COMMON

COastal Management and MOnitoring Network

for tackling marine litter in Mediterranean sea

Activity 3.1.1

II- Literature review on litter sources and impact in the Mediterranean Sea organisms

COMMON

Document Information

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This document (Deliverable 3.1.1 II) is focused on literature review of marine litter in Mediterranean Sea biota in order to define the baseline information of this impact.

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1. Impact of marine litter on marine organisms in the Mediterranean Sea

In recent years, impacts derived from the presence of marine litter in the oceans have expanded to increasingly include ingestion by marine organisms (Boerger et al., 2010; Jacobsen et al., 2010; Cole et al, 2013; Setälä et al., 2014; Avio et al., 2015; Neves et al., 2015; Guven et al., 2017; Bour et al., 2018; Giani et al., 2019) in addition to other impacts resulting from entanglement, habitat destruction and the introduction and dispersal of invasive species (Gregory, 2009). Ingestion is currently considered the most likely interaction between marine litter and organisms. In some cases, the feeding mechanisms of various species, such as filtration, do not allow to distinguish prey from litter (Moore et al., 2001; Collard et al., 2017). Several studies have shown that marine litter can be mistaken for food by a wide variety of animals including invertebrates, fish, turtles, birds, and mammals (Kühn et al., 2015).

The presence of litter, particularly plastic, has also been found in species of commercial interest. Considering that the global average annual per capita consumption of fish products was 19.7 kg in 2013 (FAO, 2017), and reached 20 kg in 2016, fisheries provided 6.7% of the total protein consumed by the population in 2016, and fishery products represented 1% of world trade in monetary terms (www.fao.org): it is a priority to assess both the direct and indirect impact of marine litter on humans (FAO, 2017).

To create the database on the ingestion of marine litter by marine organisms, an online bibliographic search was carried out using the following keywords: *marine litter ingestion*, *marine plastic ingestion*, *marine litter Mediterranean*, *marine plastic*, *marine litter and fish*, *marine debris and fish*, *marine plastic and fish, microplastic and fish, marine litter and birds, marine litter and sea turtles, microplastic and marine invertebrates, marine litter ingestion and marine mammals.*

A total of 69 documents analyzing 117 species belonging to 33 different orders were examined. Considering the 5 FAO (Food and Agriculture Organization of the United Nations) regions into which the Mediterranean Sea is divided (Tab. 1), it appears that of the 69 publications considered, 61%, 42 documents, concern the Western Mediterranean Sea while the other regions are less investigated.

Table 1. Number of publications on the impact of marine litter in biota by FAO Mediterranean Sea areas.

FAO GFCM SUBREGION	N° of studies
Adriatic Sea	13
Western Mediterranean Sea	42
Central Mediterranean Sea	9
Eastern Mediterranean Sea	8
Black Sea	0
All basin	0

A further analysis was carried out by attributing to each species the total number of specimens analyzed, the occurrence(%) of marine litter ingestion (Table 2). A colour scale from red (high percentage of ingestion) to green (low percentage of ingestion) was attributed to the different species to highlight the species where a higher percentage of ingestion was recorded. If a species was included in several articles, the available data were combined to calculate the ingestion percentage of the total database.

Table 2. Database on ingestion of marine litter in fish and invertebrate species of Mediterranean Sea, with highlighted for each species the mean occurrence (%), total number of specimens, number of GITs with marine litter and number of articles.

Species	Occurrence (%)	N° of speciments	N° GITs with marine litter	N°articles
Ascidiacea	**0.0**	**0**	**0**	**1**
Ascidia spp.	**0.0**	0	0	1
Bivalvia	**24.1**	**274**	**66**	**10**
Anomia ephippium	**0.0**	0	0	1
Crassostrea gigas	**0.0**	0	0	1
Mytilus galloprovincialis	**24.1**	274	66	8
Cephalopoda	**0.0**	**6**	**0**	**1**
Octopus vulgaris	**0.0**	6	0	1
Chondrichthyes	**21.9**	**529**	**116**	**21**
Dalatias licha	**100.0**	1	1	1
Etmopterus spinax	**2.0**	50	1	2
Galeus melastomus	**7.7**	168	13	4
Heptranchias perlo	**0.0**	1	0	1
Hexanchus griseus	**0.0**	4	0	1
Prionace glauca	**31.7**	139	44	1
Raja clavata	**13.6**	22	3	3
Raja miraletus	**100.0**	1	1	1
Scyliorhinus canicula	**37.6**	141	53	6
Squalus acanthias	**0.0**	2	0	1
Hexanauplia	**0.0**	**0**	**0**	**1**

Harpacticoida sp.	**0.0**	0	0	1
Holothuroidea	**5.7**	**35**	**2**	**2**
Holothuria forskali	**5.7**	35	2	1
Holothuria tubulosa	**0.0**	0	0	1
Hoplonemertea	**0.0**	**0**	**0**	**1**
Ototyphlonemertes sp	**0.0**	0	0	1
Malacostraca	**7.6**	**2828**	**214**	**9**
Aristaeomorpha foliacea	**0.0**	5	0	1
Aristeus antennatus	**36.9**	157	58	2
Carcinus aestuarii	**5.6**	180	10	1
Nephrops norvegicus	**0.0**	8	0	2
Pasiphaea multidentata	**0.0**	11	0	1
Plesionika martia	**0.0**	5	0	1
Plesionika narval	**5.9**	2462	146	1
Nematoda	**0.0**	**0**	**0**	**1**
Nematoda sp.	**0.0**	0	0	1
Polychaeta	**100.0**	**5**	**5**	**10**
Claudrilus sp.	**0.0**	0	0	1
Hediste diversicolor	**100.0**	5	5	1
Hesionura sp.	**0.0**	0	0	1
Megadrilus schneideri	**0.0**	0	0	1
Meiodrilus gracilis	**0.0**	0	0	1
Nerilla mediterranea	**0.0**	0	0	1
Protodrilus albicans	**0.0**	0	0	1
Protodrilus oculifer	**0.0**	0	0	1
Saccocirrus pussicus	**0.0**	0	0	1
Syllidae	**0.0**	0	0	1
Scyphozoa	**0.0**	**49**	*n.c.*	**1**
Pelagia noctiluca	**0.0**	49	*n.c.*	1
Teleosts	**27.9**	**9861**	**2746.55**	**206**
Alosa fallax	**38.5**	13	5	1
Argentina sphyraena	**0.0**	5	0	1
Argyrosomus regius	**74.5**	51	38	1
Balistes capriscus	**14.0**	50	7	1
Boops boops	**50.9**	930	473	9
Brama brama	**0.0**	9	0	1
Capros aper	**0.0**	18	0	1
Caranx crysos	**100.0**	1	1	1
Cataetyx laticeps	**10.0**	10	1	1
Centracanthus cirrus	**0.0**	10	0	1
Chelidonichthys cuculus	**0.0**	20	0	1
Chelidonichthys lucerna	**29.0**	31	9	4
Citharus linguatula	**1.7**	58	1	2
Conger conger	**0.0**	44	0	1
Coryphaena hippurus	**19.2**	308	59	3
Dentex dentex	**0.0**	1	0	1

Dentex gibbosus	**28.6**	14	4	1
Diaphus metopoclampus	**0.3**	296	1	1
Diplodus annularis	**68.8**	48	33	1
Diplodus vulgaris	**28.6**	14	4	1
Electrona risso	**6.1**	82	5	1
Engraulis encrasicolus	**30.2**	541	163	11
Epigonus telescopus	**0.0**	4	0	1
Gadiculus argenteus	**0.0**	12	0	1
Glossanodon leioglossus	**0.0**	5	0	1
Helicolenus dactylopterus	**0.4**	490	2	3
Hygophum benoiti	**6.8**	73	5	1
Hymenocephalus italicus	**0.0**	5	0	1
Lagocephalus spadiceus	**0.0**	1	0	1
Lepidopus caudatus	**0.0**	1	0	1
Lepidotrigla cavillone	**0.0**	10	0	1
Lepidotrigla dieuzeidei	**0.0**	22	0	1
Lithognathus mormyrus	**32.1**	53	17	2
Liza aurata	**56.1**	82	46	4
Lophius piscatorius	**66.7**	3	2	1
Merlangius merlangus merlangus	**20.0**	5	1	1
Merluccius merluccius	**32.0**	400	128	11
Micromesistius poutassou	**21.4**	28	6	2
Mora moro	**9.1**	99	9	2
Mullus barbatus	**27.9**	925	258	14
Mullus surmuletus	**64.0**	89	57	2
Myctophum punctatum	**4.2**	71	3	1
Naucrates ductor	**18.0**	50	9	1
Nemipterus randalli	**54.8**	135	74	1
Nettastoma melanurum	**16.7**	12	2	2
Nezumia aequalis	**0.0**	20	0	1
Oblada melanura	**36.1**	83	30	1
Pagellus acarne	**58.3**	60	35	2
Pagellus bogaraveo	**1.7**	60	1	1
Pagellus erythrinus	**31.3**	208	65	5
Pagrus pagrus	**77.8**	9	7	1
Pelates quadrilineatus	**65.2**	135	88	1
Phycis blennoides	**0.0**	73	0	3
Phycis phycis	**0.0**	1	0	1
Polyprion americanus	**32.4**	34	11	2
Pomadasys incisus	**55.2**	29	16	1
Sardina pilchardus	**31.1**	853	265	14
Sardinella aurita	**33.3**	9	3	1
Sarpa salpa	**100.0**	10	10	1
Saurida undosquamis	**55.6**	99	55	1
Schedophilus ovalis	**28.6**	7	2	2
Sciaena umbra	**100.0**	1	1	1

Scomber colias	**66.7**	33	22	1
Scomber japonicus	**47.7**	44	21	2
Scomber scombrus	**39.5**	172	68	4
Scorpaena elongata	**0.0**	1	0	1
Scorpaena scrofa	**66.7**	6	4	1
Seriola dumerili	**2.0**	50	1	1
Serranus cabrilla	**7.5**	53	4	2
Serranus hepatus	**0.0**	10	0	1
Serranus scriba	**100.0**	20	20	1
Siganus luridus	**86.7**	15	13	1
Solea solea	**17.2**	690	119	5
Sparus aurata	**52.3**	130	68	2
Spicara smaris	**5.5**	128	7	2
Spondyliosoma cantharus	**0.0**	10	0	1
Sudis hyalina	**0.0**	5	0	1
Synchiropus phaeton	**0.0**	26	0	1
Synodus saurus	**0.0**	5	0	1
Thunnus alalunga	**12.9**	31	4	1
Thunnus thynnus	**12.7**	671	85	3
Trachinotus ovatus	**24.3**	115	28	1
Trachinus draco	**3.4**	29	1	3
Trachurus mediterraneus	**50.3**	207	104	5
Trachurus picturatus	**0.4**	24	0.1	3
Trachurus trachurus	**27.7**	267	74	7
Trachyrincus scabrus	**33.3**	18	6	1
Trigla lucerna	**37.5**	24	9	1
Trigla lyra	**42.9**	56	24	2
Trigloporus lastoviza	**0.0**	5	0	1
Trisopterus minutus	**0.0**	5	0	1
Trisopterus minutus	**5.3**	19	1	1
Umbrina cirrosa	**0.0**	1	0	1
Upeneus moluccensis	**44.4**	18	8	1
Upeneus pori	**41.0**	78	32	1
Uranoscopus scaber	**30.8**	13	4	1
Xiphias gladius	**12.3**	57	7	2
Zeus faber	**0.0**	5	0	1
Turbellaria	**0.0**	**0**	**0**	**1**
Otoplanidae	**0.0**	0	0	1

1.1 Ingestion of marine litter in fish species

As mentioned above, most of the studies examined, 36 out of 69, document the ingestion of litter in fish species in the Mediterranean Sea. In total, 84 species belonging to 17 different orders were analysed. Specifically, microplastics were observed in the gastrointestinal tract of 11 species among the 20 most important for global fisheries: *Scomber japonicus, Clupea harengus, Scomber scombrus, Engraulis japonicus, Gadus morhua, Sardina pilchardus, Micromesistius poutassou, Sprattus sprattus, Scomberomorus cavalla* and *Sardinella longiceps* (FAO, 2017).

Table 3. Partial database on ingestion of marine litter in fish species of Mediterranean Sea. The occurrence (%), the total number of organisms sampled (> 30) and the number of articles related to each species are indicated. A colour scale from red (max), yellow (med) and green (min) was applied to highlight the most affected species.

Species	Occurrence (%)	N° of speciments	N° articles
Boops boops	50.9	930	9
Mullus barbatus	27.9	925	14
Sardina pilchardus	31.1	853	14
Solea solea	17.2	690	5
Thunnus thynnus	12.7	671	3
Engraulis encrasicolus	30.2	541	11
Helicolenus dactylopterus	0.4	490	3
Merluccius merluccius	32.0	400	11
Coryphaena hippurus	19.2	308	3
Diaphus metopoclampus	0.3	296	1
Trachurus trachurus	27.7	267	7
Pagellus erythrinus	31.3	208	5
Trachurus mediterraneus	50.3	207	5
Scomber scombrus	39.5	172	4
Galeus melastomus	7.7	168	4
Scyliorhinus canicula	37.6	141	6
Prionace glauca	31.7	139	1
Pelates quadrilineatus	65.2	135	1
Nemipterus randalli	54.8	135	1
Sparus aurata	52.3	130	2
Spicara smaris	5.5	128	2
Trachinotus ovatus	24.3	115	1
Saurida undosquamis	55.6	99	1
Mora moro	9.1	99	2
Mullus surmuletus	64.0	89	2

Oblada melanura	36.1	83	1
Liza aurata	56.1	82	4
Electrona risso	6.1	82	1
Upeneus pori	41.0	78	1
Hygophum benoiti	6.8	73	1
Phycis blennoides	0.0	73	3
Myctophum punctatum	4.2	71	1
Pagellus acarne	58.3	60	2
Pagellus bogaraveo	1.7	60	1
Citharus linguatula	1.7	58	2
Xiphias gladius	12.3	57	2
Trigla lyra	42.9	56	2
Lithognathus mormyrus	32.1	53	2
Serranus cabrilla	7.5	53	2
Argyrosomus regius	74.5	51	1
Naucrates ductor	18.0	50	1
Balistes capriscus	14.0	50	1
Etmopterus spinax	2.0	50	2
Seriola dumerili	2.0	50	1
Diplodus annularis	68.8	48	1
Scomber japonicus	47.7	44	2
Conger conger	0.0	44	1
Polyprion americanus	32.4	34	2
Scomber colias	66.7	33	1
Chelidonichthys lucerna	29.0	31	4
Thunnus alalunga	12.9	31	1

Taking into account the different marine habitats, it appears that most of the fish species analysed are demersal (40%), followed by pelagic (30%), benthopelagic (18%) and benthic (8%), mesopelagic species are least studied (4%).

The benthopelagic specimens reported the highest percentage of ingestion¸the presence of marine litter was recorded in 40% of individuals as can be deduced from the graph in Figure 1.

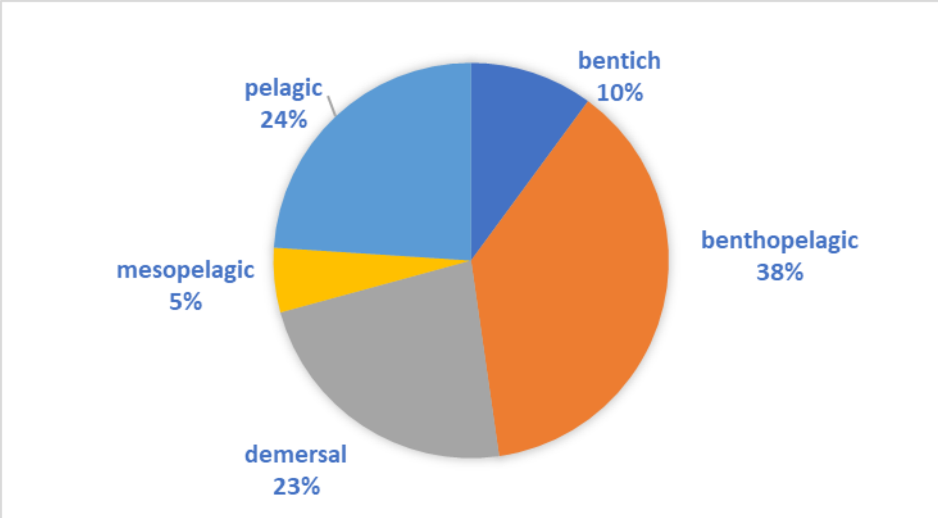

Figure 1. Percentage of fish species with marine litter in gastro-intestinal tracts by habitat from literature studies.

1.2 Additive and chemicals related to plastics in fish species

Most plastic items are not virgin polymers but are processed with the addition of many different additives (such as phthalates, bisphenol A and flame retardants); these can be added as a result of processing the material or incorporated into it, thus being chemically bound to the polymer. A detailed report was published in 2013 presenting the functional additives and dyes generally used in industry (Hansen et al., 2013). Plasticisers are substances added in some plastics to improve their performance, for example, flexibility. In the plastics industry, these additives are often introduced in large proportions depending on the polymer and its end use (between 10% and 70% of the weight of the virgin plastic material). Phthalates are the best-known category of plasticisers. Flame retardants (FR) are added to plastics when their specific characteristics require their use according to certain fire regulations (cables, transport, buildings, carpets, etc.); they are also found, for example, in plastics exposed to high temperatures (hairdryers, electronics, etc.). Additives can be organic or inorganic, brominated organic molecules (e.g. polybromodiphenyl ethers, PBDEs) are often considered the most dangerous flame retardants for their impact on human health, representing up to 50% of the weight of virgin plastic (Dris, 2016). Among the various PBDE congeners, eight (BDE-28, 47, 99, 100, 153, 154, 183 and 209 identified following the systematic numbering of Ballschmiter and Zell) are of primary interest because of the frequency with which they are found in the abiotic and biotic sector (Law et al., 2003; Law et al., 2006; Binelli et al., 2008; Guzzella et al., 2008). In particular, the congenerous 209 has often been associated with the presence of plastics as this compound seems to be one of the main additives where it is used as a flame retardant, to the point of being considered a "tracer" of plastics (Hirai et al., 2011; Gassel et al., 2013; Tanaka et al., 2013). There are very few studies in the literature that simultaneously focus on the presence of plastic and the levels of contaminants associated with it in marine fish species. Gassell and

Rochman in 2019 evaluated levels of BDE 183 and 209 in specimens of myctophids sampled in and outside the South Atlantic gyre but did not assess the ingestion of microplastics on the same organisms (Gassel and Rochman, 2019). Barboza and collaborators in 2020 determined the levels of bisphenol A (BPA) in the muscle and liver of Dicentrarchus labrax, Trachurus trachurus and Scomber colias from the North East Atlantic, showing that specimens with microplastics in the gastrointestinal tracts had significantly higher levels of BPA (Barboza et al, 2020). Only one study, so far, has focused on Mediterranean fish species. Garcia-Garin and collaborators have shown that in the muscle of specimens of Boops boops sampled in the Western Mediterranean Sea there is no correlation between the concentrations of organophosphate flame retardants and the ingestion of microplastics (Garcia-Garin et al., 2020).

1.3 Biological effects of microplastics in fish species

To evaluate the current state of art on the biological effects of microplastics in fish species, specific bibliographic research has been carried out. From the results obtained, 41 articles have been selected, all published in the last 10 years, and focused on the study of the biological effects of microplastics (MP) (Table 8 and 9) through laboratory studies (38) and in nature (3). In tables (8) and (9) is summarized the bibliography collected, for each article are specified the fish species, the characteristics of the microplastics used, the exposure time. the concentrations of microplastics, the endpoints analysed, and the main results reported by each study.

With the increase of reports on the contamination of environmental matrices and biota by microplastics, the number of ecotoxicological studies focused on the study of their biological effects on fish species has strongly increased, particularly in recent years. The polymers most used in laboratory studies (PE, PS, PVC) (Fig. 2), reflect the main constituents of environmental contamination by microplastics. Despite the increase in the use of biopolymers, considered an ecological alternative to traditional plastics, there is still little literature on the potential biological effects of these types of plastics. The experimental conditions (exposure times and concentrations) of the studies reported in the literature are very variable: acute, chronic toxicity, concentrations of MPs comparable to those found in the environment, as well as much higher concentrations.

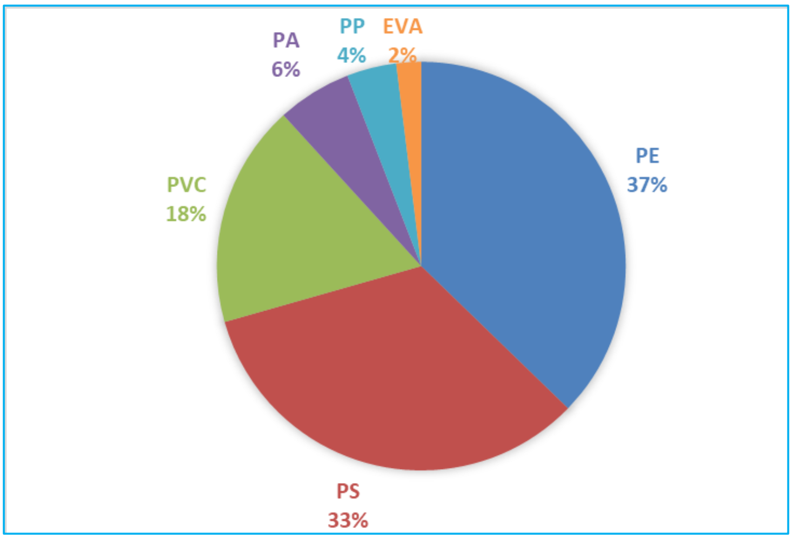

Figure 2. Polymers most frequently used (%) in laboratory studies for the evaluation of toxicological effects of microplastics.

The bibliographic research carried out has made it possible to highlight a wide range of biological effects, which have been reported and hypothesized in the dedicated literature to date. The ecotoxicological effects of MP seem to affect various levels of biological organization, starting from molecular, enzymatic/protein, histological, systemic and behavioral. Among the main effects found are histological alterations, at tissues level most exposed to contamination and accumulation of MPs: gastrointestinal tract, gills, and liver (Abbasi et al., 2018; Avio et al., 2015b; Ding et al., 2018; Lu et al., 2016). Exposure to realistic concentrations of MP may lead to the generation of obvious epithelial damage (Fig.3).

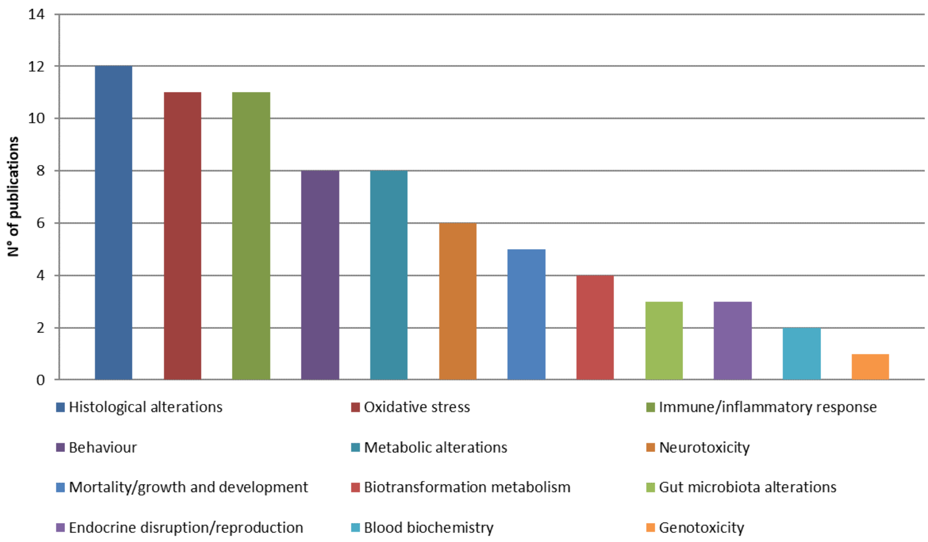

Figure 3. Classification of the most frequently reported biological effects in laboratory studies. The data was generated based on the 38 publications analysed.

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