	ALS	Demersal	1350	3.0%	Madurell 2003; Deudero & Alomar 2015	
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque, 1810)	Eastern Mediteranean	ALS	Demersal	125	16.8%	Alomar & Deudero 2017	
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque, 1810)	GSA05	WMS	Demersal	37	10.8%	Carrassón et al.1992	
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque, 1810)	GSA05	WMS	Demersal	125	15.2%	Cartes et al.2016	
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque, 1810)	GSA05	WMS	Demersal	95	6.3%	Cartes et al.2016	
Carcharhiniformes	<i>Galeus melastomus</i> (Rafinesque, 1810)	GSA05	WMS	Demersal	125	16.8%	Alomar & Deudero 2017	
Carcharhiniformes	<i>Scyliorhinus canicula</i> (Linnaeus, 1758)	GSA20	IS, CMS	Demersal	1	0%	Anastasopoulou et al. 2013	
Squaliformes	<i>Centrophorus granulosus</i> (Bloch & Schneider, 1801)	GSA20	IS, CMS	Demersal	5	0%	Anastasopoulou et al. 2013	
Squaliformes	<i>Centroscymnus coelolepis</i> (Barbosa du Bocage & de Brito Capello, 1866)	GSA05	WMS	Demersal	69	2.9%	Carrassón et al.1992	
Squaliformes	<i>Centroscymnus coelolepis</i> (Barbosa du Bocage & de Brito Capello, 1866)	GSA05	WMS	Demersal	11	9.1%	Cartes et al.2016	
Squaliformes	<i>Centroscymnus coelolepis</i> (Barbosa du Bocage & de Brito Capello, 1866)	GSA05	WMS	Demersal	54	1.8%	Cartes et al.2016	
Squaliformes	<i>Etmopterus spinax</i> (Linnaeus, 1758)	GSA20	IS, CMS	Demersal	16	6.2%	Anastasopoulou et al. 2013	
Squaliformes	<i>Etmopterus spinax</i> (Linnaeus, 1758)	Eastern Mediteranean	ALS	Demersal	323	6.0%	Madurell 2003; Deudero &	

	1758)	Mediterranean					Alomar 2015
Squaliformes	<i>Etmopterus spinax</i> (Linnaeus, 1758)	GSA 05	WMS	Demersal	9	11.1%	Cartes et al. 2016
Squaliformes	<i>Squalus acanthias</i> (Linnaeus, 1758)	GSA 17	AS	Demersal	9	44.4%	Avio et al. 2015
Squaliformes	<i>Squalus acanthias</i> (Linnaeus, 1758)	GSA20	IS, CMS	Demersal	10	0%	Anastasopoulou et al. 2013
Squaliformes	<i>Squalus blainville</i> (Risso, 1827)	GSA20	IS, CMS	Demersal	75	1.3%	Anastasopoulou et al. 2013

235

236 Blackmouth catshark (*Galeus melastomus*) is the most studied species of shark in Mediterranean
 237 Sea for plastic ingestion (Table 3), with an occurrence between 3% and 17%, much lower than
 238 those obtained in the present study.

239 A factor that could explain the differences observed between the blue shark and blackmouth
 240 catshark is the feeding habitat: while *P. glauca* is a pelagic shark which feeds from the surface to
 241 more than 600 m depth (Campana et al., 2011; Rondinini et al., 2013) following the prey
 242 distribution in mesopelagic waters (Bres, 1993; Garibaldi and Orsi Relini, 2000), blackmouth
 243 catshark is demersal and epibatial species, which lives from 150 m up to 1400 m depth and
 244 therefore they feed in deep water and on the seafloor (A. Anastasopoulou et al., 2013; Bres,
 245 1993). Although plastics litter is ubiquity in the water column, the mean concentrations of plastic
 246 floating on the surface are higher than on the seafloor (Eriksen et al., 2014; Galgani et al., 1996).

247 In addition, the high occurrence of plastic in the stomach contents of the blue sharks is also
 248 related to their opportunistic feeding strategy, playing the role of scavenger. Their position at the
 249 top of the Mediterranean food web could also increase the probability of exposure to secondary
 250 plastic ingestion as described in other Mediterranean top predator (Romeo et al., 2015).

251 Concerning the size of the specimens, juvenile blue sharks seem more likely to ingest marine litter
 252 than adults. These findings are in accordance with other studies on the occurrence of plastic
 253 ingestion in adults and juveniles of different marine species (Acampora et al., 2014; Bravo
 254 Rebolledo et al., 2013; Day et al., 1985; Denuncio et al., 2011; Hutton et al., 2008; Kühn et al.,
 255 2015; Plotkin and Amos, 1990; Schuyler et al., 2014; van Franeker et al., 2011). Such differences
 256 are probably related to their foraging strategy; in fact, larger (older) specimens are more skilled
 257 of predation having a major foraging efficiency, whereas young individuals may have a more
 258 opportunistic strategy (Bres, 1993; Kühn et al., 2015).

259 User plastics constitutes the principal category of marine litter found in blue sharks confirming the
 260 composition of marine litter observed in marine turtles (Campani et al., 2013; Gramentz, 1988;

261 Lazar and Gračan, 2011; Matiddi et al., 2017; Tomás et al., 2002), in large pelagic fishes (Karakulak
262 et al., 2009; Romeo et al., 2015) and in sharks (Alomar and Deudero, 2017; Aikaterini
263 Anastasopoulou et al., 2013; Deudero and Alomar, 2015; Garibaldi and Orsi Relini, 2000). Another
264 analogy with the Loggerhead turtle (*Caretta caretta*), a widespread species in the Mediterranean
265 Sea with high opportunistic behavior and selected as bioindicator species for the marine litter by
266 the MSFD Technical Subgroup on Marine Litter (2013), is the predominance of sheetlike and
267 fragments among shape categories (Camedda et al., 2014; Campani et al., 2013; Tomás et al.,
268 2002).

269 Mesoplastics are the predominant size class ingested, both in juveniles and in adults, followed by
270 microplastics and macroplastics. The little amount of macroplastics may be related to the
271 predominant smaller size of the shark's preys.

272 Furthermore, another factor often considered to influence the ingestion of plastic debris is their
273 color, probably in relation to those of their usual preys, which could trick the predators (Kühn et
274 al., 2015; Wright et al., 2013). The variable amount of plastic items of different colors detected in
275 the present work could be also in relation to the opportunistic feeding strategy of the blue shark
276 (Kühn et al., 2015). With regards to the possible impact of plastic items ingested, independent of
277 the amount, size and shape the chemical composition may play a major role (Wright et al., 2013).

278 Polyethylene (PE), both low density and high density followed by of Polypropylene were the most
279 abundant plastic types identified in the present study. These are in fact widespread used in
280 packaging, grocery sacks, stretch-wrap, balloons, cables or pipe insulations (Peacock Andrew J.,
281 2000). These low density polymers (Andrady, 2011) represent about 70% of floating plastics in the
282 Western of Mediterranean Sea (Suaria et al., 2016). The plastic debris isolated from the stomach
283 of the blue sharks analyzed in this study, reflect the composition and characteristics of floating
284 plastic litter found in the same study area (Suaria et al., 2016; Suaria and Aliani, 2014).

285 All things considered, blue shark could give information on the environmental status of the area,
286 not only for pollutant contamination (Alves et al., 2016), but also for plastic pollution.

287 This study adds important information to assess the source of marine litter that impact the
288 Mediterranean biodiversity suitable for futures mitigation actions. The high occurrence of plastic
289 litter in blue sharks raises a warning alarm on the impact that marine litter could have on the
290 Mediterranean population, which is already declining and listed as Critically Endangered due to
291 the impact of longline fisheries targeting other pelagic species. For this reason, in the future,

292 specific studies aimed at evaluating this impact for the blue shark in the entire Mediterranean
293 basin are needed.

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297
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