STUDY ON THE HOTSPOTS OF INTERACTIONS BETWEEN CETACEANS AND MARINE LITTER IN THE ACCOBAMS AREA

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- DRAFT REPORT -

This report has been prepared by M. Cristina Fossi and Cristina Panti of the University of Siena, in collaboration with François Galgani (IFREMER), Carlo Brandini (LAMMA), Massimiliano Rosso (CIMA), Mark Simmonds (Sciencegyre), Svitlana Liubartseva (CMCC) and Celine Mahfouz (CNRS-L). The version of this report presented to the Eighth Meeting of the Parties to ACCOBAMS (MOP8) is not yet reviewed by the Scientific Committee of ACCOBAMS. This review will be organized after MOP8 and the final version of the report will be published on the ACCOBAMS website as soon as it is available.

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Objectives of the document

*The main objectives of this document are to describe the current knowledge on the interactions between cetaceans and marine litter in the ACCOBAMS area and the hotspot accumulation area which can threaten cetacean species. The bibliographic research has been carried out considering mainly peer-reviewed papers, but also reports of projects on these issues and grey literature. An overview of the relevant projects and initiatives that dealing with ML contamination in the Mediterranean area are listed in **Annex 1**, the most relevant publications on the marine litter interaction with cetaceans and on the marine litter models in the ACCOBAMS area are reported in **Annex 2**.*

1. Marine Litter at global scale

Marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed, or abandoned in the marine environment. It is globally acknowledged as a major societal challenge of our times due to its significant environmental, economic, social, political and cultural implications. The review will then focus on to the state of contamination of the Mediterranean and contiguous areas, being the Mediterranean Sea indicated as one of the most impacted areas in the world by Marine Litter.

The pollution of the oceans due to plastic waste generates great concern for both the scientific community and society as a whole. In recent years, both political (national and international) and scientific initiatives have been developed to mitigate the consequences of the massive use of plastics and its presence in the marine environment (see Maximenko et al. (2019) for a complete summary). The United Nations Environmental Program (UNEP) defines marine litter (ML) as any persistent, manufactured or processed solid material that is discarded, disposed of or abandoned in the marine or coastal environment (UNEP,2009). These materials accumulate in both shallow and deep waters, and especially in closed basins such as the Mediterranean Sea (Barneset al., 2009; Cózar et al., 2015). Between 4.8 and 12.7 million tons of plastic waste were dumped into the ocean in 2010, an amount that is expected to increase by one order of magnitude by 2025 if no measures are implemented to improve the waste management systems. In the case of the Mediterranean, it is estimated that around 100k tons of plastic waste enter each year (Jambeck et al., 2015). Despite legislative advances in prevention, illegal dumping as well as waste transportation to the open ocean from coastal areas and river mouths is a problem that is still far from being solved.

Nowadays, marine litter is commonly observed across all oceans and marine ecosystems. Mainly represented by plastic (up to 80%) and its fragmentation products, meso- (0.5–2.5 cm) and micro-particles (<5 mm), they can be transported over long distances (Lebreton et al., 2018). Microplastic presence has been detected on coastlines where it may accumulate due to current, wave and wind actions, river outflows and direct littering at the coast (GESAMP, 2019). Moreover, it occurs on the ocean surface, along the water column, on the seafloor and in association with biota, due to entanglement or ingestion (Fossi et al., 2012, 2017; Baini et al., 2018; GESAMP, 2019; Suaria et al., 2016) (Fig. 1). In the last 50 years, since the first record available in the scientific literature published by Kenyon and Kridler in 1969, the number of species affected by plastic litter has increased steadily reaching 914 species (Kühn and van Franeker, 2020). Bearing this in mind, monitoring and assessment programs appear essential to address specific questions about the distribution of marine litter, including microplastics, and its potential impacts on marine biodiversity.

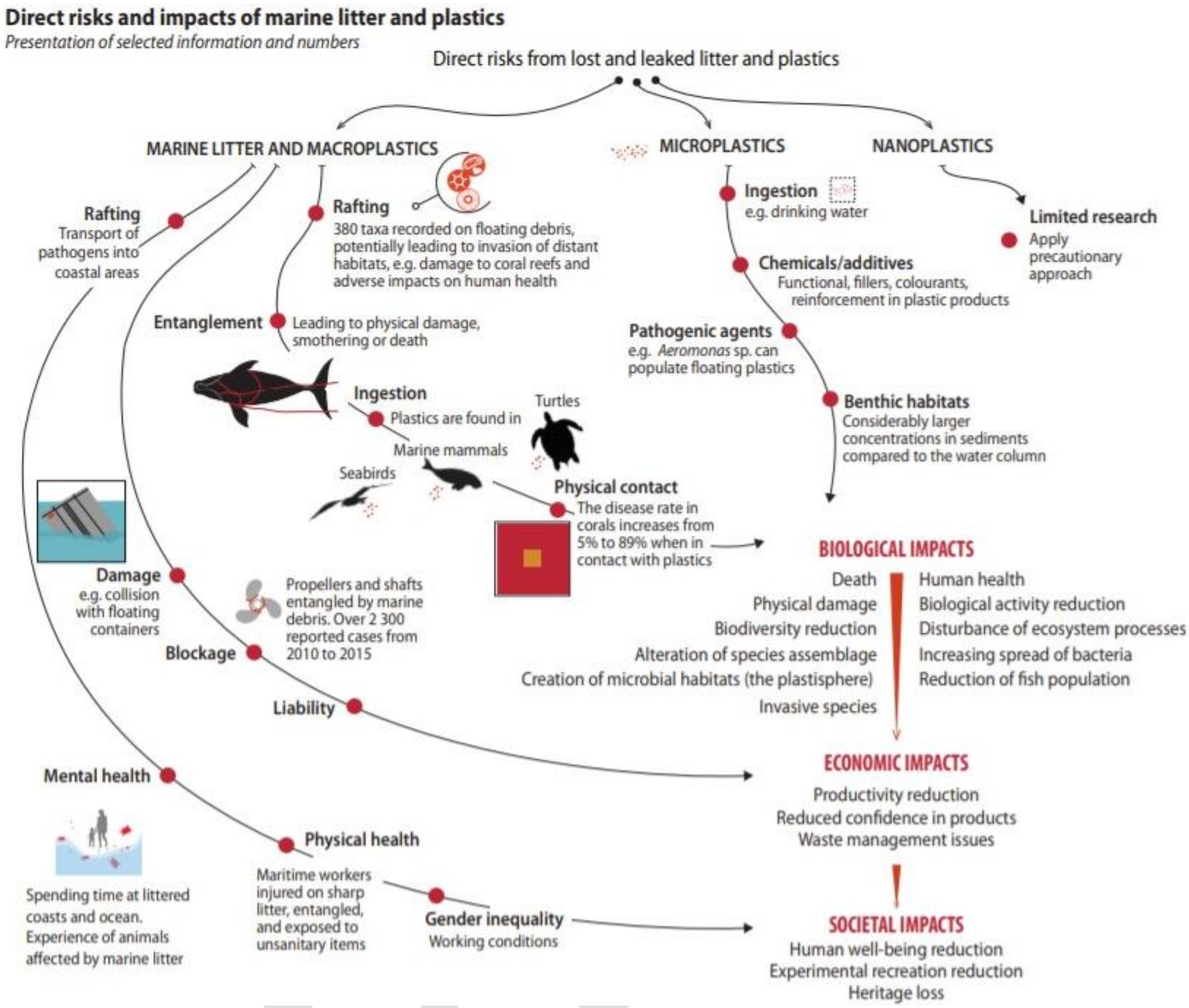


Figure 1. *Direct risks and impacts of marine litter and plastics. Source: UNEP, 2021.*

At the European level, the Marine Strategy Framework Directive (MSFD) (2008/56/EC) and at the Mediterranean level the indicators with the "Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast-IMAP" (UNEP/MAP), have been developed to protect the marine environment as well as to ensure its sustainable use. Based on several descriptors/Ecological Objectives the ultimate goal of these regulations is the achievement of Good Environmental Status (GES) for the marine waters by the EU Member States. In particular, the provisions of the MSFD Descriptor 10 and Ecological Indicator 10, respectively, aim to protect the marine ecosystems against harm caused by the emerging issue of plastic litter. As highlighted by several ocean circulation models (Fossi et al., 2017, 2018; Liubartseva et al., 2018; Mansui et al., 2015; Politikos et al., 2020), the Mediterranean Sea has been considered a sensitive plastic litter accumulation zone with an average concentration comparable to the great oceanic gyres (Cózar et al., 2015; Suaria et al., 2016; UNEP/MAP, 2015). Mainly due to the limited exchange of surface waters with the Atlantic Ocean, and intensive land- and marine-based sources of pollution significant amounts of marine litter enter and accumulate in this basin. Coastal areas and waters, in particular, face significant pressures from heavy population densities to maritime, touristic, and industrial activities leading to a decrease in the integrity of marine ecosystems (Coll et al., 2012, 2010; UNEP, 2016). While the identification of biodiversity hotspots and sensitive areas is a well-established procedure for these zones, usually resulting in the identification of Marine Protected Areas, the offshore waters are usually less investigated. Marine megafauna, such as cetaceans and marine turtles as an example, are often used as umbrella species, considering not only their ecological role but also their charismatic influence in driving conservation efforts (Germanov et al., 2018). The identification of particularly sensitive areas as well as biodiversity hotspots in the pelagic realm can be effectively run by focusing on these valuable species.

Studies evaluating the potential risk connected to the spatial distribution of plastic litter and the presence of organisms inhabiting the marine ecosystems were only recently published worldwide (Everaert et al., 2018; Jâms et al., 2020; Mazarrasa et al., 2019; Schuyler et al., 2016; Wilcox et al., 2018, 2015) and in the Mediterranean Sea (Compa et al., 2019a; Darmon et al., 2017; Fossi et al., 2017; Soto-Navarro et al., 2021). Although some risk evidences were highlighted for the most studies species, such as sea turtles and birds, there is still a lack of data regarding the simulation-based risk approach and the real threats that may affect the marine fauna (Soto-Navarro et al., 2021). Empirical data collection on the magnitude and typology of plastic litter, the spatial distribution of organisms and the potential impacts on them is needed to assess a more accurate and reliable risk scenario.

1.1 Marine litter in the Mediterranean Sea and Black Sea

Studies on marine litter in the Mediterranean basin started in the 1990s, but more attention was given to the issue after 2010, when more data became available on the abundance and distribution of marine litter, and when the first attempts to assess trends were made, microplastics entered the agenda and the mapping of impacts became a priority.

The Mediterranean Sea is a closed basin, with a coastal population of about 210 million inhabitants. Mediterranean countries are the number one tourist destination in the world, with around 360 million visitors every year, and receives waste from coastal zones, as well as from many large rivers flowing through largely urbanized cities such as the Nile River that transports more than 200 tonnes of plastic into the Mediterranean Sea per year (Lebreton et al. 2017). In addition, more than 20% of global maritime traffic passes through the Mediterranean Sea. Consequently, the basin has become one of the most marine litter-affected areas in the world (UNEP/MAP, 2015). Plastics are the prevailing type, accounting for up to 95-100% of total floating marine litter, due also to the high floatability of plastics, and more than 50% of seabed marine litter. The analysis of 80 beaches conducted in 2016 (Addamo, Laroche & Hanke, 2017) indicated that only 10 types of debris, mostly single-use plastics (cutlery/trays/straws, cigarette butts, caps/lids, plastic bottles, shopping bags) represent more than 60% of the total recorded marine litter on beaches. No change was observed in the percentage of the dominant marine litter categories between 2013 and 2018 on the beaches of 8 Mediterranean countries (Ocean Conservancy, 2018). Typically, most of the litter on beaches originates from beach/recreational activities. Glass bottles and metal beverage cans disappeared from the top ten lists in non-tourist areas in recent years because of behavioural changes.

On the sea floor of the north-western basin, plastics and fishing-related items (some of which are also made of plastic) have represented the same percentage of litter for more than 20 years (UNEP/MAP, 2017a), but information still remains scarce, especially on the specific issue of abandoned, lost or otherwise discarded fishing gear (ALDFG), which may account for a large or even the largest part of marine litter items in many areas. Particular importance is currently being paid to the emerging issues of micro- and nanoplastics and the possible release of associated Persistent Organic Pollutants (POPs) and Endocrine Disrupting Chemicals (EDCs). Concentrations of microplastics at the surface of the Mediterranean Sea are largely above 100,000 items per km2 (UNEP/MAP, 2015) and, reach maximums of more than 64 million floating particles per km2 (Van Der Hal, Ariel & Angel, 2017).

As highlighted by several ocean circulation models (Fossi et al., 2017, Fossi et al., 2018; Liubartseva et al., 2018; Mansui et al., 2015; Politikos et al., 2020), the Mediterranean Sea has been considered a sensitive plastic litter accumulation zone with an average concentration comparable to the great oceanic gyres (Cózar et al., 2015; Suaria et al., 2016; UNEP/MAP, 2015). Mainly due to the limited exchange of surface waters with the Atlantic Ocean, and intensive land- and marine-based sources of pollution significant amounts of marine litter enter and accumulate in this basin. Coastal areas and waters, in particular, face significant pressures from heavy population densities to maritime, touristic, and industrial activities leading to a decrease in the integrity of marine ecosystems (Coll et al., 2012, Coll et al., 2010; UNEP, 2016).

Also, Black Sea is a typical semi-enclosed sea, very sensitive to contamination. Due to the extremely slow replenishment of water, limited vertical intermixing and dynamic surface circulation in combination with high anthropogenic pressure from river and canal discharges, navigation, fishery, waste dumps near the coast, tourism and recreation activities, marine litter is a major concern. A recent report entitled "Marine Litter In the Black Sea" has been published by the Turkish Marine Research Foundation in 2020 (Aytan, Pogojeva, M., Simeonova, 2020), which includes all the studies carried out in the area. Marine litter pollution has been observed in the Black Sea in the last two decades: on beaches (Topçu et al., 2013; Simeonova et al., 2017; Terzi and Seyhan, 2017); on the seafloor (Topçu and Oztürk, 2010; Moncheva et al., 2016; Bat et al., 2017; Öztekin and Bat, 2017); and on the sea surface (Suaria et al., 2015). However, the existing information on ML quantities and distribution in the Black Sea water column, on the bottom and on the coast is still fragmented. The abundance and composition of the benthic litter on the western shelf (in the vicinity of the Bosporus Straits) have been reported by Topçu and Oztürk (2010). Ioakeimidis et al. (2014) reported that the mean FML density in the Constanta Bay was 291 ± 237 items km^2. This high density was explained by the great influence of the Danube River; however, the density value was comparable to those at other Mediterranean coastal sites. The studies on the impact on marine organisms is also fragmented but some studies have been recently published on zooplankton, fish species and cetaceans (Aytan, Ü., Pogojeva, M., Simeonova, 2020).

1.2 Sources and driving forces of Marine Litter

Inputs of plastics into the sea, as estimated in 2015, are at the level of over 260,000 tonnes per year or 730 tonnes per day, depending on the coastal population, which may vary depending on the country, representing more than 2% of the total inputs in the world's oceans.

At the level of Mediterranean watersheds, another study (Weiss et al. 2019) modelled plastic flows into the Mediterranean Sea, as shown in Figure 2, and the Marine litter in relation to the economic sectors in the Mediterranean Sea. Sources, amounts and impacts are report in Figure 3 (According to UNEP/MAP, 2015 & UN Environment, 2018a).

In some areas, up to 58% of the municipal solid waste collected is still disposed of in open dump sites. Of the millions of tonnes of plastic waste produced every year in Mediterranean countries, less than one third is recycled and plastics recycling is less than 6% (WWF, 2018). Bearing in mind the importance of wastewater as a pathway for waste leaking into the sea, a key challenge is that in the Mediterranean region, 21% of wastewater (25% in Southern Countries) undergoes only basic treatment, and less than 8% (1% in southern countries) undergoes tertiary treatment (UNEP/MAP, 2017a).

Key economic sectors in the Mediterranean, such as professional and recreational fisheries, aquaculture, tourism and shipping, also generate large amounts of litter that end up as marine litter.

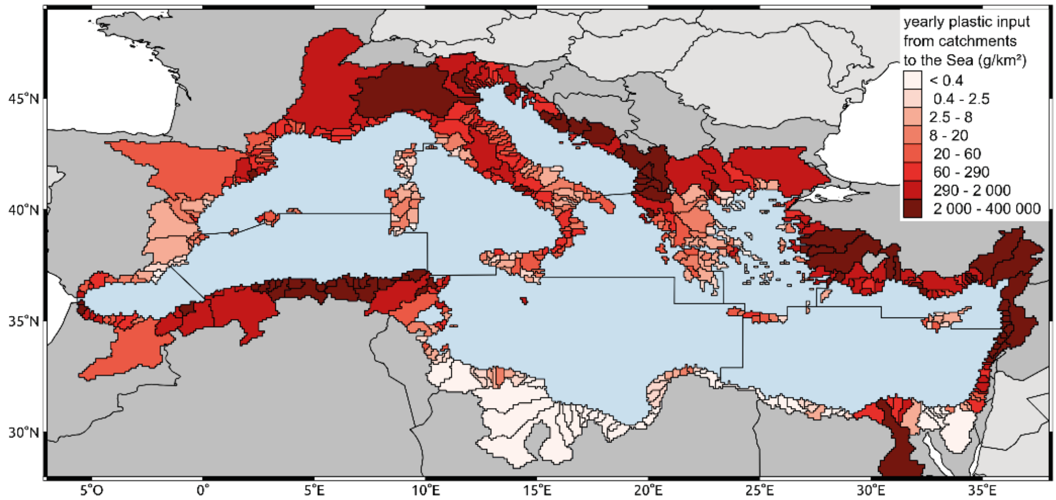


Figure 2. *Estimate of annual specific plastic flows (kg/m3) discharged by watersheds into the Mediterranean Sea. Flows calculated based on Lebreton et al. 2017 (UNEP/MAP 2021).*

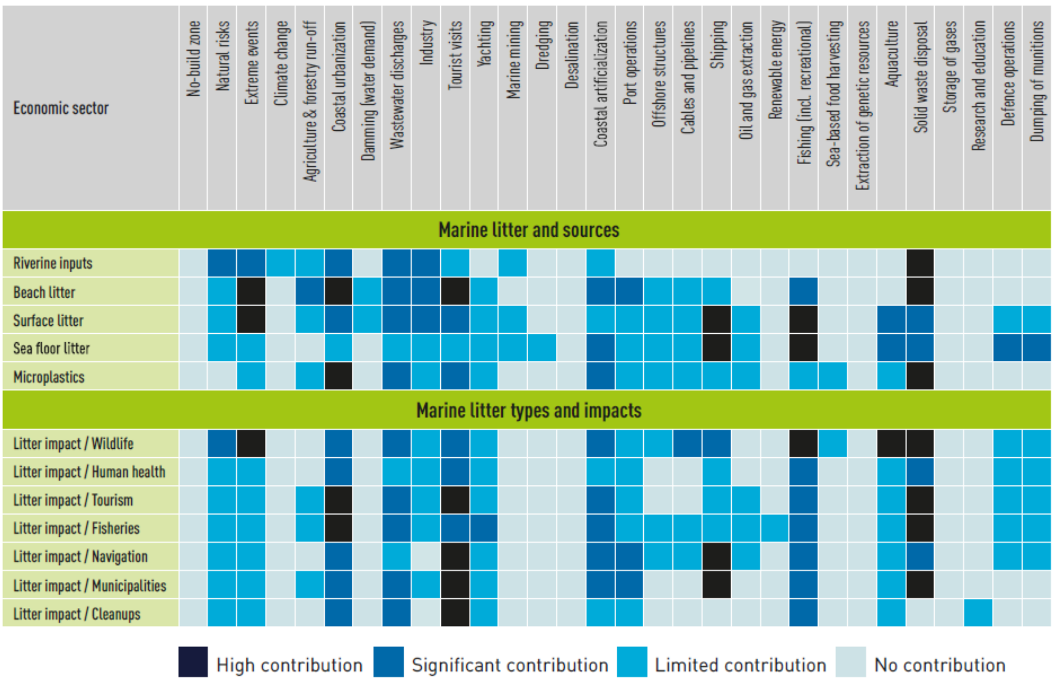


Figure 3. *Marine litter in relation to the economic sectors in the Mediterranean Sea. Sources, amounts and impacts (According to UNEP/MAP, 2015 & UN Environment, 2018a)*

1.3 Definitions and policy context

As defined by the EU commission: "Marine litter consists of items that have been deliberately discarded, unintentionally lost, or transported by winds and rivers, into the sea and on beaches.", or "Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" as defined by UNEP.

Marine litter mainly consists of plastics, wood, metals, glass, rubber, clothing and paper.

Marine litter can be classified in size classes as follows: macrolitter referring to items above 25mm in the longest dimension; mesolitter from 5 mm to 25 mm; and microlitter from 1µm to 5mm.

Sometimes the later size class is further broken down to large microplastics from 1mm to 5 mm and small microplastics from 1µm to 1mm.

The main legislative frameworks related to marine litter monitoring in the ACCOBAMS area are the EU Marine Strategy Framework Directive (2008/56/EC, 2010/477/EC, 2017/848/EC) and the Barcelona Convention Ecosystem Approach (COP19 IMAP Decision IG.22/7) but these two main pillars are integrated in additional policy and legislative frameworks for specific actions against marine litter at Mediterranean, European, EuroMediterranean and global levels are briefly presented below.

Global level

- **The UN Sustainable Development Goals.** The Sustainable Development Goals were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The Sustainable Development Goal 14 of the 2030 Agenda for Sustainable Development is dedicated to marine pollution and marine litter "By 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution".

- **The 2021-2030 UN Decade of Ocean Science for Sustainable Development.** The United Nations has proclaimed a Decade of Ocean Science for Sustainable Development (2021-2030) to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the Ocean.

- **The UN Convention on Biological Diversity (CBD) and the Post-2020 Global Biodiversity Framework. The CBD Convention** urges parties "to develop and implement measures, policies and instruments to prevent the discard, disposal, loss or abandonment of any persistent, manufactured or processed solid material in the marine and coastal environment (Decision of 2016 XIII/10 on addressing impacts of marine debris on marine and coastal biodiversity, points 6 and 8). A post-2020 Global Biodiversity Framework will be adopted at the conference that will take place in Kunming, China, in August 2022.

- **MARPOL Convention - Annex V "Prevention of Pollution by Garbage from Ships"**. Annex V related to controlling and preventing pollution from garbage, meaning pollution from solid waste, including plastic waste.

Mediterranean and EuroMediterranean level

- **Barcelona Convention Regional Plan on the Management of Marine Litter in the Mediterranean.** The main objectives are to prevent and reduce to the minimum marine litter pollution in the Mediterranean and its impact on ecosystem services, habitats, species, public health, and safety; remove to the extent possible already existent marine litter; enhance knowledge on marine litter.

- **The Ecosystem Approach (EcAp)**. The EcAp process seeks to reach the ultimate objective of achieving Good Environmental Status (GES) in the Mediterranean Sea. To this end, contracting parties have agreed to protect and restore the structure and function of marine and coastal ecosystems thus also protecting biodiversity, in order to achieve and maintain good ecological status and allow for their sustainable use. In addition, they have committed to prevent, reduce and manage the vulnerability of the sea and the coasts to risks induced by human activities and natural events. The ecological objective 10 of ECAP addresses marine litter.

- **Barcelona Convention Integrated Monitoring and Assessment Programme of the Mediterranean Sea (IMAP).** A key achievement for the Mediterranean region for quantitative, integrated analysis of the status of the marine and coastal environment based on common regional indicators, targets, and Good Environmental Status descriptions - EO 10: Marine litter: Marine and coastal litter do not adversely affect the coastal and marine environment. Below the detail on the common indicators for EO 10.

Marine Litter and the Barcelona Convention Ecosystem Approach

Ecological Objective 10 (EO10): Marine and coastal litter do not adversely affect the coastal and marine environment.

IMAP Common Indicator 22: Trends in the amount of litter washed ashore and/or deposited on coastlines (including analysis of its composition, spatial distribution and, where possible, source).

IMAP Common Indicator 23: Trends in the amount of litter in the water column including micro plastics and on the seafloor.

IMAP Candidate Indicator 24: Trends in the amount of litter ingested by or entangling marine organisms focusing on selected mammals, marine birds, and marine turtles.

- **Barcelona Convention Post-2020 Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region** (**Post-2020 SAPBIO**). The Post-2020 SAPBIO is designed to be action-oriented and made of activities tailored towards realistic objectives that countries could reasonably achieve. The Post-2020 SAPBIO includes the Post-2020 Regional Strategy for Marine and Coastal Protected Areas (MCPAs) and other effective area-based conservation measures (OECMs) in the Mediterranean and adopted the 30x30 target to achieve 30% protection coverage by 2030.

- **Union for the Mediterranean 2030GreenerMed Agenda (Thematic Axis 2).** 2030GreenerMed is a joint flagship agenda, adopted by the 42 UfM Member Countries, that supports the implementation of the 2nd Ministerial Declaration on Environment and Climate Change. The UfM 2030GreenerMed Agenda provides a regional structured framework that, based on the coordination of existing and future programmes and projects, creates political, operational and financial convergence around the following priority axes of cooperation: support the transition towards a green, circular and socially inclusive economy, based on sustainable consumption and production practices and nature-based solutions; Prevent and reduce pollution on land, air, and sea; as well as protect, preserve, manage, and restore natural resources in the Mediterranean region within an integrated ecosystem approach, including terrestrial, marine, and coastal dimensions.

- **UfM Ministerial Declaration on Environment and Climate Action adopted in 2021.** Within the renewed political commitment to the transition towards green, circular and socially inclusive economy, the Declaration highlights that the protection, restoration and sustainable management of biodiversity must be an essential part of immediate action with near and mid-term targets, to be coherent with longer-term strategies for the protection of human health and well-being.

- **The UfM Ministerial Declaration on Environment and Climate Change adopted in 2014.** With the 2014 Declaration the 42 UfM countries agreed to take action to advance cooperation and alignment on environment and climate change across the region. The Declaration sat the basis for the transition of the Mediterranean region towards a green and low emissions economy providing real opportunities for preserving natural resources, job creation, improvement of the quality of life for all, meaning an overall sustainable future. The ministerial declaration called for joint action on three interlinked axes of work: depollution; pollution prevention (through sustainable consumption and production as well as resource efficiency); and climate change.

European level

- **Marine Strategy Framework Directive (MSFD).** The first EU legal instrument to explicitly address marine litter; it required "Good Environmental Status" for marine litter to be achieved by 2020, i.e. that "properties and quantities of marine litter do not cause harm to the coastal and marine environment". Assessment of the status, target setting, monitoring, reporting, and implementation of marine litter and microlitter measures are carried out following relevant MSFD provisions and have been further specified within a Decision by the European Commission (2017/848/EU). Below the criteria for D10.

Marine Litter within the EU MSFD

Properties and quantities of marine litter do not cause harm to the coastal and marine environment (Descriptor 10)

Criteria D10C1 - Primary: The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed, are at levels that do not cause harm to the coastal and marine environment.

- ✓ amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)
- ✓ amount of litter in the water column (including floating at the surface) and deposited on the seafloor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)

Criteria D10C2 - Primary: The composition, amount and spatial distribution of micro-litter on the coastline, in the surface layer of the water column, and in seabed sediment, are at levels that do not cause harm to the coastal and marine environment.

- ✓ amount, distribution and, where possible, composition of microparticles (in particular microplastics) (10.1.3)

Criteria D10C3 - Secondary: The amount of litter and micro-litter ingested by marine animals is at a level that does not adversely affect the health of the species concerned.

- ✓ amount and composition of litter ingested by marine animals (10.2.1)

Criteria D10C4 - Secondary: The number of individuals of each species which are adversely affected due to litter, such as by entanglement, other types of injury or mortality, or health effects.

- **EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'**. The 2021 Zero Pollution Action Plan, a key deliverable of the European Green Deal, puts forth key targets to speed up reducing pollution at source. Target 5 addresses water quality improvement by reducing waste; by 2030, the EU should reduce by 50% plastic litter at sea and 30% microplastics released into the environment. Furthermore, the significant reduction of waste generation and by 50% residual municipal waste is aimed at.

- **Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment (SUP Directive)**. Where sustainable alternatives are easily available and affordable, single-use plastic products cannot be placed on the markets of EU Member States. Different measures are being applied to different products. For other single-use plastic products, the EU focuses on reducing consumption, introducing design requirements, labelling requirements, and Extended Producer Responsibility (EPR) schemes. Regulation on fishing gear is also included.
- **Directive (EU) 2018/851 amending Directive 2008/98/EC on waste (Waste Framework Directive).** Amending Directive 2008/98/EC on waste. The latest amendment contains updated measures to protect the environment and human health by preventing or reducing the generation of waste, the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use, which are crucial for the transition to a circular economy and for guaranteeing the Union's long-term competitiveness.
- **Directive (EU) 2018/852 amending Directive 94/62/EC on packaging and packaging waste (Packaging and Packaging Waste Directive).** Amending Directive 94/62/EC on packaging and packaging waste. The latest amendment contains updated measures to prevent the production of packaging waste and promote the reuse, recycling and other forms of recovering packaging waste. It also sets specific targets for recycling by 2025 and 2030.
- **European Biodiversity Strategy for 2030.** Pillar 1: Legally protect at least 30% of the EU's land area and 30% of its seas. Strictly protect at least a third of the EU's protected areas - representing 10% of the EU land and 10% of the EU sea. Effectively manage all protected areas, defining clear conservation objectives and measures and monitoring them appropriately.
- **Directive (EU) 2019/883 on port reception facilities for the delivery of waste from ships.** It regulates the discharges of waste from ships by improving the availability and use of adequate port reception facilities and the delivery of waste, including derelict fishing gear from the fishing sector. The directive further targets "fished waste" (waste collected in nets during fishing operations).
- **Directive (EU) 2015/720 amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags (Plastic Bags Directive)**. It requires the Member States to take measures such as national reduction targets and/or economic instruments (e.g. fees, taxes) and marketing restrictions (bans).

Regarding the Black Sea were numerous attempts to address the issue of marine litter on the regional level in the Black Sea basin, at the same time, until 2018 there were no concrete legal instruments dedicated specifically to the management of marine litter (Makarenko et al., 2020). Moreover, the concept of marine litter problem and definition of marine litter itself, as a legal term was neither accepted nor was well known in the Black Sea community. Despite these challenges in 2005, the Regional Activity on Marine Litter, supported by UNEP, was launched (UNEP 2005) and in 2009 the Report on Marine Litter in the Black Sea (incl. the text of the Draft Marine Litter Action Plan for the Black Sea) was elaborated and published (BSC 2009).

Draft Marine Litter Monitoring Programme for the Black Sea was not yet adopted, it is currently being considered by the national and international experts and is planned to be provided for adoption by Black Sea Commission (BSC) in the nearest future. In 2018 at the 34th Meeting of the Commission on the Protection of the Black Sea against Pollution (BSC) the "Black Sea Marine Litter Regional Action Plan" was presented.

BSC also joined the efforts of UNEP/MAP on the global level, within the work of UNEP Global Group on Indicators, in drafting the World Ocean Assessment Report II, within activities of Sustainable Ocean Initiative (SOI); implementation of European Union Marine Strategy Framework Directive and reaching the Good

Environmental Status of marine waters; circular economy and ecosystem services; agreements under relevant global and regional organizations covering our seas (i.e. General Fisheries Commission for Mediterranean (GFCM) and ACCOBAMS Agreement.

2. Marine litter interaction with cetaceans

The effects of marine litter on marine wildlife have been documented since the 1960s. However, the production of plastics and associated pollution has subsequently increased greatly, and marine debris has now been recognised as a global problem (CBD, 2016), with more than 800 species known to have been adversely affected (Fossi et al., 2018d; Kuhn and van Franeker, 2020).

For cetaceans, impacts from entanglement or ingestion can be acute or chronic. Almost two-thirds of cetacean species have been found to have ingested plastic macro-litter (2.5 cm+) and this affects species across many different habitats which exhibit different feeding techniques. This section focuses both on entanglement and ingestion.

Impacts of debris on marine fauna occur throughout the marine ecosystems (Gall and Thompson, 2015; Kühn et al., 2015). For marine mammals, impacts can be divided into those arising from entanglement, which can result in injury, drowning or strangulation, and those from ingestion, with pathology ranging from no discernible impact through to blockage of the digestive tract, suffocation and starvation (Sheavly and Register, 2007). Sub-lethal effects may compromise feeding and associated malnutrition, disease and reduced reproduction, growth and longevity (Moore et al., 2013). New data suggests when the dimension of the items ingested by marine fauna range from millimeter to nanometer in size (i.e., micro- debris 1 µm-5 mm and nano-plastics <1µm, GESAMP, 2016), this can lead to inflammation, damage of the tissues at the cellular level, or altered molecular pathways (Mattsson et al., 2015, 2017; Pedà et al., 2016). Baulch and Perry (2014) and Kühn et al. (2020) reviewed the data on plastic ingestion and entanglement rates available for cetaceans, showing an increase in the number of cases being reported over the last five decades. More than 130 papers/documents were published from 1965. Only 2 out of the 13 cetacean families analyzed have not interacted with debris, and ingestion appears to be the most common, occurring in over 60% of all cetacean species (Fossi et al 2018; Eisfeld-Pierantonio et al 2022), including species employing a variety of feeding techniques throughout the water column (Fossi et al., 2018, Fig. 4).

In contrast, entanglement events have only been documented in ∼30% of cetacean species (Fig. 4). The majority of entanglements for cetaceans are in ghost or active fishing gear (Baulch and Perry, 2014). Cetaceans tend be entangled around their neck, flippers and flukes (Moore et al., 2013; van der Hoop et al., 2014). However, for the ingestion of debris, the number of records does not reflect the magnitude of the issue, due to low detection rate and difficulty in retrieving and analyzing specimens. Sixty three percent of the 90 species of cetaceans have been reported to be affected by debris.

Items ingested are most commonly plastic (46% of all items ingested) and range in size from small fragments (<5 mm, Besseling et al., 2015; Lusher et al., 2018) to large sheets of plastic and netting over one meter long (Jacobsen et al., 2010; de Stephanis et al., 2013). However, globally, the paucity and homogeneity of data prevented a robust identification of whether, at a species level, there are certain cetacean species particularly prone to ingesting debris. This is mainly due to the difficulties in performing such analysis in these species and the lack of harmonized and standard protocols (e.g., many entanglement events or cases of debris ingestion are not reported). Seventy per cent of the documents analyzed were published after 2000, although only in the last few years were standardized protocols applied, and this can affect the reliability of the results reported.

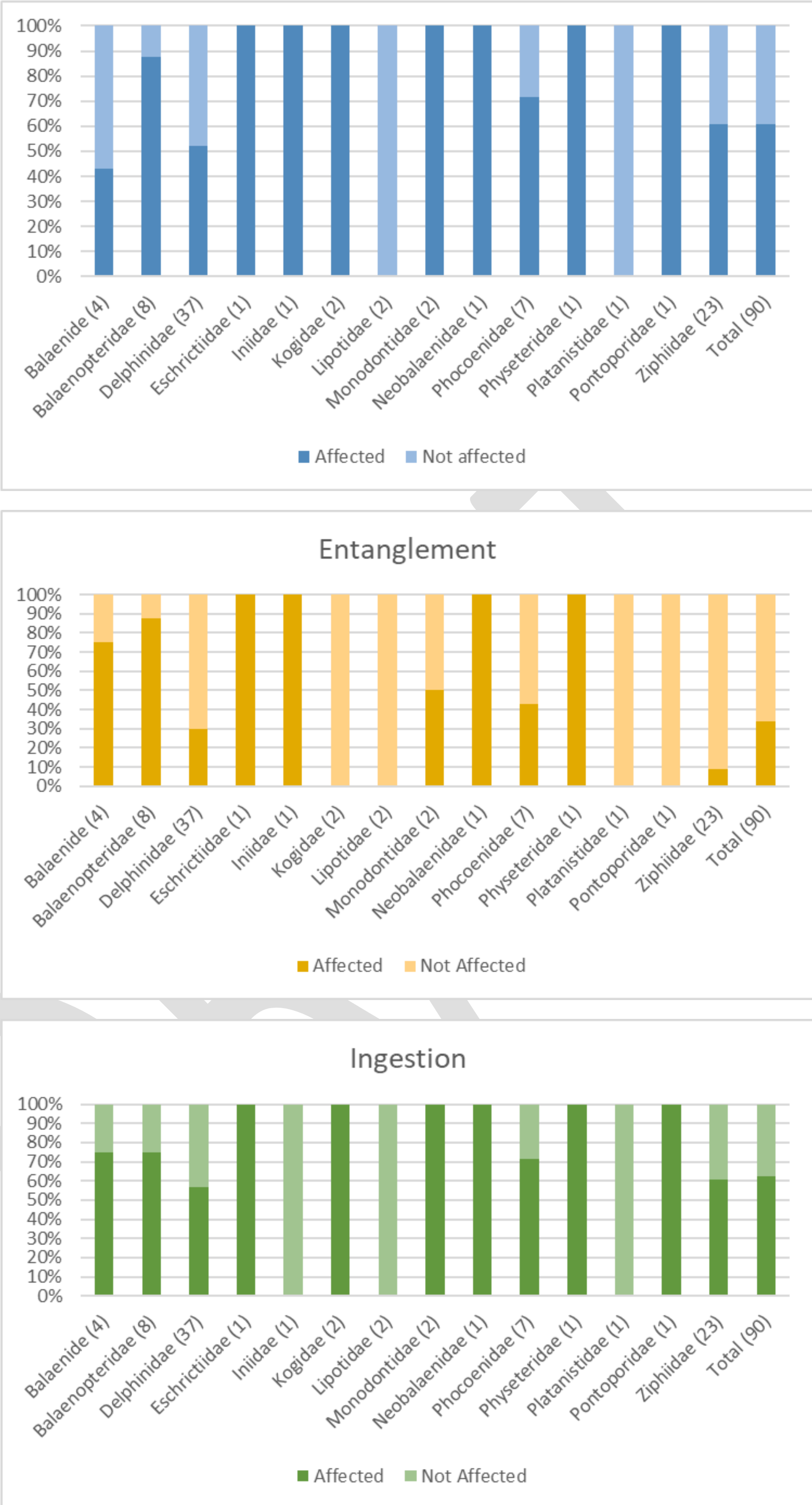


Figure 4. *Number of cetacean families affected by worldwide by marine litter (entanglement and ingestion) and separately by marine litter ingestion and entanglement. In brackets the number of species per family (modified by Fossi et al., 2018 and Eisfeld-Pierantonio et al., 2022).*

The study of microplastic ingestion by cetaceans is a challenging task, due to the difficulty in obtaining accurate samples during necropsies and analyzing large volumes (e.g., from large cetaceans). Few studies have directly identified microplastics in the digestive tracts of stranded cetaceans. Applying standard protocols for the detection and identification of microplastics in the digestive tract (Lusher et al., 2015, Panti et al., 2019), microplastics were found throughout the stomach/intestine of seven odotocetes species: *Ziphius cavirostris, Delphinus delphis, Stenella coeruleaolba, Phocoena phocoena, Orcinus orca, and Tursiops truncatus* (Lusher et al., 2018; van Franeker et al., 2018). Only one study on Mysticetes, a stranded humpback whale (*Megaptera novaeangliae*), recorded the presence of microplastic in its intestines, including fragments, and threads (Besseling et al., 2015). There are multiple possible routes of microplastic uptake, including direct ingestion from the water column while feeding, inhalation at the air-water interface, or via trophic transfer from prey items (IWC, 2013). Uptake of microplastics has been demonstrated in zooplankton species such as copepods and euphasiids (Kühn et al., 2015; Fossi et al., 2018b), which are some of the main prey of baleen whales and may thus be a source of secondary transfer of debris to cetaceans.

3. Main results of the bibliographic research on Marine Litter models distribution in the ACCOBAMS area

The first methodological step of this document consists in carrying out an accurate bibliographic research on the selected topic (hotspots of interactions between cetaceans and marine litter in the ACCOBAMS area) using the main research platform used for scientific publications (Scopus, PubMed, Google Scholar, etc.) and also grey literature (e.g. project's reports). The summary of each study has been reported under the title of the paper and the list of authors in ***Annex 2.***

Determining the amount of litter in the study area is a challenging task. Available observational data are spatially and temporally discontinuous and therefore insufficient to provide accurate information on the distribution of litter in the sea over larger regions and periods. To address this problem, most studies rely on indirect methods and numerical models. For instance, plastic concentrations based on Lagrangian simulations estimates the probability of ingestion using binomial model that takes into account the biological characteristics of the different species and the litter distribution. Darmon et al. (2017) investigated the co-occurrence of sea turtles and plastic in French Mediterranean and Atlantic waters by analyzing aerial observations and assessing the probability of sea turtles encountering floating litter.

Compa et al. (2019) produced risk maps for the entire Mediterranean Sea for several species by using the global plastic distribution model of Lebreton et al. (2012). Generalized additive models (GAM) were used to determine the exposure and risk of each species, defined as the ingestion rate considering biological characteristics such as mobility, body size, class and habitat. Fossi et al. (2017) and Guerrini et al. (2019) investigated the impact of plastic pollution and microplastics on the feeding grounds of fin whales in the Pelagos Sanctuary and used plastic distribution simulations to compute plastic concentration in their study region. The authors calculate risk as to the product of the average concentration of marine debris determined by their models and the presence/absence of fin whales in their study area. Finally, Soto-Navarro et al. (2021) created a global risk map for the Mediterranean Sea by using a high-resolution 3D marine litter dispersion model to estimate the concentration of particles according to their physical properties, combined with a larger dataset of species to estimate their exposure and vulnerability. Despite the valuable scientific relevance of the studies described, the approach adopted in most of them is still based on the numerical estimation of litter in the investigated areas and/or the predicted ingestion rate, which may not reflect the effective pressures to which marine species are exposed in the Mediterranean Sea. To produce a more accurate and reliable risk scenario, the collection of empirical data on the extent and typology of plastic litter, the spatial distribution of organisms and the potential impact on them are needed.

Although the circulation of the Black Sea is well known (Oğuz and Besiktepe, 1999; Korotaev et al., 2003; Zhurbas et al., 2004; Stanev, 2005), the fate of floating marine litter, for instance, in the open ocean remain unclear. Objects that are denser than seawater (naturally or due to biofouling) sink and accumulate on the

bottom; less dense objects float on the sea surface and are transported by currents, waves and wind; some of these floating objects are washed ashore. It is expected that areas of weak circulation act as traps for sinking marine litter and/or that floating marine litter accumulates in frontal areas.
To date, large-scale accumulation areas similar to garbage patches have not yet been observed in the Black Sea. Three-dimensional circulation modeling in the Black Sea reached a high level of maturity both in the field of structured-grid modeling (Stanev, 2005) and in the development of unstructured-grid models (Stanev et al., 2017), which are well fitted to the coastal regions.
Lagrangian observations in the Black Sea have been reported by Zhurbas et al. (2004). Recently, Silvestrova et al. (2016) demonstrated the usefulness of using the global positioning system to obtain high-quality positioning data over wide areas and long times. Lagrangian modeling in the Black Sea has been mostly used for predicting the transport and dispersal of oil spills.
According to Stanev and Ricker (2019), floating marine litter concentrations decrease in the eastern and northern areas and increased along the western coasts.
An approach based on a mesoscale circulation model combined with a particle tracking model established that the litter distribution is nearly independent of the source location and is mainly controlled by the basin circulation system of the Black Sea. The western gyre predominantly accumulates floating debris seasonally After the integration of the main cyclonic current in winter, the debris in the inner basin moves east. Retention zones along the south-western coast persist in time. Simulations demonstrate an increasing litter accumulation in summer on the North Western Shelf and shelf break. (Maladinova et al., 2020).

3.2 Main Conclusion on Marine Litter Models distribution in the Mediterranean area and Hot Spot Identification

The results show from several paper, and particularly the Javier Soto-Navarro et al 2020, that the highest concentrations of neutral particles are found in the Catalan continental shelf, the proximities of the Strait of Sicily and the Gulf of Gabes, the Adriatic Sea and the easternmost slope of the Levantine basin. For the floating particles large concentrations are also found in the Balearic Sea. On the other hand, the particles with negative buoyancy rapidly sink and reach the seafloor close to their sources, with no time to disperse. The comparison among different studies suggests that the main limitation of the modelling studies is linked to the lack of accurate in-formation about the amount of ML released into the sea from different sources. Additionally, there are several issues that could be explored in the future. One of them would be to include the effects of population fluctuation in the coastal areas due to, for instance, the touristic seasonality, as well as the seasonal variability of the river discharge. The regions of higher temporal variability mostly coincide with the ML accumulation regions (Fig. 5).

In addition, recent studies underline that the amount of transboundary litter in Mediterranean countries could be as large as 30% although both regional and seasonal differences could be significant (Macias et al, 2022). This aspect makes the management of mitigations tools difficult.

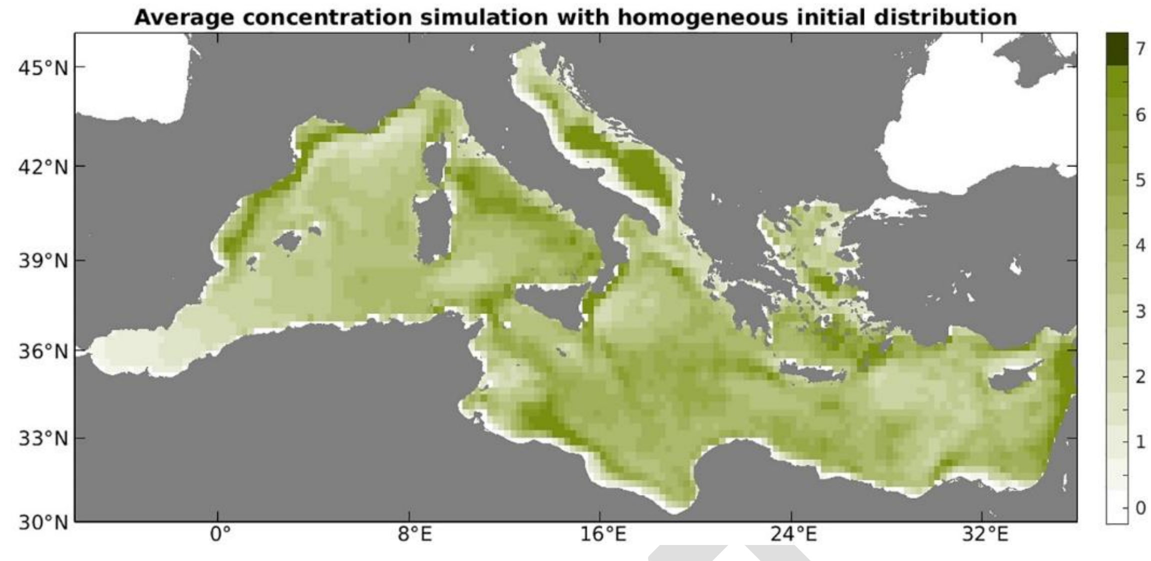


Figure 4. *Average concentration for the simulation starting from a homogeneous particle distribution over the whole basin. Units are kg/km² (From: 3D hotspots of marine litter in the Mediterranean: A modeling study (Soto-Navarro,et al. 2020).*

4. Main results of the bibliographic research on the impact of Marine Litter in Cetaceans in ACCOBAMS area

This paragraph will cover in detail the bibliographic research on impact of Marine Litter interaction (including microplastics) with Cetaceans in the ACCOBAMS area with a particular focus on the most studied area: the Mediterranean Sea. ***13 papers*** *(until June 2022) report studies (Tab.1, Annex 2) on plastic impact and interaction with cetacean species in the Mediterranean and Black Sea areas.*

While the presence of macroplastic ingestion in cetaceans is well understood both in the Mediterranean (**Tab. 1**) and globally (Baulch and Perry, 2014), microplastic ingestion in these species, particularly mysticetes, remains poorly studied due to difficulties in sampling and analysis and lack of standardisation methods (Zantis et al., 2021). Most of the ingested particles may be excreted in the faeces, and the effective rates of ingestion and excretion remain unknown. Despite that, the large number of synthetic particles in the feeding ground of marine mammals, secondary ingestion by contaminated prey and the potential release and accumulation of contaminants from ingested plastic poses a serious threat to these organisms. Promoting these types of studies and harmonising quantification systems to allow more accurate intra- and interspecific comparisons among cetacean species should be a priority for the future to better assess the impacts of plastic 148 debris and the consequences for these sentinel species, strengthening their potential role as plastic bioindicators at a wide-scale (Fossi et al., 2020).

Information on the ingestion of MPs by cetaceans in the ACCOBAMS areas is scarce, not specifically focused on the characteristics of the items found (e.g. type, colour, chemical composition and possible sources) and limited to their frequency of occurrence. Corazzola et al. (2021), who analysed various organisms stranded on the Ligurian coast in the SPAMI Pelagos Sanctuary, report a number of MPs ranging from 14 items in the striped dolphin to 59 items in the bottlenose dolphin. Similarly, Novillo et al. (2020) report an average number of 14.9 ± 22.3 items/ind. isolated from the GITs of 43 stranded specimens on the Spanish coast (Tab.1). The presence of macroplastics, especially sheetlike items, was reported in Cuvier's beaked whale, striped dolphin and bottlenose dolphin in the studies by Duras et al. (2021) and Alexiadou et al. (2019). Odontocetes, which exhibit an active feeding linked to a highly developed echolocation system used for predation and orientation (Walker and Coe, 1990), could be mainly affected by secondary ingestion of plastic when they consume contaminated prey, as reported in the available literature (Bellas et al., 2016; Compa et al., 2018; Romeo et al., 2016).

In addition, differential feeding behaviour and spatial distribution could be other factors influencing their susceptibility to the impact of plastic litter. *Ziphius cavirostris*, for which deep-diving behaviour and suction mode of feeding pattern has been described, seems to be more subjected to plastic consumption (Poeta et al., 2017; Puig-Lozano et al., 2018) than the other two species considered. *Stenella coeruleoalba* and *Tursiops truncatus* prefer a raptorial feeding pattern (Werth, 2006), which could reduce the likelihood of plastic 144 ingestion (Alexiadou et al., 2019). In addition, species inhabiting areas where litter accumulates, such as coastal areas and the seafloor, might be more prone to ingest plastic items, as confirmed by the highest number of particles found in the bottlenose dolphin and Cuvier's beaked whale, respectively, in this study and also highlighted by Puig-Lozano et al. (2018) and Alexiadou et al. (2019)

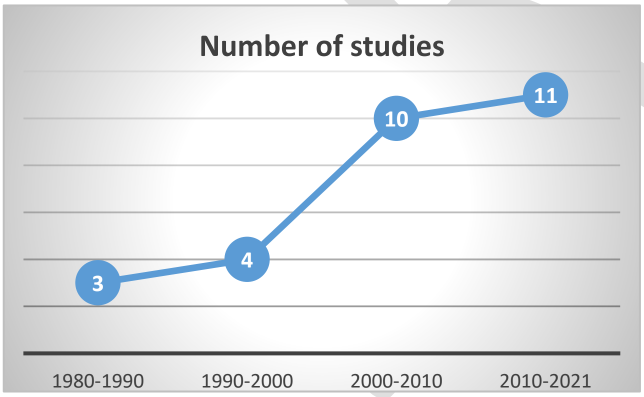
Table 1. *Current status of peer-reviewed papers published on marine litter ingestion in cetaceans in the Mediterranean Sea Sub Region proposed by MSFD. (Galli M. 2022 PhD Thesis)*

Species	Mediterranean Sea sub-region	Year of Study	n°. specimens	Occurrence %	Total n°. items	Avg. items/ind. ± sd	Plastic size	References
Physeter macrocephalus	Western Mediterranean Sea	2009-2016	13	77% (10)	n.a.	n.a.	> 25 mm	Panti et al., 2019
	Western Mediterranean Sea	2012	1	100%	59	n.a.	> 25 mm	de Stephanis *et al.*,2013
	Western Mediterranean Sea	1989	1	100%	n.a.	n.a.	> 25 mm	Viale *et al.*, 1992
	Aegean Levantine Sea	1993-2014	10	60% (6)	155	15.2 ± 42.2	> 25 mm	Alexiadou et al., 2019
	Aegean Levantine Sea	2006	8	50% (4)	n.a.	n.a.	> 25 mm	Notarbartolo-di-Sciara *et al.*, 2012
	Aegean Levantin Sea	2003	1	100%	1	n.a.	> 25 mm	Roberts 2003
	Adriatic Sea (Italy)	2014	3	100%	n.a.	n.a.	> 25 mm	Podestà *et al.*,2015
	Adriatic Sea (Italy)	2009	6	100%	n.a.	n.a.	> 25 mm	Mazzariol *et al.*, 2011
	Adriatic Sea (Italy)	1981-1985	1	100%	n.a.	n.a.	> 25 mm	Cagnolaro *et al.*,1986
Globicephala melas	Western Mediterranean Sea	2019	1	100%	41	n.a.	< 5 mm	Corazzola et al., 2021
Ziphius cavirostris	Western Mediterranean Sea	2017	1	100%	59	n.a.	< 5 mm	Corazzola et al., 2021
	Adriatic Sea	1981-1985	1	100%	n.a.	n.a.	> 25 mm	Cagnolaro *et al.*,1986
	Aegean Levantine Sea	1990-2019	4	25% (1)	n.a.	n.a.	> 25 mm	Duras et al., 2021
	Aegean Levantine Sea	1993-2014	5	20% (1)	n.a.	n.a.	> 25 mm	Alexiadou et al., 2019
Grampus griseus	Ionian and Central Mediterranean Sea	1993-2014	5	20% (1)	n.a.	2.6 ± 5.8	> 25 mm	Alexiadou et al., 2019
	Aegean Levantine Sea	1993-1999	1	100%	1	n.a.	> 25 mm	Shoham-Frieder *et al.*,2002
Tursiops truncatus	Western Mediterranean Sea	2019	2	100%	59	n.a.	< 5 mm	Corazzola et al., 2021
	Ionian and Central Mediterranean Sea	1993-2014	4	0%	n.a.	n.a.	no items	Alexiadou et al., 2019
	Aegean Sea	1990-2019	253	1% (2)	n.a.	n.a.	> 25 mm	Duras et al., 2021
	Aegean Levantine Sea	2007	1	100%	n.a.	n.a.	> 25 mm	Levy *et al.*,2009
Stenella coeruleoalba	Western Mediterranean Sea	1988-2017	43	90.5% (40)	672	14.9 ± 22.3	< 5 mm	Novillo et al., 2020
	Western Mediterranean Sea	2019	1	100%	14	n.a.	< 5 mm	Corazzola et al., 2021

	Adriatic Sea	1998	1	100%	n.a.	n.a.	> 25 mm	Pribanic et al., 1999
	Ionian and Central Mediterranean Sea	1993-2014	4	0%	n.a.	n.a.	no items	Alexiadou et al., 2019
	Aegean Levantine Sea	1990-2019	33	3% (1)	n.a.	n.a.	> 25 mm	Duras et al., 2021
Delphinus delphis	Ionian and Central Mediterranean Sea	1993-2014	2	0%	n.a.	n.a.	no items	Alexiadou et al., 2019
Phocoena phocoena	Ionian and Central Mediterranean Sea	1993-2014	5	20% (1)	n.a.	0.2 ± 0.4	> 25 mm	Alexiadou et al., 2019
	Black Sea	2002-2003	43	11.63% (5)	n.a.	n.a.	> 25 mm	Tonay *et al.*,2007
Balaenoptera physalus	Mediterranean Sea (Italian coast)	2007-2011	5	N(Phthalates concentration)	n..a	n.a.	n.a.	Fossi *et al.*, 2012

Some general conclusions can be drawn from the analysis of the publications published on this subject:

- The number of papers published on this topic has grown strongly in the last decade (Fig 6 A).
- The most studied area results the North Western Mediterranean sea focusing mainly in the SPAMI Pelagos Sanctuary (Fig 6 B).
- The most investigated species both in terms of macro and micro litter ingestion results the sperm whale followed by the striped dolphin (Fig.7).



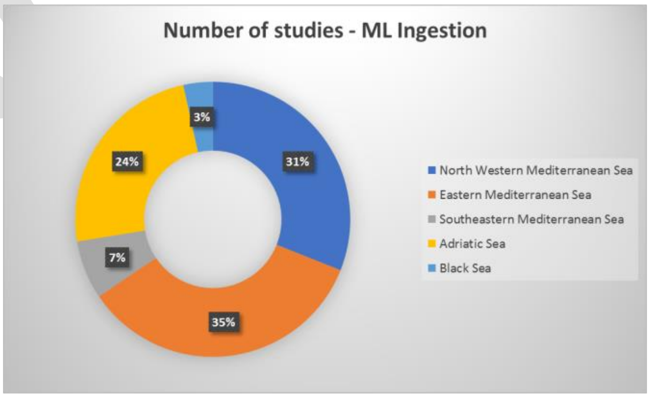


Figure 6*. Number of studies on Marine Litter interaction with Cetaceans in the ACCOBAMS area: A) Time scale; B) Spatial scale*

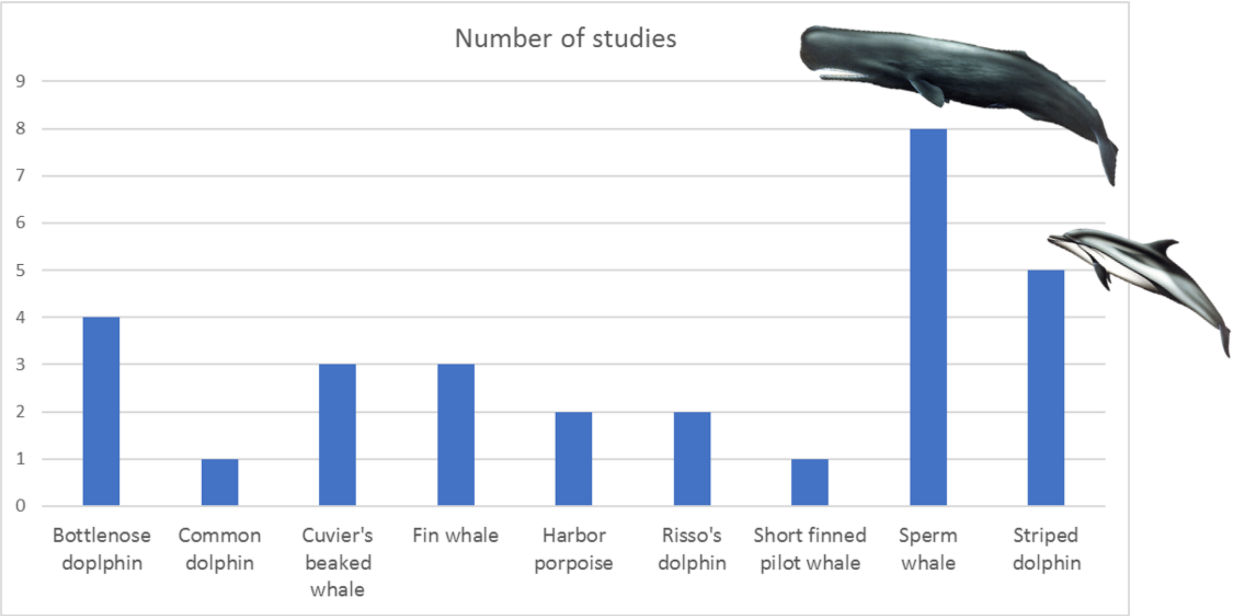


Figure 7*. Number of studies on Marine Litter interaction with different species of Cetaceans in the ACCOBAMS area*

5. Risk Analysis and hot spot identification

One of the most important challenges to be faced in order to define the potential risk of cetaceans inhabiting ACCOBAMS areas, in relation to the presence of marine litter, is linked to the identification of the Hot Spot areas, as defined by the distribution models (chapter 3 of the present document) and the potential overlap with the core area of the different species. In order to make a first contribution on this complex topic, this chapter describes two strategies, carried out by two important international projects, devoted to identifying risk assessment methodologies based on the presence of the ML and the species distributions.

Here we present the methodologies used and the preliminary results obtained from the application of risk analyses carried out in the study area by two projects and divided into the following sub-sections: **ASI and Plastic Busters MPAs (PB-MPAs) Sinergy, Plastic Busters MPAs Methodology.**

5. 1. Risk analysis approach: ASI and PB-MPAs Synergy

An important section of this report concerns the synergy between the ASI initiative and the Med-Interreg project Plastic Busters MPAs (https://plasticbustersmpas.interreg-med.eu/). A risk assessment methodology are used to define the Cetaceans risk assessment, related to hot spot areas of ML (in the Pelagos Sanctuary as a key study area) using ASI data (provided by ACCOBAMS SC to the PB-MPAs Consortium for the area concerned to the project) in a collaborative effort between UNISI, IFREMER and LaMMA Consortium.

As previously mentioned debris impact on marine wildlife has become a major issue of concern. Many species have been identified as being threatened by collision, entanglement or ingestion of debris, generally plastics, which constitute the predominant part of the recorded marine debris. Assessing sensitive areas, where exposure to debris are high, is thus crucial, in particular for cetacean and sea turtles which have been proposed as sentinels of debris levels for the Marine Strategy Framework Directive and for the UNEP-IMAP programmes.

In this section we propose the application of the methodology previously used by Darmon et al. 2016 for sea turtle Risk assessment. In this previous paper the objective was to assess sea turtle exposure to marine debris in the 3 metropolitan French fronts. Using aerial surveys performed in the Channel, the Atlantic and the Mediterranean regions in winter and summer 2011–2012, Darmon and collaborator evaluated exposure areas and magnitude in terms of spatial overlap, encounter probability and density of surrounding debris at various spatial scales. Major overlapping areas appeared in the Atlantic and Mediterranean fronts, concerning mostly the leatherback and the loggerhead turtles respectively. The probability for individuals to be in contact with debris (around 90% of individuals within a radius of 2 km) and the density of debris surrounding individuals (up to 16 items with a radius of 2 km, 88 items within a radius of 10 km) were very high, whatever the considered spatial scale, especially in the Mediterranean region and during the summer season.

The comparison of the observed mean debris density with random distribution suggested that turtles selected debris areas. This may occur if both debris and turtles drift to the same areas due to currents, if turtles meet debris accidentally by selecting high food concentration areas, and/or if turtles actively seek debris out, confounding them with their preys. The authors concluded that empirical data on sea turtles and debris distributions, such as those collected aerially, are essential to better identify the location and the factors determining risks.

We briefly describe the methodology used to define the Cetaceans risk assessment (in the Pelagos Sanctuary as a key study area) using ASI data in the PB-MPAs Consortium as previously explained.

Several steps are identified for the data processing according to the strategy previously proposed by Darmon et al 2016:

1: to define square unit (5-10 -nautical miles) for the whole Pelagos Sanctuary;

2: to calculate the amount of each variable (litter/Cetacean/ turtles/sharks, etc.) in each square;

3: to define the sampling effort in each square (hours of flight/ square, probability of sampling effort): maximum is maximum effort or number of hours of flight (1), zero is no effort;

4: to relate the amounts of each variable/ sampling effort in each square (probability of presence) maximum (1) is maximum amount of each variable (litter/ species), zero is absence

5: map the distribution (pondered by sampling effort) (each square as 0 to 1 value)

6: cross map data on litter + each variable (Cetacean/ turtles/sharks, etc.). This may be through multiplying the probability from points 3 and 4

7: analyse the distribution of cross probability (6) through various algorithms such as kernel, kriging, minimum distance. etc.

Since data on litter will come from the counts of large debris only (>20cm), a refined analysis could come from the modelling of distribution litter / microplastics in the area for the time of surveys and then cross map probabilities.

The ACCOBAMS data for Plastic Busters MPAs Consortium used in this analysis are related to observations of marine mammals, hard-shelled sea-turtles and marine litter within the survey blocks n.04, 08a, 08b,09, 10, 11, 12, 13, 20, 21 and 22b acquired during the ASI aerial survey carried out in 2018 and 2019 reported below (Fig. 8 and 9).

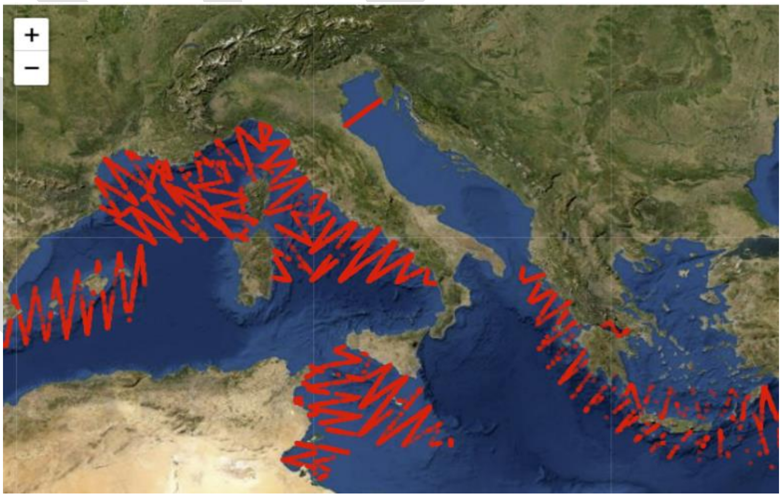


Figure 8. *Observations of marine mammals, hard-shelled sea turtles and marine litter within the survey blocks n.04, 08a, 08b,09, 10, 11, 12, 13, 20, 21 and 22b acquired during the ASI aerial survey carried out in 2018 and 2019.*

Data were analyzed **fitting a Density Surface Model** in each survey area; perpendicular distances between observations and transects have been taken into account to feed the model; other covariates, such as Beaufort sea state, have been only tested, with promising results. Finally, abundance estimates have been produced for the different areas on a 10x10 km grid. The preliminary results of this cetaceans risk assessment in the selected areas are reported in Fig. 8.

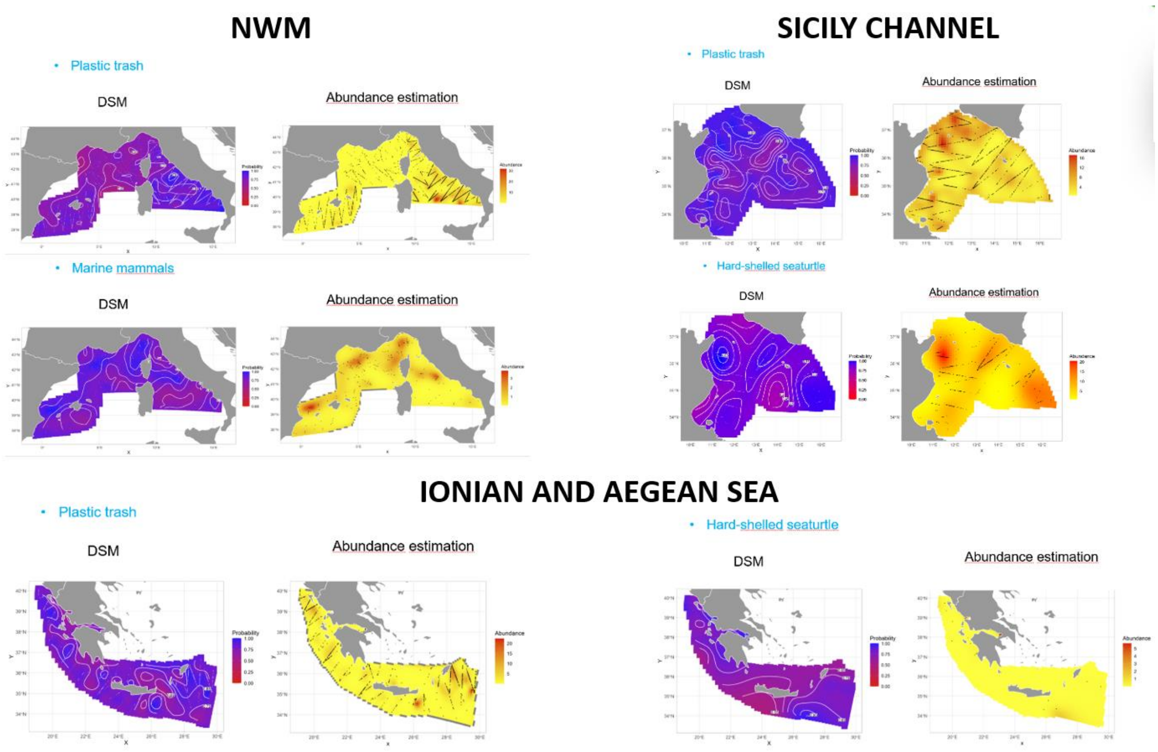


Figure 9. *Observations of marine mammals, sea turtles and marine litter within the survey blocks n.04, 08a, 08b,09, 10, 11, 12, 13, 20, 21 and 22b acquired during the ASI aerial survey carried out in 2018 and 2019. Preliminary Risk analysis (unpublished data).*

5. 2. The Plastic Busters MPAs Methodology and preliminary results

Plastic Busters MPAs is a 4-year-long InterregMed-project aiming to contribute to maintaining biodiversity and preserving natural ecosystems in pelagic and coastal marine protected areas (MPAs), by defining and implementing a harmonized approach against marine litter. The project entails actions that address the whole management cycle of marine litter, from monitoring and assessment to prevention and mitigation, as well as actions to strengthen networking between and among pelagic and coastal MPAs.

Plastic Busters MPAs consolidates Mediterranean efforts against marine litter by:

- Assessing the impacts of marine litter on biodiversity in MPAs and identifying marine litter 'hotspot' areas;
- Defining and testing tailor-made marine litter surveillance, prevention and mitigation measures in MPAs;
- Developing a common framework of marine litter actions for Interreg Mediterranean regions towards the conservation of biodiversity in Med MPAs.

The Plastic Busters MPAs project deploys the multidisciplinary strategy and common framework of actions developed within the Plastic Busters initiative led by the University of Siena and the Sustainable Development Solutions Network Mediterranean (SDSN Med). This initiative frames the priority actions needed to tackle marine litter in the Mediterranean basin and was labelled under the Union for the Mediterranean (UfM) in 2016, gathering the political support of 43 Euro-Mediterranean countries.

In this section we describe the methodological approach end the preliminary results obtained in the Plastic Busters MPAs Interreg project for the Risk assessment of marine litter and marine megafauna for the Pelagos Sanctuary (UNISI and CIMA unpublished data)

Home range analysis for marine megafauna distribution

Kernel density estimation was used to obtain marine megafauna distribution. However, considering that some transects were made in the same area (e.g. around the harbours), it was necessary to weight the effort: to do so, the Encounter Rate was chosen as the best method.

The species considered were divided in different categories:

- *Cetaceans*: striped dolphin (sc), fin whale (bp), bottlenose dolphin (tt), deep divers (deepd) which include sperm whales, risso's dolphin and cuvier's beaked whale.
- *Associated species* (birds, fish, …): jellyfish (jellyf), sun fish (mm) and giant devil ray (mb).
- *Seabirds:* different species regrouped in one group, such as Scopoli's shearwater, yelkouan shearwater, common tern, European shag (seab). Three species were then investigated due to their importance in the PNAT area: Scopoli's shearwater (cd), Yelkouan shearwater (py), Audouin's gull (ia). This last species, ia, was sighted only in PNAT.

The 1 km European Environmental Agency's (EEA) INSPIRE compliant reference grid was used as the grid for the analysis. For each cell, the total number of individuals of the same species sighted during the whole campaign was obtained (Table 2), together with the kilometres surveyed in the whole campaign were calculated.

The Encounter Rate was calculated for each cell *i,* dividing the total number of individuals of the species *j* in the cell *i* (N_{ij}), by the kilometres surveyed in the cell *i* (L_i), and normalized by the highest value after the outliers:

$$ER_{ij} = \frac{\frac{N_{ij}}{L_i}}{ER_{\max(j)}}$$

***Table 2** : Summary of the species dataset obtained during the Plastic Busters MPAs survey in the Pelagos Sanctuary during June-July 2019 (unpublished data)*

Species	**No individuals**	**No sightings**	**Cells with ER_{ij} > 0**
Fin whale (bp)	30	18	14
Deep divers (deepd)	27	15	14
Striped dolphin (sc)	829	56	50
Bottlenose dolphin (tt)	77	15	15
Jellyfish (jellyf)	1360	51	43
Seabirds (seab)	657	332	257
Giant devil ray (mb)	22	22	17
Sunfish (mm)	47	42	33
Scopoli's shearwater (cd)	471	258	204
Yelkouan shearwater (py)	169	65	57
Audouin's gull (ia)	48	34	27

Kernel density estimation (KDE) was applied using centroids of cells as a reference, with a radius of 20 km and weighted considering the ER. The radius was considered suitable considering the distribution of animals and the dispersion of the plastic litter.

The KDE was done separately, for each species (sc, bp, tt, mm, mb, cd, py, ia) or group of species (deepd, seab, jellyf). The 50% contour was then used to identify core area (HR50) of species/group_species distribution and the 90% contour to identify general distribution (HR90).

In order to assess marine litter hazard for the two considered HRs, floating litter and microplastic density was associated to the HR50 and HR90 of each species/group of species.

Regarding the cetacean distribution, it is evident the importance of the continental slope and submarine canyons for the majority of species, except bottlenose dolphins which prefer the continental shelf. For this reason, the distribution of the first three groups is concentrated in the northern western part of Pelagos, while the bottlenose dolphins are indeed more present near the coast of Tuscany.

For the associated species the distribution seems to concentrate near the coast, especially for the seabirds which are more present along the Tuscany islands. It is interesting the overlap of the jellyfish and sunfish distributions (the final data are reported in the final report of the Interreg-Med Project Plastic Busters MPAs).

Spatial risk assessment and impact on biodiversity in the Pelagos Sanctuary

To investigate the potential interactions and impacts of floating litter on the observed species during summer 2019, the mean density of sea surface floating macrolitter and MPs in the general (H90) and core (H50) distribution areas of each species were compared to the overall mean density observed in the SPAMI Pelagos Sanctuary.

The results obtained from the statistical tests revealed significantly higher concentrations of floating sea surface macrolitter in both the H90 and H50 distribution areas of the bottlenose dolphin, as well as in the seabird species Scopoli’s shearwaters and Yelkouan shearwaters. This data confirms the potential higher risk of plastic interaction and ingestion in these species, characterized by a coastal spatial distribution where litter tends to accumulate.

A risk of plastic ingestion was also highlighted for the filter-feeder giant devil ray in the H90 distribution areas of this species, probably connected with the active filtration of waters.

To understand the levels of risk to marine organisms associated with floating litter, hazard exposure maps were calculated to better represent species and plastic distribution data. Focusing on the surveyed area and aiming to draw a picture of the risk that existed in the surveyed area during the 2019 summer, an exposure map was created based on the marine megafauna encountered (Fig. 9).

The resulting risk map shows moderate to high risk in the Genoa Canyon, including its deepest part (2000 m depth). These results are consistent with the risk assessment of Fossi et al. (2017) and Guerrini et al. (2019), which demonstrate that the Liguro-Provencal basin is particularly vulnerable to plastic accumulation and may pose a serious threat to marine organisms, especially fin whales. Indeed, this area is known to play a crucial role for this species, especially during the summer feeding season (Panigada et al., 2005; Druon et al., 2012). Similarly, the western canyon regions were highlighted as affected by a moderate risk according to the results of the whole Pelagos Sanctuary. These areas were reported to be particularly impacted by floating debris by Darmon et al. (2017), who assessed the risk associated with sea turtle distribution, and Angiolillo et al. (2021), evaluating the litter distribution including MPs in different canyons of the Ligurian Sea. These areas may act as a sink for litter and plastic pollution (Angiolillo et al., 2021), representing a serious threat for all the species inhabiting and feeding in these habitats, such as the deep diver organisms (e.g., sperm whales and Cuvier's beaked whales).

In the eastern part, the highest risk was confirmed on the continental shelf of the Gulf of La Spezia, in the Tuscan Archipelago National Park and the north eastern sector of the island of Corsica, as also evidenced by a recent study by Soto-Navarro et al. (2021).

Overall, the assessed risk analysis provides reliable information on the threat posed by plastic litter in the SPAMI Pelagos Sanctuary and the potential exposure that may affect a wide range of organisms, and highlights the need to implement specific measures aimed at reducing the potential sources of plastic pollution and its impact on marine wildlife.

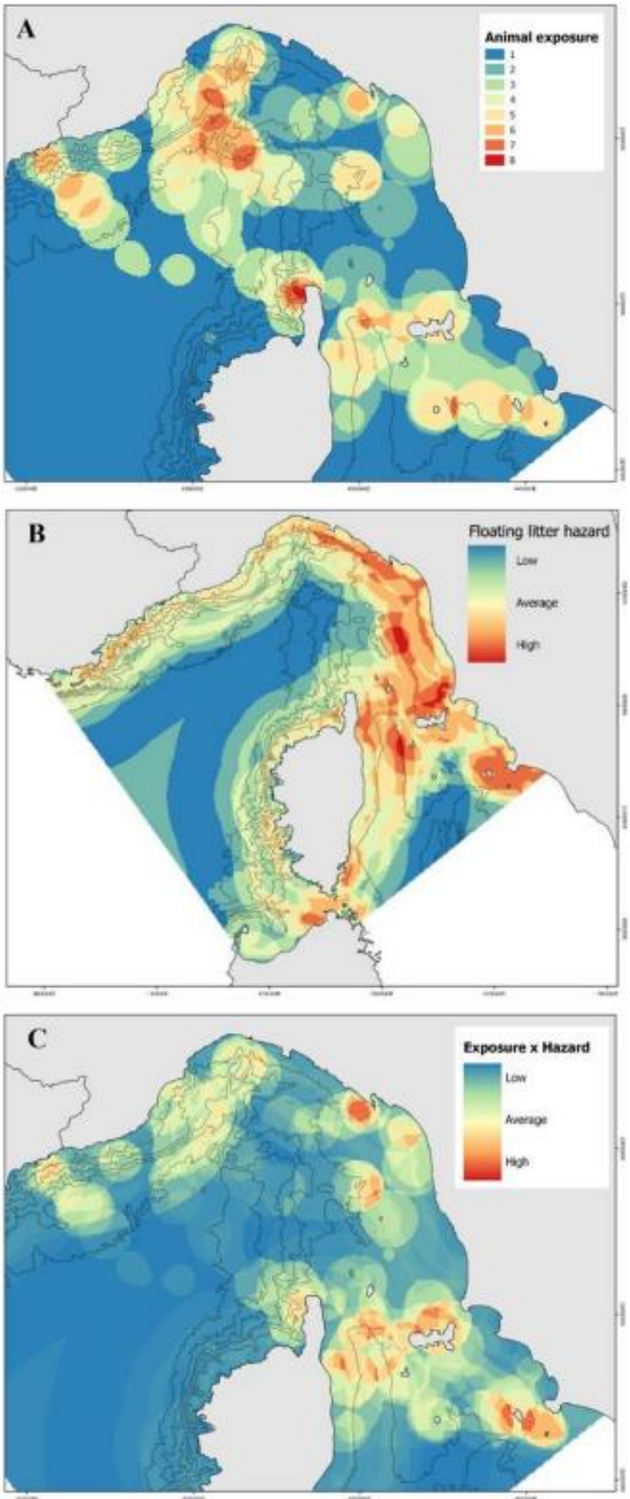


Figure 10. *Species richness according to the H90 distribution area (A) evaluated in the Pelagos Sanctuary during the sampling campaigns in summer 2019. Hazard map referring to the sea surface floating macrolitter distribution (B). Spatial risk assessment for the Pelagos Sanctuary combining exposure and hazard maps during the PB MPAs surveys (C) (Fossi et al. 2022 – unpublished data, D4.3.1 Report on the results and findings of the piloted marine litter monitoring approach to assess the impacts of marine litter on biota – Plastic Busters MPAs Med Interreg)*

6. Main Conclusions

Marine litter is a growing concern for marine animals, including cetaceans for which there is a developing body of evidence showing impacts of both entanglement and ingestion. Better understanding is needed of the current and predicted scales of impacts on cetacean species of both macro- and micro-litter in the ACCOBAMS areas. Some emerging methodological approaches, such as the "threefold approach," will help address data gaps (described in the document "Guidelines on the Best Practices to assess The Impact of chemical pollution on cetaceans/to measure the chemical contamination on cetaceans").

The relationship between this form of pollution and some cetaceans is strong and the particular feeding habits, and widespread distribution some cetacean species means that they can be proposed as ocean health indicators for macro- and micro-litter impacts at global scales, helping steer research. The species concerned are sperm whales (*Physeter macrocephalus*), for macro-litter at depth, and fin whales (*Balaenoptera physalus*), for micro-debris. Once appropriate techniques have been fully developed for non-lethal assessment, other whale species might also be used as indicators of litter pollution in their specific feeding zones. To coordinate scientific efforts to improve knowledge of marine litter (including seasonal distribution, quantification of floating marine litter in the SE Mediterranean, identify hotspots of marine litter to propose mitigation measures) and establish basin-scale monitoring on a regular basis to track changes over time

Despite the current development of the research on the interaction of marine litter and cetaceans worldwide and in the ACCOBAMS area, it is recommended to move forward in order to:

(1) Harmonize/standardized protocols for the analysis of marine litter in stranded organisms and share knowledge, facilities and samples. In particular, it is important to standardize methodologies for microplastic analysis on marine mammals simplifying and reducing the cost of these analysis;
(2) Enforcing national stranding networks to collect/share samples for different marine litter analysis and establishing an international network of all marine mammals and marine litter people (MML group/community);
(3) Share information, scientific results, images in a common and accessible database;
(4) Define the actual threat to organisms and to identify the most threatened species and hot spot areas according to season and species habitat use in EU waters;
(5)To define new methods to evaluate the exposure to plastics and plastic additives in free-ranging organisms;
(6) To evaluate the presence and effects of micro and nanoscale plastics, including sub-lethal effects;
(7) To enhance awareness raising communicating to other scientists, young people and, other citizens, stakeholders and policy makers.

ANNEX 1

Inventory of marine litter related projects and their focus

The list includes a core set of 25 projects, implemented at Mediterranean, Black Sea and European level, that focused on different aspects of the marine litter issue such as: monitoring and assessment, prevention and mitigation or the entire management cycle of marine litter pollution.

Table Annex 1. An overview of the relevant projects and initiatives that dealing with ML contamination in the Mediterranean area

ACRONYM	FULL TITLE	FUNDING SOURCE	THEMATIC FOCUS	WEBSITE
PLASTIC Busters MPAs	Preserving biodiversity from plastics in Mediterranean Marine Protected Areas	Interreg Med	monitoring & assessment - entire management cycle	link
ACT4LITTER	Joint measures to preserve natural ecosystem from marine litter in Mediterranean Marine Protected Areas	Interreg Med	entire management cycle	link
AMARE	Safeguarding the Marine Environment Together - Bridging Conservation and Stakeholder Uses in the NE Marine Protected Area	Interreg Med	monitoring & assessment	link
BASEMAN	Microplastics Analysis in European Waters	JPI Oceans	monitoring & assessment	link
COMMON	Coastal Management and Monitoring Network for tackling marine litter in Mediterranean Sea	ENI CBC Med	entire management cycle	link
DEFISHGEAR	Derelict Fishing Gear Management System in the Adriatic Region	IPA Adriatic	entire management cycle	link
INDICIT I & II	Implementation of Indicators of Marine Litter on Sea Turtles and Biota in Regional Sea Conventions and Marine Strategy Framework Directive Areas	EU DGENV	monitoring & assessment	link
MARELITT	Reducing the impact of marine litter in the form of derelict fishing gear in the Baltic sea	Interreg Baltic	prevention & mitigation	link
MARINE LITTER MED	Marine Litter MED project	EU	prevention & mitigation	link
MARLISCO	Marine Litter in European Seas - Social Awareness and Co-Responsibility	FP7	prevention & mitigation	link
MEDSEALITTER	Developing Mediterranean-specific protocols to protect biodiversity from litter impact at basin and local MPAs scales	Interreg Med	monitoring & assessment	link
SWIM-H2020 SM	Sustainable Water Integrated Management and Horizon 2020 Support Mechanism	EU	entire management cycle	link
WES	Water and Environment Support in the ENI Southern Neighbourhood Region	EU	entire management cycle	link

PLASTIC BUSTERS CAP	Fostering knowledge transfer to tackle marine litter in the Med by integrating EbA into ICZM	ENI CBC MED	Monitoring, assessment and mitigation	link
MoRiNet	Monitoring, census, removal and recycling of ghost nets: fishermen as key players in the safeguard of the sea	PO FEAMP	Monitoring, assessment, entire management cycle	link
LIFE Conceptu maris	CONservation of CEtaceans and Pelagic sea TUrtles in Med: Managing Actions for their Recovery In Sustainability	EU LIFE	Monitoring, assessment, mitigation	link
CLAIM	Cleaning litter by developing and applying innovative methods in European Seas	EU H2020	Monitoring, assessment, entire management cycle	link
Marine Litter MED II	Supports the implementation of the updated Regional Plan on Marine Litter Management in the Mediterranean approved by COP 22	EC DG ENV	Monitoring, assessment, entire management cycle	link
BlueMed Pilot Action	BlueMed Pilot Action On A Healthy Plastic-Free Mediterranean Sea	EU	entire management cycle	link
MARLESS	MARine Litter cross-border awarenESS and innovation actions	Interreg IT-HR	entire management cycle	link
MAELSTROM	Smart technology for MArinE Litter SusTainable RemOval and Management	EU H2020	entire management cycle	link
ANEMONE	Assessing the vulnerability of the Black Sea marine ecosystem to human pressures	EU	Monitoring, assessment, entire management cycle	link
EMBLAS I, EMBLAS II and EMLAS Plus	European Union for Improving Environmental Monitoring in the Black Sea (EU4EMBLAS) · Black Sea Water Quality Database	EU	Monitoring, assessment, entire management cycle	link
TUBITAK 118Y125 project	Distribution, composition, sources and ecological interactions of micro- and nanoplastics in the southeastern Black Sea	SCIENTIFIC AND TECHNOLOGICAL RESEARCH COUNCIL OF TÜRKİYE	monitoring & assessment	-

ANNEX 2 – Bibliographic research

Authors and year	Title	DOI	Abstract
Marine Litter models distribution in the ACCOBAMS area			
Maximenko et al., 2012	Pathways of marine debris derived from trajectories of Lagrangian drifters	doi.org/10.1016/j.marpolbul.2011.04.016	Global set of trajectories of satellite-tracked Lagrangian drifters is used to study the dynamics of marine debris. A probabilistic model is developed to eliminate the bias in spatial distribution of drifter data due to heterogeneous deployments. Model experiments, simulating long-term evolution of initially homogeneous drifter array, reveal five main sites of drifter aggregation, located in the subtropics and maintained by converging Ekman currents. The paper characterizes the geography and structure of the collection regions and discusses factors that determine their dynamics. A new scale Rc = (4k/|D|)1/2 is introduced to characterize tracer distribution under competing effects of horizontal divergence D and diffusion k. Existence and locations of all five accumulation zones have been recently confirmed by direct measurements of microplastic at the sea surface.
Mansui et al., 2015	Modelling the transport and accumulation of floating marine debris in the Mediterranean basin	oi.org/10.1016/j.marpolbul.2014.11.037	In the era of plastic and global environmental issues, when large garbage patches have been observed in the main oceanic basins, this work is the first attempt to explore the possibility that similar permanent accumulation structures may exist in the Mediterranean Sea. The questions addressed in this work are: can the general circulation, with its sub-basins scale gyres and mesoscale instabilities, foster the concentration of floating items in some regions? Where are the more likely coastal zones impacted from open ocean sources? Multi-annual simulations of advected surface passive debris depict the Tyrrhenian Sea, the north-western Mediterranean sub-basin and the Gulf of Sirte as possible retention areas. The western Mediterranean coasts present very low coastal impact, while the coastal strip from Tunisia to Syria appears as the favourite destination. No permanent structure able to retain floating items in the long-term were found, as the basin circulation variability brings sufficient anomalies.
Van Sebille et al., 2015	A global inventory of small floating plastic debris	0.1088/1748-9326/10/12/124006	Microplastic debris floating at the ocean surface can harm marine life. Understanding the severity of this harm requires knowledge of plastic abundance and distributions. Dozens of expeditions measuring microplastics have been carried out since the 1970s,

			but they have primarily focused on the North Atlantic and North Pacific accumulation zones, with much sparser coverage elsewhere. Here, we use the largest dataset of microplastic measurements assembled to date to assess the confidence we can have in global estimates of microplastic abundance and mass. We use a rigorous statistical framework to standardize a global dataset of plastic marine debris measured using surface-trawling plankton nets and coupled this with three different ocean circulation models to spatially interpolate the observations. Our estimates show that the accumulated number of microplastic particles in 2014 ranges from 15 to 51 trillion particles, weighing between 93 and 236 thousand metric tons, which is only approximately 1% of global plastic waste estimated to enter the ocean in the year 2010. These estimates are larger than previous global estimates, but vary widely because the scarcity of data in most of the world ocean, differences in model formulations, and fundamental knowledge gaps in the sources, transformations and fates of microplastics in the ocean.
Liubartseva et a., 2016	Regional approach to modeling the transport of floating plastic debris in the Adriatic Sea	doi.org/10.1016/j.marpolbul.2015.12.031	Sea surface concentrations of plastics and their fluxes onto coastlines are simulated over 2009–2015. Calculations incorporate combinations of terrestrial and maritime litter inputs, the Lagrangian model MEDSLIK-II forced by AFS ocean current simulations, and ECMWF wind analyses. With a relatively short particle half-life of 43.7 days, the Adriatic Sea is defined as a highly dissipative basin where the shoreline is, by construction, the main sink of floating debris. Our model results show that the coastline of the Po Delta receives a plastic flux of approximately 70 kg(km day)-1. The most polluted sea surface area (> 10 g km-2 floating debris) is represented by an elongated band shifted to the Italian coastline and narrowed from northwest to southeast. Evident seasonality is found in the calculated plastic concentration fields and the coastline fluxes. Complex source–receptor relationships among the basin's subregions are quantified in impact matrices.
Carlson et al., 2017	Combining Litter Observations with a Regional Ocean Model to Identify Sources and Sinks of Floating Debris in a Semi-enclosed Basin: The Adriatic Sea	doi.org/10.3389/fmars.2017.00078	Visual ship transect surveys provide crucial information about the density, and spatial distribution of floating anthropogenic litter in a basin. However, such observations provide a 'snapshot' of local conditions at a given time and cannot be used to deduce the provenance of the litter or to predict its fate, crucial information for management and mitigation policies. Particle tracking techniques have seen extensive use in these roles, however, most previous studies have used simplistic initial conditions based on bulk average inputs of debris to the system. Here, observations of floating anthropogenic macro debris in the Adriatic Sea are used

			to define initial conditions (number of particles, location, and time) in a Lagrangian particle tracking model. Particles are advected backward and forward in time for 60 days (120 days total) using surface velocities from an operational regional ocean model. Sources and sinks for debris observed in the central and southern Adriatic in May 2013 and March 2015 included the Italian coastline from Pescara to Brindisi, the Croatian island of Mljet, and the coastline from Dubrovnik through Montenegro to Albania. Debris observed in the northern Adriatic originated from the Istrian peninsula to the Italian city of Termoli, as well as the Croatian island of Cres and the Kornati archipelago. Particles spent a total of roughly 47 days afloat. Coastal currents, notably the eastern and western Adriatic currents, resulted in large alongshore displacements. Our results indicate that anthropogenic macro debris originates largely from coastal sources near population centers and is advected by the cyclonic surface circulation until it strands on the southwest (Italian) coast, exits the Adriatic, or recirculates in the southern gyre.
Fossi et al., 2017	Plastic Debris Occurrence, Convergence Areas and Fin Whales Feeding Ground in the Mediterranean Marine Protected Area Pelagos Sanctuary: A Modeling Approach	doi.org/10.3389/fmars.2017.00167	The Mediterranean Sea is greatly affected by marine litter. In this area, research on the impact of plastic debris (including microplastics) on biota, particularly large filter-feeding species such as the fin whale (Balaenoptera physalus), is still in its infancy. We investigated the possible overlap between microplastic, mesoplastic and macrolitter accumulation areas and the fin whale feeding grounds in in a pelagic Specially Protected Area of Mediterranean Importance (SPAMI): the Pelagos Sanctuary. Models of ocean circulation and fin whale potential habitat were merged to compare marine litter accumulation with the presence of whales. Additionally, field data on microplastics, mesoplastics, and macrolitter abundance and cetacean presence were simultaneously collected. The resulting data were compared, as a multi-layer, with the simulated distribution of plastic concentration and the whale habitat model. These data showed a high occurrence of microplastics (mean: 0.082 items/m2, STD ± 0.079 items/m2) spatial distribution agreed with our modeling results. Areas with high microplastic density significantly overlapped with areas of high macroplastic density. The most abundant polymer detected in all the sampling sites was polyethylene (PE), suggesting fragmentation of larger packaging items as the primary source. To our knowledge, this is the first study in the Pelagos Sanctuary in which the simulated microplastic distribution has been confirmed by field observations. The overlap between the fin whale feeding habitat

			and the microplastic hot spots is an important contribution for risk assessment of fin whale exposure to microplastics.
Politikos et al., 2017	Modeling the Fate and Distribution of Floating Litter Particles in the Aegean Sea (E. Mediterranean)	doi.org/10.3389/fmars.2017.00191	A circulation model is coupled to a Lagrangian particle-tracking model to simulate the transport floating litter particles in the Aegean Sea, Greece (Eastern Mediterranean). Considering different source regions and release dates, simulations were carried out to explore the fate and distribution of floating litter over 1990–2009, taking into account the seasonal and interannual variability of surface circulation. Model results depicted recurrently high concentrations of floating litter particles in the North Aegean plateau, the Saronikos Gulf, and along Evia and Crete islands. Modeled transport pathways of floating litter demonstrated that source regions are interconnected, with Saronikos Gulf being a main receptor of litter from other sources. Notably higher percent of litter exit (~35%) than enter the model domain (~7%) signified that Aegean Sea seems to act as a source rather than receptor of floating litter pollution in the Eastern Mediterranean Sea. Beached litter was found around 10%, mostly located in the western part of the Aegean Sea. This is the first modeling study to explore the transport of floating marine litter in Greek waters.
Zambianchi et al., 2017	Lagrangian Transport of Marine Litter in the Mediterranean Sea	doi.org/10.3389/fenvs.2017.00005	Concern about marine litter has been rising in the last decades, triggered by the discovery of the great mid-ocean garbage patches. The Mediterranean Sea is strongly affected by the presence of floating litter, as it has a very high amount of waste generated annually per person that eventually ends up in its waters, with plastic objects accounting for a large percentage of all manmade debris. In principle, the basin looks very vulnerable to possible accumulation of floating debris, since its dynamics is characterized by an inward surface flow of water from the Atlantic hampering surface floating items from being flushed out. Yet, no evidence of permanent litter accumulation areas has been reported so far in the Mediterranean. In this paper we utilized the largest available set of historical Lagrangian data gathered in the Mediterranean Sea to estimate the probability of debris particles to reach different subareas of the basin, with the main objective of singling out possible retention areas. Climatological reconstructions of the time evolution of litter distribution in the basin carried out on the basis of observed Lagrangian displacements suggest a general tendency of floating matter to collect in the southern portion of the basin, and in particular a long term accumulation in the southern and southeastern Levantine basin, areas not yet sampled by marine litter

			observation campaigns, whose targeted organization we strongly recommend at the end of this paper.
Ourmieres et al., 2018	The boundary current role on the transport and stranding of floating marine litter: The French Riviera case	doi.org/10.1016/j.csr.2018.01.010	The aim of the present study is to evidence the role of a boundary current and meteorological conditions in the transport and stranding of floating marine debris. The used data are from a beach survey and an inter-annual unique effort of marine debris sightings along the French Riviera in the North-Western Mediterranean region. Offshore data have been collected during oceanic cruises while beach surveys were performed around Antibes city. Debris were found on 97% of the ocean transects, with a large spatial and temporal variability, showing contrasted areas of low (~ 1 item/km2) and of high (> 10 items/km2) debris densities. Results suggest that the debris spatio-temporal distribution is related to the Northern current (NC) dynamics, the regional boundary current, with accumulation patterns in its core and external edge. By playing a role in the alongshore transport, such a boundary current can form a cross-shore transport barrier. Stranding events can then occur after strong on-shore wind bursts modifying the sea surface dynamics and breaking this transport barrier. It is also shown that episodic enhancement of the stranding rate can be explained by combining the NC dynamics with the wind forcing and the rainfall effect via the local river run-off. Conversely, off-shore wind bursts could also free the marine litter from the boundary current and export them towards the open sea.
Franceschini et al., 2019	Rummaging through the bin: Modelling marine litter distribution using Artificial Neural Networks	doi.org/10.1016/j.marpolbul.2019.110580	Marine litter has significant ecological, social and economic impacts, ultimately raising welfare and conservation concerns. Assessing marine litter hotspots or inferring potential areas of accumulation are challenging topics of marine research. Nevertheless, models able to predict the distribution of marine litter on the seabed are still limited. In this work, a set of Artificial Neural Networks were trained to both model the effect of environmental descriptors on litter distribution and estimate the amount of marine litter in the Central Mediterranean Sea. The first goal involved the use of self-organizing maps in order to highlight the importance of environmental descriptors in affecting marine litter density. The second goal was achieved by developing a multilayer perceptron model, which proved to be an efficient method to estimate the regional quantity of seabed marine litter. Results demonstrated that machine learning could be a suitable approach in the assessment of the marine litter issues.

Kalaroni et al., 2019	Modelling the Marine Microplastic Distribution from Municipal Wastewater in Saronikos Gulf (E. Mediterranean)	10.19080/OFOAJ.2019.09.555752	A three-dimensional hydrodynamic model is coupled with a Lagrangian-Individual Based Model to simulate the floating microplastics (<300μm) dispersal and transport in the Saronikos Gulf. Considering municipal wastewaters as their main source, simulations were carried out over 2011–2012. A comparison with hydrodynamic observational data has shown that the model qualitatively reproduces the main circulation structure and hydrodynamic features. To explore the fate and distribution of microplastics, model results were analyzed taking into account the seasonal variability of near-surface circulation. Simulation results gave a qualitative description of affected areas from microplastics pollution, suggesting that the most affected part of Saronikos Gulf is the coastal area that extends from Psitallia Waste water treatment plant to the east. Despite some limitations, this is a first model attempt to explore the dispersal and distribution of microplastics in the Saronikos Gulf.
Liubartseva et al., 2019	Are Mediterranean Marine Protected Areas sheltered from plastic pollution?	doi.org/10.1016/j.marpolbul.2019.01.022	Comparisons of six selected Mediterranean MPAs were conducted to find similarities and site-specific differences in coastline fluxes and sources of plastic marine litter. Output from the recently developed 2D Lagrangian model for the Mediterranean was post-processed to study (1) the National Park of ses Salines d'Eivissa i Formentera, (2) Nature Reserve of Bouches de Bonifacio, (3) North-East Malta MPA, (4) Specially Protected Area of Porto Cesareo, (5) Community Importance Site of Torre Guaceto, and (6) Ethniko Thalassio Parko Alonnisou Voreion Sporadon. Model coastline fluxes of plastic ranged from 0.4 to3.6 kg (km day)−1, which is relatively low compared to the average flux of 6.2 ± 0.8 kg (km day)−1 calculated over the Mediterranean 2013–2017. Shipping was identified as a major source of plastic litter in all MPAs studied, contributing 55%–88% of total plastic. Site-specific rankings of the top 5 land-based plastic sources revealed that sea surface kinematics control plastic drift.
Macias et al., 2019	Surface water circulation develops seasonally changing patterns of floating litter accumulation in the Mediterranean Sea. A modelling approach	doi.org/10.1016/j.marpolbul.2019.110619	Marine litter and, particularly, plastics are a growing concern at global scale. The Mediterranean Sea is among the zones in the world with the highest concentration of floating plastic debris. However, our knowledge remains limited on the spatial distribution of litter across this basin. Here, a set of different numerical model simulations were conducted to examine the dynamic conditions of the surface layer of the Mediterranean and how this drives the circulation and accumulation of floating litter. Seasonal dynamics of surface water circulation led to contrasting distribution patterns of floating litter along the year. Multiple hot

			spots of litter zones appeared across the basin in summer, while litter disperses and moves towards the Eastern Mediterranean and nearshore waters in winter. Taking into account such seasonal variability in the spatial patterns of litter in the Mediterranean seems to be key in the design of further sampling surveys and management strategies.
Ruiz-Orejón et al., 2019	Quarterly variability of floating plastic debris in the marine protected area of the Menorca Channel (Spain)	doi.org/10.1016/j.envpol.2019.06.063	Plastic pollution is widespread in all the oceans and seas, representing a significant threat to most of their ecosystems even in marine protected areas (MPAs). This study determines the floating plastic distribution in four different periods between 2014 and 2015 in the recently approved Menorca Channel MPA (Balearic Islands). Plastic debris were persistent during all sampling periods on the surface of the Channel, composed mainly by the microplastic sizes. Average particle abundances ranged from 138,293 in autumn to 347,793 during the spring, while weight densities varied from 458.15 in winter to 2016.67 in summer. Rigid plastics were the most frequent particles in all the periods analysed (from 89.40%-winter to 94.54%-spring). The high-resolution and particle distribution models corroborated that the oceanographic variability shapes different patterns of presence of plastics, and in particular the existence of areas with almost no plastics.
Stanev and Ricker, 2019	The Fate of Marine Litter in Semi-Enclosed Seas: A Case Study of the Black Sea	doi: 10.3389/fmars.2019.00660	The accumulation patterns of floating marine litter (FML) in the Black Sea and the stranding locations on coasts are studied by performing dedicated Lagrangian simulations using freely available ocean current and Stokes drift data from operational models. The low FML concentrations in the eastern and northern areas and the high concentrations along the western and southern coasts are due to the dominant northerlies and resulting Ekman and Stokes drift. No pronounced FML accumulation zones resembling the Great Pacific Garbage Patch are observed at time scales from months to a year. The ratio of circulation intensity (measured by the sea level slope) to the rate of the temporal variability of sea level determines whether FML will compact. This ratio is low in the Black Sea, which is prohibitive for FML accumulation. It is demonstrated that the strong temporal variability of the velocity field (ageostrophic motion) acts as a mixing mechanism that opposes another ageostrophic constituent of the velocity field (spatial variability in sea level slope, or frontogenesis), the latter promoting the accumulation of particles. The conclusion is that not all ageostrophicocean processes lead to clustering. The short characteristic stranding

			time of 20 days in this small and almost enclosed basin explains the large variability in the total amount of FML and the low FML concentration in the open ocean. The predominant stranding areas are determined by the cyclonic general circulation. The simulated distribution of stranded objects is supported by available coastal and near-coastal observations. It is khown that the areas that were the most at risk extend from the Kerch Strait to the western coast.
Genc et al., 2020	Modeling transport of microplastics in enclosed coastal waters: A case study in the Fethiye Inner Bay	doi.org/10.1016/j.marpolbul.2019.110747	In this study, transport and possible accumulation of microplastic marine litter in enclosed coastal waters are modeled numerically. The model is applied to the Fethiye Inner Bay, located in Fethiye-Göcek Specially Protected Area. In modeling studies, three dimensional coastal hydrodynamics, transport and water quality numerical model HYDROTAM-3D was used. The current climate was prepared by modeling long-term circulation patterns due to wind, wave and density stratifications. Following the hydrodynamic studies, the advection and diffusion of 3 mm size polystyrene particles by the coastal currents in the surface waters of Fethiye Inner Bay were simulated. The coastal regions where the microplastic pollution will be concentrated and transported were determined by the modeling scenarios. It has been found that microplastic accumulation is expected in the southwest and east coastal waters of the Fethiye Inner Bay. The results of the model will contribute to the databases for sustainable protection of the marine environments.
Mansui et al., 2020	Predicting marine litter accumulation patterns in the Mediterranean basin: Spatio-temporal variability and comparison with empirical data	doi.org/10.1016/j.pocean.2020.102268	The Mediterranean Sea is now acknowledged to be a hot spot for marine litter. However, little is known about Floating Macro Litter (FML) concentration at the scale of the entire basin; predictions regarding this would greatly help guide policymaking to fight this scourge. While previous studies have shown high spatio-temporal variability in FML distribution, the aim of this study was to accurately identify seasonal debris accumulation patterns on regional and local spatial scales across the Mediterranean basin. The objective was then to quantitatively compare this distribution model to other simulations and empirical data. We first studied FML distribution with a 2-D Lagrangian model coupled to an oceanic general circulation model (OGCM) at a horizontal resolution of 1/. From an initial homogeneous deployment, we deployed a set of virtual particles across the whole basin and tracked each particle during 3-month journeys. Then we described the FML distribution model outputs and compared them both to empirical observations at the scale of the whole basin (gathered from a review of scientific papers on surface

			debris distribution), and to other numerical FML simulations from previous studies. The results of our offshore modeled distribution of FML fully agreed with characteristic debris accumulation patterns analyzed in our review of other studies. This indicates that our model could allow the prediction of monthly litter accumulation patterns at the scale of the entire Mediterranean Sea.
Miladinova et al., 2020	Identifying distribution and accumulation patterns of floating marine debris in the Black Sea	doi.org/10.1016/j.marpolbul.2020.110964	The distribution and accumulation of floating marine debris in the Black Sea during the last few decades are analysed by the help of numerical modelling. An approach based on a mesoscale circulation model combined with a particle tracking model is applied. It is established that the litter distribution is nearly independent of the source location and is mainly controlled by the basin circulation system. The western gyre predominantly accumulates floating debris in summer. After the integration of the main cyclonic current in winter, the debris in the inner basin moves east. Retention zones along the south-western coast persist in time. The mean particle stranding time is estimated at about 200 days. Accumulation zones along the south-eastern and eastern coast are abundant in summer, and then move further northeast and north. Simulations demonstrate an increasing litter accumulation in summer on the North Western Shelf and shelf break.
Politikos et al., 2020	Modeling of floating marine litter originated from the Eastern Ionian Sea: Transport, residence time and connectivity	doi.org/10.1016/j.marpolbul.2019.110727	A Lagrangian particle tracking model coupled to a circulation was used to explore the transport, residence time and connectivity of floating litter that originated from the Eastern Ionian Sea during 2011–2014. At the end of simulations, on average 26% of litter was retained within the coastal waters of the Eastern Ionian Sea, whereas 58% was washed into offshore waters without formulating permanent accumulation areas, as the basin-wide surface circulation was characterized by considerable interannual variability. The inflow of litter into the Adriatic and Eastern Mediterranean Seas was moderate, ranging between 9% and 20%, and the beached litter was on average 9.2%, mostly located in the northern subregions. The average residence time of litter particles ranged between 20 and 80 days, implying their temporary retention before drifting offshore. Connectivity patterns depicted an exchange of litter mainly between adjacent subareas and with a northward direction.
Soto-Navarro et al., 2020	3D hotspots of marine litter in the Mediterranean: A modeling study	doi.org/10.1016/j.marpolbul.2020.111159	The 3D dispersion of marine litter (ML) over the Mediterranean basin has been simulated using the velocity fields from a high resolution circulation model as base to run a 3D Lagrangian model. Three simulations have been performed to mimic the

			evolution of ML with density lower, similar, or higher than seawater. In all cases a realistic distribution of ML sources was used. Our results show that the accumulation/dispersion areas of the floating and buoyancy neutral particles are practically the same, although the latter are distributed in the water column, 80% of them found in the photic layer (average depth of 35m). Regarding to the densest particles, they rapidly sink and reach the seafloor close to their source. The regions of higher temporal variability mostly coincide with the ML accumulation regions. Weak seasonal variability occurs at a sub-basin scale as a result of the particles redistribution induced by the seasonal variability of the current field.
Stocchino et al., 2020	Sea Waves Transport of Inertial Micro-Plastics: Mathematical Model and Applications	doi.org/10.3390/jmse7120467	Plastic pollution in seas and oceans has recently been recognized as one of the most impacting threats for the environment, and the increasing number of scientific studies proves that this is an issue of primary concern. Being able to predict plastic paths and concentrations within the sea is therefore fundamental to properly face this challenge. In the present work, we evaluated the effects of sea waves on inertial micro-plastics dynamics. We hypothesized a stationary input number of particles in a given control volume below the sea surface, solving their trajectories and distributions under a second-order regular wave. We developed an exhaustive group of datasets, spanning the most plausible values for particles densities and diameters and wave characteristics, with a specific focus on the Mediterranean Sea. Results show how the particles inertia significantly affects the total transport of such debris by waves.
Zayen et al., 2020	Microplastics in surface waters of the Gulf of Gabes, southern Mediterranean Sea: Distribution, composition and influence of hydrodynamics	doi.org/10.1016/j.ecss.2020.106832	The Mediterranean Sea has been described as one of the most affected areas by marine litter in the world. Although microplastics and their effects have been investigated in this area, most of the currently available studies have been limited to the northwestern part of the basin. This study constitutes a first attempt to determine the abundance, characteristics and composition of microplastics in near surface waters of the Gulf of Gabes (southern Mediterranean Sea, Tunisia). Samples were collected using a 200 µm-mesh size trawl net along two transects. The study revealed an average concentration of 63,739 items/km2 where fragments and films were the most frequent microplastics. Polyethylene, reformulated polyethylene and polypropylene were the most abundant plastics identified among the samples (86–100%). The influence of hydrodynamics on microplastics in the Gulf of Gabes was investigated through the use of a Lagrangian tracking model to simulate the dispersion of

			particles in water. Modelling results seem to be in agreement with the reported distribution and characteristics of microplastics in this area.
Sharma et al., 2021	Microplastics in the Mediterranean Sea: Sources, Pollution Intensity, Sea Health, and Regulatory Policies	doi.org/10.3389/fmars.2021.634934	Microplastic pollution is one of the emerging threats across the globe and is becoming a topic of intense study for environmental researchers. At present, almost all of the world's oceans and seas are contaminated with microplastics but the Mediterranean Sea has been recognized as a target hotspot of the world as the microplastic concentration in this region is approximately four times greater than the North Pacific Ocean. Because of the distinguishing semi-enclosed morphology of the Mediterranean Sea, and different plastic waste generating activities originating from surrounding countries the Mediterranean Sea is highly vulnerable to microplastic pollution. Different plastic families have been reported in the Mediterranean Sea and the Physico-chemical features of these plastic polymers play an important role in the interactions between these plastic particles and other organic matter in the water bodies. The ingestion of microplastics by marine animals is an issue of concern as microplastic acts as vectors for other harmful pollutants adsorbed onto their surface. This review provides a detailed discussion on the persistence of microplastics in the Mediterranean Sea that have been identified in surface water and also in sediments and deep sea-floor. Various sources of these synthetic materials and the intensity of low and high-density polymers pollution in the Mediterranean Sea have also been discussed. This review also focuses on the threatened species in the Mediterranean Sea and the fate of the plastisphere community in its ecosystem. In the end, we highlight a series of important regulations and policies adopted by Mediterranean countries to control and manage the microplastic pollution in this region.
Guerrini et al., 2021	The dynamics of microplastics and associated contaminants: Data-driven Lagrangian and Eulerian modelling approaches in the Mediterranean Sea	doi.org/10.1016/j.scitotenv.2021.145944	Plastic pollution is widespread in the global oceans, but at the same time several other types of hydrophobic pollutants contaminate the marine environment. As more and more evidence highlights, microplastics and polluting chemicals are intertwined via adsorption/desorption processes. A thorough assessment of their total impact on marine ecosystems thus requires that these two kinds of pollution are not considered separately. Here we compare the outcomes of two complementary, data-driven modelling approaches for microplastic dispersal and for Plastic-Related Organic Pollutants (PROPs) in the marine environment. Focusing on the Mediterranean Sea, we simulate two years of Lagrangian particle

			tracking to map microplastic dispersion from the most impacting sources of pollution (i.e. coastal areas, the watersheds of major rivers, and fishing activities). Our particle sources are data-informed by national census data, hydrological regimes, and vessel tracking data to account for spatial and temporal variability of mismanaged plastic waste generation. These particle-based simulations are complemented with a simulation of the dynamics of primary pollutants in the sea, obtained via an advection-diffusion Eulerian model. While providing further understanding of the spatiotemporal distribution of microplastics and the dynamics of PROPs at a Mediterranean-wide scale, our results call for the development of novel integrated modelling approaches aimed at coupling the dynamics of microplastics with the chemical exchanges occurring through them, thus promoting a holistic description of marine plastic pollution.
Baudena et al., 2022	The streaming of plastic in the Mediterranean Sea	doi.org/10.1038/s41467-022-30572-5	Plastic debris is a ubiquitous pollutant on the sea surface. To date, substantial research efforts focused on the detection of plastic accumulation zones. Here, a different paradigm is proposed: looking for crossroad regions through which large amounts of plastic debris flow. This approach is applied to the Mediterranean Sea, massively polluted but lacking in zones of high plastic concentration. The most extensive dataset of plastic measurements in this region to date is combined with an advanced numerical plastic-tracking model. Around 20% of Mediterranean plastic debris released every year passed through about 1% of the basin surface. The most important crossroads intercepted plastic debris from multiple sources, which had often traveled long distances. The detection of these spots could foster understanding of plastic transport and help mitigation strategies. Moreover, the general applicability and the soundness of the crossroad approach can promote its application to the study of other pollutants.
Galli et al., 2022	Microplastic abundance and biodiversity richness overlap: Identification of sensitive areas in the Western Ionian Sea	doi.org/10.1016/j.marpolbul.2022.113550	Plastic pollution in the Mediterranean Sea has been widely reported, but its impact on biodiversity has not been fully explored. Simultaneous sampling of microplastics (MP) with a manta net and surveys of large marine vertebrates were conducted along the coastal waters of Sicily (Western Ionian Sea). A total of 17 neustonic samples have been collected and 17 marine species (cetaceans, sea turtles, seabirds, and fish) have been sighted in the target area. Kernel density estimation was evaluated to highlight a possible overlap between the presence of large marine fauna and MP densities to provide a preliminary risk assessment. The highest biodiversity and MP concentration

			(0.197 ± 0.130 items/m2) were observed in the southernmost part of the studied area. The overlap between biodiversity hotspots and the occurrence of MP, potential contribute to the identification of sensitive areas of exposure in a poorly studied region.
Macias et al., 2022	Model based estimate of transboundary litter pollution on Mediterranean coasts	doi.org/10.1016/j.marpolbul.2021.113121	Plastic litter pollution is one of the major concerns for the health of marine ecosystems worldwide. This pervasive form of pollution affects all oceans and seas and it's interacting with multiple levels of the marine food webs. In the European context, several pieces of legislation try to fight against this pervasive and ubiquitous form of pollution. Recently, EU Member States have agreed to a maximum threshold of litter items per coast length (20 items/100 m coastline). One major concern among stakeholders to reach this consensus was the transboundary litter, as measures need to be implemented in the country of origin. Henceforth, a solid method to estimate the amounts of the transboundary litter to a given Member State's coasts is needed. In this contribution, we use a combination of hydrodynamic and Lagrangian models for the Mediterranean Sea in order to understand the origin of coastal litter. Simulations show that the amount of transboundary litter in Mediterranean countries could be as large as 30% although both regional and seasonal differences could be significant.
Impact of Marine Litter in Cetaceans in ACCOBAMS area			
Levy et al., 2009	Laryngeal snaring by ingested fishing net in a common bottlenose dolphin (*Tursiops truncatus*) off the Israeli shoreline	10.7589/0090-3558-45.3.834	We report an unusual snaring of the larynx in an adult, female common bottlenose dolphin (Tursiops truncatus). The dolphin was observed swimming and diving in Haifa Port, Israel, but was found dead the next day, 60 km south, on the coast. Postmortem examination revealed stranded-cordage, nylon filaments wrapped around the larynx, cutting through the soft tissue, and extending down into the forestomach, where a large mass of netting was found. The cachectic state of the dolphin and the subacute to chronic, hyper-plastic response of soft tissue surrounding the filaments lodged around the larynx, suggest a prolonged period of starvation, which led to the final weakness and wasting of the dolphin.
Mazzariol et al., 2011	Sometimes Sperm Whales (Physeter macrocephalus) Cannot Find Their Way Back to the High Seas: A Multidisciplinary Study on a Mass Stranding	doi.org/10.1371/journal.pone.0019417	Mass strandings of sperm whales (Physeter macrocephalus) remain peculiar and rather unexplained events, which rarely occur in the Mediterranean Sea. Solar cycles and related changes in the geomagnetic field, variations in water temperature and weather conditions, coast geographical features and human activities have been proposed as possible causes. In December 2009, a pod of seven male sperm whales stranded along the

			Adriatic coast of Southern Italy. This is the sixth instance from 1555 in this basin. Complete necropsies were performed on three whales whose bodies were in good condition, carrying out on sampled tissues histopathology, virology, bacteriology, parasitology, and screening of veins looking for gas emboli. Furthermore, samples for age determination, genetic studies, gastric content evaluation, stable isotopes and toxicology were taken from all the seven specimens. The animals were part of the same group and determined by genetic and photo-identification to be part of the Mediterranean population. Causes of death did not include biological agents, or the "gas and fat embolic syndrome", associated with direct sonar exposure. Environmental pollutant tissue concentrations were relatively high, in particular organochlorinated xenobiotics. Gastric content and morphologic tissue examinations showed a prolonged starvation, which likely caused, at its turn, the mobilization of lipophilic contaminants from the adipose tissue. Chemical compounds subsequently entered the blood circulation and may have impaired immune and nervous functions. A multi-factorial cause underlying this sperm whales' mass stranding is proposed herein based upon the results of postmortem investigations as well as of the detailed analyses of the geographical and historical background. The seven sperm whales took the same "wrong way" into the Adriatic Sea, a potentially dangerous trap for Mediterranean sperm whales. Seismic surveys should be also regarded as potential co-factors, even if no evidence of direct impact has been detected.
Fossi et al., 2012	Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (Balaenoptera physalus)	doi.org/10.1016/j.marpolbul.2012.08.013	Baleen whales are potentially exposed to micro-litter ingestion as a result of their filter-feeding activity. However, the impacts of microplastics on baleen whales are largely unknown. In this case study of the Mediterranean fin whale (Balaenoptera physalus), we explore the toxicological effects of microplastics on mysticetes. The study included the following three steps: (1) the collection/count of microplastics in the Pelagos Sanctuary (Mediterranean Sea), (2) the detection of phthalates in surface neustonic/planktonic samples, and (3) the detection of phthalates in stranded fin whales. A total of 56% of the surface neustonic/planktonic samples contained microplastic particles. The highest abundance of microplastics (9.63 items/m3) was found in the Portofino MPA (Ligurian Sea). High concentrations of phthalates (DEHP and MEHP) were detected in the neustonic/planktonic samples. The concentrations of MEHP found in the blubber of stranded fin whales suggested that

			phthalates could serve as a tracer of the intake of microplastics. The results of this study represent the first warning of this emerging threat to baleen whales.
de Stephanis et al., 2013	As main meal for sperm whales: Plastics debris	doi.org/10.1016/j.marpolbul.2013.01.033	Marine debris has been found in marine animals since the early 20th century, but little is known about the impacts of the ingestion of debris in large marine mammals. In this study we describe a case of mortality of a sperm whale related to the ingestion of large amounts of marine debris in the Mediterranean Sea (4th published case worldwide to our knowledge), and discuss it within the context of the spatial distribution of the species and the presence of anthropogenic activities in the area that could be the source of the plastic debris found inside the sperm whale. The spatial distribution modelled for the species in the region shows that these animals can be seen in two distinct areas: near the waters of Almería, Granada and Murcia and in waters near the Strait of Gibraltar. The results shows how these animals feed in waters near an area completely flooded by the greenhouse industry, making them vulnerable to its waste products if adequate treatment of this industry’s debris is not in place. Most types of these plastic materials have been found in the individual examined and cause of death was presumed to be gastric rupture following impaction with debris, which added to a previous problem of starvation. The problem of plastics arising from greenhouse agriculture should have a relevant section in the conservation plans and should be a recommendation from ACCOBAMS due to these plastics’ and sperm whales’ high mobility in the Mediterranean Sea.
Fossi et al., 2016	Fin whales and microplastics: The Mediterranean Sea and the Sea of Cortez scenarios	doi.org/10.1016/j.envpol.2015.11.022	The impact that microplastics have on baleen whales is a question that remains largely unexplored. This study examined the interaction between free-ranging fin whales (Balaenoptera physalus) and microplastics by comparing populations living in two semi-enclosed basins, the Mediterranean Sea and the Sea of Cortez (Gulf of California, Mexico). The results indicate that a considerable abundance of microplastics and plastic additives exists in the neustonic samples from Pelagos Sanctuary of the Mediterranean Sea, and that pelagic areas containing high densities of microplastics overlap with whale feeding grounds, suggesting that whales are exposed to microplastics during foraging; this was confirmed by the observation of a temporal increase in toxicological stress in whales. Given the abundance of microplastics in the Mediterranean environment, along with the high concentrations of Persistent Bioaccumulative and Toxic (PBT) chemicals, plastic additives and biomarker responses

			detected in the biopsies of Mediterranean whales as compared to those in whales inhabiting the Sea of Cortez, we believe that exposure to microplastics because of direct ingestion and consumption of contaminated prey poses a major threat to the health of fin whales in the Mediterranean Sea.
Alexiadou et al., 2019	Ingestion of macroplastics by odontocetes of the Greek Seas, Eastern Mediterranean: Often deadly!	doi.org/10.1016/j.marpolbul.2019.05.055	Plastic pollution is an omnipresent problem that threatens marine animals through ingestion and entanglement. Marine mammals are no exception to this rule but their interaction with plastic remains understudied in the Mediterranean Sea. Here we highlight this problem by analyzing the stomach contents of 34 individuals from seven odontocete species stranded in Greece. Macroplastic (>5 mm) was found in the stomachs of nine individuals from four species (harbour porpoise Phocoena phocoena, Risso's dolphin Grampus griseus, Cuvier's beaked whale Ziphius cavirostris and sperm whale Physeter macrocephalus) with the highest frequency of occurrence in sperm whales (60%). Gastric blockage from plastic was presumably lethal in three cases, with plastic bags being the most common finding (46%). Plastic ingestion is of particular conservation concern for the endangered Mediterranean sperm whales. A regular examination of stranded cetaceans with a standardised protocol is critical for allowing spatiotemporal comparisons within and across species.
Đuras et al., 2019	Cetacean mortality due to interactions with fisheries and marine litter ingestion in the Croatian part of the Adriatic Sea from 1990 to 2019	doi.org/10.24099/vet.arhiv.1254	Various anthropogenic threats negatively influence the survival of cetaceans in all world seas. Thanks to a long- running marine mammal surveillance program, we are able to report the results of a detailed analysis of the influence of cetacean-fisheries interactions and marine litter ingestion on cetacean mortality in the Croatian part of the Adriatic Sea over the last three decades. The total number of dead cetaceans was 459, and included 334 bottlenose dolphins (Tursiops truncatus), 40 striped dolphins (Stenella coeruleoalba), ten Risso's dolphins (Grampus griseus), six Cuvier's beaked whales (Ziphius cavirostris) and four fin whales (Balaenoptera physalus). Three hundred of them were examined postmortally. Cetacean-fisheries interaction occurred frequently in the Adriatic Sea, being detected in 96 (20.9%) of the recorded cases. Bycatch was the most abundant cetacean-fisheries interaction, with 66 (14.4%) cases recorded. Good nutritional condition and evidence of recent feeding were the most common findings recorded in bycatch cases, followed by persistent froth in the airways, edematous lungs, bruises and an amputated fluke or tail. Cetacean-fisheries interactions other than bycatch affected 30 animals and included larynx

			strangulations, long- term tail entanglement and fishing gear in the stomach. Ingestion of marine litter that was not related to fisheries was recorded in four animals. This study reveals the considerable negative anthropogenic influence on cetaceans in the Adriatic Sea, especially the bottlenose dolphin that is considered to be the most numerous cetacean species therein, and demonstrates the need for the urgent development of a cetacean bycatch reduction program. Finally, it also shows the importance of sustaining national surveillance programs to gain scientifically based knowledge important for cetacean protection and prospects for their long-term survival.
Panti et al., 2019	Marine litter: One of the major threats for marine mammals. Outcomes from the European Cetacean Society workshop	10.1016/j.envpol.2019.01.029	Marine litter is a pollution problem affecting thousands of marine species in all the world's seas andoceans. Marine litter, in particular plastic, has negative impacts on marine wildlife primarily due toingestion and entanglement. Since most marine mammal species negatively interact with marine litter, afirst workshop under the framework of the European Cetacean Society Conference, was held in 2017 tobring together the main experts on the topic of marine mammals and marine litter from academic andresearch institutes, non-governmental organisations, foundations and International Agreements. Theworkshop was devoted to defining the impact of marine litter on marine mammals by reviewing currentknowledge, methodological advances and new data available on this emerging issue. Some case studieswere also presented from European waters, such as seals and cetaceans in the North, Baltic, and Med-iterranean Seas. Here, we report the mainfindings of the workshop, including a discussion on theresearch needs, the main methodological gaps, an overview of new techniques for detecting the effects ofmarine litter (including microplastics) on marine mammals and, also, the use of citizen science to driveawareness. Thefinal recommendations aim to establish priority research, to define harmonised methodsto detect marine litter and microplastics, enforce networking among institutions and support datasharing. The information gathered will enhance awareness and communication between scientists,young people, citizens, other stakeholders and policy makers, and thereby facilitate better imple-mentation of international directives (e.g., the Marine Strategy Framework Directive) in order to answerthe question about the actual status of our oceans andfinding solutions
Guerrini et al., 2019	Modeling Plastics Exposure for the Marine Biota: Risk Maps for Fin Whales	doi.org/10.3389/fmars.2019.00299	Several anthropogenic stressors threaten the Mediterranean basin, which is currently regarded as one of the most impacted

	in the Pelagos Sanctuary (North-Western Mediterranean)		marine ecoregions globally. Among those stressors, marine plastic litter is causing increasing concern about its environmental and biological consequences, the latter being largely unknown. To improve the understanding of these aspects, here we provide a mapped indicator of the risk of plastic ingestion by the fin whale Balaenoptera physalus, an endangered cetacean whose feeding grounds are located within the Pelagos Sanctuary for Mediterranean Marine Mammals, in the north-western Mediterranean Sea. We analyse a decade (2000–2010) of advection patterns of marine plastic litter, modeled as Lagrangian particles and released from the three major sources: untreated waste along coasts, plastic discharged from rivers and along maritime shipping routes. Risk of exposure to microplastics via food ingestion for fin whales is then evaluated by interlacing the plastic litter distribution obtained via particle tracking with maps of habitat suitability based on bathymetry and satellite-derived estimates of chlorophyll-a. Our modeling results locate the highest risk values in the Central Ligurian Sea, and show that all the three main sources of plastic litter taken into account clearly contribute to impacting cetaceans in the Sanctuary, yet with spatial and interannual variability of patterns. The procedure formalized with our approach can be extended to assess the risk caused by ingestion of plastics by other taxa and/or in other MPAs, as we suggest by providing an application on the whole ecosystem of Pelagos, thus informing targeted actions to tackle the complex issue of marine litter.
Novillo et al., 2020	Evaluating the presence of microplastics in striped dolphins (Stenella coeruleoalba) stranded in the Western Mediterranean Sea	doi.org/10.1016/j.marpolbul.2020.111557	Litter is a well-known problem for marine species; however, we still know little about the extent to which they're affected by microplastics. In this study, we analyse the presence of this type of debris in Western Mediterranean striped dolphins' intestinal contents over three decades. Results indicated that frequency was high, as 90.5% of dolphins contained microplastics. Of these microplastics, 73.6% were fibres, 23.87% were fragments and 2.53% were primary pellets. In spite of the high frequency of occurrence, microplastic amount per dolphin was relatively low and highly variable (mean ± SD = 14.9 ± 22.3; 95% CI: 9.58–23.4). Through FT-IR spectrometry, we found that polyacrylamide, typically found in synthetic clothes, was the most common plastic polymer. Here, we establish a starting point for further research on how microplastics affect this species' health and discuss the use of striped dolphins as indicators of microplastics at sea.
Tonay et al., 2020	Cetaceans and marine litter in the Black Sea		Marine litter, especially plastics, is an essential source of danger for cetaceans. Since the Black Sea is a semi-enclosed sea with

			numerous rivers flowing in, marine litter accumulated here pose a serious threat to the three cetacean species inhabiting the basin vulnerable. This paper reviews the studies in the Black Sea since 1956 on the relationship between marine litter and cetaceans. Impacts of marine litter on cetaceans, especially entanglement and ingestion, have been compared with similar cases elsewhere in the world. Since there are very few studies on the relationship of marine litter and cetaceans in the Black Sea, we cannot elucidate the effect of the increase in marine litter on cetaceans in recent years, thus further and continuous studies are needed.
Gregorietti et al., 2021	Cetacean presence and distribution in the central Mediterranean Sea and potential risks deriving from plastic pollution	doi.org/10.1016/j.marpolbul.2021.112943	The Sardinian and Sicilian Channels are considered hotspots of biodiversity and key ecological passages between Mediterranean sub-basins, but with significant knowledge gaps about marine mammal presence and potential threats they face. Using data collected between 2013 and 2019 along fixed transects, inter and intra-annual cetacean index of abundance was assessed. Habitat suitability, seasonal hot spots, and risk exposure for plastic were performed using the Kernel analysis and the Biomod2 R-package. 661 sightings of 8 cetacean species were recorded, with bottlenose and striped dolphins as the most sighted species. The north-eastern pelagic sector, the coastal waters and areas near ridges resulted the most suitable habitats for these species. The risk analysis identified the Tunis, Palermo, and Castellammare gulfs and the Egadi Island as areas of particular risk of plastic exposure. The study represents a great improvement for cetacean knowledge in this region and contributes to the development of effective conservation strategies.
Corazzola et al., 2022	Analysis of the Gastro-Intestinal Tract of Marine Mammals: A Multidisciplinary Approach with a New Multi-Sieves Tool	doi.org/10.3390/ani11061824	Organs and content of the gastro-intestinal tract (GIT) of marine mammals are relevant for a variety of investigations and provide data to researchers from different fields. Currently used protocols applied to the GIT for specific analysis limit the possibility to execute other investigations and important information could be lost. To ensure a proper sample collection and a multidisciplinary investigation of the GIT of marine mammals, a new multi-sieves tool and a specific protocol have been developed. This new device and approach allowed the simultaneous sampling of the GIT and its content for the main investigations concerned. The samples collected during these preliminary trials were suitable to perform all the different research procedures considered in this work. The obtained results show that with a few and easy procedural adjustments, a multidisciplinary sampling and evaluation of the GIT of marine mammals is possible. This will reduce the risk of losing important data aimed at understanding the cause of death

			of the animal, but also biology and ecology of marine mammals, and other important data for their conservation and habitats management.

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