STUDY

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Actions of cities and regions in the Mediterranean Sea area to fight sea pollution

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RESEARCH FOR REGI COMMITTEE

Actions of cities and regions in the Mediterranean Sea area to fight sea pollution

Abstract

This study provides a comprehensive analysis of the most common types of marine pollutants in the Mediterranean Sea and focuses on the accelerating accumulation of marine litter and plastics in the Mediterranean Sea. It presents the actions taken by EU Mediterranean regions and cities to respond to diverse pollutants, waste contamination, marine litter and plastic pollution in the marine environment. Based on this assessment, policy recommendations are put forward.

This document was requested by the European Parliament's Committee on Regional Development.

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LIST OF ABBREVIATIONS

ACA	Catalan Water Agency
AGRI	Agriculture and Rural Development Committee
BAS	Brake-assist systems
BCN	Barcelona Convention
BOD	Biological Oxygen Demand
CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
CMO	Common market organisation
COD	Chemical Oxygen Demand
CoR	Committee of the Regions
CULT	Culture and Education Committee
ECOSOC	Economic and Social Committee
ECR	European Conservatives and Reformists
ECTS	European Credit Transfer System
EEC	European Economic Community
EU	European Union
ENF	Europe of Nations and Freedom
EPP	Group of the European People's Party (Christian Democrats)
FAO	Food and Agriculture Organisation of the United Nations
FPS	Frontal protection systems
GDP	Gross Domestic Product
GM	Genetically-modified

Greens/EFA	The Greens/European Free Alliance
GUE/NGL	European United Left - Nordic Green Left
ICZM	Integrated Coastal Zone Management
IFI	International Fund for Ireland
MAP	Mediterranean Action Plan
MEDPOL	Program for the Assessment and Control of Pollution in the Mediterranean
MedSeA	European Mediterranean Sea Acidification in a changing Climate
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NEAT	Nested Environmental status Assessment Tool
PAHs	Polycyclic aromatic hydrocarbons
POPs	Persistent Organic Pollutants
SMEs	Small and medium-sized enterprises
UfM	Union for the Mediterranean
UNEP	United Nations Environment Programme

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EXECUTIVE SUMMARY

KEY FINDINGS

- The historical anthropogenic pressures, accelerated in the past hundred years, combined with its natural characteristics (semi-enclosed 'accumulation' basin) make the Mediterranean Sea one of the most sensitive regions in the world to pollution.
- There are several sources of marine pollution in the Mediterranean Sea from both land- and sea-based activities, including urbanisation, industries, sewage, tourism, fisheries and shipping.
- The Mediterranean Sea is globally recognised as a major basin for accumulation of marine litter and plastic pollution. 230,000 tonnes of plastic enter the Mediterranean Sea from land-based source, each year; additionally, 20,000 tonnes could be attributed every year to the shipping activities.
- Continued monitoring and policy implementation, with the cooperation of both EU and non-EU Mediterranean countries, is therefore urgent and strategic to successfully reduce pollution and its consequences on the marine system and human health. Different kinds of policy recommendations relate to the state of knowledge, gravity and policy of existing pollutants.

Mediterranean Sea under anthropogenic pressure: addressing marine pollution

The Mediterranean Sea is a semi-enclosed basin characterised by high population density and urbanisation along the coasts, and intense maritime traffic. It has approximately 150 million inhabitants on its coasts in addition to a large number of tourists, and high levels of industrial and shipping activities that have collectively led to a rapid increase in marine pollution. This is combined with other anthropogenic drivers of environmental change including climate (e.g., sea water temperature, heatwaves, salinity, acidification, extreme events, and sea-level rise), unsustainable land- and sea-use practices and non-indigenous species. With 15-30% of all global shipping activity, and influxes of freshwater from densely populated river catchments, the Mediterranean Sea is one of the world's most heavily affected areas for marine pollution, specifically marine litter, and plastic pollution in particular. Waste, and its management, remain a key challenge in many coastal Mediterranean countries and is a major source of marine pollution. In this context, international cooperation between EU and non-EU countries is fundamental to tackle this problem.

The Mediterranean Sea has an anti-estuarine circulation that causes this basin to act as a trap for particles including pollutants and specifically, marine litter and plastics. This unique geography and oceanographic setting, along with its high population density and inefficient waste management result in a high level of marine pollution in the Mediterranean.

Marine pollution can take many forms: (i) physical, substances that are not necessarily involved in chemical or biological reactions; (ii) chemical, substances that are involved in chemical reactions, e.g. pesticides; and (iii) biological, e.g. bacteria.

Mediterranean Sea as accumulation hotspot of marine litter and plastic pollution

Due to its geomorphological configuration and its specific oceanic circulation, the Mediterranean Sea acts as a natural trap for marine litter. In the basin, 80% to 90% of marine litter is made of plastic, and it is estimated that on a yearly basis 230,000 tonnes of land-sourced plastic leak into the Sea. All the abiotic compartments are affected by this pollution, from the shores, to the surface waters, to the water column and the seabed. On the beaches, two-thirds of marine litter is comprised of just ten item types, with cigarette butts and filters being the most abundant at 27.3%, while 9 out of 10 of these items are completely or partly made of plastic. The composition of marine litter floating at the surface of the Mediterranean Sea or lying on the seafloor show a similar pattern, with plastic items representing respectively, up to 90% and 80% of the pollution. It is the same for microplastic pollution, which like macro-litter, affects all abiotic compartments of the Mediterranean Sea. Higher concentrations of these pollutants are associated with areas under high anthropogenic pressure and proximity to land-based sources of (micro)plastics. In most Mediterranean countries, the root causes of rising plastic pollution are found in the increase of plastic use, unsustainable consumption patterns, ineffective/inefficient waste management and loopholes in plastic waste management. The recreational use of Mediterranean beaches can generate up to half of the beach litter, while fisheries and aquaculture account for 2% to 15% of litter found on beaches, floating on the sea surface, or lying on the seafloor. Rough estimates show that shipping lanes can generate up to 20,000 tonnes of sea-sourced plastic litter every year.

Mediterranean EU nations, regions and cities - tools to fight marine pollution

Understanding the different stages of policy creation and implementation is necessary to address marine pollution in the Mediterranean region. Policies need to address various concerns such as the management practices implemented in waste reduction and treatments, tourism, and strategies for plastic pollution and river waste management. This study specifically examines the strategies used to implement the EU single-Use plastics directive in France, Spain, Italy, and Greece and the need for a strategy to reduce plastics which includes market restrictions, improved waste management and agreements between consumers and producers. It emphasises the need for continued efforts to achieve a good environmental or ecological status for the Mediterranean. Overall, it emphasises the importance of innovation and development of effective environmental policies for unique areas like coastal Mediterranean cities, touristic coastlines and Mediterranean islands, and the urgent need to decrease sources of marine pollution in the region.

The importance of mandatory policies in reducing pollution and achieving environmental goals in coastal cities in the Mediterranean region are highlighted. It focuses on the European Union's strategy targets for key sectors, such as consumption patterns, production and waste management to promote sustainability.

Local policies tailored to specific needs are analyzed, as well as the effectiveness of cooperation and implementation. There is a need for clear targets and monitoring indicators to achieve effective science-based environmental policies. Such policies play a significant role in managing natural resources, protecting biodiversity, and reducing marine pollution. However, measuring the effectiveness of these non-binding policies and cooperative agreements can be challenging compared

to binding European directives which apply to all EU member states, and have specific and measurable targets that make it easier to evaluate their effectiveness.

Mediterranean Interreg cooperation and cohesion programs are crucial for reducing marine pollution including marine litter and stimulate the design of effective policies. A review of the main challenges and impediments that the region faces needs to be carried out with the intention of increasing their effectiveness and broadening the range of their application. The cooperation of Mediterranean countries in implementing effective legislations to fight marine pollution is fundamental for effectual reduction of waste generation.

Science-based policy and action recommendations to fight Mediterranean marine pollution should be provided according to the level of knowledge with three stages to policy creation: (a) the discovery and characterisation phase, in which the issue is recognised as a problem and initial preventive actions can be implemented; (b) the political or decision-making phase, in which the problem is framed in policy dimensions and the legislative framework is established; and (c) the management phase, in which policy decisions and management practices are put in place.

It is essential that the fight against marine pollution in the semi-enclosed Mediterranean Sea is endorsed not only by EU countries, but that regulations are implemented by all Mediterranean countries through effective cooperation and collaboration.

1. INTRODUCTION

KEY FINDINGS

- The Mediterranean Sea is particularly vulnerable to marine pollution as a densely populated region, with an anti-estuarine oceanographic setting, as a ¨hotspot¨ for climate change, with a high number of endemic species and high biodiversity, and very intense maritime traffic.
- Marine pollution in the Mediterranean has far-reaching consequences for the marine environment, wildlife, and human health.
- Most of the marine pollution is caused by waste production and its lack of appropriate management.
- The Mediterranean Sea is globally recognised as a major basin for accumulation of marine litter and plastic pollution.

The development of early western civilisations can be linked to the Mediterranean Sea (e.g., Phoenician, Egyptian, Hellenistic, Roman and Ottoman), with coastal communities dependent on the resources provided by this sea. In modern times, this semi-enclosed basin is characterised by an accelerated population growth resulting in high population density and urbanisation, as well as rising tourism, industrial activities and very intense maritime traffic. This has led to a rapid increase in marine pollution alongside other anthropogenic drivers of change in the environment including: climate (e.g. sea water temperature, salinity, acidification, extreme events, and sea-level rise), unsustainable land and sea-use practices and non-indigenous species.

1.1. Common marine pollutants in the Mediterranean Sea

"Pollutant" is defined as any substance introduced into the environment that has undesired effects, or adversely affects the natural resource (air, soil, water and ecosystems). In this study, we consider only pollutants of anthropogenic origin. These can take many forms: (i) physical, substances that are not necessarily involved in chemical or biological reactions; (ii) chemical, substances that are involved in chemical reactions, e.g. pesticides; and (iii) biological, e.g. bacteria (MedECC, 2020) (Table 1). For clarity we define a water contaminant of anthropogenic origin as any physical, chemical, biological or radiological substance or matter that is potentially, but not exclusively, toxic for the environment.

The Mediterranean Sea is particularly vulnerable to pollution due to its specific anti-estuarine circulation (see below), its setting as a hotspot for climate change, and also for its high biodiversity and high number of endemic species. Thus, the enormous historical anthropogenic pressures, accelerated in the past hundred years, combined with its natural characteristics make the Mediterranean Sea one of the most sensitive regions in the world to pollution. The continued monitoring of marine pollution with the cooperation of both EU and non-EU Mediterranean countries is therefore urgent and strategic to successfully fight and reduce pollution, and its consequences, on the marine system and human health.

Table 1. List of the most common marine pollutants found in the Mediterranean Sea.

Categories	Type	Sources	Impacts
Physical pollutants	**Particulate matter**	Transport, industry, biomass burning, volcanic eruptions, sea salt, soil dust suspension, natural forest fires, etc.	• Pulmonary and vascular effects, genotoxic and carcinogenic outcomes and increased daily mortality (*).
	Plastic (macro/micro/nano)	Urban and storm-water runoff, sewer overflows, littering, inadequate waste disposal and management, industrial activities, tyre abrasion, construction and illegal dumping, fisheries and aquaculture, shipping, etc.	• Cause toxicity through oxidative stress, inflammatory lesions, and increased uptake or translocation (*). • Metabolic disturbances, neurotoxicity, and increased cancer risk in humans (*). • Entanglement or starvation of marine wildlife. • Liver and cell damage. • Disruption to reproductive system. • Adsorption of organic pollutants. • Vector of invasive species.
Chemical pollutants	**Nutrients**	Urban effluents, industrial discharges, agricultural runoff, aquaculture, and riverine inputs.	• May result in a high increase of phytoplankton growth and biomass, leading to eutrophication. • Eutrophication can lead to hypoxia or anoxia and may provoke harmful algal blooms and/or marine mucilage affecting fishing industries, smothering sea life, and spreading bacteria and viruses.
	Gaseous pollutants: nitrogen dioxide, sulphur dioxide, ozone	Industry, traffic and shipping emissions.	• Respiratory illness (*). • Climate change (warming and ocean acidification). • Fog, smog, acid rain.
	Trace metallic elements	Urban and industrial wastewaters, atmospheric deposition and runoff from metal contaminated sites.	• Toxicity, persistence and bioaccumulation in human tissues (*). • Toxicity, persistence and bioaccumulation in animal tissues. • Biomagnification in the food web.
	Organic pollutants	Industry (power generation, cement manufacturing, coke production and burning, etc.) Transport (heavy/light vehicles exhaust, aircraft, oil tankers/ships) Domestic (coal cooking, wood/garbage burning, cigarettes) Agriculture (waste/residual burning, pesticides).	• Mutagenic, carcinogenic, teratogenic and immunotoxic to living organisms, including microorganisms, animals and humans. • Ecotoxic effects on aquatic life and birds.
Biological pollutants	**Viruses and bacteria**	Released into the environment by various routes including water runoff and aerosols.	• Human infection through exposure to contaminated surface/ground waters (*). • Extreme precipitation events increase the supply of fecal bacteria and viruses to the coastal zone.
	Harmful Algal Blooms	Eutrophication, warming	• Human intoxication (*). • Red-tide, mucilage, anoxia. • Economic threat for fisheries, aquaculture and tourism

Emerging contaminants	**Polycyclic aromatic hydrocarbons (PAHs)**	Found in asphalt used in road construction, medicines, dyes, plastics, and pesticides. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar.	• Carcinogenic and potential neurotoxin (*). • Moderate to high acute toxicity to aquatic life and birds.
	Pesticides	Agricultural runoff and urban green spaces and parks (include herbicides and insecticides).	• Headaches and nausea (*). • Cancer, reproductive harm, and endocrine disruption (*). • Toxic to other organisms including birds, fish, beneficial insects, and non-target plants.
	Environmental oestrogens	Synthetic chemicals found in food, animal and plant products and some household items.	• Linked to breast cancer in women and prostate cancer in men (*). • Wide range of effects on the body and brain, including on emotional processing via neuropsychological factors (*). • Impact fish physiology and can affect reproductive development in both domestic and wild animals.
	Phthalates	Industrial chemicals used to soften PVC plastic and as solvents in cosmetics and other consumer products.	• Damage to liver, kidneys, and lungs (*). • Damage to the reproductive system, and can cause infertility and reproductive problems in men (*). • Toxicity impacts in animals including damage to liver, kidney, lungs and reproductive systems.
	Pharmaceuticals	Introduced through sewage from households with patients using drugs.	• Development of antibiotic-resistant strains of bacteria that can lead to a serious threat to human health (*). • Development of antibiotic-resistant strains of bacteria that can critically disturb natural bacterial ecosystems in the environment. • Under certain conditions, direct impact on fish reproduction.
	Personal Care Products	Health, beauty and cleaning products.	• Negative impact on aquatic ecosystems, especially related to endocrine disruption and reproductive disorders. • Create a layer on the water surface that hinders gaseous exchanges between the air and the sea.
	UV filters	Found in sunscreen and other topical products.	• Certain chemical filters are potential endocrine disruptors (*). • Endocrine-disruption potentially impacting animals. • Create a layer on the water surface that hinders gaseous exchanges between the air and the sea.
	Flame retardants	Used as coatings.	• Have carcinogenic properties (*). • Toxic effect on marine fauna
	Disinfection by-products	From household and domestic, hospital and industry waste.	• There is evidence of carcinogenic and mutagenic properties of these by-products in small animals.

Source: PLAN BLEU Note #40 (2021); MedECC (2020)
Note: (*) Human impact.

In 2020, a report by UNEP/MAP Plan Bleu on Mediterranean environmental status stressed the overall unsatisfactory state of the regional environment regarding air pollution, quality and quantity of water resources, waste management and nature protection. In particular, waste and its management remained a challenge in many countries, and was a major source of marine pollution. In this context, international cooperation between EU and non-EU countries is fundamental to tackle this problem.

1.1.1. Coastal waste, marine litter and plastic pollution

The main focus of the present study is on marine pollution highlighting the coastal waste generation and displacement of marine litter and plastic pollution. The focus is motivated by the fact that the large majority of pollutants are driven by waste mismanagement and knowing that the Mediterranean Sea is a hotspot for plastic pollution and marine litter. Sources of marine pollution in the Mediterranean include both point sources (such as sewage outflows and industrial discharges) and non-point sources (such as agricultural runoff and atmospheric deposition). In particular, plastic pollution is a growing concern, with a recent study estimating that the Mediterranean Sea contains nearly 11,000 tonnes of plastic (Cózar et al., 2014). This plastic pollution poses a threat to marine wildlife, as animals can mistake the plastic for food and ingest it, leading to injury or death.

For EU Mediterranean countries, policies and actions have been implemented for several years to address key pollutants (see chapter 3). Data collection from EU countries are expected to be continued within the EU Marine Strategy Framework Directive (MSFD) with the objective to help EU countries to achieve a good environmental status (GES). The trends and levels of the so-called legacy pollutants have decreased significantly in the most impacted areas in the Mediterranean Sea after the implementation of environmental measures (e.g., leaded-fuels ban, mercury regulations, anti-fouling paints ban) (UNEP/MAP/MED POL, 2011). There are, however, important emerging pollutants (e.g., pharmaceuticals) (Table 1) characterised by a very limited amount of data and understanding in terms of concentration, distribution and impacts. These deserve attention with target data acquisition and appropriate legislation. In addition, there are still point and diffuse pollution sources releasing both priority and emerging chemical contaminants in the Mediterranean Sea. From this, the successful implementation of solutions at the basin scale is needed.

1.1.2. Potential sources of marine pollution

There are several sources of marine pollution in the Mediterranean Sea including land-based activities, shipping, and sewage (Figure 1). Land-based point sources of contaminants impacting the coastal and sea environment enter primarily via treated (or non-treated) wastewater discharges and represent a major input. In terms of diffuse pollution sources, land-based run-off and atmospheric deposition (wet/dry deposition and diffusive transport) are the two major contributors to coastal areas. Sea-based sources (i.e., direct inputs from maritime and industrial activities, such as shipping, fishing, oil refining oil and gas exploration and exploitation) may be permanent chronic sources of pollution in the marine environment, and also include the potential for acute pollution events.

The most common sources of marine pollution in the region are:

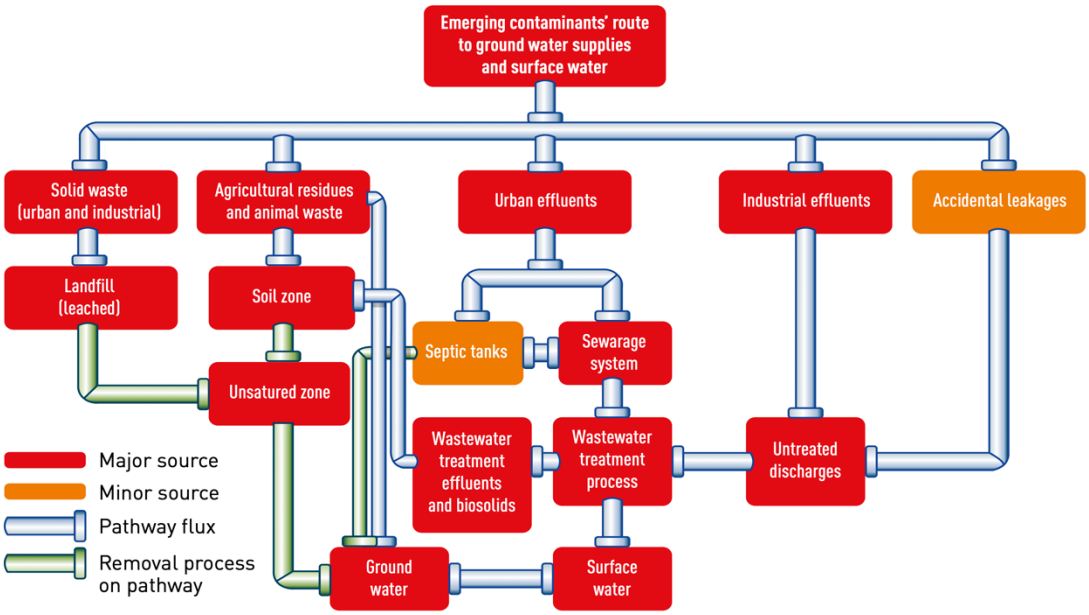
Land-based activities: This includes waste disposal, agriculture, and industrial activities that result in the release of pollutants into the sea. The discharge of untreated or partially treated wastewater, including household, industrial and agricultural runoff, is a major contributor to marine pollution in the Mediterranean.

Sea-based activities: This includes shipping, fisheries, aquaculture, and mining. The Mediterranean is a major shipping lane, with thousands of vessels traveling through the region every year. These ships release pollutants into the sea, including oil spills, ballast water discharge, and the emission of air pollutants. Fisheries and aquaculture are major source of nutrients and marine litter, mining is a major environmental concern and related to pollution is known to cause noise that can disrupt marine species and might contaminate with heavy metals.

Sewage: The discharge of untreated or partially treated sewage is a significant source of marine pollution in the Mediterranean, particularly in coastal areas where human populations are

concentrated. This sewage contains nutrients, pathogens, and organic matter, which can have adverse effects on the marine environment.

Figure 1. Potential sources and pathways for ground and surface water pollution.



Source: Barrios-Estrada et al. 2018; MedECC, 2020

1.2. Mediterranean Sea climate change hotspot

The Mediterranean region is undergoing rapid changes as a result of climatic and non-climatic forcings (Cramer et al., 2018; MedECC, 2020) and is experiencing an increase in warming that is exceeding global trends, with atmospheric warming likely to be 20% faster than the global average (Lionello and Scarascia., 2018). Ocean acidification is also evident with sea surface pH projected to decrease in line with the global average (approximately 0.3 to 0.4 units by 2100) (Hassoun et al., 2022), or to exceed the global rate of decline (Gemayel et al., 2015; Hassoun et al., 2022). Climate change combined with marine pollution could have drastic consequences on the marine systems. The main drivers of change include climate (temperature, precipitation, atmospheric circulation, extreme events, sea-level rise, sea water temperature, salinity and acidification), population increase, pollution, unsustainable land and sea-use practices and non-indigenous species. In most areas, both natural ecosystems and human livelihoods are affected (MedECC, 2020).

1.3. Mediterranean Sea as accumulation basin

The Mediterranean is a semi-enclosed basin, connected to the Atlantic Ocean and the Black Sea through respectively, the Gibraltar and the Dardanelles Straits; and artificially to the Red Sea through the Suez Canal. The main water exchange occurs in the west, through the Gibraltar Strait, where the Atlantic waters enter the Mediterranean. The Atlantic waters flow superficially, due to their lower density (lower salinity), and propagate towards the Levantine Basin, gradually losing nutrients and increasing their salinity and temperature (Malanotte-Rizzoli and Hecht, 1988). This anti-estuarine circulation causes this basin to act as a trap for particles including pollutants and specifically, marine

litter and plastics. This unique geography and oceanographic setting, along with its high population density, result in a high level of marine pollution in the Mediterranean.

1.4. Impacts of marine pollution in a multi-stressor marine system

The impacts of marine pollution in the Mediterranean are far-reaching and can affect both the ecosystem and human health. The decline in water quality can lead to decreased oxygen levels, which can cause harm to sensitive species such as coral (Gambi et al., 2003). It can negatively impact the health of the Mediterranean's marine ecosystems, including coral reefs, seagrass beds, and other habitats that support a diverse array of wildlife. This can result in a decline in biodiversity and changes in the food web. The ingestion of plastic debris and other pollutants can harm marine wildlife, including sea turtles, birds, and fish. Contamination of seafood with toxic chemicals can pose a threat to human health, as these chemicals can accumulate in the food chain (Beyer and Biziuk et al., 2009). Additionally, exposure to contaminated water can result in health problems for individuals who use the sea for work or recreation, such as fishermen or tourists.

Many of the pressures on the Mediterranean ecosystem go beyond pollution, and are a result of human activities along coastal areas and in marine waters combined with the accelerated effects of climate change (e.g.; heat waves). Another major threat is in the fact that the Mediterranean ecosystem is largely overfished (with 88 % of stocks being overfished). The impacts from fisheries also affect seafloor habitats, including benthic fauna damage, and contribute to marine litter and microplastic generation.

The effect of marine pollution is also combined with habitat loss due to coastal developments in fast-developing coastal cities and tourism sites along the Mediterranean. As well as intense maritime traffic, other pressures come from maritime activities, such as marine oil and gas extraction, which are prevalent in the Mediterranean Sea (EEA, 2019; EEA-UNEP/MAP 2021). Sulphur dioxide (SO2) and nitrogen oxide (NOx) have recently increased drastically, mainly due to shipping activity, amplifying the impact of acidification (Hassellöv et al., 2013; Jutterström et al., 2021). On average, 70% of shipping emissions are released within a distance of 400 km from the coast and can have significant air quality and marine pollution impacts on coastal regions (e.g. Corbett et al., 1999; Eyring et al., 2005; Sofiev et al., 2018; Jonson et al., 2020). It is expected that the relative contribution from international shipping to air pollutant emissions will increase, as land-based reductions in emissions occur at a faster rate.

1.5. Mitigation Strategies for Marine Pollution in the Mediterranean

The Mediterranean Sea is an accumulation zone for marine pollution, with shipping traffic, industrial and urban waste discharge, and agricultural runoff being the main sources of pollution. Addressing this issue is crucial for the preservation of the Mediterranean's unique oceanographic setting, marine biodiversity, and coastal communities.

The 2030 Agenda for Sustainable Development pledges to "ensure that all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature". Pollution puts at risk the possibility of achieving these outcomes and hence health and well-being.

Given the significant consequences of marine pollution in the Mediterranean, it is essential to develop and implement effective mitigation strategies. Effective waste management is critical to reducing marine pollution. This includes the proper treatment of wastewater, the reduction of plastic waste, and the proper disposal of hazardous waste (Löhr et al., 2017; Pettipas et a., 2016).

Addressing coastal zone management is key to reducing the impact of land-based activities on the Mediterranean's marine environment. The Mediterranean region is home to numerous coastal cities,

tourism industries, fisheries and shipping lanes, all of which contribute to the problem of marine pollution. The consequences of this pollution can be seen in the form of decreased biodiversity, altered food webs, and impacts on human health.

The shipping industry can play a significant role in reducing marine pollution in the Mediterranean. This can be achieved through the implementation of sustainable shipping practices, such as the use of low-emission fuels, the implementation of ballast water management systems, and the reduction of oil spills (Janssen et al., 2016). In addition, microplastic pollution may also be reduced through regulation of ship paint and antifouling coatings. Marine (antifouling) coating particles, i.e., abrased chlorinated rubber-, acryl-styrene-, and epoxide binder-containing particles are hypothesised as a main MP source, indicating ship "skid marks" (Dibke et al., 2021).

Efforts to mitigate marine pollution in the Mediterranean include regulation and enforcement of discharge standards, investment in treatment and waste management infrastructure, and public education campaigns. To address the issue of marine pollution in the Mediterranean, several international, regional and local agreements have been established, including the Barcelona Convention and its Protocols on the Prevention of Marine Pollution from Land-Based Sources and Activities and the Mediterranean Action Plan. These past actions aimed to reduce the sources of marine pollution and improve the management of the Mediterranean's marine environment and are discussed in chapters 3 and 4.

2. MARINE LITTER IN THE MEDITERRANEAN SEA

KEY FINDINGS

- 80-90% of Mediterranean marine litter is composed of plastic items.
- Only 10 types of items account for 66.4% of the beach litter in the Mediterranean Sea, cigarette butts/filters being the most common (27.3%).
- Tourism is the main sector contributing to beach litter (27-60%), followed by fisheries and aquaculture (5-10%).
- Shipping activities could contribute up to 20,000 tonnes of plastic per year.
- Macro-litter and microplastics are present in all the abiotic compartments of the Mediterranean Sea.
- 230 000 tonnes of plastic are leaking every year to the Mediterranean Sea. The root causes are found in the increase of plastic use, unsustainable consumption patterns, ineffective/inefficient waste management and loopholes in plastic waste management.

With a coastal population of nearly 150 million inhabitants, an influx of freshwater from densely populated river catchments and a contribution of 15-30% of the total global shipping activity (UNEP/MAP, 2012), the Mediterranean Sea has been recognised as one of the most affected areas in the world for contamination by marine litter (UNEP/MAP, 2015). Concentrations of floating plastic debris are reported to be comparable and sometimes higher than those found in the five main oceanic accumulation zones, (the subtropical gyres) (Cózar et al., 2015), the great Pacific garbage patch being the most famous.

Since the first reported observation of crude oil residue floating at the surface of the Mediterranean Sea in 1969 (Horn et al., 1970) and the observation of plastic pellets (raw material from the plastic industry) stranded on Lebanese beaches in 1977 (Shiber, 1979) and Spanish beaches in 1980 (Shiber, 1982), Mediterranean marine litter and (micro) plastic pollution have been widely studied in this semi-enclosed sea. A high diversity of studies has reported the presence and the dynamics of this contamination in different environmental compartments (shores, surface water, water column and seabed), its interaction with marine biota (from primary producers/consumers to higher organisms in the trophic chain such as sea turtles, marine mammals or birds) and its interaction with other pollutants such as the persistent organic pollutants (POPs). This chapter aims to provide an overview of the occurrence of marine litter, including microplastic pollution (pieces of plastic of less than 5mm) and meso- and macro-litter (>5mm) in the Mediterranean Sea and the possible sources of this contamination.

2.1. Mediterranean marine macro-litter

2.1.1. Mediterranean beaches

Beach macro-litter is probably the most visible form of this contamination, as every beachgoer can experience it. Moreover, it is relatively easy to monitor beach litter dynamics compared to other abiotic

compartments, such as the open sea or the seabed, simply due to the ease of access. Many initiatives at regional, national and European levels have contributed to efforts to better constrain the characteristics, dynamics and spread of this pollution, supported by established methodologies such as: the "*Guidance on Monitoring of Marine Litter in European Seas of the EU Marine Strategy Framework Directive – Technical Group on Marine Litter (MSFD-TGML)*" (Galgani et al., 2013), the "*Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area*" (OSPAR, 2010), and the NOOA "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*" (Lippiat et al., 2013).

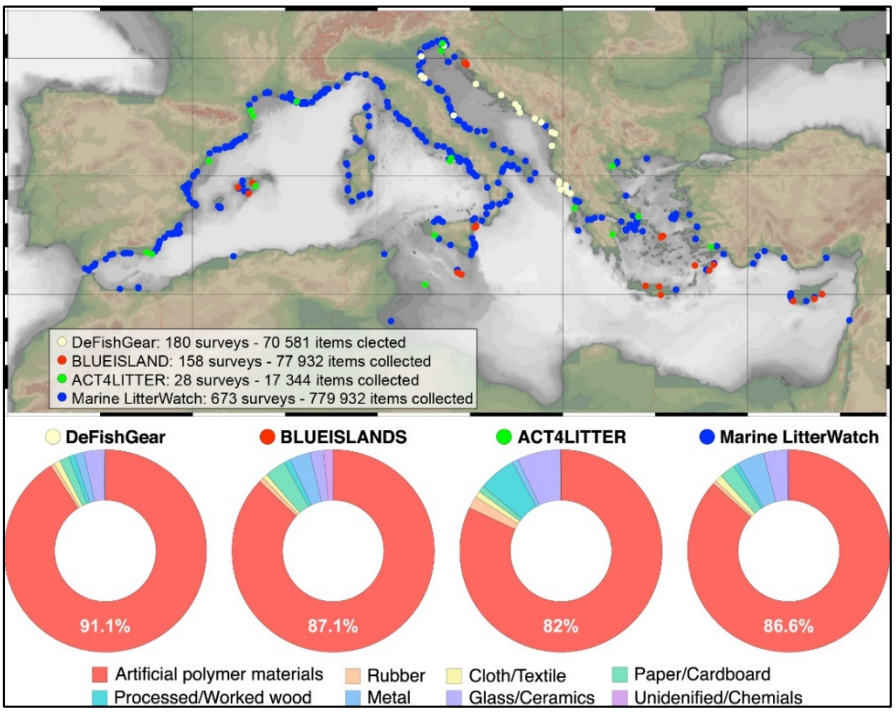
To provide an overview of the beach macro-litter across the Mediterranean Sea, the outputs of four transnational European initiatives were selected: DeFishGear (2013-2016), BLUEISLANDS (2017-2020), ACT4LITTER (2017-2018) and Marine LitterWatch (2013-ongoing). See Table 1 for a brief description of the main goals of each initiative. These initiatives were specifically selected as 1) they use the same methodological approach to characterise the beach litter, providing comparable datasets and 2) they include, partly or completely, all the European Mediterranean countries.

Table 2. Description of the four initiatives used to emphasise results of beach litter.

Project	Short description
DeFishGear	A pilot project for coordinated and harmonised actions between science-policy and society for litter-free Adriatic and Ionian Seas. It originated as a response to the need for dealing effectively with the issue of marine litter in the Adriatic-Ionian region. It aimed to facilitate efforts for integrated planning to reduce the environmental impacts of litter-generating activities and ensure the sustainable management of the marine and coastal environment of the Adriatic and Ionian Seas. https://defishgear.net/
BLUEISLANDS	This Interreg Med project aimed to identify, address and mitigate the effects of the seasonal variation of waste generated on Mediterranean islands as an effect of tourism. It addressed common challenges faced by Mediterranean islands, as the structural constrictions of sea-locked territories, in term of resources and waste management including the fragmentary knowledge of seasonal variation of waste generation, and the lack of strategic plans to promote sustainable tourism. https://blueislands.interreg-med.eu/
ACT4LITTER	This Interreg Med project implemented joint measures to preserve natural ecosystems from marine litter in Mediterranean marine protected areas (MPAs). It aimed to facilitate efforts for tackling marine litter in Mediterranean MPAs, through targeted measures towards reaching their conservation targets, and to provide MPA Managers with tools and knowledge to effectively address the issue at their level and prevent the problem from getting worse. https://act4litter.interreg-med.eu/
Marine LitterWatch	The Marine LitterWatch mobile app was developed by the European Environment Agency (EEA) in 2013 and since then it has been collecting beach litter data with the participation of pan-European organisations and communities. Communities are organised volunteer groups of citizens, such as NGOs, civil society associations and other kinds of informal groups. https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch

The aggregated results, regarding the distribution of the surveyed beaches and the composition of the beach litter from the four initiatives are presented in Figure 2. Between 2013 and 2022, a total of 1039 surveys were conducted on the beaches of the Mediterranean Sea, collecting 945,089 items. The litter is largely dominated by artificial polymer materials (i.e. plastics) accounting on average for 86.9% of all the items collected. Individually, the four selected initiatives presented similar values. with 82% of the collected items being made of plastic for ACT4LITTER (Vlachogianni et al., 2019), 86.6% for Marine LitterWatch (Marine LitterWatch database[1]), 87.1% for BLUEISLANDS (Grelaud and Ziveri, 2020[2]) and 91.1% for DeFishGear (Vlachogianni et al., 2018). These results are in line with other studies conducted in Mediterranean beaches showing the large contribution of plastic items to the litter (Asensio-Montesinos et al., 2019; Camedda et al., 2021; Fortibuoni et al., 2021; Orthodoxou et al., 2022; Prevenios et al., 2017). The average contribution of the other types of litter collected for the aggregated results as 4.0% for metal, 3.7% for glass/ceramics, 2.5% for paper/cardboard, 1.1% for cloth/textiles, 0.9% for processed/worked wood, 0.6% for rubber and 0.4% unidentified and/or chemicals.

Figure 2. Map of the surveyed beaches in the frame of the four initiatives.



Source: Vlachogianni et al., 2018; Vlachogianni et al., 2019; Grelaud and Ziveri 2020; Marine LitterWatch database.
Note: Top: map of the surveyed beaches (DeFishGear: white dots, BLUEISLANDS: red dots, ACT4LITTER: green dots, Marine LitterWatch: blue dots). Bottom: composition of the marine litter for the four initiatives.

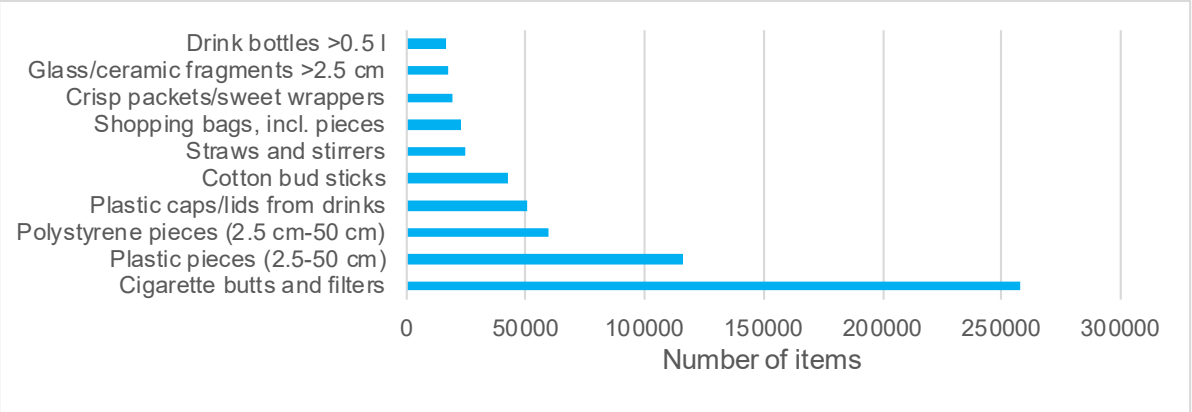
The ten most common items collected during the four initiatives represent 66.4% (627,285 items) of all the waste. Cigarette butts and filters are the most common waste as 257,717 items (27.3% of all the waste) were collected from the four initiatives (Fig. 3). They are followed by unidentified plastic pieces (116,346, 12.3%), unidentified polystyrene pieces (59,625, 6.3%), plastic caps/lids drink (50,992, 5.4%),

[1] https://www.eea.europa.eu/data-and-maps/data/marine-litter

[2] In their study, Grelaud and Ziveri (2020) also considered large microplastics (1-5mm), however, they are not taken into account here in order to ensure comparable results with the other 3 initiatives. If small microplastics were taken into account, the artificial polymer materials would represent 94.4% of the marine litter in Mediterranean islands beaches.

cotton bud sticks (42,364, 4.5%), straws and stirrers (24,564, 2.6%), shopping bags (22,668, 2.4%), glass and ceramic fragments (17,165, 1.8%) and <0.5L drink bottles (16,683, 1.8%). Apart from glass fragments, all these items belong to the artificial polymer materials category.

Figure 3. The ten most common items found on Mediterranean beaches.



Source: Vlachogianni et al. (2018); Vlachogianni et al. (2019); Grelaud and Ziveri (2020); Marine LitterWatch database

2.1.2. Mediterranean water bodies

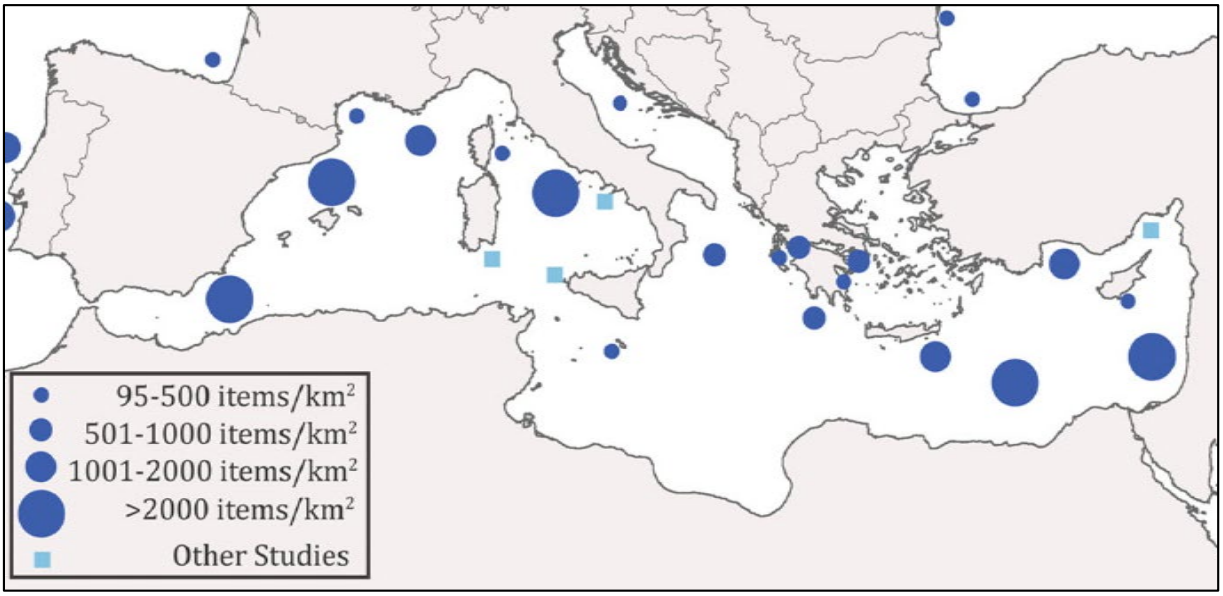
As highlighted by Ioakeimidis et al. (2017) few studies exist with respect to the assessment of floating marine macro-litter in the Mediterranean Sea. Most of them focus on the western basin and the Adriatic Sea. The concentrations of the floating debris are estimated from visual observations from the vessel. Suaria and Aliani (2014) conducted 167 surveys in the Central-Western Mediterranean Sea. Floating litter with an anthropogenic origin could be observed in 87% of the transects. An average concentration of 24.9 ± 2.4 items per square km was reported for the whole region, with the Adriatic Sea and the Algerian basin having the highest concentrations at 54.6 ± 11.1 items per square km and 52.9 ± 11.4 items per square km respectively, while the central Tyrrhenian Sea had the lowest concentrations at 4.9 ± 2.8 items per square km. Campana et al. (2018) conducted similar surveys in the western Mediterranean Sea between Spain and Italy, where floating items were observed during each of the 111 transects. They found average concentrations between 1.9 and 2.8 items per square km. Similar concentrations were found by Arcangeli et al. (2020) in the western Mediterranean Sea, ranging from 1 ± 0.1 items per square km (transect Spain – Sardinia) to 8.8 ± 1 items per square km (transect Sardinia – Sicily). Higher concentrations were reported by Fossi et al. (2017) and Palatinus et al. (2019) with averages of respectively 175.24 items per square km in the Pelagos Sanctuary in the north-western Mediterranean Sea and 175 items per square km in the central Adriatic Sea. For the eastern Mediterranean Sea, Constantino et al. (2019) reported higher concentrations compared to the western basin with 232 ± 325 items per square km. In all these studies, plastic debris were the most common floating items, with a minimum contribution of 63.6% to the floating litter (Campana et al., 2018) to more than 90%. The most common items mainly consist of plastic fragments, bottles, containers, wraps, packaging, plastic bags, plastic sheets and polystyrene objects.

2.1.3. Mediterranean seabed

Unlike the available studies on floating marine litter, the pollution of the Mediterranean seabed has been widely documented since the first reported observations in the late 1980s (Bingel et al., 1987). The concentration of litter found on the seabed of the Mediterranean Sea is highly variable depending on the location and the depth monitored (Ioakeimidis et al., 2017). The lowest concentration recorded was 24 ± 28 items per square km in the Gulf of Limassol, off Cyprus (60-400m water depth, Ioakeimidis et al., 2014), while the highest concentrations exceed 90,000 items per square km in the Tyrrhenian Sea,

off Sicily (30-300m water depth, Angiolillo et al., 2015). In general, densities higher than 500 items per square km are the most common (Fig. 4). In shallow waters (0-25m water depth) plastic debris rarely exceed 50% of the litter (Katsanevakis et al. 2004) while at greater depth it can exceed 80% (Stefatos et al., 1999; Ioakeimidis et al., 2014; Güven et al., 2013; Sanchez et al., 2013; Angiolillo et al., 2015).

Figure 4. Seafloor marine litter distribution in the Mediterranean Sea.

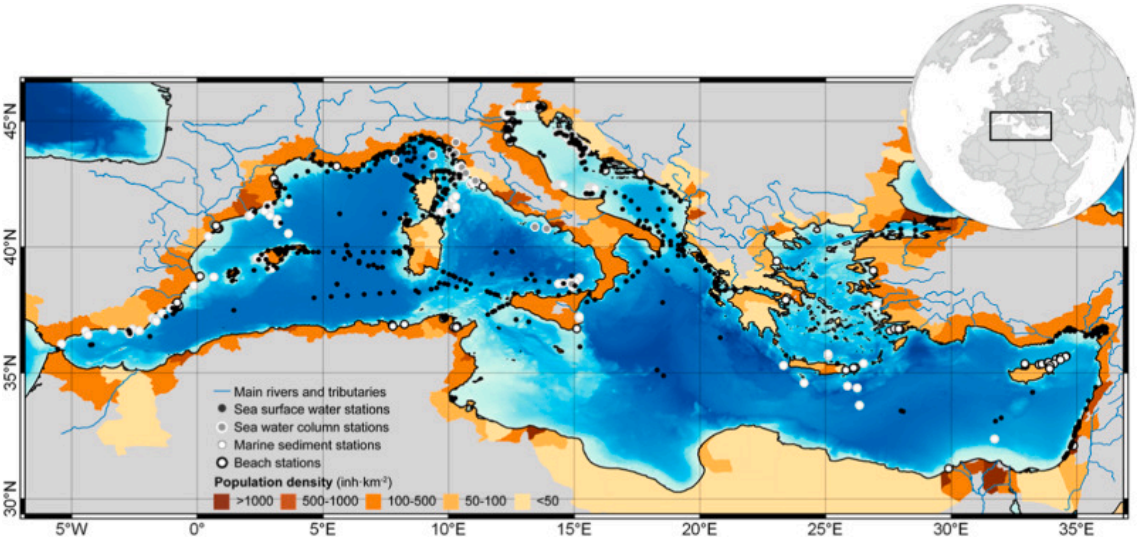


Source: Ioakeimidis et al., 2017

2.2. Mediterranean microplastic pollution

The occurrence of microplastic in the different abiotic compartments of the Mediterranean Sea has been widely studied over the last 2 decades, with about 100 scientific papers reporting their concentrations in beaches, surface water, the water column and the seabed (Fig. 5, Simon-Sánchez et al., 2020).

Figure 5. General map of microplastic sample distribution in the Mediterranean Sea.



Source: Simon-Sánchez et al., 2021

2.2.1. Mediterranean beaches

Like macro-litter, microplastics (pieces of plastic of less than 5 mm) and fibres are also accumulating on Mediterranean beaches. Beach samples were widely collected in the Mediterranean basin to estimate the contamination of sediments with this much less visible pollution. In their review, Simon-Sánchez et al. (2020) analysed the outputs from 29 scientific papers dealing with this micro-litter in Mediterranean beaches. In total, 1302 samples were collected around the Mediterranean Sea (Fig. 5) and all of them contained microplastics and/or fibres, with a median concentration of 58.6 items per kg of dry sediment. The lowest abundances were observed in Slovenian beaches with a median concentration of $7.5 \cdot 10^{-1}$ items per kg of dry sediment (Korez et al., 2019) while the highest were recorded in the Datça Peninsula in Turkey with a median concentration of $9.75 \cdot 10^{2}$ items per kg of dry sediment (Yabanlı et al., 2019). In general, greater presence of microplastics was related to areas under high anthropogenic pressure and proximity to land-based sources of (micro)plastics (Pedrotti et al., 2016). On the other hand, Grelaud and Ziveri (2020) show that the concentrations of large microplastic (1 – 5mm) on Mediterranean island beaches was closely related to the amount of beach litter accumulating on the beaches, showing a seasonal increase during the high touristic season.

2.2.2. Mediterranean water bodies

The concentrations of microplastics floating at the surface of the Mediterranean Sea are highly variable due to the complex surface hydrography characterising the basin and to different sampling methods applied to collect the samples. For the latter, the use of nets is the most common approach, although the wide range of mesh size used in the different studies has a direct impact on the microplastic densities reported (Simon-Sánchez et al., 2021). Moreover, most of the studies focussed on the coastal area to the detriment of the open sea (Fig. 4). The minimum median concentration of $6.25 \cdot 10^{3}$ items per square km was reported by Collignon et al. (2014) with a 200 µm mesh size net in the Bay of Calvi, Corsica, north western Mediterranean Sea. On the other hand, the highest median concentrations of $2.24 \cdot 10^{6}$ items per square km were reported in the Eastern Mediterranean Sea off the coast of Lebanon by Kazour et al. (2019) with a 52 µm mesh size net. It has been estimated that the median concentration of microplastic in the surface water of the Mediterranean Sea was $8.48 \cdot 10^{4}$ items per square km (Simon-Sánchez et al., 2021).

2.2.3. Mediterranean seabed

As with surface water sampling, most of the studies targeting seabed sediment focussed on the coastal area (Fig. 4). Moreover, the concentrations reported depend on the detection limit regarding the characterisation of the smaller microplastics, explaining in part why the distribution of microplastics in the sediment of the Mediterranean Sea is highly variable. The lowest concentrations were reported in the Central Mediterranean Sea in the Augusta Harbour, with average concentrations of 1.66 ± 1.77 items per kg of dry sediment (D'Alessandro et al., 2018), while the highest concentrations were reported off Lebanon with $2.43 \cdot 10^{3} \pm 2 \cdot 10^{3}$ items per kg of dry sediment (Kazour et al., 2019). In their study, Simon-Sánchez et al. (2022) demonstrated that microplastics accumulate in seabed sediments over time. Since the mid-1960s, the concentration of microplastics have increased exponentially, mimicking the global plastic production trend during the same period.

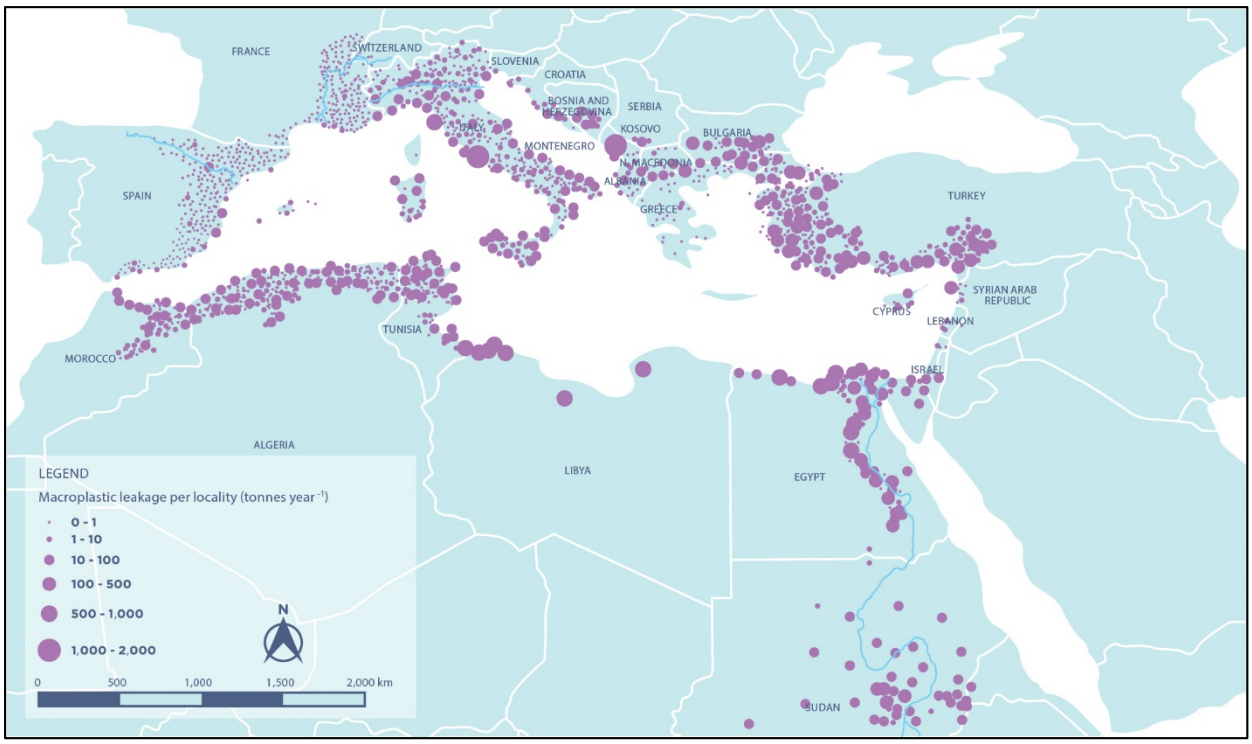
2.3. Sources of Mediterranean plastic litter

At every point of their life cycle, plastics can leak into the environment (GESAMP 2016; ISWA 2017; UNEP 2020). In particular, plastic pellets and fibres may be lost during their production, transport or conversion (UNEP 2018). At a global scale, it has been estimated that 60-99 million tonnes of

mismanaged plastic waste were produced globally in 2015 (Lebreton and Andrady, 2019). Use and disposal appear to be the main pathway for plastic to reach the environment with large volumes lost as a result of littering and a lack of environmentally sound waste management practices (UNEP, 2021). Recently, Borrelle et al. (2020) estimated that 19-23 million tonnes of plastic waste entered aquatic ecosystems from land-based sources in 2016.

With respect to the Mediterranean, the estimates of the total annual load of plastic entering the Mediterranean show discrepancies. I In 2015, plastic inputs to the sea were estimated at 260,000 tonnes per year or 730 tonnes per day (UNEP/MAP calculation based on World Bank (in Jambeck et al. 2015), and Jambeck et al. 2015), in 2020 Boucher and Bilard (2020) estimated that the annual load of plastic to the Mediterranean was 230,000 tonnes (range 150,000 – 610,000 tonnes), while Tsiaras et al. (2021) estimated annual inputs at just 17,600 tonnes. The latter estimated that approximately 3760 tonnes of plastic are currently floating in the Mediterranean which is consistent with previous projections (750–3000 metric tonnes; Cózar et al., 2015; Ruiz-Orejón et al., 2016; Suaria et al., 2016) and the estimations made by Boucher and Bilard (2000) who estimated the amount of floating plastic to 705 tonnes (range 288-1840 tonnes). Depending on the coastal population, which may vary depending on the country, the higher estimates (UNEP/MAP calculation; Boucher and Bilard, 2020) represent more than 2% of the total inputs in the world's oceans. The leakage ofmacroplastics to the Mediterranean Sea from localities situated in watersheds is shown in Figure 6.

Figure 6. Leakage of plastic from mismanaged waste into the Mediterranean Sea, per locality view.



Source: Boucher and Bilard, 2020

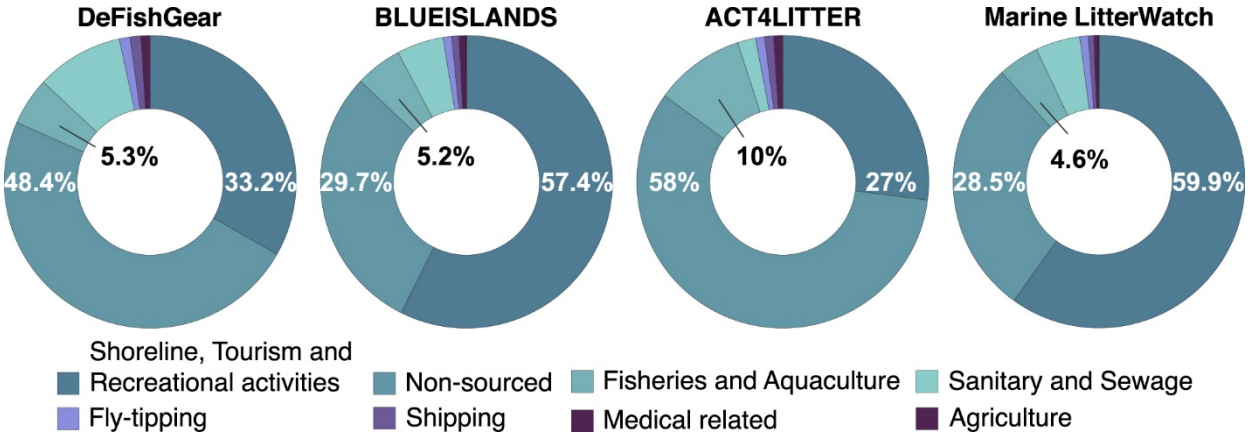
In most Mediterranean countries, the root causes of plastic pollution are found in the increase of plastic use, unsustainable consumption patterns, ineffective/inefficient waste management and loopholes in plastic waste management (UNEP, 2021). The majority of marine plastics originate from land, reaching oceans and seas through several pathways, such as rivers and sewage systems. This leakage concerns all plastic sizes, from nanoplastic particles to macroplastic debris.

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 plastics 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, 2017).

The amount of plastic leaking to the Mediterranean Sea presented here are related to land-based sources and provide a general overview of the issue. However, contributions from sea-based sources and/or key economic sectors such as fisheries, aquaculture, tourism and shipping are generally overlooked despite generating large amounts of litter that end up as marine litter. It is not possible to estimate the total contribution of sea-based activities and industries to the global burden of marine litter because very little quantification of such litter inputs exists in the scientific, peer-reviewed and grey literature (GESAMP, 2021). However, studies showing the relative contribution of specific items related to specific activities exist. On the seafloor of the Gulf of Alicante (southwest Spain), about 29% of litter was linked to fisheries, of which about 61% was made of plastic and about 25metal (García-Rivera et al., 2017). Another study from northwest Spain estimated that about 7% of the total seafloor litter were fisheries related items (Saladié et al., 2021).

In their report, Sandra et al. (2020) estimated from various sources that the litter generated by finfish and shellfish aquaculture in the Mediterranean Sea could represent 2.4% - 9.2% of the beach litter, 11.3% of the floating litter and 11.6% - 14.8% of the litter on the Mediterranean seafloor. The data obtained from the beaches (Sandra et al., 2020) are corroborated by the results obtained from the four initiatives presented here as the fisheries and aquaculture related items collected represented respectively 5.3% (DeFishGear), 5.2% (BLUEISLANDS), 10% (ACT4LITTER) and 4.6% (Marine LitterWatch) of the beach litter (Fig. 7).

Figure 7. Sources of beach litter from the four initiatives.



Source: Vlachogianni et al., 2018; Vlachogianni et al., 2019; Grelaud and Ziveri 2020; Marine LitterWatch database.

The recreational use of Mediterranean beaches can also be a large source of marine litter representing on average the largest contribution to beach litter. From the four initiatives, the contribution of items related to tourism and recreation activities (beachgoers, sports and recreation businesses, beach bars, hotels, festivals, mismanaged waste at the beach, etc,) represented 33.2% (DeFishGear), 57.4% (BLUEISLANDS), 27% (ACT4LITTER) and 59.9% (Marine LitterWatch) of the total amount of items collected respectively.

Finally, despite 15-30% of the global shipping activities take place in the Mediterranean Sea, virtually no estimation of the inputs related to this sector exist. In their study, Liubartseva et al. (2018) estimated

the inputs of plastic marine debris from shipping lanes in the Mediterranean Sea to approximately 20,000 tonnes per year. However, the value should be used with caution due to high uncertainty in underlying data and assumptions, as reported by the authors.

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3. EU TOOLS TO FIGHT MARINE POLLUTION

KEY FINDINGS

- A few strategies for reducing plastic pollution could be setting market restrictions, improving waste management and consumer/producer agreements.
- Pollution pressures increase with tourism; waste management facilities are overloaded by up to 40% during the high season.
- Management practices need implementation in touristic Mediterranean islands that are under high pollution pressures during the summer season.
- Significant progress has been made in terms of treatment and prevention, including the implementation of the single-use plastic directive and the promotion of recycling. Although more and continued efforts are needed.
- Several rivers and wastewaters reaching the Mediterranean do not reach a ´good environmental or ecological status´.

Marine pollution presents major environmental challenges facing the world today. These issues not only harm marine life, but also have far-reaching economic and social impacts. In response to this growing problem, the European Union regions and cities have taken various actions to fight different types of pollutants reaching the Mediterranean Sea.

Ocean pollution is a broad subject, with different factors of environmental pressure of very different kinds. The following table shows a review of the main sea pollutants in the Mediterranean as well as the regional actions taken to combat this issue.

Table 3. Main marine pollutants in the Mediterranean Sea and actions taken to limit or stop them.

Pollutants	Drivers	Regional Cooperation
Solid waste: organic matter Biological Oxygen Demand (BOD) and Chemical Oxygen Demand COD), excess nutrients (nitrogen and phosphorus) and pathogenic microorganisms	Uncontrolled landfills and the deficient waste collection system of agriculture, food industry, livestock, fisheries and food production	- In 1975 The United Nations: Programme for the Assessment and Control of Marine Pollution in the Mediterranean (MED POL) assist Mediterranean countries in the implementation the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources. Its objective is to improve solid waste management in the Mediterranean region and promote sustainable practice. - The Union for the Mediterranean (UfM) Solid Waste Initiative: this initiative aims to foster cooperation and collaboration

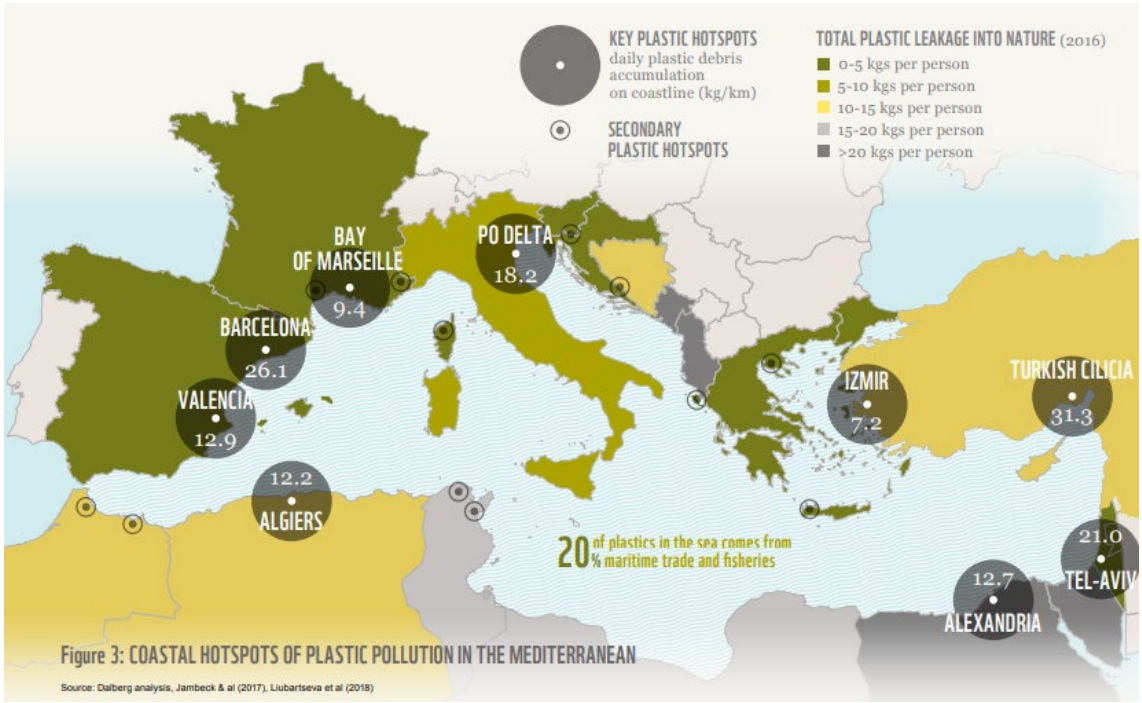
		among the countries of the Mediterranean region to address solid waste challenges.
Oil spills and contamination Polycyclic aromatic hydrocarbons (PAHs).	Ships that make up the maritime traffic (approx. 220,000 ships, more than 100 tons per day) release fuel and oil spills in their maritime operations. It is estimated that between 1990 and 2005, these maritime operations together with the usual discharges into the Mediterranean Sea from land-based facilities and maritime accidents at refineries discharged 120,000 tons of oil per year	- 1976 Barcelona Convention (BCN): This convention aims to protect the maritime environment in the Mediterranean region and to prevent pollution by oil and other pollutants.
Persistent Organic Pollutants (POPs): Pesticides and heavy metal products (arsenic, cadmium, chromium, copper, nickel, lead and mercury), polychlorinated biphenyls (PCBs), dioxins and furansare some of the most common examples	Chemical, mining and petroleum industries produce significant quantities of heavy metals which, due to poor management of industrial waste and runoff release toxic chemicals into the coastline. Although the manufacture of many of these chemicals is banned in some countries, they continue to be a cause of pollution of concern	-2001 Stockholm Convention on Persistent Organic Pollutants (POPs): This is an international treaty that aims to reduce and control the production and use of POPs worldwide. -1990 MedPAN Project: This project aims to improve POPs management in the Mediterranean region and promote sustainable waste management practices. -1971 Mediterranean Sea Initiative for the Prevention and Control of Persistent Organic Pollutants (MEDPOL): This is a coordinated effort by several Mediterranean countries and international organizations to improve the management of POPs in the region.
Heavy Metal on sediments: Chromium (Cr), Nickel (Ni), Copper (Cu) and Mercury (Hg)	Burning fossil fuel, Industrial discharge and agricultural runoffs.	1998 NU Protocol on Heavy Metals Aarhus Protocol on Heavy Metals The Executive Body adopted the Protocol on Heavy Metals in Aarhus (Denmark) on 24 June 1998. It targets three particularly harmful metals: cadmium, lead and mercury

3.1. Actions to combat marine plastic pollutant

In addition to the marine pollutants listed in Table 3.1, a rapidly emerging and accelerating marine pollutant of anthropogenic origin is marine plastic pollution (marine litter). This presents a major and urgent concern in the Mediterranean Sea that is one of the largest marine area of microplastic accumulation in the world ocean (Cozar et al., 2015; Suaria et al., 2016). According to WWF the Mediterranean Basin is the world's 4th largest producer of plastic (10% of all plastic products in the world, WWF Report 2019) and it dumps yearly, 230,000 tonnes of plastic into the ocean (Boucher and Bilard, 2020), which is equivalent to dumping 13,600 plastic bottles every minute (estimation based on the WWF Report (2019) and Boucher and Bilard (2020)).

To understand the scale of this problem, the next figure shows daily plastic accumulation in some of the most populated cities in the Mediterranean.

Figure 8. Mediterranean Hots Spots of plastic leakage into the ocean.



Source. WWF Report 2013 "How Mediterranean countries can save the ocean"

3.1.1 Limitation on the production

In July 2021, DIRECTIVE (EU) 2019/904 on the reduction of the impact of certain plastic products entered into force. How cities respond to this legislation will be reviewed in the next chapter. On the Mediterranean, France was one of the countries in adapting the law quickly and even went farther establishing restrictions related to micro plastics that are not in the directive. In the article 82 of the law "LOI n° 2020-105 du 10 février 2020" mentions that "from January 1, 2023, any producer, importer or user of a substance or mixture mentioned in the second article shall ensure to follow all relevant instructions for use aimed at preventing the release of microplastics into the environment". Among the instructions to be followed are the measures mentioned in art 82 (Table 4).

Table 4. Measures implemented by France against micro plastics.

Date	Measures
January 1 2025	Plastic microfiber filter for new washing machines.
January 1 2026	Ban on cosmetic products or other substances containing micro plastics in a "mixture intentionally made with a concentration equal to or greater than 0.01%, considered as the ratio between the mass of the micro plastic and the total mass of the sample".
January 2027	Restrictions on detergents and cleaning products.

The above restrictions are of upmost importance for the decrease in the discharge of microplastics into the Mediterranean Sea since most of these reach the sea through sewage systems. Among the products that worldwide contribute to the largest amount of microplastic debris in the oceans are the synthetic and non-synthetic fibres of clothing and cosmetics (Cózar et al., 2015; Suaria et al., 2016). By including a filter in washing machines and reducing the concentrations in cosmetics, the problem in question is directly attacked, although its later disposal will depend on local waste management. Another measure that favours the reduction of microplastics, although indirectly, is the prohibition of disposal of clothing to fashion companies.

Analysing the French policies, it can be concluded that the strategy for plastics reduction is based on setting market restrictions and ambitious targets, which raises precedents within the European Union and the Mediterranean to set higher standards in future circular economy directives and plans. An example of this is the adhesion of Nice (August 15, 2019) and also Venice (March 19, 2021) Italy to the Plastic Smart Cities initiative developed by the WWF, with the objective that coastal cities and coastal centres will aim to reduce plastic leakage into nature by 30% in the near term and achieving no plastics in nature by 2030.

Although this initiative is not mandatory (it does not establish laws or sanctions) it demonstrates an interest in pursuing global anti-pollution goals. Another example of action to prevent coastal waste generation particularly in beaches was launched in Nice (2012) to ban smoking on beaches and to establish fines, measures that are now being embraced by several coastal touristic cities such as Barcelona (2022).

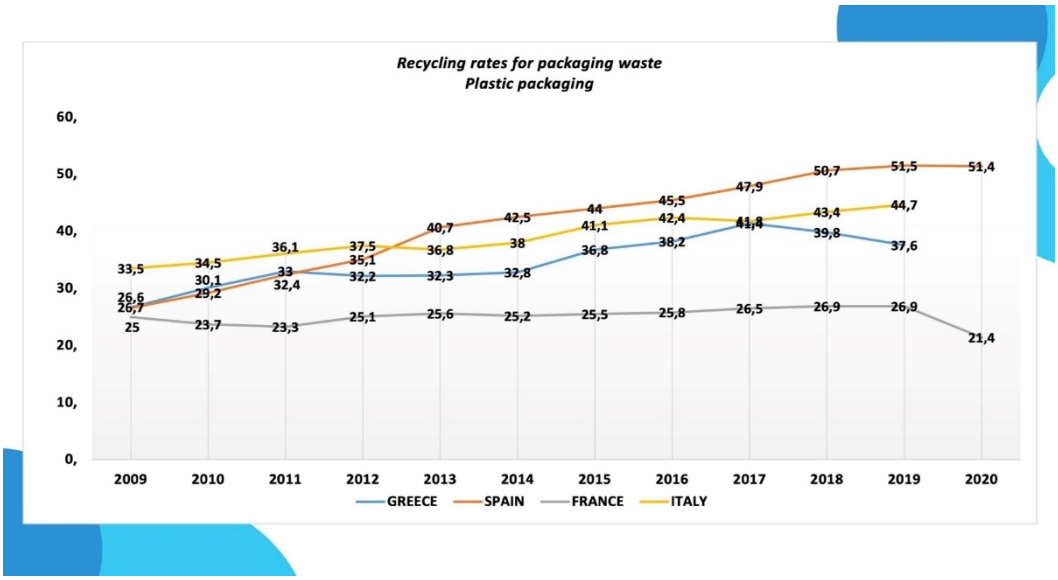
3.1.1. Beach litter

If the French strategy focuses on setting restrictions on the production system, Spain and Italy have done quite remarkable efforts to increase recycling and improve its waste system. It has been estimated that that the origin of marine plastic litter is approximately 80% on land and the remaining 20% on marine-based activities usually from three major sources: fishing waste, accidental loss of goods and spills from ships (Jambeck et al., 2015). It is estimated that in 2012 the world's population generated a

total of almost 32 million tons of garbage (Baudena et al., 2018), which was not managed properly and ended up in the world oceans. In the Mediterranean half of the plastic becomes waste in less than a year since it was produced, the rate of accumulation is high since only 9% of the plastic is recyclable (Dalberg Advisors, 2019).

In the context of designing green cities with an environmentally conscious population reducing consumption, improving waste management and increasing recycling are priority actions for the prevention of marine pollution. In the Mediterranean Spain and Italy stand out for their high percentage and increased recycling rates. The next figure shows the progression of recycling plastic waste in some EU countries of the Mediterranean.

Figure 9. Mediterranean recycling rates for packaging waste.



Source: Eurostats Statics explained (website)

According to recycling company Cicloplast (The Spanish association that represents plastic raw material manufacturers and plastics processors) in 2020 the Spanish made a 2.1% reduction in plastic packaging consumption in 2020. Of the waste treated, 54.7% was destined for recycling, an increase of 12.3 percentage points compared to 2019 and an increase of 16.4 percentage points compared to 2015. Within the communities that recycle the most within Spain the cases of the Valencian Community (16.4 kg/inhabitant) the Canary Islands (14.8 kg/inhabitant), and Catalonia (14.4 kg/inhabitant) stand out (Instituto Nacional de Estadistica, 2022)

At present, Barcelona and Valencia have waste management programs that can serve as an example to combat marine pollution. Valencia is the first Spanish city to implement a pilot return and reward project called Reciclos, in which yellow containers, with built-in technology, generate a system of points and rewards. Although at first sight the initiative does not seem to be too impressive, the number of bottles obtained in 2020 was 8% higher compared to 2019 (González Fernández, 2022).

Marseille is also moving towards the construction of smart cities. In September 2021, a system of low-energy sensors was installed in 5,000 sewers and manholes of the urban drainage system. These sensors will be used to monitor the collection of debris in the drainage system and provide early warning of potential flood hazards. The network called Sigfox will allow the city to monitor storm water

runoff to detect blockages and obstructions, which is important to prevent the release of debris into the environment.

Italy was the first country in Europe to ban micro plastics in cosmetics (2018), although this law is limited to cosmetics and does not include products such as soaps and detergents, as France does now with the recent legislation. Landfill taxes have also been introduced, with a minimum and maximum ranging from €5.2 in Campania to €28.5 in Piedmont. The result has been a decrease in the total volume of landfills from 19 to 6.9 million tons in the last 15 years. The government also supports recycling, with new targets of 50% by 2025 (Dalberg Advisors, 2019)

3.1.2. Consumer awareness

While in France, the focus is more on the production phase, in Italy and Spain on the improvement of the waste system, Greece opts for action in the final phase of the circular economy, the consumption phase. As several studies point out, there is a positive correlation between a country's accession and the quality of its public policies. Despite this, Greece has made significant efforts to improve environmental quality. Measures have been implemented to make plastic producers more responsible for the management of plastic waste generated by their products and a system of monitoring and control of producers and their products. Cities in Greece have started to implement measures to comply with the EU plastics directive and have launched several local programs.

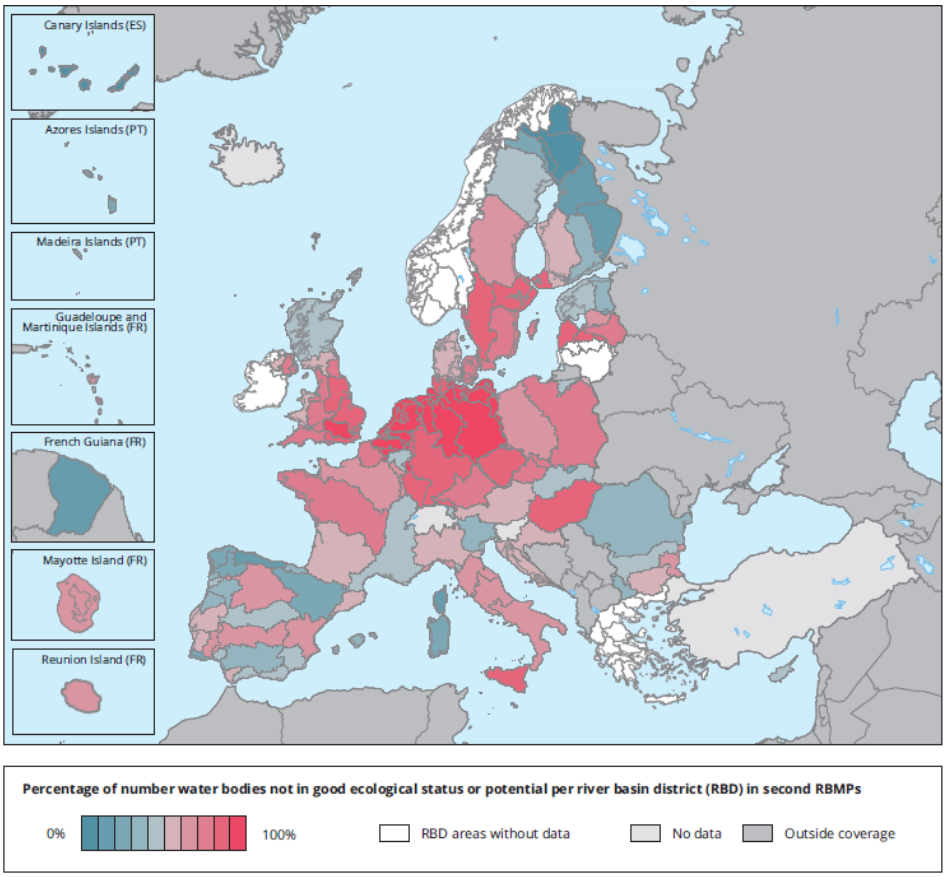
- **Athens**: A program called "Cleanliness 360 degrees" aims to improve the cleanliness and air quality in the city. The program includes measures to reduce the amount of plastic waste, such as the installation of new litter garbage cans and the promotion of separate waste collection.
- **Thessaloniki**: The city of Thessaloniki has implemented a program called "Zero Plastic" that aims to reduce the use of single-use plastics in the city. The program includes promoting sustainable alternatives to single-use plastics, educating citizens about the impacts of plastic pollution, and promoting separate waste collection.
- **Heraklion**: The city of Heraklion has launched a program called "Heraklion without plastics" that aims to reduce the amount of single-use plastics in the city. The program includes the elimination of single-use plastics from municipal buildings and the promotion of sustainable alternatives, such as reusable packaging.

The above cases are just examples of the tools that can be implemented to reduce marine pollution, they are a sample of what is achievable, and its development setting the course for the political futures of the European Union. As can be seen within each country and cities there are strong and weak points. A more efficient implementation of policies will depend on the ability to establish cooperative ties, an openness of information and the ability to meet agreed objectives.

3.2. Overview on river contamination

Another major source of pollutants to the Mediterranean Sea is the river discharge into the sea. The European Environmental Agency classified the quality of the rivers under different parameters: amount of pesticides, heavy metals, nitrates and phosphates from fertilizers, but not plastic or microplastic. (EEA Report No 7/2018). The next figure shows the Mediterranean ecological status of rivers and water measuring according to the amount of this pollutants.

Figure 10. Ecological status of the rivers in the Mediterranean basin.



Source: Results are based on WISE-SoW database including data from 24 Member States (EU-28 except Greece, Ireland, Lithuania and Slovenia). Water bodies failing to achieve good status, by RBD; see also Surface water bodies: Ecological status or potential (group) and Surface water bodies failing to achieve good status by RBD .

Source: EEA Report No 7/2018

To combat pollutants coming from rivers, the EU has two directives that regulate the properties of discharged water and the chemical state of receiving freshwater ecosystems, respectively. The EU directive 91/271/EEC defines limits for different elements in urban effluents using both static emission limits and minimum percentage load reductions. Meanwhile, the EU water framework directive (2000/60/EEC) sets minimum standards for achieving a "good" chemical and ecological status. Litter like plastic or bags or single use plastics are not regulated by different directives and does not make a difference on coastal or near to river cities.

Under this scheme several river sanitation programs have been implemented. As key example we highlight here two cases:

- The Po River, which flows through several major cities in northern Italy, including Turin, Cremona, Piacenza, Ferrara and Venice.

- And the Besós River flows through the region of Catalonia in north-eastern Spain, and flows through the cities of Sabadell, Barcelona, Santa Coloma de Gramenet and San Adrián de Besós, before reaching the Mediterranean Sea.

In the case of the Po River, the "Program of Measures" of the second hydrological planning cycle (2016-2021) includes specific actions to reduce urban and industrial wastewater pollution and improve the management of hazardous waste.

As for the Besòs River, the Catalan Water Agency (ACA) has created the Besòs River Park, which is located along the last 9 kilometres of the Besòs River, from its junction with the Ripoll River to its mouth in the Mediterranean. Despite being located in the urban area that connects Barcelona, Santa Coloma de Gramenet, Sant Adrià de Besòs, and Montcada i Reixac, the Besòs park is one of the primary green spaces in the metropolitan region of Barcelona, spanning 115 hectares. The park underwent changes aimed at transforming it into a river corridor

In spite of the previous actions and directives, we found an insufficiency in the framework and implementation of the river sanitation system. Analyses carried out (Olcina, 2002) show that the directive, is too general and do not consider the specificities of each river, causing a disharmony between implementation and administration. And in the Besòs project, there is a lack of social integration that generates contradictions between an administration that seeks to preserve the river dynamics but at the same time the construction of structures that do not favor it.

Among what is achievable is the need for more harmonized and effective regulation of river management. Stronger cooperation between cities and countries is essential to ensure that international policies and agreements are implemented and enforced. Another recommendation would be to make special regulation of plastic and pollutants near to rivers and lakes, so the policies can have more efficient results.

3.3. Tourism

Another big concern in the Mediterranean is the increasing urbanization and tourism on the coastline. The population of the Mediterranean countries was about 450 million in 1996 and is estimated to reach 520-570 million by 2030 (Sardá et al., 2020). Overpopulation of the coastline is not only worrying because of the increase in solid waste and sewage, but urbanization is altering the Mediterranean coastline. Land occupation and mining for the construction industry (sand and stone quarries) is destroying ecosystems such as wetlands and marshes. The population pressure become even more worrying if we consider that one of the main economic activities in the region is tourism. During summer months, tourists increase the total population by over one-third, with an estimated of 100 million visitors a year. Tourism is seasonally concentrated in the north western coastal areas, accounting for almost one-third of the world's international tourism. In the summer local waste management facilities become overwhelmed, increasing their capacity by up to 40%. (Sardá et al., 2020).

But is not only a matter of waste management, the excessive damages of mass tourism it related to the expansion of the urban infrastructure. In Barcelona for example, the attempts to expand the airport on land belonging to the municipality of El Prat de Llobregat have been threatening the ecological status and continuity of La Ricarda lagoon for the last decade.

The issue of finding a balance between economic growth and environmental sustainability is particularly challenging in territories with limited natural resources such as islands, where tourism is often perceived as a crucial part of the local economy. However, the increase in visitor arrivals and industry investments can create pressure beyond sustainable levels, leading to unexpected detrimental impacts on the environment and local communities. Policymakers must therefore strive to find an acceptable equilibrium between these two dimensions, in order to support economic development while minimizing negative effects on the environment and residents.

Although there has been an increased awareness about how to make tourism sustainable, ecotourism practices in the Mediterranean are still in their infancy stage. A good example of this is the case of the Mediterranean islands, were tourists engage in other forms of recreation activities in addition to ecotourism, suggesting that ecotourism is not yet a primary driver of activities in the region. For sustainable tourism to be effectively implemented, it must prioritize the systematic management of environmental degradation, generate economic benefits for receiving communities, and consider the perceptions of residents.

3.4. Insular vulnerability

The term Insular vulnerability refrers to a situation characterized by a multiplicity of physical, financial, and sociocultural weaknesses that cannot be avoided. In the Mediterreanen the status of most of the Islands are under ecological pressures that increase due his insolation (Leka et al., 2022).

As we explain in the chapter before, Tourism has become a major problem on the Islands as it is considered the only viable solution to overcome the structural constraints due to their small economies and insular physical conditions. The limited domestic market demand on many islands makes it difficult for local firms to achieve economies of scale, which is essential to efficient functioning.

But Tourism is not the only problem in the Mediterranean Islands. In a sudy made in the islands of Spain (Candela et al., 2008) intensive agricultural production and high seasonal water demand was found. Farmers commonly use inorganic nitrogen fertilizers, plant protection products, and treated wastewater for irrigation, leading to nitrate contamination in the aquifers. Majorca Island, groundwater has been found to contain high levels of nitrate, up to 700 mg/l. The aquifers that are frequently used for irrigation are vulnerable and have low replacement capacity, resulting in the presence of nitrate in groundwater. The use of plant protection products has also increased, with more pesticides being used. Also, a research on seabirds in the Selvagen Island, Majorca Island, Linosa Island, and Crete Island found higher levels of mercury and selenium (Renzoni et al., 2000).

Despite their vulnerability it is uncommon to find policies made just for the Islands. The most common cases involve changing the status of the island into a natural protected regime or into a biodiversity conservation zone, like the Red Natura (2010) in Spain. But studies had demonstrated that this is insufficient. In a research conducted to messure the amount of plastic in the natural Parks of Mallorca, the "Parque Nacional Marítimo-Terrestre del Archipiélago de Cabrera", in the Balearic Islands and the coastal waters of The Natural Park of Columbretes Islands, plastics and micropplastics were found in high proportions, proving that marine pollutants are not been detected or attacked eficienly (De Lucia et al., 2018).

Enviromental Policies on the Island does not always responde to the vulneravility and singularity of his pressures. A legislation about pollutants in this specific places it is something urgent and achievable.

3.5. Coastal cumulative pressures.

In addition to the specific problems mentioned above, there are other marine pollutants that exert great pressure in the Mediterranean.

3.5.1. Agriculture and aquaculture

Production and emissions of pollutants derive from agricultural practices, industrial development, urbanization and tourism. Persistent organic pollutants, nutrients, oils, radionuclides, heavy metals, pathogens, sediments, litter and debris are some of the contaminants of greatest concern. Agricultural activities worldwide contribute about 50% of the total source of surface water pollution, ammonium ion (NH4) from intensive livestock farming is a major contributor to environmental acidification (Islam et al., 2004)

Most pesticides are not rapidly degradable because rapid degradation could reduce their applicability. Pesticides and their residues are devastating the ecosystems and aquatic organisms, affecting all levels of the food chain. The effects of agricultural residues are associated with bioconcentration and biomagnification, leading to increasing concentrations of pesticides and other chemicals in organisms. Metals considered toxic and found in the Mediterranean include mercury, cadmium, silver, nickel, selenium, lead, copper, chromium, arsenic and zinc, which can bioaccumulate in marine organisms and interfere with metabolic processes.

Aquaculture has received special attention because of its potential to load and discharge pollutant-rich effluents. The environmental impact of aquaculture depends mainly on feed composition, feed conversion, waste generation, organic and inorganic fertilizers and other additives. Waste production contribute to significant nutrient loading in aquatic systems and subsequent discharge into receiving waters.

Intensive fish and shellfish farming in coastal areas can cause environmental disturbances due to abnormally high levels of organic matter that accumulate and affect sediment processes and oxygen concentrations. Shellfish culture, for example, can significantly affect the nitrogen cycle, For instance the Thau lagoon in France, is heavily used for oyster farming, and alterations in the nitrogen cycle result in reduced nitrogen loss by denitrification.

3.5.2. Fishing and Shipping

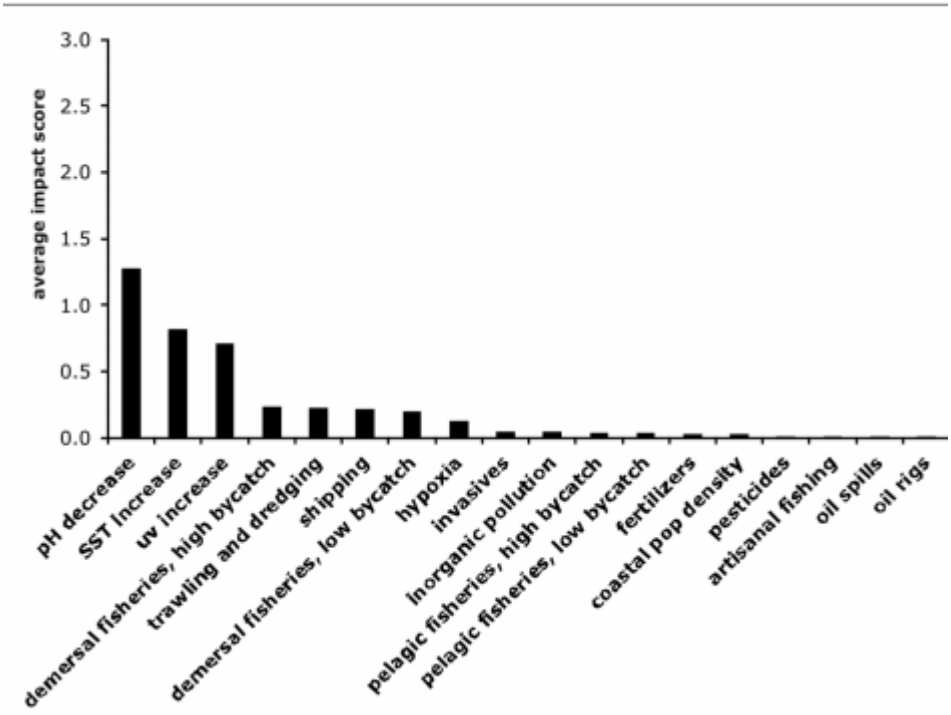
Fishing can be a major source of pollution in the Mediterranean, especially when unsustainable practices are used. Some of the most significant pollutants related to fishing in the Mediterranean include:

- **Discarded fishing gear:** Lost or abandoned fishing gear, such as nets and lines, can continue to catch fish and other marine animals, causing damage to the ecosystem and polluting the water with microplastics.
- **Bottom trawling:** This fishing technique involves dragging a weighted net along the seafloor, which can damage seafloor habitats and release sediment into the water, potentially harming marine life and increasing turbidity.
- **Overfishing:** Overfishing can disrupt the balance of the ecosystem and cause fish stocks to collapse. This can lead to a loss of biodiversity and changes in the ecosystem that can lead to pollution.

Moreover, shipping pollution can take various forms, such as oil spills, waste disposal, air and noise pollution. One of the most important sources of pollution in the Mediterranean is ship emissions, which come mainly from the burning of fossil fuels by ship engines. These emissions include sulphur oxides, nitrogen oxides, particulate matter and carbon dioxide.

Although there could be an extensive list of cumulative pressures, just the main pollutants and drivers have been mentioned in this article for a comprehensive understanding of the problem. To provide a broader view, a figure is included showing other significant pressures that should also be taken into account. The author (Micheli et al., 2013) has created an impact score in the Mediterranean and Black Sea basins considering various climatic drivers and direct compliance of the recommendations of the MSFD on achieving good environmental status.

Figure 11. Coastal cumulative pressures on the Mediterranean.



Source: Micheli et al. (2013)

4. COHESION AND ENVIRONMENTAL POLICIES

KEY FINDINGS

- Mandatory Policies to reduce pollution with specific targets made by the European Union have a wide positive range of implementation on the local level. For the same reason update mechanisms for the implementation and surveillance of these policies at local level are needed.
- European Strategy attacking three key sectors: consumption patterns, the production model and natural capital, in other words: resource extraction, production, consumption and waste disposal.
- Stimulated local policies can be more tailored to the specific needs of a city and may allow for greater flexibility in implementation.
- Cooperation relies too heavily on voluntary actions by member states and may present a lack of clear targets and indicators for measuring progress. The participants would need to find new mechanisms to achieve more effectiveness into their policies.

The Mediterranean is a region with extensive environmental policies and cooperation agreements. The first official action for the protection of the environment in the Mediterranean was taken in 1975 when sixteen Mediterranean countries and the European Economic Community (EEC) under the United Nations Environment Program (UNEP) created the Mediterranean Action Plan (MAP). The following year, the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) was created as a legal framework.

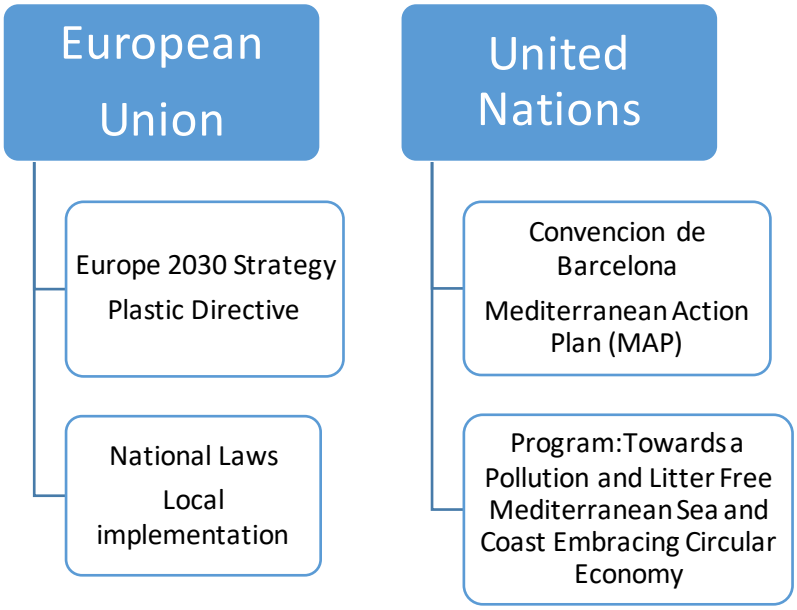
The 2030 MAP Agenda for sustainable development establish 4 objectives:

a) Pollution and litter free Mediterranean Sea and coast embracing circular economy.
b) Healthy Mediterranean ecosystems and enhanced biodiversity.
c) Climate resilient Mediterranean.
d) Sustainable use of coastal and marine resources including circular and blue economy.

Even though there are regional agreements in the Mediterranean with targets to reduce pollution on a regional basis, we find that the most comprehensive framework to address this issue and to assets how tailor policies have been put in place (Paszkowski et al., 2019), is the Europe 2030 Strategy, an action plan designed by the European Commission to address today's economic and environmental challenges. The strategy design the European policy agenda by outlining seven key objectives: digital climax, circular economy, sustainable cities, knowledge society, competitive economy, strong democracy and climate action. Out of the strategy comes a dedicated policy for plastics called "A European Strategy for Plastics in a Circular Economy (2018)", a program that set guidelines for achieving a cohesive, resource-efficient Europe and in transition to a competent low-carbon economy and environmental resilience are beginning to be put on the table.

Different authors have described the management of cooperation in the Mediterranean as a combination of regional cooperation agreements and the application of European Union Law

(Dörgő et al., 2018). The following diagram shows the benchmark we use to measure how coastal regions function within cooperation programs in the Mediterranean basin.



The Circular Economy Strategy is innovative because it establishes regional environmental and economic guidelines. A recent study points out that the European Strategy marks a turning point because it establishes the relationship of a new economy with environmental issues, attacking three key sectors: consumption patterns, the production model within the framework of the internal market, and natural capital, or, in other words: resource extraction, production, consumption and waste disposal (Fabrés Garrido, 2019).

4.1. A Zero plastic waste Europe

Subsequently, under the guidelines of the European Strategy for Plastics in a Circular Economy and the Sustainable Development Goals of the United Nations to ensure sustainable use of the oceans, The directive (EU 2019/904) on the reduction of the impact of certain plastic products on the environment was created. This instrument sets the legal basis for the European Union's policy to reduce plastic pollution, with the explicit goals of "preventing and reducing the impact of certain plastic products on the environment, in particular the aquatic environment, as well as promoting the transition to a circular economy with innovative and sustainable business models, products and materials"[3].

[3] Directive (EU 2019/904) on the reduction of the impact of certain plastic products on the environment. https://eur-lex.europa.eu/ES/legal-content/summary/single-use-plastics-fighting-the-impact-on-the-environment.html

Table 5. Circular economy of the plastic directive.

	DESIGN	PRODUCTION	CONSUMPTION	WASTE MANAGEMENT	RECYCLING
Life cycle of Plastic.	Understanding of requirements, financial objectives and strategies	Production of pure plastic made from chemicals derived from fossil fuels through a polymerization or polycondensation process	The utilization of plastic, from its processing stage to its eventual disposal as waste by the end user	Retrieval of plastic waste discarded by end-users and the classification of the waste into various groups for processing	Reuse of plastic in an economy after the transformation of waste into secondary material.
Directive measure	*- Ecolabeling with environmental consequences of the product* *- A methodology for the calculation and verification of the annual consumption of single-use plastic products.* *- Circular design of fishing gear to be reuse and.*	*- Mandatory minimum content of recycled plastic in beverage bottles.* *- Member States shall prohibit the placing on the market of single-use plastic products*	*- Consumer Awareness Campaigns* *- Marking should inform consumers of appropriate waste management options for the product or of means of disposal to be avoided*	*- Extended producer responsibility schemes.* *- Under the polluter pays principle, costs are introduced to cover the necessary expenses of waste management and awareness measures to prevent and reduce pollutants.* *waste for recycling.*	*- Reuse and recycling of the product plastic caps and plugs* *- Separate collection targets for single-use plastic beverage bottles, establishing deposit systems.* *- Creation of a national minimum annual collection rate for plastic-containing fishing gear*

The plastics directive is the legal framework under which the different EU countries and cities establish policy actions for marine plastic pollution. The following table shows the response of the different coastal cities to the new production schemes.

Table 6. Application of the plastic directive in coastal cities.

SPAIN	*ITALY*	*FRANCE*	*GREECE*
Barcelona: 2020, ban of single-use plastics in municipal facilities. - 2021 light plastic bags banned. -2022 fines for tobacco products on the beach. **Malaga**: 2018 banned the use of expanded polystyrene containers in municipal facilities. - 2018 Tax on plastic bags - 2019 banned the sale of single-use plastics in municipal facilities. **Valencia**: 2020 banned the sale of single-use plastics at events and festivals organized by the Valencia City Council. **Palma de Mallorca**: In 2020, the sale of single-use plastics was banned in all municipal facilities, including beaches and parks.	**Rome:** 2019 ban the use of disposable plastics at all public events in the city, including concerts and festivals. **Venice:** 2019 ban single-use plastic bottles, and the use of reusable bottles has been promoted. In addition, a selective waste collection program has been initiated in the city's canals to reduce water pollution. **Florence:** 2019, ban disposable plastics, including bags, cutlery, plates and straws **Naples:** 2020, banning the sale and distribution of disposable plastics. Genoa: 2021 ban the sale and distribution of disposable plastics at public events in the city was banned, and the use of reusable and compostable packaging was promoted.	**Marseille and Nice:** 2021 Ban of disposable plastic bags in stores and supermarkets. -Reducing the use of plastic bottles and single-use straws in restaurants and bars. -Installation of more recycling garbage cans on the beach and in other public areas. Promotion of sustainable alternatives such as reusable bags and refillable water bottles.	**Atenas** 2021 Skiathos banned single-use plastics, including bags, cutlery and plates.- **Skiathos** 2016 banned single-use plastics, including bags, cutlery and plates. **Hydra** - In 2018, the island of Hydra banned single-use plastic straws, stirrers and cups. **Corfu** - In 2019, the city of Corfu banned plastic bags and expanded polystyrene food packaging. **Mykonos** - In 2019, the island of Mykonos banned plastic bags, straws and single-use cups. Syros - In 2020, the island of Syros banned single-use plastics, including bags, straws, cutlery and plates.

In conjunction with the previous section, two modalities of action (restrictions on production, waste management and recycling) under the new EU circular economy guidelines have been presented so far. In both cases it can be seen that when agreements are binding at the regional level, they end up being applied at the local level, following time and quantifiable measures (Durán y Lalaguna, 2016). Another component that could be analyzed are the measures of the plastics directive on fishing gear, which establishes guidelines for local authorities to establish policies of Producer and Consumer

Responsibility for those who do not collect marine litter. Although there is no data available at the local level that can generate an analysis on the effectiveness of this measure, some countries are already implementing laws in this regard. Italy, for example, passed in 2019 the "Salva Mare" law[4], which authorizes fishermen to collect the plastic that remains in their nets when fishing to prevent them from throwing it away again, without having to face the crime of illegal transport of waste and having to pay for its disposal as was previously the case.

Analyzing the plastic directive we found that mandatory policies to reduce pollution made by the European Union have a wide positive range of implementation on local level. For the same reason update mechanisms for the implementation and surveillance of this policies at local level are needed. On the other hand, local policies can be more tailored to the specific needs of a city and may allow for greater flexibility in implementation. Although it may be more difficult to measure their impact, they can be equally effective and, in some cases, more effective than European policies.

4.2. Cooperation policies

But not all policies are placed under a mandatory dynamic. For the design, consumption and recycling steps, the directive provides a more open scope for action. After a long process of negotiations and cooperation (Hackenesch et al., 2020) regional agreements come into play to coordinate cooperation plans, awareness-raising campaigns and technological designs. To achieve these objectives, the Mediterranean has the following marine agreements and programs.

- **Integrated Coastal Zone Management (ICZM):** This is a planning approach that seeks to manage coastal and marine resources in the Mediterranean in an integrated manner. It focuses on improving natural resource management, coastal planning and development, biodiversity conservation and marine pollution prevention.
- **Program for the Assessment and Control Pollution in the Mediterranean (MEDPOL):** A regional network for monitoring and assessment of the marine environment in the Mediterranean. It focuses on pollution monitoring and control in the region, as well as on improving scientific knowledge on water quality and marine biodiversity.

The above programs are in turn categorized under environmental objectives on which they work at the local level. The following are examples of the implementation of these objectives in different Mediterranean coastal cities.

4.2.1. Monitoring and citizen science programs

Monitoring and citizen science programs are important in the fight against marine pollution because they provide a way to gather data on the presence, extent, and impacts of pollutants in the marine environment. By engaging citizens in monitoring efforts, a larger amount of data can be collected over a wider geographic area, which can help identify patterns and trends in pollution that might not be

[4] Disposizioni per il recupero dei rifiuti in mare e nelle acque interne e per la promozione dell'economia circolare (legge «Salva Mare»). (22G00069) (GU Serie Generale n.134 del 10-06-2022)

apparent through traditional monitoring methods. This data can then be used to inform policies and management decisions aimed at reducing pollution and protecting marine ecosystems.

In addition to providing valuable data, citizen science programs can also increase public awareness of the issue of marine pollution and empower individuals to take action to reduce their own contributions to pollution. This can lead to changes in behavior and consumer choices that support more sustainable and environmentally friendly practices.

In this context, it is important to note the existence of the EU's MSFD which aims to address marine pollution and promote sustainable use of the oceans and seas. On Monitoring and citizen sciences programs we found some interesting initiatives.

- **Nested Environmental status Assessment Tool (NEAT**) A free software tool designed to evaluate the environmental status of the marine environment, primarily within the European MSFD, but can also be used to assess impacts in the sea, such as the effects of human activities on marine biodiversity and climate change.
- **The European Mediterranean Sea Acidification in a changing climate (MedSeA)** project, funded by the European Commission under Framework Program 7 from 2011-2014, involved 22 institutions (including 6 associated partners) from 12 countries. MedSeA assessed uncertainties, risks, and thresholds related to Mediterranean acidification at organismal, ecosystem, and economic scales. The project also aimed to disseminate scientific knowledge to a wider audience while suggesting adaptation and mitigation policy measures that would vary from region to region.

In addition to generating cooperative links between citizens, research projects and policy makers, the previously mentioned programs generate examples that are replicated locally along the Mediterranean coastline, some of which are:

- **Athens.** The company UBITECH has developed an environmental monitoring system based on sensors and drones that can detect and warn about sea pollution. It is also working on the development of smart buoys to monitor water quality and prevent pollution.
- **Spain,** the "Marnoba" project (2019-2021) aims to improve the capacity of early warning systems for detecting and monitoring marine litter off the coast of the Murcia region.
- **Italy,** the "Clean Sea" project (2013-2016) was a joint program of several coastal cities that included the monitoring of marine litter and the implementation of management plans to reduce its impact on the marine environment.
- **Greece,** the "Blue Islands" program (2017-2020) included the implementation of monitoring systems to track marine litter on several islands in the country, and the implementation of clean-up and awareness campaigns to reduce its impact.
- **France**, the "Port Propre" project (2016-2021) is an initiative of the city of Marseille that seeks to reduce marine litter in the city's port through the implementation of monitoring systems and the conduct of cleanup and awareness-raising actions.

4.2.2. Environmental technology

- **Italy:** Marine technology projects are being developed for the production of clean energy from waves and ocean currents. Seawater desalination systems are also being investigated to combat water shortages in some areas**.**

- **Spain:** The company Seaplace is developing a system to generate clean energy from wave energy. Drones are also being used to monitor and prevent marine pollution, and wastewater treatment systems are being developed to prevent pollution.
- **Barcelona y Valencia.** Imagin Planet initiative put in place devices called Seabin with the capacity to collect 90,000 bags, 35,700 cups, 16,500 bottles and 166,500 plastic utensils per year, and an annual average of between 1 and 1.4 tons of waste**.**
- **Torino.** "Il Po d'Amare" The initiative aims to capture plastic waste transported by the Po, which with its 652 km touching 4 regions, is the main vehicle of pollution in the Adriatic Sea. A system of fixed barriers and shallow draft vessels ("Sea Hunter") will be used to contain and trap the plastic, which after collection will be destined for treatment and recycling.
- **Barcelona.** The city has installed the Dessalinitzadora del Llobregat plant on the Mar Bella beach, which uses renewable energy to produce drinking water from seawater. In addition, the port of Barcelona has an electric recharging station for ships**.**
- **Marseille:** Marseille is developing the OTEO (Offshore Turbine for Energy Optimisation) project, which consists of installing a floating wind turbine in the sea to supply renewable energy to the city. The city has implemented a real-time monitoring system for seawater quality, which uses sensor and satellite technology to identify potential sources of pollution.
- **Venice:** The city is experimenting with the use of floating barriers to reduce erosion and pollution in the city's canals. In addition, it is studying the use of tidal energy turbines to generate renewable energy from the currents of the Venice lagoon.

4.2.3. Creation of protected areas

- **Ibiza:** Natura 2000 Management Plan West Coast of Ibiza, which includes five protected areas of the European ecological network that will be considered a Special Area of Conservation (SAC) The management plan, he explained, covers a total of 7,651.79 hectares of land and sea, located in the municipality of Sant Josep de Sa Talaia. In addition, it includes an ecological corridor between the SACs of Cap Llentrisca and Porroig.
- **Murcia:** 2018. Marine Reserve of Fishing Interest of Cabo de Palos-Islas Hormigas in the Region that has an area of 18,480 hectares and aims to protect and conserve the fishing resources and marine ecosystems of the area.
- **Palermo and Sicily**. 2019 Capo Gallo-Isola delle Femmine Marine Reserve in the province of, which extends over 2,500 hectares and is home to a wide variety of marine species, such as corals, sponges and algae.
- **Zakynthos:** 2019 The country's first marine national park on the island of, which extends over 13,000 hectares and aims to protect and conserve marine and coastal biodiversity.

The implementation of maritime policies in local Mediterranean cities is essential for the protection and conservation of the marine environment and the sustainability of economic activities that depend on the sea. These policies are fundamental to ensure the proper management of natural resources and the protection of biodiversity, and may include initiatives such as reducing marine pollution, protecting marine habitats and species.

However, measuring the effectiveness of these non-binding policies can be difficult in comparison to European directives. European policies are binding and apply to all EU member states, allowing for

easier comparison between countries and cities. In addition, European directives often include specific and measurable targets, which makes it easier to evaluate their effectiveness.

4.3. Cooperation and cohesion programs

Cohesion and integration programs are crucial for reducing marine pollution including marine litter. In the Mediterranean, cooperation has achieved significant progress. Since the creation of the Mediterranean Action Plan (MAP, 1975) and the Barcelona Convention (1976) a cooperative effort among Mediterranean countries for the protection of the marine environment and its sustainability has developed. Recently several countries in the region have joined the Clean Seas Campaign, a global initiative launched by the United Nations Environment Program (UNEP) to reduce plastic litter, and the transnational European Cooperation Programme for the Mediterranean area (Interreg MED[5], 2014), which focuses on the sustainable development of the region. These efforts demonstrate a commitment to protecting the marine environment and ensuring its sustainability.

Table 7 shows the projects related to marine pollution developed by Interreg MED programme from 2014 to 2020. This table can bring some clarity to what has been achieved and what is expected for the future.

Table 7. Interreg Mediterranean cohesive projects.

Project.	Goals	Description.
PROTEUS (2017-2021) (Blue growth) https://proteus.interreg-med.eu	Promoting security and safety by creating a Mediterranean cluster on maritime surveillance.	Maritime Surveillance (MS) aims at providing to the involved key actors the necessary methods and systems to achieve effective data exchange concerning various maritime risks and sectors (Port control, piracy, pollution and trafficking monitoring, border control, defense, fisheries controls)
IBLUE (2017-2019) (Blue growth) https://iblue.interreg-med.eu	Investing in sustainable blue growth and competitiveness through 3-pillar business model.	Seek for implementation and regulation of Sustainable yachting sector in MED.
BLUE CROWDFUNDING (2020-2022) (Blue growth) https://blue-crowdfunding.interreg-med.eu	Capacity Building of Blue Economy Stakeholders to Effectively use Crowd funding.	Address the following blue economy sectors: blue energy, maritime safety, maritime transport, maritime tourism, fisheries and aquaculture.

[5] https://interreg-med.eu/

BLUEFASMA (2020-2022) (Blue growth) https://bluefasma.interreg-med.eu	To trigger changes in fishing/aquaculture.	BLUEFASMA inspires innovation capacity of Small and medium-sized enterprises (SMEs) maritime clusters and networks in MED islands and coastal areas to support blue circular economy growth in fishing/aquaculture.
PSAMIDES (2019-2022) (Blue growth) https://psamides.interreg-med.eu	Ports small and medium alliance for sustainable development.	Ports authorities, clusters and technological & research centers working together as an integrated business ecosystem to optimize the performance of small and medium-sized ports through the implementation of innovative tools that help manage tourism flows, control costs more efficiently, provide more services to users and particularly boost the eco-innovation of these ports while reducing the negative environmental impact resulting from tourism activity.
PEFMED (2017-2022) (Green growth) https://pefmed.interreg-med.eu	Uptake of the Product Environmental Footprint across the Mediterranean agrofood regional productive systems to enhance innovation and market value.	Generates a life cycle assessment of the agrofood system, and targets reduce waste or emissions.
RE-LIVE WASTE (2018-2021) (Green growth) https://re-livewaste.interreg-med.eu	Improving innovation capacities of private and public actors for sustainable and profitable Recycling of Livestock Waste.	Agriculture and livestock are key sectors in the MED area. The regions involved in the project are characterized by intensive cattle and pig farming, producing a large amount of waste that represent a major source of pollution, an environmental challenge for society and an economic problem for farmers. There is a great untapped potential for MED region.
RAINWASTE (2018-2021) (Green growth) https://reinwaste.interreg-med.eu	Remanufacture the food supply chain by testing innovative solutions for zero inorganic WASTE	New strategy for the growth of Europe, makes a new call to promote circular economy and, consequently, to continue working on developing new

		product Markets that are climate neutral and circular. This new framework offers funding opportunities, investing in technologies to support innovation in companies and industries
BLUEISLANDS (2018-2020) (Sustainable tourism) https://blueislands.interreg-med.eu	Minimizing the cost of tourism in Mediterranean islands through waste prevention actions and circular economy.	A systematic effort to properly identify, address and mi tigate the effects of the seasonal variation of waste generation on MED islands as an effect of tourism.
CASTWATER (2017-2019) (Sustainable tourism) https://castwater.interreg-med.eu	Support sustainable tourism water management in Med coastal areas, by improving the monitoring and assessment of the water sustainability performance of the tourism sector.	The project's main outputs include the promotion of widespread uptake of water sustainability indicators and evaluation criteria to measure the tourism sector performance in water efficiency.
PLASTIC BUSTERS (2018-2022) (Sustainable tourism) https://plasticbustersmpas.interreg-med.eu/	Maintaining biodiversity and preserving natural ecosystems by consolidating Mediterranean efforts to address marine litter.	Funded project aiming to cover the whole management cycle of marine litter, from monitoring and assessment, to prevention and mitigation.
MEDSEALITTER (2017-2019) (Biodiversity protection) https://medsealitter.interreg-med.eu/	Developing Mediterranean-specific protocols to protect biodiversity from litter impact at basin and local marine protected area (MPA) scales.	For EU marine waters, the Marine Strategy Framework Directive (MSFD) aims to achieve GES by 2020.
ACT4LITTER (2017-2020) (Biodiversity protection) https://act4litter.interreg-med.eu/	Reviewing the most promising proposed measures to effectively tackle the issue of marine litter and select those that could be implemented.	A selection of measures with the goal of the development of MPA-specific action plans for implementation in a future project. Those plans will be complemented by a realistic and operational governance plan at transnational level.

EcoSUSTAIN (2017-2019) (Biodiversity protection) https://ecosustain.interreg-med.eu/	Project developed to measure the state-of-the-art water quality monitoring systems.	Water quality monitoring will be improved by means of state-of-the-art ICT providing live, early warning messages directly from a sensor-equipped buoy or by means of long-term monitoring based on satellite imagery processing.
TUNE UP (2020-2022)(Biodiversity protection) https://tune-up.interreg-med.eu/	Tackling the need for a strategic and collaborative approach to biodiversity protection.	Based on vertical and horizontal subsidiarity, to achieve coordination among institutions at all involved levels, as well as to integrate funding, resources and plans. The goal was to test and capitalize a multi-stakeholder/multi-level governance tool based on River/Wetland.
PHAROS4MPAS (2018-2019) (Biodiversity protection) https://pharos4mpas.interreg-med.eu/	Protocols to monitor climate change response in the Mediterranean.	Documenting these changes is a key task to support Integrate Coastal Zone Management (ICZM) and to inform maritime spatial planning (MSP).

Although the cohesion programs have a broad potential and fulfill several indispensable themes, there are still several challenges that international cooperation needs to address. One of the main difficulties in making international agreements mandatory and ensuring their effective implementation is to achieve consensus among all parties involved. Negotiations between different countries or groups can be complex, and it can be difficult to find common ground on issues such as legal obligations, funding, and enforcement mechanisms. This can result in lengthy negotiation processes and delays in ratification and implementation of agreements.

Another difficulty is ensuring that all parties comply with their obligations. This can be due to a lack of resources or political will, as well as competing priorities or differing interpretations of the agreement.

Enforcement can also be a challenge. Even when agreements have clear enforcement mechanisms, such as fines or sanctions, enforcing compliance can be difficult, particularly in the case of non-state actors who may be difficult to hold accountable. In some cases, countries may also be reluctant to ratify or implement agreements due to concerns about the impact on their economies.

Another difficulty is the integration of non-European Mediterranean countries into regional environmental policies. The majority of Mediterranean countries are not part of the European Union, are not regulated by the European Commission, and often do not have the same environmental legislations, of the European countries. This makes it challenging to implement policies that apply to all countries in the region. Furthermore, even in countries that are part of the EU, implementing effective policies and plans to reduce marine litter has been challenging. Many programs have failed

to achieve their intended outcomes, often due to a lack of funding, insufficient monitoring, and weak enforcement mechanisms. For example, the EU's MSFD, which aims to protect the marine environment and reduce marine litter, has not been fully implemented by all member states.

To address these challenges, it is essential to develop cohesive and integrated policies and implementation plans that involve all countries in the region, including non-European countries. This will require a coordinated approach that prioritizes cooperation, funding, and effective monitoring and enforcement mechanisms. Programs like Interreg Next Med (approved by the European Commission on 12/12/2022) are aiming to address these challenges, including a specific objective of better cooperation governance for the Mediterranean. The implementation of the guidelines offered by this program will be an interesting point of references to cohesion and integration in the region.

5. CONCLUSIONS AND RECOMMENDATIONS

This assessment focuses on Mediterranean Sea pollution, a region which is a global hotspot for the introduction of harmful materials into the environment. It summarises the current scientific knowledge as well as the actions implemented by the cities and regions of Mediterranean EU countries to reduce the generation and dispersion of these pollutants. A major goal is to effectively fight the accelerated accumulation of marine litter and plastic pollution in the Mediterranean, refine existing legislations and implement monitoring for emerging pollutants that need urgent science-based regulation.

Mediterranean coastal zones, or transitional systems, have complex and diverse ecosystems that require effective protection and management to ensure their conservation and sustainable use. This involves analysing individual activities and their impacts, as well as their synergistic effects on the environment. In particular, land-based activities, estuaries, coastal zones and the marine environment are intrinsically interconnected. To effectively manage coastal zones, a methodology that focuses on interdisciplinary resource management is needed, including policy definition, resource allocation, sustainability, ecosystem health and conservation. Some actions to limit marine-based pollution (fisheries, aquacultures, shipping, mining) already exist, however, sometimes face challenges in terms of effective implementation and are thus limited.

It is essential that the fight to reduce marine pollution in the semi-enclosed Mediterranean Sea is endorsed not only by EU countries, but that are implemented by all Mediterranean countries through effective cooperation and collaboration.

According to the policy process outlined by Massoud (2013) the creation of policy could be divided into three stages: (a) the discovery phase, in which the issue is recognised as a problem and controversy surrounds its significance; (b) the political or decision-making phase, in which the problem is framed in policy dimensions and the legislative framework is established; and (c) the management phase, in which policy decisions and management practices are put in place. (Massoud et al., 2003). This analysis provides a framework to develop recommendations and policies to reduce the main marine pollutants.

5.1.1. Actions on emerging pollutants and policy gaps

Emerging pollutants. In the first phase (the characterisation phase) it is recommended that key information on emerging new pollutants such as pharmaceuticals, UV filters, flame retardants, pesticides, etc. is acquired. For example, river input into the Mediterranean Sea as a main outflux of agricultural, urban and industrial runoff, coastal wastewater treatment plants and touristic coastal systems.

Microplastic. After a review of the current legislation on plastics, it has been found that there are no specific regulations for the growing problem of microplastics. The first recommendation would therefore be to establish microplastic pollution as a priority issue in the Mediterranean agenda, capable of leading to binding agreements.

- Primarily, it is recommended to establish bans and reduction targets in the manufacture of fabrics and cosmetics.
- Close monitoring to prevent microplastic entry into the oceans is required in all water-channels including rivers and sewage outflows.

- Increase international cooperation between countries from the northern, eastern and southern Mediterranean Sea to better constrain both floating marine litter and sea-sourced litter, which represent an important knowledge gap.
- Microplastic pollution may also be reduced through effective strict regulation of ship paint and antifouling coatings.

Marine noise pollution. The excessive noise created by human activities in the ocean affect marine fauna, including changes in animal behaviour, communication disruption, hearing damage, stress and even death. Some species of whales and dolphins use sound for communication, navigation and feeding, and exposure to high levels of noise can interfere with these crucial activities. Sources of marine noise pollution include shipping, oil and gas exploration, construction and maintenance of offshore structures, and military activities.

Some examples to reduce noise levels are:

- Establishing particularly sensitive sea areas in the Mediterranean: Establishing areas where noise levels are restricted can help limit the impact of human activities on marine life. Such areas should include migratory routes, breeding grounds and biodiversity hotspots.
- Modifying vessel designs: Changes in vessel design can help reduce noise levels, such as using quieter propellers or hull designs.
- Implementing speed restrictions: Reducing vessel speed can help reduce noise levels and lower the impact on marine life.

5.1.2. Update regulations

For the second phase (the political or decision-making phase) there is a need to update existing regulations to ensure effectiveness. In order to successfully manage coastal areas, it is crucial to analyse individual activities and their impacts on the environment, as well as their combined effects. Land- and sea-based activities affecting estuaries, coastal zones and the marine environment are all interconnected, therefore it is important to implement a holistic and integrated approach to coastal planning, management, protection and restoration.

Rivers, wastewater treatment and harbours. The challenge in managing water pollution in the Mediterranean region lies not in a lack of information and policies, but rather in the implementation of these policies by the signatory countries. This is particularly evident given the varying levels of economic development among the Mediterranean nations.

Examples of alternative, and improvement of, wastewater treatment are:

- For improved wastewater treatment, it is important for developers to consider factors such as the area's climate, topography, and socioeconomic conditions. Further research is needed to optimise current methods.
- Rather than installing costly sewer systems that combine waste and increase volume, decentralising treatments can be a more effective solution.
- Implementing a cyclical approach that includes reusing treated effluent for agriculture can reduce spending on fertilisers and is safe for use.
- Neglecting to recover organic wastewater from urban areas results in the loss of valuable resources that could be used for agricultural purposes.

- Creating expert networks and promoting cross-border knowledge transfer can strengthen long-term regional cooperation and sustainable development between EU and non-EU Mediterranean countries.
- Providing tailored training and capacity-building programs for technicians, engineers, and employees of authorities and non-governmental organisations.
- Ecosystem inventories and assessment on the levels of pollutants at transboundary locations and alarm points are needed and should be shared in all Mediterranean countries.
- In periods of heavy rains, overflows, due to excess capacity of sanitation systems usually occur, dragging a large amount of waste of a very varied nature, which ends up in the rivers and sea. In Spain, specifically designed nets (TechnoGrabber®, https://www.tecnoconverting.com/products/tecno-grabber/) are deployed amongst other in coastal cities (Tarragona, Sabadell) to intercept and retain most of the solids when the spillways are in operation.
- The Jellyfishbot (https://www.jellyfishbot.io/) is a compact and robust robot that collects floating waste and oil autonomously or remotely. It has been deployed in French harbours such as Marseille or Cannes.

Fisheries and Aquaculture. Fisheries and Aquaculture can contribute to environmental pollution through various sources such as discharge of untreated waste, use of chemicals and release of excess nutrients. The main pollutants associated with fisheries and aquacultures include: organic matter that reduce oxygen levels and harm aquatic life, excess nutrients such as nitrogen and phosphorus, which can promote the growth of harmful algal blooms and lead to eutrophication, and antibiotics and heavy metals such as mercury and lead which can lead to antibiotic resistance of bacteria and heavy metal poisoning of other marine biota, respectively.

It is necessary to create a specific regulation for the excess of nutrients in aquaculture. The goal will be to create an index that will serve as a reference for what is considered a good environmental status. Established methods to quantify and limit nutrient discharges can be used to implement legislation. This method should consider the amount of nutrients and chemicals considered safe for the marine environment and human consumption, and then become a reference of "good ecological status".

Remarkably, fisheries and aquaculture are one of the main sources of beach, floating and seafloor litter. EU policies for Mediterranean countries should implement the Voluntary Guidelines on the Marking of Fishing Gear to combat, minimise and eliminate abandoned, lost or otherwise discarded fishing gear, and to identify and recover lost fishing gear. This could be facilitated with initial compensation for marine litter recovery.

5.1.3. Improvement on the management phase

Finally, the third phase (the management phase) can be illustrated by the implementation of initiatives and plans in coastal cities, similar to the stages outlined in the EU single-use plastic directive. The single-use plastics directive has found an innovative way to set restrictions on plastic production and recycling by inserting a circular economy scheme. The directive is innovative in several ways, but it leaves gaps in the way in which countries and cities must comply with the new regulations. The main concerns are waste management, data collection and unification, which, although mentioned, do not specify a mandatory policy to be implemented. The following examples are a sample of what can be done at the local level in coastal areas:

- **Waste characterization and monitoring program**. There is a need for the creation of common regional data where the main waste inputs by sector can be quantified and monitored. This information should be more accessible and frequent. Although the plastic directive mentions the importance of increased monitoring, there is still a lack of knowledge about the characteristics of the waste generated. This knowledge will allow the development of target policies for the reduction and reuse of discarded items. The case of Spain can be used as a reference for the increase of recycling rates in the Mediterranean area.
- The use of technology such as smart waste bins that alert waste management teams when they are full. This can help to optimise waste collection routes and reduce the amount of time and resources required for waste collection.
- Awareness campaigns oriented to beach users are proven to significantly decrease the amount of beach litter associated with the recreational use of the beach. The promotion of such awareness campaigns should be implemented in highly touristic coastal destinations.
- Surveillance of debris and litter on the main Mediterranean commercial routes.
- Promote international cooperation between countries from the northern, eastern, and southern Mediterranean Sea to better constrain both floating marine litter and sea-sourced litter, particularly along the main Mediterranean commercial routes. Scarcity of data on floating marine litter represents an important knowledge gap. The recently approved Interreg NEXTMED program is aiming to address some of these knowledge gaps and cooperation strategies.
- Adapting packaging that is not possible to ban with alternative sustainable solutions.

5.1.4. Marine pollution in Mediterranean touristic hotspots

One-third of the world's international tourism is concentrated in Mediterranean countries. In the summer season, Mediterranean touristic coastlines, including islands, host a far greater population with exponentially increased pressure on coastal environments and marine systems. Tourism is beneficial for local economies, but it also places a great burden on the local infrastructures, especially for waste management systems and coastal environments.

Environmental policies on Mediterranean islands do not always respond to the vulnerability and singularity of their anthropogenic pressures. The main pressures on the islands come from difficulties in achieving economies of scale due the limited domestic market demand. To address this problem the following actions are recommended:

- Improve knowledge about waste streams, build common guidelines and improve synergies among Mediterranean islands' communities.
- Promote sustainable tourism and fuel local loops of the circular economy.
- Limit the generation of coastal litter by improving overall awareness of the problem amongst tourists and locals.
- Limit the impact of tourism by implementing a visiting fee for litter-free coastal attractions, ensure that visitors take home self-generated waste and encourage volunteering in beach clean-ups.

At a regional scale, the island of Sardinia (Italy) provides a good example of actions to reduce the pressure of tourism by implementing a restricted access to several iconic beaches. The objective is to protect them from mass tourism, a source of litter and habitat destruction, by charging a fee at the

entrance and limiting the number of visitors. For example, in some beaches, once the fee is paid, the visitors receive a biodegradable bracelet, its colour depending on the day of the week, and only visitors with a bracelet can access the beach. Moreover, the visitors have to comply with rules including: no littering, no smoking, prohibition to remove sand, stones and shells, prohibition to use soaps and shampoos, obligation to use a mat between the beach towel and the sand. The access to toilets and showers is included in the fee. For instance and depending on the beach, the number of visitors allowed per day ranges from 60 (Cala Coticcio and Cala Brigantina) up to 1,600 (Cala Sisine) with sometimes the necessity to book online a two hours´ time slot; while the fees range from one euro to three euros. These measures have been implemented to protect the beaches and ensure sustainable tourism on the island and are good examples of measures that can be implemented at the regional level in over-visited places.

In coastal regions, local waste management facilities become overwhelmed during summer, increasing their capacity by up to 40%.

Possible actions to implement:

- During peak touristic season, a comprehensive waste management plan must be developed, and steps taken to ensure that all stakeholders are aware of the plan.
- Monitor and evaluate the impact of tourism on the environment through indicators such as water and energy consumption or waste generation.
- Engage local communities in waste management programs to ensure that they are effective and sustainable.
- Awareness campaigns oriented to beach users are proven to significantly decrease the amount of beach litter associated with the recreational use of the beach.
- Implement regulations for smoke-free beaches to reduce cigarette related littering.

Among these recommendations a specific target to be reinforced will be to amplify the spectrum of products banned by the European single-use plastics directive and to launch a specific programme dedicated to increase biodegradable and reusable packaging. There are still a variety of unnecessary single-use plastics that should be reduced. The EU single-use plastics directive was made according to the most commonly found plastic litter. But if in addition to conducting an investigation of what becomes waste, an analysis of the unnecessary plastic products in circulation were to be carried out, the results would give a higher spectrum of what can be reduced.

Similarly, a specific science-based program for the development and implementation of biodegradable and/or reusable packaging to replace single use plastic products is considered necessary for the entire region.

On the other hand, among the positive actions found in this study we highlight the microplastic regulations made by France. Regarding cities, the zero waste attempts made by Nice and Venice are exemplary. Similarly, innovations in waste management carried out by Spanish cities are promising and could be replicated at the regional level.

A priority that is found necessary in the region is the vigilance of the measures suggested by the results of the Interreg cohesion programs and/or established by the directives and international cooperation agreements. The efforts, funds and innovations already made, will lack coherence and effectiveness if official surveillance and effective ways of implementation at the local and regional level are not implemented. In this sense, there are few or inexistent mechanisms to ensure the operation and enforcement of these covenants.

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This study provides a comprehensive analysis of the most common types of marine pollutants in the Mediterranean Sea and focuses on the accelerating accumulation of marine litter and plastics in the Mediterranean Sea. It presents the actions taken by EU Mediterranean regions and cities to respond to diverse pollutants, waste contamination, marine litter and plastic pollution in the marine environment. Based on this assessment, policy recommendations are put forward.

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