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Agenda Item 5: Specific Matters for Consideration and Action by the Meeting, including draft Decisions

Study on trends and outlook on marine pollution, maritime traffic and offshore activities in the Mediterranean

UNEP/MAP
Athens, 2021

Note by the Secretariat

Background

At the Thirteenth Meeting of the Focal Points of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (Floriana, Malta, 11-13 June 2019), the Secretariat presented the MED QSR and the Status of Environment and Development (SoED), as well as the progress made in addressing identified gaps while proposing further measures to standardise monitoring and reporting formats for pollution from ships.

With a view to contributing to the preparation of the 2023 MED QSR and the MED2050, and in light of the gaps identified and related assessment exercises (for example, the SoED identified a lack of comprehensive knowledge about offshore activities), the Secretariat was requested to update existing information to prepare a Study on marine pollution from ships (accidental and operational pollution, marine litter, air pollution, etc...) as well as maritime traffic trends in the Mediterranean.

In order to achieve this objective, REMPEC, in consultation with the Contracting Parties and in collaboration with the Plan Bleu Regional Activity Centre (PB/RAC), the Mediterranean Pollution Assessment and Control Programme (MED POL), and the Specially Protected Areas Regional Activity Centre (SPA/RAC), prepared a study on trends and outlook on marine pollution from ships and activities and of maritime traffic and offshore activities in the Mediterranean, in the framework of the Programme of Work 2020-2021 of the Mediterranean Action Plan of the United Nations Environment Programme (UNEP/MAP). The Study was prepared to support Contracting Parties to the Barcelona Convention in taking well informed decisions, in the context of the preparation of the Draft Decision: Mediterranean Strategy for the Prevention, Preparedness, and Response to Marine Pollution from Ships (2022-2031) (UNEP/MED WG.515/19).

The information provided in this Study reproduced in the Annex to the present document, has been collected through the review of a variety of literary sources: scientific and technical reports, policy briefs and guidelines, books and research articles, website content, etc. Data on a world-wide and a European scale was collected to draft the overview section for each of the main topics. For the description of pollution status and impact, data, examples and case studies exclusively from the Mediterranean were selected. As far as measures are concerned, (addressing pollution prevention, mitigation and remediation), an overview taking into consideration international, European and Mediterranean ones was compiled. The main focus was given to policy and governance measures but operative measures (tools, actions, pilot activities) were also compiled. Among all the identified literary sources, priority was given to the most recent ones (preferably published in the last 5 years), in order to provide as much as possible an updated picture of marine pollution from maritime traffic and offshore activities. As second criteria for literary source selection, priority was given to those presenting data with a regional or sub-regional geographic scope (e.g. Western Mediterranean, Adriatic Sea, etc.). Where this was not available, a compilation of site-specific data was undertaken, aiming to provide a good geographical coverage of the entire Mediterranean.

For the description of maritime traffic and oil and gas activities, and for related incidents and spills, the Lloyd's List Intelligence, the Clarkson Offshore database and the MEDGIS-MAR database were consulted. Moreover, this Study was completed with data and figures from a technical report on Maritime Traffic Trends in the Mediterranean for the period 2020-2050, prepared by REMPEC.

The conclusion chapter (chapter 4) presents a summary of key findings and elaborates on the future outlook on marine pollution. Moreover, knowledge gaps and recommendations related to each topic are also presented. A main cross-topic gap is represented by the lack of data at regional scale for the different typologies of pollution. As the IMAP system is still under implementation, data available (from research studies and projects) has generally limited geographic scope within the Mediterranean and often suffers from a lack of harmonization in methods, approaches, techniques, impairing comparability and limiting the possibility of delivering effective prevention and remediation measures.

ANNEX

Study on trends and outlook of marine pollution from ships and activities and of maritime traffic and offshore activities in the Mediterranean

Contents

Acronyms and definitions

ACCOBAMS	Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
Adriatic Sea	It is the northernmost arm of the Mediterranean Sea, extending from the Strait of Otranto (where it connects to the Ionian Sea) to the northwest and the Po Valley.
BC	Black Carbon
Bcf	Billion Cubic Feet
Boped	barrels of oil equivalent per day
BRI	Belt and Road Initiative
BWM	Ballast Water Management
CCH	Cetaceans Critical Habitats
CFCs	Chlorofluorocarbons
CI	Common Indicator
cIMMA	Candidate Important Marine Mammals Area
CLC	Civil Liability Convention
CO	Carbon monoxide
CO_2	Carbon dioxide
COVID-19	Corona Virus Disease 2019
DW	Dry Weight
DWT	Dry Weight Tonnage
Eastern Med.	Geographical sea area faced by following countries Cyprus, Greece, Israel, Lebanon, Syrian Arab Republic and Turkey.
EBSA	Ecologically and Biologically Significant marine Area
ECA	Emission Control Area
EcAp	Ecosystem Approach
EMSA	European Maritime Safety Agency
EO	Ecological Objective
EU	Europe/European
FAO	Food and Agriculture Organization
FfL	Fishing for Litter
GES	Good Environmental Status
GHG	Green-House Gas
HFO	Heavy Fuel Oil
HNS	Hazardous and Noxious Substances
IMAP	Integrated Monitoring Program
IMDG	Code International Maritime Dangerous Goods Code
IMMA	Important Marine Mammals Area
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
MAS	Maritime Assistance Services
MAU	Mediterranean Assistance Unit
Mbbl	one thousand barrels
MDO	Marine Diesel Oil
MED POL	Mediterranean Pollution Assessment and Control Programme
MEPC	Marine Environment Protection Committee
MFO	Marine Fuel Oil
ML	Marine Litter
MMbbl	one million barrels
MP	Micro-Plastics

MSFD	Marine Strategy Framework Directive
NECA	Nitrogen Emission Control Area
NIS	Non-Indigenous Species
NO_x	Nitrogen Oxides
NPS	New Policies Scenario
O&G	Oil and Gas
ODS	Ozone Depleting Substances
OIN	Offshore Intelligent Network
OPCR	Oil Pollution Preparedness, Response and Co-operation
OPOL	Offshore Pollution Liability
PB/RAC	Plan Bleu Regional Activity Centre
POM	Particulate Organic Matter
PSSA	Particularly Sensitive Sea Area
QSR	Quality Status Report
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
Ro-Ro	Roll-on/Roll-off
SCA	Suez Canal Authority
SDS	Sustainable Development Scenario
SECA	Sulphur Emission Control Area
SO_2	Sulphur Dioxide
SoED	Status of Environment and Development
SPA/RAC	Specially Protected Areas Regional Activity Centre
SPAMI	Special Protected Area of Mediterranean Importance
SWOT	Strength Weakness Opportunities Threats
TEN-T	Trans-European Networks
TEU	Twenty-Foot Equivalent
TSS	Traffic Separation Scheme
UNEP/MAP	United Nations Environmental Program/Mediterranean Action Plan
VOCs	Volatile Organic Compounds
Western Med.	Geographical sea area faced by following countries Algeria, France, Italy, Libya, Malta, Morocco, Spain, Tunisia.

1 SUMMARY

Maritime traffic and offshore oil and gas (O&G) exploration and production are key maritime activities in the Mediterranean and represent important drivers of marine pollution in the basin. They generate a variety of different pressures on the marine environment: loss or discharge of solid wastes contributing to marine litter pollution, emissions of gaseous pollutants and particles in the atmosphere, emission of continuous and impulsive underwater noise and vibrations, release of oil and other contaminants in the marine waters, introduction of invasive species though ballast water and hull fouling. In this report we have compiled knowledge about maritime traffic and offshore O&G activities and their impacts on the marine environment, focusing on four main aspects: pollution from oil and chemicals, marine litter, air pollution, non-indigenous species (NIS) and underwater noise.

Notwithstanding its limited size, the Mediterranean is significantly affected by both commercial and passenger traffic. Most of the Mediterranean commercial traffic is internal (about 58%). However, the basin also plays an important role for international merchant shipping, travelling along the Suez-Gibraltar route and entering the basin from the Bosporus Strait, as well as for the Mediterranean seaborne traffic. In the period 2010-2019, seaborne trade to and from countries in the Mediterranean has increased by 284 million tonnes. Dry bulks have grown the most in tonnes, while containerized cargos have grown the most in relative terms. Liquid bulks have only grown marginally (3%), while non-containerized general cargo has declined. In the same period, port calls increased by about 75%, with a particularly large increase in those due to passenger vessels.

Mediterranean merchant transport is expected to grow in the future, driven by two major factors: the doubling of the Suez Canal and the 21st Century Maritime Silk Road. Both commercial and passenger traffic are expected to increase in the Mediterranean. However, future projections of maritime traffic evolution are highly uncertain, being affected by a wide range of geo-political factors, trading policies and socio-economic crisis, as recently demonstrated by the COVID-19 impact on global shipping markets, with ripple effects on any maritime transport, from container ships to oil tankers.

Compared to other regions, the Mediterranean Sea is a small producer of offshore oil and gas. While offshore gas explorations have expanded in recent years, there have been no major discoveries of offshore oil fields after 2010. As an important number of old offshore platforms are approaching the end of operational lifetime, their decommissioning is a challenge to be addressed in the near future. Offshore oil production is projected to slightly decrease in the Mediterranean, while offshore gas extraction is expected to significantly increase, due to the expansion of the sector in the Levantine basin, involving also deep and ultradeep waters.

Regarding oil and chemical pollution, a sharp decreasing trend in major incidents has been documented in the last decades worldwide and in the Mediterranean. It can be concluded that the impact of the international regulatory framework adopted through the International Maritime Organization (IMO), as well as of technical improvements and of cooperation activities undertaken at regional level is very positive, especially as far as prevention of accidental pollution is concerned. Nowadays operational pollution from ships is a major source of oil pollution in the Mediterranean region. Up to 1,500-2,000 events of operational oil spill are estimated to occur yearly in the basin. The distribution of oil spills is well correlated with major shipping routes, crossing the Mediterranean from east to west and linking the major ports.

Illicit discharges of oil, oil mixture and other Hazardous and Noxious Substances (HNS) from ships is a problem of big concern for the Mediterranean. Quantitative estimations of spilled volumes due to illicit discharges in the Mediterranean is highly uncertain, 50,000-100,000 tons has been provided as possible estimation of volume of oil illicitly discharged every year. While enhanced effectiveness and rapidity of detection can be assumed for the future, also thanks to on-going research and innovation (e.g. on the use of satellites), it is not possible to say whether the sanction systems would evolve and will be able to favour the implementation of these pollution prevention measures.

No specific estimation of litter originating from ships in the Mediterranean Sea is yet available. Existing data show correlation between marine litter distribution and main maritime routes. Particularly, fishing related marine litter has been showed to be predominant in areas characterized by intense fishing activities,

Ship emissions contribute significantly to air pollution in the Mediterranean Basin. Despite in-port ship emissions represent only a small fraction of the global emissions associated with shipping, they can have important environmental effect on coastal regions of the Mediterranean Sea, which often have harbours located near urban and industrial centres. From the 1st of January 2020, the IMO Global Sulphur Cap has come to its full extent. MARPOL VI standards are expected to reduce SO_x emissions by approximately 75% from typical operations using residual fuels. In addition, the possible designation of the Mediterranean Sea as an Emission Control Area for sulphur oxides has been estimated to be able to lower the emissions in the Mediterranean by additional 78.7% for SO_x and 23.7% for PM2.5, when comparing to the implementation of the IMO Sulphur Cap.

Corridors are recognized as the main vector of introduction of Non-Indigenous Species (NIS) in the Mediterranean, followed by shipping and aquaculture. Ships' ballast water is of particular concern as a vector of introduction of invasive alien species in the Mediterranean Sea because of the large quantities of ballast water coming from different marine environments around the world being discharged at Mediterranean ports. Despite the moderate number of propagules transported, in comparison with the ballast water vector, biofouling on ships' hulls is a relevant vector for NIS introduction.

Background noise levels in the Mediterranean are higher than in any other ocean basin. Correlation has been found in many Mediterranean ports and coastal areas between underwater continuous noise and maritime traffic, including passenger traffic (ferries) and leisure boating.

Some elements regarding the outlook have been also identified in this Study. The Mediterranean merchant transport is expected to grow, driven by the doubling of the Suez Canal and the 21st Century Maritime Silk Road, part of the Belt and Road Initiative of the Chinese government. Both commercial and passenger traffic are expected to increase in the Mediterranean, including in the first case the strengthening of the already occurring shift towards mega container ships, and in the second the continuous growth of the cruising sector. Offshore oil production is projected to slightly decrease, while offshore gas extraction is expected to significantly increase due to the expansion of the sector in the Levantine basin, involving also deep and ultradeep waters. Regarding oil and chemical pollution, a sharp decreasing trend in major shipping incidents has been documented: it is reasonable to expect that this situation will stabilize, if not improve further, in the future and an even lower occurrence of large oil spills due to incidents can be expected. Operational pollution and illicit discharges are still a problem for the pollution of the Mediterranean waters and it is not possible to say whether the sanction systems in place would evolve and if it would yield a better prevention of pollution. Regarding marine litter pollution, based on the existence of measures recently put in place, one can expect the quantity of waste discharged from shipping and fishing activities would be reduced in the next future and this pollution pressure on the Mediterranean marine environment will decrease. In the case of air pollution, thanks to the measures in place and possible new ones, one can expect the emissions from the shipping sector in the Mediterranean will be reduced in the medium/long term. Given corridors represent the main vector for NIS introduction in the Mediterranean, followed by vessels, it is not possible to estimate whether and when the implementation of measures preventing NIS introduction by ships would result in tangible results at regional scale. Finally, the implementation of the full portfolio of policy and innovative technological measures could decrease underwater noise impacts, while the expected increase in the Mediterranean maritime traffic is expected to increase the pressure.

From the results of the Study, a list of gaps (both knowledge gaps and actions gaps) has been derived and recommendations have been identified in order to fill them. They are reported in the conclusive chapter.

2 BACKGROUND

At the 15th Meeting of the Contracting Parties to Barcelona Convention - COP15, held in Almeria, Spain in January 2008, Parties agreed to progressively apply the ecosystem approach (EcAp) to the management of human activities that may affect the Mediterranean marine and coastal environment for the promotion of sustainable development. With the adoption of the EcAp strategy, and its roadmap for implementation, Contracting Parties have committed to implement EcAp in the Mediterranean with the ultimate objective of achieving the Good Environmental Status (GES) of the Mediterranean Sea and its coastal zone by 2020. The GES has been defined through eleven Ecological Objectives (EO) and corresponding twenty-eight operational objectives. Operational objectives' achievement is being monitored with the help of 61 indicators (27 common and 34 candidate indicators) for the Mediterranean, providing the framework for the development on an Integrated Monitoring and Assessment Programme (IMAP) as a way to evaluate the status and achievement of GES through regular assessments of the Mediterranean Sea and coastal environment.

IMAP describes the strategy, themes, and products that the Barcelona Convention Contracting Parties are aiming to deliver, through collaborative efforts inside the UNEP/MAP Barcelona Convention, over the second cycle of the implementation of the Ecosystem Approach Process (EcAp process), i.e. over 2016-2021, in order to assess the status of the Mediterranean Sea and coast, as a basis for further and/or strengthened measures (UNEP (DEPI)/MED IG.22/28).

The Quality Status Report (QSR) in 2017 and the State of Environment and Development Report in 2019 are built on the structure, objectives and data collected under IMAP. The 2017 QSR is the first assessment product based on the MAP Ecological Objectives and IMAP indicators; it builds upon existing data and is complemented with inputs from numerous diverse sources where appropriate.

Regarding common indicator 19 "Occurrence, origin (where possible), extent of acute pollution events (e.g. slicks from oil, oil products and hazardous substances, and their impact on biota affected by this pollution", related to the Ecological Objective 9 of IMAP, the 2017 MED QSR conclude that: "despite the progress achieved in mitigating oil spill incidents from ships, it is clear that continuous monitoring of illicit discharges occurrences as well as cumulative effects and impacts, and continuous monitoring of accidental post-spill consequences on biota and ecosystems are needed".

At the Thirteenth Meeting of the Focal Points of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (Floriana, Malta, 11-13 June 2019), the Secretariat presented the MED QSR and the Status of Environment and Development (SoED), as well as the progress made to address identified gaps while proposing further measures to standardise monitoring and reporting formats for the pollution from ships. Particular reference was made to the on the common indicator 19.

With a view to contributing to the preparation of the 2023 MED QSR, and in light of the gaps identified and related assessment exercises (for example, the SoED identified a lack of comprehensive knowledge about offshore activities), the Secretariat proposes to update existing information to prepare a Study on marine pollution from ships (accident and operational pollution, marine litter, air pollution, etc...) and maritime traffic trends in the Mediterranean.

In order to achieve this objective, the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), in collaboration with the Plan Bleu Regional Activity Centre (PB/RAC), the Mediterranean Pollution Assessment and Control Programme (MED POL), and the Specially Protected Areas Regional Activity Centre (SPA/RAC), issued an open call for the provision of consultancy services to prepare a study on trends and outlook of marine pollution from ships and activities and of maritime traffic and offshore activities in the Mediterranean.

The main objective of the consultancy services is to elaborate a "Study on trends and outlook of marine pollution from ships and activities and of maritime traffic and offshore activities in the Mediterranean" in the framework of the Programme of Work 2020-2021 of the Mediterranean Action Plan of the United Nations Environment Programme (UNEP/MAP).

2.1 Methodology

The information provided in this Study have been collected thought the review of a variety of literature sources: scientific and technical reports, policy briefs and guidelines, books and research articles, web sites contents, etc. Data at world-wide and European scale have been collected to draft the overview section for each of the main topics. For the description of pollution status and impacts, data, examples and case studies exclusively from the Mediterranean have been selected. As far as measures are concerned, (addressing pollution prevention, mitigation, remediation), an overview considering international, European and Mediterranean ones has been compiled. The main focus has been given to policy and governance measures but operative measures (tools, actions, pilot activities) have also been compiled. Among all the identified literature sources, priority has been given to the most recent ones (preferably published in the last 5 years), in order to provide as much as possible an updated picture of marine pollution from maritime traffic and offshore activities. As second criteria for literature source selection, priority has been given to those presenting data with a regional or sub-regional geographic scope (e.g. Western Mediterranean, Adriatic Sea, etc.). When this was not available, a compilation of site-specific data has been provided, trying to provide a good geographical coverage of the entire Mediterranean.

For the description of maritime traffic and oil and gas activities, and for incidents and spills related to them, the Lloyd's List Intelligence, the Clarkson Offshore database and the MEDGIS-MAR database have been consulted. Moreover, this Study has been completed with data and figures from a technical report on Maritime Traffic Trends in the Mediterranean for the period 2020-2050, prepared through REMPEC (2020) [1].

The IMAP system include already Ecological Objectives and Common Indicators (or Candidate Indicators) useful for the scope of this Study, namely:

- EO2 Non-Indigenous species - Common Indicator 6: Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas;
- EO3 Pollution - Common Indicator 19: Occurrence, origin – where possible, extent of acute pollution events (e.g. slicks from oil, oil products and hazardous substances), and their impact on biota affected by this pollution;
- EO10 Marine litter - Common Indicator 22: Trends in the amount of litter washed ashore and/or deposited on coastlines; Common Indicator 23: Trends in the amount of litter in the water column including microplastics and on the seafloor; Candidate indicator 24: Trends in the amount of litter ingested by or entangling marine organisms, focusing on selected mammals, marine birds, and marine turtles;
- EO11: Energy including underwater noise: Candidate indicator 26: Proportion of days and geographical distribution where loud, low, and mid-frequency impulsive sounds exceed levels that are likely to entail significant impact on marine animals; Candidate indicator 27: Levels of continuous low frequency sounds with the use of models as appropriate.

Implementation of IMAP is still in progress and the data related to these indicators are not yet available from the IMAP system, therefore this Study has been based on external sources of information, as described above.

The conclusive chapter (chapter 4) presents a summary of key findings and elaborates on future outlook of marine pollution. Knowledge gaps and recommendations related to each topic are presented. A main cross-topic gap is represented by the lack of data at regional scale for the different typologies of pollution. Being the IMAP system still under implementation, data available (from research studies and projects) have generally limited geographic scope within the Mediterranean and often suffer from a lack of harmonization in methods, approaches, techniques, impairing comparability and limiting the possibility to derive effective prevention and remediation measures.

2.2 References

[1] REMPEC (2020). Maritime traffic trends in the Mediterranean for the period 2020-2050.

3 MARINE POLLUTION FROM SHIPS, MARITIME TRAFFIC AND OFFSHORE OIL&GAS ACTIVITIES

3.1 Maritime traffic and offshore O&G activities, trends and outlook

3.1.1 Maritime traffic

3.1.1.1 Overview

Maritime transport remains the backbone of worldwide trade, as more than the 80% of merchandise trade by volume is carried by sea. In 2018, global merchant maritime traffic kept increasing globally (2.7% by volume), although below the historical benchmark of 3.0% (1970-2017) and the 2017 rate (4.1%) (UNCTAD, 2019a) [1].

The Mediterranean Sea covers less than 1% of the world oceans. However, this sea basin is strategically located at the interface of the three continents of Asia, Europe and Africa and at the crossroads of three maritime corridors. The Strait of Gibraltar connects the Mediterranean to the Atlantic Ocean and to the Americas, the Bosporus Strait to the Black Sea and therefore to Eastern Europe and Central Asia, and the Suez Canal to the Red Sea and from there to the South and Southeast Asia. Given its strategic position, the Mediterranean offers routes for the exchange of goods between Europe and Asia, as well as for the transport of oil and gas from the Persian Gulf, the Black Sea and North Africa countries to European and extra European countries.

The Mediterranean is one of the major areas for load and discharge of crude oil, accounting for the 18% of the global traffic (Plan Bleu, 2014) [2]. According to REMPEC (2020) [9], in 2019, Oil and Chemical Tankers calling to ports or passing through the Mediterranean represented 27% of the word fleet. The Suez Canal, together with the 320 km SUMED pipeline (running from the Gulf of Suez to Alexandria and providing a land-based alternative route to the Suez Canal to transport oil from the Persian Gulf to the Mediterranean), in 2015 transported 5.4 million barrels per day (b/d) of crude oil and petroleum products, accounting for the 9% of the world seaborne oil trade (SRM and AlexBank, 2018) [3]. Still in 2015, crude oil and petroleum products transported across the Bosporus and Dardanelles straits accounted to 2.4 million barrels per day. Together, the Suez Canal/SUMED pipeline and the Turkish Straits accounted for 13.24% of the world's seaborne trade in 2015 (U.S. EIA 2017) [4].

Given its geographic characteristics, shipping is also highly important for passengers transport between Mediterranean countries and within the same country (also to connect the numerous Mediterranean islands with the mainland) (Plan Bleu, 2014 [2]; Randone et al., 2019 [5]). Moreover, the Mediterranean is the second largest market globally (after Caribbean) for cruising, accounting for 17.3% of worldwide cruises in 2019 (MedCruise, 2018) [6].

According to the Lloyd's list intelligence database[1], the Mediterranean includes 706 ports: 497 in Southern Europe, 96 in North Africa and 113 in the Eastern Mediterranean[2]. A great number of ports are located in Italy (191) and in Greece (153). Some of these ports rank among the 100 most important ones according to various criteria (Table 1).

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[1] Consulted in June 2020.

[2] Few North Africa ports included in Lloyd's database are located along the Atlantic costs of Morocco and Western Sahara, while Southern Europe includes some internal water ports. Callings to these ports cannot be unbundled by provided statistics.

Table 1. Port ranking according to different parameters in the Mediterranean Sea. Source: Plan Bleu, 2014 [2]

Top Ports Calls*	Top Ports DWT*	Top Container Ports**	Top Cargo Volume Ports**
Barcelona, Spain	Gibraltar, Gibraltar	Valencia, Spain	Marseilles, France
Leghorn, Italy	Fos, France	Algeciras, Spain	Algeciras, Spain
Genoa, Italy	Algeciras, Spain	East Port Said, Egypt	Valencia, Spain
Gibraltar, Gibraltar	Gioia Tauro, Italy	Gioia Tauro, Italy	Genoa, Italy
Valencia, Spain	Augusta, Italy	Tanger, Morocco,	Trieste, Italy
Algeciras, Spain	Valencia, Spain	Barcelona, Spain	Alexandria and El-Dekheila, Egypt
Alexandria, Egypt	Piraeus, Greece	Genoa, Italy	Barcelona, Spain
Piraeus, Greece	Genoa, Italy	La Spezia, Italy	
Algiers, Algeria	Barcelona, Spain	Haifa, Israel	
Venice, Italy	Naples, Italy.	Ahsdod, Israel	

*Lloyd's MIU, 2008
**World Shipping Council, 2011

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Figure 1. World main maritime shipping routes, also highlighting the role of the Mediterranean Sea in global traffics. Source: Jean-Paul Rodrigue, 2017 [7].

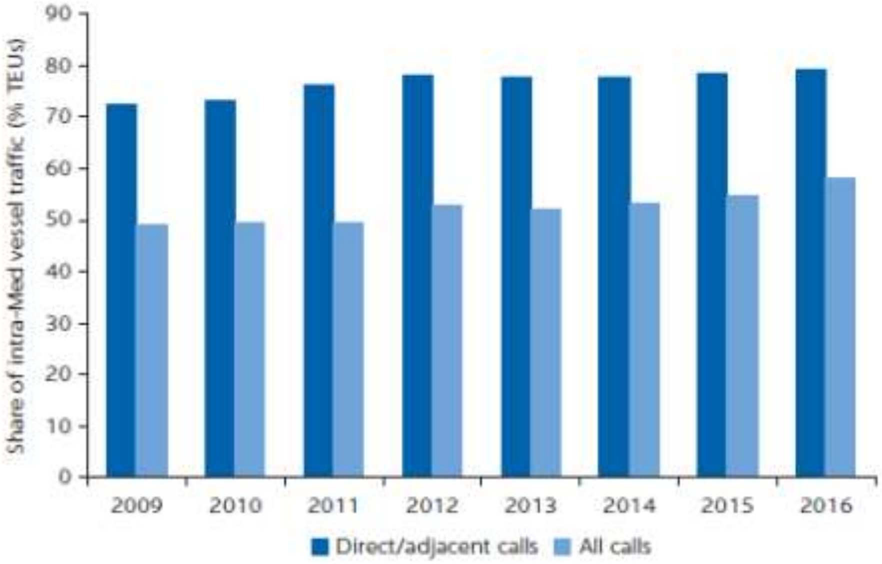
It is not surprising that the Mediterranean, notwithstanding its limited size, attracts a significant share of the overall world maritime traffic. REMPEC (2008) [8] estimated that in 2006 the Mediterranean accounted for 15% of all port calls made globally by merchant vessels over 100 GT. According to REMPEC (2020) [9], Mediterranean port calls in 2019 due to passenger and merchant vessels (see

Table *2* for details on considered vessel categories) were about 453.000, made by 14,403 ships. These, together with ships transiting through the basin without making a port call (5,251 in 2019), represented a little more than 24% of the global fleet of ships.

Maritime transport is a very important economic sector of the Mediterranean Blue Economy. It was estimated that the sector (including maritime transport services, port services and shipbuilding) provides jobs to about 550,000 people and generates a Gross Added Value of 27 billion euros (Plan Bleu, 2014) [2].

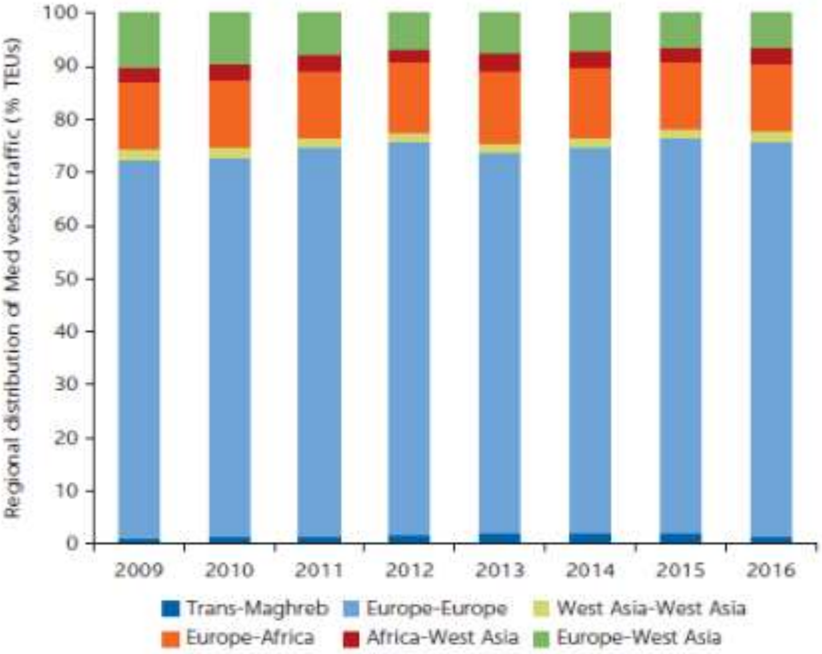
Most of the Mediterranean commercial maritime traffic is internal (Plan Bleu, 2010) [9]; the proportion of internal traffic increased from 49% in 2009 to 58% in 2016, due to the growth in transhipment (transfer of containers from one carrier to another or from a transport mode to another) and coastal or short-sea traffic among Mediterranean ports (Figure 2). The great majority of intra-Mediterranean traffic occurs among European countries (Figure 3; Arvis et al., 2019 [11]).

The Mediterranean is also important for international shipping, travelling along the Suez-Gibraltar route and for the Mediterranean seaborne traffic, i.e. ship movement between a port within the Mediterranean and a port outside the basin. Extra-Mediterranean traffic of Mediterranean ports is mainly with European countries, accounting to the 40-50% of the total if direct/adjacent calls are considered (Figure 4). The short sea shipping of goods between the Mediterranean ports and main EU ports reached 601 million tons in 2018, accounting to the 31% of the total EU short-sea shipping (EUROSTAT, 2020) [15].



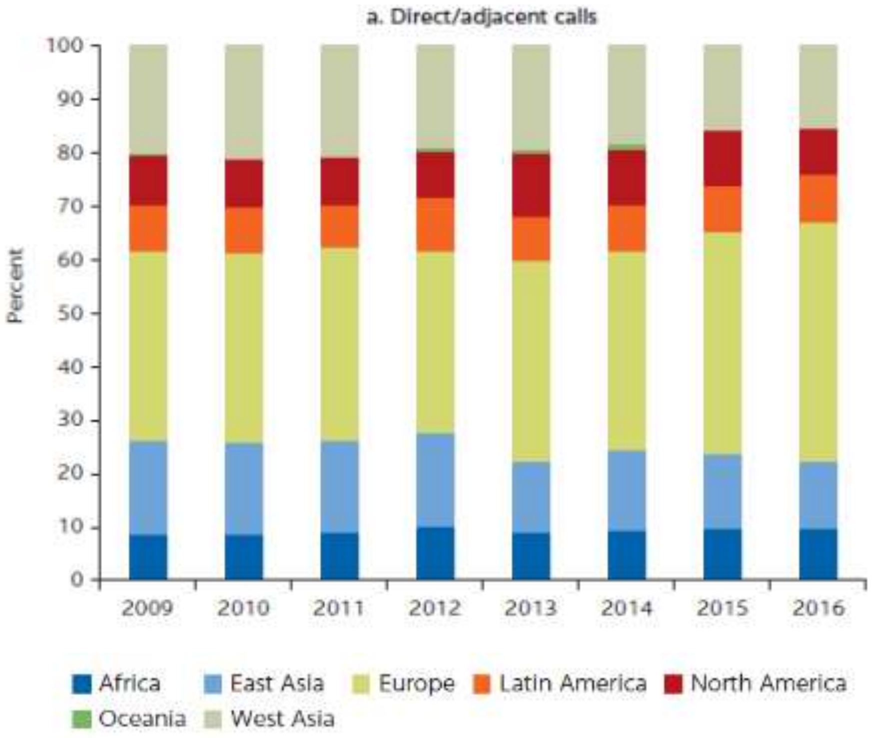
Source: World Bank calculations based on data from Lloyd's List Intelligence (see annex 2A).
Note: Data for 2016 cover only May and June.

Figure 2 Share of intra-Mediterranean traffic (% of total Mediterranean TEU). Source: Arvis et al. (2019) [11].



Source: World Bank calculations based on data from Lloyd's List Intelligence (see annex 2A).
Note: Data for 2016 cover only May and June; Med. = Mediterranean.

Figure 3. Intra-Mediterranean traffic distribution by sub-regions (percentage of total EU traffic; all port calls are considered) Source: Arvis et al. (2019) [11].



Source: World Bank calculations based on data from Lloyd's List Intelligence (see annex 2A).
Note: Data for 2016 cover only May and June.

Figure 4. Extra Mediterranean traffic of Mediterranean ports by region (percentage of total twenty-foot equivalent (TEU) traffic). Source: Arvis et al. (2019) [11].

Vessel activity and fleet data

REMPEC (2020) provides an analysis of the Mediterranean fleet and port calls in 2019, as well as their historical trend in the period 2010-2019 (see section 3.1.1.2). Such analysis is based on data extracted from the Lloyd's list intelligence database. This database is very rich and includes data for a high number of different vessel typologies. For the scope of REMPEC (2020) [14] and of this study, these detailed typologies have been grouped in more general categories coherently with the internationally recognised StatCode 5 coding system (IHS Markit, 2017) [16] (

Table *2*).

The activity of vessels passing through the Mediterranean Sea without calling a port in 2019 counted 5,251 vessels with a total dwt of 510 million (Table 3). These were mainly larger vessels (bulk carriers, container ships and oil and chemical tankers). The average dwt was 97,000; the largest were the container carriers, which also were the most frequent. Still in 2019, there were 14,403 ships in the Mediterranean Sea that made 453,000 calls. A little more than 24% of the global fleet of ships called ports or passed through the Mediterranean in 2019 (Table 4). The share was higher for the large cargo carriers, with container ships at the top.

Passenger vessels, mostly ferries, accounted for 42.8% of the total port calls. Container carriers had 18% of the total port call, while other dry and ro-ro vessels 16.9%, tankers 16.8% and bulk carriers 5.6%. In dwt-terms, bulk carriers and tankers dominate with 71% of the capacity (Table 4). 4,399 (30.5%) of the individual ships are smaller than 10,000 dwt. Figure 5 shows the age profile of the fleet of ships that called ports in the Mediterranean in 2019. The majority of the ships are built in the last 15 years, but there is a long tail of old ships. Overall, the fleet sailing in the Mediterranean is younger than the global fleet. Smaller ships (below 10,000 dwt) are in general older than larger ones.

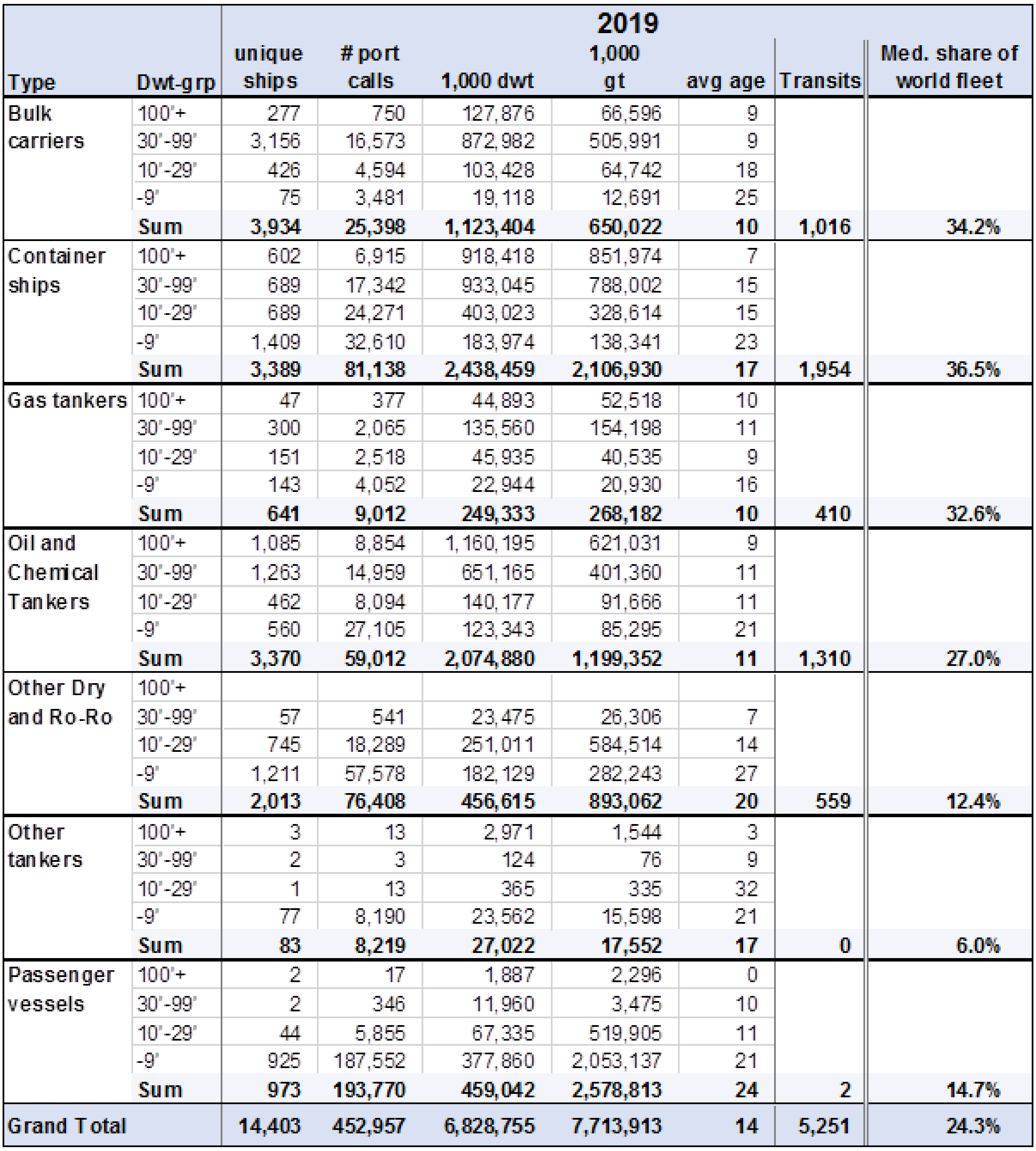
Table 2. Classification of vessel typologies considered by the Lloyd's list intelligence database into wider categories.

Category considered for this study	**Lloyd's vessel typologies**
Bulk carriers	Bulk carrier, Bulk carrier with container capacity, Bulk ore carrier
	Combined bulk and oil carrier, Combined ore and oil carrier
	Bulk aggregates carrier, Bulk cement carrier, Wood chip carrier
Container ships	Fully cellular containership, Fully cellular refrigerated
	General cargo with container capacity
Other dry and Ro-ro cargos	Roll on Roll off, Roll on Roll off with container capacity, Vehicle carrier, Landing craft
	General cargo, Livestock, Reefer, Semi-sub HL vessel
	Tanker vehicle and container carrier, Tanker with Ro/Ro for road tanker
Passenger vessels	Ferry, Hydrofoil, Passenger (cruise), Passenger Ro/Ro, Passenger vessel (unspecified)
Gas tankers	LNG carrier, LPG carrier, Combined LNG and LPG gas carrier, Compressed natural gas carrier
Oil and Chemical tankers	Acid tanker, Asphalt tanker, Chemical tanker, Combined chemical and oil tanker, Crude oil tanker, Edible oil tanker, Fish oil tanker, Product tanker, Wine tanker
Other tankers	Fruit juice tanker, Molasses tanker, Semi-sub HL tank, Tanker (unspecified), Tank barge, Water ship

Table 3. Transits through the Mediterranean in 2019; Source: (REMPEC, 2020) [9]

Vessel type	No. transits	1,000 dwt
Bulk carriers	1,016	79,348
Container ships	1,954	273,739
Gas tankers	410	30,856
Oil and Chemical Tankers	1,310	115,542
Other Dry and Ro-Ro cargos	559	10,597
Passenger vessels	2	3
Grand Total	**5,251**	**510,085**

Table 4. Number of ships and port calls in 2019; Source: (REMPEC, 2020) [9]



		2019						
Type	Dwt-grp	unique ships	# port calls	1,000 dwt	1,000 gt	avg age	Transits	Med. share of world fleet
Bulk carriers	100'+	277	750	127,876	66,596	9		
	30'-99'	3,156	16,573	872,982	505,991	9		
	10'-29'	426	4,594	103,428	64,742	18		
	-9'	75	3,481	19,118	12,691	25		
	Sum	**3,934**	**25,398**	**1,123,404**	**650,022**	**10**	**1,016**	**34.2%**
Container ships	100'+	602	6,915	918,418	851,974	7		
	30'-99'	689	17,342	933,045	788,002	15		
	10'-29'	689	24,271	403,023	328,614	15		
	-9'	1,409	32,610	183,974	138,341	23		
	Sum	**3,389**	**81,138**	**2,438,459**	**2,106,930**	**17**	**1,954**	**36.5%**
Gas tankers	100'+	47	377	44,893	52,518	10		
	30'-99'	300	2,065	135,560	154,198	11		
	10'-29'	151	2,518	45,935	40,535	9		
	-9'	143	4,052	22,944	20,930	16		
	Sum	**641**	**9,012**	**249,333**	**268,182**	**10**	**410**	**32.6%**
Oil and Chemical Tankers	100'+	1,085	8,854	1,160,195	621,031	9		
	30'-99'	1,263	14,959	651,165	401,360	11		
	10'-29'	462	8,094	140,177	91,666	11		
	-9'	560	27,105	123,343	85,295	21		
	Sum	**3,370**	**59,012**	**2,074,880**	**1,199,352**	**11**	**1,310**	**27.0%**
Other Dry and Ro-Ro	100'+							
	30'-99'	57	541	23,475	26,306	7		
	10'-29'	745	18,289	251,011	584,514	14		
	-9'	1,211	57,578	182,129	282,243	27		
	Sum	**2,013**	**76,408**	**456,615**	**893,062**	**20**	**559**	**12.4%**
Other tankers	100'+	3	13	2,971	1,544	3		
	30'-99'	2	3	124	76	9		
	10'-29'	1	13	365	335	32		
	-9'	77	8,190	23,562	15,598	21		
	Sum	**83**	**8,219**	**27,022**	**17,552**	**17**	**0**	**6.0%**
Passenger vessels	100'+	2	17	1,887	2,296	0		
	30'-99'	2	346	11,960	3,475	10		
	10'-29'	44	5,855	67,335	519,905	11		
	-9'	925	187,552	377,860	2,053,137	21		
	Sum	**973**	**193,770**	**459,042**	**2,578,813**	**24**	**2**	**14.7%**
Grand Total		**14,403**	**452,957**	**6,828,755**	**7,713,913**	**14**	**5,251**	**24.3%**

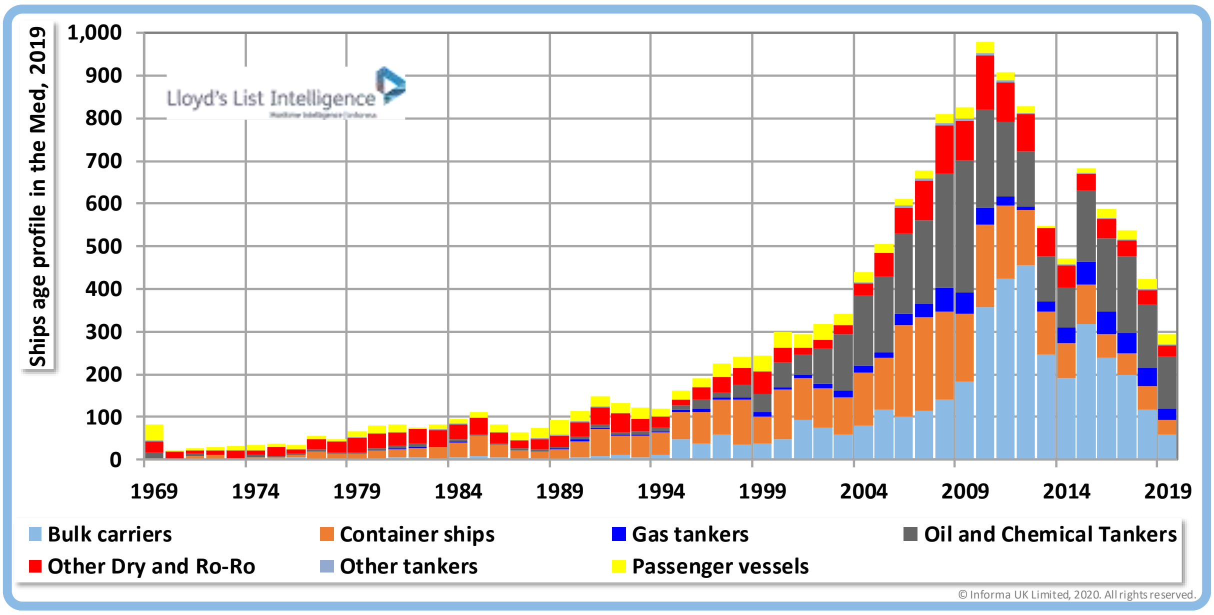
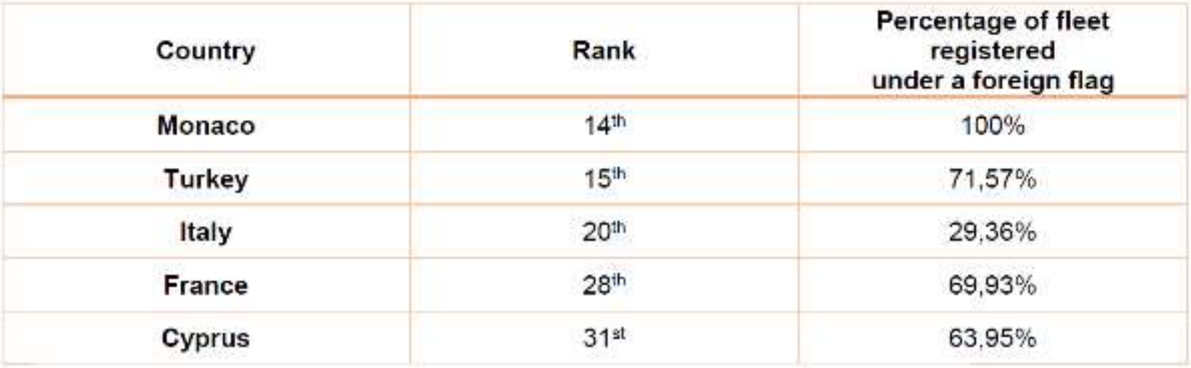


Figure 5. Fleet age profile for ships calling ports in the Mediterranean in 2019. Source: REMPEC (2020) [9].

In terms of flag registries, no Mediterranean coastal State is amongst the top 5 major flags of registration flags (UNCTAD, 2017b) [13] but 6 of them are amongst the top 35 ship-owning countries (by vessels' dwt) (UNCTAD, 2017a) [11]: Malta (6th, 99 million), Greece (9th, 75 million), Cyprus (12th, 34 million), Italy (17th, 16 million), Turkey (26th, 8 million), France (30th, 4 million=. Malta (1st), Greece (2nd) and Cyprus (3rd) are the three top flag registries in Europe. Ships registered under a national flag of all Mediterranean coastal States represent approximately 13,34 % dwt of the total world dwt in 2017, largely owing to Malta (5,43%) and Greece (3,88%), followed by Cyprus (1,81%); Italy (0,86%) and Turkey (0,43%). Together these 5 countries account for 12.41% dwt of ships registered under Mediterranean Coastal States national flags.

In terms of fleet ownership, Greece classifies as the top ship-owning country worldwide, followed by Japan, China, Germany and Singapore (UNCTAD, 2017a) [11]. These five countries accounted for 49.5% of the world's dwt in 2017. Aside from Greece, 5 Mediterranean coastal States are amongst the top 35 ship-owning countries (by vessels' dwt), as shown in Table 5.

Table 5. Ship-owning Countries- Ranking of Mediterranean Coastal States; Source: UNCTAD (2017a)[1]



Country	Rank	Percentage of fleet registered under a foreign flag
Monaco	14th	100%
Turkey	15th	71,57%
Italy	20th	29,36%
France	28th	69,93%
Cyprus	31st	63,95%

Cruise sector

The Mediterranean is the most popular cruise destination for European travellers and the second largest market globally for the industry, accounting for 15.8% of cruises in 2017 (MedCruise Association 2018*) [6]* (*Figure 6*).

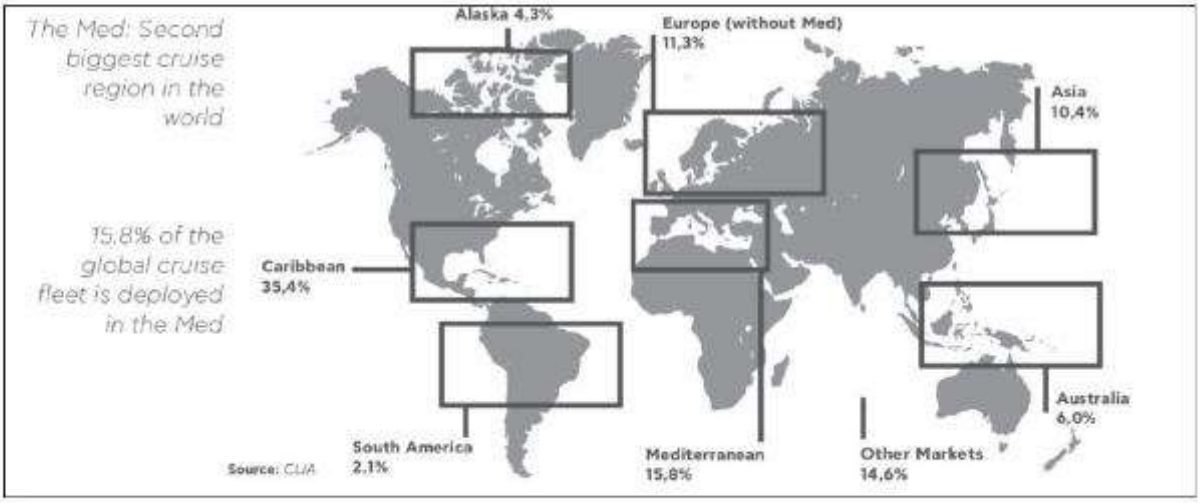
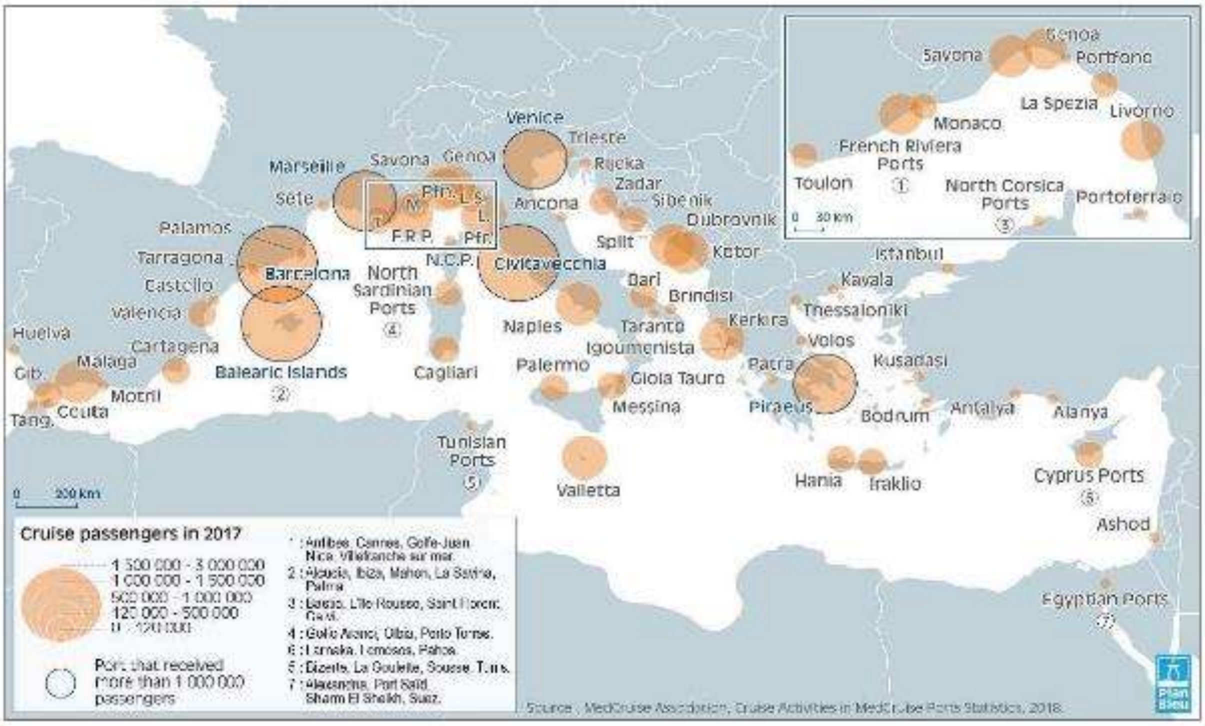


Figure 6. Global cruise fleet deployment shares in 2017. Source: MedCruise Association (2018) [6].

Ports accommodating more than 120,000 cruise passengers a year are considered major ports. 36 ports in the Mediterranean fall under this category, 25 of which being located in the Western Mediterranean area, 7 in the Adriatic and 4 in the Eastern Mediterranean area (Figure 7). Ports with fewer than 120,000 cruise passenger traffic in 2017 include 15 Western Mediterranean ports, 11 Eastern Mediterranean ports and 6 ports located in the Adriatic (MedCruise Association, 2018) [6].

The total number of cruise passenger movements in the Mediterranean ports during 2018 reached 28,04 million, representing the highest record in the history, at a level slightly higher than the one registered in 2013 (MedCruise Association, 2018) [6]. The number represents a +8.2% variation in comparison with 2017 [6]. From 2011, the total number of cruise passenger in the Mediterranean never went down of 25 million (Figure 8). The deployment of bigger vessels in the Mediterranean and the adjoining seas is evident by the continuous increase of the average number of cruise passengers that reach a destination per call. In 2018, the average number of hosted passengers per cruise call was 2.202. In 2000 each cruise call in the Med resulted in 845 passenger movements on average. Within 10 years, the average number of passengers per call moved up of 1.357, resulting in latest value of 2.202 (MedCruise Association, 2018) [6].



Source : MedCruise Association, Cruise Activities in MedCruise Ports Statistics, 2018.

Figure 7. Cruise passengers per cruise call in the Mediterranean (2017). Source: REMPEC, 2019.

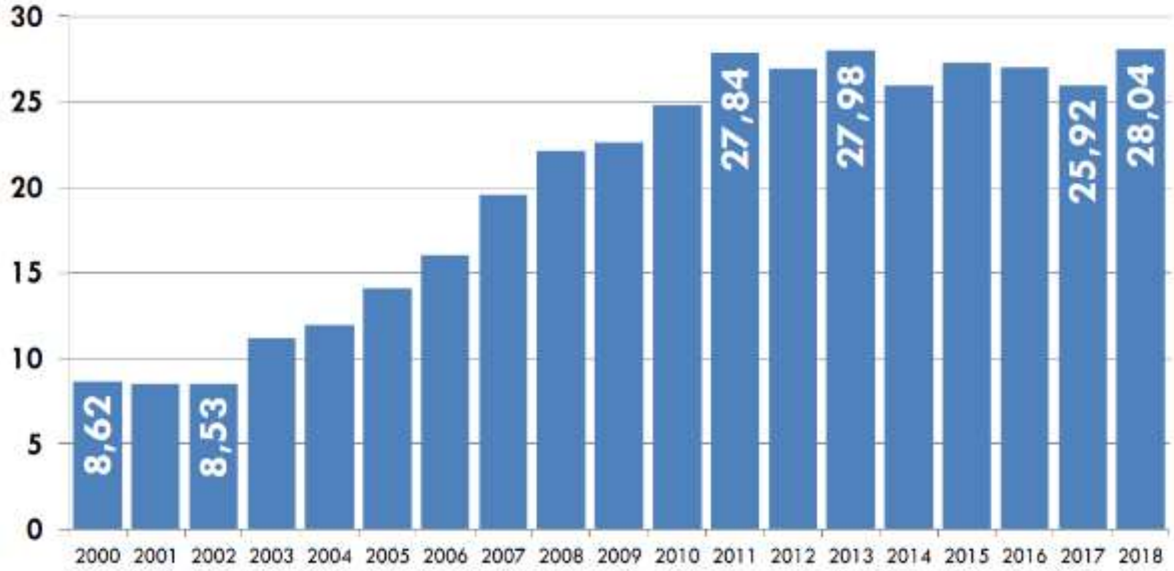


Figure 8. Cruise passenger movements (millions) in Mediterranean ports. Source: MedCruise Association, 2018 [6].

Vessels distribution and major traffic routes in the Mediterranean basin

The Mediterranean Sea is not homogenously travelled; some areas and well-known routes are characterised by higher traffic intensity. In line with previous assessments, (see in particular Randone et al., 2019) [5], in this study the distribution of traffic intensity was evaluated through vessel density. The map of vessel density at the global scale confirms the Mediterranean as a worldwide hot-spot of maritime traffic (Figure 9).

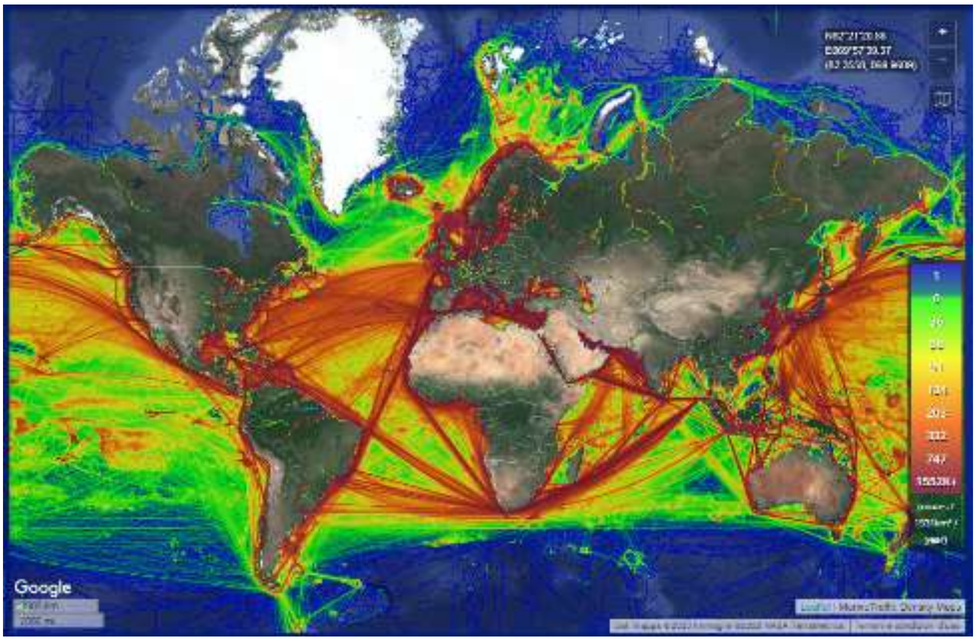


Figure 9. 2018 Vessel density, expressed as number of vessels per km^2. Source: https://www.marinetraffic.com/, consulted on July 2020.

The European Marine Observation and Data Network (EMODnet) Human Activities portal[3] provides access to GIS data (geotiff) on vessel density for a grid of 1 km^2 cells covering all EU waters and some neighbouring areas. Vessel density is expressed as hours of vessels presence per square kilometre per month, and are derived from AIS data purchased from Collecte Localisation Satellites (CLS). These data are also available for the entire Mediterranean Sea and for different typologies of vessels.

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[3] https://www.emodnet-humanactivities.eu/, consulted in June 2020.

The map in Figure 10 reports the 2018 annual vessel density in the Mediterranean for all typologies of monitored vessels; the annual density was obtained summing all monthly geotiff for 2018[4] (this was done for this and for the other following maps referring to specific traffic categories). The same map also depicts main cargo ports (with and without oil terminals) and other ports (including passengers, yachting and fishing ones). The latter information was also provided by the EMODnet Human Activities portal. Main cargo ports were selected according to Randone et al., 2019 [5]. Finally, oil refineries included in the map were extracted from the Clarkson Offshore & Energy Map portal[5].

When all typologies of vessel are considered, the Western Mediterranean, the Aegean Sea, the Levantine Sea and the Adriatic and Ionian Seas are the busiest areas of the basin (as also remarked in Plan Bleu, 2014 [2]). High vessel density also occurs close to coastal areas of the Northern and Eastern Mediterranean countries, representing both the internal traffic, which is the prevalent component in the basin as discussed above (Plan Bleu, 2010 [9]), and the traffic due to typical nearshore activities (fishery and yachting, in particular). High density is also evident in front of major ports, due to ship stationing.

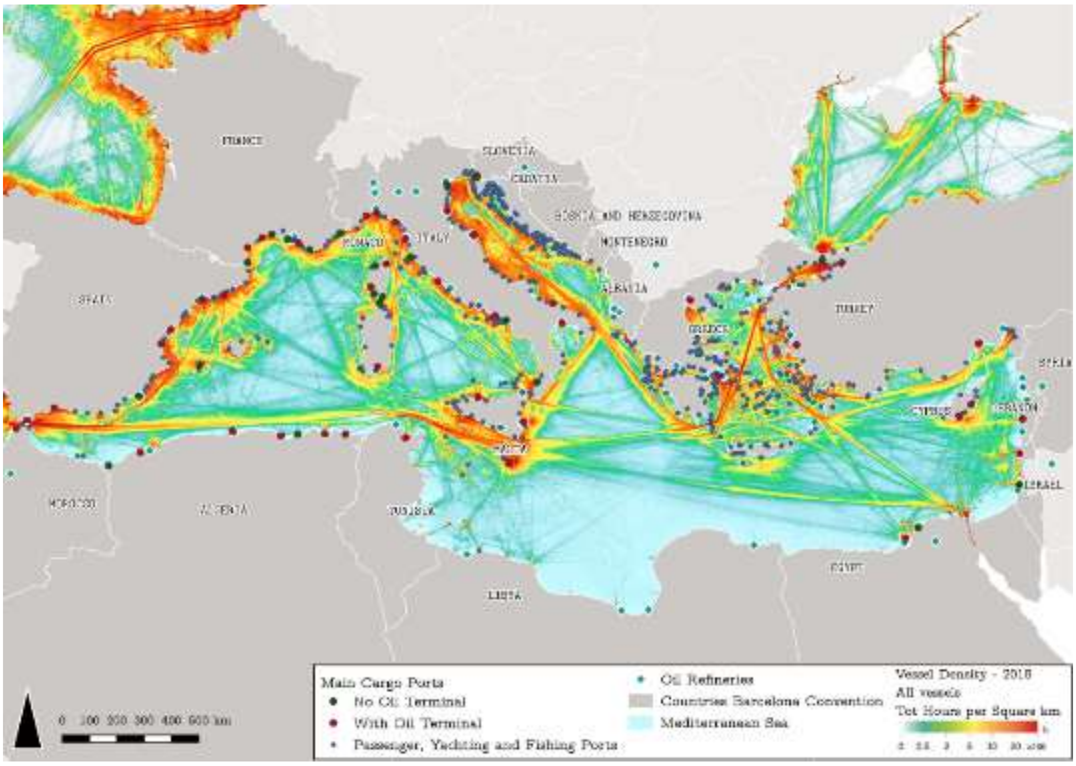

Figure 10. Annual density (2018) of vessels transiting in the Mediterranean. Data sources for vessel density and ports: EMODnet Human Activities portal; data source for oil refineries: Clarkson Offshore & Energy Map portal; data retrieved on 02.06.2020.

The maps of vessel density by categories of vessels reveals specific characteristics and distribution of the different typologies of maritime traffic. Passenger traffic is quite exclusively concentrated in the Northern countries of the shore (Figure 11). This surely reflects the importance of maritime tourism for the Northern rim of the basin. Passenger traffic is mainly due to ferries and other typologies of passenger vessels which in Southern Europe mainly connects different ports within the same countries, including those serving the numerous Mediterranean islands (Figure 12). Italy and Greece handle the most passengers in Europe, respectively about 80,500 and 72,000 in 2018 considering both embarking and disembarking (and excluding cruise passengers); this correspond to the 38% off all EU passengers (EUROSTAT, 2020b [17]). Passenger traffic also follows seasonal patterns, with an increase of traffic intensity in summer (Randone et al., 2019 [5]).

Cruising contributes to passenger traffic. This activity is concentrated along the northern shores of the Mediterranean Sea: the great majority of cruise ports (more than 75%) are in Italy, Spain, France, Greece, Croatia and Slovenia (Caric et al., 2019) [18] and cruise traffic is concentrated in the Western Mediterranean and the Adriatic Sea.

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[4] It was not possible to use 2019 data, as at June 2020 the monthly series of data for this year was not completed.

[5] https://www.clarksons.net/maps, consulted in June 2020.

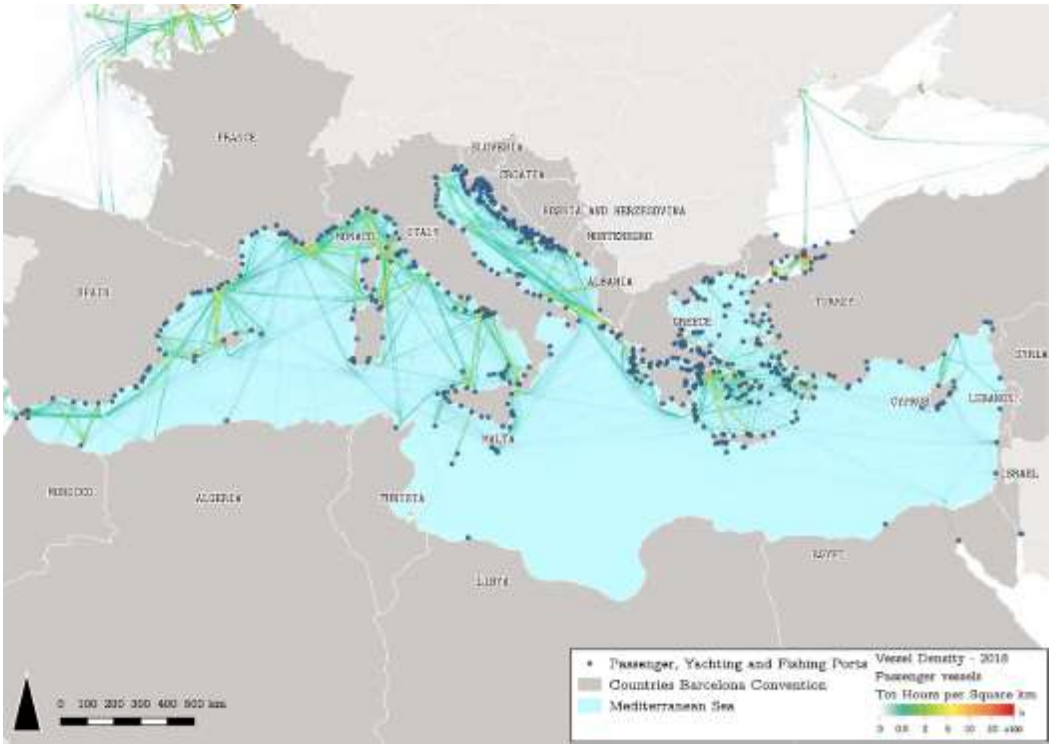
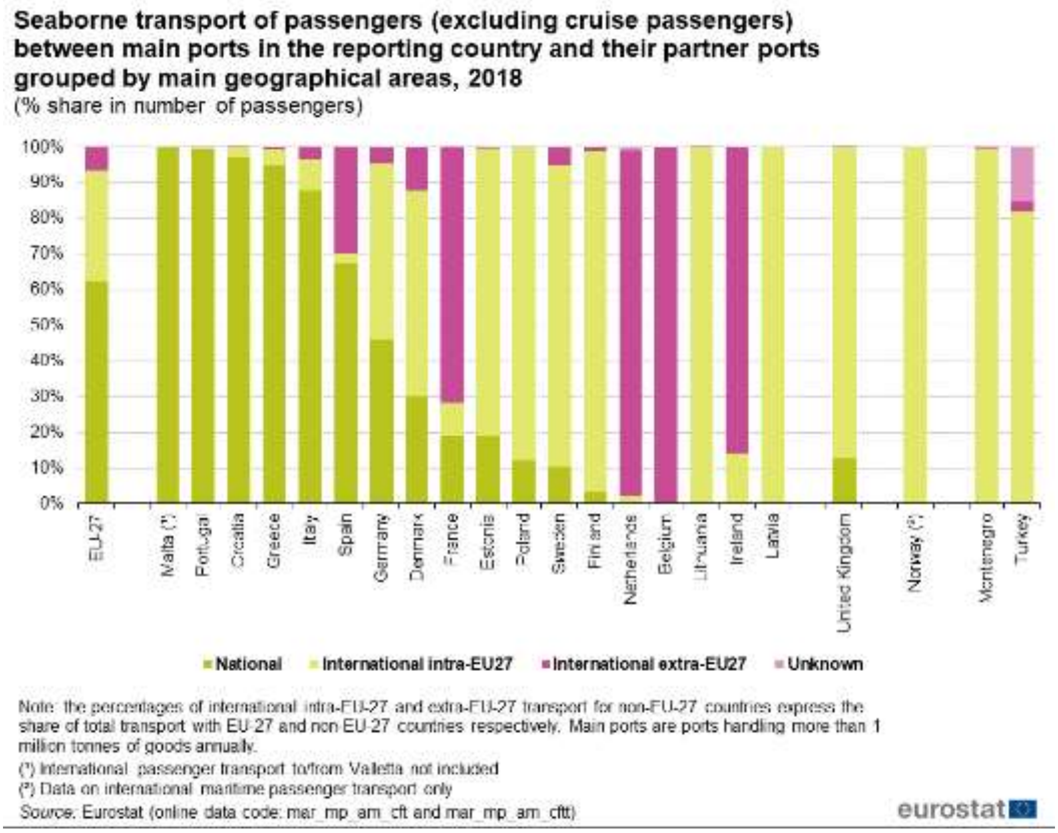


Figure 11. Annual density (2018) of passenger vessels transiting in the Mediterranean. Data sources for vessel density and ports: EMODnet Human Activities portal; data retrieved on 02.06.2020.


Seaborne transport of passengers (excluding cruise passengers) between main ports in the reporting country and their partner ports grouped by main geographical areas, 2018
(% share in number of passengers)

Note: the percentages of international intra-EU-27 and extra-EU-27 transport for non-EU-27 countries express the share of total transport with EU-27 and non EU-27 countries respectively. Main ports are ports handling more than 1 million tonnes of goods annually.
(¹) International passenger transport to/from Valletta not included
(²) Data on international maritime passenger transport only
Source: Eurostat (online data code: mar_mp_am_cft and mar_mp_am_cftt)

Figure 12. Seaborne transport of passengers (excluding cruise passengers) between main ports, 2018. Source: EUROSTAT, 2020b [17].

Figure 13. Cruise traffic by MedCruise regions in 2018. Source: MedCruise, 2018 [19].

Major routes crossing the Mediterranean are dominated by cargo and tanker maritime traffic (Figure 14 and Figure 16). This is in particular the case of the route crossing the basin longitudinally from the Suez Canal to the Gibraltar Strait, two of the world's major congestion points for maritime traffic, and the one reaching the Mediterranean from the Black Sea through the Bosporus, the Marmara Sea and the Dardanelles. Large container ships mostly take the route from Eastern to Western Mediterranean, to then continue to the North European ports (Figure 15), while smaller cargos are directed to Mediterranean ports which are reached also by trans-shipment (Randone et al., 2019) [5]: smaller feeders conveys containers to hubs located along the Suez-Gibraltar route (e.g. Tangiers, Algeciras, Malta and the ports in Southern Italy). Ro-Ro routes are mainly intra-Mediterranean.

The East-West route and the one from the Black sea are also used to transport oil to Mediterranean terminals and other ports west of Gibraltar from the areas of oil production (Middle East, Persian Gulf, North Africa, Black Sea region) (Piante and Ody, 2015) [20]. In particular, the Suez Canal is the entering point in the Mediterranean of the Northern branch of a main oil route gathering oil tankers from Saudi Arabia, the United Emirates, Kuwait and Iran, and reaching the Mediterranean and Western Europe ports (Girin and Carpenter, 2018) [21].

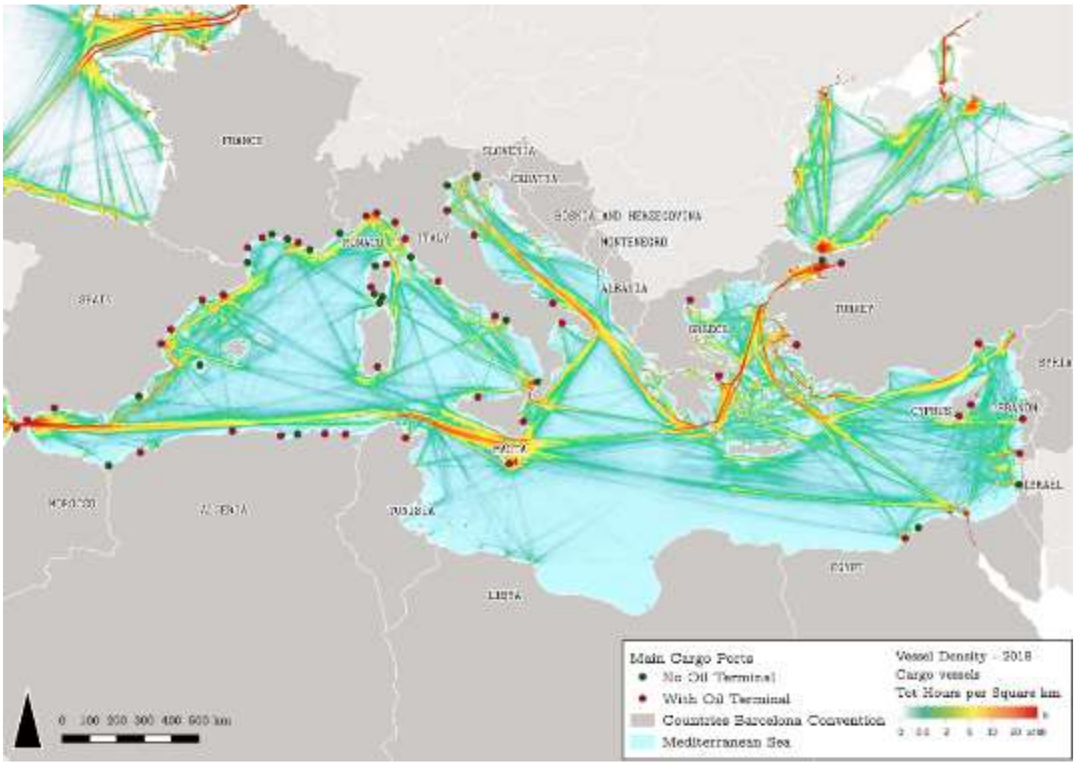


Figure 14. Annual density (2018) of cargos transiting in the Mediterranean. Data sources for vessel density and ports: EMODnet Human Activities portal; data retrieved on 02.06.2020.

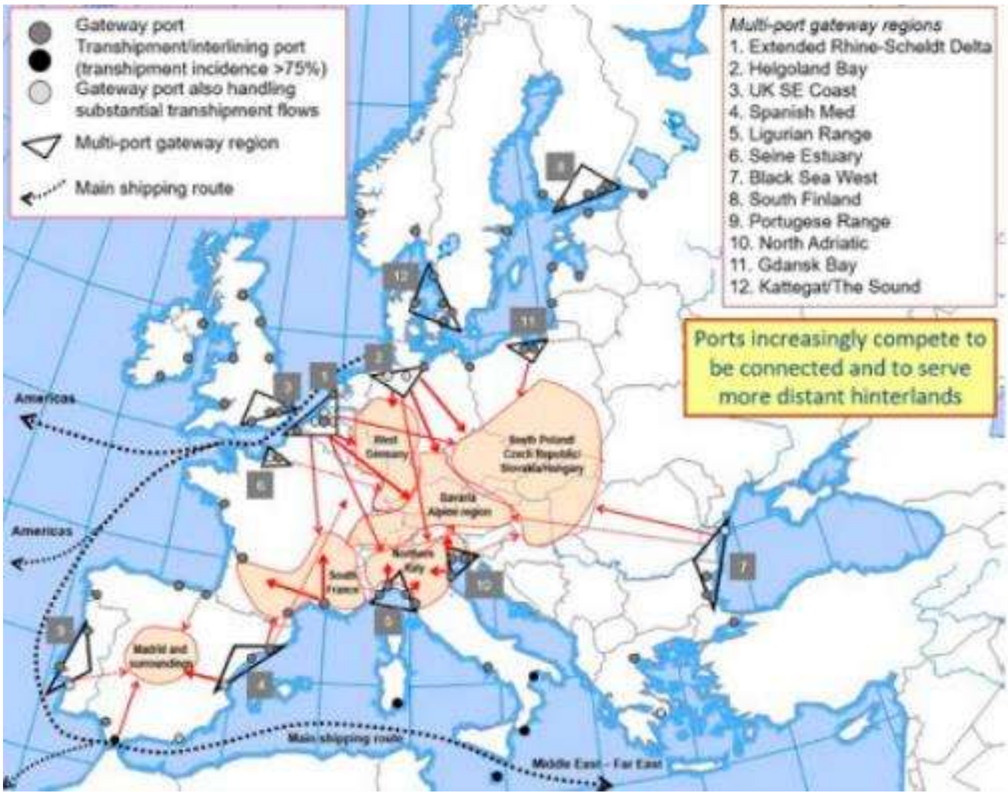


Figure 15. The European container port system. Source: Tadini, 2019 [22].

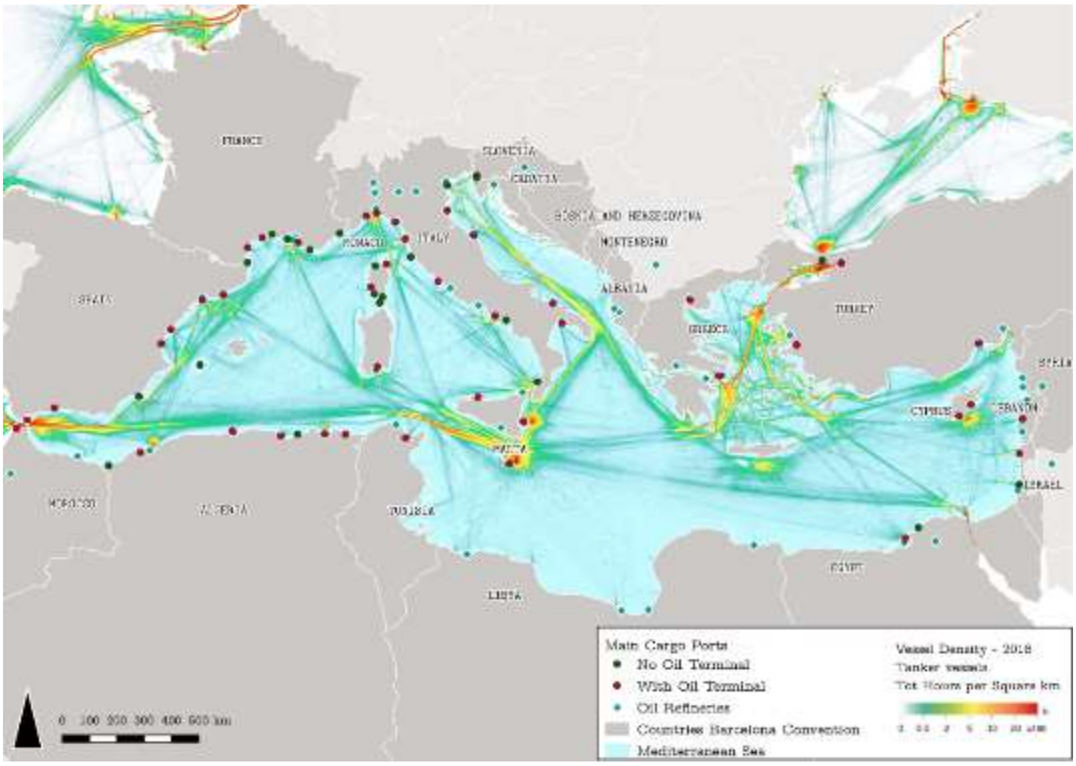


Figure 16. Annual density (2018) of tankers transiting in the Mediterranean. Data sources for vessel density and ports: EMODnet Human Activities portal; data retrieved on 02.06.2020.

3.1.1.2 Historical trends

In 2018 total volumes of international maritime trade reached 11 billion tons (Figure 17), continuing the increasing historical trend, even if the 2018 growth rate was lower (2.7%) than the one registered in previous years (4.1% in 2017) (UNCTAD, 2019a [1]). UNCTAD identifies a range of downside risk that intensified in 2018 and contributed to slowdown the maritime transport growth, including trade tension, protectionism, the Brexit, geopolitical turmoil and issues affecting country-specific economic development. In 2018, 7.8 billion tons were classified as dry cargos (including containers) and 3.2 billion tons as tankers. Crude oil accounted to less than one fifth of all goods delivered by shipping, still losing market share (oil was the most transported good in 1970) (UNCTAD, 2019b) [27].

World fleet carrying capacity has increased drastically in recent years (Figure 18). The growth has characterised all maritime transport segments but general cargos, and has been particularly rapid for bulk carriers. Between 2009 and 2019, the share of bulk carrier on total carrying capacity rose from 35% to 43%, whereas the share of oil tankers decreased from 35% to 29% (although in absolute their carrying capacity increased). World container port throughput also shows a continuously increasing trend, particularly marked in 2017-2018 (Figure 19).

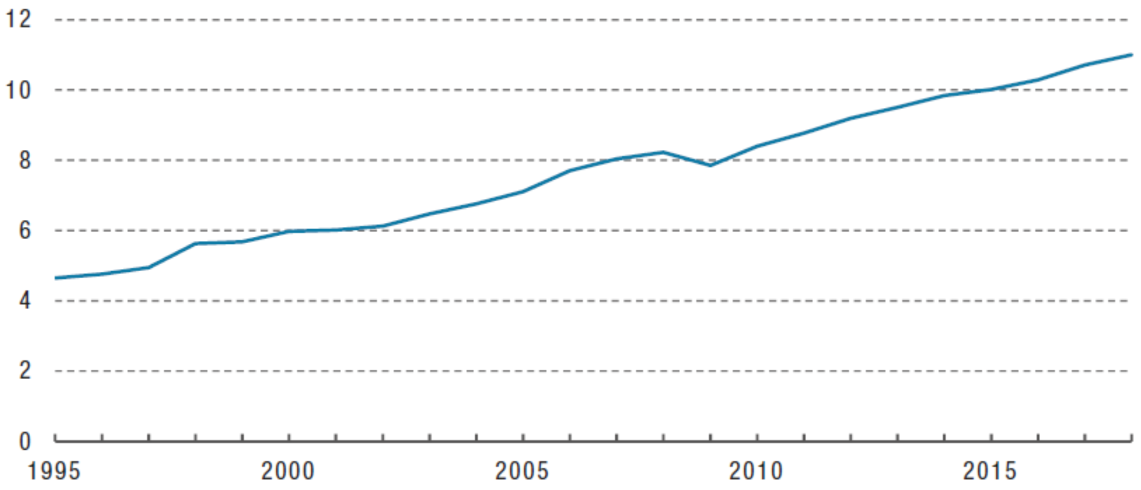
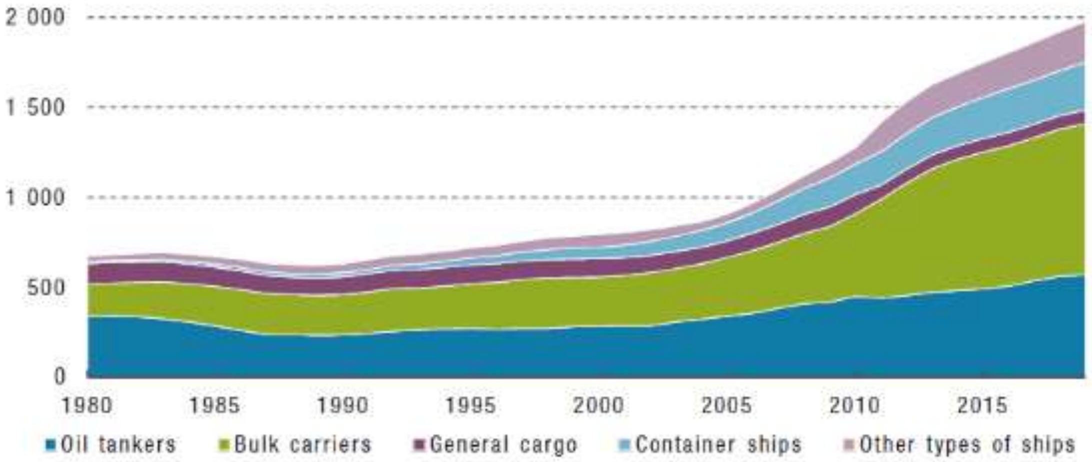


Figure 17. Goods loaded worldwide in billions of tons. Source: UNCTAD, 2019b [27].



Sources: UNCTADstat (UNCTAD, 2019a); Clarksons Research.
Note: Commercial ships of 100 gt and above; beginning-of-year figures.

Figure 18. World fleet by principal vessel type (millions of DWT). Source: UNCTAD, 2019b [27].

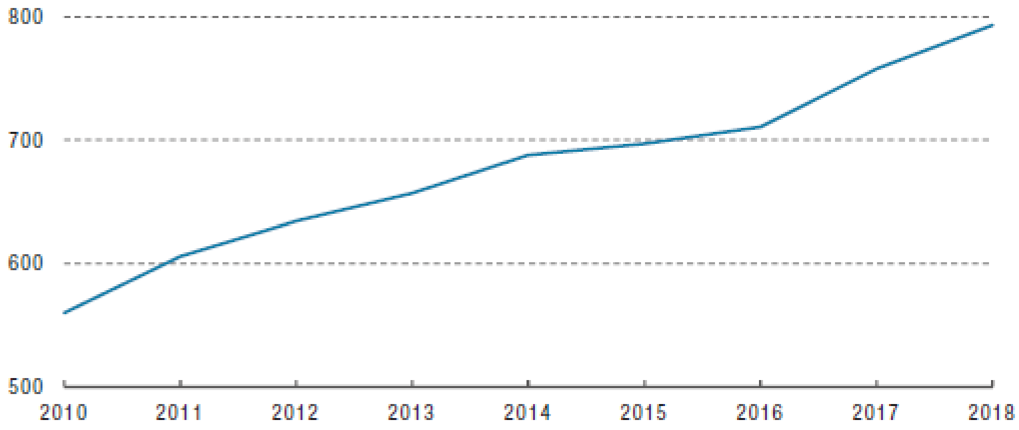


Figure 19. World container port throughput in millions of TEUs. Source: UNCTAD, 2019 b [27].

Seaborne trade to and from countries in the Mediterranean has increased by 284 million tonnes since the end of 2009 to 2019 (Figure 20). Dry bulks have grown the most in tonnes (+158 million) while containerized cargos have grown the most in relative terms (+87%). Liquid bulks have only grown marginally, +3%, while non-containerized general cargo has declined by 3%. The decline of liquid bulks in the years leading up to 2014 correlate well with the global trend. The turnaround point was the sharp drop in oil prices mid-2014, which gave a boost to the oil trade.

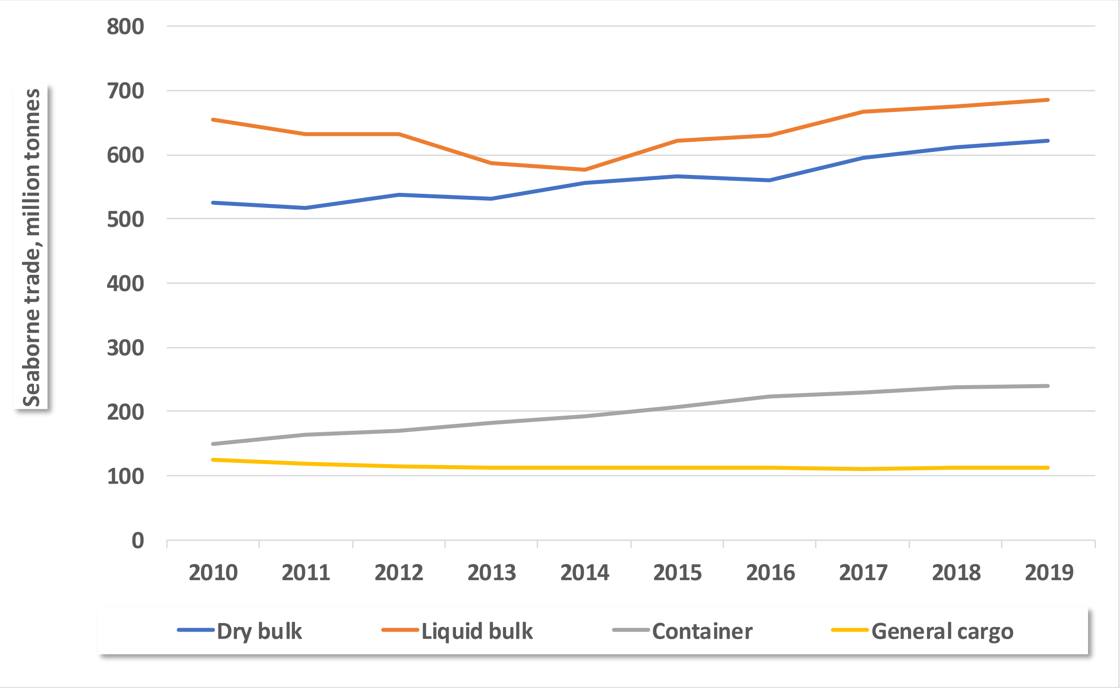


Figure 20. Mediterranean seaborne trade in 2010-2019 expressed in million tonnes. Source: REMPEC (2020) [9].

Mediterranean Port calls also increased significantly in the period 2010 2019 (+74.5%) (Figure 21 and Table 6). Passenger port calls experienced the highest increase (+163%) in the analysed period (however with a fluctuating trend), in particular in the last two years. According to REMPEC (2020) *[9]*, this is likely not entirely due to increased traffic. The ability to adequately capture the highly frequent parts of the ferry traffic has been improved since 2010.

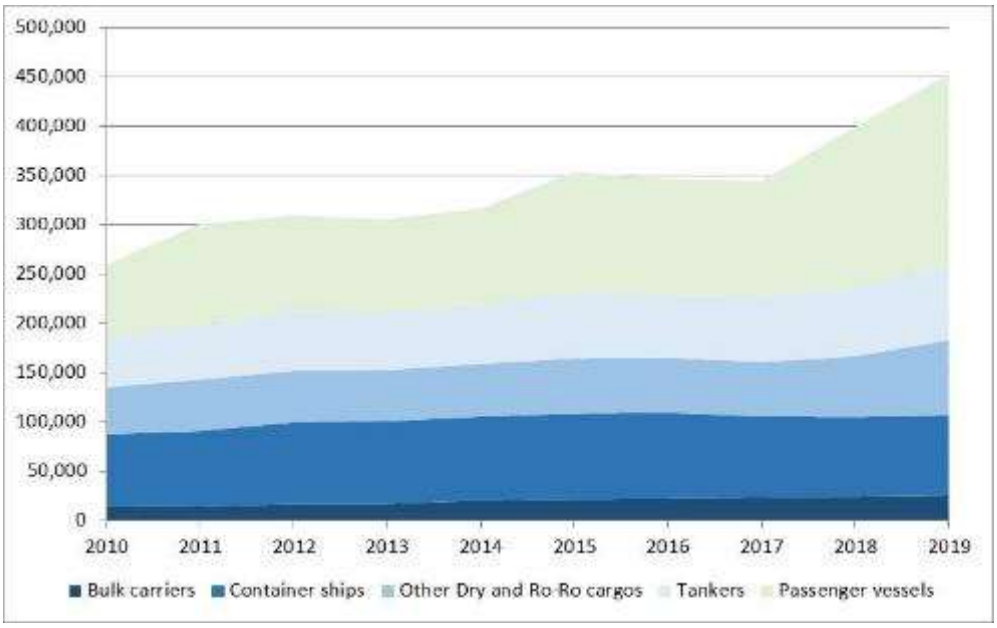


Figure 21. Historical trend of port calls in the Mediterranean in the period 2010 – 2019. Data Source: REMPEC (2020) [9].

Table 6. Port calls in 2010 and 2019 and their percentage variations. Data Source: REMPEC (2020) [9].

	2010	**2019**	**% variation 2010-2019**
Bulk carriers	14,594	25,398	74.0%
Container ships	72,849	81,138	11.4%
Other Dry and Ro-Ro	47,859	76,408	59.7%
Tankers	50,607	76,243	50.7%
Passenger vessels	73,672	193,770	163.0%
All vessels	**259,581**	**452,957**	**74.5%**

Other dry and Ro-Ro cargos, tankers and bulk carriers show a similar trend, characterised by a gradual increase of the number of port calls, which however is higher in the last two years (2018-2019) for the first category of vessels. Container ships shows a different historical trend (Figure 22). The 2019-2010 variation is positive also for this category of vessels (+11.4%), even if lower than those characterising the other typologies. However, after a rapid increase, the number of port calls of container ships shows an evident decreasing trend since 2016.

Average vessel size and related carrying capacity of container ships has significantly increased worldwide over the years (Randone et al., 2019) [5], towards vessel gigantism. Moreover, the enlargement of the Suez Canal (opened in February 2016) allowed larger vessels entering the Mediterranean. It was estimated that in 2017 the average size of container ships transiting the canal increased by 21% compared to 2014 (SRM and AlexBank, 2018) [3] (Figure 23). This has likely contributed to the limited increase in port calls observed for container ships compared to the other vessel categories over the period 2010-2019, as well as to negative yearly variation. The trend of port calls does not correspond to a similar trend for container trade, which significantly increased over the entire considered period (Figure 20). Large container ships, often do not call in Mediterranean ports, but transit the Mediterranean, taking the route from the Suez Canal to the Strait of Gibraltar, to continue to Northern European ports. A continuous, rapid growth in container traffic for the major East and West Mediterranean ports (Figure 25) is highlighted by (Grifoll et al., 2018) [29] for the period 2000-2015 (Figure 24). The traffic share between the two Mediterranean sub-regions remain approximately constant in the period; the Eastern Mediterranean quota varies between 52% (2012) and 56% (2010).

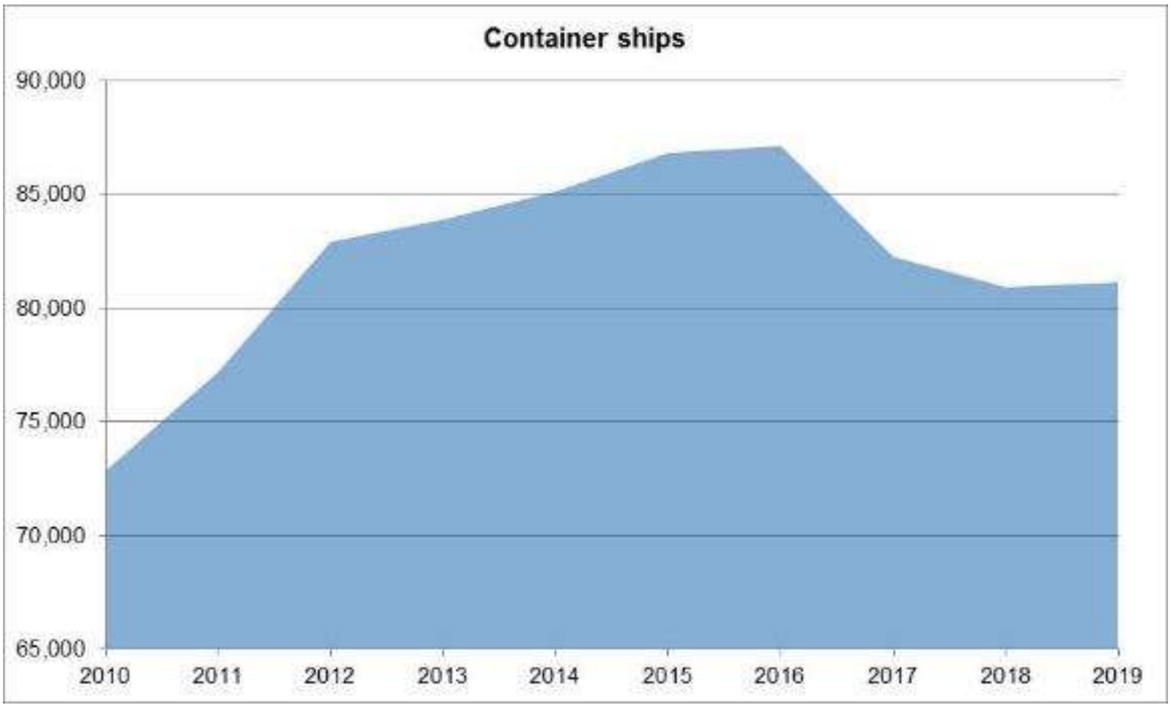


Figure 22. Historical trend of port calls in the Mediterranean for container ships in the period 2010 – 2019. Data Source: REMPEC (2020) [9].

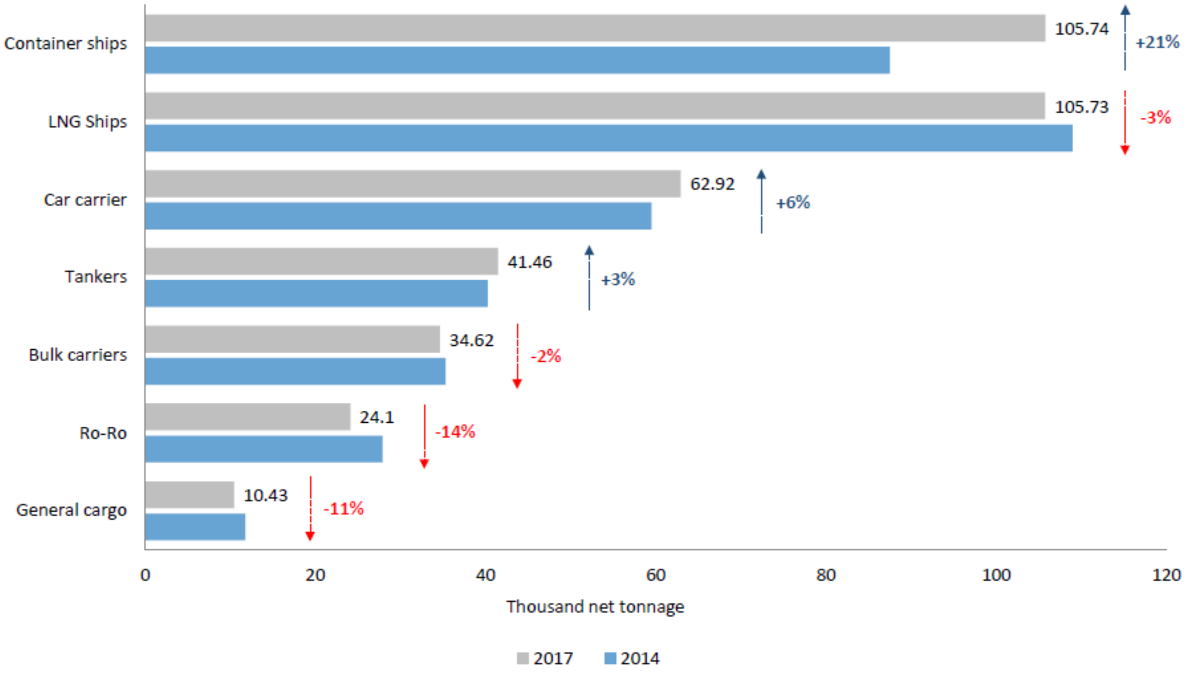


Figure 23. Average net ton by ship type: comparison between 2014 and 2017. Source: SRM and AlexBank, 2018 [3].

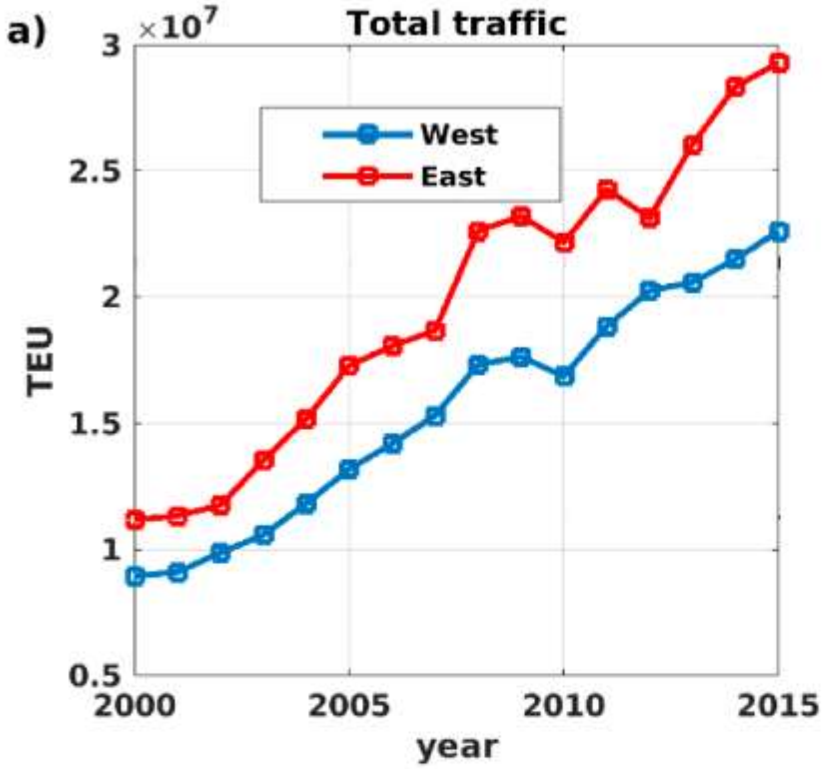


Figure 24. Evolution of container traffic in East and West Mediterranean. Source: Grifoll et al, 2018 [29]

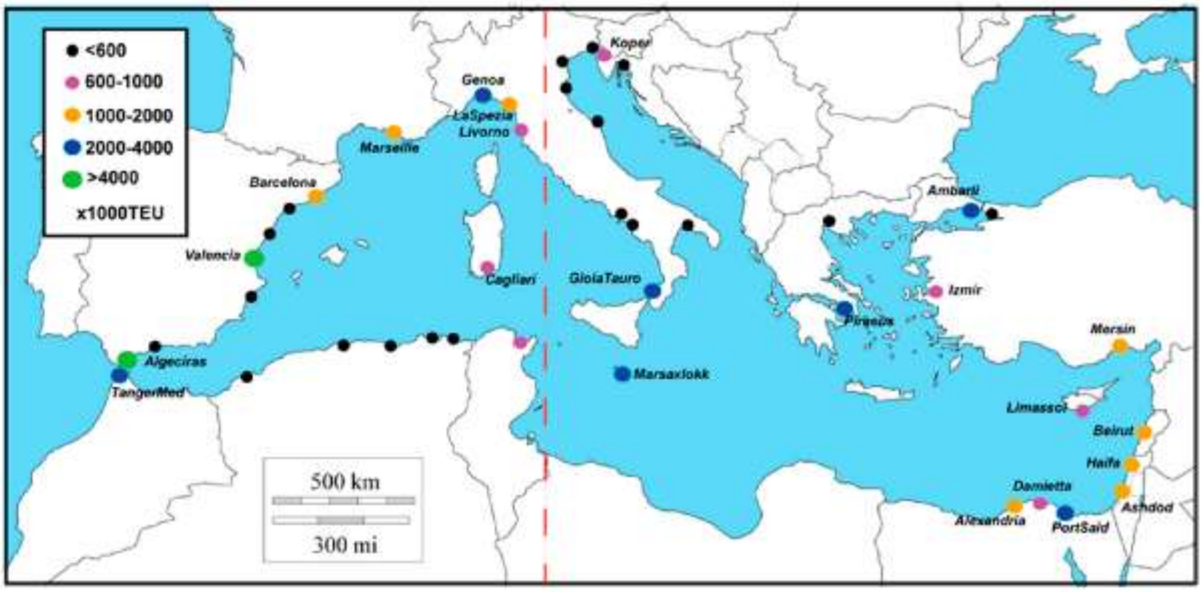


Figure 25. Container throughput in main Mediterranean ports in 2015. Source: Grifoll et al, 2018 [29]

Tanker port calls increased between 2010 and 2019 by 51% (Figure 26). The great majority of liquid tanker traffic in the Mediterranean is due to oil and chemical tankers, which in 2019 represented 77.4% of all port calls of this type of vessels (80.6% in 2010).

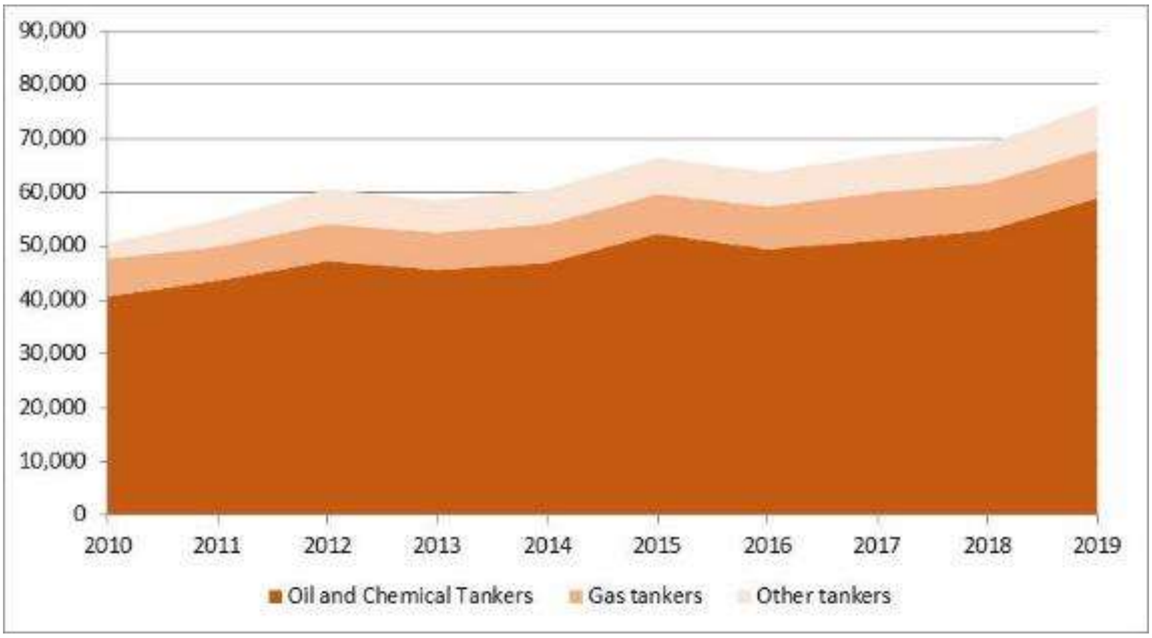


Figure 26. Historical trend of port calls in the Mediterranean for different typologies of tankers in the period 2010 – 2019. Data source: REMPEC (2020) [9].

The historical evolution of the number of ships shows a fluctuating trend, with an overall increase between 2010 and 2019 of 7% (Table 7). While the number of bulk carriers, tankers and passenger vessels increased in the period, that of container ships and other dry and Ro-Ro cargos decreased coherently with an increase in the size of these typologies of vessels (Figure 27). The analysis illustrated in REMPEC (2020) underlines that in 2019 (compared to 2010) ships are in general larger and younger, although some of the vessels are old (Figure 5).

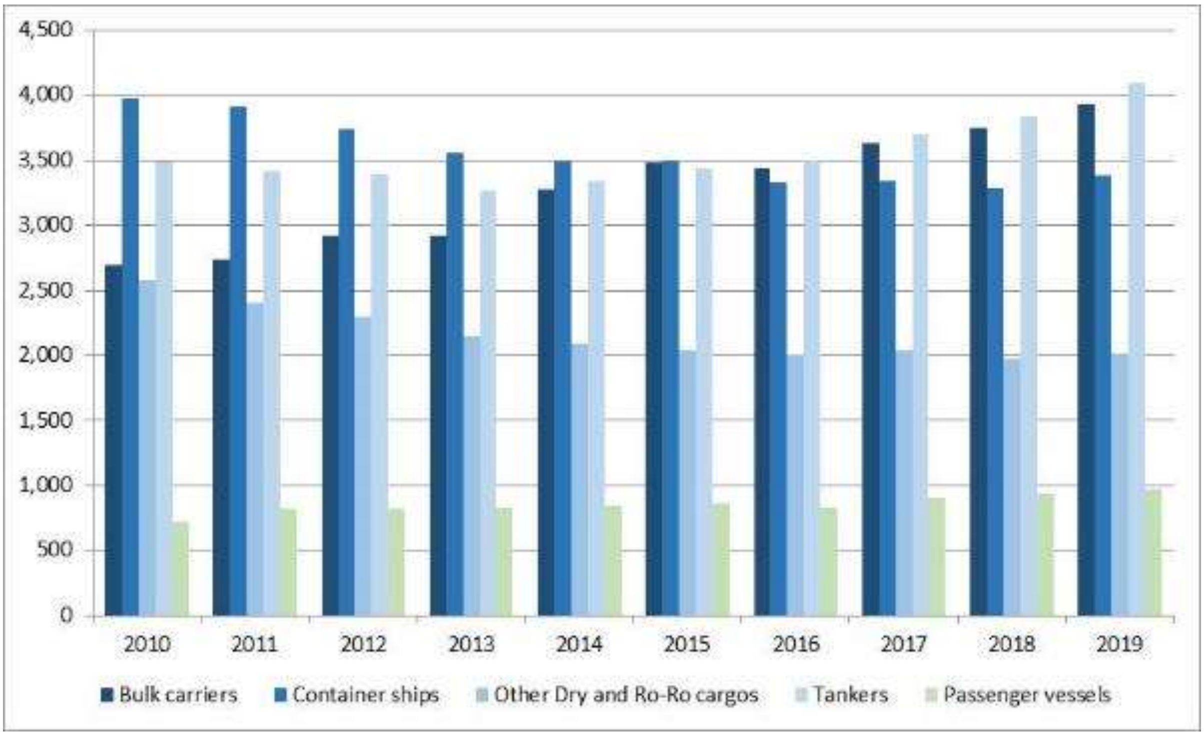


Figure 27. Historical trend of number of ships in the Mediterranean for different typologies of vessels in the period 2010 – 2019. Data source: REMPEC (2020)[9].

Table 7. Numbers of ships in 2010 and 2019 and their percentage variations. Data Source: REMPEC (2020) [9]

	2010	**2019**	
Bulk carriers	2,695	3,934	46.0%
Container ships	3,976	3,389	-14.8%
Other Dry and Ro-Ro cargos	2,579	2,013	-21.9%
Tankers	3,493	4,094	17.2%
Passenger vessels	723	973	34.6%
Total	**13,466**	**14,403**	**7.0%**

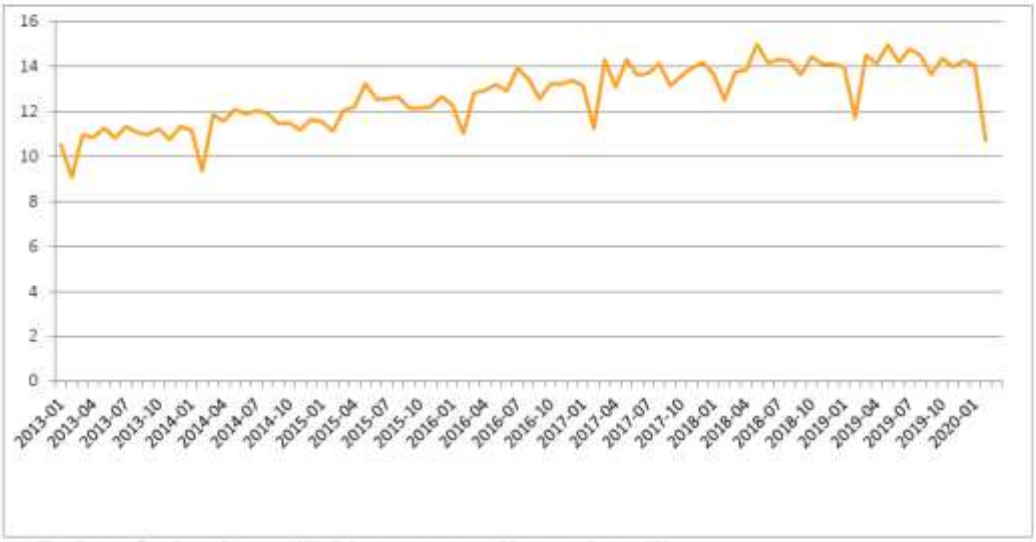
3.1.1.3 Outlook

Future projections of maritime traffic are affected by high uncertainty (UNCTAD, 2019a [1]). Merchant maritime transport is driven by international trade, which itself is driven by the global economy and the globalisation process. Economic development also influences the demand for passenger transport, in particular the one due to the tourism sector. Given its global dimension, maritime traffic is influenced by other issues which have an effect on economic development, including geo-political factors, worldwide trade policies and the possible occurrence of major socio-economic crisis.

The rapid spread of COVID-19 in 2020 has clearly demonstrated the worldwide dimension of maritime transport and its vulnerability. The crisis has significantly affected global shipping markets, decreasing the demand for goods from China, with ripple effects on any maritime transport, from container ships to oil tankers (Berti, 2020) [23]. Between end of January and mid-February, the demand for Chinese crude tankers drastically dropped from an average value of 3.4 billion tons miles per day in 2019 to almost zero. Global container trade volumes declined by 8.6% in February 2020, compared to the same month in 2019 (Figure 29); the decline was particularly marked in the Far East (-17.5%) and significant in North America (-7.0%) and Europe (-4.0%). In particular, the crisis strongly affected larger vessels (Figure 30). As response, shipping operators have massively started idling vessels (ITF, 2020) [24]. At the same time, it shall be noted that some forms of maritime traffic played a significant role as trigger of the COVID-19 outbreaks. This is actually the case of cruising: Ito et al (2020) [25] noticed that COVID-19 infection rates in countries that continued to accept cruise ships until March 2020 were higher than those in countries that did not.

*Middle East to China Route for VLCC, Suezmax and Aframax Tankers
Source: VesselsValue February 2020

Figure 28. 2020 Chinese crude tanker demand. Source: Berti (2020) [23].



In million Twenty-foot Equivalent Units (TEU). Source: International Transport Forum, CTS

Figure 29. Global container trend volumes, January 2013-February 2020. Source: ITF, 2020 [24].

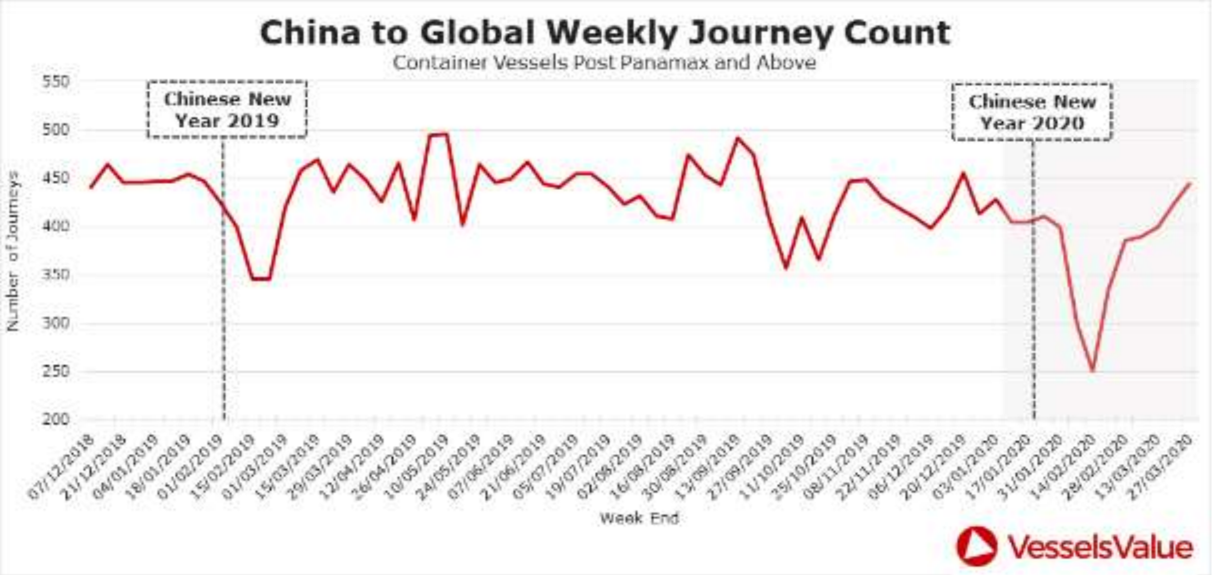


Figure 30. China to global weekly journey count for container vessels Post Panamax and above. Source: https://ship.nridigital.com/ship_may20/coronavirus_impact_global_shipping, accessed in July 2020.

In May 2020, the Union for the Mediterranean organised a webinar on the impacts of COVID-19 on Mediterranean maritime transports and ports. The webinar highlighted the vulnerability of maritime networks, port efficiency and hinterland connectivity in the Mediterranean due to crisis situations. It also considered that as a consequence of the COVID-19 crisis, the future supply chains should be shorter, more diversified and regional, thus pointing to a possible improvement of short-sea shipping[6]. The effects of COVID-19 lockdown measures on maritime traffic have been investigated also at local scale. In the Venice lagoon and the adjacent coastal areas of the Adriatic Sea, Depellegrin et al., (2020) [26] report a reduction by -69% of vessel activity in March-April 2020, compared to the same period in 2017. Tankers are the only vessels which did not experience a reduction; fishing vessel activity decreased by -84%, while activity of passenger vessels and cargo respectively by -78% and -31%.

Worldwide crisis as the COVID-19 one and related effects on the global economy are hardly to predict and add on top of other factors of uncertainty affecting the outlook of the maritime sector. Future projections and possible evolution of the maritime traffic discussed below do not consider the effect of this recent socio-economic crisis, which must still be investigated in details.

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[6] https://ufmsecretariat.org/impacts-covid-ports-maritime-transport-mediterranean/, accessed on July 2020.

At global level, UNCTAD (2019a) [1] projects an annual increase of commercial maritime trade of 3.4% for the period 2019-2024. Container trade is expected to grow more consistently (4.5%) than dry bulk (3.9%) and tanker (2.2%) trades. According to DNV GL (2019) [30], global seaborne trade is expected to increase by 2.3% (on average annually) in the period 2018-2030 (Figure 31), specifically: crude oil 1.5%, oil products 2.9%, natural gas 7.2%, bulk 1.7%, container 3.6%, and other cargo 2.3%. DNV GL long-term outlook projects a slowdown of the growth, which in the period 2030-2050 is about 0.3% (on average annually), including increase and decrease of specific segments: crude oil -2.1%, oil products 0.0%, natural gas 3.2%, bulk -0.1%, container 1.5%, other cargo 0.6%. As the global demand for coal and oil is expected to peak in the long term, their trade will also peak, reducing their seaborne trade by more than two thirds and one third, respectively.

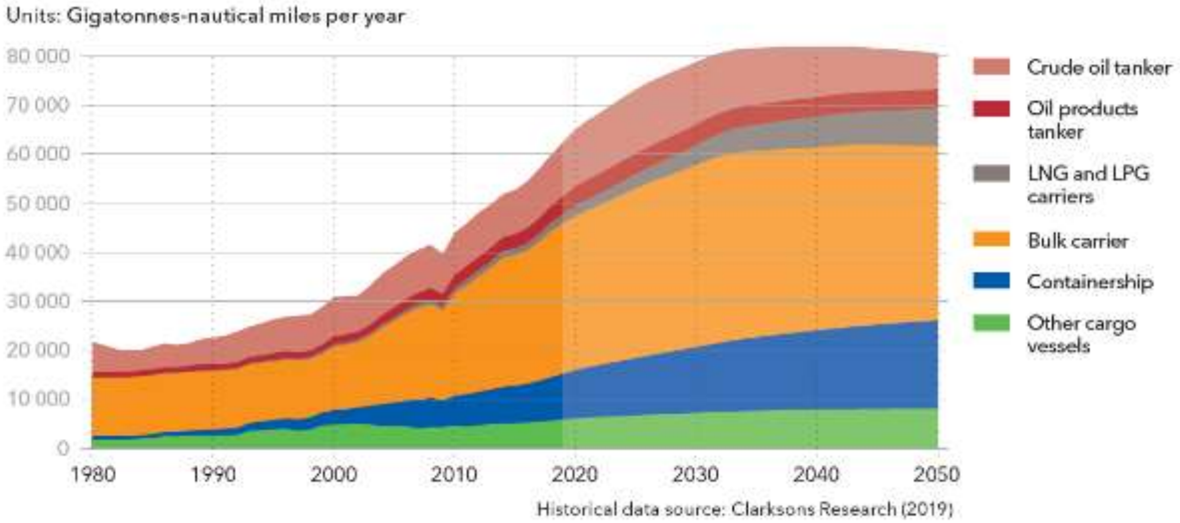


Figure 31. World seaborne trade. Source: DNV GL (2019) [30] .

Long-term projections of maritime traffic have been also developed by REMPEC (2020), in particular considering two scenarios characterised by different economic growths (Table 8), per capita energy consumptions and mix of energy sources. Scenario 2 is characterised by an early peak in energy consumption, a rapid decline in oil and coal consumption met by natural gas and renewables, and a lower GDP growth.

Table 8. GDP growth rates used in the two scenarios REMPEC (2020) [9].

	avg 2010-2019	avg 2020-2029	avg 2030-2050
Scenario 1			
OECD	2.0%	0.9%	1.5%
non-OECD	5.3%	3.6%	3.8%
World	**3.8%**	**2.6%**	**3.0%**
-India	7.3%	5.0%	5.3%
-China	7.8%	4.9%	4.0%
Scenario 2			
OECD	2.0%	0.6%	0.9%
non-OECD	5.3%	3.3%	3.2%
World	**3.8%**	**2.3%**	**2.4%**
-India	7.3%	4.6%	4.5%
-China	7.8%	4.5%	3.4%

At the global scale, bulk commodities dominate shipping today with the so-called major bulks, i.e. crude oil, petroleum products, iron ore, coal and grain in the lead. However, liquefied natural and petroleum gases have grown rapidly as have containerized general cargo. Figure 32 provides a view of the development of seaborne trade in a 2010-2050 perspective in scenario 1. In this scenario, dry bulk cargos keep their dominance, while liquid bulk growth flattens. Containerized cargo maintains the growth momentum, partly on the expense of non-containerized general cargo growth.

The global seaborne trade development in scenario 2 lands 5 billion tonnes lower than in scenario 1. 87% of the lower growth relate to the carriage of dry and liquid bulk commodities. Under this scenario, the trade with coal, crude oil and petroleum products is considered to decline 2.7 billion tonnes from 2019.

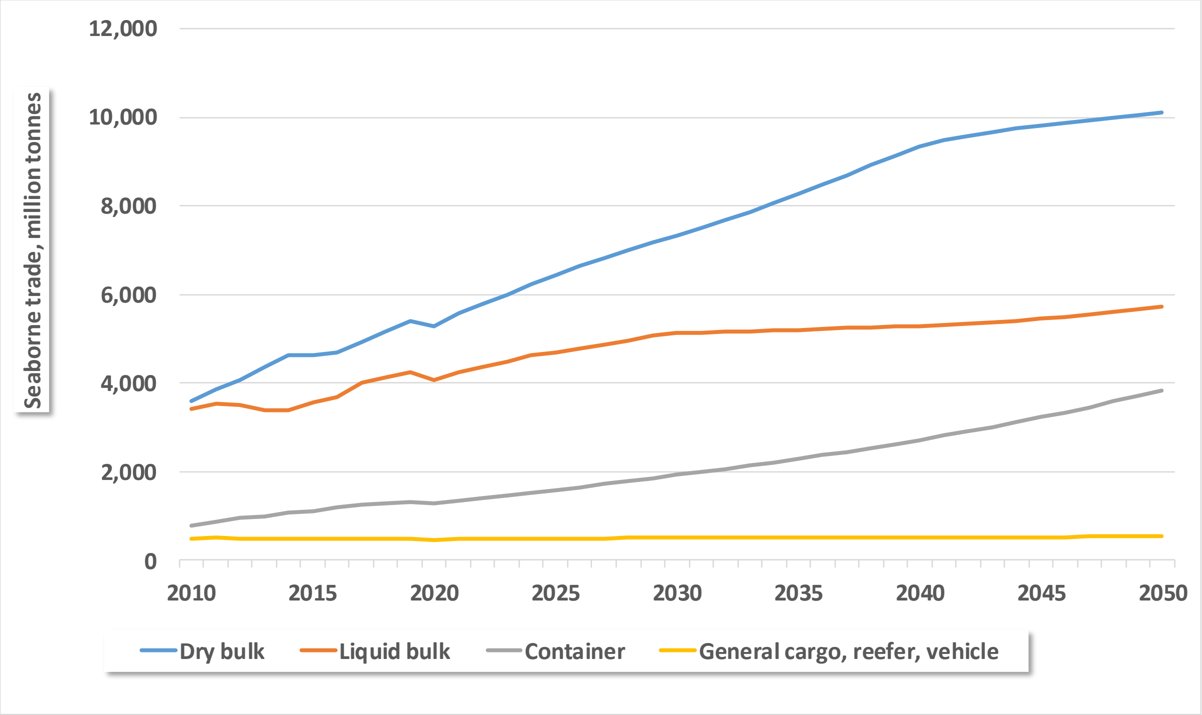


Figure 32. Global seaborne trade 2010-2050, scenario 1, million tonnes. Source: REMPEC (2020) [9].

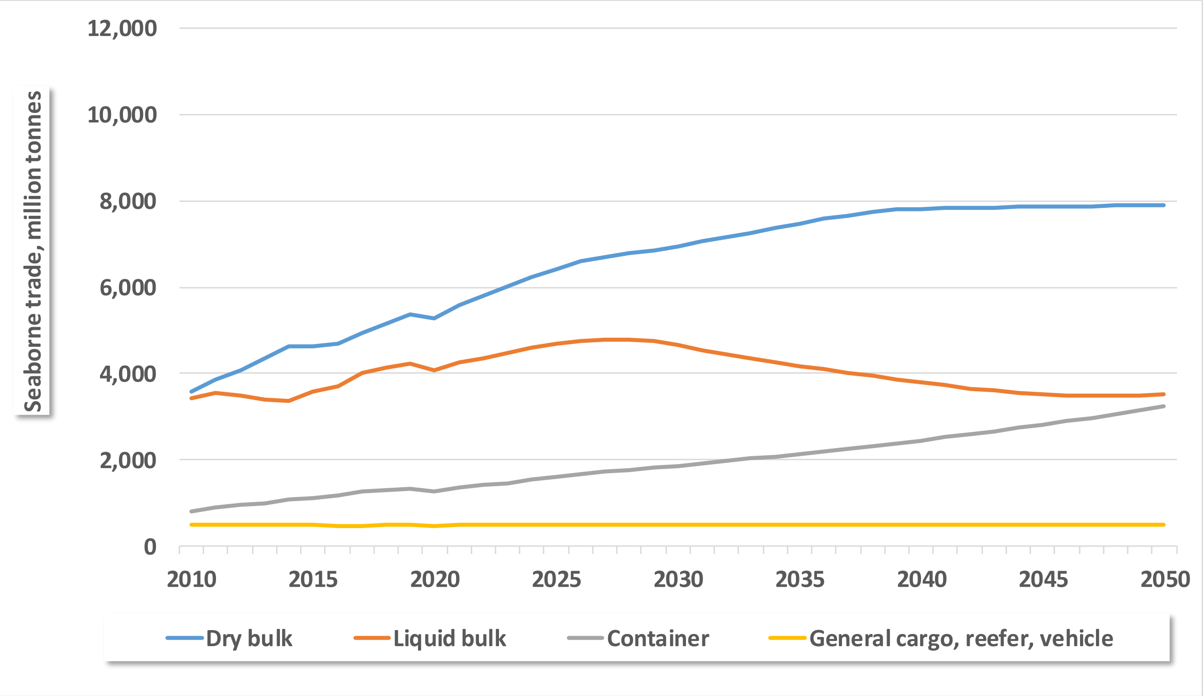


Figure 33. Global seaborne trade 2010-2050, scenario 2, million tonnes. Source: REMPEC (2020) [9].

In line with the global expansion, it is expected that maritime transport will increase in the Mediterranean in the coming years, both in terms of traffic intensity and number of routes (Piante and Ody, 2015 [20]; Randone et al., 2019 [5]). The growth in maritime transport in the Mediterranean will be driven by two main factors:

– The quite recent (early 2016) doubling of the Suez Canal already increased the number of ships and in particular of tons of goods travelling in the two directions across the canal (Figure 34 and Figure 35). The annual number of vessels passing the canal, increased from 17,148 in 2014 (before the enlargement of the canal) to 18,880 in 2019 (+10.1%). The increase of cargo tonnage was even higher, from 822 million of tons in 2014 to 1,031 million of tons in 2019 (+24%). The completion of the enlargement allows the transit of bigger ships, with a deeper draught (up to about 20 m). The biggest ships transiting through the canal are containerships; thanks to the canal improvement, the size of transiting container vessels has followed the naval gigantism (SRM and AlexBank, 2018) [3]. Passages through the Suez Canal are expected to continue growing in the next years, further contributing to the increase in the Mediterranean merchant maritime traffic. Actually, the new configuration of the Suez Canal can now accommodate 97 ships per day (on average 51.7 vessels per day transited across the Canal in 2019, according to Suez Canal Authority statistics) versus a value of 47 ships per day before the enlargement (Boske and Harrison, 2017 [31]; Tadini, 2019 [32]).

- Maritime traffic in the Mediterranean will be further affected by the Belt and Road Initiative (BRI). This is a long-term and vast initiative lunched in 2013 by the Chinese government aiming to address infrastructure gaps, increase collaboration and improve connectivity between China (and more in general South East Asia) and Europe. The 21st Century Maritime Silk Road is the marine component of the BRI, running from Chinese coasts across the Indian Ocean to East Africa and then via the Red Sea and the Suez Canal to the Mediterranean, till the Norther Adriatic. The BRI also foresees important investments in ports and inland logistic, along the maritime silk road. This route is already used to ship large quantity of goods from South East Asia to the European markets; once completed, the BRI will further increase the maritime traffic along this route.

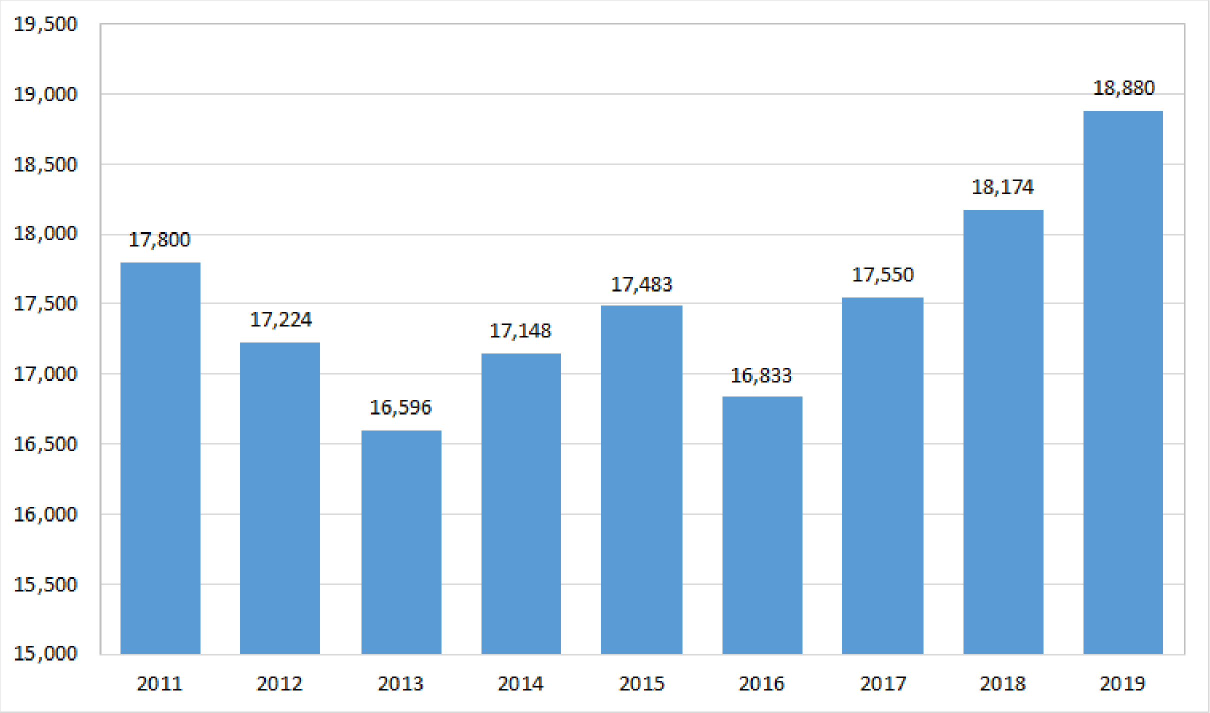


Figure 34. Number of vessels per year transiting though the Suez Canal in the two directions. Data source: SCA – Suez Canal Authority [33].

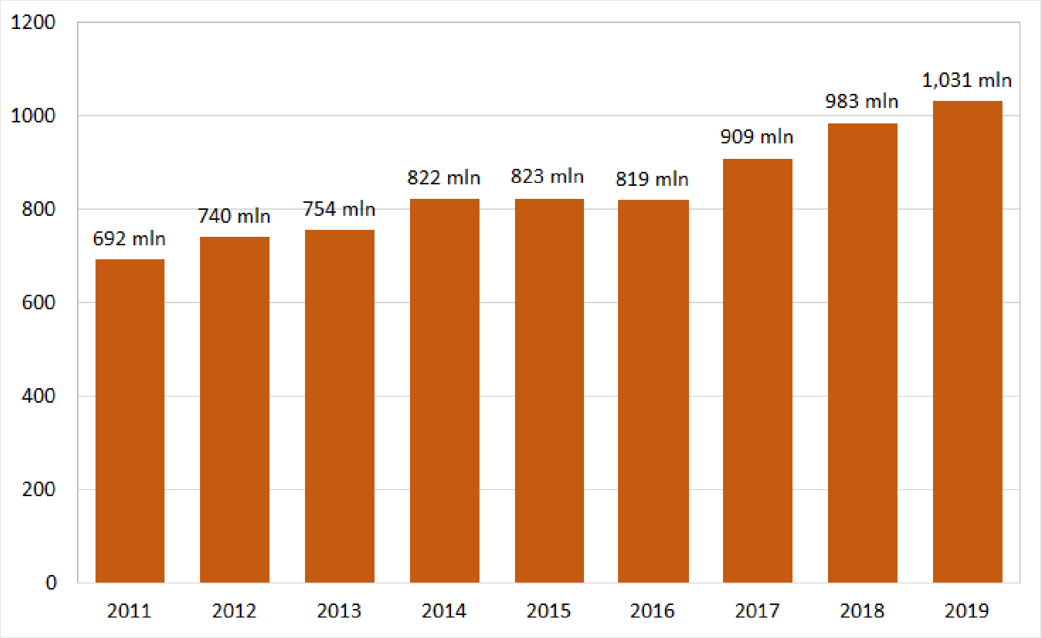


Figure 35. Cargo tons per year transiting though the Suez Canal in the two direction. Data source: SCA – Suez Canal Authority [33].

Figure 36. The Belt and Road Initiative. Source: Cai, 2017 [34].

Beyond these two drivers, other factors will influence the future of maritime traffic in the Mediterranean: the competition of the Panama Canal which was expanded in 2016 with the Suez Canal (Boske and Harrison, 2017) [35], the evolution of the energy demand and the change in the energy mix, the implementation of the Trans-European Networks (TEN-T) initiative “Motorways of the Sea”, etc. (Piante and Ody, 2015) [20]. Maritime traffic in the Mediterranean basin is undoubtedly expected to increase, however all these elements make quantitative estimation of future projections an uncertain exercise.

According to Varone and Novario (2018) [36], the following trends can be expected in the future for the Mediterranean:

- An increase of the already relevant short-sea shipping component of the Mediterranean maritime traffic, including exchanges between Mediterranean countries.
- A growth in container ship trades (Figure 37). According to DOCKTHEFUTURE (2019) [41], container handling demand in Europe will grow between 2.7% and 3.1% in the short term (2018-2021): the Eastern Mediterranean/Black Sea market (together with Scandinavian/Baltic market) will be characterised by slightly higher rates (Figure 38).
- A strengthening of the already mentioned phenomenon of mega container ships.
- An increase also in the traffic of non-containerized goods, including oil, chemicals and LNG. Tanker traffic is expected to increase in particular in the Eastern Mediterranean, due to growing exporting routes from the Caspian and the Persian Gulf, including the expansion of existing pipelines and the construction of new ones (Piante and Ody, 2015) [20]. The growing demand for natural gas and the recent discovery of new large offshore gas reserves in the Eastern Mediterranean (see section 3.1.2) will also increase LNG shipping in the region.
- A substantial growth for passenger maritime traffic, driven by the increase of tourists in the region.

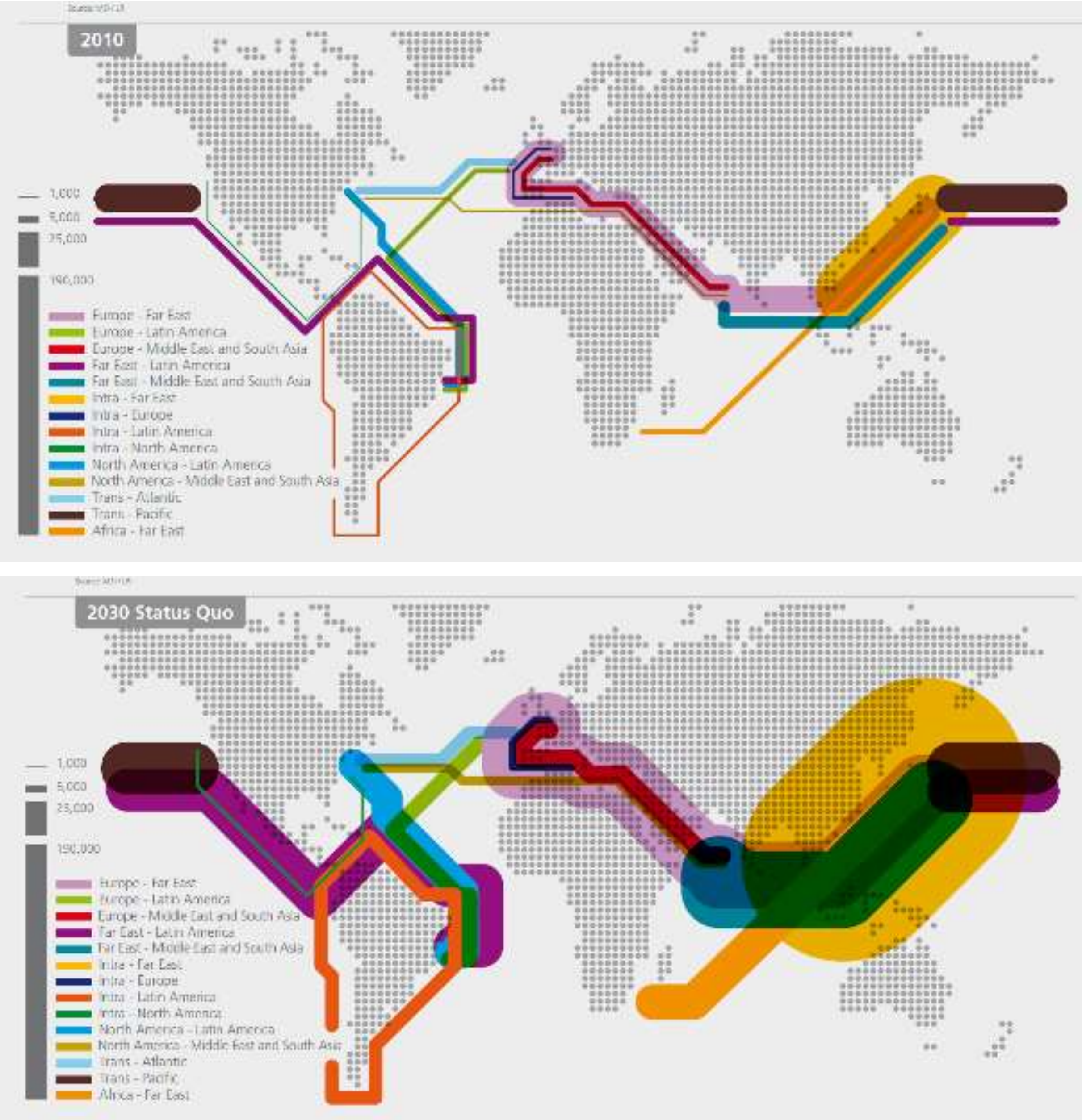
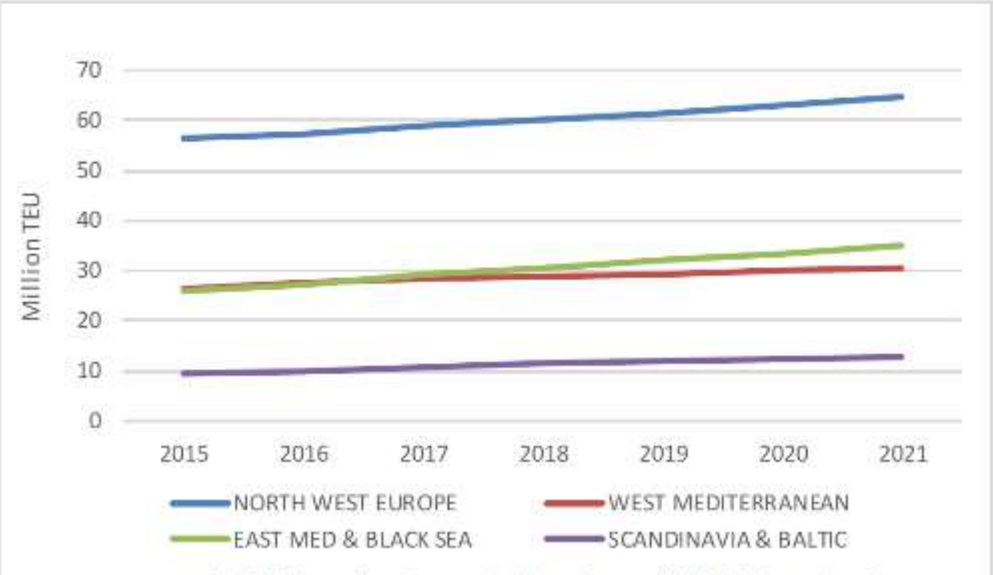


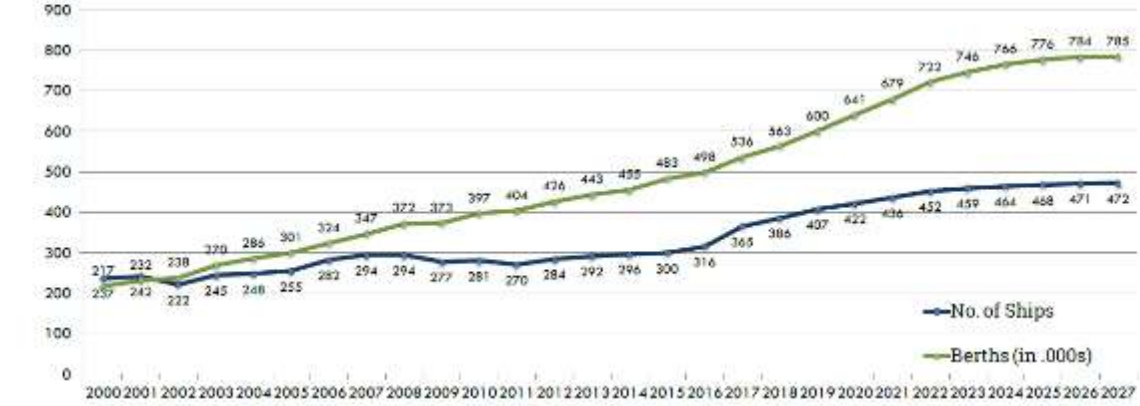
Figure 37. Seaborne container trade in 2010 and 2030 (thousand TEU). Source: Lloyd's Register, QinetiQ, and University of Strathclyde, 2013 [37].



ISL 2018 based on Drewry Maritime Research 2017Q3 Container Forecaster

Figure 38. Forecast of container growth by European Regions. Source: DOCKSTHEFUTURE, 2019 [41].

Eventually, MEDTRENDS highlight passenger traffic will continue increasing, as direct consequence of tourism growth in the region. Cruise tourism is likely to significantly increase too. The Mediterranean accounts for a growing share of the global cruises (17.3% in 2019, 16.7% in 2018), which is projected to further expand in the next years (MedCruise, 2018) [19] (Figure 39).



Source: Cruise Industry News 2018-2019 Annual Report

Figure 39. Global cruise fleet (ships and berths) in the period 2000-2027. Source: MedCruise, 2018 [19].

Long-term quantitative projections of seaborne trade in the Mediterranean have been developed very recently by REMPEC (2020) considering the same assumption used for the global scenarios illustrated at the beginning of this section. In 2019, dry bulk seaborne trade accounted for 34% of the total trade in the Mediterranean. Liquid bulk trade accounted for 41%, containerized general cargo trade for 14% and non-containerized general cargo trade for 7%.

In scenario 1, dry bulk seaborne trade will show the strongest growth in tonnes while containerized trade will grow the fastest. The growth in liquid bulk trade will slow down but will recover towards the end. Non-containerized general cargo trade will decline slightly (Figure 40). The shipments of crude oil and petroleum products dominate the liquid bulk trade with an 84% share of the total in 2019. Growth is expected to continue and reach a peak at around 2030. After the peak, crude oil volumes will decline all the way to 2050, while the product volumes will hold up a few more years before the decline. LNG seaborne trade is expected to steadily increase in scenario 1.

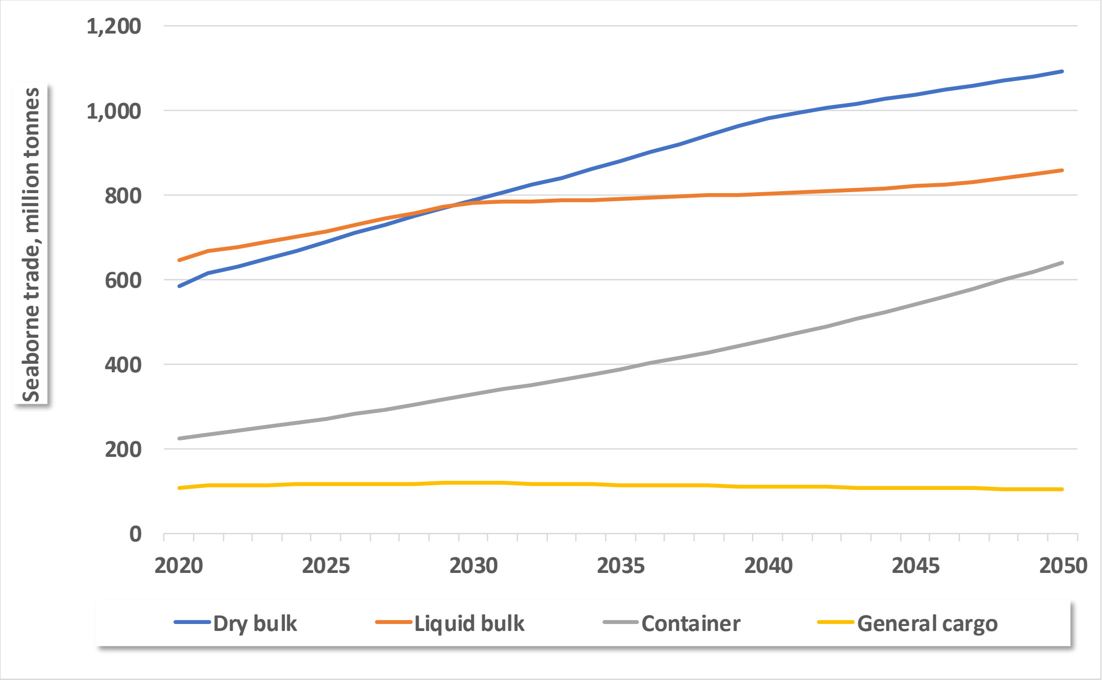


Figure 40. Mediterranean seaborne trade 2020-2050, scenario 1, million tonnes. Source: REMPEC (2020) [9].

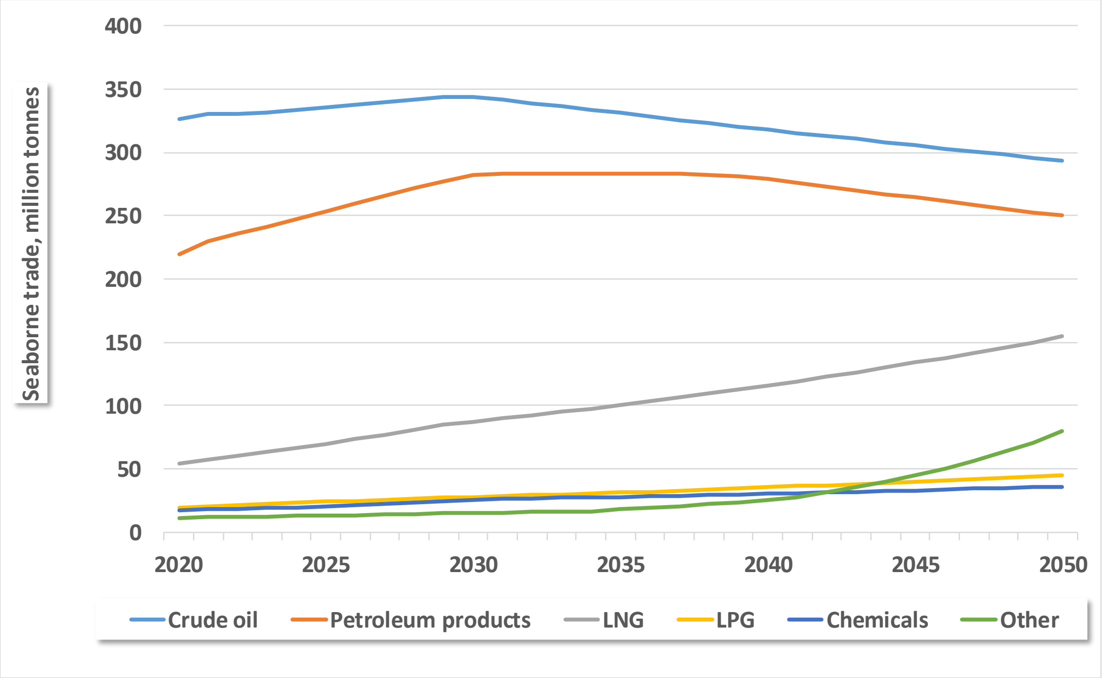


Figure 41. Mediterranean liquid bulk seaborne trade 2020-2050, scenario 1, million tonnes. Source: REMPEC (2020) [9].

In scenario 1, the average dwt-sizes of the ships grow for all vessel types. This does not mean that all the largest ships will increase in size. It is more a consequence of the fact that new ship deliveries are larger than the ships they replace. There is also an expectation that the efficiency of the fleet utilisation is improved over the next 30 years. This first and foremost the case for the container carriers.

In all the three future years (2025, 2030 and 2050) considered in the analysis, the overall Mediterranean fleet (including both vessels making port calls and those just transiting along the basin) will represent the 23% of the global fleet, a value very close to 2019 one (24%). The future number of port calls tend to decrease (by -11.2% in 2050; Table 9), while the number of transit is expected to increase (+38.2% in 2050; Table 10) confirming the role of the Mediterranean within the global maritime trade (in particular for container ships and bulk carriers). However, future trends differ for the different categories of vessels. Under this scenario, bulk carriers would experience an increase both in the number of port calls and transits. The number of port calls due to container ships are expected to be more or less constant, while their transit along the Mediterranean will significantly increase. Port calls of

Other dry and Ro-Ro cargos and those of tankers are expected to decrease, while their transit will keep more or less constant in the case of the first category of vessels or will increase in the case of tankers.

Table 9. Comparison of number of port calls in 2019, 2025, 2030 and 2050 – Scenario 1. Data Source: (REMPEC, 2020) [9]

	Port calls						
	2019	2025	Dif. 2025-2019	2030	Dif. 2030 - 2019	2050	Dif. 2050 - 2019
Bulk carriers	25,398	27,681	9.0%	32,837	29.3%	38,149	50.2%
Container ships	81,138	79,429	-2.1%	79,347	-2.2%	81,375	0.3%
Other Dry and Ro-Ro cargos	76,408	77,503	1.4%	74,586	-2.4%	54,766	-28.3%
Tankers	76,243	70,151	-8.0%	65,263	-14.4%	54,108	-29.0%
Passenger vessels	193,770	191,616	-1.1%	189,404	-2.3%	174,024	-10.2%
Total	**452,957**	**446,380**	**-1.5%**	**441,437**	**-2.5%**	**402,422**	**-11.2%**

Table 10. Comparison of number of transits in 2019, 2025, 2030 and 2050 – Scenario 1. Transit of passenger vessels are not considered as they are negligible in 2019 and null in the future years. Data Source: (REMPEC, 2020) [9]

	Transits						
	2019	2025	Dif. 2025 - 2019	2030	Dif. 2030 - 2019	2050	Dif. 2050 - 2019
Bulk carriers	1,016	1,152	13.4%	1,292	27.2%	1,589	56.4%
Container ships	1,954	2,044	4.6%	2,201	12.6%	3,031	55.1%
Other Dry and Ro-Ro cargos	559	540	-3.4%	534	-4.5%	577	3.2%
Tankers	1,720	1,697	-1.3%	1,837	6.8%	2,058	19.7%
Total	**5,249**	**5,433**	**3.5%**	**5,864**	**11.7%**	**7,255**	**38.2%**

Under scenario 2, the seaborne trade is expected to grow less than in scenario 1, from 1,658 million tonnes in 2019 to 2,059 million tonnes in 2050. The largest difference is in the liquid bulk trade which will be 343 million tonnes lower in scenario 2 than in scenario 1. The dry bulk trade is 187 million tonnes lower, the container trade 100 million tonnes lower while the general cargo trade is a mere 7 million tonnes lower.

While trade of dry bulks and containers are expected to increase, those of general cargo and liquid bulk in particular would decrease under this scenario (Figure 42). Crude oil and petroleum products are expected to decrease sharply by 316 million tonnes. Other liquid bulks, mostly biofuels, will increase by 83 million tonnes, LNG by 46 million tonnes and chemicals by 12.

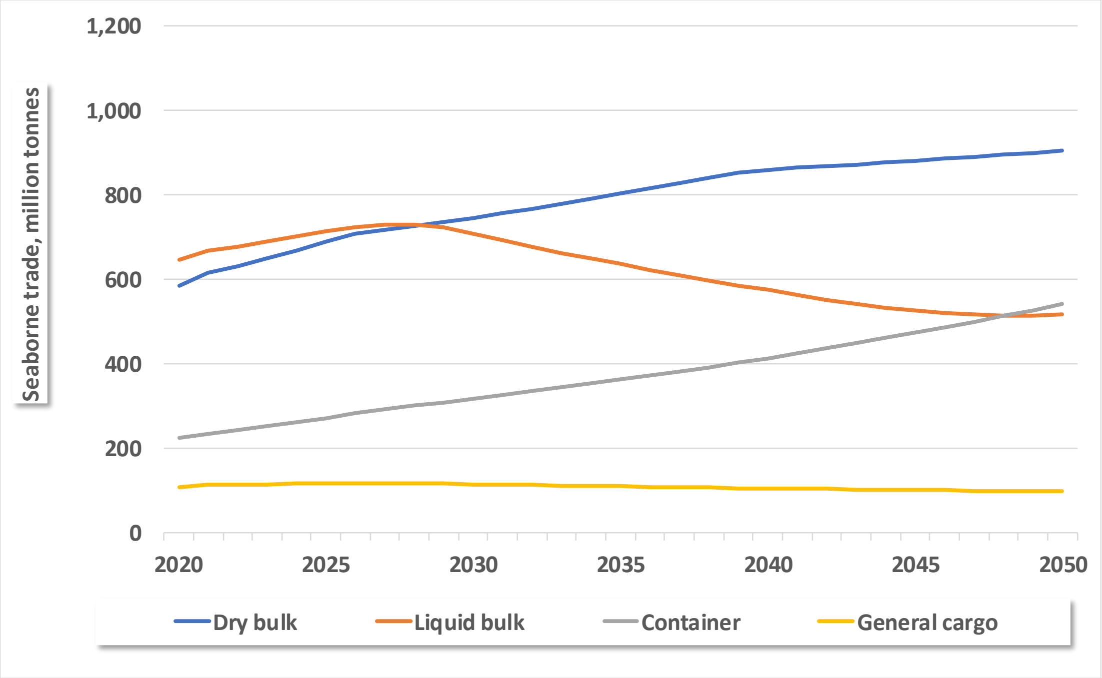


Figure 42. Mediterranean seaborne trade 2020-2050, scenario 2, million tonnes. Source: REMPEC (2020) [9].

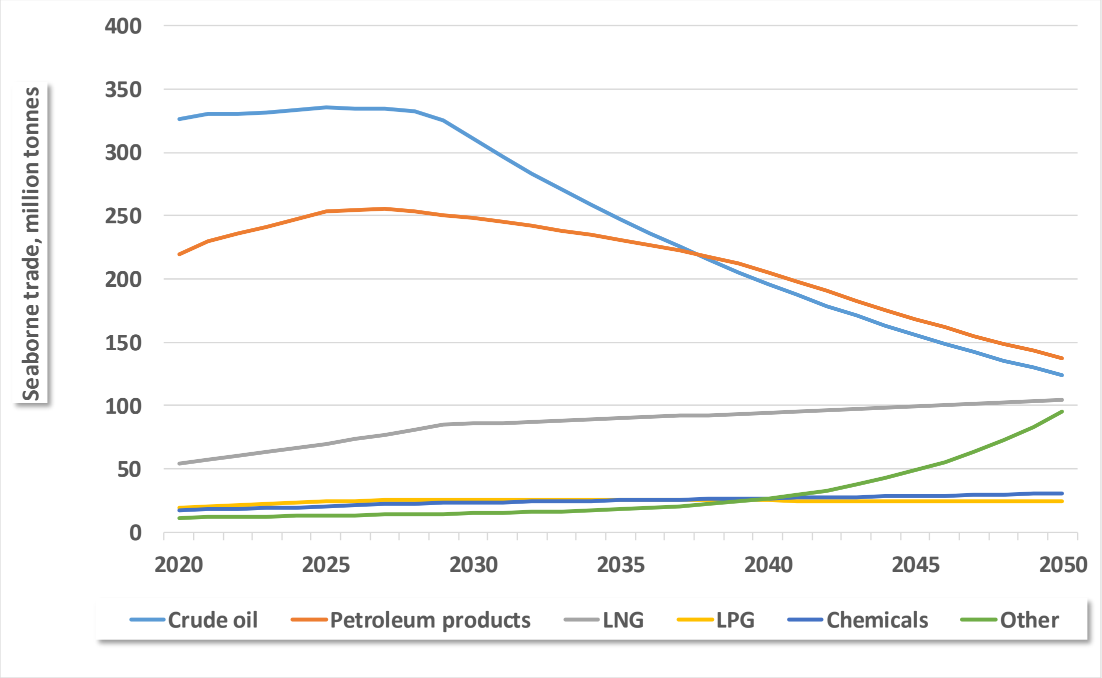


Figure 43. Mediterranean liquid bulk seaborne trade 2020-2050, scenario 2, million tonnes. Source: REMPEC (2020) [9].

The 2050 forecast in scenario 2 shows port call numbers that are 91,000 lower than in 2019 (Table 11) and clearly lower than projections for scenario 1 at 2050. There are some dramatic changes among vessel type and size ranges. There are about 12,500 fewer container carrier port calls (comparing 2050 with 2019), while tanker calls (in particular oil and chemical tankers' ones) are significantly lower (-52%). Under this scenario, coal shipments have decreased sharply, but the growth in the shipments of grain, steel and various minerals make up for the difference, determining an increase in port calls due to bulk carriers. Under scenario 2, the number of vessels that pass through the Mediterranean without calling a port is expected to be about the same as in 2019, with a slight increase (+6.8% at 2050) which is however much more limited that the once characterising scenario 1. Future number of transits tend to increase for bulk carriers and containers ships and to decrease for other dry and Ro-Ro cargos and in particular for tankers.

In all the three future years (2025, 2030 and 2050) considered in the analysis, the overall Mediterranean fleet (including both vessels making port calls and those just transiting along the basin) will represent the 23% of the global fleet, a value very close to 2019 one (24%) and equal to that of scenario 1.

Table 11. Comparison of number of port calls in 2019, 2025, 2030 and 2050 – Scenario 2. Data Source: (REMPEC, 2020) [9]

	Port calls						
	2019	2025	Dif. 2025 - 2019	2030	Dif. 2030 - 2019	2050	Dif. 2050 - 2019
Bulk carriers	25,398	27,681	9.0%	31,070	22.3%	31,619	24.5%
Container ships	81,138	79,429	-2.1%	76,340	-5.9%	68,678	-15.4%
Other Dry and Ro-Ro cargos	76,408	77,503	1.4%	71,516	-6.4%	51,133	-33.1%
Tankers	76,243	70,151	-8.0%	59,441	-22.0%	36,533	-52.1%
Passenger vessels	193,770	191,616	-1.1%	189,404	-2.3%	174,024	-10.2%
Total	**452,957**	**446,380**	**-1.5%**	**427,771**	**-5.6%**	**361,987**	**-20.1%**

Table 12. Comparison of number of transits in 2019, 2025, 2030 and 2050 – Scenario 2. Transit of passenger vessels are not considered as they are negligible in 2019 and null in the future years. Data Source: (REMPEC, 2020) [9]

	Transits						
	2019	2025	Dif. 2025 - 2019	2030	Dif. 2030 - 2019	2050	Dif. 2050 - 2019
Bulk carriers	1,016	1,152	13.4%	1,227	20.8%	1,244	22.4%
Container ships	1,954	2,044	4.6%	2,123	8.6%	2,555	30.8%
Other Dry and Ro-Ro cargos	559	540	-3.4%	520	-7.0%	537	-3.9%
Tankers	1,720	1,697	-1.3%	1,679	-2.4%	1,268	-26.3%
Total	**5,249**	**5,433**	**3.5%**	**5,549**	**5.7%**	**5,604**	**6.8%**

3.1.2 Offshore oil and gas

3.1.2.1 Overview

Offshore activities provide an important component of the global oil and natural gas production. More than a quarter of worldwide oil and gas supply is produced offshore, mainly in the North Sea, the Middle East, the marine area off Brazil, the Gulf of Mexico and the Caspian Sea. At global level, oil offshore production has been stable since 2000, while offshore natural gas production has consistently increased (by more than 50%) (Figure 44) (IEA, 2018) [45]. Figure 44 also shows that offshore oil production has partially moved to deep-water to keep supply around 25 mb/d. In the past decade, the largest oil and gas offshore fields have been discovered in deep-water (water depth above 400 m), which also accounted for more than 50% of the discovered conventional oil and gas offshore reserves. More than half of the newly discovered offshore hydrocarbon resources were gas, including the large fields of Zohr and Leviathan in Eastern Mediterranean (IEA, 2018) [45].

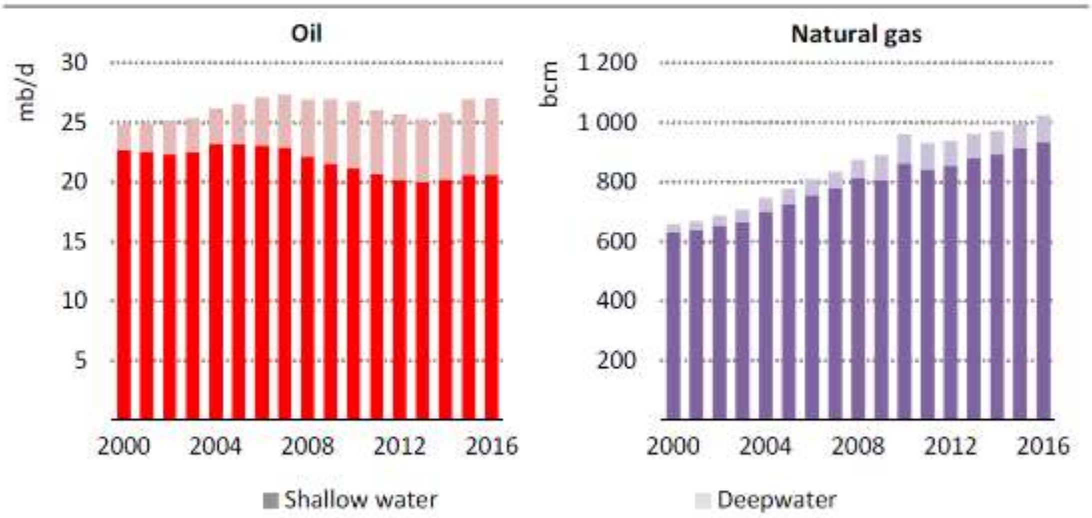


Figure 44. Trend of global offshore oil and natural gas production in the period 2000 – 2016 (mb/d = million barrels per day; bcm = billion cubic meters. Source: IEA (2018) [42].

Compared to other regions, the Mediterranean Sea can be considered a relatively small producer of offshore oil and gas, although the history of such activity goes back to the beginning of the twentieth century (Kostianov and Carpenter, 2018) [43]. Today, main offshore oil producers in the Mediterranean are Egypt and Libya. Indeed, as further discussed below, in the case of Egypt the great majority of offshore oil fields and the biggest ones (e.g. El Morgan, 2,700 mmbbl of oil reserve; October, 1,150 mmbbl; Ramadan, 1,000 mmbbl) are located in the Gulf of Suez[7] (see Figure 49 and Table 13). Other countries such as Italy and Tunisia (and to a minor extent Greece and Spain) contribute with a more marginal production (Figure 56). Egypt is also the main offshore gas producer in the Mediterranean (major and most fields are located in front of the Northern coast of the country), historically followed by Italy. In recent years the Italian production of offshore natural gas significantly decreased, while the production of Israel has greatly increased, in particular thanks to the discovery of and production in the rich Leviathan gas field (Figure 58). Libya, Croatia and Tunisia contribute marginally to the offshore production of natural gas in the Mediterranean basin. However, in the next years other Eastern Mediterranean countries are expected to enter significantly as producers in the offshore gas market; this is for example the case of Cyprus where big offshore gas fields have been recently discovered.

According to the database available through the Clarksons Research Offshore Intelligence Network (OIN), which has been used in this Study, other Mediterranean countries do not have significant offshore oil and/or gas production in place. Some of them had drilling activities in the past (e.g. France and Cyprus) or plan to start drilling activities in the future (e.g. Cyprus and Malta) (Piante and Ody, 2015) [20]. Oil and gas exploration occur also along the coasts of other Mediterranean states, such as Algeria and Turkey (Kostianov and Carpenter, 2018) [43].

Four major areas of oil and gas production can be currently identified in the Mediterranean basin: (i) the Southern Levantine Sea where Egyptian and Israeli offshore production occur (mainly gas), (ii) the Channel of Sicily (Italian and Tunisian activities), (iii) the Gulf of Gabes (Tunisia) and the neighbouring Libyan marine area, and (iv) the northern Adriatic, where most of the Italian offshore gas activities are concentrated and where Croatian gas production is located. Greek offshore oil and gas activities are concentrated in the marine area facing Kavala, in the northern Aegean, while Spanish offshore oil production occurs in the fields offshore of Tarragona. Concession contracts have been signed for drilling in the waters of Montenegro in 2016 with drilling scheduled to begin in February 2021 (previously scheduled for August 2020 but postponed due to COVID-19 crisis).

Clarksons Research recently (January 2020) published a detailed map of oil and gas activity and concession in the Mediterranean. The following figures, extracted from the Clarksons Research map, illustrate offshore oil and gas activities in the four main areas of the Mediterranean. Given its importance for the Egyptian oil production and considering its direct connection (through the canal of Suez) with the Mediterranean, the map of offshore activities in the Gulf of Suez is also reported (Figure 49). Figure 50 illustrates the legend in common to all maps.

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[7] Data available in the Clarksons Research Offshore Intelligent Network (OIN) database enables to discriminate Egyptian offshore fields located in the Mediterranean from those in the Gulf of Suez. However, oil and gas production data are aggregated and cannot be used to distinguish among the two different areas of offshore activity.

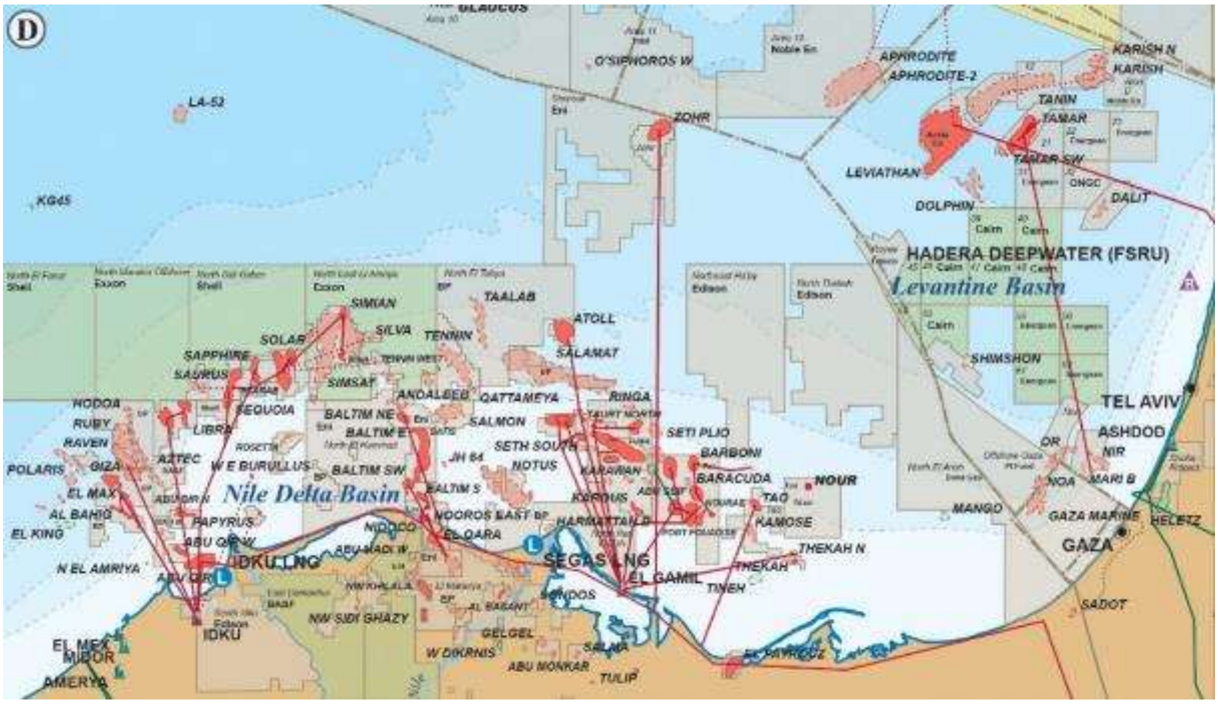

Figure 45. Oil and gas activity and concession in the Southern Levantine Basin. Source: Clarksons Research OIN, map data correct as January 2020.

Figure 46. Oil and gas activity and concession in the Channel of Sicily. Source: Clarksons Research OIN, map data correct as January 2020.

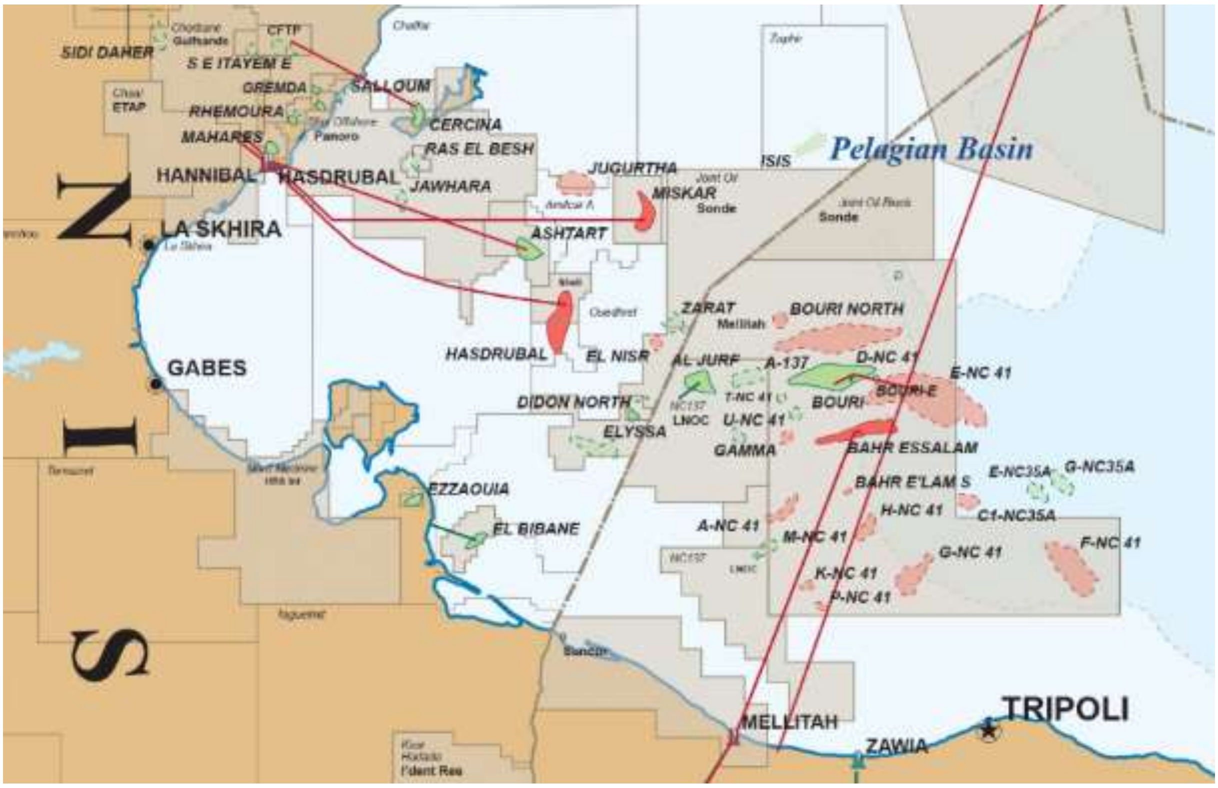

Figure 47. Oil and gas activity and concession in Gulf of Gabes (Tunisia) and the neighbouring Libyan marine area. Source: Clarksons Research OIN, map data correct as January 2020.

Figure 48. Oil and gas activity and concession in the Northern Adriatic. Source: Clarksons Research OIN, map data correct as January 2020.

Figure 49. Oil and gas activity and concession in the Gulf of Suez. Source: Clarksons Research OIN, map data correct as January 2020.

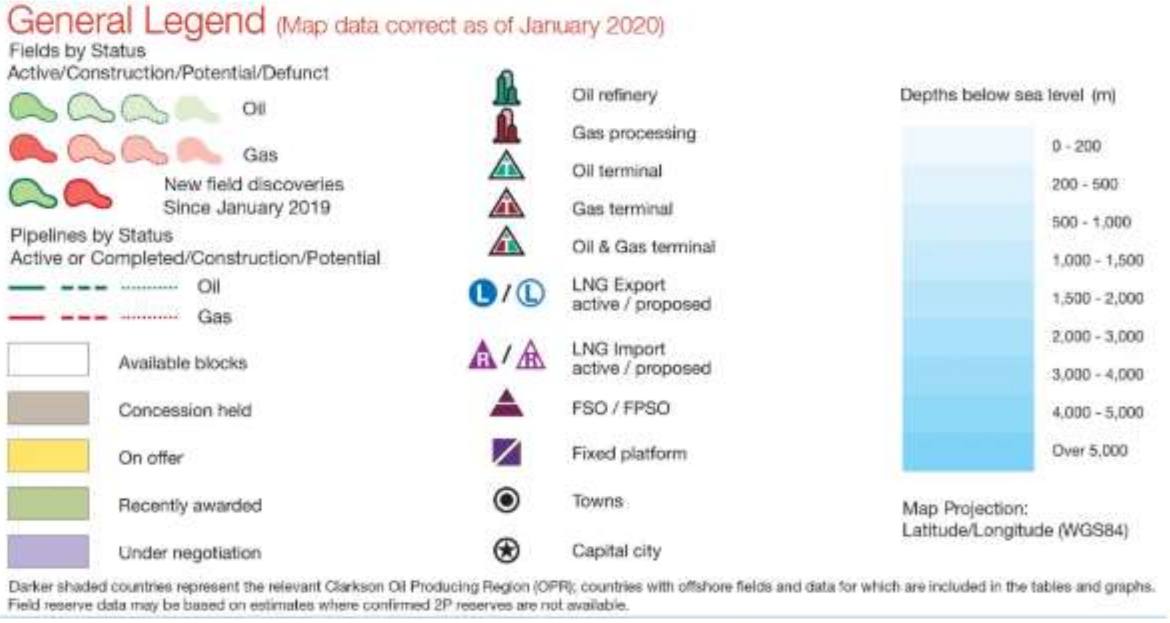

Figure 50. Legend of maps from Figure 45 to Figure 48. Source: Clarksons Research OIN, map data correct as January 2020.

Clarksons Research OIN records a total number of 323 offshore fields in the Mediterranean; the majority of fields are gas reservoirs (243). The analysis of fields' distribution confirms that most of the oil production is concentrated in the Gulf of Suez. Numbers reported in Table 13 have been extracted from the "Fields & Platforms" database included in OIN, selecting all fields per country. Typology of fields (gas, oil and mixed oil and gas) has been checked for each single field, as this information is not provided in the overall table that can be exported for each country.

The status of oil, gas and mixed fields in the Mediterranean (thus considering only the fields located in this basin) is visualised in the graphs from Figure 51 to Figure 53. 44% of gas fields are in the production status, while another 36% are classified as "discovery". 33% of oil fields and 50% of mixed fields are considered in production, with still a significant portion categorised as "discovery" (respectively 47% and 33%). Out of the 78 fields recorded in the Gulf of Suez (all oil or mixed oil/gas fields), 58 (74%) are considered under production.

Table 13. Number of oil and gas offshore fields for each Mediterranean country. Note that some of the countries own fields which are located outside the Mediterranean; related numbers are provided for completeness of the information. The total number of Mediterranean fields consider those located within the basin (marine areas highlighted in blue). Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

Country	**Marine area**	**Gas fields**	**Oil Fields**	**Oil and Gas Fields**	**Total**
Albania	Adriatic Sea	1	0	0	1
Croatia	Adriatic Sea	9	0	0	9
Cyprus	Eastern Mediterranean	4	0	0	4
Egypt	Gulf of Suez	0	66	12	78
Egypt	Eastern Mediterranean	90	3	3	96
France	Atlantic coast	0	4	0	4
Greece	Aegean Sea	2	6	0	8
Greece	Ionian Sea	0	0	1	1
Israel	Eastern Mediterranean	14	0	1	15
Italy	Adriatic Sea	92	7	4	103
Italy	Ionian Sea	4	0	0	4
Italy	Central Mediterranean	3	6	1	10
Lebanon	Eastern Mediterranean	1	0	0	1
Libya	Central Mediterranean	15	7	3	25
Morocco	Atlantic coast	1	3	0	4
Spain	Atlantic coast	2	0	0	2
Spain	Western Mediterranean	1	12	0	13
Tunisia	Central Mediterranean	7	19	5	31
Turkey	Black Sea	10	0	0	10
Turkey	Marmara Sea	1	0	0	1
Turkey	Eastern Mediterranean	0	2	0	2
Total in the Mediterranean Sea		243	62	18	323
Total		257	135	30	422

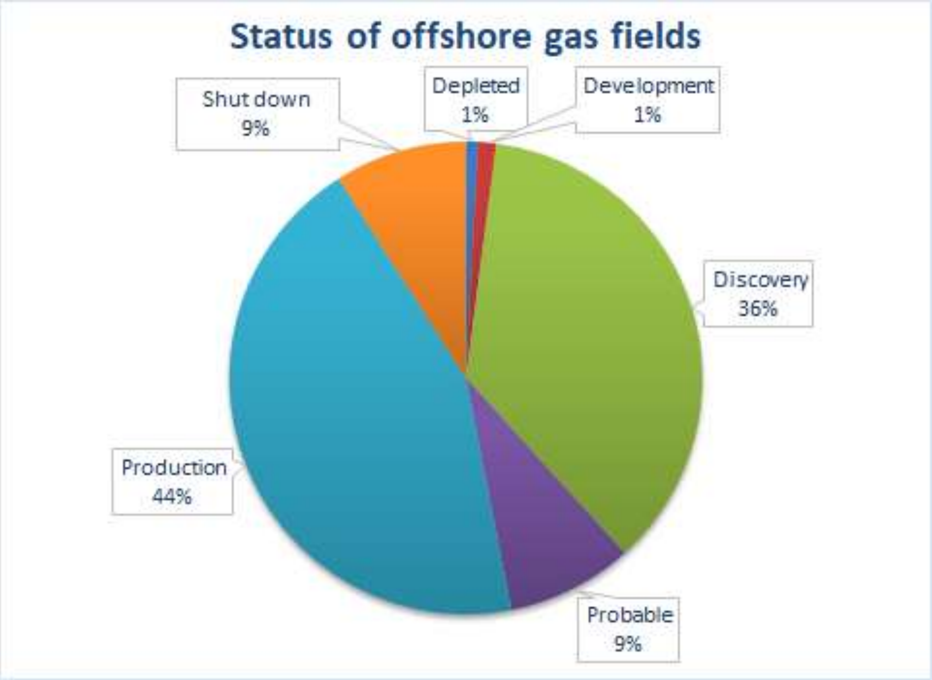

Figure 51. Status of offshore gas fields in the Mediterranean. Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

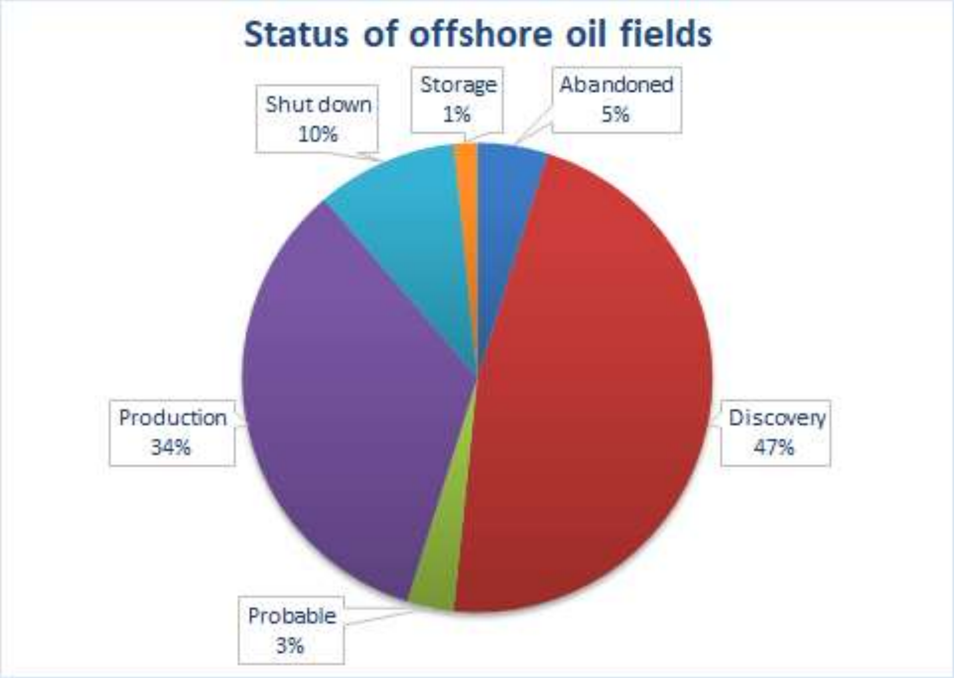

Figure 52. Status of offshore oil fields in the Mediterranean. Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

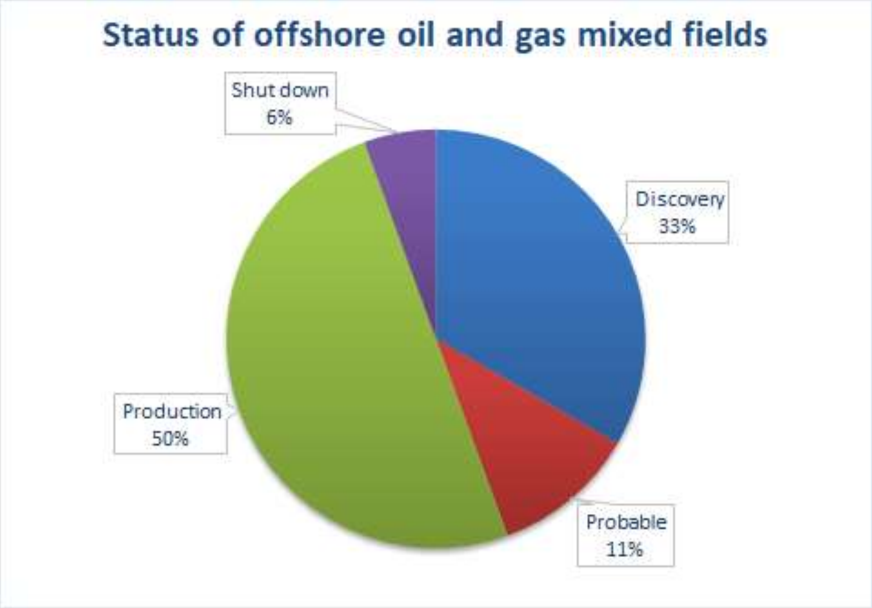

Figure 53. Status of offshore oil and gas mixed fields in the Mediterranean. Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

The great majority of known offshore fields is concentrated in shallow water, defined by the Clarksons Research OIN as areas with a depth < 500 m: 81% for gas fields, 95% for oil fields and 72% for mixed fields. Indeed, a consistent quota of shallow fields are located in areas with a depth lower than 100 m (respectively 65%, 58% and 55%). All the 78 recorded oil or mixed fields of the Gulf of Suez are located in very shallow water (maximum depth 85 m, average depth 38 m). In relative terms, a significant number of gas fields (32) occur in deep-water and even ultra-deep-water (13). This is due to the recent expansion of the sector at major depths, in particular in the Levantine Sea where biggest gas reserves, recently discovered, are located, including: Zohr (Egypt, 1,450 m, 22,000 bcf, discovered in 2015), Leviathan (Israel, 1,645 m, 21,930 bcf, discovered in 2010), Tamar (Israel, 1,677 m, 10,970 bcf, discovered in 2009), Karish North (Israel, 1,750 m, 9,000 bcf, discovered in 2019), Calypso (Cyprus, 2,074 m, 7,000 bcf, discovered in 2018) and Glaucus (Cyprus, 2,063 m, 4,550 bcf, discovered in 2019). The tendency of the gas sector to move to higher depth is also evident from Figure 54.

A similar tendency is not detected for oil fields. The number of deep-water (6) and ultra-deep-water fields (2) containing oil (including mixed ones) is very limited. Moreover, the offshore oil sector did not register major discoveries after 2010 (Figure 54; in 2010 the Leviathan field including 600 mmbbl of oil was discovered).

Table 14. Number of offshore fields in shallow water (< 500m), deepwater (< 500 m and < 1500 m) and ultra-deepwater (< 1500). Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

	Number	**Average depth**
Gas - Shallow water	198	80
Gas - Deepwater	32	832
Gas - Ultra deepwater	13	1790
Oil - Shallow water	59	93
Oil - Deepwater	3	808
Oil - Ultra deepwater	0	0
Oil/Gas - Shallow water	13	77
Oil/Gas - Deepwater	3	690
Oil/Gas - Ultra Deepwater	2	2044

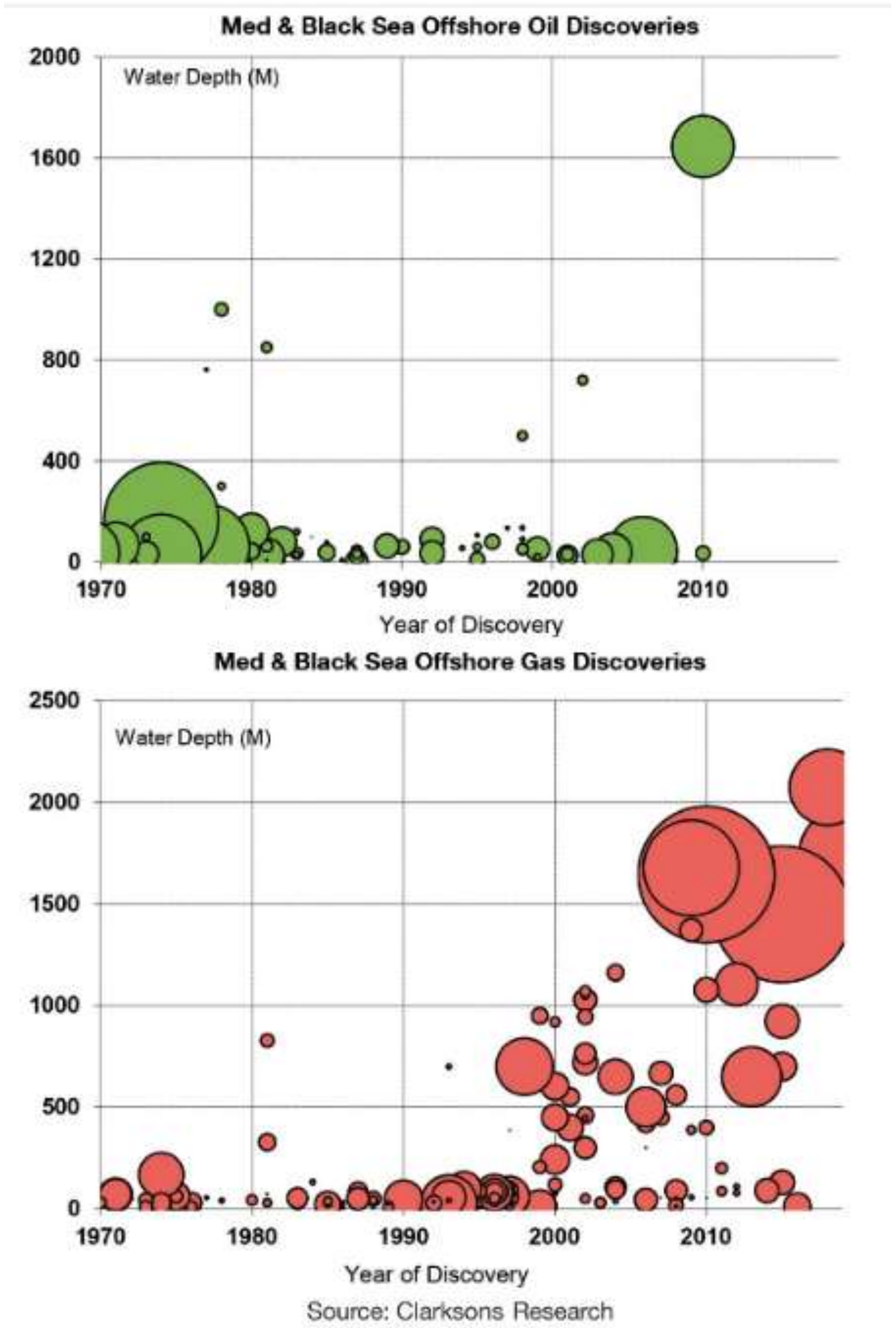

Figure 54. Offshore oil and gas discovery in the Mediterranean; the size of circles is proportional to the size of discovered field. Source: Clarksons Research OIN, graph included in the Mediterranean Oil and Gas Map; data January 2020.

The great majority of known fields (230) is located beyond 12 nautical miles (usually the limit of territorial waters), including 20 fields which are located further than 100 km from the coast. Actually, the distribution of fields in nearshore (<12 nautical miles) and offshore (>12 nautical miles) waters change according to the characteristics of the different marine sub-basins. In the narrow and relatively shallow Adriatic Sea, about 41% (46 out of 113) of know fields are located nearshore. In the Eastern Mediterranean, fields out of the 12 nautical miles represent 88% (104 fields out of 118). All offshore fields but one in the Gulf of Suez are located nearshore, due to the geomorphological conformation of this marine area.

The Clarkson Research OIN database provides data on volumes of oil and gas reserves, although just for less than 50% of the recorded offshore fields. Table 15 and Table 16 illustrate the distribution of gas and oil fields by classes of reserve volumes in the Mediterranean Sea, considering only fields which are classified in the discover, production, development or probable status. The analysis of available data shows that a great number of oil fields are of small dimension (30.4% have reserves between 1 and 50 mmbbl), while gas fields tend to be more homogenously distributed among classes of reserve volumes.

Table 15. Number and percentage of oil fields by classes of volume of oil reserves; data are expressed in millions of barrels (mmbbl). Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

	Number of fields	**% of fields**
No data	36	52.2%
1 - 50 mmbbl	21	30.4%
51 - 100 mmbbl	2	2.9%
101 - 200 mmbbl	5	7.2%
201 - 500 mmbbl	3	4.3%
> 500 mmbbl	2	2.9%

Table 16. Number and percentage of gas fields by classes of volume of gas reserves; data are expressed in billion cubic feet (bcf). Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

	Number of fields	**% of fields**
No data	123	52.1%
1 - 100 bcf	31	13.1%
101 - 500 bcf	37	15.7%
501 - 1000 bcf	19	8.1%
1001 - 5000 bcf	22	9.3%
> 5000 bcf	4	1.7%

Offshore platforms are structures including facilities for exploring, extracting, storing and even processing oil and gas contained in offshore fields. Larger fields can host more than one platform. Clarkson Research OIN registers 432 offshore platforms in the Mediterranean Sea and the Gulf of Suez (differently from offshore fields, data on Egyptian offshore platforms are not disaggregated for the two areas) (Table 17). The great majority of platforms is owned by Egypt (53%) and Italy (33%). The vast majority of the platforms are still active (375, 86.8%), while 43 platforms (9.9%) are categorised as “shut down”. A marginal number of platforms are in a different status: decommissioned (3 platforms in Italy), installed (2), probable (7), total loss (1) and under construction at yard (1).

Table 17. Number of offshore platforms for each Mediterranean country. Note that Egypt incudes platforms located both in Eastern Mediterranean and in the Gulf of Suez. Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 08.06.2020.

Country	**Number of platforms**
Croatia	20
Egypt	229
Greece	7
Israel	3
Italy	143
Libya	7
Spain	3
Tunisia	19
Turkey	1

3.1.2.2 Oil and gas pipelines

The Mediterranean seabed is furrowed by numerous pipelines. Many of these pipelines connect offshore gas and to a minor extent offshore oil platforms and fields to the mainland. EU Mediterranean countries are an important transit zone for oil and gas, linking Northern African – and in the future Eastern Mediterranean – production to the European demand. Oil is mainly shipped through tankers, while several natural gas pipelines lay on the Mediterranean seafloor) (Piante and Ody, 2015) [20], in particular:

- The Tangier (Algeria) – Tarifa (Spain) pipeline across the Gibraltar Strait. It is part of the Maghreb–Europe Gas Pipeline (MEG; also known as the Pedro Duran Farell pipeline), connecting the land-based Hassi R'mel field in Algeria through Morocco with Cordova in Spain. It supplies Spain, Portugal and Morocco with Algerian natural gas,

- The Megdaz pipeline; it begins in the Hassi R'mel field in Algeria and crosses the Alboran Sea between the port of Beni Saf (Algeria) and the city of Almeria (Spain).
- The Balearic pipeline, providing natural gas from the town of Denia in Spain to the Balearic Islands of Ibiza and Mallorca, thus integrating them into the Spanish gas system.
- The Trans-Mediterranean pipeline; this important infrastructure starts, as others mentioned above, from the Hassi R'mel field in Algeria, running to Tunisia, where, from the Cape Bon region it crosses the Channel of Sicily, reaching the Italian coast at Mazara del Vallo. From there, the pipeline continues along Sicily and across the Strait of Messina to reach northern Italy.
- The Greenstream pipeline, running from western Libya to the port of Gela in Sicily (Italy).
- The Arish-Ashkelon pipeline, connecting the Arab Gas pipeline with Israel. This latter originates near Arish and is a system of overland pipelines exporting the Egyptian gas to Jordan, Syrian Arab Republic and Lebanon, with branches of underwater and overland pipelines to and from Israel. The Arish-Ashkelon pipeline is actually the underwater branch of this complex system connecting the two countries of Egypt and Israel.

Shorter natural gas pipelines connect offshore LNG terminals to the mainland, as in the case of the FSRU Toscana LNG terminal in front of the Italian coast between Livorno and Pisa and the Adriatic LNG terminal located in front of the Po delta in Italy.

In addition to the existing ones, other important pipelines are planned to increase gas supply to Europe:

- The Eastern Mediterranean pipeline (EastMed) aims to connect the big natural offshore gas fields of the Levantine basin (in particular the Leviathan and Aphrodite fields respectively in Israel and Cyprus) to Greece mainland through Cyprus and Crete. The overall project foresees also the construction of an extension of the pipeline (called Poseidon), crossing the Ionian Sea from Igoumenitsa in Greece to Apulia region in Italy.
- The Trans-Adriatic pipeline (TAP) is a project aiming to link Italy (and potentially the rest of the Western Mediterranean) to the rich gas reserves of the Caspian Sea. The underwater branch of the pipeline shall connect Apulia region in Italy to Albania. From there, the overland pipeline shall continue crossing northern Greece until the border with Turkey, where it is expected to be connected with the existing Trans Anatolian pipeline (TANAP) and from this to the South Caucasus pipeline.
- Finally, GALSI (in Italian: Gasdotto Algeria Sardegna Italia) is a planned mixed submarine and overland pipeline which shall export Algerian gas to northern Italy through an alternative route to already existing ones. The planned pipeline would start from the Hassi R'mel field in Algeria. The first underwater section would connect the Algerian coastline with southern Sardinia in Italy. Then, the pipeline would cross Sardinia, to be submerged again between Olbia (Northern Sardinia) and Piombino in Tuscany.

A part from pipelines connecting offshore fields to the mainland, no major oil submarine pipelines are present in the Mediterranean Sea.

Figure 55. Active and proposed oil and gas pipelines in the Mediterranean. Source: Clarksons Research OIN; map retrieved on 09.06.2020.

3.1.2.3 Historical trends

Clarksons Research OIN database provides historical data of offshore oil and gas production for the “Mediterranean producing region”, encompassing the Mediterranean, Black and Caspian Seas (Clarksons Research, 2020) [44]. To produce historical trends focused on the Mediterranean only, national data on oil and gas production has been retrieved from the Clarksons Research dataset. According to this dataset, in the period 1980 - 2019:

- The following countries show offshore production of both oil and gas in the Mediterranean: Egypt, Italy, Libya and Tunisia. Egyptian data provided by Clarksons Research includes oil and gas offshore production both in the Mediterranean Sea and in the Gulf of Suez. Productions coming from the two Egyptian marine regions cannot be distinguished; therefore, the reconstructed Mediterranean historical trends include both areas.
- Greece and Spain have offshore production of oil but not of gas;
- Israel and Croatia have offshore production of gas but not of oil.
- The following countries do not have any offshore production: Algeria, Albania, Bosnia and Herzegovina, Cyprus, Lebanon, Malta, Monaco, Montenegro, Morocco, Slovenia and Syrian Arab Republic.
- In France, offshore oil production comes from fields located in the Bay of Arcachon and neighbouring areas. French offshore production data have thus not been used to elaborate historical trends in the Mediterranean.
- Turkish offshore gas production is located in the Black Sea (being also marginal if compared to other countries). This offshore production data has therefore not been considered for the development of the Mediterranean time series.

The graph in Figure 56 reproduces the historical trend of offshore oil production in the Mediterranean Sea. In the period 1980-2019, the offshore oil production has shown a fluctuating trend, with a peak in the early 90s of the last century, followed by a decreasing trend between 1991 and 2001. Since 2001, production shows a marked variability and varied between a minimum of about 387,100 bpd (2016) and a maximum of about 532,300 bpd (2008), with an average value of 473,800 bpd. At global level (Figure 57), production has remained substantially stable since 2001, around an average value of 25,340,000 bpd. The comparison of the two historical series (Mediterranean and global) also confirms the marginal role played by the Mediterranean Sea in terms of offshore oil production (1.9% on average in the period 2001-2019). Egypt and Libya are the two leading producers for the time series. Egypt shows a more stable trend, while Libyan production is characterized by a larger variability, in particular after 2011, due to geopolitical circumstances. Italy, Tunisia, Greece and Spain are characterized by a decreasing trend. For these two latter countries, production of offshore oil was very limited in the last decade (about 2,100-2,200 bpd yearly).

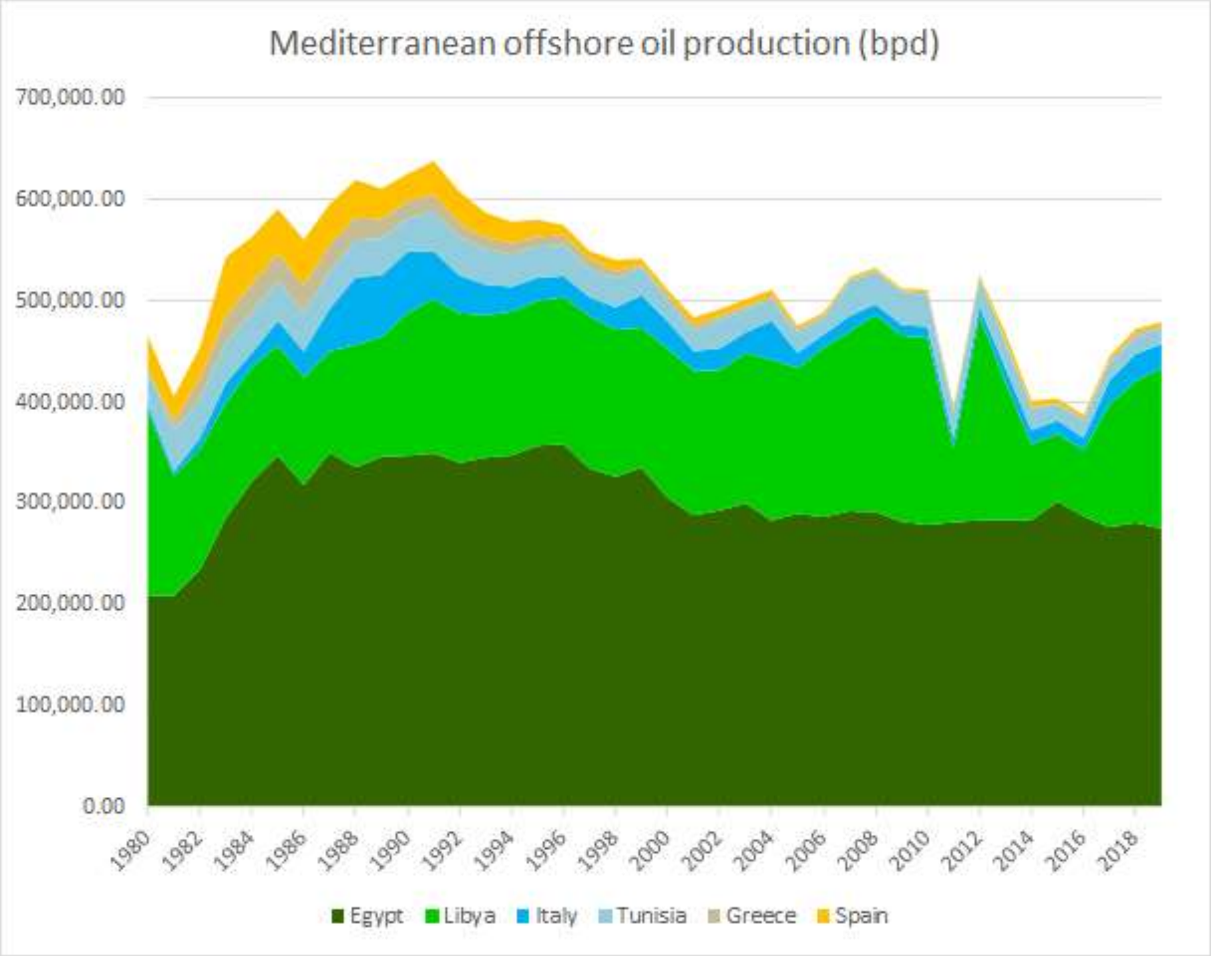

Figure 56. Trend of offshore oil production in the Mediterranean Sea (bpd = barrels per day). Data source: Clarksons Research Offshore Intelligent Network. Data retrieved on 29.06.2020.

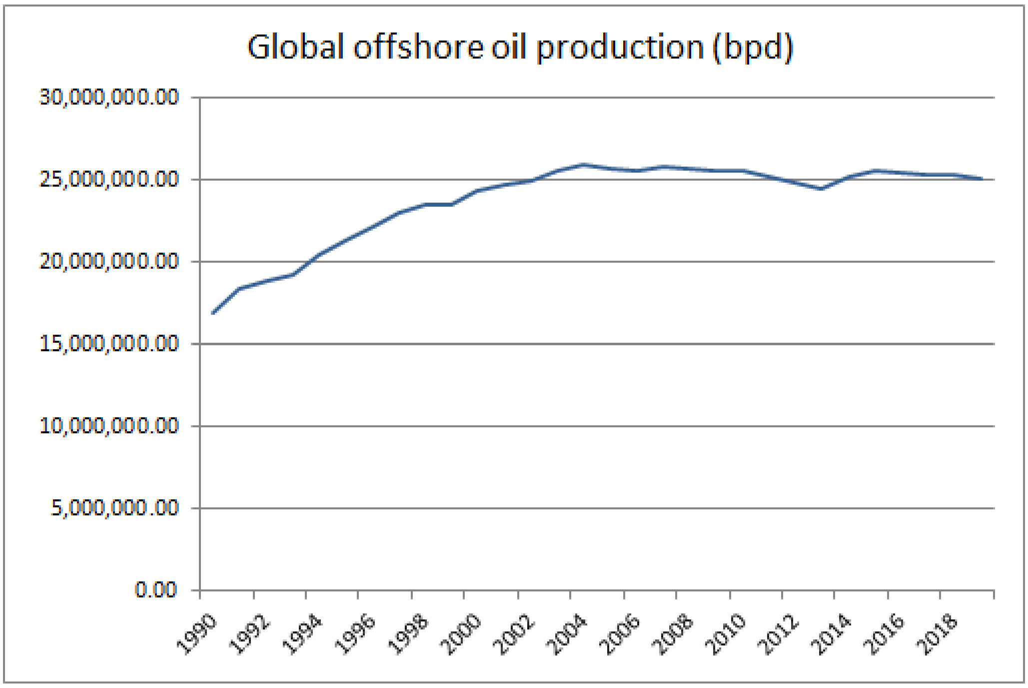

Figure 57. Trend of global offshore oil production (bpd = barrels per day). Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 04.06.2020.

The graph in Figure 58 reproduces the historical trend of offshore gas production in the Mediterranean. In the period 1980-2019 the offshore gas production shows a clear and marked increase. In the first decade of the period, Italy was the major offshore gas producer of the Mediterranean. Successively, it was largely surpassed by Egypt, which shows a marked increase in production at the beginning of the current century. The Egyptian historical trend is characterized by a sharp decrease between 2012 and 2016 and a successive rapid increase in the following years, due also to the discovery of large fields in the Eastern Mediterranean, such as Zohr (discovered in 2015 and entered in production in 2017) with an estimated gas reserve of about 22,000 bcfd. At the Mediterranean scale, the marked decreased of Egyptian offshore gas production between 2012 and 2016 was partly offset by Israel. This new player came into the scene in 2013 and gradually increased its gas production, thanks to the discovery of big gas fields, as in particular Tamar – the first ultra-deep field in the Mediterranean - with an estimated gas reserve of about 1,677 bcfd (discovered in 2009 and entered in production in 2013) and Leviathan with an estimated gas reserve of 1,645 bcfd (discovered in 2010 and entered in production in 2019).

The Mediterranean trend is coherent with the continuously increasing trend of offshore gas production at the global level and increased even more strongly (by 47 times in the last 30 years) than the global trend (by 3 times in the last 30 years) (Figure 59). Compared to the offshore oil production, the Mediterranean Sea plays a more significant role on global gas production. In the period 2005-2019, the Mediterranean offshore gas represents on average the 6% of the global production.

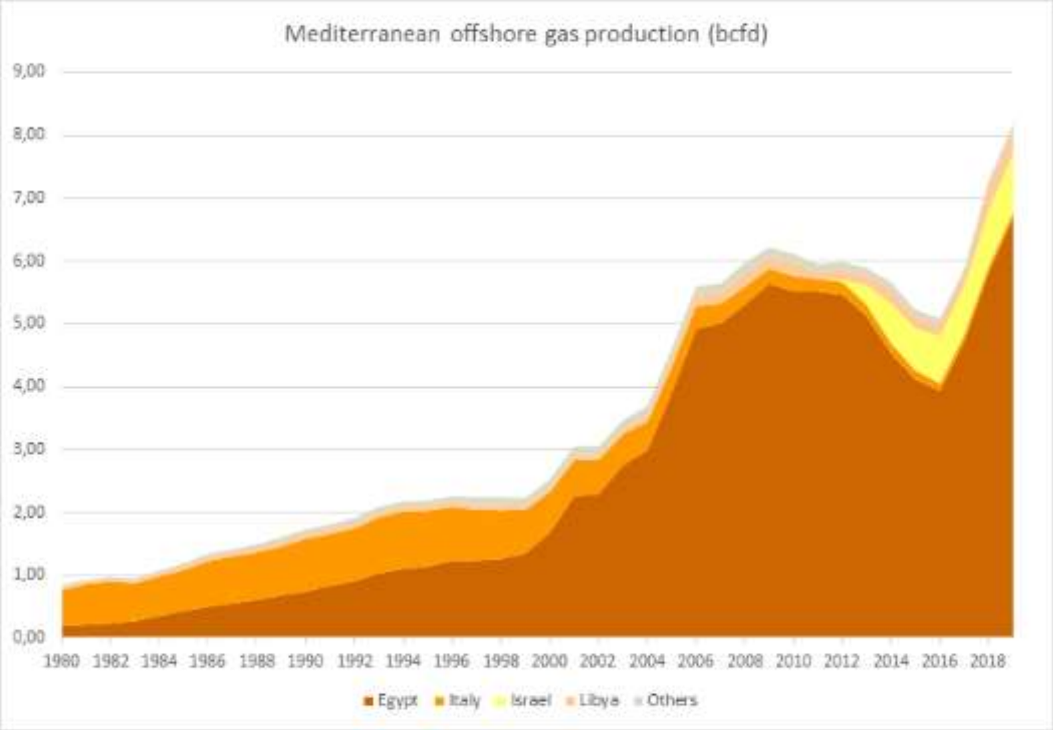

Figure 58. Trend of offshore gas production in the Mediterranean Sea (bcfd = billion cubic feet per day. Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 04.06.2020.

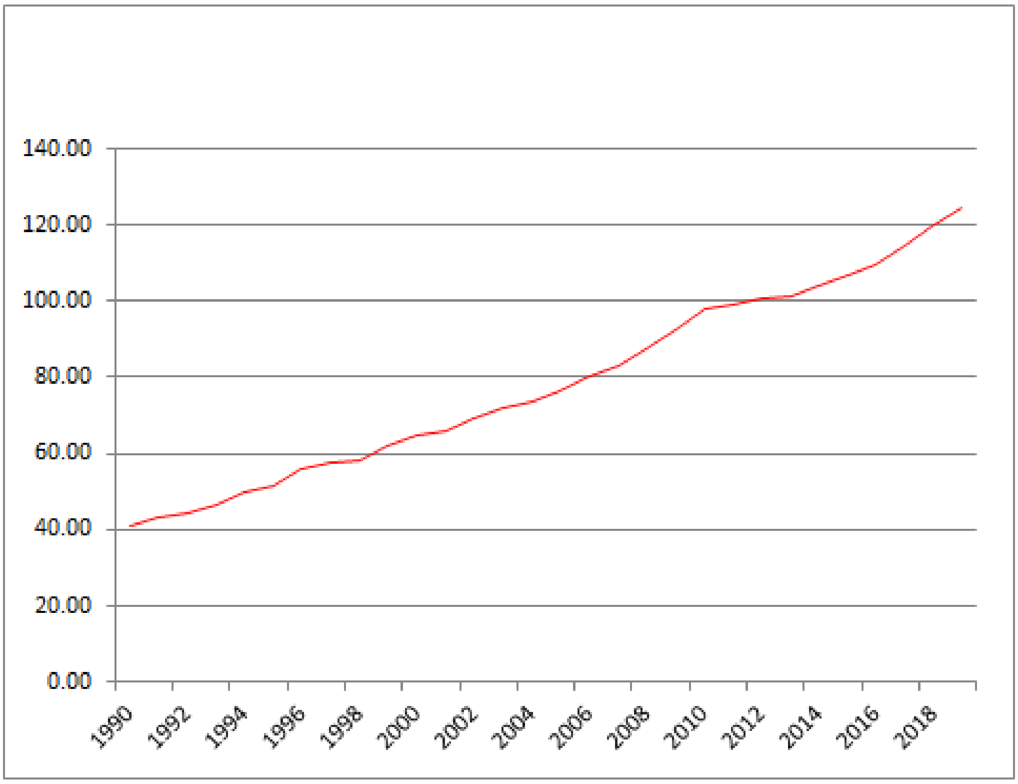

Figure 59. Trend of global offshore gas production (bcfd = billion cubic feet per day). Data source: Clarksons Research Offshore Intelligent Network, data retrieved on 04.06.2020.

3.1.2.4 Outlook

The definition of future scenarios and projections of offshore oil and gas production at the Mediterranean regional scale is not an easy exercise. Indeed, the available literature reports only partial and to some extent not homogenous information. The analysis is complex as it depends on various factors, including the global oil and gas demand and price, the costs of offshore oil and gas extraction compared to those of onshore activities (including those related to the "shale revolution"[8]), technological advancement, the outcomes of on-going and future exploration, the regulatory framework for offshore activities, the targets set by evolving environmental and energy-related policies and geo-political issues, particularly relevant for the Eastern Mediterranean (Piante and Ody, 2015 [20]; IEA, 2018 [45]).

At global scale, it is expected that offshore energy will continue playing a significant role in meeting the world's energy needs in the future. IEA (2018) [45] provides two alternative scenarios for offshore energy at 2040. The New Policies Scenario (NPS) considers the existing policy frameworks and announced intentions, while the Sustainable Development Scenario (SDS) deals with more ambitious, but still realistic, climate, air quality and energy access goals. Offshore gas production is expected to increase in both scenarios, although more for the NPS, while offshore oil production slightly increases under NPS and decreases under SDS (Figure 60). The NPS scenario projects a shift from shallow waters (due to the depletion of their fields) to deep water and even ultra-deep water for oil production (Figure 61).

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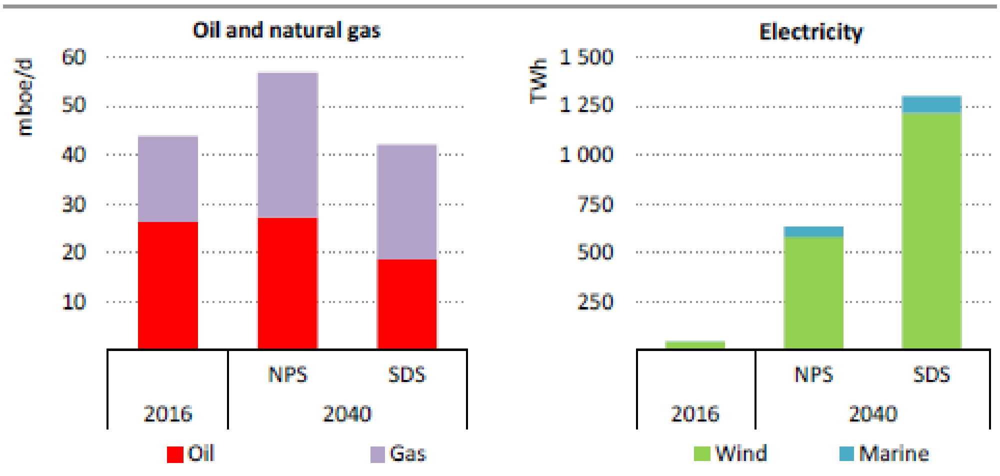
[8] The "Shale Revolution" refers to the combination of hydraulic fracturing and horizontal drilling that enabled (US in particular) the extraction of oil and natural gas from shale rock formations.



Offshore energy production remains robust in both scenarios, although the fortunes of oil, gas and wind power vary depending on the policies in place

Note: mboe/d = million barrels of oil equivalent per day.

Figure 60. Global offshore energy production by scenario. Source: IEA (2018) [45].

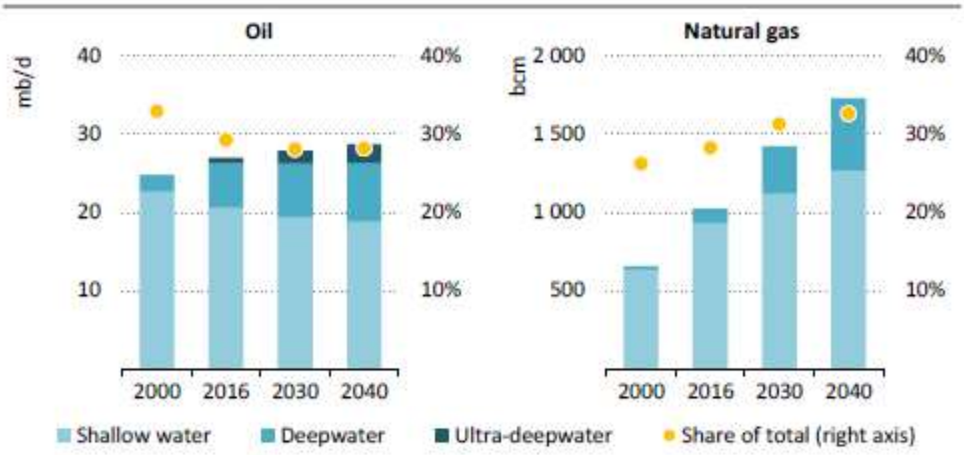


Figure 61. Global offshore oil and natural gas production by water depth in the NPS scenario. Source: IEA (2018) [45].

In the Mediterranean, offshore exploration is expected to further increase, in particular in the Eastern Mediterranean (Piante and Ody, 2015 [20]; Kostianoy A.G., and Carpenter A., 2018 [43]), as even demonstrated by the recently discovered big offshore gas fields in Israel, Egypt and Cyprus. According to the map in Figure 62, exploration contracts in 2015 covered 23% of the Mediterranean surface, while an additional 21% was covered by area for potential offshore oil and gas development (open areas) and areas with on-going calls for tenders (bid block areas) (Piante and Ody, 2015 [20]). The Levantine basin alone has been estimated to hold up to 3.45 trillion m^3 of recoverable natural gas and 1.7 billion barrels of recoverable oil. These resources are only partially exploited and their majority is concentrated in the offshore territories of Egypt, Cyprus and Israel, with additional potential for Syria, Lebanon and Palestine (El Katiri, 2016) [39]. Among these, Lebanon started first exploration of offshore oil and gas between 2019 and 2020 (Offshore, 2019) [40]. It shall be noted that not all the on-going and future explorations will lead to actual production, as this depends on other economic, regulatory, environmental and geopolitical factors, as mentioned above.

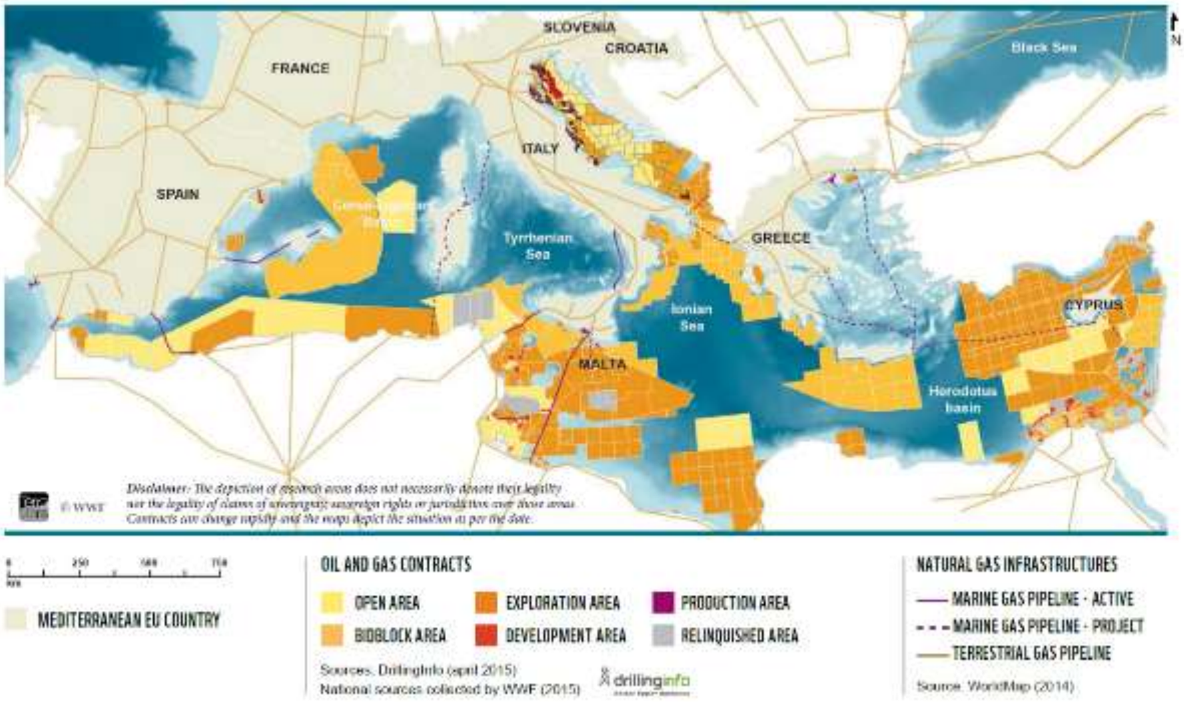


Figure 62. Offshore oil and gas exploration in the Mediterranean Sea. Source: Piante and Ody, 2015 [20].

Clarksons Research (2020) [44] provides short- and long-term projections for the Mediterranean producing region, which, however, in the Clarksons Research analysis does not only include the Mediterranean Sea but also encompasses the Black and Caspian Seas. In the short term (2020-2021) offshore oil production is expected to register a decline by 2% yearly in this region. A decreasing trend is also projected by 2030 (Figure 63). A more focused analysis, considering only the Mediterranean, has been provided by Clarkson Research specifically for this Study. The graph in Figure 64 shows the historical trend of offshore oil production for the period 1982-2019 (the same provided in Figure 56), as well as projections at 2030. Between 2019 and 2030, oil production at sea is projected to decrease by about -6.5% in the whole period.

On the contrary, offshore gas production is expected to increase consistently both in the short- and medium-term (Clarksons Research, 2020) [44]. According to the analysis, this is the only component expected to clearly increase in the Mediterranean producing region, as onshore gas production is expected to decrease, while onshore oil production to be stable (Figure 63) In 2020, the offshore gas production is expected to increase by 10%, in particular thanks to the contribution of Eastern Mediterranean countries. In Israel, offshore gas supply is project to increase by 80% in 2020, as a result mainly of the Leviathan field entering in production at the end of 2019. Moreover, the expected start-up in 2021 of the Karish field would further increase Israeli production in the short term. In Egypt, the Zohr field is expected to further feed the country production of offshore gas, by 9% over the period 2020-2021. In the medium term, further exploitation of fields recently entered in production (e.g. the Leviathan field), future exploitation of already discovered fields (e.g. Aphrodite in Cyprus) and further exploration are expected to underpin the growth of the sector (by CAGR of 3.9% between 2020 and 2030).

The MEDTRENDS project (Piante and Ody, 2015) [20] reports forecasts of future gas production in the Mediterranean Sea, which were elaborated on the basis of past trends data and expected future demand (Figure 65). Although numbers are different from those commented above (due to different assumptions), they confirm a significant growing production of offshore gas in the region. In the period 2020-2030 the Mediterranean offshore production of oil is projected to stabilize around the average value of 451,000 bpd, with a 5.9% decrease compared to 2019 production.

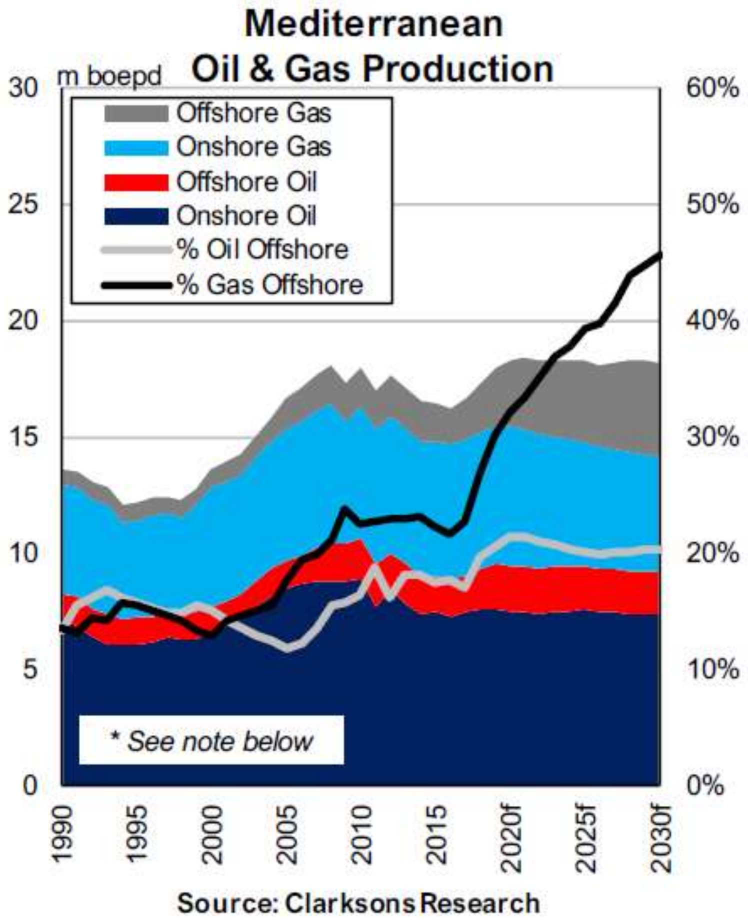


Figure 63. Historical and future trend for the Mediterranean producing region, encompassing the Mediterranean, Black and Caspian Seas. (boped = barrels of oil equivalent per day). Source: Clarksons Research (2020) [44].

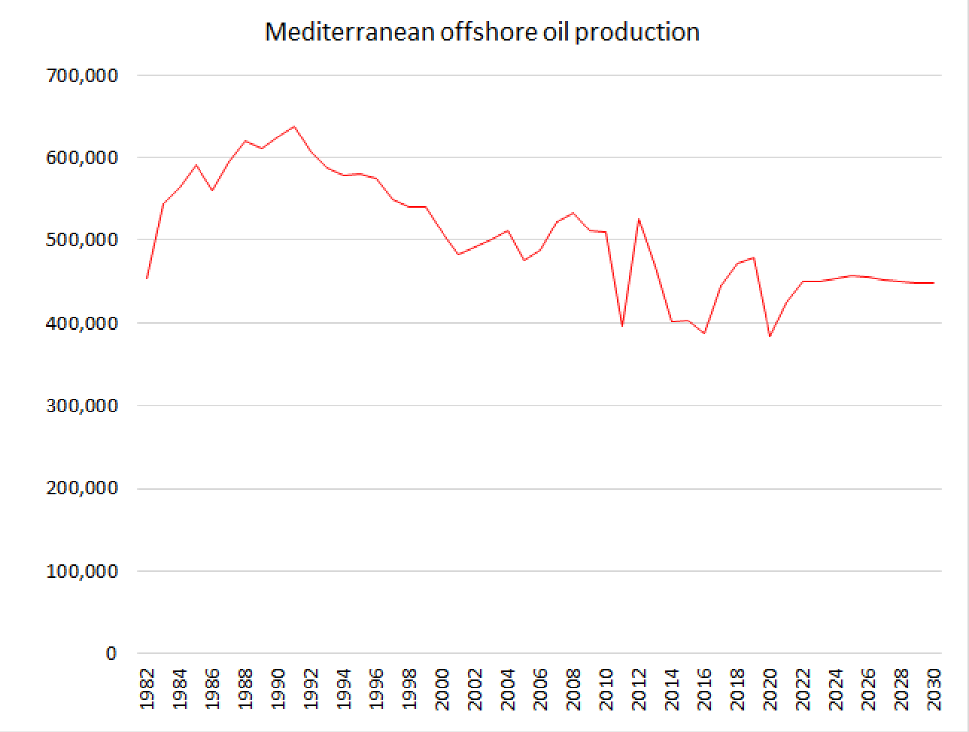


Figure 64. Historical and future trend of offshore oil production for the Mediterranean Sea in the period 1982-2030 (bpd = barrels per day). Source: Clarksons Research, original elaboration for this Study.

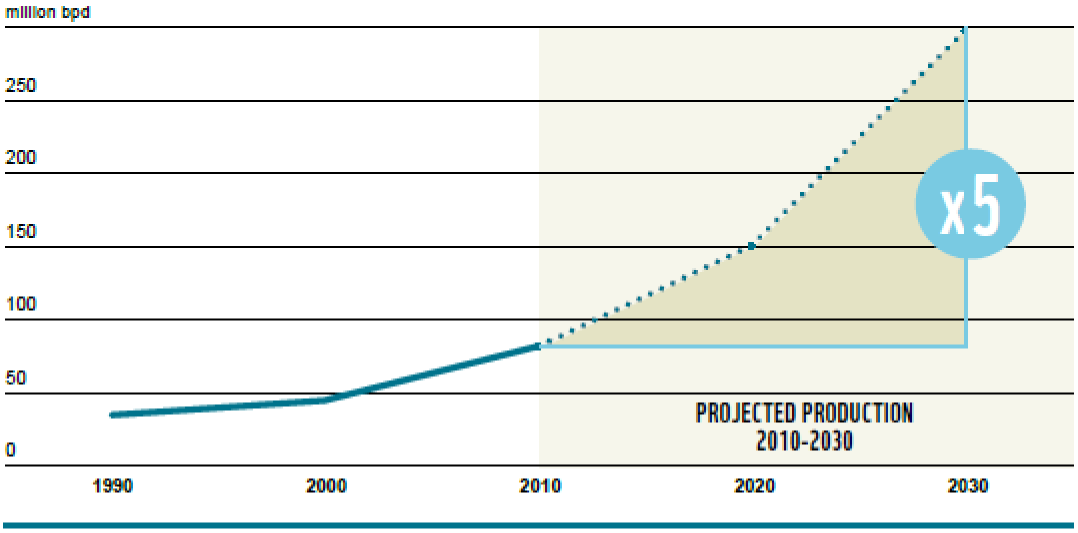


Figure 65. Offshore gas production in the Mediterranean Sea, based on past trends. Source: Piante and Ody, 2015) [20].

Indeed, future scenarios can be significantly influenced also by offshore activities performed by other countries which are currently not contributing to the production but are expected to own large gas reserves (e.g. Algeria; Hafner et al., 2012 [46]). In the Levantine Sea, besides Cyprus also Lebanon and Syrian Arab Republic have untapped gas (and to some extent oil) fields potential (Oil magazine, 2016 [47]; Szoke, 2016 [48]). However, the role that the Eastern Mediterranean will play as offshore gas producer, and in particular as suppliers to European countries, will be also influenced by geopolitical issues, which are of particular concern in the area (Szoke, 2016 [48]).

A significant number of Mediterranean offshore platforms are expected to progressively reach the end of their operational lifetime. 107 offshore platforms (out of 432) registered by Clarksons Research OIN were installed more than 40 years ago (34 in Italy, 68 in Egypt and 5 in Tunisia), and 43 (installed also after 1980) are categorised as shut down. The offshore sector is therefore expected to deal with decommissioning in the next future, not only in the Mediterranean. This is a worldwide challenge. Major offshore decommissioning hotspots are identified in the North Sea, the Gulf of Mexico, Southeast Asia, Latin America, West Africa and the Arabian Gulf. Additionally, five countries (Australia, China, India, Italy and Egypt) are considered smaller hotspot for decommissioning (Oudenot, 2018) [49]. For example, Italy already decommissioned 49 obsolete offshore platforms between 1966 and 2005; at least 20 additional offshore platforms will come to the end of their lifetime by 2021 and even more are expected to be decommissioned by 2030 (Grandi et al, 2017) [50].

At the end of their productive life, offshore platforms are generally removed completely and disposed of onshore, with high costs and damage of the ecosystems which established on these structures and the marine life they hosted (van Elden, 2019) [51]. Alternative options include partial removal, reuse for other purposes and nearby relocation (Figure 66). Today, around the world few regions have implemented Rigs-to-Reefs programs (e.g. extensive experience has been developed in the Gulf of Mexico), aiming to re-purpose obsolete offshore platforms as artificial reefs (Bull and Love, 2019) [52]. The Site of Community Importance SIC IT4070026 “Relitto della piattaforma Paguro” (Paguro gas platform wreck) provides a Mediterranean example. This is an artificial reef derived from a gas platform that collapsed in 1965 at 12 nm off Marina di Ravenna (Italy, Adriatic Sea). During the period of 1990-2000, dismantled jackets from about 20 other Italian offshore platforms were disposed in the area, creating an artificial reef. This complex has been significantly colonised by marine flora and fauna species and is now a destination for intense diving activity Grandi et al. (2017) [50].

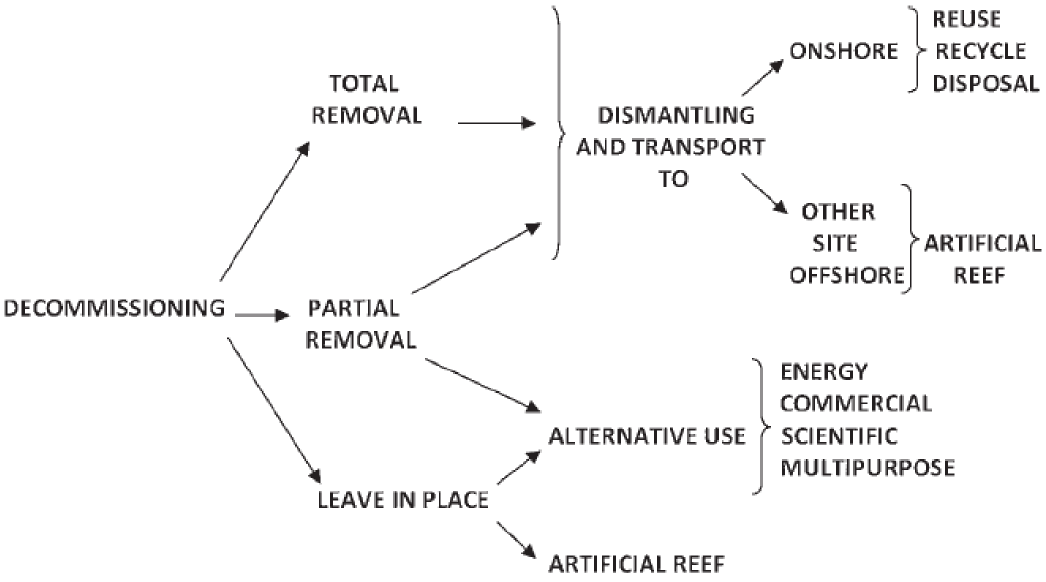


Figure 66. Decommissioning options. Source: Grandi et al, (2017 [50])

The future destiny of obsolete offshore platforms is context and site specific and the selection of the preferable option shall be based on agreed and clear criteria (such as decommissioning costs, impacts on air and water quality, impacts of marine life, impacts on ecosystem services, technical feasibility, environmental and economic benefits of the adopted option, etc.). In some cases, the natural value and related services (e.g. for fisheries and maritime tourism) of the ecosystems created on an offshore platform can make opting for reefing options, while in others restoration to the previous state might be preferred van Elden, 2019) [51]. In other cases, re-use of offshore platforms shall be preferred. The project “Multi-Use in European Seas” (MUSES) investigated options for the re-use of Italian northern Adriatic offshore platforms in a multi-use perspective. For example, the re-use of an offshore platform can be implemented combining aquaculture and tourism activities, such as diving, recreational fishing, environmental education and gastronomic experiences. Offshore platforms can be also re-used for the offshore production of renewable energy, hosting wave energy devices, wind turbines and/or solar panels (Castellani et. al., 2017) [53].

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3.2 Oil and chemical pollution

3.2.1 Overview

Maritime traffic on the world's oceans has increased dramatically over the past 20 years, thus increasing the risk of pollution caused by shipping (Tournade, 2014) [1]. Although environmental regulations are strict, particularly under the MARPOL Convention (International Convention for the Prevention of Pollution from Ships), polluting substances continue to be discharged into the sea, often illegally (EMSA, 2012) [2]. Shipping activities generate a variety of chemical pollution pressures through release of oil and other chemicals. Spills can occur in case of accident, during routine operations, in ports, as well as at sea. They can be voluntary or accidental, resulting from a human decision, a human error or a technical failure.

Not only sea-based but also land-based sources are relevant for oil and chemical pollution, including: (i) discharges of oil with rivers and floods; (ii) discharges of untreated or insufficiently treated municipal sewage and storm water (urban runoff); (iii) discharges of untreated or insufficiently treated waste water from coastal industries; (iv) accidental or operational discharges of oil from coastal refineries, oil storage facilities, oil terminals and reception facilities; and (v) emissions of gaseous hydrocarbons from oil-handling onshore facilities (terminals, refineries, filling stations) and from vehicles exhausts (traffic).

Marine pollution caused by accidental spills is a well-known global concern. Oil tanker accidents account for 10–15% of all the oil that enters the ocean world-wide every year (Tornero et al., 2016) [3]. Around 35 per cent comes from regular shipping operations (World Ocean Review, 2014) [4]; this includes oil released during incidents involving all other types of vessel, as well as oil from illegal tank cleaning. The largest share, amounting to 45 per cent (World Ocean Review, 2014) [4], comes from inputs from municipal and industrial effluents and from routine oil rig operations, together with a small amount from volatile oil constituents which are emitted into the atmosphere during various types of onshore burning processes and then enter the water. A further 5 per cent comes from undefined sources (World Ocean Review, 2014) [4]. This includes smaller inputs into the sea by polluters who go undetected. These percentages naturally do not apply for example to 2010 and other years in which major oil spills have occurred. The Deepwater Horizon disaster (2010) alone released around 700,000 tons of oil into the sea – more than two-thirds the amount that would normally enter the marine environment over the course of an entire year (World Ocean Review, 2014) [4].

The distribution of oil spills from 1970 and 2019 (Figure 67) (IPTOF, 2020 [5]) highlights the Mediterranean as one of the world hot-spot areas for this type of events.

Figure 67. Number of oil spills (>7 tons) from 1970 to 2019. Source: IPTOF (2020) [5].[9]

Over the last fifty years there has been a marked downward trend in oil spills from tankers in the world. Statistics for the frequency of oil spills greater than 7 tons are illustrated in Figure 68. The average number of spills per year in 1970 was about 79 and now is reduced of over 90% to a low of 6 (ITOPF, 2020) [5].

Shipping is also the most important mode of transport for a significant number of chemicals, referred to as Hazardous and Noxious Substances (HNS). HNS are defined as “any substance other than oil which, if introduced into the marine environment, is likely to create hazards to human health, to harm living resources and marine life,

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[9] Note from original source of the map: “This map represents nearly 90% of the spills (>7 tons) recorded in the ITOPF database. Records without specific location information have been omitted. Please note that approximated geographic coordinated have been used to map some records.

to damage amenities or to interfere with other legitimate uses of the Sea", in accordance with the OPRC-HNS Protocol (2000)[10]. HNS can comprise of inorganic or organic chemical compounds, minerals, etc. for use within or derived from the manufacturing, petrochemical, textile, pharmaceutical, food and agrichemical industries. According to the data compiled by the European Maritime Safety Agency (EMSA), incidents resulting in HNS release happen regularly in European waters (EMSA, 2020) [7]. The ecological hazards involved in these spills are less recognized and understood than those involving oil pollution (Neuparth et al., 2011) [8].

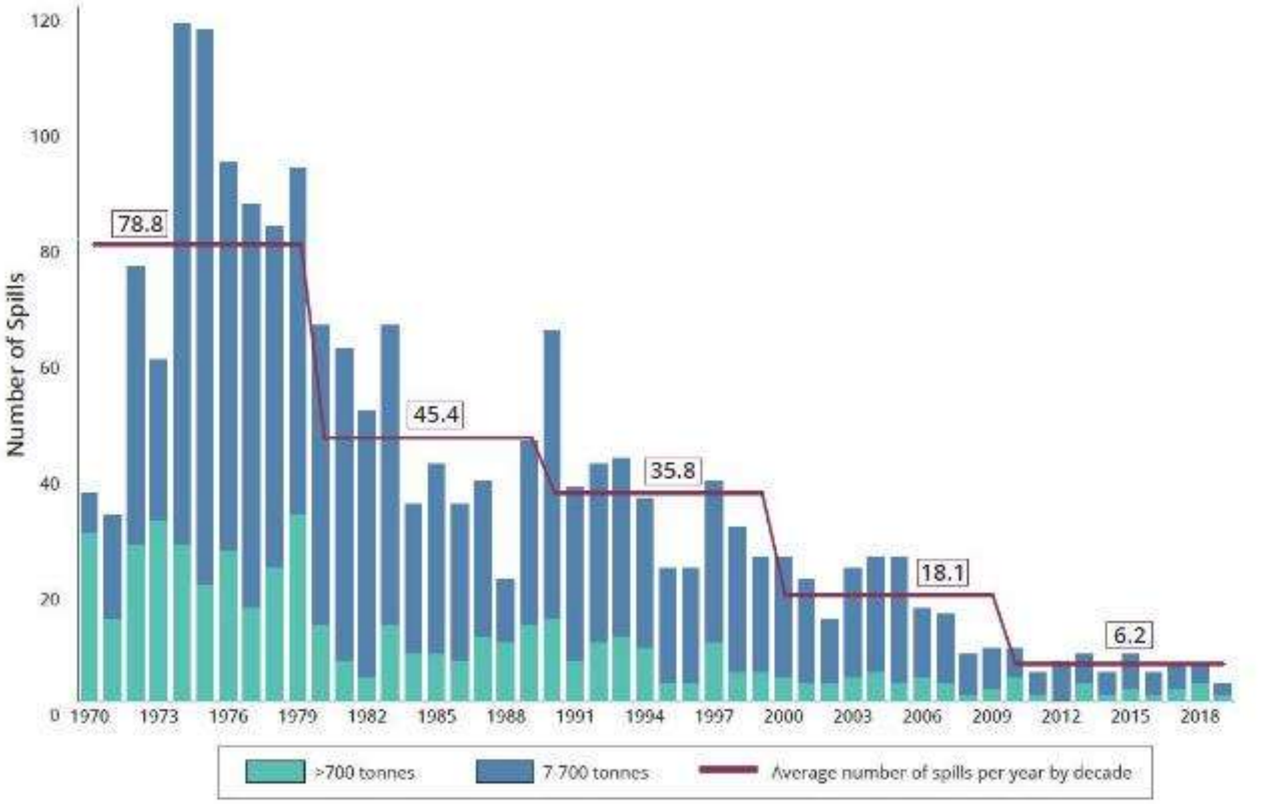

Figure 68. Number of oil spills (>7 tons) from 1970 to 2019. Source: IPTOF (2020) [5].

The degree of the damage caused by an oil spill event depend upon the quantity spilled, the chemicals involved and the sensitivity of the marine area impacted as well as the wind and weather conditions at the moment of the accident. Crude oil is not a single substance but it is composed of thousands of chemicals and its chemical composition changes dynamically after release into the environment. Moreover, there are thousands of different kinds of crude and refined oils. The polycyclic aromatic hydrocarbons (PAHs) often comprise up to 10% of the organic compounds in crude oil and can be used as tracer for the general distribution of petroleum hydrocarbons in the environment associated with a spill. Oil spills are also an importance source of Volatile Organic Compounds (VOCs) such as hexane, heptane, octane, nonane, benzene-toluene-ethylbenzene-xylene isomers (BTEX), and other lighter substituted benzene compounds (Tornero et al., 2016) [3].

Operational discharges relate to ship-based pollution also represent a source of pollution from oil and other contaminants. Vessel-related operational pollution include releases of bilge water from machinery spaces and ballast water of fuel oil tanks. Although environmental regulations for these operations are quite strict, operational discharges are still frequent and are still detected in the Mediterranean (Kostianoy & Carpenter, 2018) [9]. The chronic pollution resulting from operational discharges is more difficult to assess than that caused by large catastrophic spills. Discharges are not limited to oil but also involve other contaminants such as detergents and cleaners, lubricants, and chemicals from refrigerating equipment and fire-extinguishers. The inventory of pollutants emitted can be valuable for evaluating their environmental impacts. However, this issue seems to have been overlooked and information on this regard is rather limited (Honkanen et al., 2013 [10]; McLaughlin et al., 2014 [11]).

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[10] OPRC-HNS Protocol: Protocol on Preparedness, Response and Cooperation to Pollution Incidents by Hazardous and Noxious Substances, 2000

Offshore oil and gas production represent another source of contamination for the marine environment. Rock cuttings from drilling (drill cuttings) and formation water brought up with the hydrocarbons (produced water) are considered the largest sources of contaminants entering the sea from regular offshore oil and gas operations (Bakke et al., 2013) [12]. This becomes particularly relevant considering that the oil and gas industry is shifting to deeper regions of the ocean, where even less is known about effects on the species that inhabit them and where proper regulatory frameworks to minimize damage to the environment can be more complicated.

The drilling of wells generates significant quantities of wastes (Tornero et al., 2016) [3]. Drilling fluids (drilling muds) are used to lift formation cuttings to the surface, control subsurface pressures, lubricate drill strings, bottom hole cleaning and cooling, and maintenance and stability of uncased sections of the borehole. Produced water means water which is produced in oil and/or gas production operations and is a combination of formation water, condensation water and re-produced injection water; it also includes water used for desalting oil. Produced water represents the largest waste stream generated in the offshore production activities, in both volume and quantity of pollutants.

Accidental spills from offshore installations include well blowouts, acute or slow releases from subsea equipment and pipelines, structural failure or damage of production or pumping platforms, and platform-tanker loading activities. Oil pollution from oil and gas installations, especially well blowouts, can differ substantially from ship-sourced oil spills, principally due to the potentially larger quantity and prolonged release of fresh oil (Tornero et al., 2016) [3].

3.2.2 Pollution status and trends

Girin and Daniel (2018) [13] and Girin and Carpenter (2018) [14] report that the overall oil pollution in the Mediterranean waters is the sum of four different sources (without indication of shares), namely:

- Accidental spills on the land, from storage tanks, road/rail/pipeline accidents, acts of war or vandalism, with the oil being carried to the sea by rivers. There are no statistics at national level of those spills, which are generally very small. Oil spills from pipelines around in the Mediterranean did definitely occur, but the number, volume and location of those spills cannot be assessed due to a lack of accessible documentation.
- Ships and coastal storage accidents or acts of war, releasing without warning a large quantity of oil in a particular place. These are quite rare: less than one per decade on average for spills over 10 tons.
- Operational spills from shipping: Operational spills are legal when made in compliance with MARPOL convention requirements (ref. paragraph 3.2.7). When this is not the case, we have the occurrence of illicit discharges. Permitted operational spills take place weekly, as an overall average, and are estimated as being up to daily on some heavy traffic routes, where they are most concentrated. They are voluntary and individually small (less than 10 tons). There is no information available on the contribution of the tanker, cargo, container, fishing, leisure, cruise and defence fleets to the total input of oil in the Mediterranean. The same applies to offshore oil exploration and exploitation activities.
- Natural seeps on the seabed: there is some evidence to suggest that natural spills occur in some places, indicative of the presence of fossilized oil and gas seeping from underground reservoirs.

It is very difficult to estimate volumes of oil coming to the sea from the above-mentioned land-based sources; thus, this information for the Mediterranean Sea is lacking, except for some estimates of the impact of refineries (Kostianoy & Carpenter) [9].

All ports and oil terminals present a potential danger of oil pollution. For example, along the coasts of the Western Mediterranean, more than 17 major oil ports and 15 refineries are found especially along the Italian and Spanish coasts. Algeria is one of the top three oil producers in Africa and is a potential source of oil pollution on the southern shore of the Western Basin of the Mediterranean Sea since it has six coastal terminals for the export of petroleum products in Oran, Arzew, Algiers, Bejaia, Skikda and Annaba, together with five oil refineries (three in coastal cities – Skikda, Arzew and Algiers), located along its coastline (Benmecheta et al., 2016) [15].

Also military activities represent another source of oil pollution in the Mediterranean. The most recent serious military incident in the Mediterranean Sea region resulted in a large oil spill and occurred in 2006. In July 2006 on the coast of Lebanon around 15,000–30,000 tons of heavy fuel oil was spilled into the sea after the Jiyeh power plant be bombed by the Israeli Air Force on July 14 and 15 during the 2006 Israel-Lebanon conflict. A 10 km wide oil spill covered 170 km of coastline, killed fish and threatened the habitat of endangered green sea turtles.

Operational pollution, also known as operational discharge, refers to the release of pollutants from vessels in the general operation of the ship. These operational activities include emissions from a vessel engine, the chronic discharge of sewage, tank residues, bunker oils and garbage, etc. It is generally understood that a ship is allowed to leave a permanent stream of oily water in its wake for several hours, or even several dozen hours, so long as the concentration of oil in the discharged waste does not exceed 15 parts per million (ppm). If the discharge remains within the given amount, then the operational pollution is legal in nature. On the other hand, if the amount exceeds 15 ppm, there is a case of illicit discharge.

While accidental pollution rarely occurs within the Mediterranean waters, operational pollution has become a common practice in the basin, representing the main source of marine pollution from ships. The 2017 Mediterranean Quality Status Report [16] presents a map of oil spills detection by satellite for year 2016 (Figure 69). The concentration of oil spills clearly indicates the main shipping routes in the Mediterranean Sea and the coastal areas where ports are located as most dense are for oil spills occurrence, which can be considered as proof that shipping activities are a major cause of oil pollution.

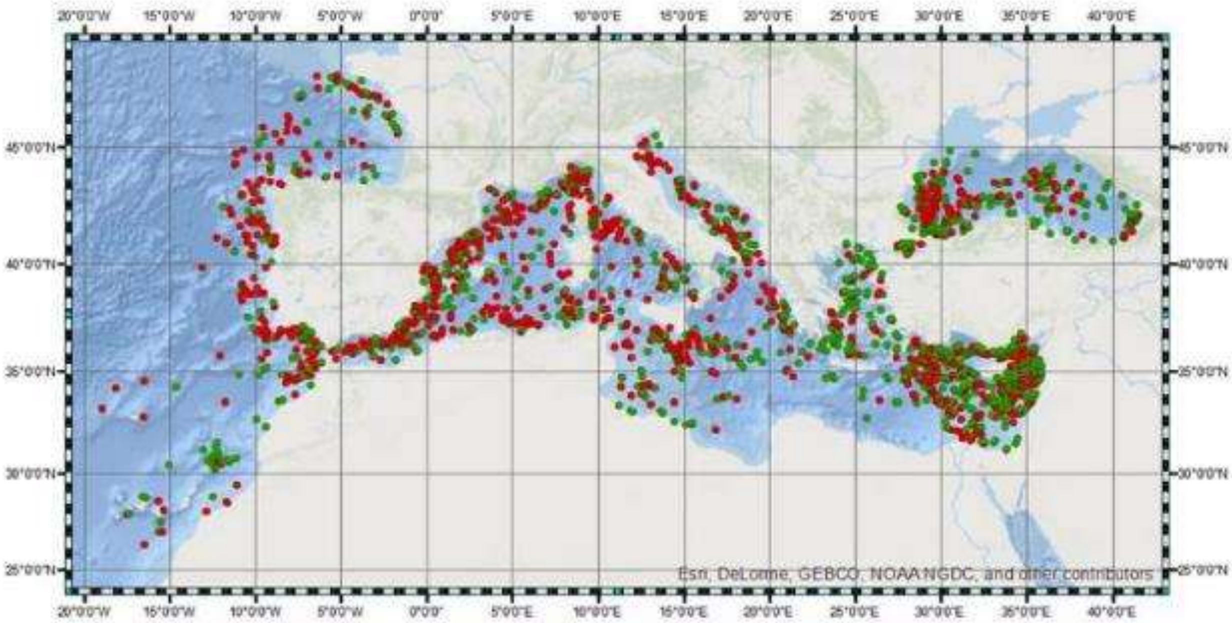

Figure 69. Spills detected in 2016 by satellite Class A (red dots on the map): the detected spill is most probably oil (mineral or vegetable/fish oil) or a chemical product. Class B (green dots on the map): the detected spill is possibly oil (mineral/vegetable/fish oil) or a chemical product. Source: UNEP/MAP (2017) [16].

3.2.2.1 Incidents

Recording of oil spill incidents in the Mediterranean started in early 1960s, although oil pollution events surely occurred also in previous times. It is rather evident that the first and second world conflicts added oil pollution to the Mediterranean Sea due to the numerous war actions involving ships, submarines and aircrafts.

The great majority of larger oil spills (larger than 6,000 tons) recorded since the 1960s occurred before 1981 (Table 18). After that year, there were only four major oil spill accidents in the Mediterranean: three due to ships incidents, as reported in Table 18, and a fourth one, due to the Jiyeh power plant in Lebanon, which bombed by the Israeli Air Force on July 14 and 15, 2006 (15,000 – 30,000 tons of fuel oil were spilled) (Kostianoy and Carpenter, 2018) [9]. Unfortunately, after 1981 incidents also include the biggest ever event occurred in the Mediterranean: 144,000 tons oil spill resulting from the MV Haven accident in front of the port of Genoa, Italy. REMPEC[11] reports another major incident not listed in the table below, which occurred on 13 March 1994 and involved the Nassia crude oil tanker, which was hit by a cargo ship in the Bosporus strait. The incident caused a spill of about 95,000 tons of crude oil in the sea. Notwithstanding post 1981 dramatic events, there is no doubt that the improvement and technological progress in shipping construction (including double hulls and segregated tanker arrangements) maintenance, operation and routing have contributed in reducing drastically the number of major oil spill events due to ships incidents.

The total amount of oil spilled in the Mediterranean Sea because of major incidents listed in Table 18 accounts to 537,600 tons in 52 years. The annual average value is about 10,000 tons; however as noted above most of the incidents and spilled oil volume occurred before 1981 (Kostianoy and Carpenter, 2018) [9].

Table 18. List of major oil spills due to ship accidents occurred in the Mediterranean between 1966 and 2017. Source: based on information included in Kostianoy and Carpenter, 2018 [9].

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[11] https://www.rempec.org/en/our-work/pollution-preparedness-and-response/response/accident-map

Date	Vessel name	Location of the incident	Spilled quantity
15.05.1966	Fina Norvege	Sardinia (Italy)	6,000 tons
01.11.1970	Marlena	Sicily (Italy)	15,000 tons
11.06.1972	Trader	Greece	37,000 tons
25.04.1976	Ellen Conway	Port of Arzew (Algeria)	31,000 tons
30.06.1976	Al Dammam	Agioi Theodoroi (Greece)	15,000 tons
10.08.1977	URSS I	Bosporus Strait (Turkey)	20,000 tons
25.12.1978	Kosmas M.	Antalya (Turkey)	10,000 tons
02.03.1979	Messiniaki Frontis	Crete (Greece)	16,000 tons
15.11.1979	MT Independenta	Bosporus Strait (Turkey)	64,000 tons
23.02.1980	Irenes Serenade	Navarino Bay (Greece)	100,000 tons
29.12.1980	Juan Antonio Lavalleja	Port of Arzew (Algeria)	37,000 tons
29.03.1981	Cavo Cambanos	Corsica (France)	18,000 tons
29.03.1981	Sea Spirit and Hesperus	Gibraltar (UK)	12,200 tons
11.04.1991	MV Haven	Genoa (Italy)	144,000 tons
26.12.2000	Castor	Nador (Morocco)	9,900 tons
10.09.2017	Agia Zoni II	Piraeus and off the coast of Salamina (Greece)	700-2,500 tons

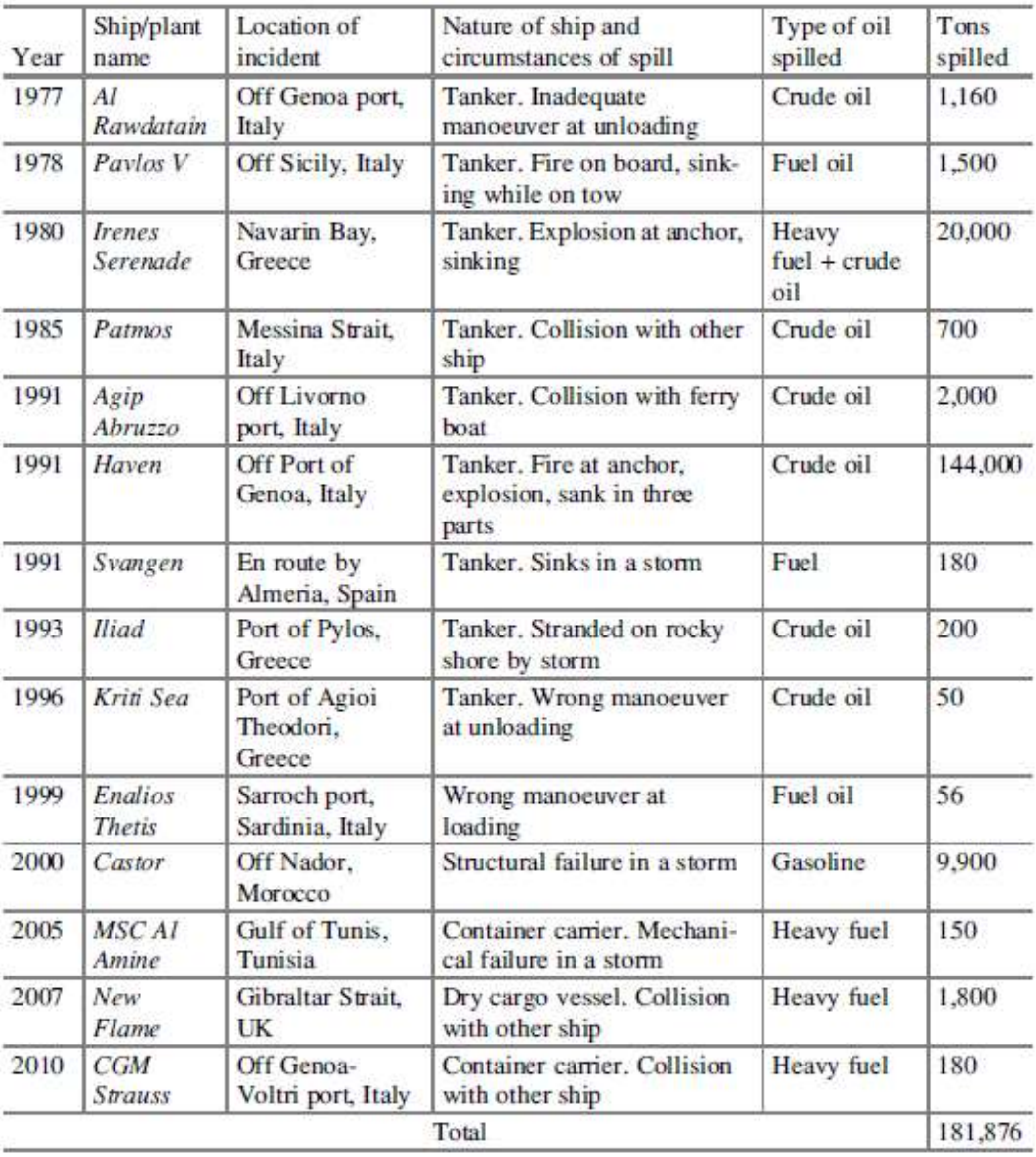
Girin and Carpenter (2018) [13] provide another list of 14 accidental oil spills identified through the CEDRE's database for the period 1970-2015 (Table 19). This list partially overlaps and partially complements, with smaller events, the one reported in Table 18. A comparison between the two tables, even of same event reported in both tables, is not an easy exercise: numbers actually depends on what is considered an oil spill and what are the assumptions on considered sources of such oil spills. Despite these differences, also Table 19 highlights that most of the events (10 out of 14) occurred before 2000.

Moreover, according to UNEP-MAP (2017) [16] also quantities of HNS (Hazardous Noxious Substances) accidentally spilled considerably reduced in the period 1994 – 2013: since 2003 to 2013 HNS release due to accidents become insignificant if compared to the previous years. One of the worst HNS spill in the Mediterranean was the sinking of the Continental Louis in 1991 in the Eastern Mediterranean; the ship transported 51,600 tons of iron.

Considering data between 1994 and 2013, UNEP/MAP (2019) [17] reports that approximately 32,000 tons of oil have been released into the Mediterranean Sea as a result of incidents. The proportion of incidents involving oil spills dropped from 56% for the period 1977 - 1993, to 40% for the period 1994 – 2013. 61% of these incidents resulted in a spillage of less than 1 tonne (UNEP/MAP, 2019) [17]. In the Mediterranean, the quantities of harmful or noxious substances (HNS) accidentally spilled have considerably decreased during the period 1994 - 2013 and have become insignificant since 2003 (UNEP/MAP, 2019) [17].

A recent study conducted at European level (Fernández-Macho, 2016) [18] has shown that European Atlantic countries are, in general, at higher risk of being affected by oil spills than Mediterranean and Baltic countries, with the United Kingdom most affected. The study developed a new risk index for analysing the potential vulnerability of coastal regions to oil spills at sea. The index revealed that the west coast of the UK was at highest risk of being affected by an oil spill at sea. Of the 25 regions most at risk from an oil spill, 20 were along the UK coast and the top three were all in the UK — Torbay, Swansea and Blackpool. Of the remaining five regions, four were in Greece (Argolida, Arkadia, Korinthia and Voiotia) and one was a Spanish region (Ceuta), on the north coast of Africa. At the country level, countries on the Atlantic European coast, including, (in order of risk) the UK, Germany, Netherlands, France, Spain and Portugal, had the highest risks from oil spills. However, the Mediterranean countries of Greece, Italy, and Turkey were also among those at the most risk.

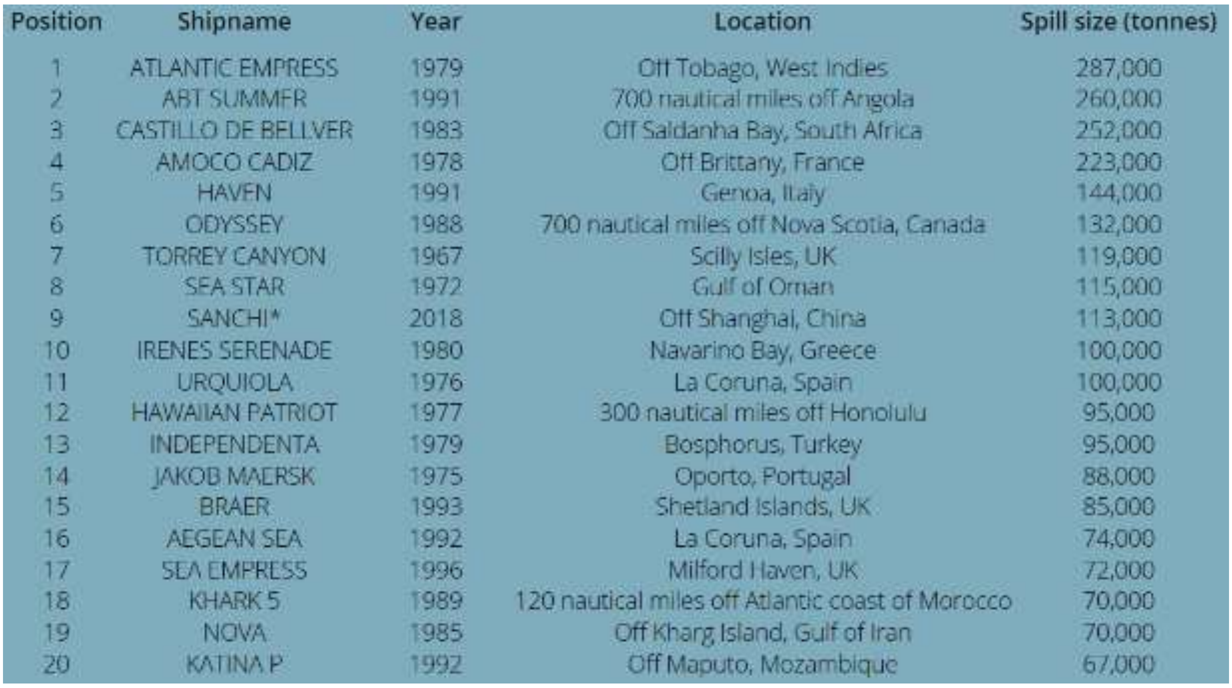
Table 19. Oil spills by ship accidents in the Mediterranean Sea in the period 1970-2015 registered in CEDRE's database. Source: Girin and Carpenter, 2018 [14]; based on CEDRE data.



Year	Ship/plant name	Location of incident	Nature of ship and circumstances of spill	Type of oil spilled	Tons spilled
1977	*Al Rawdatain*	Off Genoa port, Italy	Tanker. Inadequate manoeuver at unloading	Crude oil	1,160
1978	*Pavlos V*	Off Sicily, Italy	Tanker. Fire on board, sinking while on tow	Fuel oil	1,500
1980	*Irenes Serenade*	Navarin Bay, Greece	Tanker. Explosion at anchor, sinking	Heavy fuel + crude oil	20,000
1985	*Patmos*	Messina Strait, Italy	Tanker. Collision with other ship	Crude oil	700
1991	*Agip Abruzzo*	Off Livorno port, Italy	Tanker. Collision with ferry boat	Crude oil	2,000
1991	*Haven*	Off Port of Genoa, Italy	Tanker. Fire at anchor, explosion, sank in three parts	Crude oil	144,000
1991	*Svangen*	En route by Almeria, Spain	Tanker. Sinks in a storm	Fuel	180
1993	*Iliad*	Port of Pylos, Greece	Tanker. Stranded on rocky shore by storm	Crude oil	200
1996	*Kriti Sea*	Port of Agioi Theodori, Greece	Tanker. Wrong manoeuver at unloading	Crude oil	50
1999	*Enalios Thetis*	Sarroch port, Sardinia, Italy	Wrong manoeuver at loading	Fuel oil	56
2000	*Castor*	Off Nador, Morocco	Structural failure in a storm	Gasoline	9,900
2005	*MSC Al Amine*	Gulf of Tunis, Tunisia	Container carrier. Mechanical failure in a storm	Heavy fuel	150
2007	*New Flame*	Gibraltar Strait, UK	Dry cargo vessel. Collision with other ship	Heavy fuel	1,800
2010	*CGM Strauss*	Off Genoa-Voltri port, Italy	Container carrier. Collision with other ship	Heavy fuel	180
			Total		181,876

The Mediterranean trend of pollution incidents is coherent with that observed at the global level. The rates of incidents have decreased globally and regionally despite the increase in maritime traffic, also thanks to the impact of the international regulatory framework adopted through IMO and cooperation activities at the regional level (UNEP-MAP, 2017) [16]. 19 of the 20 largest oil spills ever recorded worldwide (including the two Mediterranean events of Haven and Irenes Serenade and the incident occurred to the Independenta on the Bosporus Strait in 1979) occurred before 2000 (Table 20). The amount of oil spilled from tanker incidents has reduced by 95% since the 1970s. The average number of oil spills greater than 700 tons was 24.5 in the 1970s and has drastically decreased to 1.8 in the present decade (Figure 70). Causes of larger oil spills (calculated for the period 1970-2019) are collision (30%), grounding (32%), hull failure (13%), fire and explosion (11%), equipment failure (4%), others such as weather damages or human errors (7%) and unknown (3%) (ITOPF, 2020) [5]. A marked decreasing trend over the same period is evident also for spill events realising between 7 and 700 tons.

Table 20. Major oil spills since 1967; quantities have been rounded to nearest thousand. Source: ITOPF, 2020 [5]



Position	Shipname	Year	Location	Spill size (tonnes)
1	ATLANTIC EMPRESS	1979	Off Tobago, West Indies	287,000
2	ABT SUMMER	1991	700 nautical miles off Angola	260,000
3	CASTILLO DE BELLVER	1983	Off Saldanha Bay, South Africa	252,000
4	AMOCO CADIZ	1978	Off Brittany, France	223,000
5	HAVEN	1991	Genoa, Italy	144,000
6	ODYSSEY	1988	700 nautical miles off Nova Scotia, Canada	132,000
7	TORREY CANYON	1967	Scilly Isles, UK	119,000
8	SEA STAR	1972	Gulf of Oman	115,000
9	SANCHI*	2018	Off Shanghai, China	113,000
10	IRENES SERENADE	1980	Navarino Bay, Greece	100,000
11	URQUIOLA	1976	La Coruna, Spain	100,000
12	HAWAIIAN PATRIOT	1977	300 nautical miles off Honolulu	95,000
13	INDEPENDENTA	1979	Bosphorus, Turkey	95,000
14	JAKOB MAERSK	1975	Oporto, Portugal	88,000
15	BRAER	1993	Shetland Islands, UK	85,000
16	AEGEAN SEA	1992	La Coruna, Spain	74,000
17	SEA EMPRESS	1996	Milford Haven, UK	72,000
18	KHARK 5	1989	120 nautical miles off Atlantic coast of Morocco	70,000
19	NOVA	1985	Off Kharg Island, Gulf of Iran	70,000
20	KATINA P	1992	Off Maputo, Mozambique	67,000

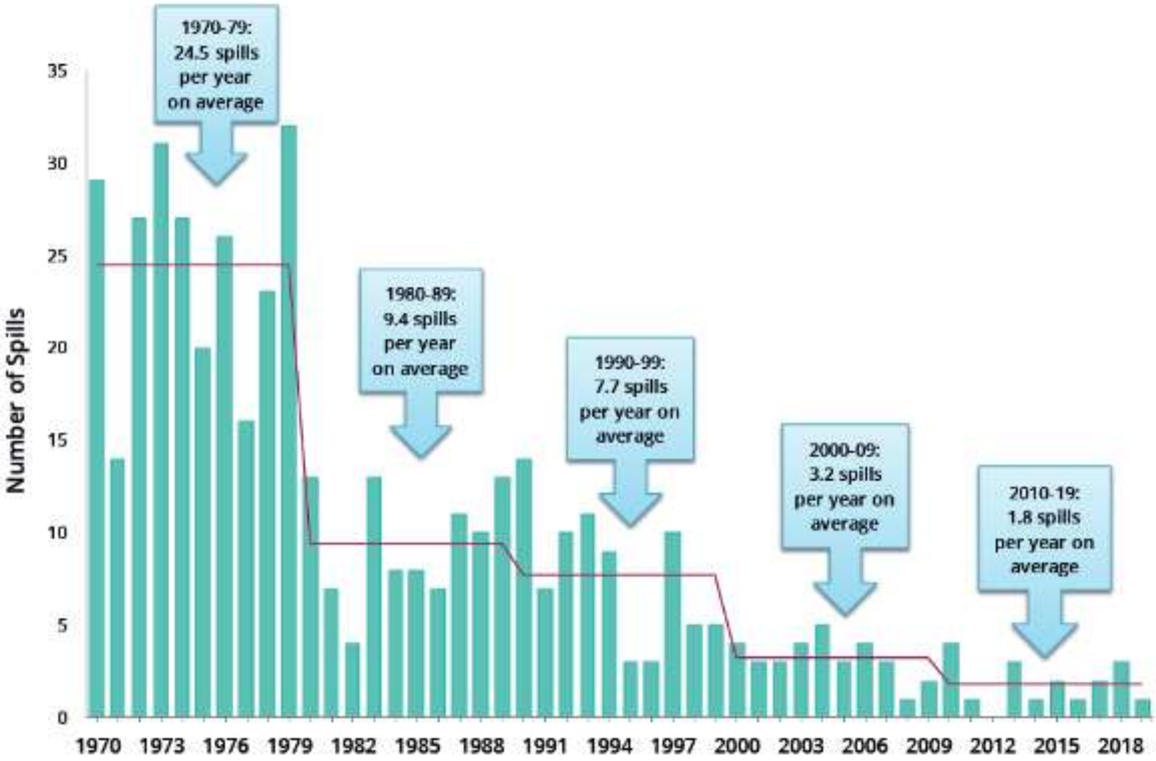


Figure 70. Number of large spills (>700 tons) worldwide: Source: ITOPF, 2020 [5].

The International Oil Compensation Funds (IOPC Funds) provide financial compensation for oil pollution damage occurring in its worldwide Member States, resulting from spills of persistent oil form tankers[12]. The IOPC database provides a different way to look at ship incidents involving oil spills, in particular highlighting monetary compensation, which have been granted through the fund because of oil spill impacts. Table 21 reports the Mediterranean incidents causing oil spills, which were followed by claims and/or recourse actions managed by the IOPC Funds.

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[12] https://iopcfunds.org/

Table 21. Oil spill incidents in the Mediterranean with claims and/or recourse actions managed through the IOPC Funds. Abbreviations: US$ = American Dollar, FFR = French Frank, Din = Dinar, £ = English Pound, Llt = Italian Lira, € = Euro. Source: https://iopcfunds.org/incidents/incident-map (consulted in July 2020).

Vessel	**Date**	**Place**	**Cause**	**Quantity of spill (tons)**	**Gross tonnage**	**Compensation paid**
Patmos	21.03.1985	Strait of Messina (Italy)	Collision	700	51,627	Nil
Oued Gueterini	18.12.1986	Algiers (Algeria)	Discharge	15	1,576	US$ 1,133 FFr 708,824 Din 5,650 £ 126,120
Agip Abruzzo	10.04.1991	Livorno (Italy)	Collision	2,000	98,544	Nil
Haven	11.04.1991	Genoa (Italy)	Fire and explosion	Unknown	109,977	LIt 71,584,970,783 FFr 23,510,228
Iliad	09.10.1993	Pylos (Greece)	Grounding	200	32,511	Nil
Kriti Sea	09.08.1996	Agioi Theodori (Greece)	Mishandling of oil supply	30	62,678	€ 3,774,000
Slops	15.06.2000	Piraeus (Greece)	Fire	1,000-2,500	10,815	€ 4,022,099
Spabunker IV	21.01.2003	Gibraltar	Sinking	Unknown	647	Nil
Alfa I	05.03.2012	Elefsis Bay (Greece)	Collision with submerged wreck	Unknown	1,648	€ 12,000,000
Agia Zoni II	10.09.2017	Saronic Gulf (Greece)	Sinking	550	1,597	Still open incident

The map in Figure 71 illustrates maritime incidents causing oil or noxious substances spills, which occurred in the period 2000-2009 in the Mediterranean, along with other information (e.g. main shipping routes). Within the present Study, we developed two maps providing similar information for the period 2010-2019, using data on incidents extracted from the Lloyd's list intelligence database. Maps commented below provide a zoom on the 2000-2009 and 2010-2019 periods.

According to Table 18, only one incident with major oil spill occurred during each of the decade. Mapped events are of lower magnitude and are therefore coherent with the decreasing trend in the number of major oil spills due to incidents registered both globally and at the Mediterranean scale.

Figure 71. Maritime accidents with oil or noxious substances spills occurred in the period 2000-2009 in the Mediterranea. Source: GRID-Arendal, 2013; https://www.grida.no/resources/5920.

From the Lloyd's list intelligence database, we retrieved data on 93 ship incidents occurred in the Mediterranean over 2010-2019, which implied a spill of oil or other noxious substances[13]. The first map (Figure 72) shows the geographic distribution of the recorded incidents and their categorization according to the year of occurrence[14]. The consultation of the report of each single incident enabled also to identify the typology of spilled substances, which were categorised as oil (including crude oil, oily water, fuels and lubricating oil) and other noxious substances (mainly dirty ballast water, but also including wastewater, LNG and coal dust). The 77.4% of the recorded incidents were responsible for oil spills, while the 15.1% for spills of other noxious substances. Information on the spilled pollutants is not available for 7 cases (7.5%). The distribution of ships incidents categorised by typology of spills is reported in Figure 73.

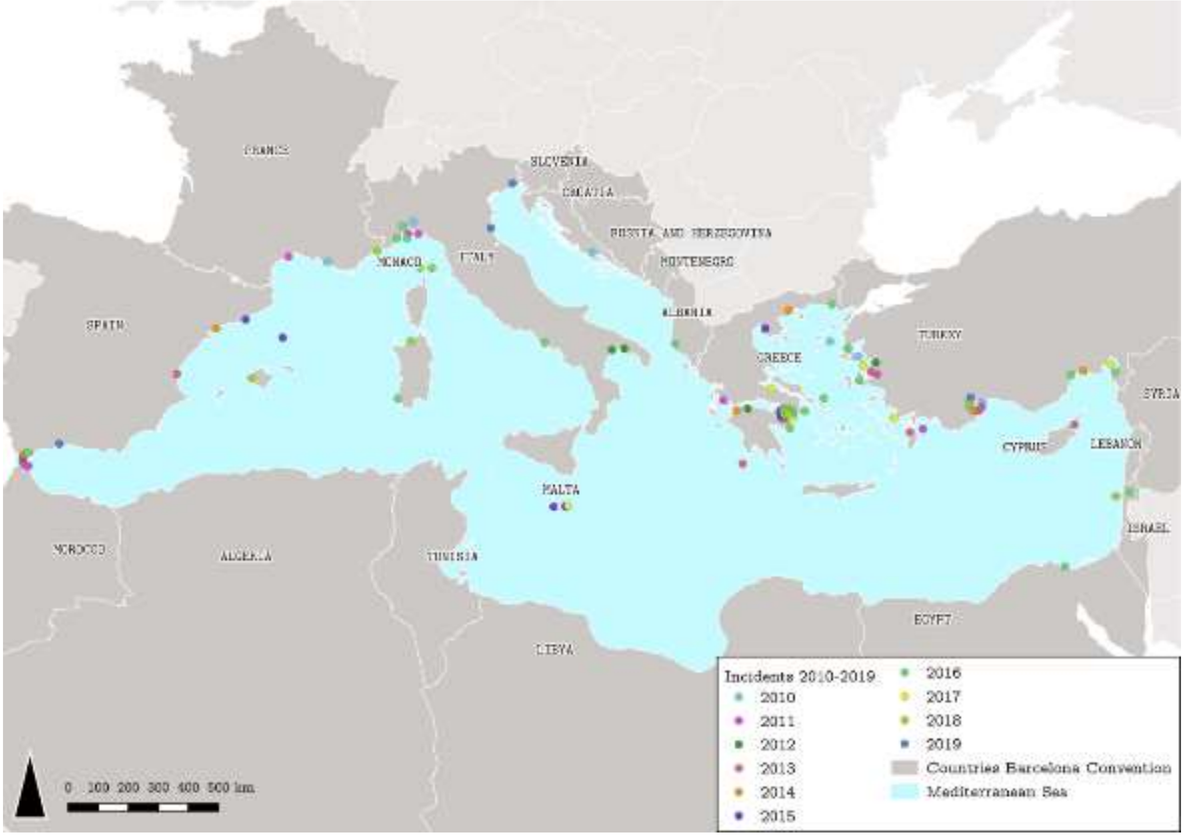

Figure 72. Ship incidents causing pollutant spills in the Mediterranean in the period 2010-2019. Data source: Lloyd's list intelligence database, data retrieved on 29.06.2020.

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[13] Querying the Lloyds' database on incidents for the Eastern and Mediterranean regions and for events causing pollution leads to the identification of 94 events (for the period 2010-2019). These events were singularly checked. One of the 94 incidents was discarded as it actually occurred in the Caribbean, as resulted from the consultation of its causality report. This brings the total number of considered incidents with spills to 93.

[14] The point displacement function was used to allow the proper visualization of incidents occurring in the same area in the 2010-2019 maps. Therefore, the maps report the approximate location of considered incidents.

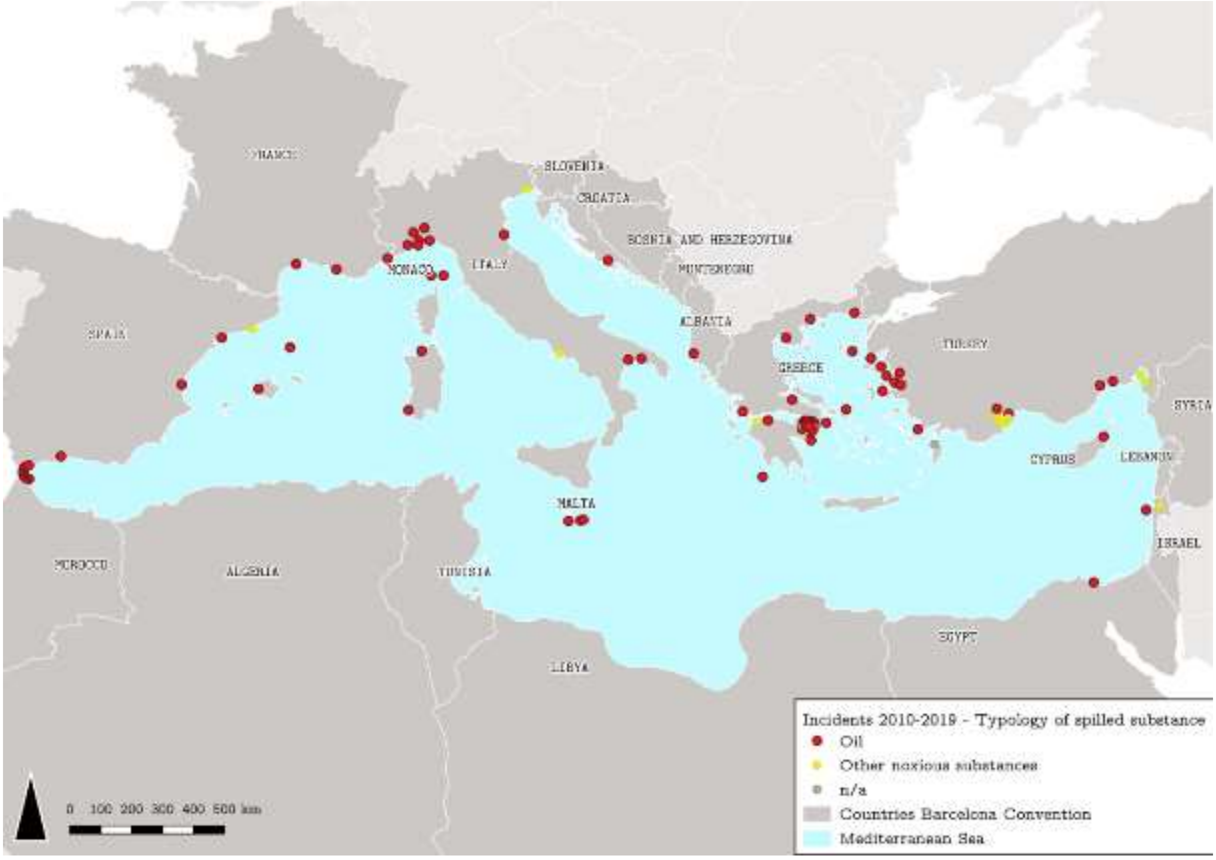

Figure 73. Ship incidents causing marine pollution in the Mediterranean in the period 2010-2019, categorized by typology of spilled substance- Data source: Lloyd's list intelligence database, data retrieved on 29.06.2020.

Container ships were responsible for the highest percentage (31.2%) of the 2010-2019 incidents registered by Lloyds, which led to oil or other pollutant spills (Figure 74). Other dry and Ro-Ro cargos and tankers also contributed significantly to the overall number of incidents. Tankers' incidents involved quite exclusively oil and chemical tankers (15 out of 16 cases) and just in one case a gas tanker.

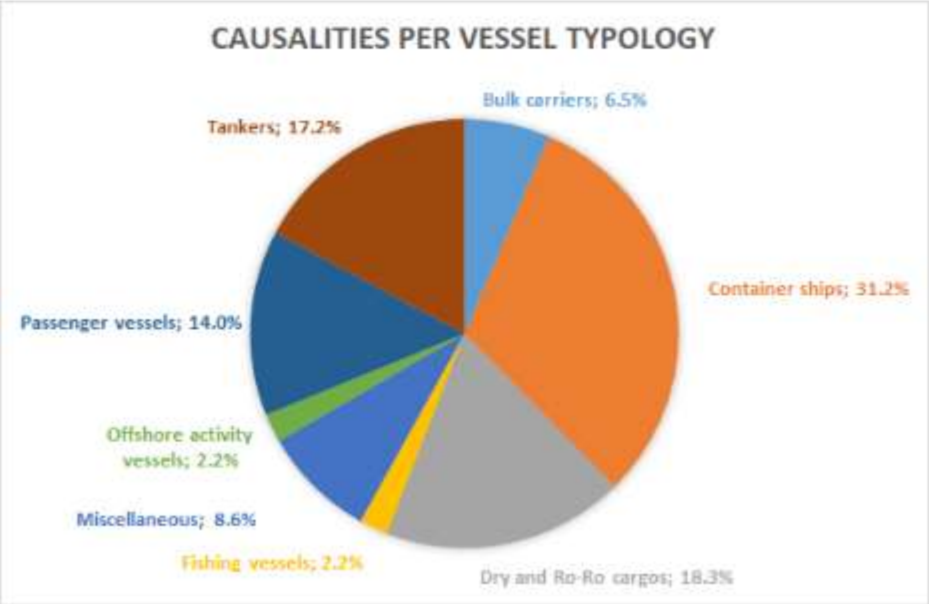

Figure 74. Ship incidents causing marine pollution in the Mediterranean in the period 2010-2019 per vessel typology. Data source: Lloyd's list intelligence database, data retrieved on 29.06.2020.

REMPEC manages MEDGIS-MAR, the Mediterranean Integrated Geographical Information System on Marine Pollution Risk Assessment and Response. This repository contains various typologies of data, provided and updated by Mediterranean coastal states, including data on accident from 1977 to 2018. These data have been filtered selecting the accidents, which have caused release of pollutants to the marine environment[15]. Specifically, 682 events were identified: the great majority (68.9%) are small events causing release of less than 7 tons of oil or other pollutants to the sea. The 19.5% are medium size events (7-700 tons) and the 6.5% are major events (>700 tons) (Figure 75).

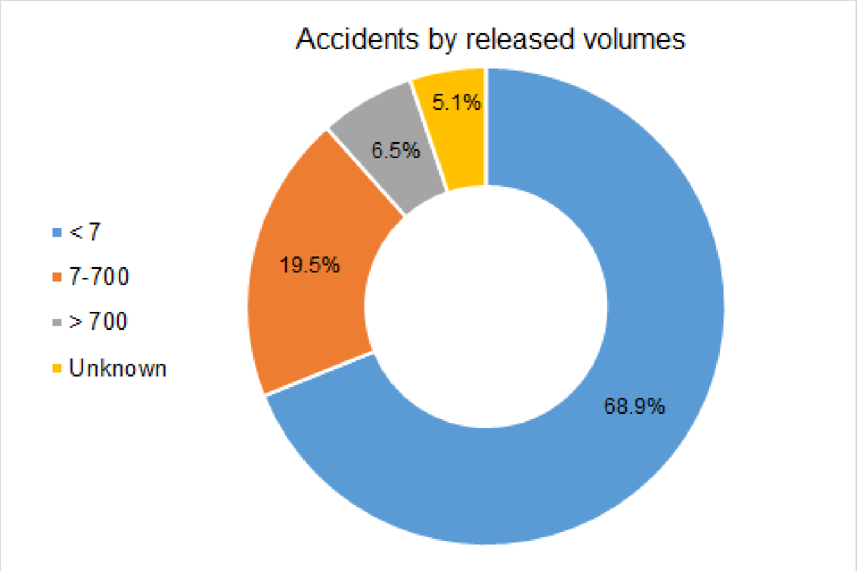

Figure 75. Accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by classes of pollutant volumes (tons). Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

In more than half of the cases, the typology of released substance is unknown. This uncertainty is particularly high for small events (<7 tons) and tends to drastically decrease for larger events (Figure 76). Non-volatile oil has been detected in the 26% of accidents if all cases are considered, and in the 56% and 34% of accidents if respectively medium (7-700 tons) and larger (>700 tons) accidents are taken into consideration. Volatile oil is also relevant for medium and large size cases, including mainly fuels. Other hazardous substances (like lubricants, other liquid chemical, solid chemical, ammonium nitrate, nitric acid, phosphoric acid, iron oxide and others) are the most commonly reported for large size accidents (41%).

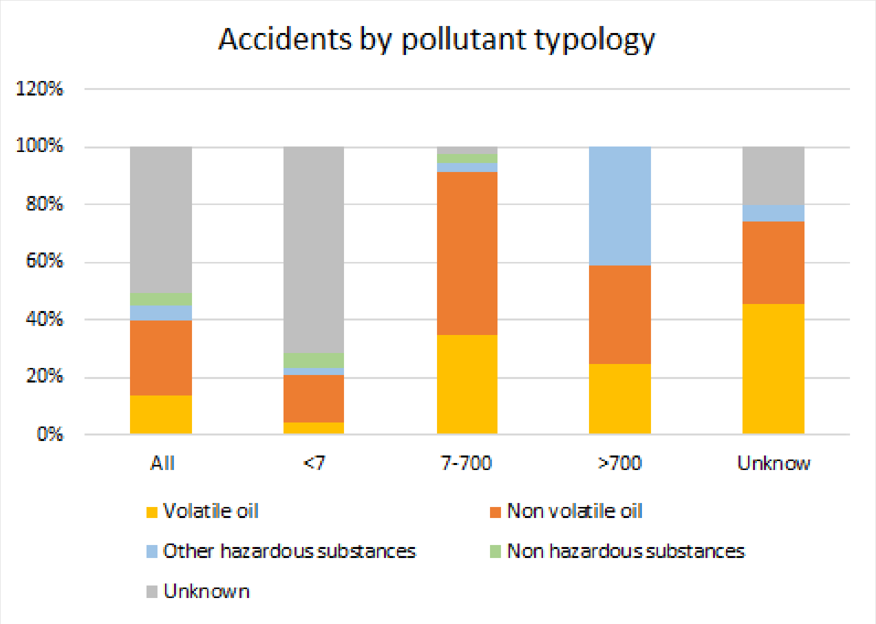

Figure 76. Accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by typology of released pollutant. Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

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[15] In particular, MEDGIS-MAR data on incidents were filtered considering records with the field “Pollution = YES” OR the field “Pollution interval” different from a null value.

MEDGIS-MAR data refer to a wide variety of accident typologies (Figure 77). Differently from the Lloyds' database, these data do not strictly deal with maritime accidents, and are not focused on shipping only. The largest number of cases are classified as others (41%) and deal with a heterogeneous variety, including: accidental discharges, few cases of illegal discharges (5), incidents during bunkering operation, leaking from land, generic mechanical damages, problems in war operations and a high number of unknown causes. Grounding (17%), foundering (11%) and collision (9%) are the most frequent causes of maritime incidents involving shipping. An important component of the MED-GIS database (9%) also deals with oil and gas leaks, which can be due to accidental discharges, tank overflow, pipelines leakages and other typologies of undefined cases.

Vessels are involved in the 85.3% of the reported accidents (the remaining 14.7 are unspecified or other than vessels). 38.5% of accidents are related to tankers, within which oil tankers deal with 31.1% of considered cases (Figure 78). Other vessel typologies more frequently involved in the registered accidents are other dry and Ro-RO cargos (22.3%) and, to a lesser extent, vessels used for harbouring operation and services (Miscellaneous; 10.1%).

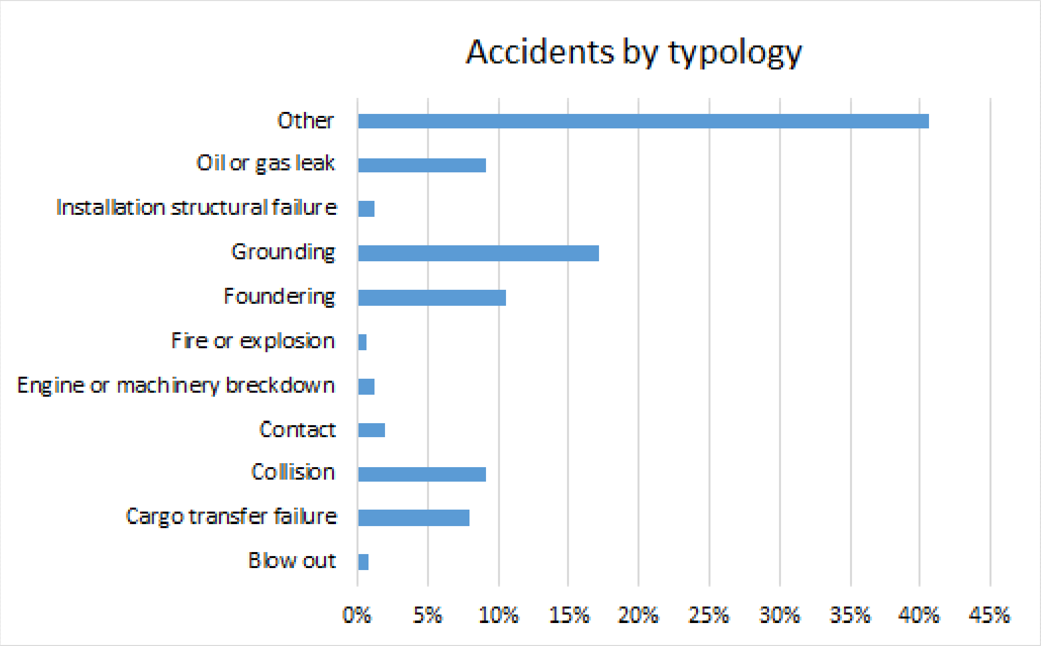

Figure 77. Accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by typologies. Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

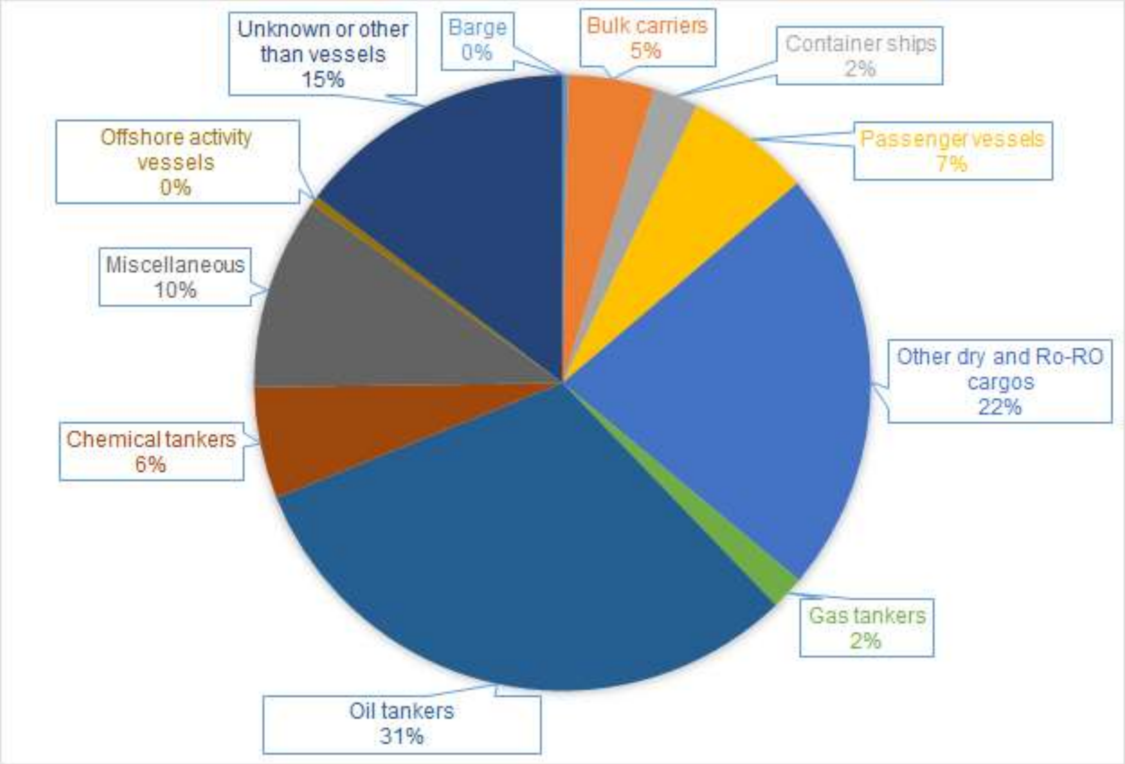

Figure 78. Accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by vessel typologies, Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

Such a wide variety of cases is responsible for the high number of accidents recorded by MEDGIS-MAR, also in the last decade (272 incidents between 2009 and 2018). Moreover, there is evidence of an increase in the number of accidents reported to REMEPEC, which is most likely due to a better compliance by the Contracting Parties of the Barcelona Convention to report causalities, as required by the 2002 Prevention and Emergency Protocol (UNEP-MAP, 2017) [16], as well as likely to an improvement in detection and monitoring capacities. Although this dataset is not indicated to reconstruct a temporal trend of maritime incidents in the Mediterranean Sea, it clearly highlights that causalities realising small volumes of oil and other pollutants to the Mediterranean Sea are still numerous and require continuous monitoring and reporting. MEDGIS-MAR were also used to map accidents causing realise of oil and other pollutants to the sea. The maps in Figure 79 e Figure 80 illustrate the distribution of the 682 events and their categorization, by quantities and typology of released pollutants, respectively. The map in *Figure 81* focuses on incidents where release of chemical substances (HNS) was recorded, and illustrates the different type of contaminant released.

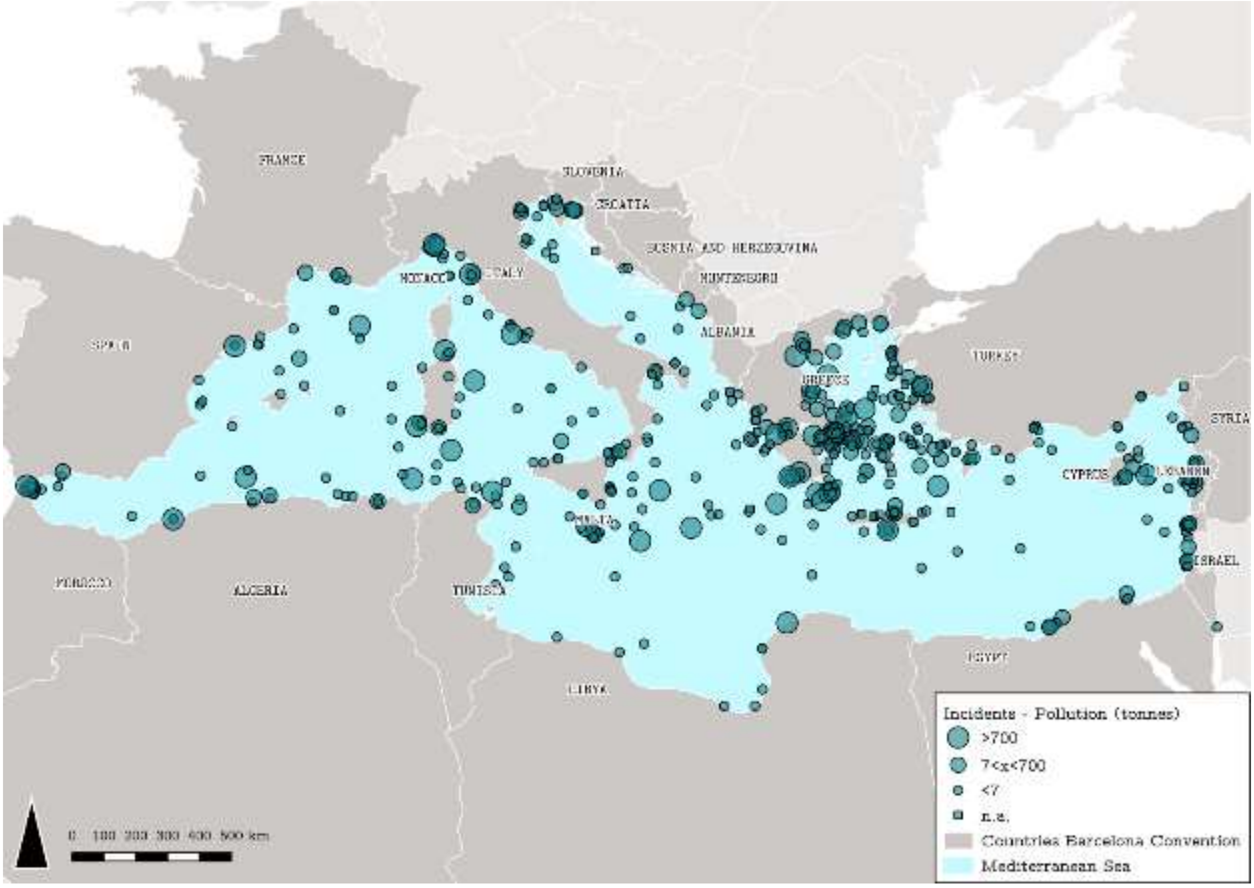

Figure 79. Map of accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by classes of pollutant volumes. Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

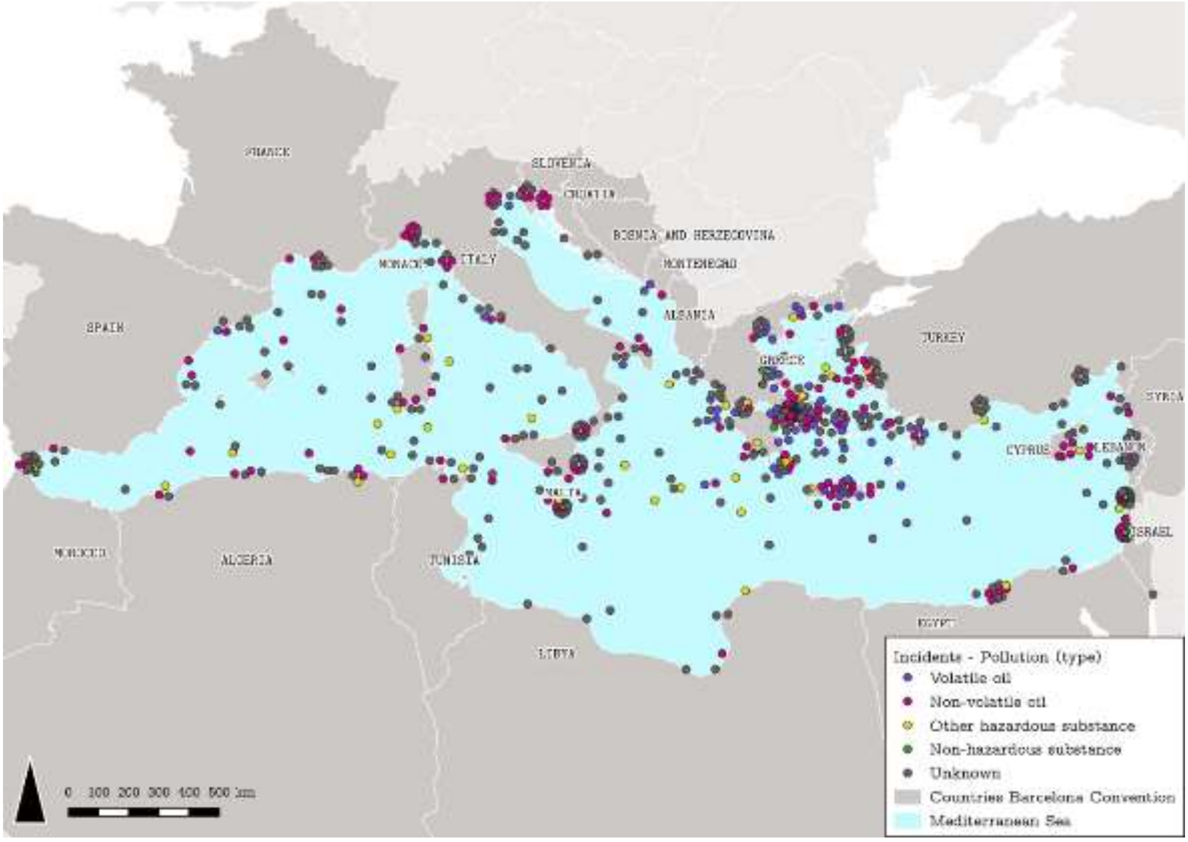

Figure 80. Map of accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by typology of pollutants. Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

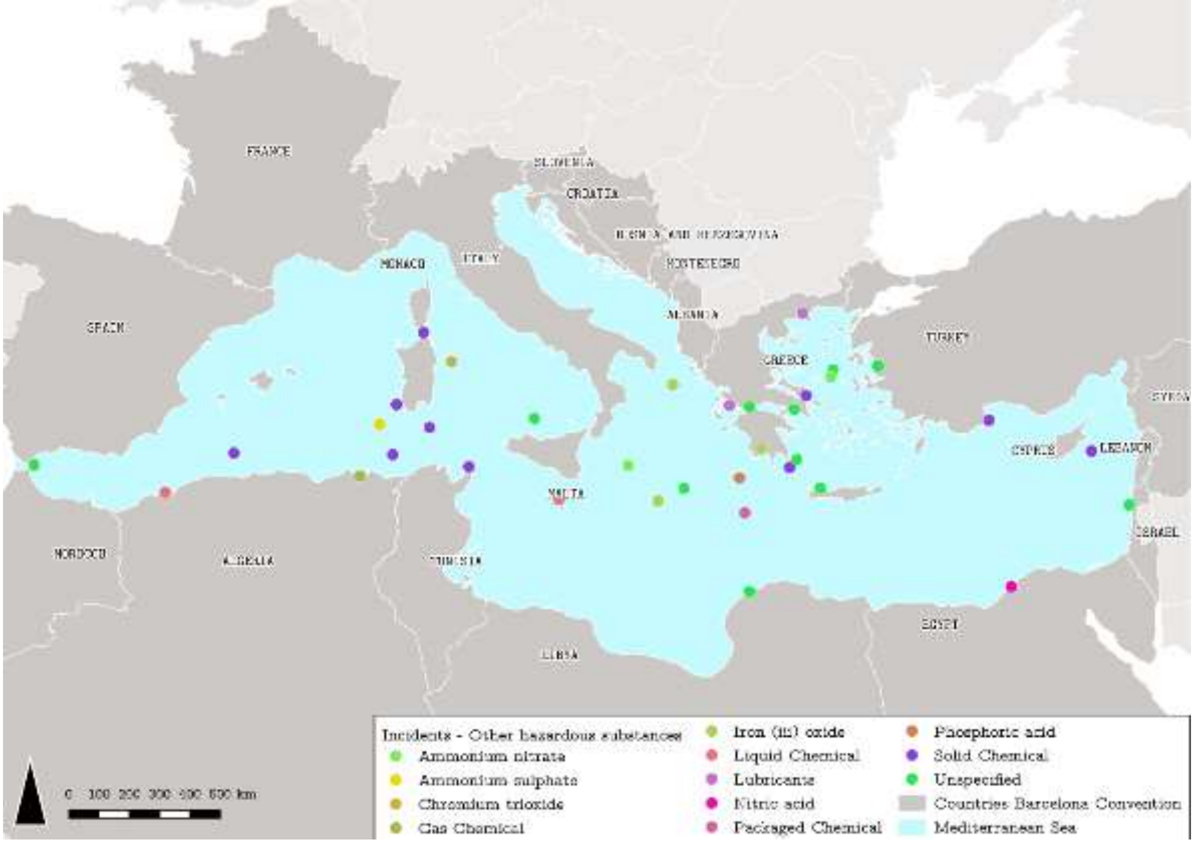

Figure 81. Map of accidents causing release of HNS to the Mediterranean in the period 1977-2018, categorized by type of pollutant. Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020.

The analysis of the compendium of maps reported in this section highlights some common elements on the distribution of maritime incidents in the Mediterranean Sea:

- The rate of incidents has decreased regionally, despite the increase in maritime traffic, also thanks to the impact of the international regulatory framework adopted through IMO and cooperation activities at the regional level.
- Causalities realising small volumes of oil and other pollutants to the Mediterranean Sea are still numerous and require continuous monitoring and reporting.
- Most of the incidents occur near the coast and in particular close to major ports and anchoring areas. This is for example the case of the ports of Piraeus in Greece, Antalya in Turkey, Genoa and Savona in north Italy, Augusta and Gioia Tauro in south Italy, Dekheila in Egypt, Larnaca and Limassol in Cyprus, etc.
- A high concentration of incidents occurs in the Aegean Sea, one of the busiest areas of the Mediterranean, due to the shipping route coming from the Black Sea, as well as the numerous connections of the numerous islands with the mainland.
- The Strait of Gibraltar is another highly sensitive area.
- Few incidents are located offshore. An example of this typology of incident is the one occurred on the 7th of September 2015 in the Balearic Sea, when the Nele Maersk reported an oil spill of about 35 tons (data from Lloyd's database). A more recent case is the one occurred on the 7th October 2018, when the Tunisian vessel Ulysse collided with the Cypriot container ship CSL Virginia north of Cape Corsica. The incident released 600 tons of heavy fuel oil into the Mediterranean Sea, causing a 3-mile long spill[16] (Figure 82).

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[16] https://www.rempec.org/en/our-work/pollution-preparedness-and-response/response/accident-map

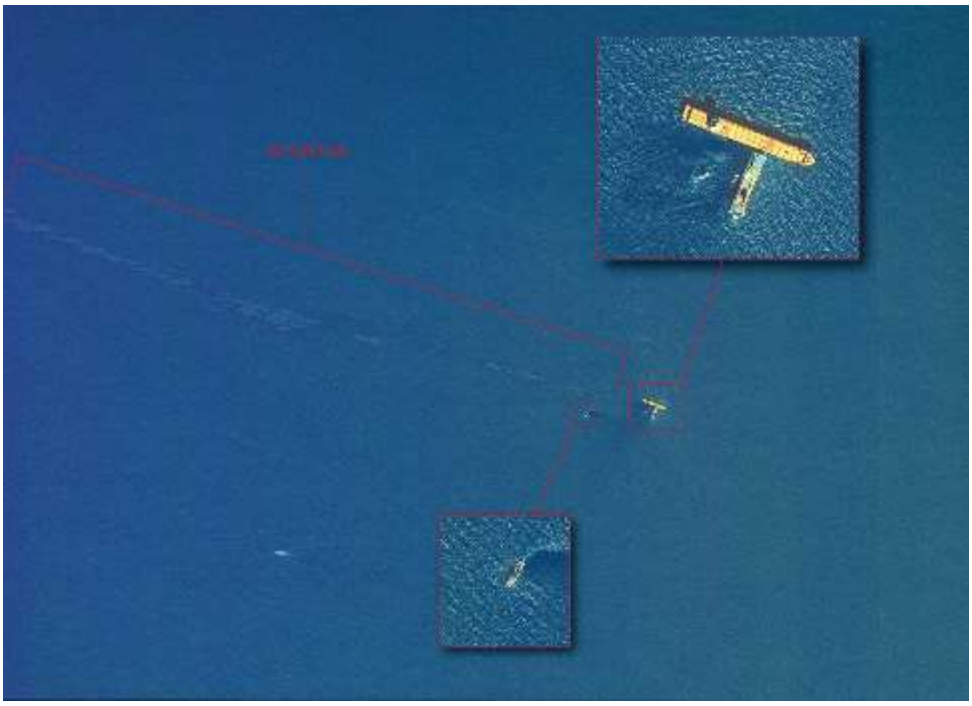

Figure 82. Satellite image at 50 cm resolution showing the collided ships and subsequent oil trail off the coast of Corsica (9/10/2018): Source: WorldView-2 © European Space Imaging; https://www.euspaceimaging.com/major-oil-spill-in-the-mediterranean/ (consulted in July 2020).

3.2.3 Operational pollution and illicit discharges

Operational spills (or operational pollution) refers to voluntary or accidental release of oil, oily residues, oily ballast water or other oil and chemical products from ships into the marine environment. They can result from human decision, error or technical failure. They are legal if made in high seas, out of areas recognized as "special area" by IMO and within an accepted limit of 15 parts of oil per million. Operational discharges are illegal anywhere over the 15-ppm limit, and below that limit in the special zones (Girin and Carpenter, 2018) [13].

According to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL), the entire Mediterranean Sea is identified as special area for oil[17]. Therefore, in the Mediterranean any discharge into the sea of oil or oily mixture from the cargo area of an oil tanker is prohibited. In case of ships of 400 gross tonnage and above, any discharge into the sea of oil or oily mixture is also prohibited, except when the following conditions are satisfied:

- the ship is proceeding en route
- the oily mixture is processed through an oil filtering equipment meeting MARPOL requirements
- the oil content of the effluent without dilution does not exceed 15 parts per million
- the oily mixture does not originate from cargo pump-room bilges on oil tankers, and
- the oily mixture, in case of oil tankers, is not mixed with oil cargo residues[18].

Operational pollution from ships is a major problem in the Mediterranean region. Operational oil spills have become a common practice in the basin and represent the main source of oil pollution from ships. Small oil spills (in the range of 1-10 tons) take place weekly in the Mediterranean and even daily along major traffic routes. It is estimated that they account up to a yearly number of 1,500-2,500 oil spill events in the basin (Kostianoy and Carpenter, 2018) [9].

As shown in Figure 69, the distribution of operational oil spills in the Mediterranean is correlated with major shipping routes). High density of oil spills occurs along the major west-east axis connecting the Strait of Gibraltar through the Channel of Sicily and the Ionian Sea with the different distribution branches of the Eastern Mediterranean. High density also characterised the routes towards the major discharge ports on the northern shore of the Adriatic Sea, the Ligurian Sea, the Tyrrhenian Sea, and the marine area in front of the Piraeus and Barcelona ports (Abdulla & Linden, 2008) [21]. This is confirmed also by previous data, as summarized in Figure 83.

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[17] http://www.imo.org/en/OurWork/Environment/SpecialAreasUnderMARPOL/Pages/Default.aspx

[18] https://www.rempec.org/en/our-work/pollution-prevention/oil-pollution/oil-pollution/introduction

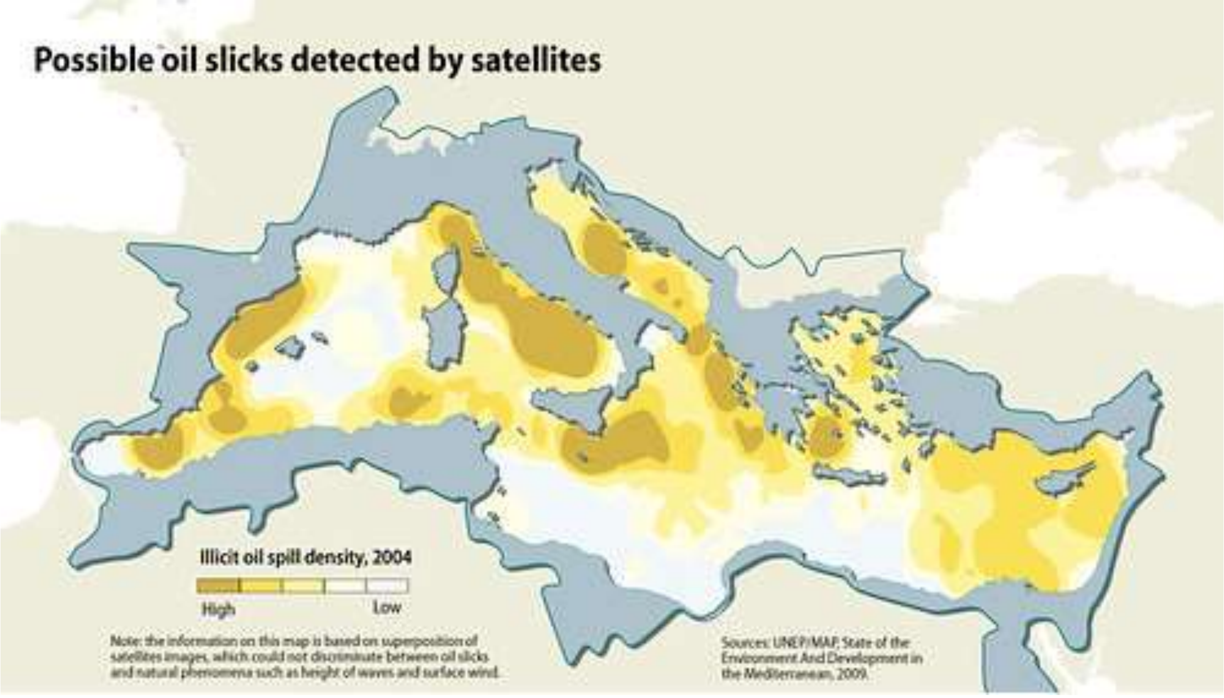


Figure 83. Hot spots for oil spills. Source: data from Abdulla and Linden (2008) [21]; map from GRID-Arendal (2013), https://www.grida.no/resources/5888.

Analysis at a more detailed scale confirm that operational spills represent a major problem for the Mediterranean marine environment. This is for example the case of oil slicks observed from 2007 to 2011 in the Levantine basin, an area characterised by intense shipping and important offshore activity (in particular for gas extraction) (Figure 84).

The correlation between detected oil spills and major shipping routes emerge clearly from other sub-regional and even national case studies. The great majority of possible oil slicks reported in Figure 85 is distributed along man shipping lines crossing the Adriatic Sea and is most likely due to operational spills. In the Adriatic Sea, oil slicks are also caused by operation activity occurring in the numerous offshore platforms. Similar maps and consideration for this sub-basin are also reported in Morovic et al. (2018) [22] and Perkovic et al. (2018) [23]. Oil slicks detected in Spanish water in the period 2011-2014 are distributed along the shipping route to the Strait of Gibraltar and in front of major ports (Figure 86).

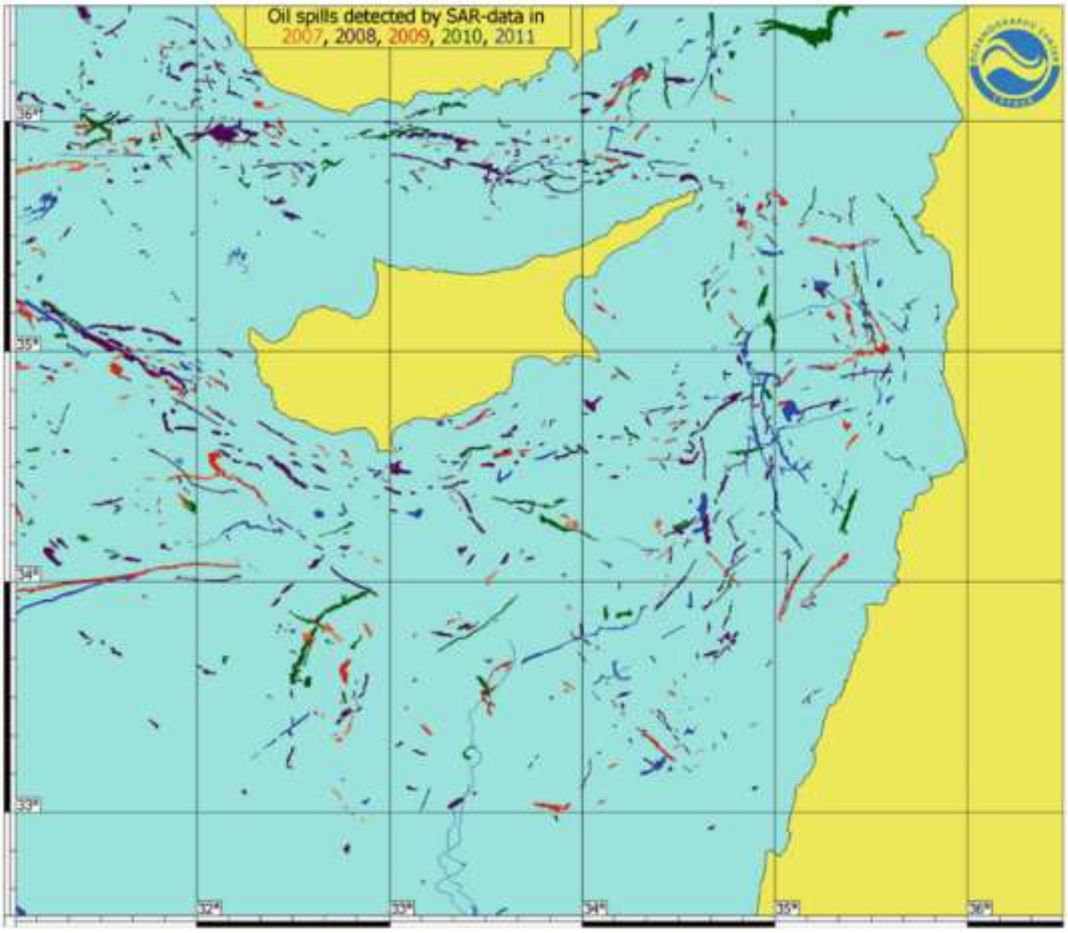


Figure 84. Oil slicks observed in the Levantine basin through SAR images in the period 2007-2011.Source: Zodiatis et al., 2012 [24]

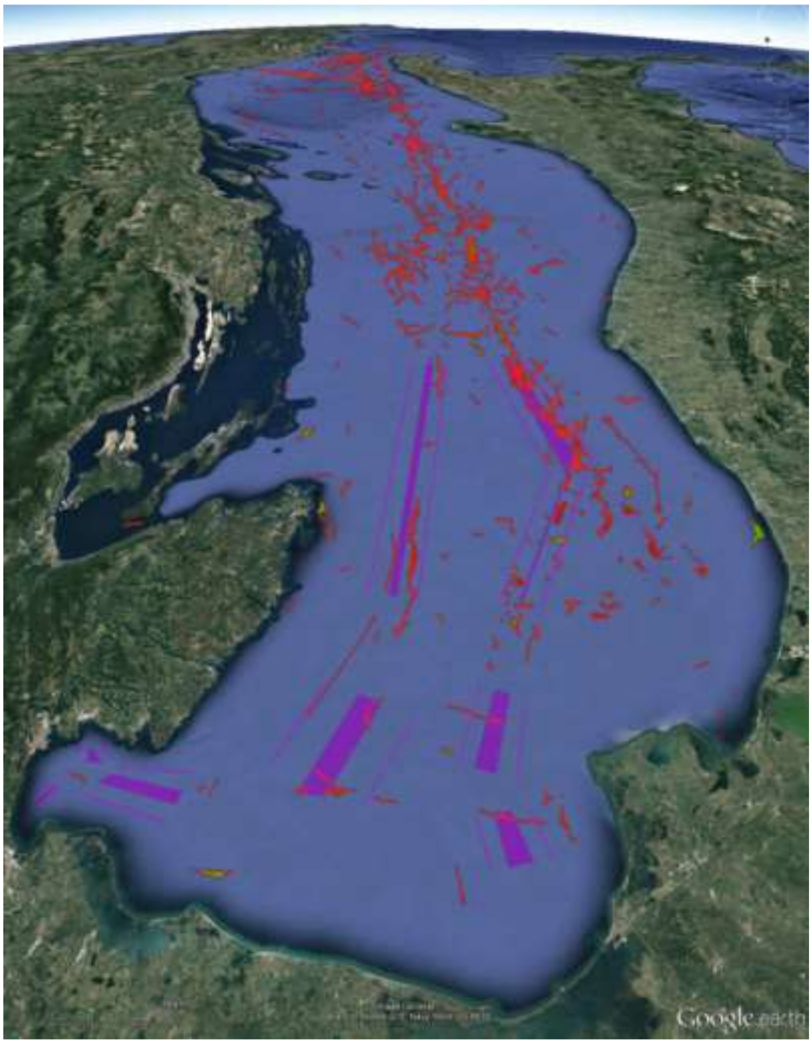


Figure 85. Possible oil spills in the Adriatic in the period 2011-2016. Source: Perkovic et al., 2018 [25], based on CleanSeaNet data.

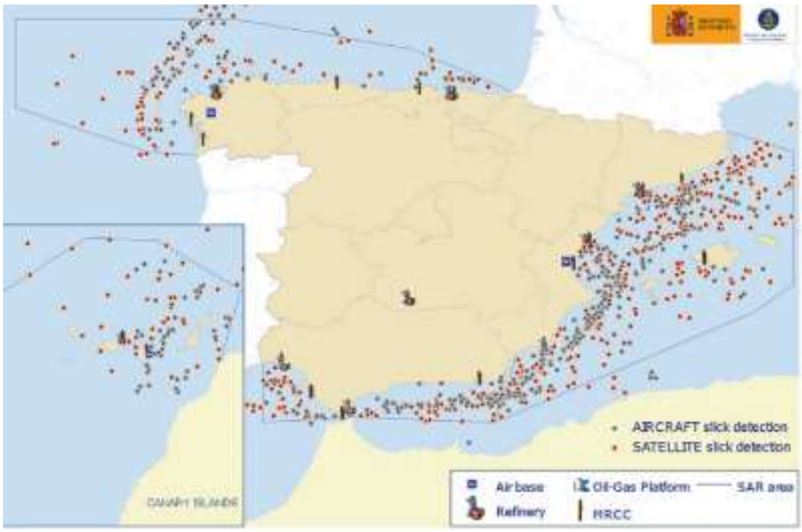


Figure 86. Aircraft and satellite slick detections in Spanish water in the period 2011-2014. The CleanSeaNet system, developed in 2006 and based on remote sensing surveillance, is progressively providing a clearer picture of the position on both accidental and illegal pollution, and potential slicks are spotted on a daily basis. Satellites cover a great area, being a powerful surveillance tool. During 2015, the satellite Sentinel was already in operation providing images with very high resolution. Spain gives feedback to EMSA for the satellite detections by sending an aerial or maritime unit. Source: De la Torre and Albaiges, 2018 [26].

Illicit discharges of oil, oily mixture and other HNS from ships represents a problem of big concern (UNEP-MAP, 2017) [16]. Surveillance and monitoring of illicit discharges are still critical issues and major gaps. Little structured data is available on illicit discharges from ships in the Mediterranean, as they are mostly illegal operations. No sufficient data are available to reconstruct historical trends. Marine surveillance requires aerial means and equipment (planes; airborne radars; sampling sets) or special technology such as the use of satellite images. Great progress has been made over the last decade on close to real time acquisition and exploitation of radar satellite imagery (Ferraro, 2007 [20]; Girin and Carpenter, 2018 [13]). There has been along the past decade considerable development of techniques to estimate the thickness of a spill recorded on satellite imagery, in order to monitor oil spills for statistical purposes. Those techniques are now close to being fully effective. The CleanSeaNet platform of EMSA provides a satellite-based oil spill monitoring and vessel detection service, which is a good resource, but only available in principle to EU Members.

A regionally centralized system for the systematic surveying of the Mediterranean waters is not yet available. However, the Mediterranean Network of Law Enforcement Officials relating to the International Convention for the Prevention of Pollution from Ships (MARPOL) within the framework of the Barcelona Convention (MENELAS), for which REMPEC acts as Secretariat, is active (also referred to in paragraph 3.2.7). In the framework of MENELAS, several facilitating tools to report illicit ship pollution discharges are integrated: the Mediterranean Integrated Geographical Information System on Marine Pollution Risk Assessment and Response (MEDGIS-MAR) (https://medgismar.rempec.org/), includes a data layer related to illicit ship pollution discharges; the reports provided by Parties to MARPOL which are requested to submit their annual reports to the Secretariat of the International Maritime Organization (IMO); the Ship-Source Pollution (SSP) reports due from European Union Member States under the implementation of Directive 2005/35/EC.

In addition, a significant number of projects have been promoted in the Mediterranean (also by REMPEC and the European Maritime Safety Agency - EMSA), in the fields of oil spill detection and monitoring of maritime activities (Zodiatis and Kirkos, 2018) [19]. For example, REMPEC implemented the Marine & Coastal Environmental Information Services Project (MARCOAST) Project and the Aerial & Satellite surveillance of Operational Pollution in the Adriatic Sea (AESOP) Project, between 2007 and 2009 and has organised a number of activities, for instance, the Coordinated Aerial Surveillance Operations for illicit ship pollution discharges (opérations de surveillance coordonnée aérienne des rejets des navires en Méditerranée – OSCAR-MED) in October 2009 and June 2013.

Quantitative estimations of illicit discharges and related spilled volumes show large differences and a high uncertainty. Based on a wide literature review, Kostianoy and Carpenter (2018) [9] estimated that the total volume of oil yearly discharged into the Mediterranean due to operational spills ranges from 1,600 to 1,000,000 tons per year. This very large range and uncertainty is not a peculiar characteristic of the Mediterranean basin, but affects other regional sea as well. For example, estimate for the Baltic Sea ranges between 20 and 60,000 tons per year (Kostianoy and Lavrova, 2014) [27]. Kostianoy and Carpenter (2018) [9] consider the lower extreme (1,600 tons per year) of the Mediterranean range too small and the upper extreme (1,000,000 tons per year) likely being too large; they suggest 50,000-100,000 tons per year as possible estimation of volume of oil illicitly discharged every year into the Mediterranean Sea.

3.2.4 Accidental post-spill consequences on biota and ecosystems

Oil spills can seriously affect the marine environment both as a result of physical smothering and toxic effects. The severity of impact depends on the quality and type of oil spill, the ambient conditions and the sensitivity of the affected organisms and their habitats to the oil. A wide range of impacts have been studied and documented in the scientific and technical literature over several decades.

Oil may impact the environment by one or more of the following mechanisms (ITOPF, Technical Information Paper n. 13) [27]:

- physical smothering with an impact on physiological functions
- chemical toxicity giving raise to lethal or sub-lethal effect or causing impairment of cellular functions;
- ecological change, primarily the loss of key organisms from a community and the takeover of habitats by opportunistic species
- indirect effect, such as the loss of habitat or shelter and the consequent elimination of ecologically important species.

The nature and duration of the effects of an oil spill depend on a wide range of factors. These include: the quantity and the type of spill; its behaviour in the marine environment; the location of spill in terms of ambient conditions and physical characteristics; the season and the prevalent weather conditions.

The characteristics of the spilt oil are important in determining the extent of damage, for example, toxic effects are less likely for heavy fuel oil (HFO) as the chemical components of the oil has low biological availability. In contrast this kind of spill has the potential to cause widespread damage in the intertidal zone of shoreline through smothering.

The following impacts can be expected on marine organisms (ITOPF, Technical Information Paper n. 13) [27]:

- Plankton. The sensitivity of planktonic organisms to exposure to oil has been established and there would appear to be potential for far-reaching impact. However, the typically massive over-production of young life stages provides a buffer for recruitment from adjacent areas not affected by the spill, such that significant declines in adult populations following spills have not been observed.
- Fish. Despite the susceptibility of juvenile stages of fish to relatively low concentrations of oil in the water column, adult fish are far more resilient and effects on wild stock levels have seldom been detected. Mass mortalities are rare.
- Seabirds. Seabirds are the most vulnerable open water creatures and in major accidents large numbers may perish. Fouling of plumage is the most obvious effect of oil on birds and a major cause of mortality due to loss of plumage insulation and ingestion of oil in the attempt to clean it out.
- Marine mammals and reptiles. Whales, dolphins and other cetaceans may be at risk from floating oil when surfacing to breathe or breach. Seals are more likely to encounter and suffer from the effects of oil, because they spend time onshore. Floating oil may be a threat to marine reptiles (turtles in the Mediterranean) too: loss of eggs and hatchings may occur if oil strands on sand beaches or if nests are disrupted during clean-up operations.
- Shallow inshore waters. Damage in shallow waters is most often caused by oil becoming more mixed into the water column by strong wave action or by the inappropriate use of dispersants too close to the shore.
- Seagrass. Floating oil is most likely to pass over seagrasses beds with no ill effects. However, if oil or its toxic components become mixed into these shallow inshore waters at sufficiently high concentrations, seagrass and associated organisms may be impacted.
- Shorelines. Shorelines are exposed to the effects of oil more than any other part of the marine environment. However, much of the flora and fauna on the shore are inherently resilient. This tolerance also gives many shoreline organisms the ability to withstand and recover from spill effects.
- Rocky and sandy shores. Exposure to the scouring effects of wave action and tidal currents means that rocky and sandy shores are the most resilient to the effects of a spill. The scouring also usually enables natural and rapid self-cleaning to take place.
- Soft sediment shores. While fine sediments are not as readily impacted as other substrates, oil can become incorporated through flocculation with sediments stirred up by storm activity or penetration through worm burrows and open plat stems
- Saltmarshes. While a single event is unlikely to cause more than temporary effects, longer term damage can be inflicted by repeated, chronic oiling or by aggressive clean-up activities.

Seabirds and chronic pollution from oil. Source: IFAW, 2013 [28]

Seabirds are particularly vulnerable to oil because this substance damages the insulating properties of their plumage, which they require to survive in a maritime environment. Seabirds that spend most of their time afloat and that have little contact with the coast are the most vulnerable to oil pollution. Small amounts of oil in the plumage cause a bird to give up feeding and most casualties are due to starvation. Large amounts of oil on the plumage cause instant immobility and possibly immediate death through suffocation and drowning.

Possible changes in the (wintering) distribution of seabirds should be taken into consideration with regard to the vulnerability of certain areas, and a deeper understanding of offshore habitat requirements is therefore needed. The Greenland Sea, Icelandic waters, Bay of Biscay, Portuguese and Spanish Atlantic coasts, Macaronesia, the Mediterranean and the Black Sea are data-deficient in terms of knowledge regarding their sensitivity to oil pollution.

Direct effects on seabird populations, such as on survival rates and age structure, are rarely detected because specific long-term studies involving individually marked birds need to be in place in the area affected by the spill before it actually happens.

The amount of oil spilled is less important than the season in which spillage occurs, and the location of that spillage. Relatively small spills (including discharges corresponding to chronic oil pollution) may lead to substantial damage and mortality. In this context, the key factors determining the gravity of wildlife casualties by oil are the densities of marine birds present in an affected area at any given time, and the vulnerability of the species present to oil pollution.

Some case studies are reported in the boxes below, illustrating the results of oil spill impacts in some Mediterranean areas.

Example 1: Eurobulker sinking. The sinking of the tanker Eurobulker in Southern Evoikos gulf (Aegean Sea, Greece) in September 2000 resulted in a spill of 700 tons of crude oil. The environmental impact of the spill was studied by the National Centre for Marine Research. The hydrocarbon concentrations in water, sediment and coastal benthic organisms were measured and the response of the benthic communities to the disturbance caused by the oil spill was studied along the direction to the coast and over three sampling seasons. The most severe and direct effects were evidenced on the muddy benthic communities of the accident site and the stations in the close vicinity sampled shortly after the spill. The effects included reduction of the species richness and community diversity, but the communities reached full recovery 8 months later.

The impact of the spill was more indirect and delayed in the coastal stations, whereas the hydrocarbon measurements indicated, the pollutants were transported later and induced their effects on the benthic communities 6 months after the accident (Zenetos et al., 2004) [30]. Comparative historical data from studies carried out in the area of the accident in the frame of environmental assessment and trawling assessment studies, were used for evaluating the effects on the ecological indices after the accident. This comparison has shown a sharp drop in species number, from an average of 23 to 8 species/0.05 m^2, was observed at the accident site. Among the taxa that were eliminated are the echinoderms and some crustaceans. However, 4 months after the accident the species number raised to 16 and remained constant until the end of the 8-month study period (17 species/0.05 m^2) (Zenetos et al., 2004) [30].

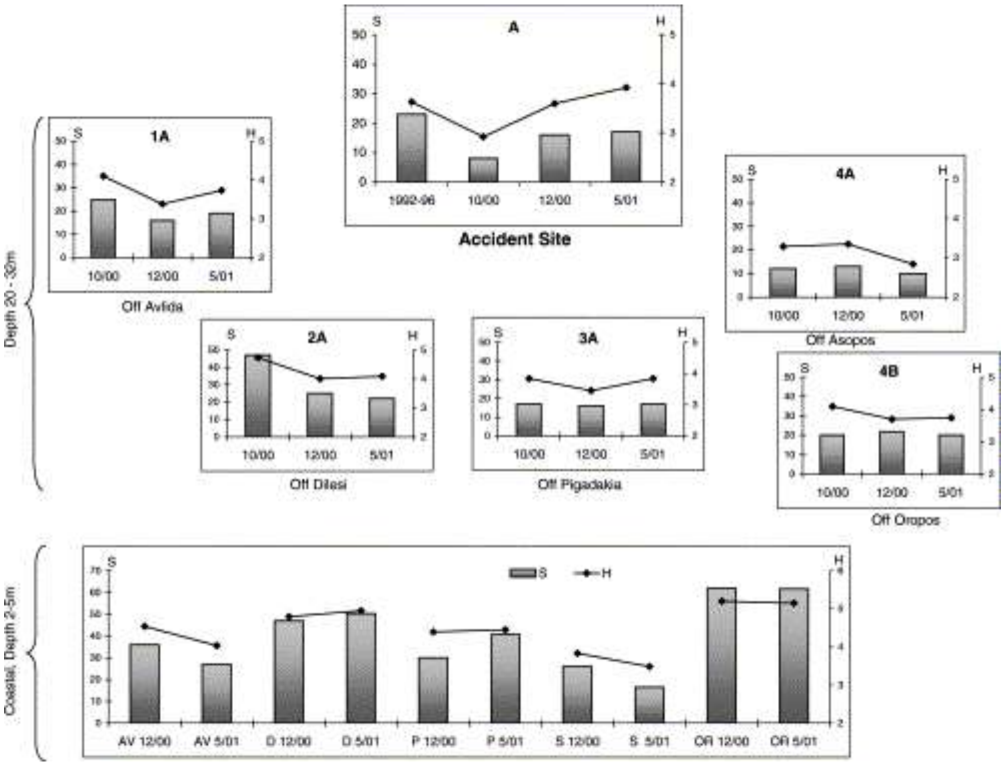


Figure 87. Temporal changes in the ecological indices (S: number of species, H: community diversity) at the sampling sites over the 8-month study period. The position of the plot frames in the figure represents the geographical orientation of the sampling sites in relation to the accident site. Source: Zenetos et al. (2004) [30].

Example 2: Agia Zoni II sinking. On 10 September 2017, the chemical/product tanker Agia Zoni II sank in the Piraeus anchorage area. Oil was observed on the sea surface the same day which in the following days stranded along approximately 4 km of shoreline on Salamis Island, as well as approximately 25 km of the Piraeus/ Athens Riviera shoreline on the mainland. The relevant authorities managed to almost completely seal the tanker, but a large oil slick was released contaminating the island's beaches. The oil slick covered the shores along the island of Salamina and southern Athens. Vessels and environmental experts were dispatched by the authorities to clean up the spilled oil

Following the incident, the Institute of Oceanography of the Hellenic Centre for Marine Research (H.C.M.R.), under the direction of the Ministry of Shipping and Island Policy and taking into account the provisions of paragraphs 3.5.13 and 3.15.1 of the National Emergency Plan on oil pollution incidents has carried out a series of systematic surveys to monitor the possible short-term and medium-term impacts of the incident on the marine ecosystem of the Saronikos Gulf.

The general outcomes from the environmental impact assessment were (REMPEC, 2019) [31]: (i) the major consequences of the oil spill were constrained along the shoreline and specifically in the areas of Salamis, Ellhniko and Glyfada for a period of three months following the incident, not major findings regarding the presence of petroleum hydrocarbons were identified along the shoreline after December 2017, (iii) marine organisms seem unaffected by the incident, while also there are no evidence of bioaccumulation in respect to the incident, and (iii) regarding seabed mapping there were no petroleum residues detected in the zone of 3 to 20 m depth of the studied areas following the conclusion of clean-up operations.

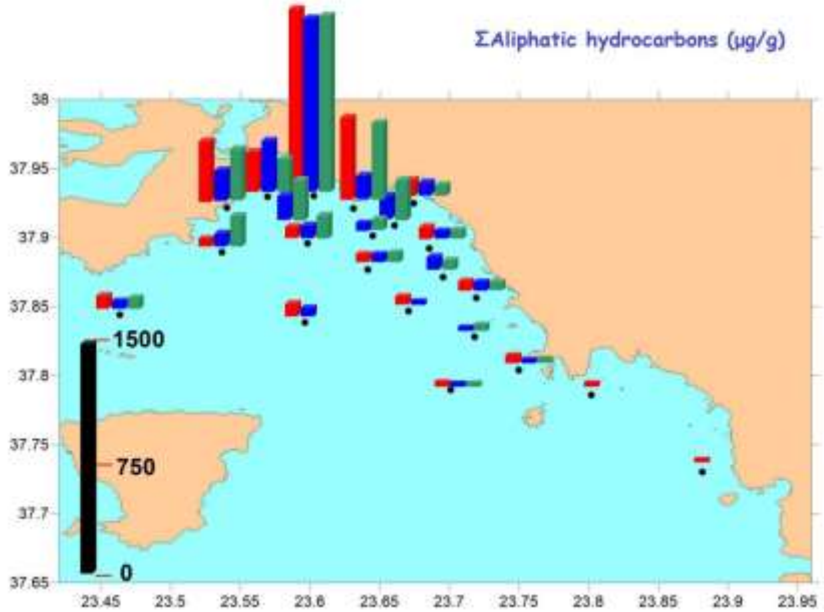


Figure 88. Concentrations of total aliphatic hydrocarbons (in μg/g of dry sediment) for the collected sediment samples on September 21-22nd 2017 (red colour), November 13-14th 2017 (blue colour) and January 23-24th 2018 (green colour) in the open Saronikos Gulf. Source: REMPEC (2019) [31].

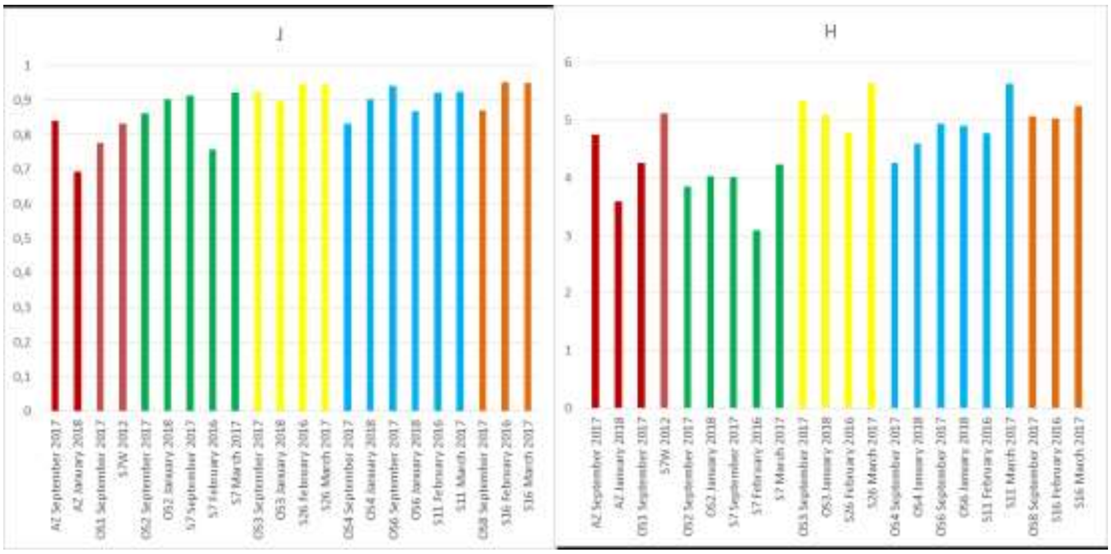


Figure 89. Shannon Diversity index (H') and evenness index (J) in the sampling stations and comparative data before the Agia Zoni II incident. Source: REMPEC (2019) [31].

Example 3: Jiyeh power plant (Lebanon) bombing. On 13th and 15th July 2006, the Jiyeh power plant located 30 km south of Beirut, directly on the coastline, was hit by Israeli bombs. About 15000 to 20000 tons of heavy fuel oil spilt into the Mediterranean Sea. The fuel oil spilled from the Jiyeh power plant reservoirs has affected about 140 km of the Lebanese coast situated to the north of the spill site. Its impact on the marine ecosystem was obviously felt. The sandy beaches and vermetid terraces were the most polluted part of the coast where massive mortality of Gastropods, Crustaceans, Echinoderms, Fish and macroscopic algae was recorded, especially in the moderately and heavily polluted sites. The meiobenthic fauna has been also affected by the oil spill impact, especially on the sandy beaches exposed to wave movement and constantly polluted by fuel oil. At 10 meters depth, the meiobenthic community seemed not to be affected. The five species of fish collected from different sites exhibit PAHs concentrations less than the maximum admissible concentration recommended by AFSSA, WHO and EPA. The mussels from two other sites located to the north of the spill site were highly contaminated by PAHs in direct relation to their distance from the Jiyeh power plant (Khalaf et al., 2006 [32]).

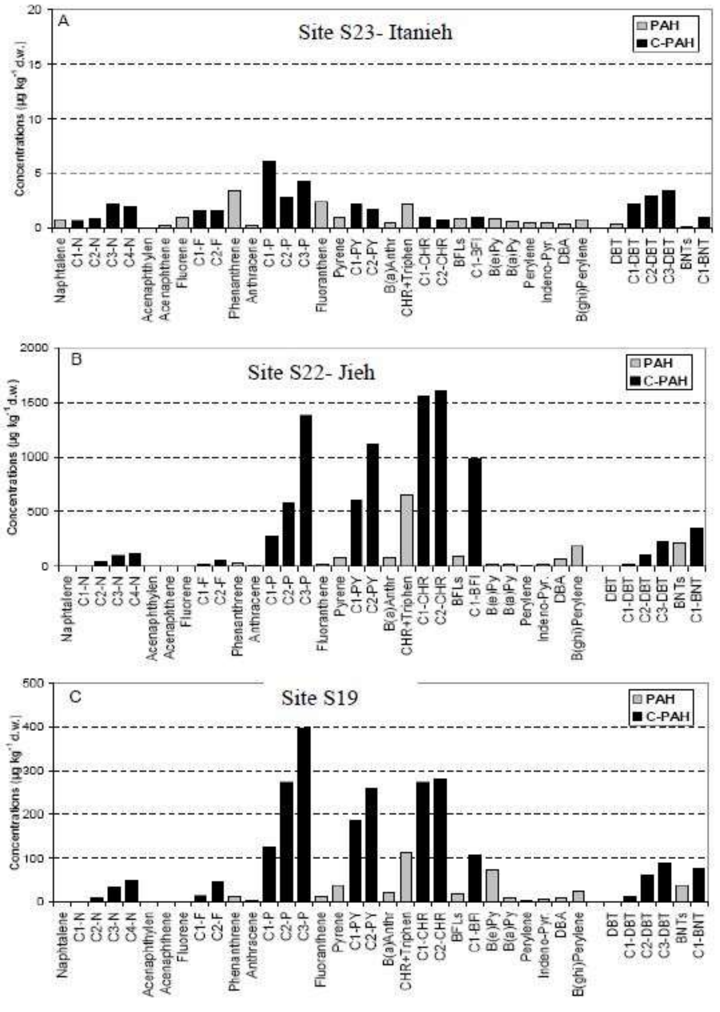


Figure 90. Chemical fingerprints of PAH and sulphur heterocyclic compounds in the three samples of mussels collected in the south of Lebanon (A, site S23 Itanieh), near the electric power plant in Jiyeh (B, site S22 Jiyeh) and

Impacts from Hazardous and Noxious Substances

Properties of HNS which can impact on safety, environmental assets and socioeconomic activity include the substances' flammable, reactive, toxic, explosive, corrosive, etc. potential. However, it is the physical fate of the HNS once it is released into the wider environment which determines if these properties will have an impact. The fate also determines if it is possible to deploy counter-pollution response techniques, and which options should be chosen. Considering their fate, HNS include the following groups of substances:

- Evaporators: Comprises all volatile liquids which are less dense than sea water;
- Floaters: Comprises all non-volatile liquids which are less dense than sea water;
- Sinkers: Comprises all products which are denser than sea water, and;
- Dissolvers: Comprises all products which are soluble in sea water.

According to the OPRC-HNS Protocol 2000, HNS material can comprise:

- Refined products derived from oil,
- Other noxious or dangerous liquid substances,
- Liquefied gases,
- Gases,
- Solid bulk materials with chemical hazards,
- Liquids with flash points not exceeding 60°C, and
- Packaged dangerous, harmful and hazardous material.

In addition to the toxicity hazards to humans, HNS material can have lethal effects on marine organisms. The toxicity of a substance is dependent on how large a dose is required to kill an organism, the more toxic a substance the smaller the dose required.

Incidents involving releases to marine waters have the benefit of sea and air dilution, to reduce the concentration of a substance to below a lethal dose. However, lower doses can produce sublethal effects to marine organisms over a wider area. Sublethal effects may produce some form of impairment which may be detrimental to individual organisms, species, populations or marine communities over a longer term, depending upon the persistence of the released HNS in the marine environment. The stress induced by sublethal effects will reduce the ability of marine organisms to survive. Such effects include damage to fins, pre-cancerous growths, damage to internal organs, skeletal deformities and/or reduction in reproductive success. Effects may not be readily detectible in individuals but could cause changes in the community structure of a marine area impacted by an HNS incident.

Where not directly, toxic some forms of HNS material can damage the marine ecosystems by causing changes in the environment. Such changes include variation in salinity and pH, together with deoxygenation when material is broken down or used biologically in the marine environment (e.g. palm oil, fertilisers, etc.). Changes in environmental conditions can induce lethal effects in marine ecosystems.

3.2.5 Accidental post-spill major socio-economic impacts

Oil spills can determine a wide variety of impacts on human activities, damaging economic sectors but also hindering the utilization of marine and coastal ecosystems by local communities, determining economic and societal impacts.

The assessment of the cost of an oil spill deals with a more comprehensive set of damages than the assessment of compensation purposes. In the more general approach, private costs and collective or public damages are included Figure 91. Private costs are those related to the fisheries and seafood sector (extractive, transport, processing and marketing firms) and to tourism on coastal areas (Garza-Gil et al., 2006) [34]. These are private costs because a limited group of individuals is affected and they are associated to economic activities for which market values are available. Collective or public losses are usually identified with cleaning and restoration costs. However, lost recreation opportunities for residents (use of beaches, landscape, etc.) and passive use losses (cultural, existence and heritage values) are social damages not suitable for compensations because they have no markets to be interchanged and, consequently, market prices are not available. Nevertheless, there are non-market valuation methods available and accepted as reliable to estimate collective non-marketed losses.

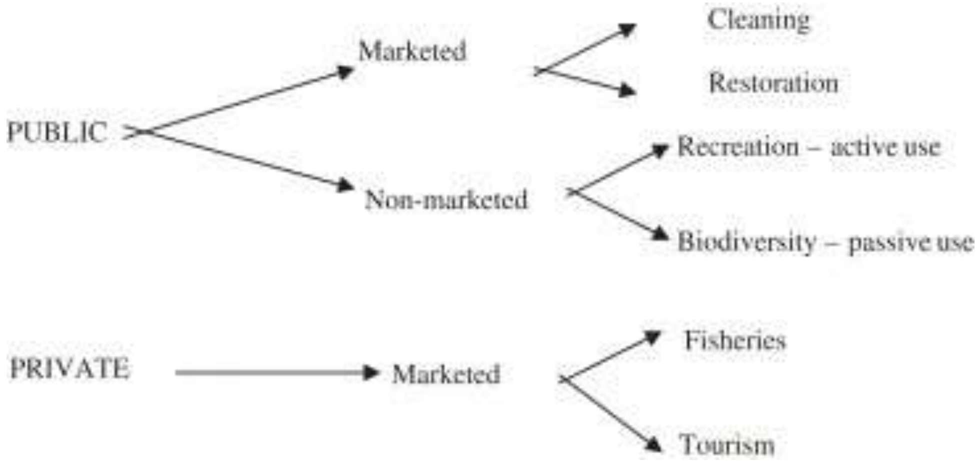


Figure 91. Components of social costs of an oil spill. Source: Garza-Gil et al., 2006 [34].

When dealing with the economic impact of an oil spill one can assume that the total cost of an oil spill can be approximated by the compensation eventually paid to claimants. Compensation for oil pollution caused by tankers is governed by four international conventions: the 1969 and the 1992 International Convention on Civil Liability for Oil Pollution Damage (“CLC 1969” and “CLC 1992”) and the 1971 and 1992 conventions on the Establishment of an International fund for Compensation for Oil Pollution Damage (“1971 Fund” and “1992 Fund”). These conventions together create an international system where reasonable costs of clean-up and damages are met, first by the individual tanker owner up to the relevant CLC limit through a compulsory insurance and then by the international IOPCFs, if the amounts claimed exceed the CLC limits (Christos et al, 2010) 104. *Table 21* reports the Mediterranean incidents causing oil spills, which were followed by claims and/or recourse actions managed by the IOPC Funds.

For example, on 5th March 2012, the Greek tanker ALFA I (1,648 GT; built 1972) entered in contact with a submerged wreck in Elefsis Bay, Greece. This resulted in a 30m lateral shear to the hull and ALFA I sunk shortly after. At the time of the incident it is reported that ALFA I was carrying 300 tonnes of Intermediate Fuel Oil (IFO) 180, 1,499 tonnes of Heavy Fuel Oil (HFO) 380 and ~250 tonnes of Marine Gas Oil (MGO). An unknown amount of oil (but estimated to be less than 100 tonnes) was spilt at sea. Booms were placed around the wreck of the vessel while salvage operations took place. By the end of April 2012, all the pumpable oils located in the wreck were successfully recovered, counting for 90% of the estimated amount of oil on board at the time of the incident. Manual clean-up of the contaminated shoreline in Elefsis Bay was carried out from March to the following June by a local contractor, primarily to remove contaminated beach material. ITOPF arrived on site shortly after the incident at the request of the vessel’s insurer, to work with the owner-appointed surveyors and the oil spill response contractor to survey the incident area and understand the extent of the pollution. ITOPF worked subsequently with the IOPC Funds on the assessment of claims for the clean-up activities. An amount of €12 million was paid as compensation to the main clean-up contractor.

Refunding pollution damages: the Prestige case study (Atlantic Sea)

Source: IOPC 2020 (https://www.iopcfunds.org/?generate_case_study_pdf=1916&custom_lang=)

On 13 November 2002, the Bahamas-registered tanker Prestige (42,820 GT), carrying 76,972 tonnes of heavy fuel oil, began listing and leaking oil some 30 kilometres off Cabo Finisterre, Galicia, Spain. On 19 November, while under tow away from the coast, the vessel broke in two and sank some 260 kilometres west of Vigo, Spain. The bow section sank to a depth of 3,500 metres and the stern section to a depth of 3,830 metres. The break-up and sinking released an estimated 63,200 tonnes of cargo.

Over the following weeks, oil continued to leak from the wreck at a declining rate. It was subsequently estimated that approximately 13 700 tonnes of cargo remained in the wreck.

Due to the highly persistent nature of the Prestige’s cargo, released oil drifted for an extended period of time with winds and currents, and travelled great distances. The west coast of Galicia was heavily contaminated and oil eventually moved into the Bay of Biscay affecting the north coast of Spain and France. Traces of oil were detected in the United Kingdom (the Channel Islands, the Isle of Wight and Kent).

Major clean-up operations were carried out at sea and on shore in Spain. Significant clean-up operations were also undertaken in France. Clean-up operations at sea were undertaken off the coast of Portugal.

Between May and September 2004, some 13,000 tonnes of cargo were removed from the fore part of the wreck. Approximately 700 tonnes were left in the aft section.

The total amount awarded, as per compensation of the impacts, after some amendments, was EUR 1,439.08 million (pollution damage EUR 884.98 million + pure environmental and moral damages EUR 554.10 million), as follows:

- the amount awarded to the Spanish State is EUR 1,357.14 million (pollution damage EUR 803.04 million + pure environmental and moral damages EUR 554.10 million).
- the amount awarded to the French State is the full claimed amount i.e. EUR 5 million.
- the Supreme Court decided to include VAT in the compensation awarded to the Spanish and French States.
- the amount awarded to individual claimants in Spain and France is EUR 44 million.

Impacts on fisheries and mariculture

Oil spills can cause serious damage to fishery and mariculture resources through physical contamination, toxic effects on stock and by disrupting business activities. The nature and extent of the impact on seafood production depends in the characteristics of the spilled oil, the circumstances of the incident and the type of fishing or aquaculture activity affected. The most important impacts on these activities are (ITOPF, Technical Information Paper n. 11) [35].

- Damage and loss mechanisms. Fishing gear and cultivation equipment may be oiled, leading to the risk of catches or stock becoming contaminated or activities being haltered until gear is cleaned or replaced. While adult free-swimming fish and wild stocks of commercially important marine animals in the open sea seldom suffer long term-damage from oil spills, caged animals and seafood products that are cultivated in fix locations are potentially are greater risk because they are unable to avoid exposure to oil contaminants. Damage to seafood may also be caused as a result of measures taken to combat an oil spill such as use of dispersant, aggressive or inappropriate clean-up techniques, such as washing with high pressures. The seasonal cycle of fishing and mariculture, together with the type of oil are able to influence the degree of damage. However it is very difficult to distinguish the effect of an oil spill from changes arising from other events, like natural fluctuation, variation in fishing effort, climatic effects, and contamination from other sources.
- Toxicity. The toxic effects of oil depend on the concentrations of the light aromatic components in the oil and the duration of exposure to these components. Toxicity effects can range from sub-lethal behavioural effects to localized mass mortalities of marine life.
- Physical contamination. Oil can foul boats, fishing gear and mariculture facilities and can then be transferred to the catch or produce. Flotation equipment, such as buoys and floats, lift nets, cast nets and fixed traps extending above the sea surface are particularly at risk of contamination by floating oil. Lines, dredges, bottom trawls and the submerged parts of cultivation facilities are usually protected. Shoreline cultivation facilities (e.g. intertidal oyster racks) are especially vulnerable. When fish farming facilities become physically impacted by floating oil, the oiled surface may themselves be a source of secondary contamination until they are cleaned.
- Tainting. Taint is commonly defined as an odour or flavour that is foreign to a food product. Oil contamination of seafood can readily be detected as a petroleum taste or smell. Bivalve molluscs and other filter-feeding, sedentary animals are particularly vulnerable to tainting, since they filter substantial quantities of water and so risk ingesting dispersed oil droplets and oiled particles suspended in the water column.
- Public health concerns. The occurrence of contamination in seafood organisms or products following a major spill can lead to public health concerns and may give raise to the imposition of fishing restrictions. He main concerns regard the presence of polycyclic aromatic hydrocarbons (PAHs) in the oil. Crude oil spills give rise primarily to contamination by low molecular weight PAHs which usually have little or no carcinogenic potential, but are of concern for their acute toxicity. Heavy fuel oils generally contain a greater proportion of high molecular weight PAHs, including those that can be actively carcinogenic.
- Loss of market confidence and business disruption. Public health concerns and the detection of taint are likely to lead to produce beige withdrawn from the market. A loss of primary market confidence may also occur leading to price reductions or outright rejection of seafood products by commercial buyers and consumers. Media coverage of oil contamination can have implications for the marketability of seafood. After the Amoco Cadiz oil spill for example, the French government called for oysters and other seafood thought to be affected by the oil spill to be removed from the market to avoid human health effects resulting from ingesting food In addition to the short-term effects on the fishing industry, such government-induced bans have the potential to affect consumer demand in the long run by reinforcing consumer worries about health risks, potentially to an irrational extent [36]. Not only fisheries, but also tourism, is significantly affected by public perceptions following oil spills [36]. In addition to media coverage, public perception about the severity of the oil spill and the resulting danger for the population can also be influenced by other factors such as government action.

Impacts on tourism

Disruption of traditional coastal activities such as bathing, boating, angling and diving can have a consequent effect for hotels, restaurants and bar owners, as well as sailing schools, camp sites, caravan parks and the many other businesses and individuals who gain their livelihood from tourism (ITOPF – Technical Information Paper 12) [38]. In heavy weather, oil can be carried inshore by airborne spray from waves breaking against a rocky shore. Buildings, cars and caravans along a seafront or close to the shore can become spotted with oil and require cleaning and, in some cases, repainting. The physical disturbance to coastal area and recreational pursuits from a single oil spill is usually comparatively short-live. Once shoreline are clean, normal trade and activity would be expected to resume, although media attention may cause disproportionate damage to the image of the local tourist industry, aggravating economic losses by contributing to a public perception of prolonged wide-scale pollution (ITOPF –

Technical Information Paper 12) [38]. Oil spills can directly affect tourism-based communities through direct impact of oil on beaches and waterfront property, in addition to damaging the reputation of the area through decreased public perception and adverse media coverage [36]. The economic losses of decreased tourism will be reflected in many subsectors such as accommodations, transportation, professional guide companies, tourist entertainment and novelty activities, and recreational fisheries. Tourism suffered greatly as a result of the Exxon Valdez with an observed decrease in visitor spending by 35% in the region compared to the pre spill level, and 59% of local tourism businesses reported spill-related cancellations. This decrease also translates directly to reduction in earnings of retail and restaurant establishments servicing the tourism industry [5]. Further, area businesses and institutions not associated with or affected by the spill can sustain damage from brand name affiliation.

Impacts on ports, marinas and fishing harbours (Source: ITOPF – Technical Information Paper 12 [38])

Oil spills can cause considerable disruption to normal port operations while vessels undergo cleaning or in the case vessel movements have to be curtailed. Large vessels, leaving or entering the port, should move at slow speed to reduce wash that could disturb booms and other deployed resources, as well as to minimize the spread of floating oil around the port. Port, marinas and fishing harbours are usually enclosed by sea defences to protect moored vessels against adverse sea conditions. If oiled, these structures can be difficult to clean and they may become a source of secondary pollution. Once oil has entered a marina or a port the hull of vessels, mooring lines and berths can become oiled. Hull can be usually cleaned while still in the water, if undertaken with minimal delay. To avoid secondary pollution, run off should be collected. However, some cleaning agents are likely to damage the gel coat of fibre-glass vessels. In general, the sheltered nature of ports and harbours and the ready availability of spill response equipment allow for a rapid and effective response to a spill of oil, particularly if a comprehensive contingency plan is available.

Impacts on industrial water intakes (Source: ITOPF – Technical Information Paper 12 [38])

Sea water is widely used in a broad range of industries: as a coolant for thermal and nuclear power station and refineries, as a feedstock and as a coolant for desalination plants. The possibility the oil will be entrained into the water flow depends on the type of oil, the weather conditions and the design of the intake itself. Occasionally, following an oil spill, water intake of electricity power plants are shut down as a precaution against damage to machinery and to avoid the more extensive shout-down of the entire plant should condenser tubes and other equipment need to be cleaned. Seawater can also be used to warm Liquefied Natural Gas (LNG) when transforming it from a liquid to a gas prior to distribution of gas in pipelines. Debris screens are unlikely to cope with oil contamination, with a real risk oil is distribute through the resto of the plant. The experience with multistage flash instillation desalination plants has been that a certain level of oil can be tolerated without contamination of the fresh water product or undue effect on heat exchangers. On the other hand, reverse osmosis systems rely on semi-permeable membranes to remove salt from seawater and oil contamination could foul the surface of these membranes.

3.2.6 Impact from offshore O&G activities

O&G activities pose a threat to the marine environment, the seabed and sea-bottom habitats and species, both during the exploration phase and the production phase for many years, depending on the oil type, the location of the eventual spill and the area in which the contamination occurs, since oil contamination can persist in the marine environment. When oil spills from offshore oil installation occur, the expected impacts are the same or similar to those described in the previous paragraphs. But many of the impacts of offshore activities on marine environments are uncertain, due to the complex interactions between many different species within marine ecosystems and difficulties associated with conducting research at depth.

Moreover, technological innovations have helped offshore drilling move further out into deep and ultra-deep waters. The multiplication of O&G wells in increasingly deep waters undoubtedly brings greater consequences and threats for the environment and natural resources, including the fact that deep environments, with their peculiar species and processes, are pretty less known and difficult to study.

Oil spills are not the only potential hazards posed by offshore O&G activities (Figure 92). Other long- and short-term risks are primarily associated with (a) contamination due to drilling wastes (muds, produced waters, by-products, etc.); emissions from drilling sites and potential runoffs, (b) natural gas/oil leaks and spills, and (c) direct effects on human health. The drilling fluids circulated through the well hole contain toxic materials (including oil/grease, arsenic, chromium, cadmium, lead, mercury, & naturally occurring radioactive materials). The composition of drilling muds and produced waters varies widely depending on location & depth of well; and type of drilling fluid. Produced waters potentially impacting the surface or groundwater are typically disposed of in a deep aquifer, but there is still the threat of accidental release from temporary storage. Contributing to air pollution are also the potential emissions of hydrogen sulphide present in natural gas deposits.

From an extended analysis of research results about the impacts off offshore extractions on marine ecosystem components in the Mediterranean, Mangano and Sarà (2017) [40] identified some major issues. In general, both the abiotic and biotic ecosystem components were highly resilient and showed short recovery times. The sedimentary physical component grain size appeared to remain unaffected by the presence of platform infrastructures, even if the dynamic of water currents at the bottom of the drilling platform resulted influenced by the presence of these structures, creating potential erosion phenomena (Frascari et al., 2000) [41]. The presence of heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs) represented the biggest effects on sediments, depending on the temporal and spatial scale considered. Some elements showed several anomalies (not linear in trend) in concentrations mainly in proximity to the anodes (e.g. cadmium; De Biasi et al., 2007 [42], Gomiero et al., 2011 [43]). The macrobenthic communities, both in terms of infaunal specimens inhabiting the soft seabed around the platform's legs and the encrusting macrofouling species, decreased in terms of abundance and biomass. However, these communities seemed to display different structures with respect to control areas (Manoukian et al., 2010 [44], Punzo et al., 2015 [45]). Overall, the powerful attraction of the submerged portions of the platforms, true hotspots of biodiversity, may be considered in a context of non-indigenous species (NIS) establishment, representing potential bridgeheads for new invasions, and focal areas that can drive and enhance the pathways of spread (Zenetos et al., 2005 [46], Bolognini et al., 2015 [47]).

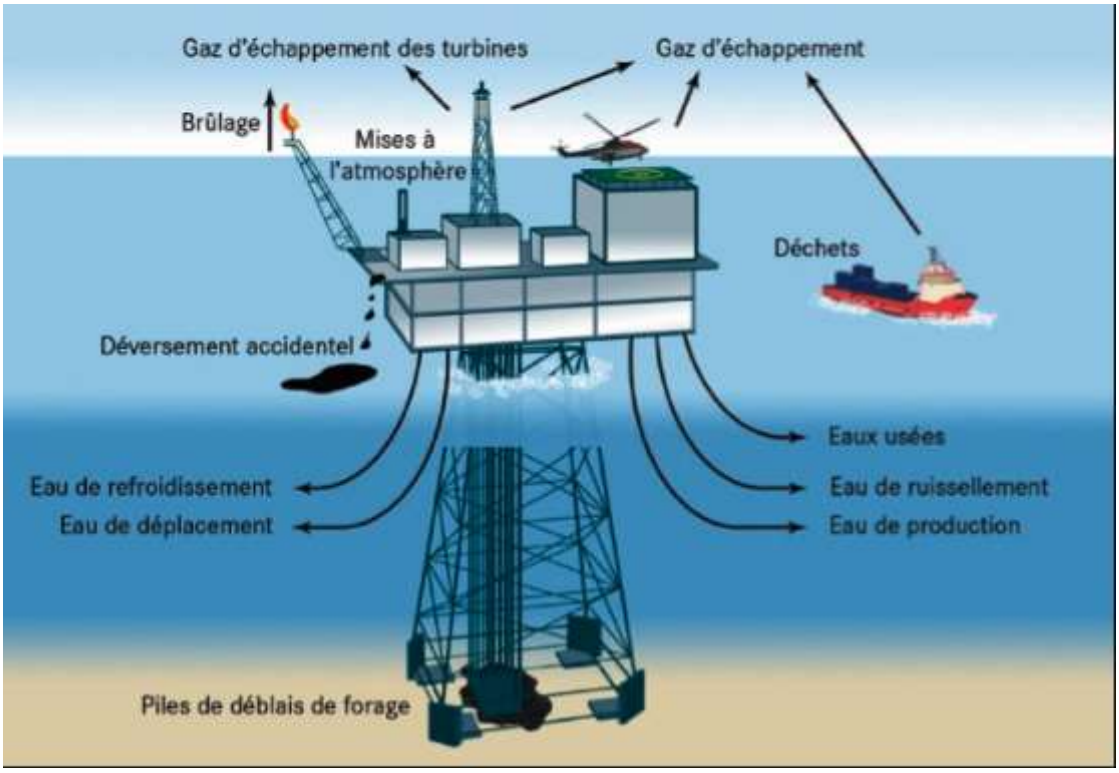


Figure 92. Environmental impact of Oil and Gas Activities. Source: OSPAR Commission (2010), 2010 Quality Status Report (qsr2010.ospar.org).

3.2.7 Measures

3.2.7.1 Prevention measures

Measures defined at international level

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. In 1997, a Protocol was adopted to amend the Convention and a new Annex VI was added which entered into force on 19 May 2005. MARPOL has been updated by amendments through the years. The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes. Special Areas with strict controls on operational discharges are included in most Annexes.

In relation to oil and chemical pollution the following Annexes are relevant (Source: IMO Web Site):

Annex I - Regulations for the Prevention of Pollution by Oil. It overs prevention of pollution by oil from operational measures as well as from accidental discharges; the 1992 amendments to Annex I made it mandatory for new oil tankers to have double hulls and brought in a phase-in schedule for existing tankers to fit double hulls, which was subsequently revised in 2001 and 2003.

The MARPOL convention introduced a number of important concepts, such as a requirement for new oil tankers to be fitted with segregated ballast tanks, so as to obviate the need to carry ballast water in cargo tanks. This was superseded by the requirement for oil tankers delivered from 1996 onwards to be fitted with a double hull. As far as operational oil pollution is concerned, the many innovations introduced by MARPOL on allowable discharges of bilge water through the oily water separator (with the well-known 15ppm standard), or oily waters from the cargo tanks, through the oil discharge and monitoring system, have been introduced.

Annex II - Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk. It includes details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk; some 250 substances were evaluated and included in the list appended to the Convention; the discharge of their residues is allowed only to reception facilities until certain concentrations and conditions (which vary with the category of substances) are complied with. In any case, no discharge of residues containing noxious substances is permitted within 12 miles of the nearest land. Regulations governing the carriage of chemicals by ship are also contained in the International Convention for the Safety of Life at Sea (SOLAS).

Annex II Regulations sets out a pollution categorization system for noxious and liquid substances. The four categories are: Category X: Noxious Liquid Substances which are deemed to present a major hazard to either marine resources or human health and which discharge into the marine environment is prohibited; Category Y: Noxious Liquid Substances which are deemed to present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and for which there is a limitation on the quality and quantity of the discharge into the marine environment; Category Z: Noxious Liquid Substances which are deemed to present a minor hazard to either marine resources or human health and for which less stringent restrictions on discharge are imposed; and Other Substances: substances which are considered to present no harm to marine resources, human health, amenities or other legitimate uses of the sea and which are not subject to any requirements of MARPOL Annex II.

Annex III - Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form. It contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications. For the purpose of this Annex, “harmful substances” are those substances which are identified as marine pollutants in the International Maritime Dangerous Goods Code (IMDG Code) or which meet the criteria in the Appendix of Annex III. Chemicals which are carried in packaged form, in solid form or in bulk are regulated by Part A of SOLAS Chapter VII - Carriage of dangerous goods, which includes provisions for the classification, packing, marking, labelling and placarding, documentation and stowage of dangerous goods.

Designation of Areas of Special Attention under MARPOL Annex1

The MARPOL Convention assigns certain sea areas the denomination of "special areas" in which, for technical reasons relating to their oceanographically and ecological conditions and to their sea traffic circumstances, the adoption of special mandatory methods for the prevention of marine pollution is required. Under the Convention, these special areas are provided with a higher level of protection than other areas of the sea. The Mediterranean Sea has been designated as a Special Area under MARPOL Annexes I (oil) and V (garbage).

Discharges in special areas. Any discharge into the sea of oil or oily mixtures from ships of 400 gross tonnage and above shall be prohibited, except when all of the following conditions are satisfied: the ship is proceeding en route; the oily mixture is processed through an oil filtering equipment meeting the requirements of regulation 14.7 of

MARPOL Annex I; the oil content of the effluent without dilution does not exceed 15 parts per million; the oily mixture does not originate from cargo pump-room bilges on oil tankers; and the oily mixture, in case of oil tankers, is not mixed with oil cargo residues. Discharge in Special Areas from oil tankers. Any discharge into the sea of oil or oily mixture from the cargo area of an oil tanker shall be prohibited while in a special area.

Minimizing risk of collision

Navigation management measures can also act as environmental protection measures as far as they contribute to prevent release of pollutants in the marine environment. Ships routeing. The objective of ships' routeing is to improve the safety of navigation, and therefore the prevention of marine pollution by ships, in converging areas and in areas where the density of traffic is great or where freedom of movement of shipping is inhibited by restricted sea room, the existence of obstructions to navigation, limited depths or unfavourable meteorological conditions. Traffic separation schemes (TSS) and other ship routeing systems have now been established in most of the major congested shipping areas of the world, and the number of collisions and groundings has often been dramatically reduced. IMO's responsibility for ships' routeing is enshrined in Chapter V of the International Convention for the Safety of Life at Sea, 1974 (SOLAS), which recognises the Organization as the only international body for establishing such systems. As well as traffic separation schemes, other routeing measures adopted by IMO to improve safety at sea include two-way routes, recommended tracks, deep water routes, precautionary areas, and areas to be avoided. Some Ship’s Routeing Systems have already been established in the Mediterranean. However, there may be scope for creating additional systems, at least in narrow passages and in the region of the most sensitive coastal areas.

Identification of Particularly Sensitive Areas (PSSA). In order to protect marine environment from oil and chemical pollution it is also possible to identify maritime zones that require additional protection from international shipping and request their designation as PSSA. This is done by applying the IMO Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas (PSSAs) These guidelines include criteria to allow areas to be designated as PSSAs if they fulfil a number of criteria, including: ecological criteria, such as unique or rare ecosystem, diversity of the ecosystem or vulnerability to degradation by natural events or human activities; social, cultural and economic criteria, such as significance of the area for recreation or tourism; and scientific and educational criteria, such as biological research or historical value. When an area is designated as a PSSA, certain protective measures are used to control the maritime activities in that area, such as routeing measures, including TSS and areas to be avoided; strict application of MARPOL discharge and equipment requirements for ships, such as oil tankers; installation of VTS; and others. These associated protective measures become mandatory under the relevant international conventions (e.g. SOLAS, MARPOL, etc.) and, therefore, must be complied with by international shipping.

Control of Maritime Traffic. According to SOLAS chapter V on Safety of Navigation, specifically regulation 12, Vessel Traffic Services (VTS) contribute to safety of life at sea, safety and efficiency of navigation and protection of the marine environment, adjacent shore areas, work sites and offshore installations from possible adverse effects of maritime traffic. SOLAS Contracting Governments undertake to arrange for the establishment of VTS where, in their opinion, the volume of traffic or the degree of risk justifies such services, following the guidelines developed by the Organization, without prejudice of the rights and duties of Governments under international law or the legal regimes of straits used for international navigation and archipelagic sea lanes. Maritime Traffic Control Systems, including VTS, are already established in some areas of the Mediterranean. There have already been incidents where coastal States have lost track of vessels which may pose a threat of pollution and there may be a case for establishing additional Maritime Traffic Control Systems in the Mediterranean region in order to effectively implement the 2002 Prevention and Emergency Protocol. Through the SafeMed II Project, considerable efforts were made to enhance the capacities of Mediterranean coastal States related to the prevention of maritime accidents, particularly in relation to VTS management.

Assistance to ships in distress

IMO Resolution A.949(23) Guidelines on places of refuge for ships in need of assistance are intended for use when a ship needs assistance but the safety of life is not involved. A second resolution, A.950(23) Maritime Assistance Services (MAS), recommends that all coastal States should establish a maritime assistance service (MAS).

The following *Table 22* reports the status of transposition of all IMO conventions. This is relevant to understand the state of implementation of the policy instruments, and it is relevant not only for oil and chemical pollution prevention, but also for the other topics, presented in the next chapters of this Study.

Table 22. State of transposition of IMO conventions by Mediterranean countries. Source: IMO web site consulted on 25-09-2020

As at 15/09/2020	IMO Convention 48	SOLAS Convention 74	SOLAS Protocol 78	SOLAS Protocol 88	SOLAS Agreement 96	LOAD LINES Convention 66	LOAD LINES Protocol 88	TONNAGE Convention 69	COLREG Convention 72	CSC Convention 72	CSC amendments 93	SFV Protocol 93	Cape Town Agreement 2012	STCW Convention 78	STCW-F Convention 95	SAR Convention 79	STP Agreement 71	Space STP Protocol 73	IMSO Convention 76	INMARSAT OA 76	IMSO amendments 2006	IMSO amendments 2008	FACILITATION Convention 65	MARPOL 73/78 (Annex I/II)	MARPOL 73/78 (Annex III)	MARPOL 73/78 (Annex IV)	MARPOL 73/78 (Annex V)	MARPOL Protocol 97 (Annex VI)	London Convention 72	London Convention Protocol 96	INTERVENTION Convention 69	INTERVENTION Protocol 73	CLC Convention 69	CLC Protocol 76	CLC Protocol 92	FUND Protocol 76	FUND Protocol 92	FUND Protocol 2003	NUCLEAR Convention 71	PAL Convention 74	PAL Protocol 76	PAL Protocol 90	PAL Protocol 02	LLMC Convention 76	LLMC Protocol 96	SUA Convention 88	SUA Protocol 88	SUA Convention 2005	SUA Protocol 2005	SALVAGE Convention 89	OPRC Convention 90	HNS Convention 96	HNS PROT 2010	OPRC/HNS 2000	BUNKERS CONVENTION 01	ANTI FOULING 2001	BALLASTWATER 2004	NAIROBI WRC 2007	HONG KONG CONVENTION
Albania	x	x	x			x		x	x					x		x							x	x	x	x	x						d	x	x	x	x			d	d	d	x	x	x	x	x			x	x			x	x		x	x	
Algeria	x	x	x	x		x	x	x	x					x		x			x	x			x	x	x	x	x				x	x	d		x		x							x		x	x	x	x	x	x								
Bosnia & Herzegovina	x							x											x	x																										x	x												
Croatia	x	x	x	x		x	x	x	x	x		x		x		x			x	x			x	x	x	x	x	x	x		x	x	d		x		x	x		d	d	d	x	x	x	x	x			x	x				x	x	x	x	
Cyprus	x	x	x	x		x	x	x	x	x				x		x	x	x	x	x			x	x	x	x	x	x	x				d	x	x	x	x							x	x	x	x					x			x	x	x	x	
Egypt	x	x	x	x		x	x		x					x			x	x	x	x			x	x	x	x	x		x	x	x	x	x	x	x					x		x		x		x	x			x	x			x	x	x	x		
France	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	d	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x			x	x	x	x	x	x
Greece	x	x	x	x		x	x	x	x	x				x		x	x	x	x	x			x	x	x	x	x	x	x				d	x	x	x	x	x		d	d		x	x	x	x	x	x	x	x	x			x	x	x	x		
Israel	x	x	x	x		x		x	x	x				x					x	x			x	x	x		x								x		x									x	x				x								
Italy	x	x	x	x		x	x	x	x	x		x		x		x			x	x			x	x	x	x	x	x	x	x	x	x	d	x	x	x	x	x	x							x	x			x	x				x	x			
Lebanon	x	x	x			x	x	x	x	x				x		x			x	x			x	x	x	x	x				x		x		x											x	x				x				x	x	x		
Libya	x	x	x	x		x	x	x	x					x		x			x	x			x	x	x	x	x		x				x							x	x					x	x				x								
Malta	x	x	x	x		x	x	x	x					x		x			x	x			x	x	x	x	x	x	x				d	d	x	d	x						x		x	x	x				x			x	x	x	x	x	x
Monaco	x	x				x		x	x							x			x	x			x	x	x	x	x	x	x		x	x	d		x		x									x	x				x								
Montenegro	x	x	x	x		x	x	x	x	x				x		x			x			x	x	x	x	x	x	x	x		x	x	d		x		x	x					x			x	x	x	x	x					x	x	x		
Morocco	x	x	x			x		x	x	x				x	x	x			x					x	x	x	x	x	x	x	x	x	d		x	x	x	x						x	x	x	x			x	x	x			x	x	x	x	
Slovenia	x	x	x	x		x	x	x	x	x				x		x							x	x	x	x	x	x	x	x	x	x	d		x		x	x					x		x	x	x			x	x	x		x	x	x			
Spain	x	x	x	x		x	x	x	x	x		x	x	x	x	x			x	x		x	x	x	x	x	x	x	x	x	x	x	d	x	x	x	x	x	x	d	d	d	x	d	x	x	x	x	x	x	x			x	x	x	x		
Tunisia	x	x	x	x		x	x	x	x	x				x	x	x			x	x			x	x	x	x	x	x	x		x	x	d		x		x									x	x			x	x				x	x			
Turkey	x	x	x			x	x	x	x	x				x		x			x	x			x	x	x	x	x	x							x		x	x						x	x	x	x	x	x	x	x		x	x	x	x	x		x

x= ratification

d=denunciation

Measures defined at European level (Carpenter, 2018 [48])

Under the Directive on Safety of Offshore Oil and Gas Operations (2013/30/EU), the EU has put in place a set of rules to help prevent accidents, as well as respond promptly and efficiently should one occur

- before exploration or production begins, companies must prepare a "Report on Major Hazards" for their offshore installation. This report must contain a risk assessment and an emergency response plan
- companies must keep resources at hand in order to put them into operation when necessary
- when granting licenses, EU countries must ensure that companies are well financed and have the necessary technical expertise
- technical solutions which are critical for the safety of operators' installations must be independently verified. This must be done prior to the installation going into operation
- national authorities must verify safety provisions, environmental protection measures, and the emergency preparedness of rigs and platforms. If companies do not respect the minimum standards, EU countries can impose sanctions, including halting production
- information on how companies and EU countries keep installations safe must be made available for citizens
- companies will be fully liable for environmental damages caused to protected marine species and natural habitats. For damage to marine habitats, the geographical zone will cover all EU marine waters including exclusive economic zones and continental shelves
- under the directive, citizens can express opinion and comments on the environmental effects of planned offshore oil and gas exploration operations and must be duly informed by the authorities of their Member States.

European Maritime Safety Agency (EMSA). Currently, there are three Action Plans for pollution preparedness and response developed by EMSA: the first one, applicable to oil (hereinafter referred to as the “EMSA Oil Action Plan”), identifies the Mediterranean Sea, particularly the area along the tanker route from the Black Sea, as a priority area in European waters which requires additional action. The second one pertains to HNS matters (hereinafter referred to as the “EMSA HNS Action Plan”). The third one is EMSA’s Action Plan for Response to Marine Pollution from Oil and Gas Installations (hereinafter referred to as the “EMSA Offshore Action Plan”).

EMSA Earth Observation Services comprise two elements: (i) Earth Observation for Integrated Maritime Services which includes vessel detection and target activity detection in support of EU maritime border control activities undertaken by FRONTEX, the agency which coordinates and develops European border management, including its maritime borders; (ii) CleanSeaNet (CSN), the European satellite-based oil spill and detection service. CSN is a European satellite-based oil spill and vessel detection service which assists participating States in: identifying and tracing oil pollution on the sea surface; monitoring accidental pollution during emergencies; and contributing to the identification of polluters. These tasks are requirements of Article 10 of the 2005 EU Directive on ship-source pollution.

Union Civil Protection Mechanism (UCPM). The UCPM facilitates cooperation in the field of Civil Protection to improve the effectiveness of systems for preventing, preparing for and responding to natural and man-made disasters, including marine environment emergencies. The Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021) should make use of relevant aspects of the UCPM, and reflect them as appropriate actions to be addressed by REMPEC.

Maritime Strategy Framework Directive. The Marine Strategy Framework Directive (2008/56/EC) establishes a framework for community action in the field of marine environment policy. In particular, it requires Member States sharing a marine region or sub-region to cooperate to ensure that the measures required to achieve the objectives of the Directive are coherent and coordinated across the marine region or sub-region concerned. To achieve this coordination, Member States are obliged to use existing regional institutional cooperation structures, including those under the Regional Sea Conventions, making every effort to coordinate their actions with third countries having sovereignty or jurisdiction over the waters concerned. Member States are also obliged, as far as possible, to build upon relevant existing programmes and activities developed in the framework of structures stemming from Regional Sea Conventions.

At European level, prevention measures are in place also in the form of penalties. According to Directive 2005/35/EC of the European Parliament and of the Council of 7 September 2005 on ship-source pollution and on the introduction of penalties for infringements, discharges of oil or other noxious substances from ships must be regarded as an infringement and punished accordingly when committed with intent, recklessly or as a result of grossly negligent behaviour. The Directive makes such discharges of polluting substances an offence when carried out in: the internal waters, including ports, of a Member State; the territorial waters of a Member State; straits used for international navigation subject to the regime of transit passage, as laid down in the 1982 United Nations Convention on the Law of the Sea; the exclusive economic zone (EEZ) of a Member State; the high seas.

Measures defined in the context of the Barcelona convention

In the framework of the Barcelona convention three Protocols are available to protect the marine environment from oil and chemical pollution from ships and offshore activities. These are the Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft (Dumping Protocol); the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources (LBS Protocol); and the Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal (Hazardous Wastes Protocol). MED POL is the Regional Activity Centre (RAC) responsible for the implementation of these three protocols. The second RAC with specific relevance to marine pollution from ships is REMPEC, administered by the International Maritime Organization (IMO) in cooperation with UNEP. REMPEC's main fields of action are in the prevention of pollution of the marine environment from ships and the development of preparedness for and response to accidental marine pollution and cooperation in case of emergency.

The Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021) lists the priority issues to be addressed when implementing the 2002 Prevention and Emergency Protocol and include, for each of these issues, precise commitments and a timetable for the implementation of the twenty-two objectives to be achieved by 2021.

Illicit discharge

The Mediterranean Network of Law Enforcement Officials working to MARPOL, within the framework of the Barcelona Convention (MENELAS), is a network of individuals from participating States supported by an electronic information system. MENELAS aims at improving the understanding and cooperation between its members in the different stages of the enforcement process, i.e. detection, investigation and enforcement measures taken by the competent authorities following possible violation.

REMPEC has been actively working towards setting-up a sound basis for developing marine pollution surveillance and monitoring systems in the region, by providing up-to-date knowledge on technical aspects of remote sensing. REMPEC supports the organization of Coordinated Surveillance Operation in the Mediterranean (OSCAR-MED).

Ships in distress

REMPEC has prepared the Guidelines on the Decision-Making Process for Granting Access to a Place of Refuge for Ships in Need of Assistance, which were adopted in 2008 by the COP 15. Currently there are at least three regional agreements on search and rescue, one in the West Mediterranean and two in the North-West Mediterranean, which include the sharing of towing capacity. In this connection, REMPEC, responding to the mandate given under the Regional Strategy (2005-2015), prepared, under the SAFEMED Project, Emergency

Towing Arrangements in the Mediterranean Sea, which represent an indispensable tool for coastal States to fulfil their obligations when responding in distress situations.

3.2.7.2 Marine pollution preparedness and response measures

Measures defined at international level

At an international level, the legal framework dealing with the preparedness for and response to marine pollution, is based on two legal instruments (Source: REMPEC Web Site):

- the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 1990), adopted on 30 November 1990 and entered into force on 13 May 1995, which provides an international framework for preparedness (contingency planning), for response (international assistance) and for cooperation (research and development and technical cooperation); and
- the Protocol on Preparedness, Response and Cooperation to Pollution Incidents by Hazardous and Noxious substances (OPRC-HNS Protocol), adopted on 15 March 2000 and entered into force on 14 June 2007, which complete the OPRC Convention by providing a global framework to facilitate international co-operation and mutual assistance in preparing for and responding to major pollution incidents or threats of marine pollution by introducing the same principles with regards to incidents involving HNS.

The HNS Convention establishes the principle that the ‘polluter pays’ by ensuring that the shipping and HNS industries provide compensation for those who have suffered loss or damage resulting from an HNS incident. The shipping, oil, gas, chemical, petrochemical and other HNS industries are committed to paying such compensation through an international system, and the HNS Convention provides the framework just such a system. The HNS Convention benefits all State Parties (producing, receiving and coastal States) by establishing a system of strict liability and clear claims criteria. HNS covered by the Convention include: oils; other liquid substances defined as noxious or dangerous; liquefied gases; liquid substances with a flashpoint not exceeding 60˚C; dangerous, hazardous and harmful materials and substances carried in packaged form or in containers; and solid bulk materials defined as possessing chemical hazards. The current HNS Convention was adopted in 2010, amending a previous instrument that had been adopted in 1996. However, the 2010 HNS Convention has still not entered into force; States must ratify it before this can happen.

IMO has issued Guidelines for the Development of Shipboard Marine Pollution Emergency Plans in 2010 These guidelines indicate that the plan must provide specific guidance for dealing with a range of issues, for example, pipe leakage, tank overflow, hull

Compensation measures

Compensation for oil pollution caused by tankers is governed by four international conventions: the 1969 and the 1992 International Convention on Civil Liability for Oil Pollution Damage (“CLC 1969” and “CLC 1992”) and the 1971 and 1992 conventions on the Establishment of an International fund for Compensation for Oil Pollution Damage (“1971 Fund” and “1992 Fund”). These conventions together create an international system where reasonable costs of clean-up and damages are met, first by the individual tanker owner up to the relevant CLC limit through a compulsory insurance and then by the international IOPCFs,

The Offshore Pollution Liability Association Ltd (OPOL) is an industry mutual agreement open to offshore operators in many Focal States. Member companies benefit from a guarantee that other companies in the scheme will pay for any liabilities they are financially unable to pay for themselves up to set financial limits ($125 million for remediation costs and $125 million pollution damage). Following an incident, claims are not made directly against OPOL itself, but against the member company liable for damage and loss. OPOL is not a compensation fund nor is it a guarantee against a company's bankruptcy for the company itself. This mutualisation of insolvency risk borne by the third parties helps reduce insurance costs and reassure regulators and the public of the financial capacity of offshore licensees. The criteria on OPOL membership also adds a layer of industry mutual monitoring that complements the regulatory scrutiny of companies' financial capacity at licensing.

OPOL membership requires operators to accept strict liability for damage and loss and is a prerequisite of licensing in the UK. Membership of the scheme also satisfies Ireland's licensing terms for offshore operations. However, OPOL's $250 million cap on reimbursement and compensation per incident may not cover all damage and loss from the worst accidents.

Measures defined in the context of the Barcelona convention

The basis for regional cooperation in the fields of prevention and of preparing for and responding to marine pollution from ships in the Mediterranean are set out in the Protocol concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea (2002 Prevention and Emergency Protocol). The 2002 version of the Protocol covers prevention of, preparing for and responding to marine pollution from sea-based sources. Its text was also updated to align this with the texts of other relevant international legal instruments developed since the adoption of the 1976 Protocol, and in particular with the text of the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 1990), taking also into account the contribution of the European Community to the implementation of international standards related to maritime safety and prevention of pollution from ships.

Reliable national systems for preparedness and response is considered to be the single most important factor which determines the effectiveness and the success of responses to marine pollution incidents. There is no regional centralized system of surveying the Mediterranean waters. Under the Barcelona convention each Party shall establish a national system for responding promptly and effectively to oil pollution incidents. The legislation, designation of national authorities, contingency plan, international cooperation, training and exercises and response equipment available for response to Oil and HNS spills are the main elements of a National Preparedness and Response System. These activities shall be developed in accordance with the article 6 of the OPRC Convention and article 4 of the OPRC-HNS Protocol.

Reporting obligations and requirements are requested to the Members of the Barcelona Convention on Legal and regulatory measures, as well as on Operational measures (COP 20 on Decision IG.23/1 - "Revised reporting format for the implementation of the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols - UNEP(DEPI)/MED IG.23/23, Decision IG.23/1:

REMPEC is in charged to provide assistance to the Parties involved in a pollution event. Assistance can include expert advice or those other parties making available specialised personnel, products, equipment, etc. to help deal with that pollution. REMPEC can provide remote assistance, such as providing information and advice by telephone, communicating on behalf of the state(s) involved in a pollution incident, advising on other sources of information if it is not available from REMPEC and also coordinating regional assistance. REMPEC is also able to provide on-site assistance, with REMPEC officers or representatives of the Mediterranean Assistance Unit (MAU) providing advice at the site of an accident. One of the most important activities of REMPEC has been to provide assistance to individual Contracting Parties in the event of marine pollution incidents. Reliable national systems for preparedness and response are therefore seen as the single most important factor in determining the effectiveness and success of response to such incidents.

Contingency planning and early warning *(Source: UNEP/MAP, 2016 [49])*

The 2002 Prevention and Emergency Protocol to the Barcelona Convention, as well as the OPRC 90 Convention and its 2000 OPRC-HNS Protocol, recognise the importance of sub-regional, bilateral and multilateral, agreements for cooperation in accidental marine pollution preparedness and response, as important tools for enhancing national capacities of States participating in such agreements. At the sub-regional level, REMPEC has continuously and actively assisted the Contracting Parties in preparing and implementing sub-regional contingency plans and agreements such as South-Eastern Mediterranean (Cyprus, Egypt and Israel), South-Western Mediterranean (Algeria, Morocco and Tunisia), and the Adriatic Sea (Croatia, Italy and Slovenia), and has participated to activities in the framework of the RAMOGEPOL (France, Monaco and Italy) and the Lion plan (France and Spain). The existing sub-regional contingency plans and agreements contain provisions for cooperation in prevention of maritime incidents, which is expected to further reduce the risk of accidental marine pollution, and which may be also included in future sub-regional agreements. The Centre has also assisted in the implementation of the POSOW Project, involving Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia and Spain and aiming at establishing a regional cooperation synergy through the enhancement of knowledge and capacities of operators, professionals and volunteers in the field of marine pollution and is involved in the second phase of the project extended to Algeria, Egypt, Lebanon, Libya, Morocco, Tunisia and Turkey.

To date the following plans were developed in different region of the Mediterranean (Source: REMPEC Web Site):

- Ramoge between France, Italy, Monaco
- Lion between France and Spain
- South-Eastern Mediterranean between Cyprus, Egypt and Israel
- South-Western Mediterranean between Algeria, Morocco and Tunisia
- The Adriatic between Croatia, Italy and Slovenia
- South-Eastern Mediterranean between Cyprus, Greece and Israel
- South Eastern Mediterranean between Cyprus, Egypt and Greece.

The Mediterranean Network of Law Enforcement Officials relating to MARPOL within the framework of the Barcelona Convention (MENELAS), for which REMPEC acts as Secretariat, is a network of individuals from participating States, supported by an electronic information system. The overall objective of MENELAS is to facilitate cooperation between its members in order to improve the enforcement of the international regulations regarding discharges at sea from ships as laid down in the MARPOL Convention. REMPEC has also been active on enhancing the knowledge of legal personnel, prosecutors and magistrates and facilitating judicial cooperation and the establishment of possible common procedures to improve the level of enforcement and the prosecution of discharge offenders, which ultimately led to the establishment of the Mediterranean Network of Law Enforcement Officials relating to MARPOL within the framework of the Barcelona Convention (MENELAS),

Technical and decision support tools

REMPEC Guidelines (Source: REMPEC Web Site).

Oil preparedness and response. Guide for combating accidental marine pollution in the Mediterranean (REMPEC, 2000); Mediterranean Oiled Shoreline Assessment Guidelines (REMPEC, 2009); Guidelines for the use of dispersants for combating oil pollution at sea in the Mediterranean region (REMPEC, 2011); Mediterranean Oil Spill Waste Management Guidelines (REMPEC, 2012).

HNS preparedness and response. Theory and practice of foams in chemical spill response (REMPEC, 1992). The significance of a material safety data sheet (REMPEC, 2001); Personal protective equipment and monitoring devices for maritime chemical emergencies (REMPEC, 2003); Risks of gaseous releases resulting from maritime incidents (REMPEC, 2018).

REMPEC has also developed and/or updated the following tools in the framework of the MTWG:

- a Mediterranean Integrated Geographical Information System (GIS) on Maritime Traffic in the Mediterranean Sea and on Marine Pollution Risk Assessment and Response (MEDGIS-MAR);
- a Maritime Integrated Decision Support Information System on Transport of Chemical Substances (MIDSIS-TROCS);
- a Waste Management Decision Support Tool; and
- Other long-implemented.

Response measures (Source: REMPEC Web Site).

The Mediterranean Assistance Unit (MAU) was established by decision of the Contracting Parties to the Barcelona Convention, within the framework of the Emergency Protocol, at its Eighth Ordinary Meeting (Antalya, Turkey, October 1993). The Mediterranean Assistance Unit (MAU) is network of experts in the field of preparedness for and response to marine pollution that can be mobilized to provide onsite and remote assistance to the Contracting Parties impacted by a pollution. To facilitate the mobilization of MAU experts and reduce burdens from Mediterranean coastal States, a MAU special fund managed by REMPEC has been established in the framework of the Barcelona Convention to secure the funds required to mobilise an expert to cover up to a one-month mission on-site.

Notification of Incidents. The notification and verification of the initial information concerning pollution incidents shall be done at the national level. After receiving and verifying the initial incident report, other Parties should be notified either directly or through REMPEC using a pollution report (POLREP). To facilitate the notification procedure, REMPEC has established an online Emergency Communication Procedure that enables Contacting Parties to notify and exchange information about incidents. (Source: REMPEC Web Site):

Response Options to Oil Spill Three groups of actions could be considered: i) to treat the major part of spilled oil at open sea, in order to limit the quantity which need to be dealt with on shore; ii) to attempt to stop, or rather to limit, the spreading of spilled oil by "attacking" its leading edges (and in particular its downwind edge), thus protecting the coastline likely to be affected; iii) to protect the coast with all available means and prepare for the shore clean-up operation.

The oil spill response methods and techniques. 1. Elimination of the source of oil (or other pollutant); 2. Spill containment and protection of sensitive resources; 3. Removal of spilled oil from the sea surface (It includes the mechanical recovery of spilled oil and those, considered as chemical: the use of dispersants and of other treatment products); 4. Removal of stranded oil (shoreline clean-up) (In spite of the various methods and techniques deployed to combat an oil spill while the oil is still afloat (offshore), it is most likely that a smaller or a greater part of the spilled oil, will reach the shoreline. Past experience shows that a large number of oil spills and almost all of those occurring relatively close to shores result in a more or less severe coating by oil of beaches, rocks or any other coastal formations. 5. Transport, storage, treatment and final disposal of collected oil/oiled material (Temporary storage and final disposal of oil and oiled material collected during an oil spill accident are two issues which are often neglected in the planning of oil combating operations. A vast quantity of oil and oily debris can result from a major oil spill and careful planning is needed in order to provide for its disposal. There is a number of disposal techniques and the selection of the most adequate one will depend on many factors, some of which can be determined and elaborated in advance. The response mechanisms and organizational structures for Oil and HNS are similar. However, at the technical level, response skills have to adapt for the distinct hazards posed by HNS.

Modelling oil spills

In the framework of the Mediterranean Assistance Unit (MAU), oceanographic-meteorological centres from six Mediterranean countries have signed an agreement with REMPEC through the Mediterranean Operational Network for the Global Ocean Observing System (MONGOOS - former MOON) providing, on request, oil spill forecast to all Mediterranean countries.

The MEDESS-4MS Project co-financed by the European Regional Development Fund (ERDF) and implemented in cooperation with REMPEC provides a tool enabling all Mediterranean countries to compare the most appropriate oil spill forecasting models for a selected area in the region and to assess oil spill potential impact toward socio-economic and environmental assets gathered in a geographical information system, including inter alia updated data on national response capacity.

Very many studies are available for the Mediterranean dealing with modelling of oil spills dispersal (e.g. Alves et al., 2015 [51], Janeiro et al., 2014 [52], Oilta et al., 2012 [53]), beaching probability (e.g. Goldman et al, 2015 [54], Jimenez et al., 2016 [55]), coastal vulnerability and associated risk (e.g. Al Shami et al., 2017 [56], Liubarseva et al, 2015 [57], Zodiatis et al., 2016 [60], Garcìa-Olivares et al., 2017 [58]) as. A complete review of EU funded projects addressing Mediterranean oil spills (risk assessment and response capacity is also available Zodiatis & Kirkos, 2017 [59]. Reviews on modelling of oil pollution in the Eastern and Western Mediterranean are also available (see Zodiatis et al., 2018 [61] and Cucco & Daniel 2016 [62] respectively).

Example – Beaching probability maps. Numerical model can be used to evaluate probability of beaching for oil spill originating from one single or from a number of points in the Mediterranean. Jimenez et al., 2016 [55] computed beaching probability maps considering as oil source the main tanker line going from Strait of Gibraltar to Suez Canal traversing the Mediterranean Basin. They have equally distributed a set of points along the route and they have released test particles in each selected point in the same way as for a point source. Then, they have computed the percentage of particles reaching each coastline segment coming from all the points in the line and distributed every 70–100 km along the route. The results are shown in Figure 93. The results show that the northern Mediterranean shore would be much less affected than the southern coastline. In the southern coastline, the most affected regions correspond to segments in the northern Tunisian coast and the coastline close to Alexandria, from the Nile’s Delta to Gulf of Kanais (orange, yellow and green segments in *25*), that spanning a coastline length of about 250 km.

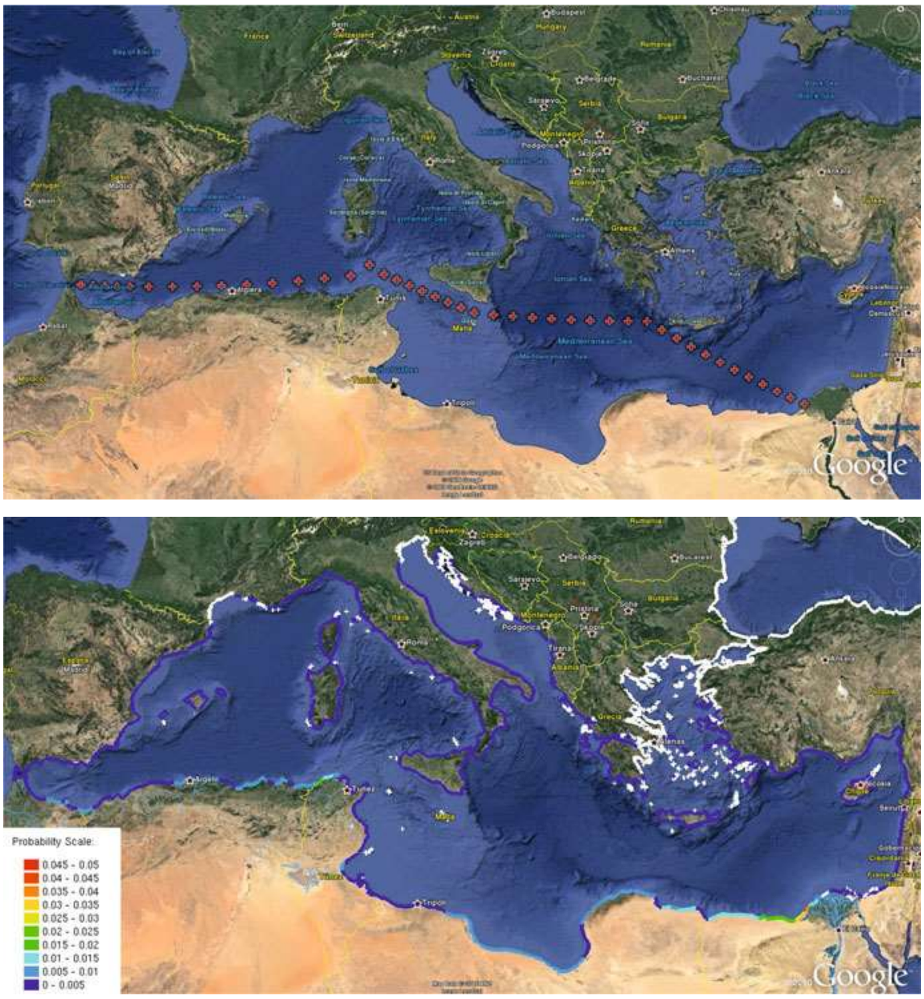


Figure 93. (Above) Selected point sources associated with the oil tanker route joining the Suez Canal with the Gibraltar Strait. (Below) Oil beaching probability map associated with the main oil tanker route joining the Suez Canal with the Gibraltar Strait. The vertical line in Gibraltar Strait indicates the percentage of particles which reach the Atlantic Ocean. Source: Jimenez et al., 2016 [55].

Example of responses to oil spills

M/C Haven spill. On April 11, 1991, an explosion on the M/C Haven resulted in a fire and the release of approximately 145,500 metric tons (t) of heavy Iranian crude oil near Genoa, Italy, in the industrialized coastal region of the northern Ligurian Sea. Approximately 30,000 t of cargo oil was released to the sea, of which only one-tenth reached the shoreline beaches along the Italian Riviera. An environmental assessment of the affected region indicated injury from the spilled oil to subtidal Posidonia/Cymodocea (seagrass) beds and the deep-sea benthic community and associated commercial fisheries. This was one of the first oil spills in which it was documented that oiled, shallow subtidal sediments (<10 m) were efficiently cleaned and large amounts of residual oil reached the deep sea bottom (100 to 400 m) as a result of burning cargo (Martinelli et al., 1995) [63].

Grounding of Costa Concordia. On 13 January 2012, only hours after leaving the Italian Port of Civitavecchia, the Costa Concordia cruise ship – with more than 4,200 passengers and crew on board – hit a rocky outcrop, ran aground, and rolled onto its side as it sailed off Giglio Island in Italy (Figure 94). With 2,500 tons of fuel in her tanks, the Costa Concordia was immediately considered a high-risk accident in terms of possible oil spills. The Coast Guard and Civil Protection authorities immediately reacted by triggering off a search and rescue operation and elaborate risk mitigation measures. In case of failure of the debunkering operation, a spillage might have polluted a marine environmental protected area of the Tuscan Archipelago National Park. Every day, starting from the 16th of January and until the fuel unloading operations finished, the MEDSLIK-II model was run to produce forecasts for a possible oil spill sourced from the Costa Concordia. Daily bulletins were provided to the Italian Coast Guard Operational Centre. To compute the possible scenarios of fuel leaks, the oil spill model MEDSLIK-II was operationally linked [64] with a suite of ocean circulation models including (1) the basin-scale Mediterranean Forecasting System MFS; two sub-regional models: (2) the Western Mediterranean WMED, (3) the Tyrrhenian Sea TYRR; and (4) the high-resolution Interactive Relocatable Nested Ocean Model (IRENOM) (see Zodiatis et al., 2018 [60] and references therein).

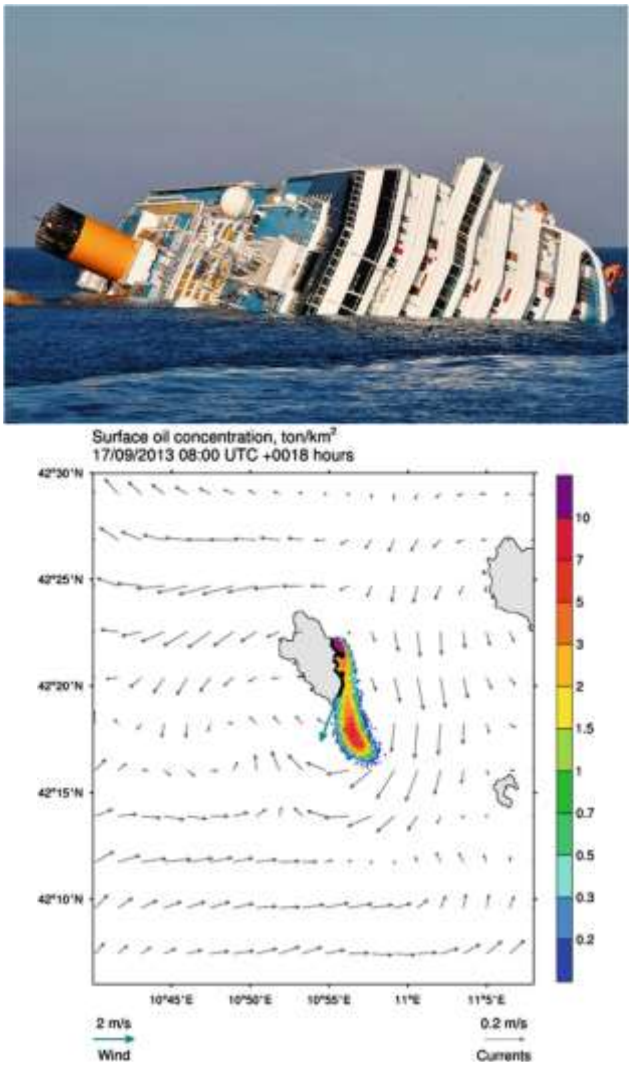


Figure 94. Costa Concordia accident (up) (Photo: Getty). Source: http://www.mirror.co.uk/news/world-news/doomed-costa-concordia-was-carrying-5432140. *Example of an oil spill forecast during the Costa Concordia parbuckling in September 2013 (down). Source: Zodiatis et al., 2018 [60].*

Collision involving CSL Virginia. (Source: Cedre Web Site) On 7 October 2018, the Tunisian vessel Ulysse collided with the Cypriot container ship CSL Virginia north of Cape Corsica. The collision smashed a hole in the hull of the CSL Virginia. The breached tanks released upwards of 600 tons of heavy fuel oil into the Mediterranean Sea, causing a 3-mile long spill. Spill response vessels and equipment were deployed by the French and Italian authorities to carry out cleanup operations. Oil recovery was aided by overflights conducted by surveillance planes. Very soon after the collision, bunker fuel spilled out of one of the damaged tanks of the CSL Virginia and into the sea. On 8th October, the highest level of the French maritime emergency management system was activated by the Maritime Prefect for the Mediterranean. A crisis management team was set up to implement the strategic response to the incident as well as a response management team. The Maritime Prefect also requested the activation of the RAMOGEPOL Plan.

Figure 95. CSL Virginia accident. Source: Marine Investigation Report by BEA mer "Collision: CSL VIRGINIA struck by ULYSSE on 7 October 2018, off cap Corse" 2019.

The sea state (initially slight) deteriorated over the days following the incident, causing the fuel oil to disseminate, drifting in more or less fragmented strings and patches over an area several tens of nautical miles long and preventing effective containment and recovery of the oil. The largest oil slicks were monitored by aerial surveys on a near-daily basis, conducted according to the weather conditions which were not improving, and buoys were deployed to help track their movements. During the days following the incident, due to very rough seas, new leaks of oil seeped out of the container ship's damaged tank. Other tugs reinforced the response effort: Rablé, Chambon Bora, Taape, VB Crau, and VB Rhône. The fragmented nature of the slicks meant that surface nets and weir skimmers could be used to facilitate recovery on the water. This large-scale offshore response mobilised over 500 people (comprising a total of over 96,000 hours of work), up to 41 vessels (French and Italian) and 13 aircraft: helicopters, planes and drones (Italian and French, including French Navy and Customs). The deployment of these resources resulted in the recovery of the majority of the oil at sea, but part of it nonetheless washed up on the French Mediterranean shores. Onshore response was activated in the following days when oil reached the Pampelonne beach in Ramatuelle, in the Var area (France).

3.2.7.3 Measures protecting specific sectors from spills

Fisheries and mariculture can be particularly affected by impacts from oil spills. In the immediate aftermath of an oil spill, the primary goal of the seafood sector is to safeguard human health and this is the main reason closures are imposed and implemented on both fisheries and mariculture. Closures can be either self-imposed by those engaged in the seafood sector or formally enforced by the authorities. Usually, in the immediate aftermath of an incident, these measures are implemented on a precautionary basis.

In 2016 the International Oil Pollution Compensation (IOPC) Fund Secretariat adopted best practice guidelines developed to aid Member States to manage fishing and harvest closures in a standardised manner. The guidelines set out a logical process for authorities to consider when determining the level of intervention in the fisheries and mariculture sectors following an oil spill (Cariglia, 2017) [65]

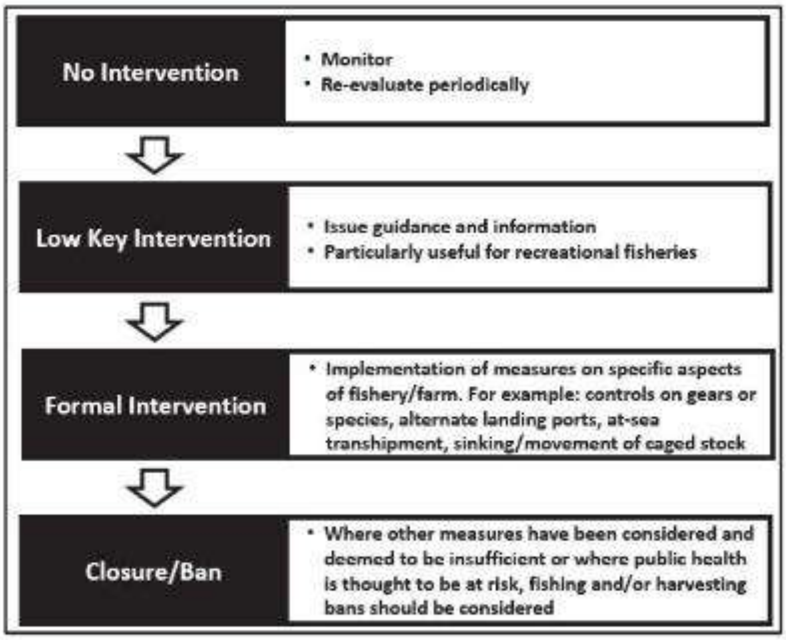


Figure 96. Guidance for governments on logical process for considering the implementation of emergency management measures on fisheries and mariculture during a spill. Source: Cariglia, 2017 [65].

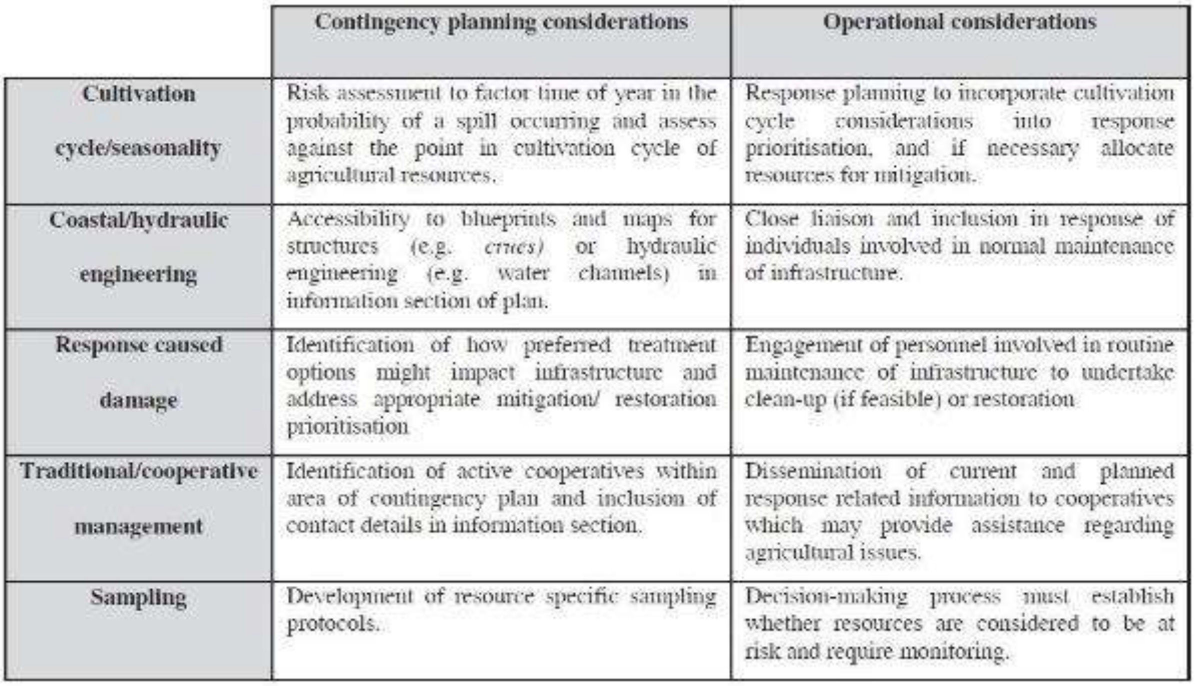
The guidelines recognise the importance of implementing harvest closures for two reasons (harvest has been used to relate to both wild capture fishing and mariculture): 1. To safeguard human health and safety and; 2. as a precautionary measure in the early stages of an incident, where the potential to pose a risk to health and safety and/or significant economic disruption is unknown. However, they also emphasise that other, lower level intervention restrictions could, with appropriate planning and foresight, be implemented, avoiding the need to fully cease harvesting.

The following practical recommendations (Cariglia, 2017) [65] could assist in expanding the suite of practicable and feasible mitigation measures, beyond fishing and harvest closures to attempt to mitigate physical and economic impacts of oil spills:

- Active engagement between local fisheries governance and central authority overseeing oil spill preparedness and response.
- Fixed facilities and fisheries cooperatives. Owners and operators of fixed facilities should be encouraged to identify oil spill specific measures in their general contingency plans (for mitigating the risk of escapees, pollution from farms, etc.).
- Integration of activity-specific seafood sector contingency planning into general oil spill response planning: (i) Characterisation of the seafood sector within the designated plan area; (ii) Identification of potentially feasible mitigation measures depending on fishery/ facility type; (iii) Operational consideration of how these measures might be implemented (e.g. permitting requirements, standard operating procedures); (iv) Development of criteria on thresholds that will result in fishing and harvesting closures. Crucial to this is the development of seafood safety standards, as well as emergency sampling procedures to be implemented in the event of a spill.

Coastal agriculture can also be affected by oil spills. In many countries around the world tidal agriculture is an important contributor to the economy, closely dependent on the intertidal zone at the land-sea interface, and these industries can be highly vulnerable to oil spills (Cariglia & Laruelle, 2017) [66]. Specific activities that can be considered as tidal agriculture include salt production and the rearing of high value/speciality livestock (e.g. salt marsh lamb). Recognition that agriculture-specific issues exist in certain areas vulnerable to marine oil spills can inform area planning and preparedness activities, which in turn may have implications at the operational and post-response phases, ultimately resulting in a reduction of social impacts and economic costs.

Table 23 Overview of agriculture resource-specific considerations when dealing with oil spills (Cariglia & Laruelle, 2017 [66].



	Contingency planning considerations	**Operational considerations**
Cultivation cycle/seasonality	Risk assessment to factor time of year in the probability of a spill occurring and assess against the point in cultivation cycle of agricultural resources.	Response planning to incorporate cultivation cycle considerations into response prioritisation, and if necessary allocate resources for mitigation.
Coastal/hydraulic engineering	Accessibility to blueprints and maps for structures (e.g. *crues)* or hydraulic engineering (e.g. water channels) in information section of plan.	Close liaison and inclusion in response of individuals involved in normal maintenance of infrastructure.
Response caused damage	Identification of how preferred treatment options might impact infrastructure and address appropriate mitigation/ restoration prioritisation	Engagement of personnel involved in routine maintenance of infrastructure to undertake clean-up (if feasible) or restoration
Traditional/cooperative management	Identification of active cooperatives within area of contingency plan and inclusion of contact details in information section.	Dissemination of current and planned response related information to cooperatives which may provide assistance regarding agricultural issues.
Sampling	Development of resource specific sampling protocols.	Decision-making process must establish whether resources are considered to be at risk and require monitoring.

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3.3 Marine litter

3.3.1 Overview

Marine litter poses a global challenge, being found widespread in the marine environment. It varies in origin, size, composition, as well as in the pathways it takes to the sea and the impacts it determines on nature, society and economy. It has been estimated that 86 million tons of plastics have accumulated in the world's oceans, while 4.6-12.7 million tons are added every year (Jambek, 2015) [1].

Litter enters the seas from both land-based sources, from ships and other installations at sea, from point and diffuse sources, and can travel long distances before being stranded. Plastics typically constitute the most important part of marine litter sometimes accounting e.g. for up to 100 % of floating litter, while other materials sink to the ground. On beaches, most studies have demonstrated densities in the 1 item m^{-2} range except for very high concentrations because of local conditions, after typhoons or flooding events. Floating marine debris ranges from 0 to beyond 600 items km^{-2}. On the sea bed, the abundance of plastic debris is very dependent on location, with densities ranging from 0 to >7700 items km^{-2}, mainly in coastal areas (Bergmann et al., 2015) [2]. Enclosed seas such as the Mediterranean or Black Sea may harbour some of the highest densities of marine litter on the seafloor, reaching more than 100,000 items km^{-2} (Galgani et al. 2000) [3]. Recent studies have demonstrated that pollution of microplastics, particles <5 mm, has spread at the surface of oceans, in the water column and in sediments, even in the deep sea. Concentrations at the water surface ranged from thousands to hundred thousand of particles km^{-2} (Bergmann et al., 2015) [2].

It is well established that marine litter, and in particular plastics, affect marine organisms and habitats. Marine litter impacts organisms at different levels of biological organization and habitats in a number of ways, namely through entanglement in, or ingestion of, litter items by individuals, through chemical transfer, as a vector for transport of biota and by altering or modifying assemblages of species e.g. by providing artificial habitats or through smothering. Each year, millions of animals that live in the oceans are debilitated, mutilated and killed by marine litter. Marine litter is a threat not only to marine species and ecosystems but also carries a risk to human health and has significant implications to human welfare, impacting negatively vital economic sectors such as tourism, fisheries, aquaculture or energy supply and bringing economic losses to individuals, enterprises and communities

3.3.2 Pollution status and trends

Sources

Vast majority of marine litter comes from land-based sources, however, in some regions, sea-based sources (shipping, fisheries) are very important. A given site or region can be subject to marine litter pollution from a number of sources, which can be local, regional or even distant, as litter can be transported to a specific area by ocean currents and wind drift.

Seabased sources for marine litter include merchant shipping, ferries and cruise liners, commercial and recreational fishing vessels, military fleets, research vessels, pleasure craft, and offshore installations such as oil and gas platforms, drilling rigs, and aquaculture sites. In some areas such as the North Sea or the Baltic Sea, the large diversity of items and the composition of the litter recorded indicate that shipping, fisheries and offshore installations are the main sources of litter found on beaches (Fleet et al. 2009) [3]. In some cases, litter can clearly be attributed to shipping, sometimes accounting for up to 95 % of all litter items in a given region, a large proportion of which originates from fishing activities, often coming in the form of derelict nets (e.g. Alngiolillo et al., 2015 [4]; Consoli et al., 2018 [5]. In addition, litter originating from fisheries/aquaculture behaviour often reaches very high proportions (>50%) of all marine litter in remote areas, where contributions from other sources are small (Convey et al., 2002) [5]. For example, Whiting (1998) [7] found that commercial fishing, merchant shipping and recreational boaters contributed over 85% of all litter found on uninhabited islands in Northern Australia

Estimates suggest that shipping is responsible for between 12% (IMO, 2012) [8] and 20% (EMSA, 2013) [9] of global discharges of waste at sea. However, regional variability and differences in definitions, as well as patchy observations, cause uncertainty in estimates. For shipping operators, discharging waste is advantageous because of the operational costs which can be saved, and the competitive advantage this may provide over compliant operators (EMSA 2009). Ship construction and recycling represent a further potential source of marine litter, with modern practices generating potentially large amounts of microplastics. At shipyards and offshore sites shot-blasting (with plastic pellets) is often used to remove paints from ship hulls. Similarly, hull coatings applied in shipyards are often polymer-based, such as epoxy.

A specific evaluation of litter originating from ships in the Mediterranean Sea is not yet available. However, with an evaluation of inputs from ships at 6 million tons worldwide and 30% of the maritime traffic worldwide occurring in the Mediterranean Sea, one may expect more than a million tons of garbage coming from ships to the

Mediterranean (UNEP/MAP, 2015) [12]. Items found on Mediterranean beaches indicate a predominance of land-based litter, stemming mostly from recreational/tourism activities (40% - 50% and more). Household-related waste, including sanitary waste, is also of great relevance (40%). The amount of litter originating from recreational/tourism activities greatly increases during and after the tourism season. Smoking related wastes in general also seems to be a significant problem in the Mediterranean. Finally, the fishing industry is of significance, as well as the shipping industry, especially off the African coast (UNEP/MAP, 2015) [12].

The IPA-Adriatic DeFishGear project provided valuable data on beach litter from its one-year long surveys carried on beaches in the seven countries of the Adriatic-Ionian macro-region, namely Albania, Bosnia and Herzegovina, Croatia, Italy, Greece, Montenegro and Slovenia. More specifically, 180 beach transects were surveyed in 31 locations, covering 32,200 m^2 and extending over 18 km of coastline. Shoreline sources -including poor waste management practices, tourism and recreational activities, which accounted for 33.4% of total marine litter items collected on beaches. When looking at the sea-based sources of litter (i.e. fisheries and aquaculture, shipping) these ranged from 1.54% to 14.84% among countries, with an average of 6.30% at regional level for beach litter (2017 Mediterranean Quality Status Report).

A quite large range of variation of marine litter source distribution has been showed by site specific data. For example, reports from Greece classify as land-based the 69 % and as vessel-based the 26 % of the sources of litter (Koutsodendris et al. 2008) [50]. In the north-western Adriatic beaches litter originating from boat activities and fishery/farming behaviour contributes substantially to the overall amount (16.8%) (Munari et al., 2016) [27]. In the Gulf of Alicante (Spanish Mediterranean), the merchant ship routes and the largest metal accumulation zone appeared to be correlated (Garcìa Rivera et al., 2017) [13]. In the deep submarine canyons of the North-western Mediterranean Sea (La Fonera and Cap de Creus canyons), under the main shipping lanes, marine litter was found to be dominated by marine-sourced heavy items. In the canyons the 17% of identified litter was from fishing activities (Tubau et al., 2015) [14].

Despite the scarcity and inconsistency of derelict fishing gear related data, this has been recognized as an issue of major concern in the Mediterranean. The findings of the recent regional survey organized by UNEP/MAP-MED POL on this topic in the Mediterranean indicated that derelict fishing gear and ghost nets are considered to be a serious problem (UNEP/MAP, 2015) [12]. Fishing litter may be predominant in areas characterized by intense fishing activities, such as the western Mediterranean Sea (Mordecai et al., 2011) [15]. In the Tyrrhenian Sea the occurrence of marine litter was found mainly caused by fishing gears (Angiolillo et al., 2015) [16], particularly lost lines, accounting for about 50% in the Italian regions of Campania and Sardinia and up to 80% in Sicily. The explored off-shore deep rocky banks in Sicily host numerous commercially relevant fishing stocks, that attract local recreational and professional fishing boats, likely responsible for the great abundance of lines found in this area [16]. Derelict fishing gears are found on the seabed in general, and in submarine canyons in particular. This was observed for example in the Sardinian continental margin (Central Western Mediterranean) at depths ranging from 100 to 480 m (Cau et al., 2017 [17]. Also in the Strait of Sicily channel a Remotely Operated Vehicle (ROV) operated at depths ranging between 20 and 220 m, observed debris on the seafloor belonging to fishing gears: marine litter composition analysis allowed to identify demersal fishing, mainly represented by long-lines (LLS), as the most important activity carried out on the explored banks (Consoli et al., 2018) [5].

Instead, a recent survey conducted on some Mediterranean beached showed that litter from shoreline sources, such as tourism and recreational activities and poor waste management practices, accounted for 38% (range: 14.4%-74%) of all litter collected; while the amount of litter from fisheries and aquaculture was at a level of 3% (range: 0.7–8.8%) ; sanitary and sewage related items accounted for 7%, while shipping, fly-tipping and medical related items accounted for 1% each (Vlacogianni et al., 2020) [18]. Similarly, a survey on some Croatian beaches showed that the 31.68% of items originated from shoreline activities, the 12.66% from fishing and aquaculture, the 5.37% from sanitary and sewage-related litter, the 2.6% from fly-tipping, the 2.5% from shipping, 1% was medically related and 0.08 came from agriculture (Mokos et al., 2019) [19].

However, it should be kept in mind that shipping (including cruising) and/or fisheries and aquaculture cannot be excluded from being potential sources of some of the litter items attributed to shoreline sources [20]. In fact, a comprehensive survey of benthic marine litter in the Adriatic Sea showed that for most of the items it was not possible to univocally attribute a specific source or a specific activity of origin. Mix source represented the major part (62%) of debris, followed by fisheries (22%), vessels (10%) and land (6%) (Figure 97). 70% of litter items coming from fisheries (including aquaculture) was collected from stations up to 30 m depth, while for offshore stations the main source of litter was land (56%) and vessels (48%) (Pasquini et al., 2016) [21].

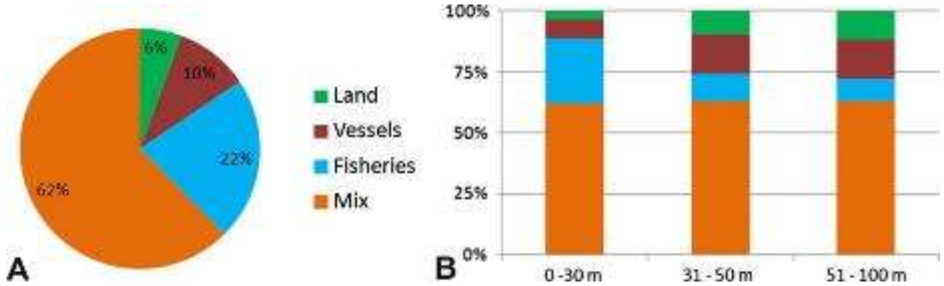


Figure 97 Composition of benthic marine litter based on the activity of its origin (A) and distribution of activity of litter origin according to depth stratum (B). Source: Pasquini et al., 2016 [21].

Beach litter

Despite the fact this study is focused on sea-based sources of pollution (from maritime traffic and offshore activities), a mention to beach litter seems opportune. In fact, this type of pollution represents a part of the complex issue of marine litter pollution. In addition, as illustrated below, it is common to find on the shores marine litter ordinated from sea-based sources. Moreover, the IMAP system with Common Indicator 22 indicates the need to monitor "Trends on the amount of litter washed ashore and or *deposited on coastlines*". Standing stock evaluations of beach litter reflect the long-term balance between inputs, land-based sources or stranding, and outputs from export, burial, degradation and clean-ups (UNEP/MAP, 2015) [12]. The majority of studies performed to date have demonstrated densities in the 1 item/m^2 range but show a high variability depending the use or characteristics of each beach (see Table 24 for an overview).

Table 24. Beach litter densities reported for Mediterranean beaches. Source: Vlachogianni et al, 2020 [24]

Study area	No of surveyed beaches	Average litter density (items/m^2)	Reference
Slovenia	3	1.2	Palatinus, 2008 [26]
Slovenia	6	1.5	Laglbauer et al, 2014 [28]
Italy	5	0.2	Munari et al, 2016 [30]
Slovenia	3	0.45	Vlachogianni et al., 2018 [20]
Montenegro	2	0.37	Vlachogianni et al., 2018 [20]
Italy	7	0.28	Vlachogianni et al., 2018 [20]
Greece	10	0.24	Vlachogianni et al., 2018 [20]
Albania	3	0.22	Vlachogianni et al., 2018 [20]
Croatia	4	2.9	Vlachogianni et al., 2018 [20]
Bosnia & Herzegovina	2	0.17	Vlachogianni et al., 2018 [20]
Italy	5	1.06	Vlachogianni et al., 2018 [20]
Spain	56	0.116	Asensio-Montesinos et al., 2019a
Morocco	14	0.054	Nachite et al., 2019

In a beach macro-litter survey (Vlachogianni et al., 2020) [24] carried out in 23 sites located along the Mediterranean coastline, the vast majority of litter items (90%) were made out of artificial polymer materials, a category of litter dominant on beaches all over the world. The second most abundant group of litter items found were glass/ceramics (3%) (Figure 98). Items made of metal and paper accounted for 2% each, while rubber for 1%, processed wood for 1% and cloth/textile for 1%.

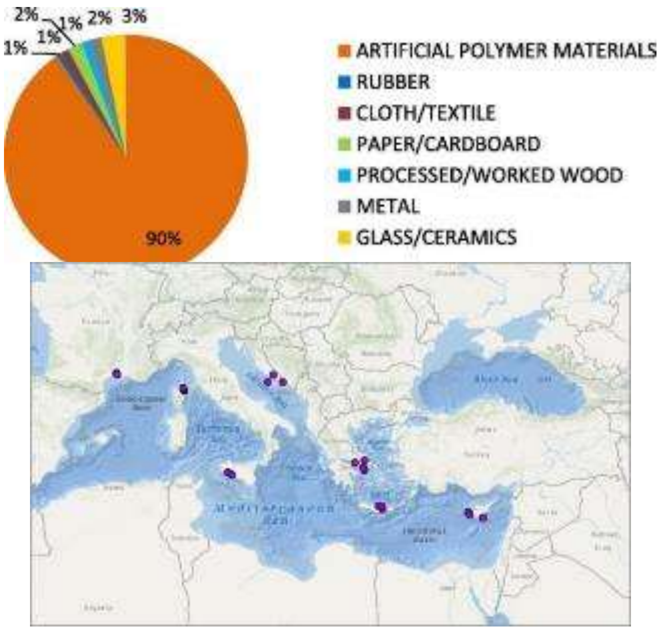


Figure 98 Characterization of beach litter from 23 sites along the Mediterranean coastline. Source: Vlachogianni et al., 2020 [20]

Similar results are available from the survey conducted in 56 sites in the Province of Alicante, in the Spanish south-eastern coast the coast of Spain. Litter items were composed by different materials: plastic (82.6%), paper and cardboard (5.6%), pottery and ceramics (3.4%), metal (3.2%), cloth (2.3%), glass (1.5%), rubber (0.6%), wood (0.5%) and other unknown materials (0.3%) (Asensios-Montesinos, 2019) [31].

In Morocco, a total amount of 14 beaches, located between Tangier at the West and Saïdia at the East, were surveyed. Litter density varied from 0.154 to 0.001 items m^{-2} respectively for Marina Smir (in autumn) and Nador-Kariat Arekmane (in spring), the average value for all beaches being 0.06 ± 0.04 items m^{-2} (Driss et al., 2017) [34] (Figure 99).

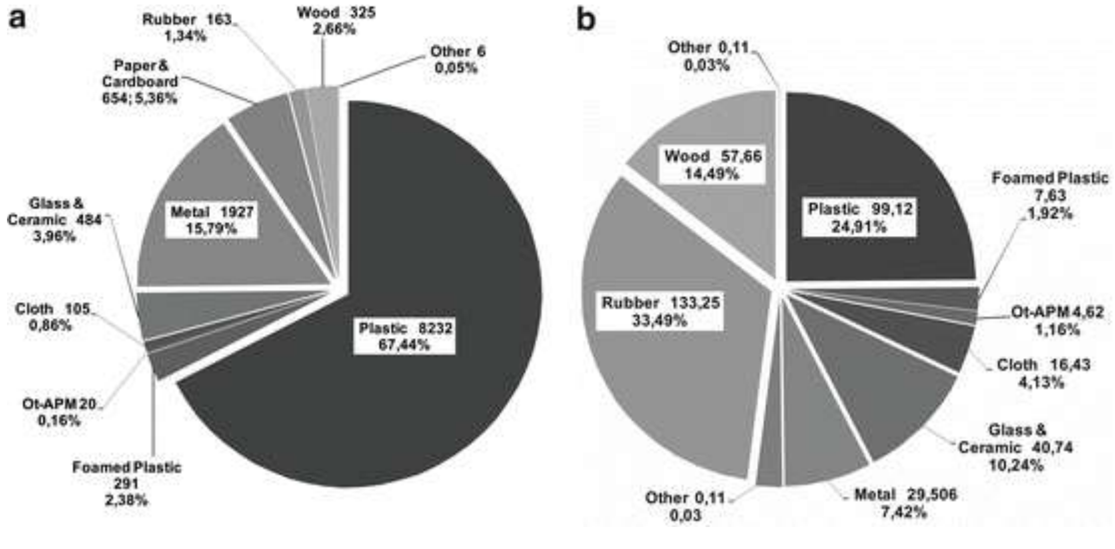


Figure 99 Composition of litter items (a) number of items and percentage of total collected items; (b) weight of items in kg and percentage of total weight of collected items from beach litter surveys on the Mediterranean Moroccan coastline. Source: Driss et al., 2017 [34].

Floating litter

Floating litter comprises the mobile fraction of debris in the marine environment, as it is less dense than seawater. Polymers comprise the majority of floating marine debris, with figures reaching up to 100%. Although synthetic polymers are resistant to biological or chemical degradation processes, they can be physically degraded into smaller fragments and hence turn into micro litter, measuring less than 5 mm (UNEP/MAP, 2015) [12].

The Mediterranean Sea is often referred to as one of the places with the highest concentrations of litter in the world. Actually, for floating microplastics, concentrations are in the same range as in the 4 sub-tropical gyres. The abundance of plastic debris shows strong spatial variations, with mean densities ranging from 0 to more than 7,700 items km^{-2} [2] and extreme concentrations reaching 64 million items/km^{2} (Levantine Sea). Mediterranean sites show the greatest densities owing to the combination of a densely populated coastline, shipping in coastal waters and negligible tidal flow. Moreover, the Mediterranean is a closed basin with limited water exchange through the Strait of Gibraltar.

For floating litter, very high levels of plastic pollution are found, but densities are generally comparable to those being reported from many coastal areas worldwide. In the northern Mediterranean Sea, in an offshore area of ca. 100 × 200 km between Marseille and Nice and also in the Corsican Channel, floating debris was quantified during marine mammal surveys. A maximum of 55 pieces km^{-2} was recorded with strong spatial variability (Gerigny et al. 2011) [32]. The abundance of floating macro and mega litter in Mediterranean waters has been reported at quantities measuring over 2 cm range from 0 to over 600 items per square kilometre (2017 MED QSR and references therein). Plastics are predominant among floating marine macro- and micro-litter items.

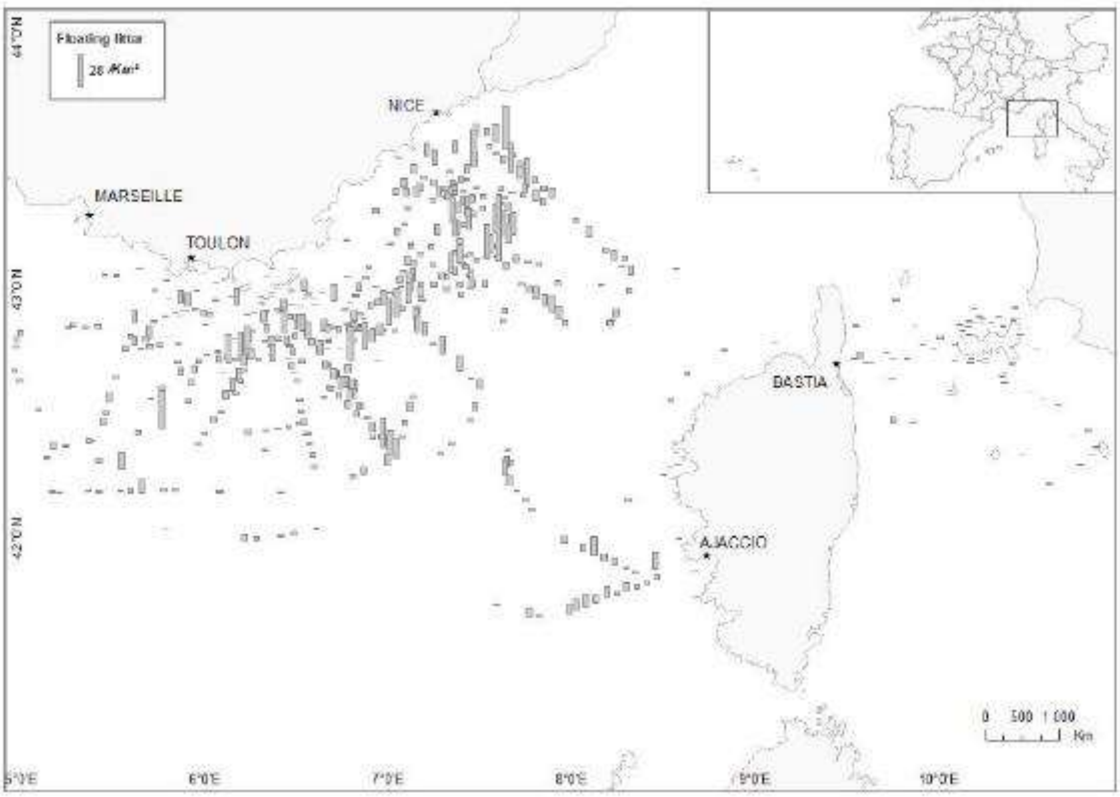


Figure 100 Distribution of floating litter in the north-western Mediterranean Sea (2006-2008) (visual observations). IFREMER/SHOM map using data from the Ecocean/ParticipeFutur project for initial MSFD assessment. Source: Gerigny et al., 2011 [32].

A large-scale survey in the Mediterranean Sea found 78 % of the observed objects larger than 2 cm to be of anthropogenic origin (Suaria and Aliani, 2014) [35]. Plastic constituted 96 % of these. While highest densities (>52 items km^{-2}) were reported from the Adriatic Sea and Algerian basin, lowest densities (<6.3 items km−2) were recorded in the central Thyrrenian and Sicilian Sea. Densities in other areas ranged between 11 and 31 items km^{-2} (Suaria and Aliani 2014) [35]. The highest densities of man-made litter found in the Adriatic Sea and along the North-western African coast, could be connected to the heaviest densities in coastal population. North African countries in particular, have the highest rates of growth in coastal population densities, including touristic densities. In addition, in many North African developing countries, appropriate recycling facilities have not been fully implemented yet (UNEP, 2009). Maritime traffic can also play a role in this distribution: the main shipping corridor used by ships entering or leaving the Strait of Gibraltar runs exactly along the Algerian slope, where the highest densities of man-made litter were found (Suaria and Aliani 2014) [35].

Approximately 82% of the recorded floating litter items, mainly consisting of fragments, bottles, containers, wraps, packaging, and shopping bags. Styrofoam accounted for 13.6% mainly consisting of fragmented fish boxes. In the Adriatic Sea, the 59% of all litter items was styrofoam. In terms of size class, the vast majority (86.7%) of the recorded floating litter items were smaller than 50 c m; 52.9% were between 10 and 50 cm; 34.7% were <10 cm; 10.4% were between 50 and 100 cm, and only 2% accounted for litter items >1 m (Suaria and Aliani 2014) [35].

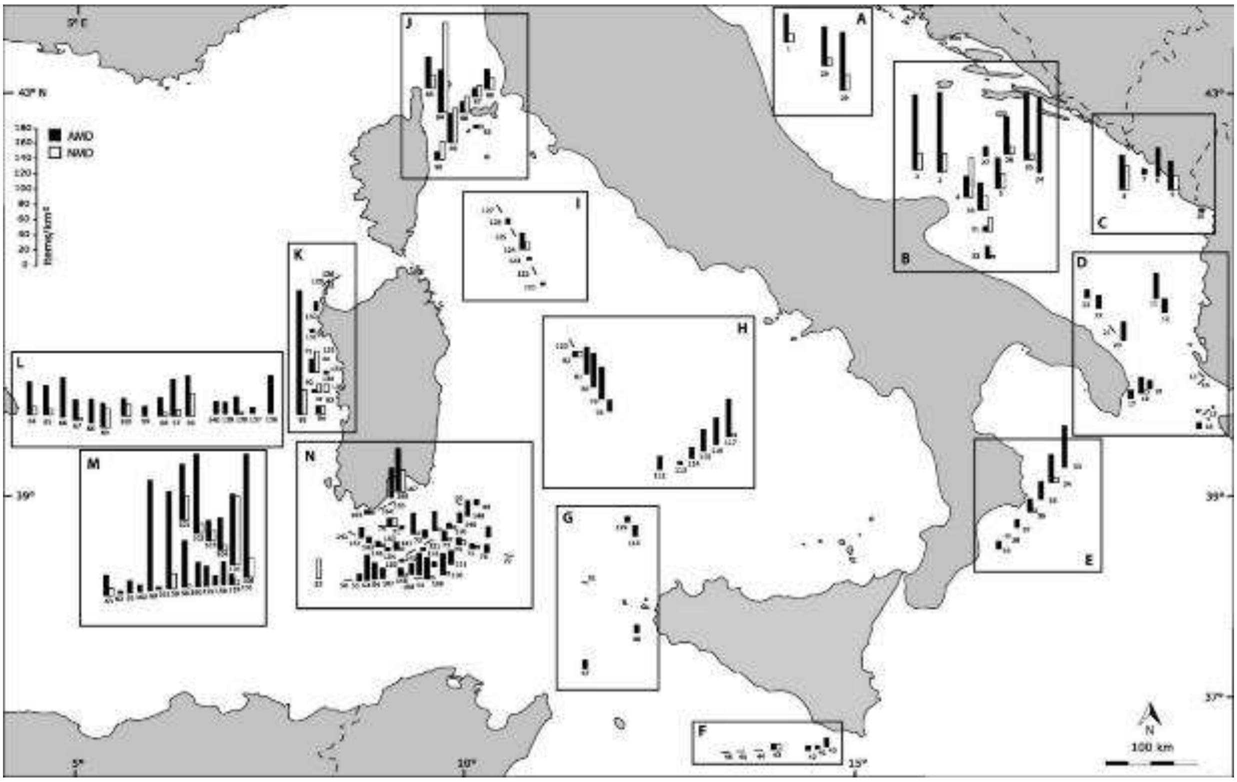


Figure 101 Map of the central-western Mediterranean Sea showing the study area, the location of all transects and sectors and the distribution of Anthropogenic Marine Debris (black bars) and Natural Marine Debris (white bars) densities (expressed as number of items/km2) in all surveyed transects. Source: Suaria and Aliani 2014 [35].

Anthropogenic Marine Debris represented 78% (1,095 objects) of all sighted objects, 82% of which (898 items) were plastic items (mainly fragments, bottles, containers, wraps, packaging and shopping bags), 13.6% (149) were styrofoam objects (entire or fragmented fish boxes), and 4.4% (48) were other man-made objects such as manufactured wood, aluminium cans, glass bottles, tetra pack containers, rubber strips, paper and cardboard boxes. On the whole, 95.6% of all man-made objects (74.7% of all sighted objects) were petrochemicals derivatives (i.e. plastic and styrofoam). The vast majority of all sighted objects (86.7%) were smaller than 50 cm. 52.9% (579 objects) of all Anthropogenic Marine Debris were between 10 and 50 cm in length, 34.7% (380 objects) were less than 10 cm in length, 10.4% (114 objects) were between 50–100 cm and only 22 objects (2%) were greater than 1 m (Suaria and Aliani, 2014) [35].

The Adriatic Sea as an area with higher density of floating debris was confirmed by a more recent survey (Arcangeli et al. 2018) [38] (4.7 ± 0.5 items/km^2), followed by the Sicilian-Sardinian Channels (2.8 ± 0.5) and it was least in the Ionian (1.9 ± 0.2 items/km^2) and Ligurian Seas (1.8 ± 0.2 items/km^2). The density of the natural debris fraction was instead higher in more coastal areas (Ligurian Sea, Bonifacio Strait, Ionian Sea, and Tyrrhenian Sea), while lower occurrences were recorded in the Sicilian-Sardinian Channels. This generally suggests different patterns of distribution of the floating materials, and different origins of the anthropogenic and natural fractions.

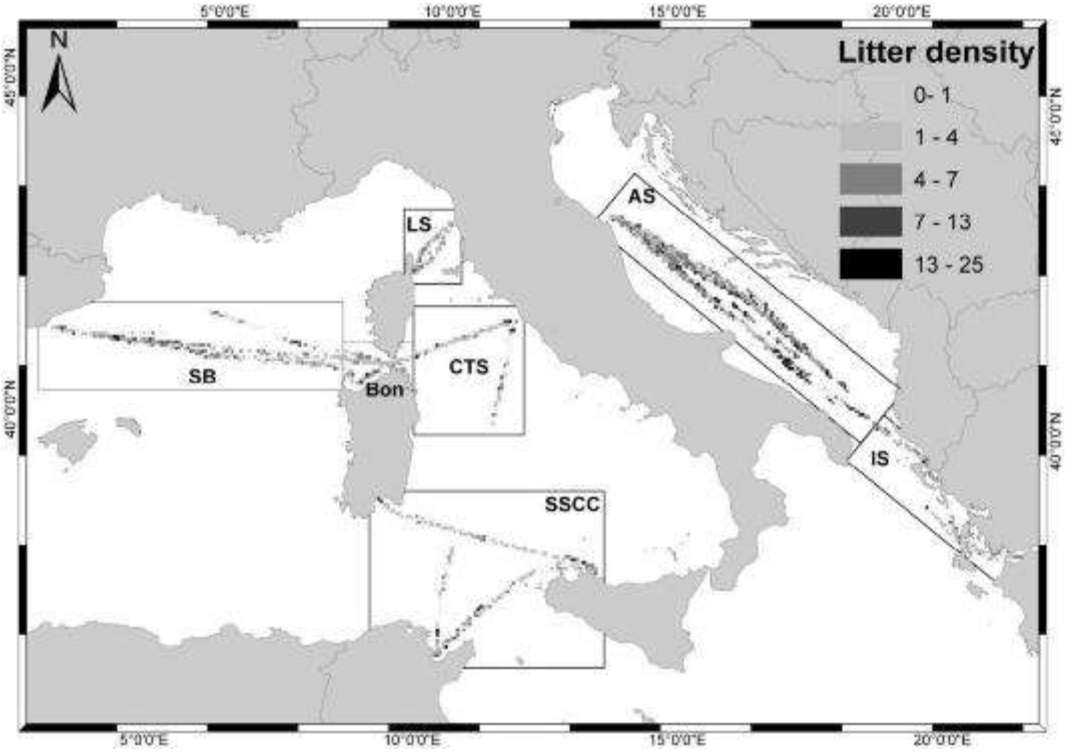


Figure 102 Density of litter calculated per cell of 5 × 5 km in the seven areas of the study. Source: Arcangeli et al. 2018 [28].

Higher floating debris densities were recorded in the Levantine sub-basin, within the eastern Mediterranean Sea (32 days survey, 137 transects, 1784 km). The density of floating litter varied between 18 and 1593 items km^{-2} average 232 ± 325 items km^{-2}), and small plastic debris accounted for >90% of the items surveyed. These values tend to be higher than densities reported for the central and western Mediterranean areas, which may be related to the circulation patterns and inputs from coastal sources. Significant correlations of floating macro litter density with wind force and sea state were found (Costantino et al., 2019) [45].

Seabed litter

Most litter is comprised of high-density materials and hence sinks. Even low-density synthetic polymers, such as polyethylene and polypropylene, may sink under the weight of fouling or additives. The geographical distribution of plastic debris on the seafloor is highly impacted by hydrodynamics, geomorphology, and human factors. Continental shelves are proven accumulation zones, but they often gather smaller concentrations of marine litter than canyons; debris is washed offshore by currents associated with offshore winds and river plumes (UNEP/MAP, 2015) [12].

Regarding composition of marine litter, plastics have been showed to be ubiquitous in the marine environment, in vast quantities, and are present even on the most remote areas of the planet. This is evident in certain areas of the globe for which plastics can be found in excess, consisting more than 80% of the recorded marine litter items. Such areas (hot-spots) can also be found in the Mediterranean Sea.

Figure 103 Worldwide plastic seafloor hot-spots areas where plastic exceed 80%. Source: Ioakeimidis et al. (2017).

Ioakeimidis et al. (2017) compiled 15 studies from the Mediterranean Sea, dedicated on the assessment and accumulation of seafloor marine litter with the use of otter-trawlers. The results are summarized in the distribution map of Figure 104.

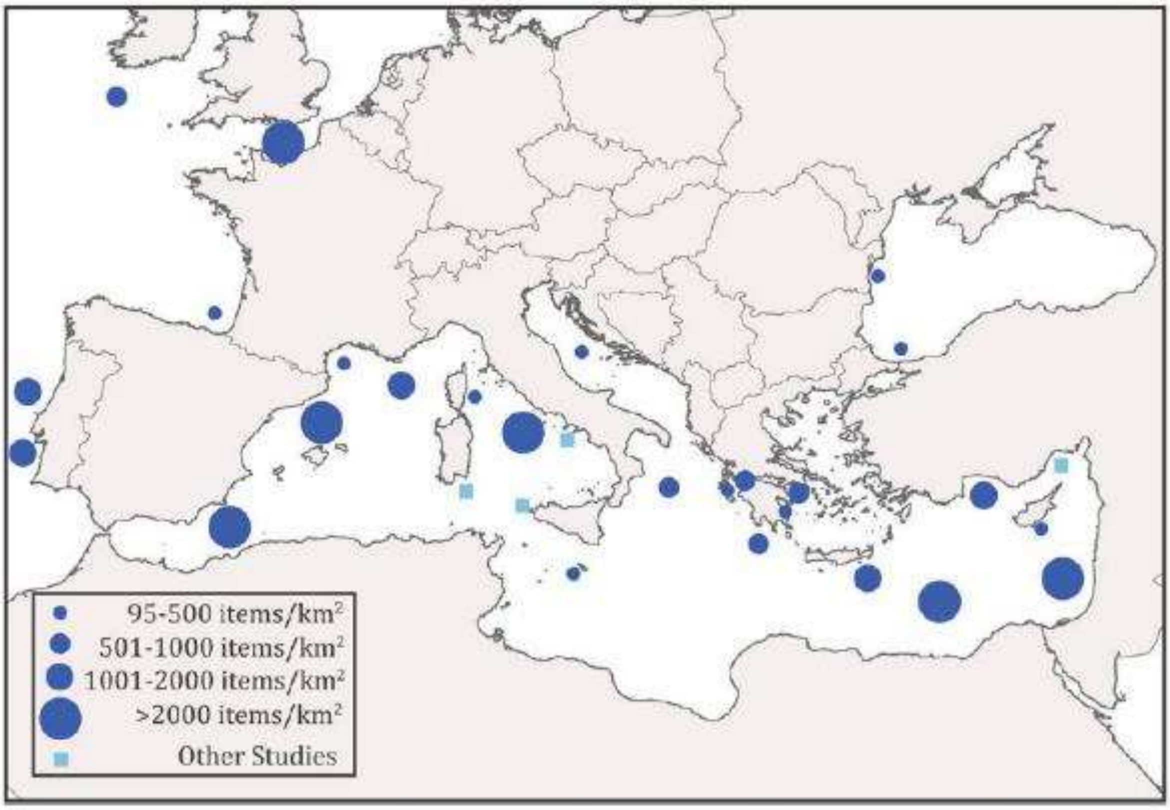


Figure 104 Seafloor marine litter distribution in the Mediterranean and other European Seas. Source: Ioakeimidis et al. (2017).

The abundance and composition of benthic litter in the Northern and Central Adriatic Sea were investigated at 67 stations with bottom trawl nets (Pasquini et al., 2016) [21]. Average density of benthic litter was 913 ± 80 items/km^2, ranking the Adriatic as one of the most polluted basins worldwide. Plastic was dominant in terms of numbers (80%) and weight (62%), and mainly consisted in bags, sheets and mussel nets. Higher quantities of litter were found in coastal areas, especially in front river mouths, coastal cities and mussel farms. In deep waters, litter hotspots were associated with most congested shipping lanes, indicating an additional litter input to the basin.

Benthic litter composition resulted to be largely driven by the vicinity to local sources, i.e. mussel farming installations and most congested shipping routes. The average densities of the six litter categories collected in the survey were: plastic 706 ± 72 items/km^2 (49 ± 25 kg/km^2); glass 71 ± 18 items/km^2 (4 ± 1 kg/km^2); other 56 ± 18 items/km^2 (14 ± 8 kg/km^2); metal 29 ± 7 items/km^2 (9 ± 6 kg/km^2); natural 25 ± 7 items/km^2 (4 ± 2 kg/km^2); rubber 25 ± 5 items/km^2 (3 ± 1 kg/m^2). Plastic appeared ubiquitous (Figure 105). Plastic litter hot-spots were located especially in front of the Po river estuary and touristic seaside cities. Metals and glass were more abundant in offshore stations (51–100 m depth), close to major shipping routes. Glass was abundant also in inshore stations (0–30 m depth) located in front of main Northern Italian harbours, Venice and Trieste. High densities of "other" material (clothes, shoes and other miscellaneous) were found up to 30 m depth in front of largest cities of the Northern coast, and between 51 and 100 m depth along the major shipping routes. Natural (mainly worked or processed wood) was abundant along the Central coast, up to 30 m, while rubber (balloons, tyres, fishing bobbins, boots and gloves) represented a poorly represented category, heterogeneously distributed in the surveyed area (Pasquini et al., 2016) [21],

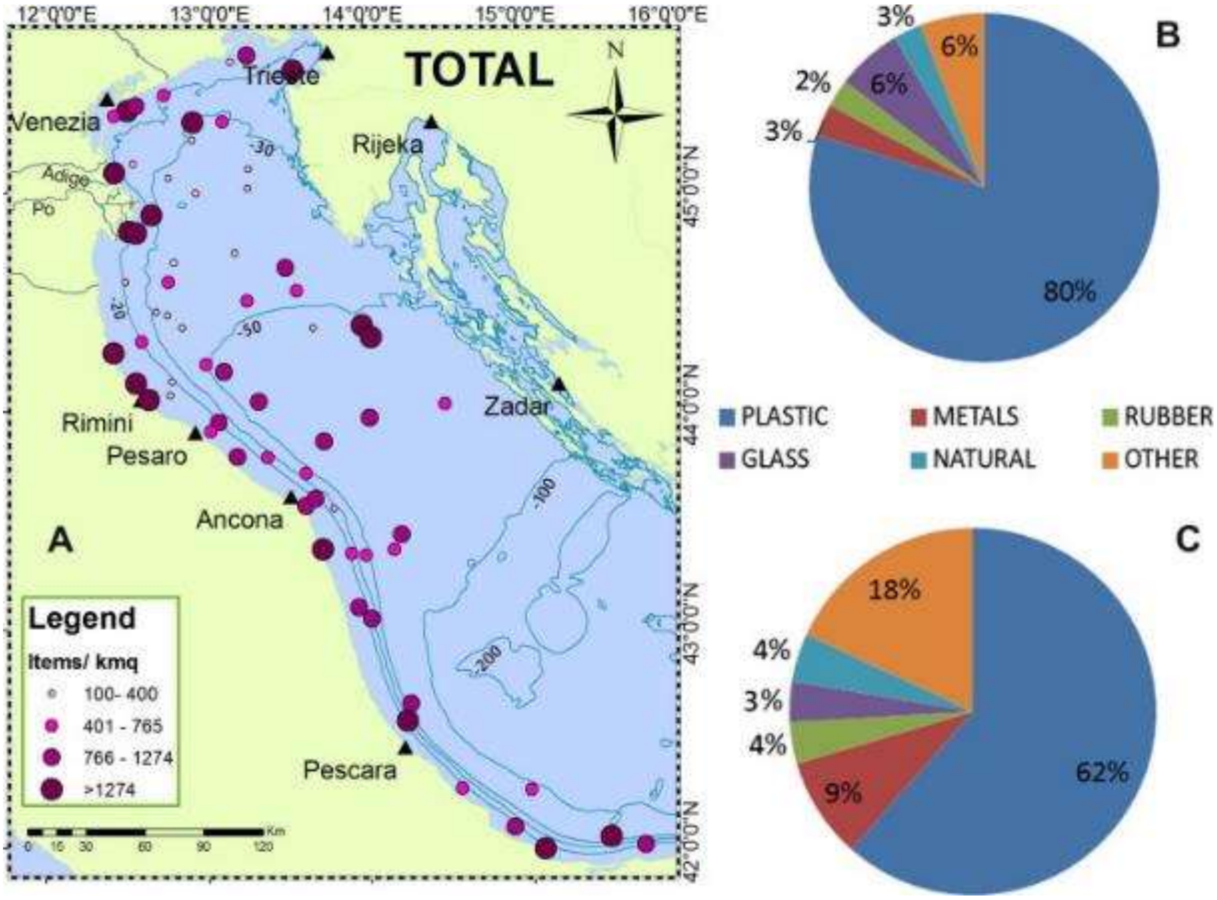


Figure 105 Spatial distribution and composition of benthic litter. Spatial distribution of the total litter collected on the sea floor (A) and total marine litter composition in terms of numbers (B) and weight (C). Source: Pasquini et al., 2016 [21].

The above results have been confirmed, in terms of composition of sea floor marine litter, by a recent survey conducted in the Adriatic-Ionian macroregion (Fortibuoni et al., 2019) [23] where plastics were largely dominant (86.3%) and the large majority (77%) of litter items found during the surveys consisted of short-term & single-use objects (with slight differences in different countries, from 73% in Croatia to 86% in Montenegro). The top 10 most abundant sub-categories represented the large majority of litter found (82.5%). The sub-category "sheets, industrial packaging, plastic sheeting" was the most abundant (28.3%), followed by "bags" (14%), "food containers incl. fast food containers" (9%), "plastic bottles" (8%) and "mussel nets, oyster nets" (6%).

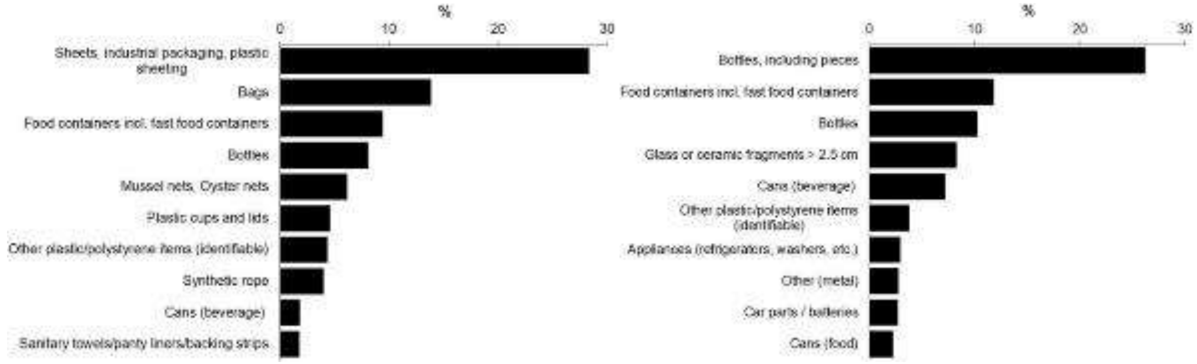


Figure 106 Top 10 items collected on the seafloor of the Adriatic-Ionian macroregion through trawl surveys (left) and scuba visual surveys (right) [23]-

Another survey carried out in the Moroccan Mediterranean Sea showed amounts ranging from 26 ± 68 to 80 ± 133 kg/km^2 (Loulad et al., 2019) [29]. The results are similar to the amount recorded in the Central Adriatic Sea (82 ± 34 kg/km^2) by Pasquini et al. (2016) [23] and a little higher to the densities found by Alvito et al. (2018) in Central-Western Mediterranean Sea. Plastic represented 73% of the debris collected, followed by rubber (12%), textile (8%), metal (3%), glass (0.32%), and some unidentified materials (2.70%). Analysis of results shows that the abundance and the distribution of marine debris were strongly influenced by the local anthropogenic activities and by rivers inputs

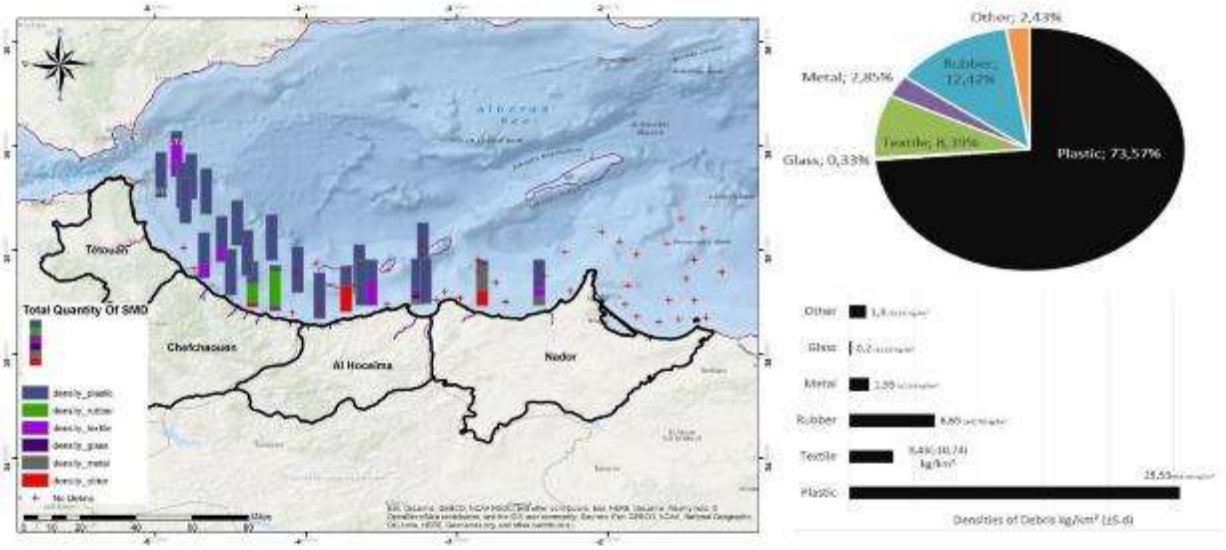


Figure 107 Results of a seabed litter survey in the Moroccan Mediterranean Sea. The distribution and the abundance of each categories of marine debris (kg/km2) between Cape Spartel (5°50W) and Saidia (2°17W). Source: Loulad et al., 2019 [29].

Microplastics

One of the first studies evaluating the floating particles in the Mediterranean Sea covered the central and western areas [72] during two sampling campaigns (2011 and 2013). Seventy-one samples were collected with a manta trawl. Floating plastic was found in all the sampled sites, with an average particle concentration of 147,500 items/km^2 and the maximum concentration was 1,164,403 items/km^2. These results were used to estimate the floating plastic in the entire Mediterranean region in a total value of 1455 tons of dry weight (DW).

A survey in the central Mediterranean (Suaria et al., 2016) [36] (*Figure 108*) estimated the presence of 1.25 million plastic fragments/km^2 on average. Among the highest values, 10 kg / km^2 have been measured between Tuscany (Italy) and Corsica (France) and 2 kg/km^2 have been measured offshore of the western coast of Sardinia (Italy) and along the northern part of the Apulia (Italy) coast.

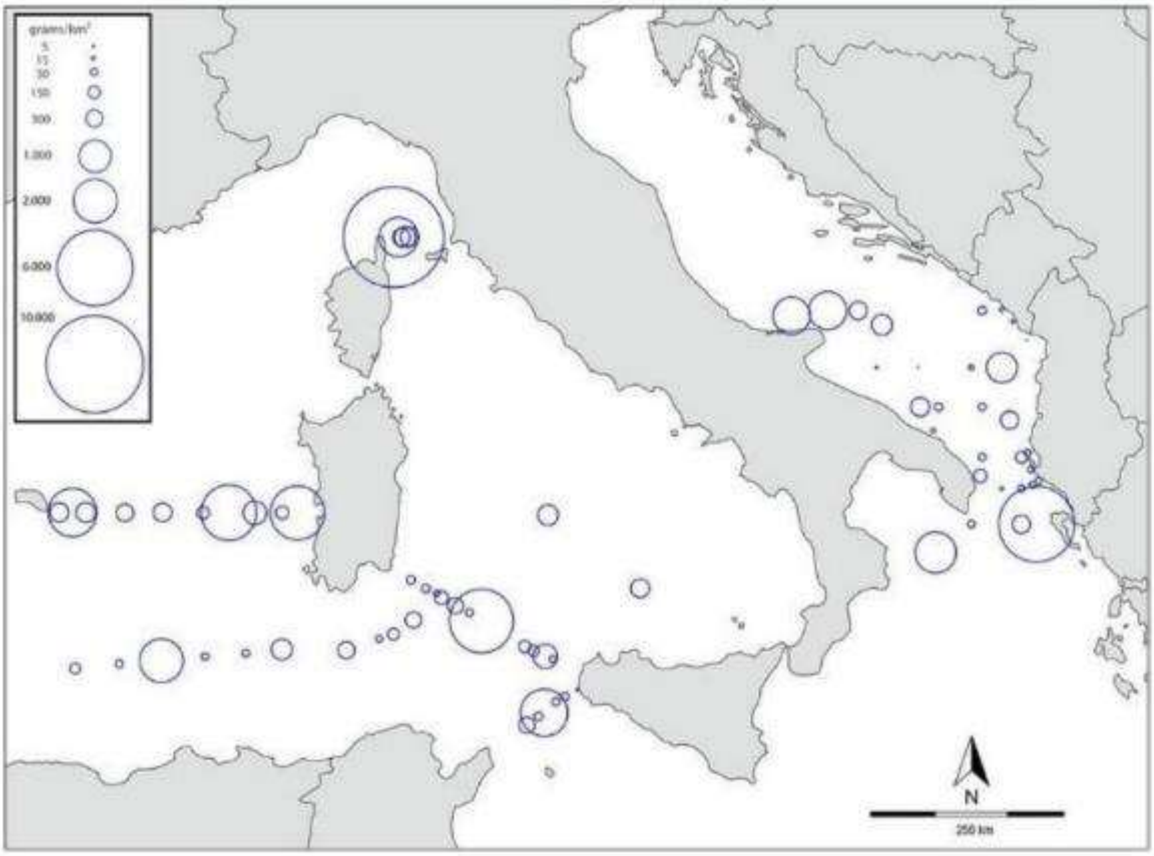


Figure 108 Map of the central-western Mediterranean Sea showing the distribution of plastic densities expressed as grams of plastic per km^2. Source: Suaria et al., 2016 [36].

In the Adriatic Sea Gajst et al. [75] assessed MPs of sea-surface in the Slovenian part of the Trieste Bay in the Northern Adriatic Sea. During the 20 months that last this study, a high average concentration of 406,000 MPs particles up to 5 mm per km^2 were found, and over 80% of the particles were identified as PE. In another study [76], floating MPs were assessed in the north-western Adriatic Sea to evaluate the possible contribution of two significant potential sources: the lagoon of Venice and the Po River. MPs were found in all samples, albeit with high spatial and temporal variability. The peak concentrations were found at the offshore station of the Pellestrina transect (10,400,000 particles/km^2) and the two landward stations off the Po Delta (2,100 and 4,300,000 particles/km^2).

These results highlighted the influence of river discharges, hydrodynamic and meteorological factors on short time scales. As in the previous study at the Adriatic Sea, PE was the polymer more frequently found, followed by PP, and most of the particles were secondary MPs (83.5%). In another study, the occurrence of macro and meso-plastics of 2.5–5 cm were determined in the Adriatic Sea following the MSFD TG10 protocol. The results showed an average macro-plastic density of 251 ± 601 items/km^2. In a more recent work, floating macro and MPs in the Central Adriatic Sea in front of Croatia coasts were assessed. The average concentration of floating macro-plastics was 175 items/km2, and for the floating MPs was 127,000 particles/km^2, similar values as other published studies from the Mediterranean Sea.

The assessment Ligurian and Tyrrhenian Seas showed that the composition of floating meso- and MPs average concentration was 28,376 ± 28,917 particles/km^2, and an average mass of 268.61 ± 421.18 g/km^2 [79]. The particle shape ratio was 65% fragments, 19% films, 10% lines, 4% foams, and 2% pellets.

In another article [62], the eastern section of the Gulf of Lion was assessed. The selected stations were investigated between 2014 and 2016. MPs and meso-plastics were found in every station with highly variable concentrations and masses. Concentrations ranged from 6,000 items/km^2 to 1·106 items/km^2 (with an average of 112,000 items/km^2), and mass ranged from 0.30 g/km^2 to 1018 g/km^2 DW (mean 61.92 ± 178.03 g/km^2).

However, coastal pressures are as well influenced by hydrodynamic conditions. For example, 20 samples were collected in the Balearic Sea during summertime using a manta trawl net to examine the concentrations of floating plastic debris [80]. The higher particle concentration was 4,576,115 items/km^2 at the north of the Balearic Promontory. Another study along the Lebanese coast (Eastern Mediterranean Basin) [81] showed that water was highly contaminated in MPs with abundances of 6.7 MPs/m^3. In the southern part of the Mediterranean Sea some floating MPs patch were found. Sea surface MPs were evaluated in 17 sites along the Israeli Mediterranean coast [82]. In this study, MPs between 0.3–5 mm were investigated and found in all samples, with a mean abundance of 7.68 ± 2.38 particles/m^3 or 1,518,340 particles/$^{km2.}$ In some cases, MPs particles were found floating in large patches. One of these patches contained an extraordinary number of plastic particles; 324 particles/m^3 or 64,812,600 particles/km^2. Microplastic abundances mean values were 1–2 orders of magnitude higher than abundances reported in other parts of the world.

As can be seen, the comparison of the results of the different reports is not possible because of the high spatial and temporal variability of floating particles distribution due to the influence of land sources, river discharges, and hydrodynamic conditions. In addition, the different works present differences in sampling approaches, nets size, and analytical approaches used to examine particles. Overall, an extremely high spatial-temporal variability in sea-surface MP concentrations has been suggested for the Mediterranean Sea using model-based assessments, without any stable long-term accumulations, underlying the importance and convenience of MPs fluxes quantification (frequency) instead of individual MP concentration measurements [34].

Trends

Marine litter trends are not clear with quantities having slightly decreased over the last 20 years in some locations, notably in the western Mediterranean. At the same time no change in litter quantities are evident in the convergence zones from oceanic basins or beaches. In other locations, however, including the deep seafloor, densities have increased (Bergmann et al., 2015) [2]. Gerigny et al. (2919) have showed a significant increase in the quantities of debris in the French Mediterranean seafloor, over 24 years. In the same area the densities of total debris, plastics and fishing gears are stable, demonstrating that density and weight of seafloor litter are complementary and should not be considered separately for trend analysis. Other recent studies have showed that marine litter pollution is increasing and is becoming extensive environmental issue for the Adriatic Sea and Ionian Sea (Munari et al. 2016 [30]; Pasquini et al. 2016 [42]; Renzi et al. 2018 [43], 2019 [44]; Vlachogianni et al. 2018 [20]).

3.3.3 Environmental impacts

Marine litter impacts organisms at different levels of biological organization and habitats in a number of ways, namely through entanglement in, or ingestion of, litter items by individuals, through chemical transfer, as a vector for transport of biota and by altering or modifying assemblages of species e.g. by providing artificial habitats or through smothering. Marine litter has been demonstrated to have deleterious impact on individuals, with direct lethal or sublethal effects. It seems inevitable that entanglement and ingestion by/of marine debris will alter the biological and ecological performance of individuals, compromising an individual's ability to capture food, digest food, sense hunger, escape from predators, and reproduce—as well as decreasing body condition and compromising locomotion, including migration (CBD, 2012) [51]. The fragmentation of plastic litter can be caused by abiotic factors as well as through biological processes (Kühn et al., 2015). Incidences of microplastics ingestion are of particular concern since they are widely distributed and of small sizes, hence a wide range of organisms may ingest them. The smaller the particle the greater is the availability to small animals, which are of special concern, since they form the base of the food web. Deposit- and filter feeding marine fauna will be especially susceptible to the uptake or ingestion of microplastics, as well as planktonic invertebrates in oceanic gyre regions where microplastics concentrations are high (CBD, 2016) [52]. Moreover, under ordinary environmental conditions, the availability of hydrophobic pollutants in seawater increases due to adsorption onto plastic litter, which increases their environmental persistence, highlighting the importance of plastics as vectors of pollutant transfer across organisms.

According to Deudero & Alomar (2015) [47], the interaction and effects of marine litter with biota is classified into the two main subgroups: (a) ingestion and entanglement and (b) colonisation/rafting. Fish were found to be influenced by both subgroups, with the greatest proportion of interactions (67%) related to the use of marine litter deployed on the seafloor or floating objects as shelter, however caution has to be taken when interpreting these results as they consider a low number of studies. Marine mammals and sea turtles are affected by plastic only through ingestion/entanglement, while invertebrates, algae and seagrass colonised marine litter objects.

Entanglement

Derelict fishing gear, which includes fishing line, nets, rope, lures, light sticks, and crab/lobster/fish traps, represented 72% of all entanglements. Lost fishing gear may impact the environment in a large number of different ways, including (i) continued catching of target species, (ii) capture of non-target fish and shellfish, (iii) entanglement of sea turtles, marine mammals, sea birds, and fish in lost nets and debris, (iv) ingestion of gear-related litter by marine fauna, (v) physical impact of gears on the benthic environment, and (vi) the ultimate fate of lost gear in the marine environment with degradation products being introduced to the food chain (UNEP/MAP, 2015) [12]. These situations have been observed also in the Mediterranean.

For example, in north-western Adriatic Sea, along the coast of Chioggia (Italy) a mean density of 3.3 (± 1.8) litter items/100 m^2 was recorded (Melli et al., 2017) [53], with a strong dominance of fishing- and aquaculture-related debris, accounting for 69.4% and 18.9% of the total, respectively. In this site litter-fauna interactions were high, with most of the debris (65.7%) entangling or covering benthic organisms, in particular habitat constructors such as the endangered sea sponge *Geodia cydonium*.

In a study area located in Milazzo Cape (Sicily, Italy - South-Eastern Tyrrhenian Sea) the debris density ranged from 0.24 to 8.01 items/100 m^2, with an average of 3.49 (±0.59) items/100 m^2 (Consoli et al., 2019) [55][54]. The derelict fishing gear, mainly fishing lines, were the main source of marine debris, contributing 77.9% to the overall litter. In the site the entanglement of sessile arborescent species was the principal impact of marine litter items: the 91.1% of the observed impacts on benthic fauna were caused by longlines entanglement.

Along a rocky seafloor flanking the upper reaches of the Malta Graben, separating the Maltese Islands from the Pelagian Islands and from Pantelleria, derelict fishing gear, mainly FAD ropes, represented the main source of marine debris, contributing 96.2% to the overall litter (Consoli et al., 2020) [39]. About 47% of debris items (about 83% FAD ropes) entangled colonies of the protected black coral *Leiopathes glaberrima*. They caused significant damage to the habitats and the associated benthic species, many of which are protected by international conventions and directives. Ropes were present everywhere, mostly entangling colonies of black coral; the observed specimens showed signs of damage caused by the friction of derelict longlines against their chitinous ramifications which were partially colonised by epibionts such as hydroids and sponges.

Marine litter entanglement has also a major impact on large vertebrates, (Fossi et al., 2012) [46]. Marine debris was found to be a major impediment for sea turtle hatchlings on a Mediterranean beach (Triessning et al., 2012) [41]. Hatchlings were severely entangled in fishing nets and entrapped in simple containers such as plastic cups and cut-open canisters. The overall debris density at the study site averaged 1.03 items m^2, mostly plastic, and 2 out of 3 hatchlings had contact with such debris on the way to the sea. Marine debris is a new aspect of habitat quality for sea turtle nesting site monitoring and conservation efforts and may help explain the long-term decline in nest numbers on this beach.

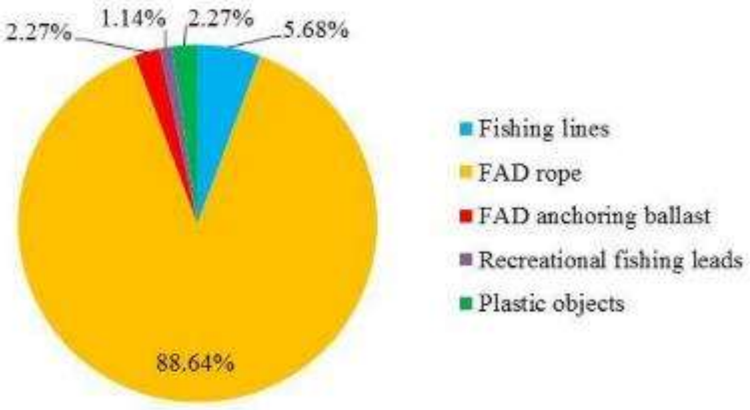


Figure 109 Percentage of litter items interacting with sessile fauna in the Sicily channel. Source: (Consoli et al., 2020) [39]

Ingestion

Marine litter ingestion is one of the main threats to biodiversity in the Mediterranean. Ingestion has been reported in various organisms ranging from invertebrates to vertebrates, including endangered species. Marine organisms may deliberately ingest litter items because of their resemblance to prey or accidentally ingest litter while they are feeding on their prey, e.g. by filter feeding or hunting on shoals (or as a result of secondary ingestion (debris already ingested by prey). Depending on litter size and species, marine litter particles may be egested or accumulate in the gastrointestinal tract, and could cause physical and mechanical damage, such as abrasion, inflammation, blockage of feeding appendages or filters, obstruction of gastrointestinal tract or may cause pseudo-satiation resulting in reduced food intake. Marine litter, in particular microplastics (<5 mm), also represents a direct and indirect vector for the introduction of chemical substances into the food-web, he sub-lethal and the chronic effects of litter ingestion could compromise the species and consequently ecosystems having long term implications.

According to the review prepared by Deudero & Alomar (2015) [47], in the Mediterranean, the species affected by ingestion are mainly large-sized organisms, such as the baleens B. physalus and P. macrocephalus, with ingestion rates of 100%, and the large elasmobranch C. maximus (83%), followed by the turtle C. caretta. The fish M. punctatum presented an ingestion rate of 100%, despite its small size, however only one individual was assessed. The invertebrate Holothuria forskali was determined to ingest plastic (monofilaments). General litter and plastics were the main litter types ingested by organisms. Plastic items and monofilaments were present in 60% of individuals showing more than 1% ingestion. The elasmobranch G. melastomus was found to ingest metal items.

Pelagic species showed variable levels of litter ingestion, depending on the species (*Figure 110*). Mesopelagic fishes from the Myctophydiae family were affected by litter, followed by medium-sized pelagic fishes, such as *Boops boops*, and epipelagic fishes, such as Schedophilus ovalis, the dolphin-fish *Coryphaena hippurus*, *Seriola dumerili* and *Balistes carolinensis*. Juveniles of Trachurus spp. were less affected by litter.

The loggerhead sea turtle (*Caretta caretta*) is the most abundant chelonian in the Mediterranean and may ingest plastic bags mistaken for jellyfishes when they feed in neritic and offshore habitats. This is a very sensitive species to marine litter and one of the most studied. Despite the fact that the loggerhead is able to ingest any kind of waste, plastic items seem to be more significant than other kinds of marine litter. The turtle demonstrates great tolerance of anthropogenic debris ingestion, and the species is generally able to excrete these items (Casale et al., 2008) [48]; Camedda et al., 2014 [49] observed that sea turtles released anthropogenic materials in feces for longer than a month of hospitalization, with most of the litter expelled within the first 2 weeks.

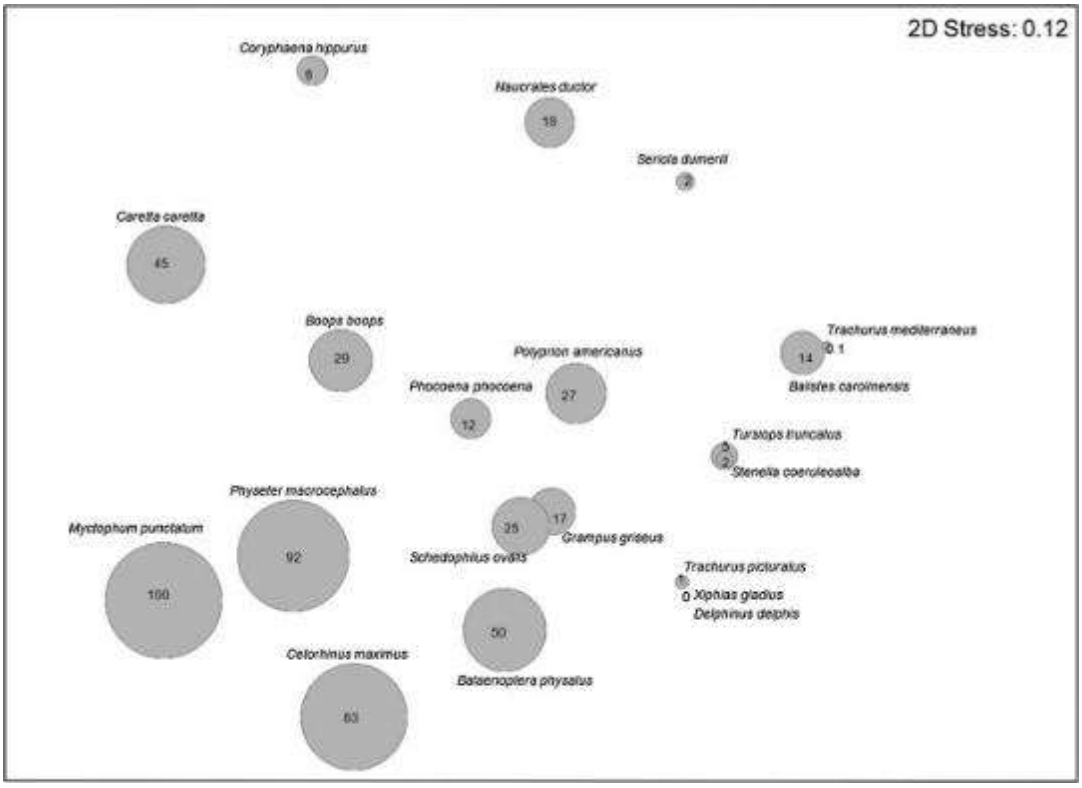


Figure 110 Non-multidimensional scaling (MDS) calculated for pelagic species (marine mammals, fishes, sea turtles) for mean values of litter ingestion after normalisation and Euclidean distance. Bubble reflect mean litter ingestion % per species. Source: Deudero & Alomar (2015) [47],

All Mediterranean turtles (*Caretta caretta*, *Chelonia mydas* and *Dermochelys coriacea*) and some marine mammals (*Physeter macrocephalus*, *Balaenoptera physalus*, *Tursiops truncatus*, *Grampus griseus* and *Stenella coerulealba*) were found to be affected by litter ingestion (Fossi et al., 2018) [56]. Marine litter ingestion in seabirds is a well-documented phenomenon on a global scale however poorely documented in the Mediterranean (for Procellariiformes, Suliformes and Charadriiformes). Cases of marine litter ingestion were also documented in marine invertebrates such as Annelids, Crustaceans, Echinoderms and Molluscs (Fossi et al., 2018) [56]. With particular regards to habitat, litter ingestion has also been reported in species from different habitats, with most studies conducted on demersal (32.9%), pelagic (27.7%) species, followed by benthic (14.7%), benthopelagic (16.5%), neritic (5.3%) and mesopelagic (2.9%) species (Fossi et al., 2018) [56].

Plastic litter has been documented to be ingested by blue sharks (*Prionace glauca*), categorized as “Critically Endangered” in the Mediterranean Sea by IUCN, caught in the Pelagos Sanctuary SPAMI (North-Western Mediterranean Sea). The results showed that 25.26% of sharks ingested plastic debris of wide scale of sizes from microplastics (<5 mm) to macroplastics (>25 mm). The polyethylene sheetlike user plastics, widely used as packaging material, are the most ingested debris (Bernardini et al., 2018) [57].

The presence of plastic debris was also documented in the stomach contents of large pelagic fish (*Xiphias gladius*, *Thunnus thynnus* and *Thunnus alalunga*) caught in the Mediterranean Sea between 2012 and 2013. Results highlighted the ingestion of plastics in the 18.2% of samples. The plastics ingested were microplastics (<5 mm), mesoplastics (5–25 mm) and macroplastics (>25 mm) (Romeo et al., 2015).

3.3.4 Measures

Measures defined at international level

At international level, the International Convention for the Prevention of Pollution from Ships (1973 as modified by the 1978 and 1997 Protocols), MARPOL, is one of the most important international conventions regulating the marine environment. It was developed by the International Maritime Organization (IMO) aiming to preserve the marine environment by fully eliminating pollution by operational discharges of oil and other harmful substances from ships, and to minimize accidental spillage of such substances. Together with its six annexes covering pollution by oil, chemicals, harmful substances in packaged form, sewage, garbage and airborne emissions, MARPOL works as a whole: the articles mainly deal with jurisdiction, powers of enforcement and inspection, while more detailed anti-pollution regulations are contained in the annexes. In that respect it is also necessary to refer to the so called “Special Areas”, with specific and more stringent discharge criteria on operational discharges, which are included in most of the MARPOL Annexes.

In this context the Mediterranean was designated a Special Area for the purposes of Annex V of the MARPOL 73/78 Convention. The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) at its 57th Session (31st March – 4th April 2008) adopted a MEPC resolution establishing the date on which the MARPOL Annex V (Regulations for the Prevention of Pollution by Garbage from Ships) special area regulations shall take effect in the Mediterranean Sea. Consequently, for all ships, as from 1st May 2009, disposal into the Mediterranean Sea was prohibited: this applies to all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags; and all other garbage, including paper products, rags, glass, metal, bottles, crockery, dunnage, lining and packing materials. Under Annex V, the Mediterranean Sea area was defined as a special area due to its oceanographic and ecological condition and the particular heavy maritime traffic, low water exchange, endangered marine species, etc. This meant special considerations had to be implemented for port state control, such as placards for passengers’ ships, garbage management plans (Resolution MEPC.220-63), garbage record books, cargo residues, and a shipboard incinerator.

In July 2011, MEPC 62 adopted the revised MARPOL Annex V, which entered into force on 1 January 2013. This Annex also obliges Governments to ensure the provision of adequate reception facilities at ports and terminals for the reception of garbage.

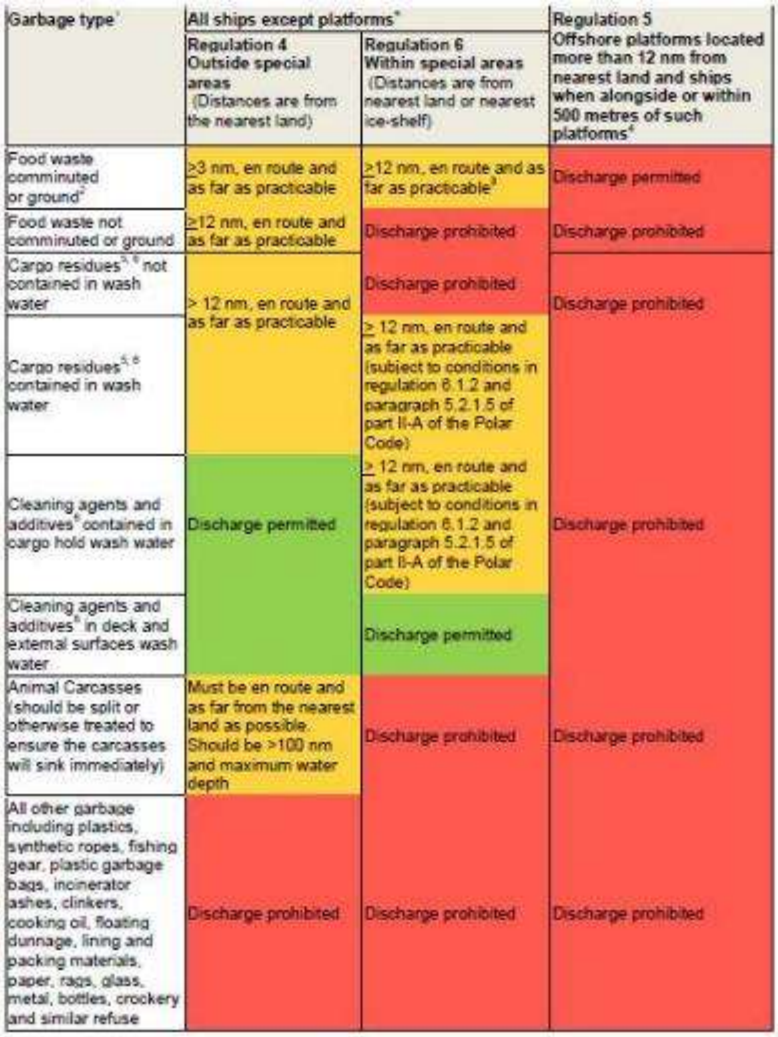
Although MARPOL regulations have become stricter over the years, it is still allowed to – under specific conditions – discharge certain waste types at sea. Table 25 reports the summary of restrictions to the discharge of garbage into the sea under regulation 4, 5, and 6 of MARPOL Annex V and chapter 5 of part II-A of the Polar Code (source: IMO).

MEPC adopted in 2018 the IMO Action Plan aims to address marine plastic litter from ships (IMO, 2018) [61] enhancing existing regulations and introducing new supporting measures to reduce marine plastic litter from ships. The Action Plan provides IMO with a mechanism to identify specific outcomes, and actions to achieve these outcomes, in a way that is meaningful and measurable. The Plan builds on existing policy and regulatory frameworks, and identifies opportunities to enhance these frameworks and introduce new supporting measures to address the issue of marine plastic litter from ships.

Specific identified measures include: a proposed study on marine plastic litter from ships; looking into the availability and adequacy of port reception facilities; consideration of making marking of fishing gear mandatory, in cooperation with the Food and Agriculture Organization (FAO); promoting reporting the loss of fishing gear; facilitating the delivery of retrieved fishing gear to shore facilities; reviewing provisions related to the training of fishing vessel personnel and familiarization of seafarers to ensure awareness of the impact of marine plastic litter; consideration of the establishment of a compulsory mechanism to declare loss of containers at sea and identify number of losses; enhancing public awareness; and strengthening international cooperation, in particular FAO and UN Environment.

A global project (GloLitter Partnerships Project) has been (UNEP(DEPI)/MED IG.22/28) recently launched by IMO and the Food and Agriculture Organization of the United Nations (FAO), targeting some of the objectives of the IMO Action Plan, and aiming to prevent and reduce marine plastic litter from shipping and fisheries. The project will assist developing countries identify opportunities to prevent and reduce marine litter, including plastic litter, from within the maritime transport and fisheries sectors, and to decrease the use of plastics in these industries, including identifying opportunities to re-use and recycle plastics. The GloLitter project will develop guidance documents, training material and toolkits to help enforce existing regulations, including IMO's International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V.

Table 25. Restrictions to the discharge of garbage into the sea under regulation 4, 5 and 6 of MARPOL Annex V chapter 5 of part II-A of the Polar Code. Source: REMPEC (2019) [60] reporting information from IMO

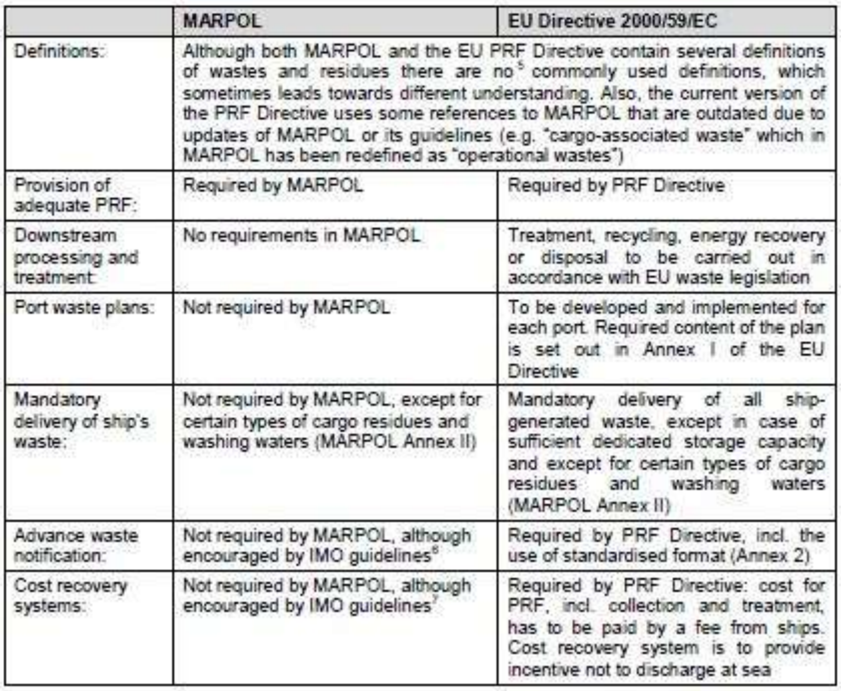


Garbage type[1]	All ships except platforms[4]		Regulation 5 Offshore platforms located more than 12 nm from nearest land and ships when alongside or within 500 metres of such platforms[4]
	Regulation 4 Outside special areas (Distances are from the nearest land)	**Regulation 6 Within special areas** (Distances are from nearest land or nearest ice-shelf)	
Food waste comminuted or ground[2]	≥3 nm, en route and as far as practicable	≥12 nm, en route and as far as practicable[3]	Discharge permitted
Food waste not comminuted or ground	≥12 nm, en route and as far as practicable	Discharge prohibited	Discharge prohibited
Cargo residues[5, 6] not contained in wash water	> 12 nm, en route and as far as practicable	Discharge prohibited	Discharge prohibited
Cargo residues[5, 6] contained in wash water		≥ 12 nm, en route and as far as practicable (subject to conditions in regulation 6.1.2 and paragraph 5.2.1.5 of part II-A of the Polar Code)	
Cleaning agents and additives[6] contained in cargo hold wash water	Discharge permitted	≥ 12 nm, en route and as far as practicable (subject to conditions in regulation 6.1.2 and paragraph 5.2.1.5 of part II-A of the Polar Code)	Discharge prohibited
Cleaning agents and additives[6] in deck and external surfaces wash water		Discharge permitted	
Animal Carcasses (should be split or otherwise treated to ensure the carcasses will sink immediately)	Must be en route and as far from the nearest land as possible. Should be >100 nm and maximum water depth	Discharge prohibited	Discharge prohibited
All other garbage including plastics, synthetic ropes, fishing gear, plastic garbage bags, incinerator ashes, clinkers, cooking oil, floating dunnage, lining and packing materials, paper, rags, glass, metal, bottles, crockery and similar refuse	Discharge prohibited	Discharge prohibited	Discharge prohibited

Measures defined at European level

In 2000 the European Union adopted a specific regulatory tool addressing the issue of preventing pollution of the marine environment by waste from ships. The purpose of Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues is to reduce the discharges of ship-generated waste and cargo residues into the sea, especially illegal discharges, from ships using ports in the European Union, by improving the availability and use of port reception facilities for ship-generated waste and cargo residues, thereby enhancing the protection of the marine environment. Although the purpose of this PRF Directive is similar to the main goal of MARPOL, there are some differences regarding their key requirements (see Table 26).

Table 26. Overview of the main differences regarding PRF requirements between MARPOL and EU Directive 2000/59/EC. Source REMPEC (2019) [60] reporting information from the Secretariat of the Basel Convention



	MARPOL	EU Directive 2000/59/EC
Definitions:	Although both MARPOL and the EU PRF Directive contain several definitions of wastes and residues there are no[5] commonly used definitions, which sometimes leads towards different understanding. Also, the current version of the PRF Directive uses some references to MARPOL that are outdated due to updates of MARPOL or its guidelines (e.g. "cargo-associated waste" which in MARPOL has been redefined as "operational wastes")	
Provision of adequate PRF:	Required by MARPOL	Required by PRF Directive
Downstream processing and treatment:	No requirements in MARPOL	Treatment, recycling, energy recovery or disposal to be carried out in accordance with EU waste legislation
Port waste plans:	Not required by MARPOL	To be developed and implemented for each port. Required content of the plan is set out in Annex I of the EU Directive
Mandatory delivery of ship's waste:	Not required by MARPOL, except for certain types of cargo residues and washing waters (MARPOL Annex II)	Mandatory delivery of all ship-generated waste, except in case of sufficient dedicated storage capacity and except for certain types of cargo residues and washing waters (MARPOL Annex II)
Advance waste notification:	Not required by MARPOL, although encouraged by IMO guidelines[6]	Required by PRF Directive, incl. the use of standardised format (Annex 2)
Cost recovery systems:	Not required by MARPOL, although encouraged by IMO guidelines[7]	Required by PRF Directive: cost for PRF, incl. collection and treatment, has to be paid by a fee from ships. Cost recovery system is to provide incentive not to discharge at sea

Directive 2019/883 of the European Parliament and of the Council of 17 April 2019 regulating the availability of port reception facilities and the delivery of waste to those facilities aims to protect the marine environment by reducing discharges of waste from ships, and to improve efficiency of maritime operations in ports, by seeking to ensure that more waste is delivered on shore, in particular garbage, including waste from the fishing sector such as derelict fishing gear. It also aims to contribute to the Circular Economy, by improving the adequacy of waste reception facilities, in particular as regards their environmental operation. This new Directive repeals the existing Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues and amends Directive 2010/65/EU Directive 2010/65/EU on reporting formalities for ships arriving in and/or departing from ports of the Member States.

Measures defined in the context of the Barcelona convention

Within the framework of the Barcelona Convention, the Mediterranean countries adopted in 1980 a Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources. In this Protocol, the importance of dealing with the problem of marine litter was recognized. The Protocol was amended in 1996, and Annex I defined as one of the categories of substances «Litter as any persistent manufactured or processed solid material which is discarded, disposed of, or abandoned in the marine and coastal environment».

The most important instrument to combat pollution from marine litter in the Mediterranean is represented by the Regional Action Plan for Marine Litter Management (UNEP, 2013) [59] which aims to:

a) Prevent and reduce to the minimum marine litter pollution in the Mediterranean and its impact on ecosystem services, habitats, species in particular the endangered species, public health and safety;
b) Remove to the extent possible already existent marine litter by using environmentally respectful methods;
c) Enhance knowledge on marine litter; and
d) Achieve that the management of marine litter in the Mediterranean is performed in accordance with accepted international standards and approaches as well as those of relevant regional organizations and as appropriate in harmony with programmes and measures applied in other seas.

The Regional Action Plan foresees specific measures concerning the prevention of pollution from sea-based source, including ships such as: to charge reasonable cost for the use of port reception facilities or when applicable, apply No-Special-Fee system; to provide ships using the Contracting Parties ports with updated information relevant to the obligation arising from Annex V of MARPOL Convention; to promote "fishing for litter" practices; to prevent any marine littering from dredging activities; to combat dumping, including littering on the beach, illegal sewage disposal in the sea, the coastal zone and rivers.

The Regional Action Plan foresees the implementation of measures to remove the existing marine litter from accumulations/hotspots of pollution:

- Implement National Marine Litter Cleanup Campaigns on a regular basis;
- Participate in International Coastal Cleanup Campaigns and Programmes;

- Apply as appropriate Adopt-a-Beach or similar practices and enhance public participation role with regard to marine litter management;
- Apply Fishing for Litter in an environmentally sound manner, based on agreed guidelines and best practice, in consultation with the competent international and regional organizations and in partnership with fishermen and ensure adequate collection, sorting, recycling and/or environmentally sound disposal of the fished litter; and
- Charge reasonable costs for the use of port reception facilities or, when applicable apply No-Special-Fee system.

The Regional Action Plan also includes measures concerning an integrated monitoring program, based on ecosystem approach ecological objectives:

- Prepare the Regional Marine Litter Monitoring Programme, as part of the integrated regional monitoring programme;
- Establish in the year 2016 the Regional Data Bank on Marine Litter which should be compatible with other regional or overarching databases and
- Establish by the year 2014 Expert Group on Regional Marine Litter Monitoring Programme, in the framework of the Ecosystem Approach implementation.

The EU-funded “Marine Litter-MED” Project aimed to support UNEP/MAP and the Southern Mediterranean Contracting Parties of the Barcelona Convention to implement key common measures provided for in the Regional Plan on Marine Litter Management in the Mediterranean, and the updated National Action Plans to achieve Good Environmental Status (GES).

The main focus of the project was on:

- Enhancing the implementation of selected ML policy/regulatory prevention and reduction common measures at sub-regional/national levels and sharing of related best practices as identified in the updated NAPs in Southern Mediterranean/EU Neighborhood countries;
- Developing and applying regionally harmonized approaches, guidelines and tools to ensure effective implementation of selected measures (participation of all Contracting Parties, including EU on non-cost basis);
- Establishing regional coordination mechanisms for ML prevention and management in the Mediterranean to maximize synergies through cooperation and exchange of best practices; and
- Establishing regional coordination mechanisms for ML with other regional actors and European Regional Seas Conventions, with a particular focus on collaboration with the Black Sea Commission.

The project is developing of a set of technical guidelines within the framework of Article 14 of the Marine Litter Regional Plan. REMPEC, as an acting organ under the framework of Barcelona Convention, committed to the mission of environmental protection, has been actively undertaking assignments addressing the issue of marine litter. The Centre has been coordinating the relevant activities assigned by the EU-funded “Marine Litter-MED” Project and the Cooperation Agreement between the Italian Ministry for the Environment Land and Sea (IMELS) and UNEP, to explore ways to provide incentives for ship-generated waste to be discharged at ports rather than at sea, in particular by adopting the No-Special-Fee system for the use of port reception facilities. A study has been developed based on a literature review on existing best practices in the Mediterranean, as well as other European Regional Seas, for the application of charges at reasonable costs and of the No-Special-Fee system for the use of port reception facilities REMPEC (2019) [60], In addition the Centre implemented pilots, holded national meetings and developed the “Guidance Document to Determine the Application of Charges at Reasonable Costs for the Use of Port Reception Facilities or, when Applicable, Application of the No-Special-Fee System, in the Mediterranean” and the “Operational Guidelines on the Provision of Reception Facilities in Ports and the Delivery of Ship-Generated Wastes in the Mediterranean”, both adopted by Contracting Parties to the Barcelona Convention in 2019 (UNEP/MED IG.24/22 (EXCERPT: Decision IG.24/11)).

Under the Regional Strategy for Prevention and Response to Marine Pollution from Ships (2005-2015), REMPEC, in close cooperation with IMO, developed the Guidelines concerning Pleasure Craft Activities and the Protection of the Marine Environment in the Mediterranean. The purpose of these Guidelines is to assist Governments when developing, improving and enacting domestic laws and taking appropriate measures, with a view to implementing international and regional regulations applicable to the prevention of pollution of the marine environment from pleasure craft activities. They are also intended to users of pleasure craft and managers of marinas to encourage them to apply proper environmental practices and to comply with the relevant requirements, and should also serve to assist in planning and developing the environmental performance of marinas.

REMPEC was mandated to ensure synergies between the Regional Action Plan for Marine Litter Management and the IMO Action Plan aims to address marine plastic litter from ships. In this context, a dialogue has been established to establish synergies between the upcoming Marine Litter Med II and the GloLitter Partnerships Project.

Key prevention and reduction measures

In addition to policy measures, targeting marine litter pollution prevention, operational measures can also be implemented, for example addressing remediation actions. Fishing for Litter is one of the most important measures that would lead to the reduction and removal of marine litter from sea. It has become one of the most successful concepts by involving one of the key stakeholders, the fishing industry. The initiative not only involves the direct removal of litter from the sea but also raises awareness of the problem inside the industry as a whole. All types of marine litter are targeted, depending on the gear type used. Most are from the seafloor, collected with bottom contacting gear. Filled bags of litter are deposited on the quayside, where the participating harbours monitor the waste before moving the bag to a dedicated skip for disposal. The objectives and aims of the scheme can gain the support of the fishing industry, port authorities, and local authorities. Furthermore, it can contribute to changing practices and culture within the fishing sector, provide a mechanism to remove marine litter from the sea and seabed, and raise awareness among the fishing industry, other sectors, and the general public. Fishermen are usually not financially compensated for their engagement, but the disposal logistics are free (UNEP/MAP, 2015) [12].

As described above, FfL is envisaged by the UNEP/MAP Regional Action Plan for Marine Litter Management. In addition, UNEP/MAP has developed a "Guide on best practices for Fishing for Litter in the Mediterranean" (2016). The Guide aims to provide technical guidance on the mechanism to remove litter from the sea in an environmentally friendly manner, ensuring negative impacts on marine environment and ecosystems are avoided, and to provide guidance on the process of involving the stakeholders responsible for the implementation and coordination of FfL practices.

Ffl has also been recognized by European governments as a method that could help to achieve a Good Environmental Status (GES) in the European seas by 2020 as part of the EU Marine Strategy Framework Directive (MSFD, 2008/56/CE).

An example of fishing for litter practice in the Mediterranean is represented by the pilot activities conducted in the Adriatic-Ionian macroregion in the framework of DeFishGear (Derelict Fishing Gear Management System in the Adriatic Region) project co-funded (2014–2016). Six scientific institutions operating in five countries (Italy, Slovenia, Croatia, Montenegro and Greece) were involved. A SWOT analysis was conducted at the end of the experience (Ronchi et al., 2019) [62] and showed that the greatest weaknesses in Fishing for Litter in the Adriatic-Ionian macroregion are related to legislative and bureaucratic factors. One problem common in all countries was the lack of an overarching legislation that addressed marine litter and the consequent lack of a coordinated approach to marine litter. Uneven and uncoordinated national and subnational policies and fragmented authority and governance led to the uneven implementation of the FfL scheme in the region and of policies aimed at reducing marine litter.

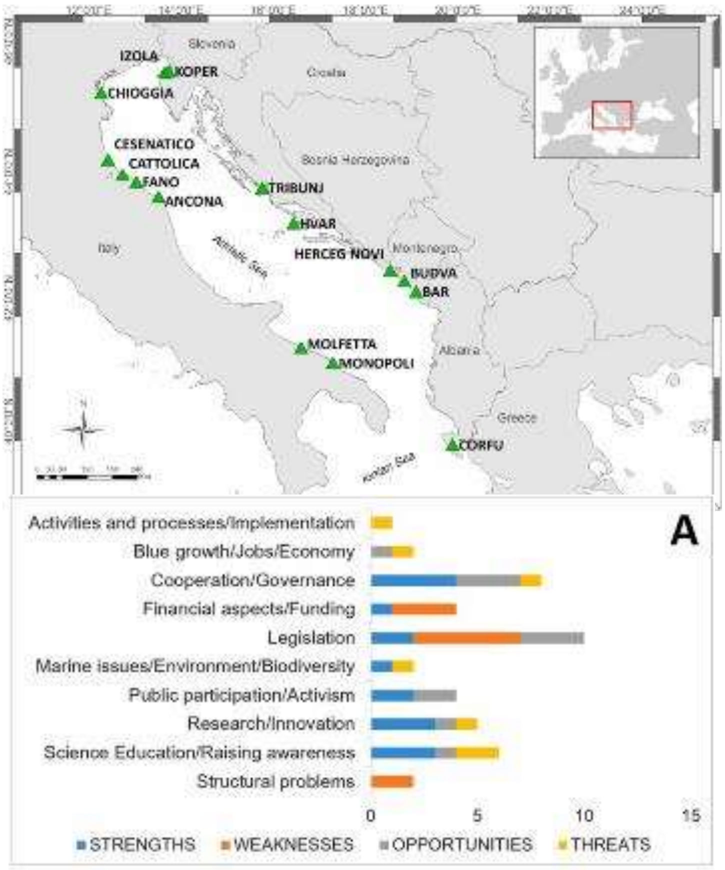


Figure 111 Harbours where FFL pilot projects were implemented in the framework of the DeFishGear project (above) and Strengths, Weaknesses, Opportunities and Threats distribution (number of factors) among the categories for the countries of the Adriatic-Ionian macroregion (A). Source: (Ronchi et al., 2019) [50]

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3.4 Air pollution

3.4.1 Overview

Maritime shipping relies heavily on fossil fuels. About 3.5 million barrels of high sulphur residual fuel oil (bunker fuel) per day were consumed by the sector in 2017, which represent about 50 per cent of the global fuel oil demand (McKinsey and Company, 2018) [1]. Most of this fuel oil has high sulphur content, which results in the emission of sulphur oxides into the atmosphere. The sector consumes just over 1 million barrels per day of marine gas oil, which is a lower-sulphur, higher-value distillate oil (Hellenic Shipping News Worldwide, 2018) [2]. This represents only 5 per cent of the global demand for diesel and gas oil, the majority of which is consumed in the heavy-duty trucking sector (Hellenic Shipping News Worldwide, 2018) [1].

Marine transportation accounts globally for 33% of all trade-related emissions from fossil fuel combustion, including 3.3% of global carbon dioxide (CO_2) (Crist, 2009) [3], (Cristea et al, 2013) [4]. Emissions depend on the type of fuel, engine, and engine efficiency. Fuels include marine diesel oil (MDO), marine fuel oil (MFO), and heavy fuel oil (HFO). While difficult to quantify, marine shipping emissions have increased over the last 50 years (Cristea et al, 2013) [4]. Notably, nearly 70% of conventional pollutants and GHGs emissions from ships occur < 400 km from the land (Cristea et al, 2013) [4].

Emission of exhaust gases and particles from seagoing ships contribute significantly to the total emissions from the transportation sector (Corbett and Fischbeck, 1997 [5], Eyring et al., 2005a [6]), thereby affecting the chemical composition of the atmosphere, climate and regional air quality and health. Key compounds emitted are carbon dioxide (CO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), sulphur dioxide (SO_2), black carbon (BC) and particulate organic matter (POM).

Recent studies suggest that oceangoing ships consumed between 200 and 290 million metric tons (Mt)1 fuel and emitted around 600–900 Tg CO_2 in 2000 (Corbett and Köhler, 2003 [7], Endresen et al., 2003 [8], Endresen et al., 2007 [9], Eyring et al., 2005a [6]). These studies have estimated around 15% of all global anthropogenic NO_x emissions and 4–9% of SO_2 emissions are attributable to ships.

Emissions of NOx and other ozone precursors from shipping lead to tropospheric ozone (O3) formation and perturb the hydroxyl radical (OH) concentrations, and hence the lifetime of methane (CH4). The dominant aerosol component resulting from ship emissions is sulphate ($SO_4$2−, hereafter SO_4), which is formed by the oxidation of SO_2. NOx emissions from shipping are relatively high because most marine engines operate at high temperatures and pressures without effective reduction technologies. SO_2 emissions are high because of high average sulphur content (2.4–2.7%) in marine heavy fuels used by most oceangoing ships (Endresen et al., 2005 [10]).

Furthermore, emissions from ships are transported in the atmosphere for hundreds of kilometers away, thus contributing to air quality deterioration on land, even if they are emitted at sea (Eyring et al., 2010). Since ship exhaust gases contribute to the worldwide pollution of air and sea, ships are facing an increasing number of rules and regulations as well as voluntary appeals from international, national and local legislators. Some solutions have been proposed for improving air quality in coastal areas and ports. These include the establishment of reduced speed zones, emissions control areas, and adaptation of shoreside electrification technologies for vessels while they are at berth (Smith et al., 2014 [11]; Winkel et al., 2015 [12]).

3.4.2 Pollution status and trends

Ship emissions contribute significantly to air pollution in the Mediterranean Basin. The contribution of ship emissions to the total sulphate aerosol column burden over the Mediterranean in summer was estimated to be the 54% (Marmer & Langann, 2005) [13]. Harbours are particularly influenced by emissions from ships, and this can give relevant contributions to local air pollution (Isakson et al, 2001) [13], (Cooper, 2003) [14], (Saxe & Larsen, 2020) [15].

International shipping generates about 2% of global CO_2 emissions with a quite stable contribution of about 800 million tons per year (International Chamber of Shipping, 2019) [16] (Figure 112).

Figure 112 Total international shipping CO_2 emission estimates. Source: Third IMO GHG Study and ICCT in International Chamber of Shipping (2019) [16].

In Europe, GHG emissions from total transport activities (land-based plus sea-based) emissions increased by roughly one quarter between 1990 and 2016 (including international aviation but excluding international shipping). Transport's share of the EU's total GHG emissions increased from 15 % to 24 % during the same period. This is mainly a result of the continued reliance of the EU transport system on fossil fuels and of growing transport demand. Important new EU legislation has recently been agreed on to reverse this trend, but it remains to be seen to what extent this can offset the expected increase in transport demand. The road sector is key within the transport sector, and in 2016 it accounted for 72 % of all GHG emissions from transport (including international aviation and international shipping). Passenger cars and vans account for 72.5 % of road transport emissions, followed by trucks and buses at 26.3 %. Shipping and aviation are the second and third biggest sources of transport GHG emissions after road transport, and international aviation has seen rapid growth in GHG emissions over the last two decades (EEA, 2020).

More in detail, it is estimated that international shipping in Europe caused in 2015 emissions of about 134 million tons of CO_2, 1,230 kt of SO_2, 2,830 kt of NO_x and 175 kt PM2.5. These quantities compare to 3.6% of land-based CO_2 emissions in the EU-28, 44% of land-based SO_2, 36% of NO_x emissions, and 13% of PM2.5 emissions, the largest share of emissions emerging from container ships, followed by tankers and cargo ships (IIASA, 2019) [16]. Considering CO_2, the Mediterranean represents about 40% of the overall European shipping emission share. The countries in the Mediterranean region (the 21 Contracting Parties of the Barcelona Convention) contributed in 2015 to the global CO2 emissions from land base activities with 1970 millions of tonnes (United Nations Sustainable Development Goals Indicators[19]), with a contribution from shipping of the 3.0% when compared to land base emissions, with a slightly lower, but comparable, value of the relative contribution reported at European level.

The spatial pattern of NO_x emissions mirrors closely the fuel consumption volumes, while for SO_2 and PM the emission controls in the SECA regions (Baltic Sea and the North Sea) cause large differences. Up to 57% of all emissions from international shipping in Europe occur in the Mediterranean Sea (Figure 113).

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[19] https://unstats.un.org/sdgs/indicators/database/

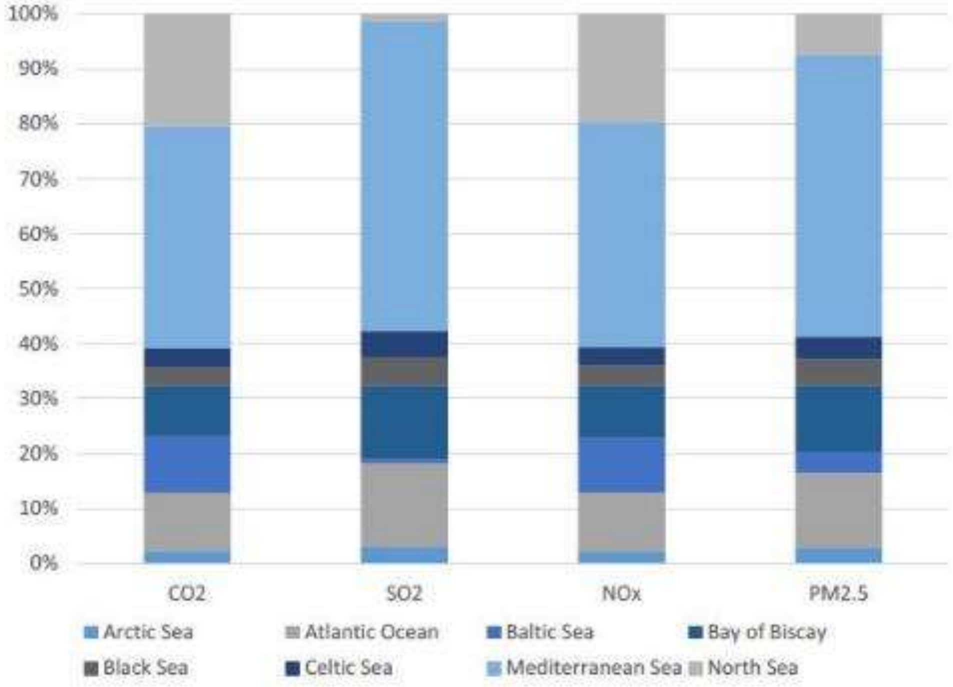


Figure 113 Emissions from international shipping in 2015, by Sea region. Source: IIASA, 2019 [18].

Up to one third of emissions is emitted in the 12 nm zones along the coasts, and about two thirds in the adjacent 200 nm zones, most of which in dedicated shipping corridors in variable distances to the coast. Berth or in ports activities account for only a few percent of all emissions from international shipping. In the Mediterranean Sea, about two thirds of emissions originate from the EU waters (IIASA, 2019) [18].

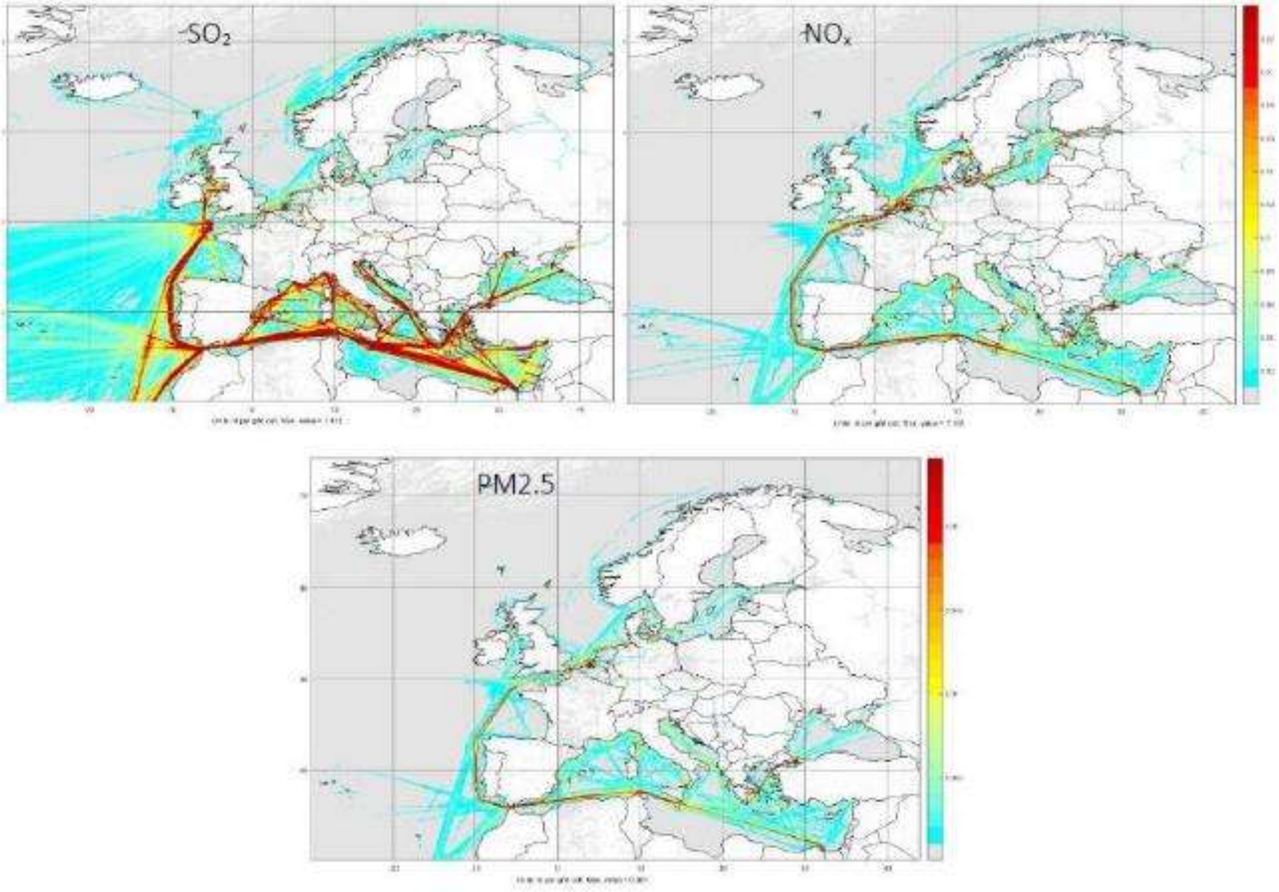
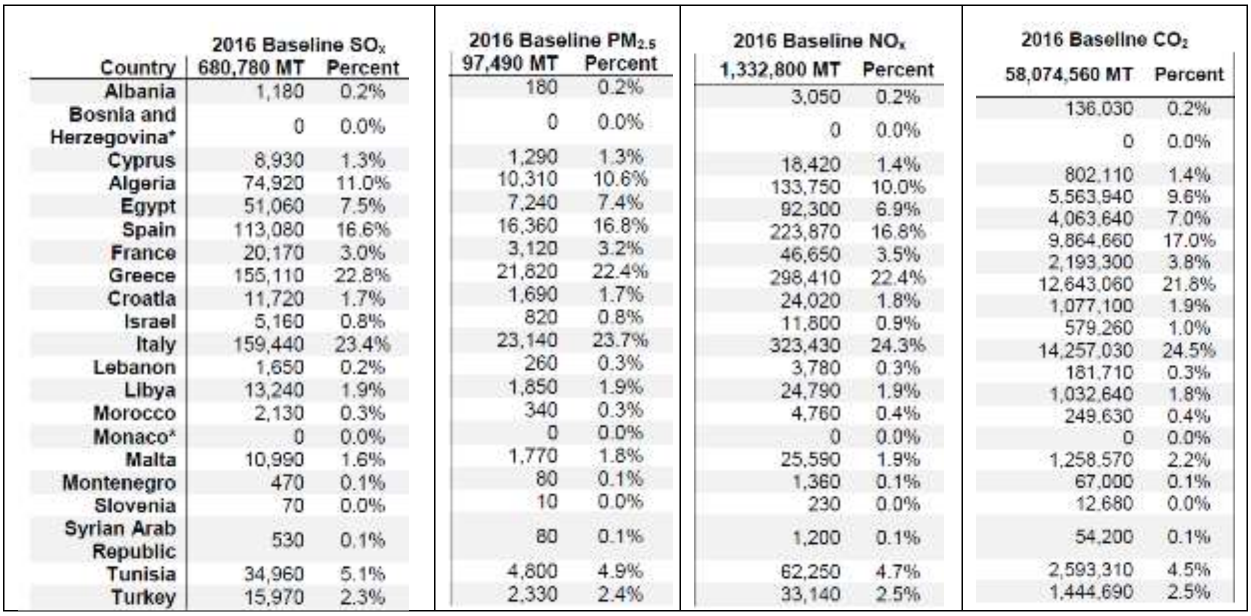


Figure 114 Gridded emissions of SO_2 and NO_x (upper panel) and $PM_{2.5}$ (lower panel) in 2015. Source: IIASA, 2019 [18].

REMPEC (2019) [19] reported national allocation of emissions, performed using gridded emissions results and land+water area designations, determined by the Flanders Marine Institute), based on international treaties and geospatial attribution of water areas to the nearest country[20] (Table 27).

Table 27. National allocation by marine regions of shipping pollutant emissions in Mediterranean Sea area. Bosnia and Herzegovina as well as Monaco do not show any counts of emissions in their EEZ's because of an artefact of the resolution used to model the emissions. Source: REMPEC (2019) [19]



	2016 Baseline SO_x		2016 Baseline $PM_{2.5}$		2016 Baseline NO_x		2016 Baseline CO_2	
Country	**680,780 MT**	**Percent**	**97,490 MT**	**Percent**	**1,332,800 MT**	**Percent**	**58,074,560 MT**	**Percent**
Albania	1,180	0.2%	180	0.2%	3,050	0.2%	136,030	0.2%
Bosnia and Herzegovina*	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Cyprus	8,930	1.3%	1,290	1.3%	18,420	1.4%	802,110	1.4%
Algeria	74,920	11.0%	10,310	10.6%	133,750	10.0%	5,563,940	9.6%
Egypt	51,060	7.5%	7,240	7.4%	92,300	6.9%	4,063,640	7.0%
Spain	113,080	16.6%	16,360	16.8%	223,870	16.8%	9,864,660	17.0%
France	20,170	3.0%	3,120	3.2%	46,650	3.5%	2,193,300	3.8%
Greece	155,110	22.8%	21,820	22.4%	298,410	22.4%	12,643,060	21.8%
Croatia	11,720	1.7%	1,690	1.7%	24,020	1.8%	1,077,100	1.9%
Israel	5,160	0.8%	820	0.8%	11,800	0.9%	579,260	1.0%
Italy	159,440	23.4%	23,140	23.7%	323,430	24.3%	14,257,030	24.5%
Lebanon	1,650	0.2%	260	0.3%	3,780	0.3%	181,710	0.3%
Libya	13,240	1.9%	1,850	1.9%	24,790	1.9%	1,032,640	1.8%
Morocco	2,130	0.3%	340	0.3%	4,760	0.4%	249,630	0.4%
Monaco*	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Malta	10,990	1.6%	1,770	1.8%	25,590	1.9%	1,258,570	2.2%
Montenegro	470	0.1%	80	0.1%	1,360	0.1%	67,000	0.1%
Slovenia	70	0.0%	10	0.0%	230	0.0%	12,680	0.0%
Syrian Arab Republic	530	0.1%	80	0.1%	1,200	0.1%	54,200	0.1%
Tunisia	34,960	5.1%	4,800	4.9%	62,250	4.7%	2,593,310	4.5%
Turkey	15,970	2.3%	2,330	2.4%	33,140	2.5%	1,444,690	2.5%

Folkert Boersma et al. (2015) [20] found that average per ship NOx emission factors in the Mediterranean Sea fell by ~46% in 2009 (overall emissions fell by 69%) and stayed relatively constant afterwards. The temporal evolution of average ship speed shows a distinct, 30% reduction from 2008 to 2009, and persistently lower ship speeds in successive years. The authors interpreted this as direct evidence that the practice of slow steaming, i.e. reducing ship speed to save fuel, has been implemented widely, resulting in detectable reductions in ship NOx emissions. Figure 115a shows a strong overall increase in the emissions (red crosses) of 71% between 2005 and 2008, followed by reduction back to 2005 levels in 2009. Ship NOx emissions over the Mediterranean Sea remain around the 2009 level for subsequent years. The temporal evolution of the ship density detected by the satellite-borne altimeter over the Mediterranean Sea is also shown Figure 115a (black diamonds). The altimeter-detected ship density increases over the Mediterranean Sea, most notably after 2007. This increase in shipping implies that: (1) ever more or ever larger ships are sailing through the Mediterranean Sea; or (2) ships are sailing at lower speeds, which would increase their residence time in the Mediterranean Sea.

These results indicate that the implementation of slow steaming in 2009 has contributed to offsetting the 2005–2007 increase in NOx emissions over European shipping lanes, but the relative contribution of the shipping sector to total European NOx emissions increased from 11% in 2005 to 14% in 2012.

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[20] It is important to note that many Mediterranean coastal States have not formally defined exclusive economic zones, and that the areas to which emissions are attributed here do not necessarily reflect any official territorial claims.

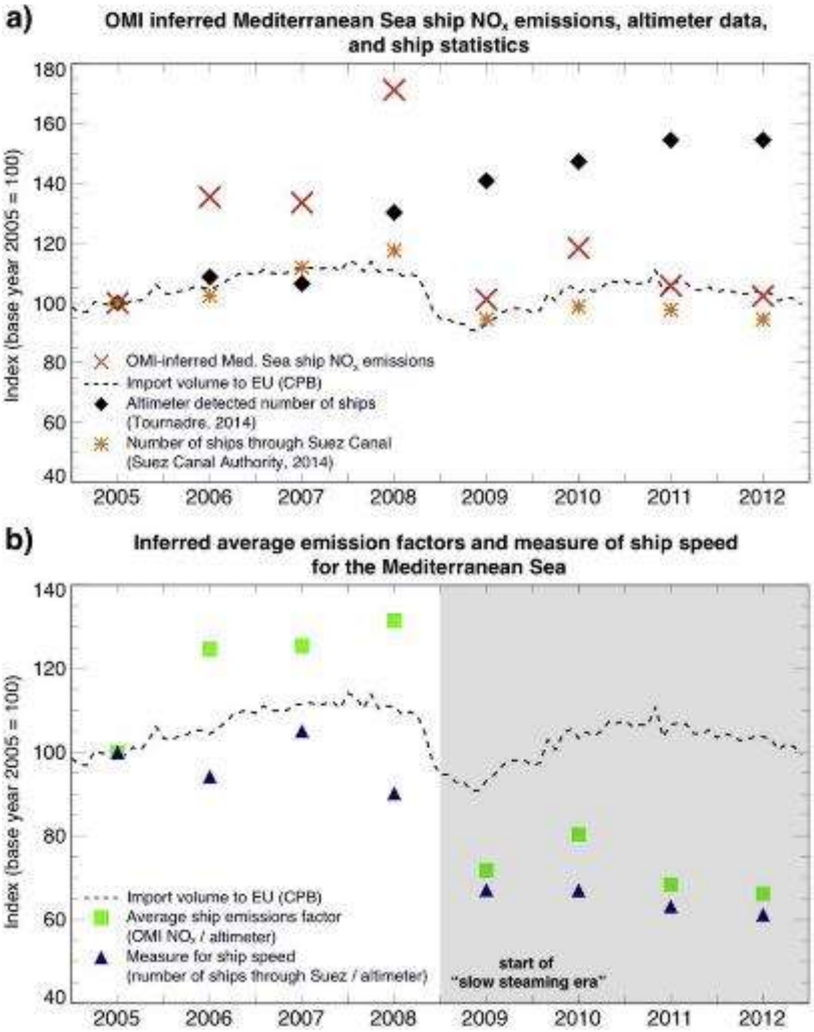


Figure 115 a) Temporal evolution of: OMI-inferred ship NOx emissions for the Mediterranean Sea (red crosses); import volume to the European Union (dashed line, (CPB 2014)); number of ships detected by the satellite-borne altimeter over the Mediterranean Sea (black diamonds) (Tournadre 2014); and the number of ships passing through the Suez Canal per year (orange asterisks (Suez Canal Authority 2014). (b) Average ship NOx emission factor indicated by the green squares. The average ship speed of ships in the Mediterranean Sea (equation (2)) indicated by dark blue triangles. All data in both plots were indexed with respect to the year 2005. Source: Folkert Boersma et al. (2015) [20].

3.4.3 Environmental impacts

The impact of ship emissions is of global and local scale. The first concerns mainly emissions during the navigation phase. The main environmental impact of ship emissions at global level is represented by the contribution to emissions of climate-altering pollutants. The climate-forcing impacts from shipping are linked to the by-products of Heavy Fuel Oil, and to a lesser extent, Marine Diesel Oil (MDO) combustion. These by-products are: Carbon Dioxide (CO_2) which has a direct, global and long-lasting climate forcing impact, Black carbon (BC) which also has a direct but somewhat lesser and more regionally constrained impact than CO_2. Black carbon's warming impact is linked mainly to surface deposition and heat absorption in snow- and ice-covered areas (e.g. the poles and high-altitude glaciers). Nitrogen Oxides (NO_x) is formed by high temperature combustion in ship engines and acts as a precursor to tropospheric ozone (O_3), itself a powerful greenhouse gas. In certain conditions however, NO_x emissions can lead to a rise in methane (CH_4) destruction and can thus contribute to reduced atmospheric warming. Sulphur dioxide (SO_2). SO2 is transformed into sulphate (SO_4) in the atmosphere which is thought to have a net cooling impact on climate. Carbon Monoxide (CO) is a precursor to both tropospheric ozone and methane. Of these, CO_2 has by far the largest long-term impact and the remainder of this chapter will focus on this greenhouse gas, although, as pointed out in Box 1, the climate impact of other HFO and MDO by-products should not be ignored.

At local level, in-port ship emissions represent only a small fraction of the global emissions associated with shipping (Dalsøren et al., 2008) [21]. However, they can have important environmental effect on coastal regions, which often have harbours located near urban and industrial centres. This is particularly the case of the Mediterranean Sea. Numerous studies have been published with the aim of evaluating the emissions of ships in ports (Saxe and Larsen, 2004 [22]; Battistelli et al., 2012 [23]; Saraçoglu et al., 2013 [24]; Fan et al., 2016 [25]; Merico et al., 2017 [27]; Nunes et al., 2019 [28]; Sorte et al., 2019 [29]; Chen et al., 2018 [30]).

For example, in Brindisi (Italy), an important port-city of the Adriatic Sea, the characterization of pollution sources for PM2.5 was studied (Cesari et al., 2014) [31]. Contributions from eight sources were estimated: crustal (16.4 ± 0.9% of PM2.5), aged marine (2.6 ± 0.5%), crustal carbonates (7.7 ± 0.3%), ammonium sulphate (27.3 ± 0.8%), biomass burning-fires (11.7 ± 0.7%), traffic (16.4 ± 1.7 %), industrial (0.4 ± 0.3%) and a mixed source oil combustion–industrial including ship emissions in harbour (15.3 ± 1.3%). It was not possible to separate the in-port ship emission contribution from industrial releases. But the correlation of estimated contribution with meteorology showed directionality with an increase of oil combustion and sulphate contribution in the harbour direction with respect to the direction of the urban area and an increase of the V/Ni ratio.

Merico et al. (2017) [32] assessed impact on gaseous and particulate pollutants from shipping emissions in four port-cities in the Adriatic-Ionian region: Brindisi and Venice (Italy), Patras (Greece), and Rijeka (Croatia). The contribution to total PAHs concentrations (gas plus particulate) was 82% in Venice and 56% in Brindisi, with a different partition between gas and particles, likely consequence of the different meteorological conditions in the two areas. Impacts on PM2.5 ranged between 0.5% (Rijeka) and 7.4% (Brindisi), those on PM10 were between 0.3% (Rijeka) and 5.8% (Brindisi). Particle number concentration contributed from 6% (Venice) to 23% (Brindisi), thereby an impact 2–4 times larger with respect to that on mass concentrations. This indicates that particle number concentration, even if not included in the European air quality standards, could be a more suitable metric to investigate the impact of this specific source. Shipping impacted on gaseous pollutants (NOX and SO2) much more with respect to PM2.5 or PM10. The inter-annual trends of the impacts on particulate matter concentrations and on PAHs was evident in some of the sites (Figure 116). Impacts on PM concentration showed a decreasing trend in Venice and Rijeka even when ship traffic increased. This is likely due to the decrease of the primary contribution to particle mass concentrations, due to the implementation of the European legislation on the use of low-sulphur content fuels. However, the effect was not present on other pollutants like PAHs concentrations. In Brindisi, measurements were taken after enforcement of European legislation and this decrease was not observed.

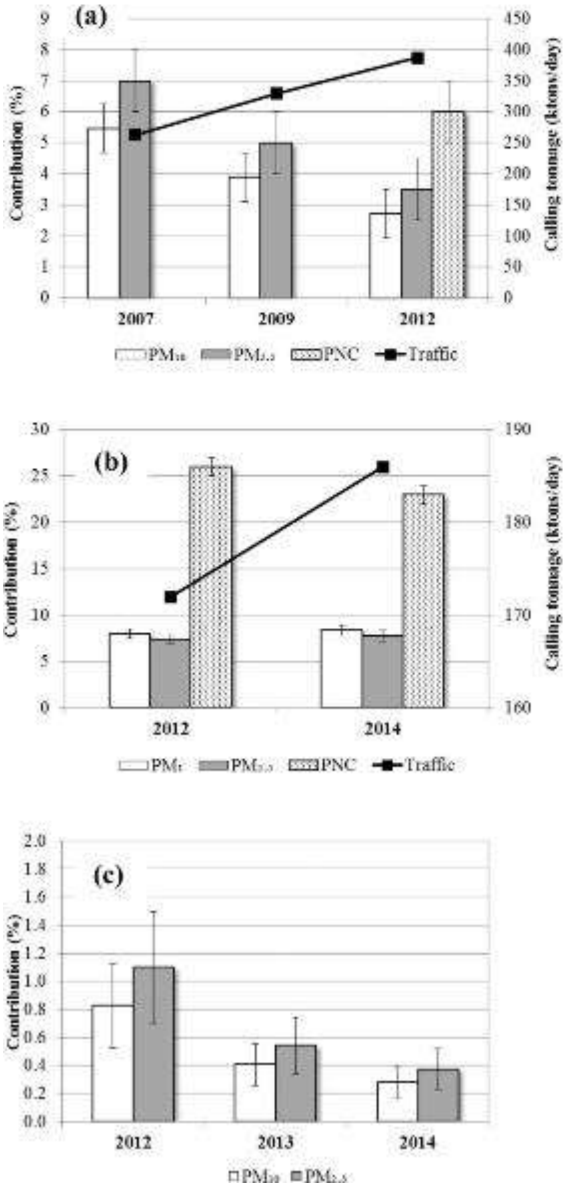


Figure 116 Trends of shipping contributions to PM2.5, PM10, and PNC concentrations, with indication of ship traffic (in ktons/day gross tonnage of ships) in Venice (a), Brindisi (b), and Rijeka (c). Source: Merico et al. (2017) [32]

In Barcelona (Pérez et al., 2016) [33] showed that around 50–55% PM10 and PM2.5 measured at the port was generated by harbour activities: mineral matter from road dust and construction works of a new port area, vehicle traffic and fuel oil combustion. The estimated contribution of harbour emissions to the urban background reached 9–12% for PM10 and 11–15% for PM2.5 and is linked to primary emissions from fuel oil combustion but also to the formation of secondary aerosols. The results demonstrated the prevalence of shipping emissions in Barcelona over the bulk fuel oil combustion processes. The contribution of fuel oil combustion was higher at the port than at the urban area (2.9 vs. 1.0 µg/m3 in PM10), reflecting direct emissions from shipping in the harbour area, although the difference is not so high taking in account that the port is an emission zone and the urban site represents the background of Barcelona.

Some studies specifically deal with emissions from cruise ships and impacts on city ports air quality. For example, in Greek ports (Papaefthimiou et al., 2016) [34] NOx was found dominant (2487.9 tons), In terms of the total in-port inventory, followed by SO_2 and PM2.5 (995.3 and 121.3 tons respectively), while the total emissions of greenhouse gases (GHG) were 124,767.8 tons CO_2-eq (for CO_2, N_2O, and CH_4). Emissions during hoteling corresponded to 89.2% of total, and significantly outweighed those produced during the vessels' manoeuvring activities (10.8% of total).

A study conducted in the port of Naples (Murena et al., 2018 [34]) highlighted that cruise ship emissions are particularly important when considering peak values. When 1-h peak concentrations are considered, the contribution of cruise ships to pollution can reach the 86.2% but on the average it is 5.18% during high season (Jun–Sept) and 3.65% in the solar year.

Not only atmospheric concentration of pollutants is affected by ship emissions, but also depositions of nitrogen and sulfur compounds that have been shown to increase significantly along the shipping routes in the western Mediterranean (Aksoyoglu et al., 2016) [19]. The deposition of oxidized nitrogen (mostly HNO_3) is estimated to be higher due to the ship traffic. Also Dry deposition of SO_2 seems to be significant along the shipping routes.

Impacts on human health

The health impacts of exposure to atmospheric particulate matter, including that emitted by ships, are described in the literature. Shipping was the third among the top six air pollution emission source categories (of a total of 16) posing an emerging health risk, after road transport and space heating and air conditioning (Héroux et al., 2015) [35]. Sipping/oil combustion emissions were shown to contribute with 1–10% of PM10 mass (up to 19% for oil combustion sources) and 2–17% of PM2.5 mass (up to 20% for oil combustion) in Mediterranean coastal cities.

A recent study (Viana et al., 2020) [37] estimated the PM2.5-attributable impacts in the form of premature mortality and cardiovascular and respiratory hospital admissions, from long-term exposure to shipping emissions. Health impact assessment (HIA) was performed in 8 Mediterranean coastal cities, using a baseline conditions from the literature and a policy case accounting for the MARPOL Annex VI rules requiring cleaner fuels in 2020. Long-term exposure to ship-sourced PM2.5 accounted for 430 (95% CI: 220–650) premature deaths per year, in the 8 cities, distributed between groups of cities: Barcelona and Athens, with >100 premature deaths/year, and Nicosia, Brindisi, Genoa, Venice, Msida and Melilla, with tens of premature deaths/year. According to the authors, the more stringent standards in 2020 would reduce the number of PM2.5-attributable premature deaths by 15% on average. This study provided a comparative assessment of the health burden of shipping emissions across Mediterranean coastal cities, which may provide decision support for urban planning with a special focus on harbour areas, and in view of the reduction in sulphur content of marine fuels due to MARPOL Annex VI in 2020.

3.4.4 Measures

World-wide measures

The key international regulatory framework regarding the requirements to control emissions from ships is established by Annex VI of MARPOL. MARPOL Annex VI, first adopted in 1997, limits the main air pollutants contained in ships exhaust gas, including sulphur oxides (SOx) and nitrous oxides (NOx), and prohibits deliberate emissions of ozone depleting substances (ODS). MARPOL Annex VI also regulates shipboard incineration, and the emissions of volatile organic compounds (VOC) from tankers.

Annex VI includes a global cap of 4.5% m/m on the sulphur content of fuel oil and calls on IMO to monitor the worldwide average sulphur content of fuel.

Annex VI also contains provisions allowing for special SOx Emission Control Areas (SECAs) to be established with more stringent controls on sulphur emissions. In these areas, the sulphur content of fuel oil used onboard ships must not exceed 1.5% m/m. Alternatively, ships must fit an exhaust gas cleaning system or use any other technological method to limit SOx emissions. The Baltic Sea Area is designated as a SOx Emission Control area in the Protocol. The North Sea was adopted as SOx Emission Control Area in July 2005.

Annex VI prohibits deliberate emissions of ozone depleting substances, which include halons and chlorofluorocarbons (CFCs). New installations containing ozone-depleting substances are prohibited on all ships. But new installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

Finally, Annex VI also sets limits on emissions of nitrogen oxides (NOx) from diesel engines. A mandatory NOx Technical Code, which defines how this shall be done, was adopted by the Conference under the cover of Resolution 2. The Annex also prohibits the incineration on-board ship of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).

Following entry into force of MARPOL Annex VI, the Marine Environment Protection Committee (MEPC), agreed to revise MARPOL Annex VI with the aim of significantly strengthening the emission limits in light of technological improvements and implementation experience. MEPC 58 (October 2008) adopted the *revised* MARPOL Annex VI and the associated NOx Technical Code 2008, which entered into force on 1 July 2010. The main changes to MARPOL Annex VI are a progressive reduction globally in emissions of SOx, NOx and particulate matter and the introduction of emission control areas (ECAs) to reduce emissions of those air pollutants further in designated sea areas. Under the revised MARPOL Annex VI, the global sulphur limit is reduced from current 3.50% to 0.50%, effective from 1 January 2020, subject to a feasibility review to be completed no later than 2018.

MEPC 70 (October 2016) considered an assessment of fuel oil availability to inform the decision to be taken by the Parties to MARPOL Annex VI, and decided that the fuel oil standard (0.50% sulphur limit) shall become effective on 1 January 2020. The limits applicable in ECAs for SOx and particulate matter were reduced to 0.10%, from 1 January 2015. Progressive reductions in NOx emissions from marine diesel engines installed on ships are also included, with a "Tier II" emission limit for engines installed on a ship constructed on or after 1 January 2011; and a more stringent "Tier III" emission limit for engines installed on a ship constructed on or after 1 January 2016 operating in ECAs (North American Emission Control Area and the U.S. Caribbean Sea Emission Control Area).

The IMO's Energy Efficiency Design Index (EEDI), approved in July 2011, is the first globally-binding design standard aimed at abating climate change from shipping. It applies to (almost) all new ships and entered into force in 2013. The index requires new ships to become more energy efficient, with standards that will be made increasingly more stringent over time.

In 2018 IMO adopted the Initial IMO Strategy on Reduction of GHG Emissions from Ships. Key points are (International Chamber of Shipping, 2019 [16]):

- Carbon intensity of the ship to decline through implementation of further phases of the energy efficiency design index (EEDI) for new ships
    - To review with the aim to strengthen the energy efficiency design requirements for ships with the percentage improvement for each phase to be determined for each ship type, as appropriate;
- Carbon intensity of international shipping to decline
    - To reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008; and
- GHG emissions from international shipping to peak and decline
    - To peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out as called for in the Vision as a point on a pathway of CO2 emissions reduction consistent with the Paris Agreement temperature goals.

The strategy also includes a list of candidate measures for further CO2 reduction that will be considered by IMO, including measures that can be implemented before 2023) (International Chamber of Shipping, 2010 [16]).

From 1st January 2020 the IMO Global Sulphur Cap full extent and is enforced by the World's Port State Control authorities. Ships trading outside of existing sulphur Emission Control Areas (ECAs) have to burn compliant low sulphur fuels. With the exception of a minority of ships that have elected to use LNG or install Exhaust Gas Cleaning Systems ('scrubbers'), the majority of ships comply using a variety of fuels with a sulphur content of 0.5% or less. This is compared to the 3.5% sulphur content which has been permitted outside of ECAs since 2012 (International Chamber of Shipping, 2019 [16]).

Figure 117 summarized the limits imposed on the sulphur content of the fuel oil used on board ships, which have been subject to a series of step changes over the years.

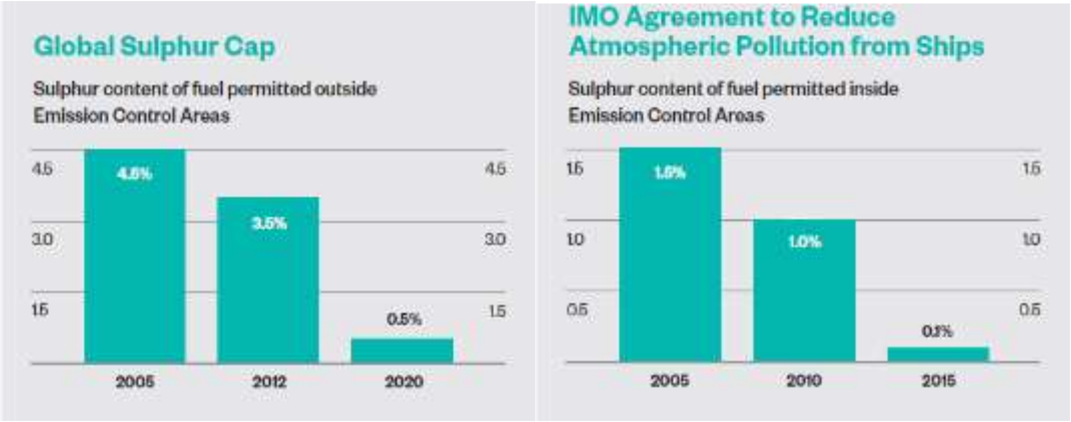


Figure 117. Global Sulphur Cap – IMO Agreement to reduce atmospheric pollution from ships. Source: International Chamber of Shipping, 2019 [16]

EU measures

The codified legislation addressing sulphur oxides emissions from shipping in the EU is Directive (EU) 2016/802 regulating the sulphur content of certain liquid fuels. It contains the latest limits for marine fuels mentioned above which were introduced by Directive 2012/33/EU, amending Directive 1999/32/EC, and is the result of a sustained period of legislative development. Directive 1999/32/EC was amended in 2005 by Directive 2005/33/EC to reflect the provisions of Annex VI of IMO's Marine Pollution Convention, MARPOL 73/78. Under these provisions, the Baltic, the North Sea and the English Channel were designated as SOx-ECAs, with the corresponding obligation to limit the sulphur content of fuel used in those areas to 1,5%. EU law was aligned to the new MARPOL limits (2008 amendment of Annex VI to the MARPOL Convention) in 2012 by means of Directive 2012/33/EU. In both the 2005 and 2012 amendments of the Directive, the fuel sulphur standards were also applied to passenger ships operating a regular service outside the SOx-ECAs.

Improving the environmental performance of maritime transport has been on the EU agenda for a decade, starting with the 2009 Maritime Transport Strategy, the 2011, Transport White Paper, and more recently the 2016 strategy for low-emission mobility and the 2017 Valletta declaration. The European Parliament has also adopted resolutions calling for the EU to take more responsibility for shipping emissions. In 2013, the Commission set out a strategy for progressively integrating maritime emissions into EU climate policy, relying on three consecutive steps: (i) Monitor, report and verify CO_2 emissions from maritime transport; (ii) Define Greenhouse gas reduction targets for the maritime transport sector; (iii) Develop further measures, including market-based measures, in the medium to long term.

Since 2018, the EU Regulation on monitoring, reporting and verification of CO_2 emissions from maritime transport (Regulation (EU) 2015/757) requires shipping companies to monitor their CO_2 emissions, fuel consumption and other relevant information during navigation to or from ports in the EEA, when they transport cargo or passengers for commercial reasons.

In 2019, the Commission presented the European Green Deal – a roadmap that sets out how to make Europe the first climate-neutral continent by 2050, boosting the economy, improving people's health and quality of life, caring for nature, and leaving no one behind. The European Green Deal covers all sectors of the economy, including waterborne transport. In this context, the European Commission will look into extending the Emissions Trading System to cover the maritime sector, along with other possible measures aimed at enhancing the sector's contribution to the fight against climate change.

EU scale benefit of a Med SOx ECA

Further controls of emissions from international shipping could improve air quality for a large share of European population, given that about half of the EU population lives within 50 km distance from the Sea.

A SECA in the 12 nm zones of EU Member States would reduce SO_2 emissions by about 15 percent compared to the baseline situation, and by 50 percent if extended to the 200nm zones of EU Member States. Applied to all coastal States in the Mediterranean, a 12 nm SECA would lead to about 25 percent lower emissions, and the 200 nm zone to 80 percent lower Sox (IIASA, 2019) [18].

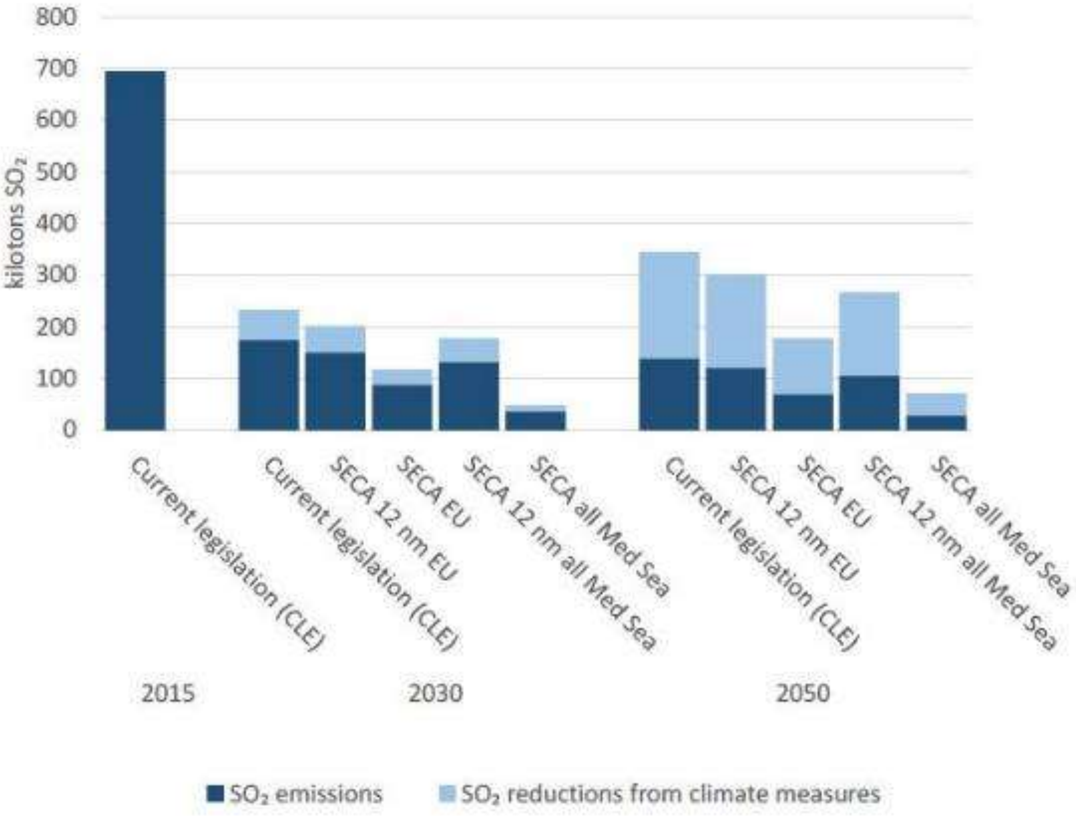


Figure 118. SO_2 emissions from international shipping in the European Seas, measures applied in the Mediterranean Sea. Source: IIASA (2019) [18].

Reductions would occur also for PM2.5: a SECA in EU waters of the Mediterranean Sea could reduce PM2.5 concentrations on average by 0.5 µg/m3 compared to the baseline levels in 2050, and by up to 1 µg/m^3 in Algeciras/ES, Valencia/ES and Marsaxlokk/MT. Tier III standards for NOx could deliver an additional 0.2 to 0.3 µg/m^3 in port cities by 2050. SECAs and NECAs covering the whole Mediterranean Sea could reduce ambient PM2.5 concentrations in non-EU ports typically by 1 µg/m^3 in 2050 IIASA (2019) [18]. Largest improvements could occur along the coast of Mediterranean countries, and in particular along the North African coast. Here the concentrations of PM2.5 could decrease by up to 1.2 µg/m^3 in 2030 and up to 1.5 µg/m^3 in 2050 (IIASA, 2019) [18].

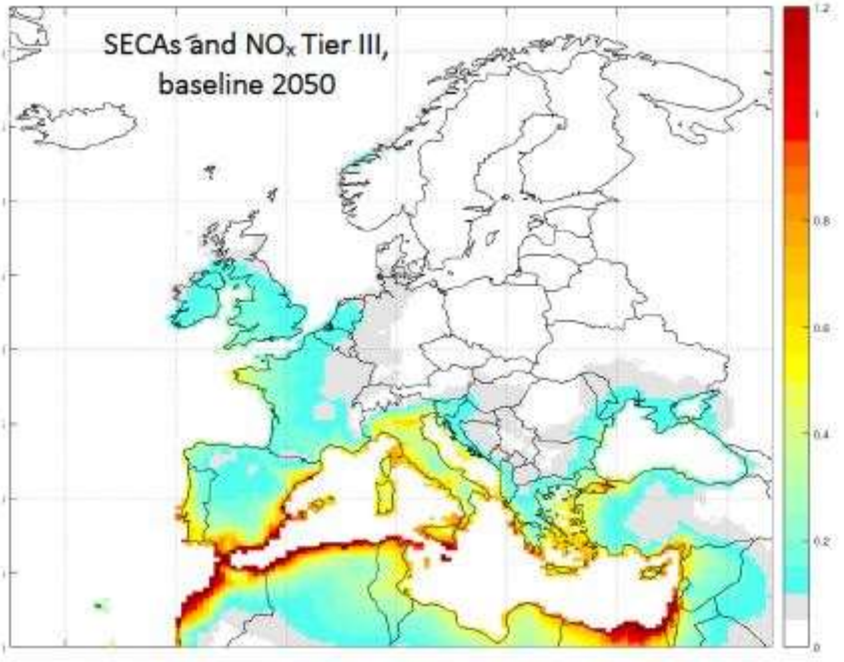


Figure 119. Decrease of ambient PM2.5 concentrations (µg/m3) in 2050 from implementation of SECAs and Tier III standards for NOx in all European Sea regions. Source: IIASA (2019) [18].

Med SOx ECA

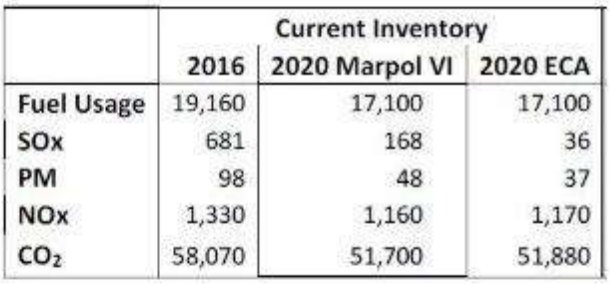
To tackle the hazardous effects of pollutants emitted from ships, in particular the Sulphur oxides (SOx), on human health and the environment in the Mediterranean Sea, the possible designation of the Mediterranean Sea as an Emission Control Area for sulphur oxides (Med SOx ECA) has been considered by the Contracting Parties to the Barcelona through the Regional Strategies for Prevention of and Response to Marine Pollution from Ships (2005-2015) and (2016-2021).

In accordance with the Technical and Feasibility Study conducted by REMPEC (REMPEC, 2019 [19]), the designation of Med SOx ECA would result in the following outcomes:

- emissions would be lowered by 78.7% for SOx and 23.7% for PM2.5, when comparing to the IMO sulphur cap (0.5%).
- the potential to avoid 1,000 premature deaths, more than 2,000 cases of childhood asthmas.
- acidification impacts on aquatic systems by wet sulphate and dry sulphate depositions would be reduced by 1.16% and 1.95% respectively, while the maximum percent decreases could reach 14.23% and 48.13% respectively in certain parts of the region.
- a reduction in haze with improved visibility, which would be notably felt over the Straits of Gibraltar and northern Morocco and Algeria, and along the main shipping lane connecting the Straits of Gibraltar, Malta, and towards the Suez.

Table 28 indicates the amounts of fuel usage and the emissions considered by the Study.

Table 28. Summary of total fuel usage and criteria and GHG emissions for the 2016 baseline, MARPOL VI, and the proposed Med ECA scenarios. Source: REMPEC (2019) [19]



	Current Inventory		
	2016	2020 Marpol VI	2020 ECA
Fuel Usage	19,160	17,100	17,100
SOx	681	168	36
PM	98	48	37
NOx	1,330	1,160	1,170
CO_2	58,070	51,700	51,880

The Study also examined spatial patterns of fuel consumption in the Mediterranean. This has been showed to be driven by regional shipping patterns Figure 120. The highest fuel consumption is observed at the western end of the Mediterranean Sea at the entrance to the Straits of Gibraltar, in the central Mediterranean Sea off of the north coast of Tunisia, and at the eastern end of the Mediterranean Sea at the entrance to the Suez Canal. Relative fuel consumption spatial patterns are unchanged in the various scenario years.

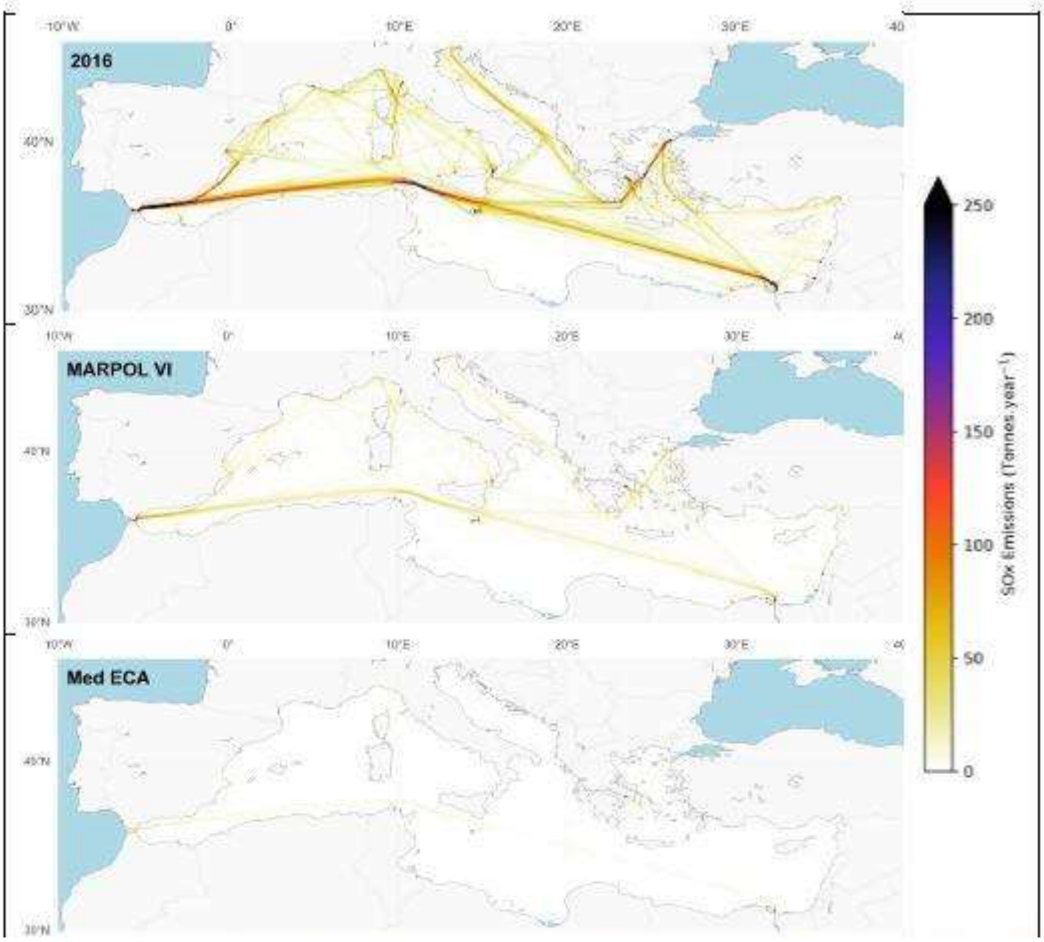
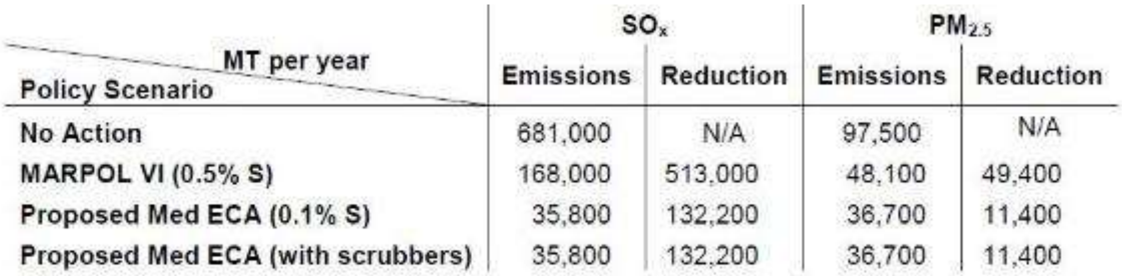


Figure 120. SOx emissions under 2016 baseline, 2020 MARPOL VI, and the 2020 proposed Med ECA scenarios. Source: REMPEC (2019) [19]

MARPOL VI standards are expected to reduce SOx emissions by approximately 75% from typical operations using residual fuels. Implementing SECA standards would enable to achieve about a 95% reduction in SOx emissions from ships compared with current operations. PM reductions of about 51% are associated with MARPOL VI, and SECA standards would increase that to about 62% reduction in emissions (REMPEC, 2019) [1] (see Table 29 and Figure 121).

Table 29. Estimated SOx and PM2.5 emissions under different Mediterranean regulatory and compliance scenarios. Source: REMPEC (2019) [19]



MT per year / Policy Scenario	SO$_x$		PM$_{2.5}$	
	Emissions	Reduction	Emissions	Reduction
No Action	681,000	N/A	97,500	N/A
MARPOL VI (0.5% S)	168,000	513,000	48,100	49,400
Proposed Med ECA (0.1% S)	35,800	132,200	36,700	11,400
Proposed Med ECA (with scrubbers)	35,800	132,200	36,700	11,400

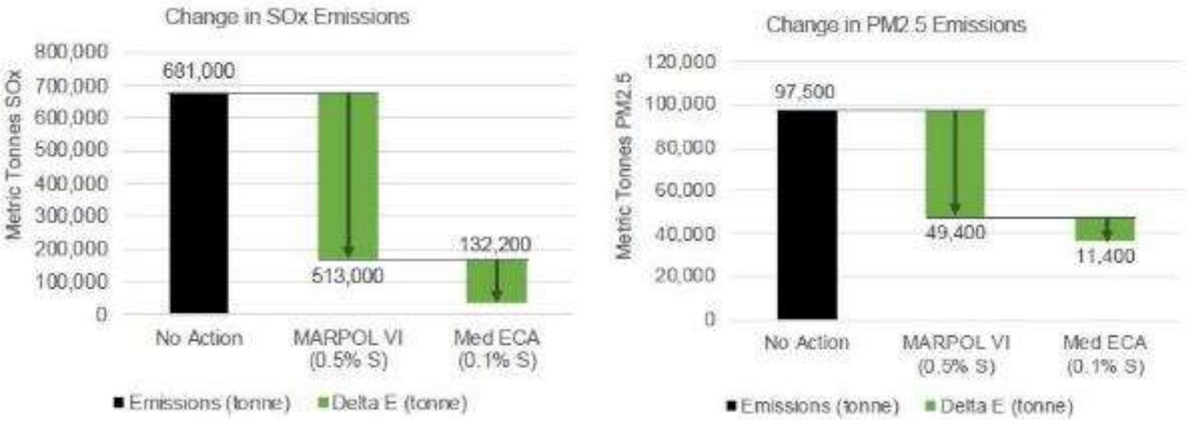


Figure 121. Change in SOx and PM2.5 emissions under different Mediterranean regulatory scenarios. Source: REMPEC (2019) [19].

Decreases in wet (Figure 122) and dry sulphate (SO_4) deposition associated with the proposed Med ECA show similar orders of magnitude as for SOx, but follow different patterns. Decreases in wet sulphate deposition are largest in the western and northern Mediterranean and show reductions in SO4 deposition occurring far inland. Reductions in dry sulphate deposition are more closely correlated to the high traffic shipping lanes. Taking this study area as a whole, the average reduction in wet sulphate deposition is 43.3 g.ha-1.yr-1, and the maximum observed reduction is 3,127.8 g.ha-1.yr-1 (REMPEC, 2019) [19].

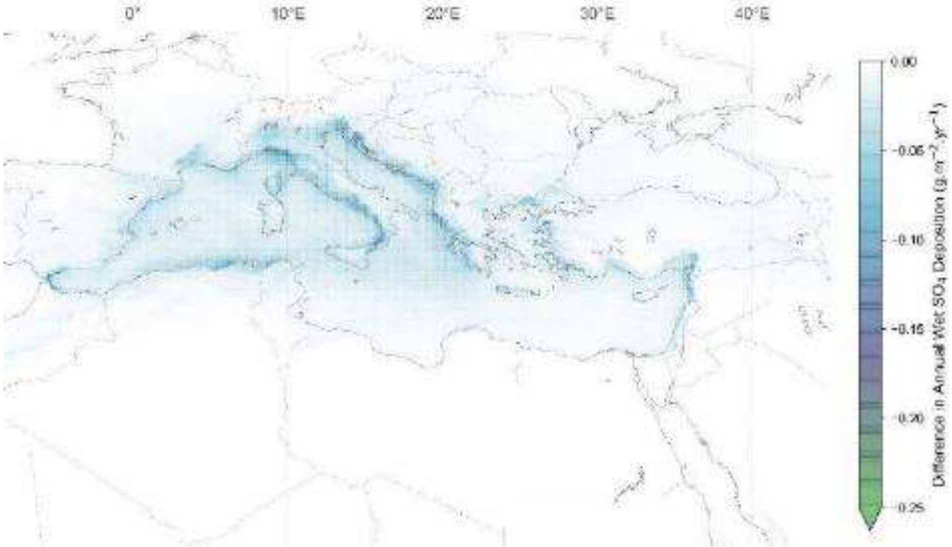


Figure 122. Decrease in annual wet sulphate deposition between MARPOL VI and the proposed Med ECA. Source: REMPEC (2019) [19].

Emissions reductions by ships operating in the Mediterranean Sea area will reduce concentrations of ambient air pollution and reduce exposure of PM2.5 for communities of people living in Mediterranean coastal States. These improved exposure conditions are associated with additional health benefits, namely reduced risk of premature cardiovascular and lung cancer mortality and reduced risk of childhood asthma Figure 123. Health benefits from SECA implementation are smaller than the avoided mortality and morbidity from adopting global MARPOL VI standards; this is expected given the emissions reduction from 0.5% S to 0.1% S is smaller than the first step to SECA conditions. This is a condition that will be likely for all SECA proposals considered after 2020 implementation of MARPOL VI.

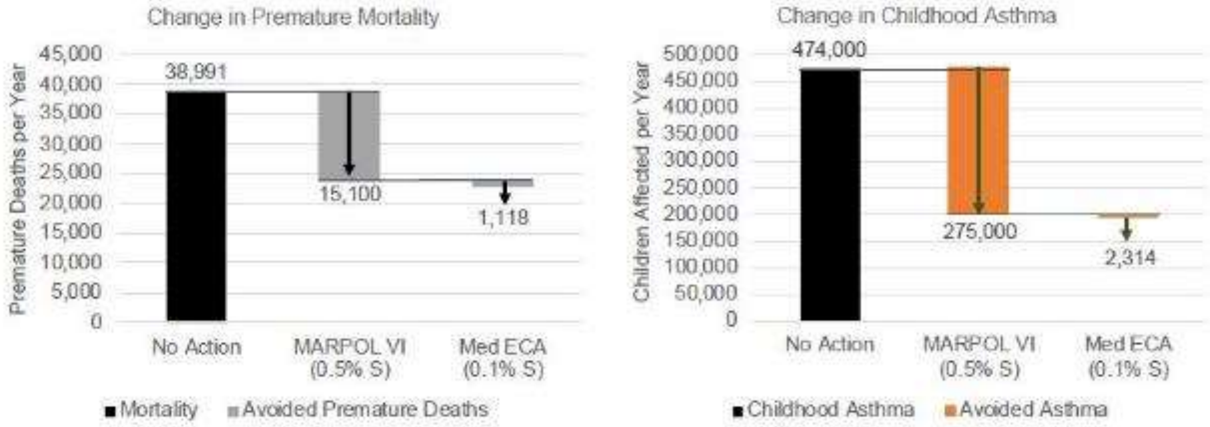


Figure 123. Change in lung cancer and cardiovascular mortality, and childhood asthma morbidity Source: REMPEC (2019) [19].

The Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols at their 21st Meeting, adopted Decision IG.24/8 on the Road Map for a Proposal for the Possible Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides Pursuant to MARPOL Annex VI, within the Framework of the Barcelona Convention, which outlines the process and details the related activities.

Figure 124 Main steps of the Road Map for a Proposal for the Possible Designation of the Mediterranean Sea.

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3.5 Non-indigenous species

3.5.1 Overview

With the human population increasing steadily, and the mobility of people and goods at an unprecedented intensity at global scale, the spread of NIS has been accelerating in the last decade (Seebens et al., 2017) [1]. As a result, the spread of NIS is now a hot issue at global scale (Dawson et al., 2017) [2], and the so-called "biological invasions" are at the forefront of research in many disciplines such as economics, ecology, conservation and food security. The Mediterranean Sea, in particular, is one of the seas that is most affected by NIS, in terms of high rate of introduction, number of taxa recorded and duration of permanence (Galil, 2008) [3]; Zenetos et al., 2012 [4]; Nunes et al., 2014 [5]; Marchini et al., 2015 [6]). Mediterranean biodiversity is indeed quite rich in NIS belonging to several groups such as macrophytes, fishes, molluscs, polychaetes, bryozoans and crustaceans (Harmelin et al., 2016 [7]; Zenetos et al., 2017 [8]).

Over the last two decades, changes in the Mediterranean marine biodiversity related to introduction of NIS have been reported as the consequences of an intense maritime traffic (Petrocelli et al, 2019 [9]; Sardain et al., 2019 [10]); corridors (Galil, 2006 [11]; Galil et al., 2017 [12]); and aquaculture activities (Savini et al., 2010) [13]. In the last decade, the species richness of marine organisms in the Mediterranean Sea has been reported to have reached ~17,000 taxa, among which some 820 can be considered NIS (Maninno et al., 2018) [14]. According to UNEP/MAP (SPA/RAC - MAMIAS, 2020) [18] this number reaches 1,200 when considering cumulative introductions since the end of the XVIII century (*Figure 125*). NIS include marine species across all taxa, from phytoplankton to fish, with zoobenthic species representing the higher percentage (43.2%), followed by demersal fish (14.4%) and benthic plants (11.9%) (*Figure 126*). These numbers of NIS in the Mediterranean basin are continually evolving, as checklists of NIS are subjected to frequent changes due to morphological similarities and the consequent erroneous identification of taxa or insufficient historical records, and to data from new molecular high-throughput analyses and new phylogenetic studies.

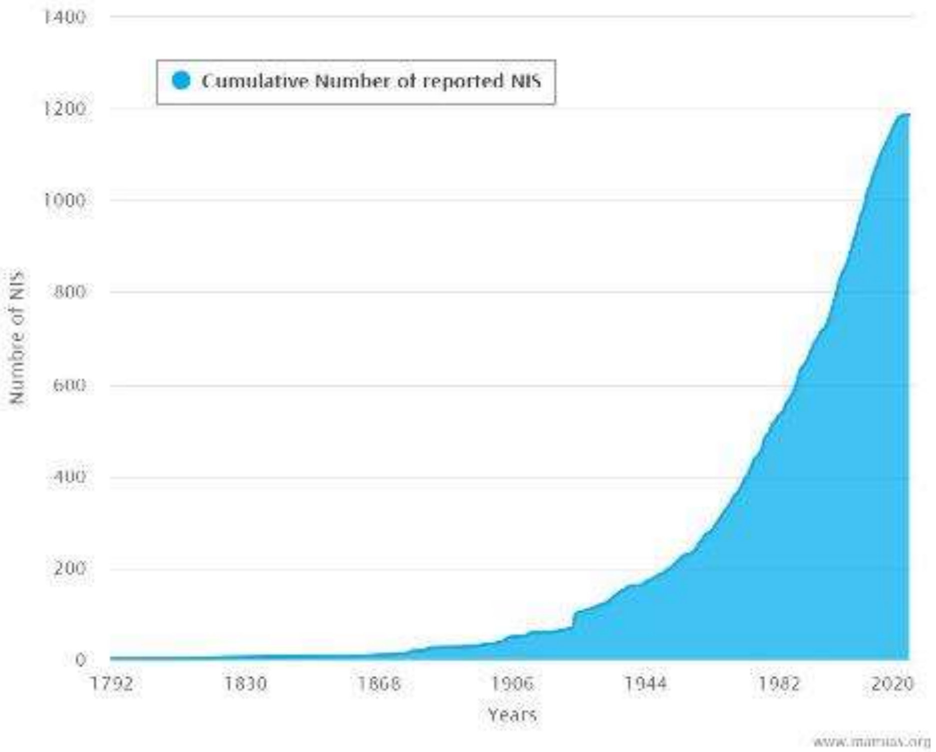


Figure 125 Cumulative number of new marine non-indigenous species (NIS) recorded (1792-2020). Source: MAMIAS [18].

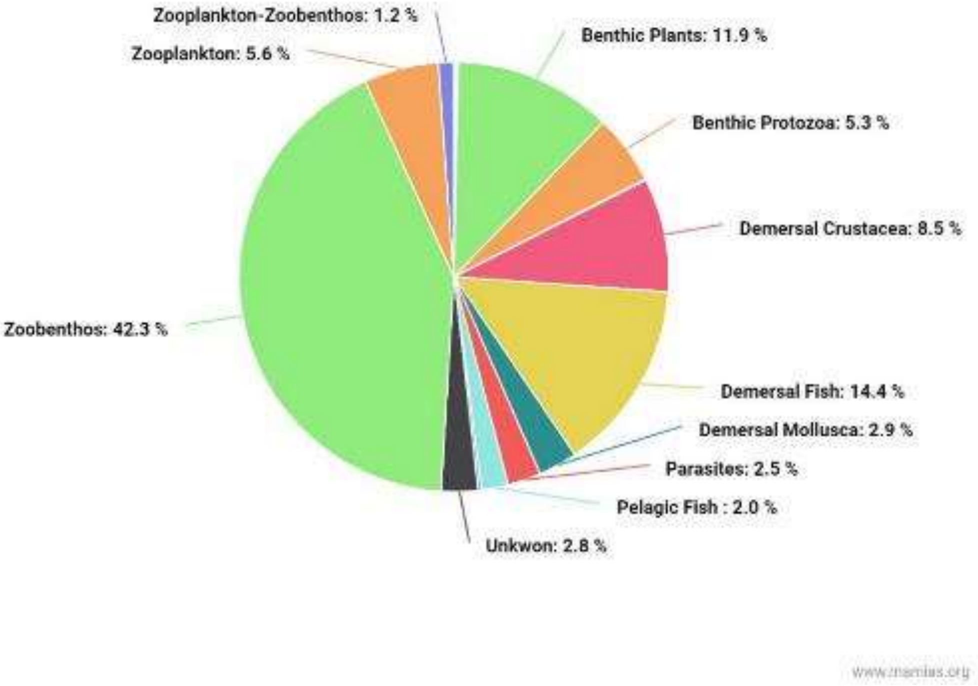


Figure 126 Distribution of non-indigenous species (NIS) per Ecofunctional Groups (2020). Source: MAMIAS [18].

Shipping is considered the major pathway for non-indigenous species (NIS) introductions worldwide, transporting organisms and propagules mainly in ballast water or as foulers on vessel hulls (Carlton 1985 [15]; Hewitt et al. 2009 [16]; Galil et al. 2014 [17]; Bailey 2015 [12]).

Corridors are estimated to represent the main vector for NIS in the Mediterranean (33.7%), followed by vectors associated with shipping (fouling 17%; ballast waters 6%; other related to shipping in general 6%).

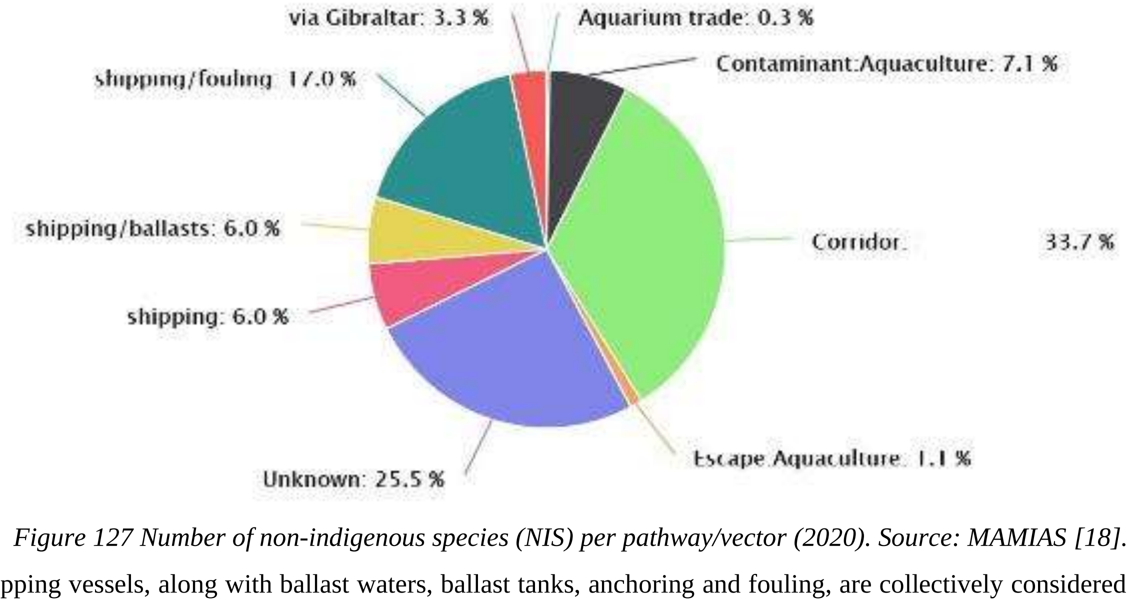


Figure 127 Number of non-indigenous species (NIS) per pathway/vector (2020). Source: MAMIAS [18].

Shipping vessels, along with ballast waters, ballast tanks, anchoring and fouling, are collectively considered as a vector of introduction. Ships' ballast water is of particular concern because of the large quantities of ballast water coming from different marine environments around the world being discharged at Mediterranean ports. Ballast sediments are also of concern for management as they provide a substrate for a variety of marine species, notably dinoflagellates (UNEP/MAP, 2012) [19].

Combining global cargo ship movements with port environmental conditions and biogeography to quantify the probability of new primary invasions by ballast water, Seebens et al. (2013) [20] considered that invasion risk in the Mediterranean is high. Ports are also important sites for invasion probability. In addition to large ports serving transoceanic vessels, many smaller ports and marinas serve as local transport hubs. In ports and marinas, artificial structures, such as docks and floating pontoons, provide suitable habitats to host opportunistic fouling species, and therefore facilitate and accelerate the stepping-stone introduction process known for NIS (Darbyson et al. 2009 [21]; Davidson et al. 2010 [22]; Mineur et al. 2012 [23]; Airoldi et al. 2015 [24]; López-Legentil et al. 2015 [27]).

Recreational boating plays an important role both in the leisure activities of residents and in nautical tourism in the Mediterranean: 55% of 'superyachts' worldwide register a Mediterranean port as their home port (Superyacht Business Happening 2015) [25]. Often, they are berthed next to commercial ports, in the vicinity of shellfish farms, or close to marine protected areas, thus serving as an overlooked and unregulated vector for secondary spread of fouling NIS and posing a threat to cherished habitats (Galil et al., 2018) [26]. Unsurprisingly, records of NIS from marinas are increasing (Galil et al., 2018 and references therein) [26].

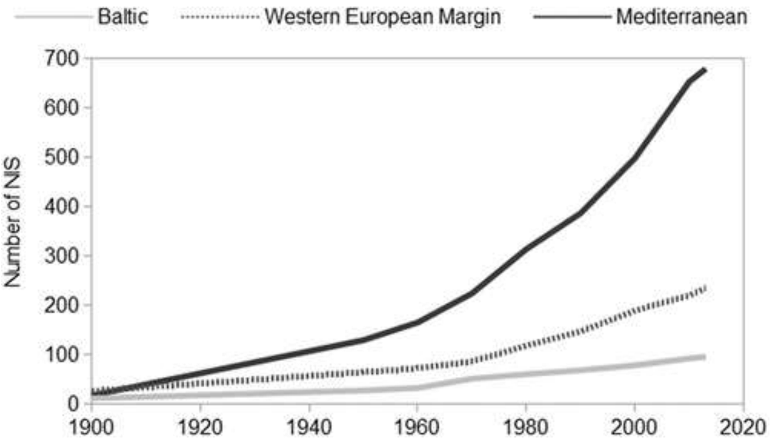
Despite the moderate number of propagules transported, in comparison with the ballast water vector, biofouling on ships' hulls is a relevant vector for NIS introduction (Drake and Lodge 2007 [30]; Sylvester et al. 2011 [31]. The level of biofouling on boat hulls is dependent on cleaning and antifouling habits, the duration of berthing time, the frequency of boat use and the assemblages of the surrounding artificial environment. The biofouling process typically begins with a simple layer of biofilm, subsequently colonised by macrofouling organisms, ranging from very small patches of a single taxon to species-diverse assemblages covering most of the hull.

Impacts of NIS in the Mediterranean are well known and they include also impacts on human health and to human activities. The jellyfish *Rhopilema nomadica* has been reported to negatively affect coastal power-generation installations, whilst impacting fisheries, human health and tourism. *Lagocephalus sceleratus* and *Pterois volitans*, both Lessepsian migrants[21], are examples of a toxic and a venomous fish species, respectively. Yet another Lessepsian fish migrant, the bluespotted cornetfish (*Fistularia commersonii*), is an extremely voracious predator which is aggressive when occurring in schools, whilst the two rabbitfish species *Siganus luridus* and *Siganus rivulatus* have largely displaced the native *Sarpa salpa* in the Levantine swathes of the Mediterranean Basin.

3.5.2 Introduction of Non-Indigenous Species: status and trends

In the last decade, the species richness of marine organisms in the Mediterranean Sea has been reported to have reached ~17,000 taxa, among which some 820 can be considered NIS (Katsanevakis et al., 2013 [32]; Galil et al., 2016 [33]; Zenetos et al., 2017 [35]). These have included marine species across all taxa, from phytoplankton to fish. These numbers of NIS in the Mediterranean basin are continually evolving, as checklists of NIS are subjected to frequent changes due to morphological similarities and the consequent erroneous identification of taxa or insufficient historical records, and to data from new molecular high-throughput analyses and new phylogenetic studies. However, only around 12% of all of NIS in the Mediterranean are today considered as invasive, or potentially invasive (Rotter et al., 2020) [36].

Galil et al. (2014) [17] studied the NIS richness in the European seas and pointed out that the number of NIS was substantially greater for the Mediterranean than the Western European margin or Baltic Sea. Of the 879 multicellular NIS reported in the European Sea, 95 were found in the Baltic, 237 along the Western European margin and 680 from the Mediterranean. The number of NIS recorded increased over the period 1970–2013 (Figure 128). In the Mediterranean NIS have increased by 204% (in the Baltic by 86%, and in the Western European margin by 173%).



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[21] The Lessepsian migrants (also called Erythrean migrants) are the marine species migrated across the Suez Canal, usually from the Red Sea to the Mediterranean Sea, and more rarely in the opposite direction. The phenomenon is still occurring today. It is named after Ferdinand de Lesseps, the French diplomat in charge of the canal's construction.

Figure 128 Cumulative number of non-indigenous species (NIS) recorded in the Baltic Sea, Western European Margin and Mediterranean Sea. Source: Galil et al. (2014) [17].

In the Mediterranean most of the introduced species have been recognized as NIS (77.6%), cryptogenic species[22] have been estimated to account for 16.5%, and questionable (debatable) species [23], (i.e.) have also been recorded (5.9%).

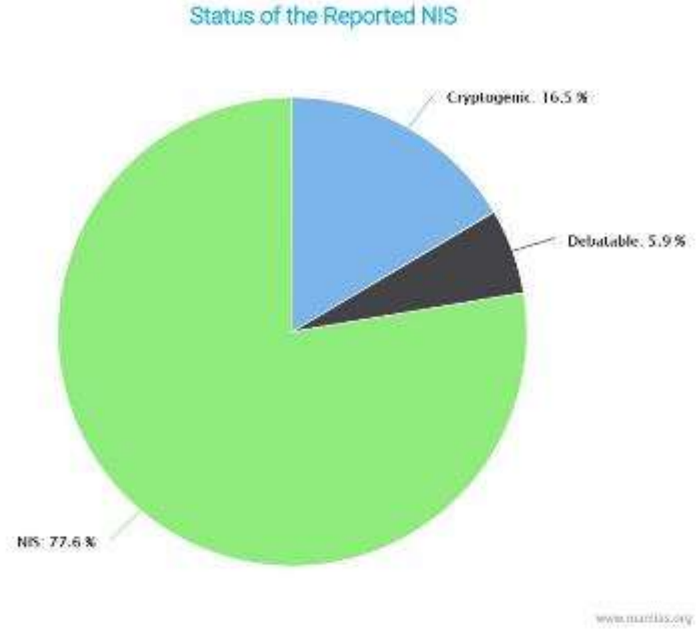
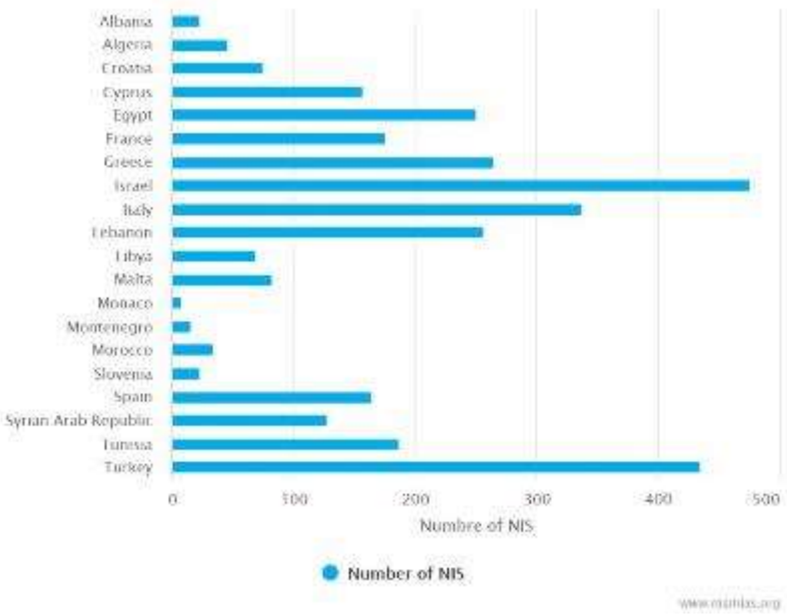


Figure 129 Status of reported NIS in the Mediterranean. Source: SPA/RAC – MAMIAS, 2020 [18].

Distribution by country shows a strong geographical pattern in NIS richness. In the Mediterranean the countries with the greatest number of NIS cluster are Israel and Turkey, followed by Italy, Greece, Lebanon and Egypt (*Figure 130*). The 46.2% of Mediterranean NIS has been recorded in the Eastern Mediterranean (SPA/RAC – MAMIAS, 2020[18]) (*Figure 131*).



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[22] Species with no definite evidence of their native or non-indigenous status, due to unknown origin or to unclear mode of introduction from native range: natural spread vs human mediated (Tsiamis et al., 2019) [34].

[23] NIS with insufficient information or new entries not verified by experts or NIS with unresolved taxonomic status (Tsiamis et al., 2019) [34].

Figure 130 Number of non-indigenous species (NIS) recorded by country in the Mediterranean Sea. Source: SPA/RAC – MAMIAS, 2020 [18].

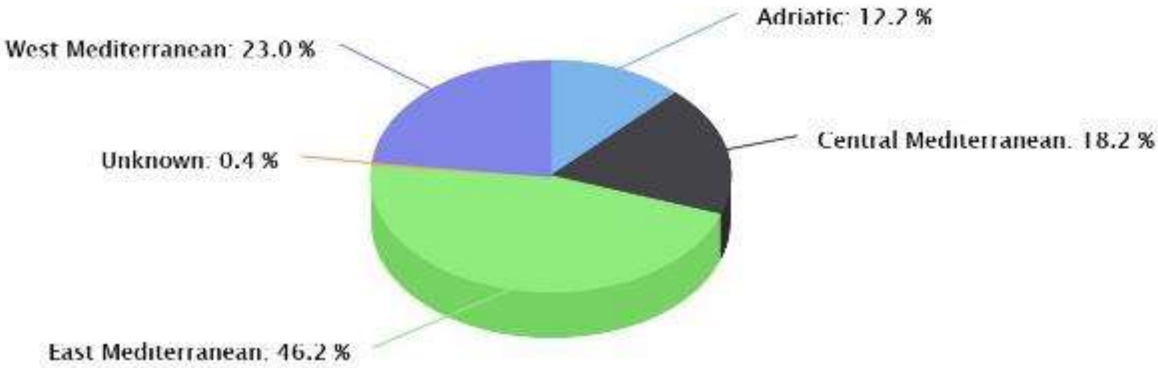

Figure 131 Number of reported NIS per EcAp sub-region. Source: SPA/RAC – MAMIAS, 2020 [18].

A higher percentage of vessel-introduced NIS is noticeable among the most widespread NIS: 26% in the Mediterranean, (80% and 77 % in Baltic and Western European margin, respectively), considering post-1990 widespread NIS (Galil et al., 2014) [17].

Approximately 350 NIS are estimated to have entered the Mediterranean via the Suez Canal after 1970, of which were 280 Lessepsian immigrants[24] and approximately 70 entered by ship via the Suez Canal. The pace of Lessepsian migration has been decreasing, particularly in the last decade, despite the expansion of the Canal (Zenetos, 2017) [32]. Of the 280 Lessepsian immigrants, approximately 200 species are established, but only 50 are invasive and spreading across the Mediterranean. The rest are locally established and their distribution is limited to the eastern Mediterranean. One of the latest invasive Lessepsian species is the lion fish (*Pterois miles*), which, within 6 years of its establishment (2012-2017), spread to the central Mediterranean (Karachle et al., 2017) [37].

In the Mediterranean Sea, like in the rest of the world, globalization, transoceanic canals and advances in ship building contributed to a dramatic increase in shipping introduced NIS. In particular, the replacement of ‘dry ballast’ by water in the early 20th century favoured transport of taxa with pelagic life stages and holoplanktonic taxa, which previously were unlikely to survive in transport. The increase in vessel traffic during and following the second world war left its mark in new cohorts of NIS: turf-forming macroalgae, blue crabs, veined rapa whelks and many more, recorded with increasing frequency near or in harbour’s (for reviews (Galil et al., 2018) [26]. The result has been a marked increase in the number of NIS species across the Mediterranean, with the highest numbers recorded in the Eastern Mediterranean.

Once established, NIS may spread further, transported by the multitudinous vessels plying the sea, both commercial and recreational, other vectors (e.g. mariculture), and with currents. Some (e.g. the swimming crab *Callinectes sapidus*, the reef building tubeworm *Ficopomatus enigmaticus*, the sea squirt *Styela plicata*) have attained a Mediterranean-wide distribution, while others are expanding rapidly (Galil et al., 2018) [26].

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[24] Species that have arrived in the Mediterranean by moving in the waters.

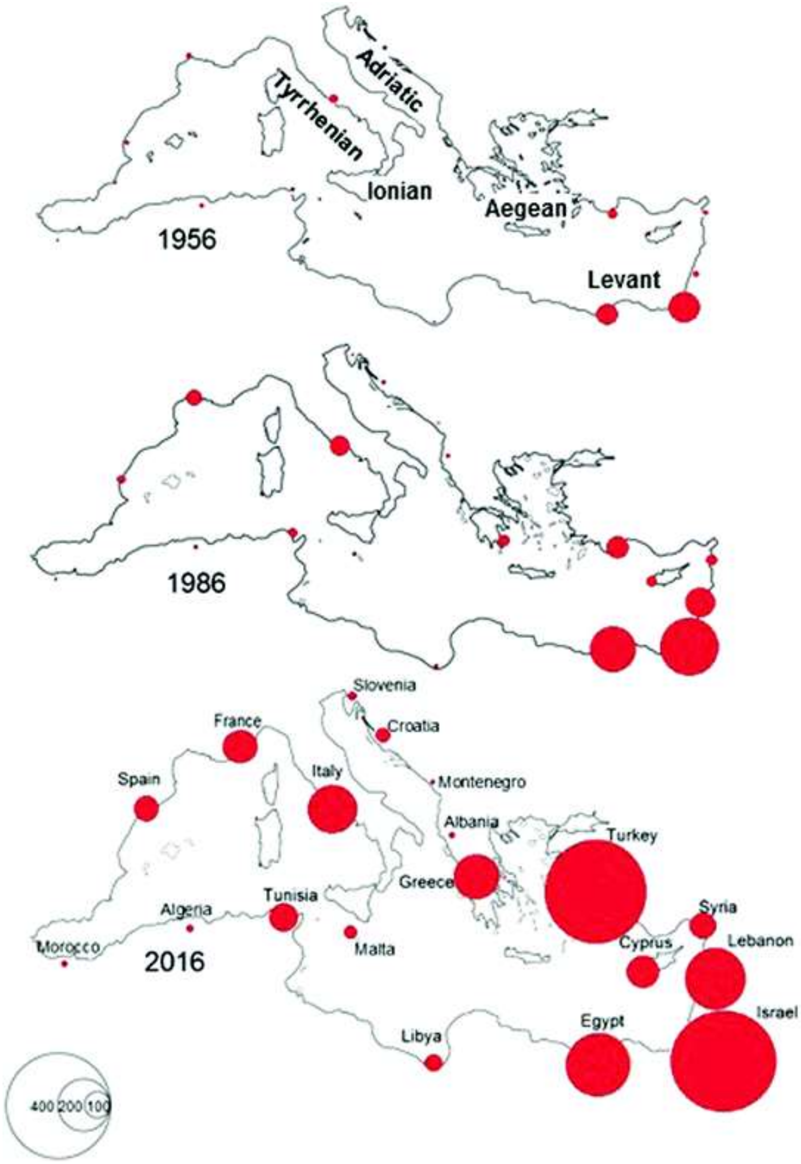

Figure 132 Map of the Mediterranean Sea showing number of non-indigenous species (NIS) per country in 1956, 1986 and 2016. Size of circles is proportional to the number of NIS. Source: Galil et al. (2018) [26]

The most recent distribution of number of NIS per country is available from SPA/RAC – MAMIAS (2020) [18], and it confirms the highest numbers recorded in the Eastern Mediterranean (*Figure 133*).

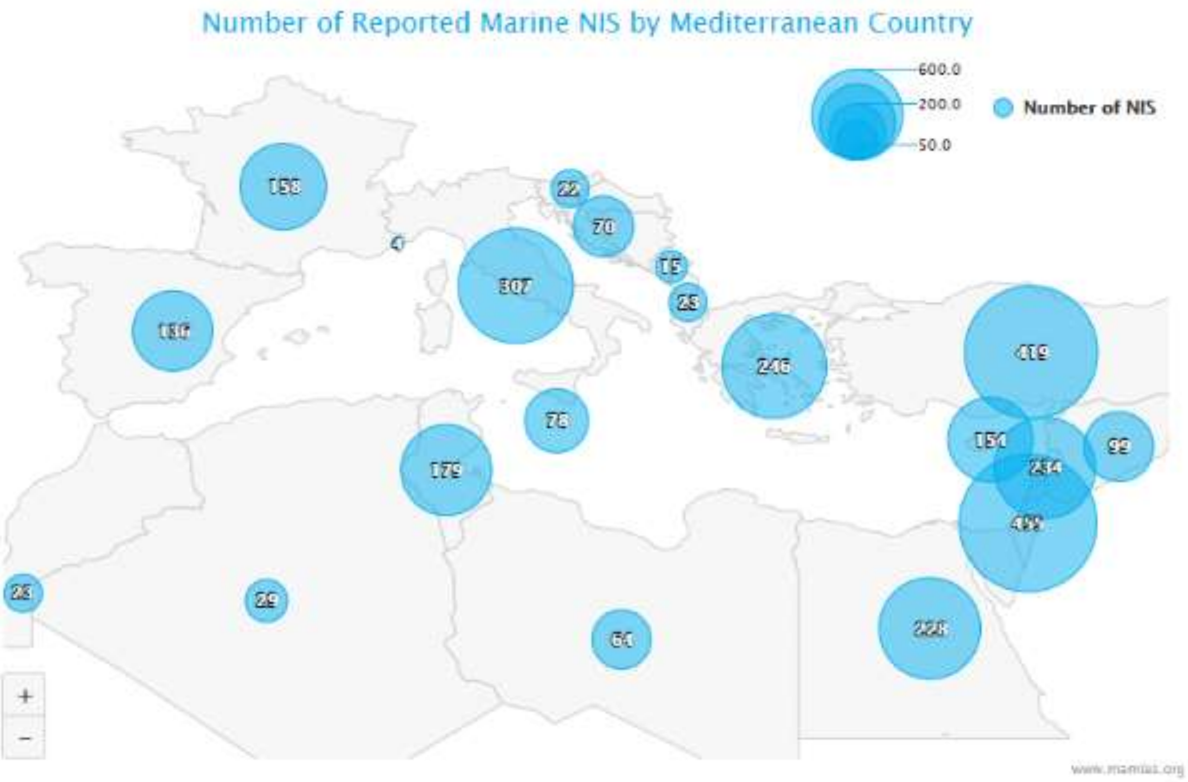

Figure 133 Distribution of number of reported NIS per country. Source: SPA/RAC – MAMIAS, 2020 [18].

The increasing trend across the decades of the XX and XXI century area showed in Figure 134, also highlighting the relative contribution of the different vectors. Records from the last decade have finally showed a decrease in the number of new NIS introduced in the Mediterranean. According to a study considering all the European seas (https://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species-1/assessment, last accessed in June 2020), the rate of introduction, which peaked between 2000 and 2005, has since shown a declining trend in all regional seas, as reflected at Pan-European level (see data series for the Mediterranean sub-regions in Figure 135). While NIS introductions still occur, the rate of NIS introductions decreases in the time period 2006-2017. The decreasing trend can be assigned to polices effectiveness as well as to other reasons, such as decreasing pool of potential NIS species, variations in sampling effort or available expertise.

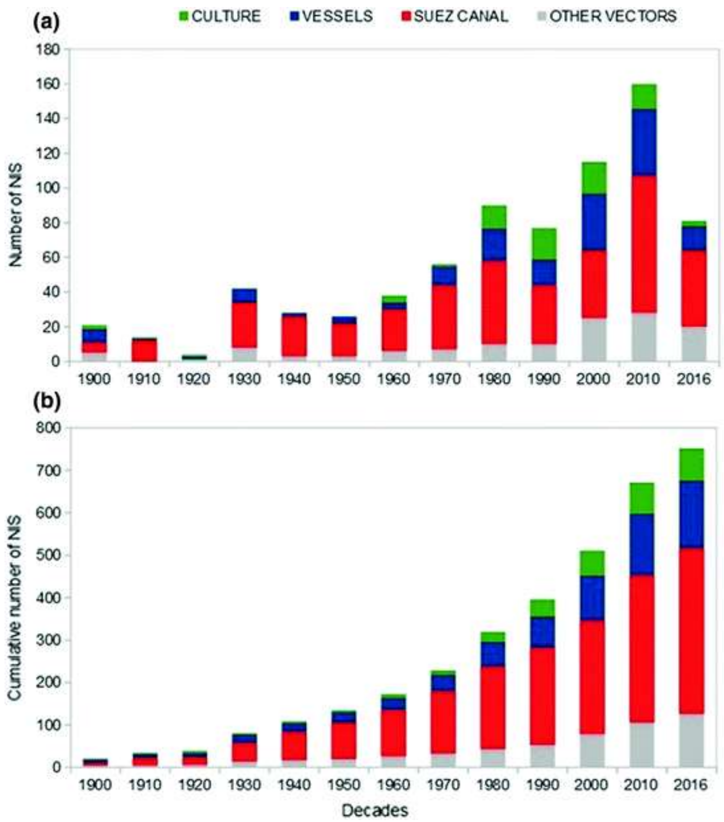

Figure 134 (a) Number of NIS in the Mediterranean Sea introduced in the decades between 1990 and 2016 by different vectors; (b) cumulative number of NIS. Source: Galil et al., 2018 [26].

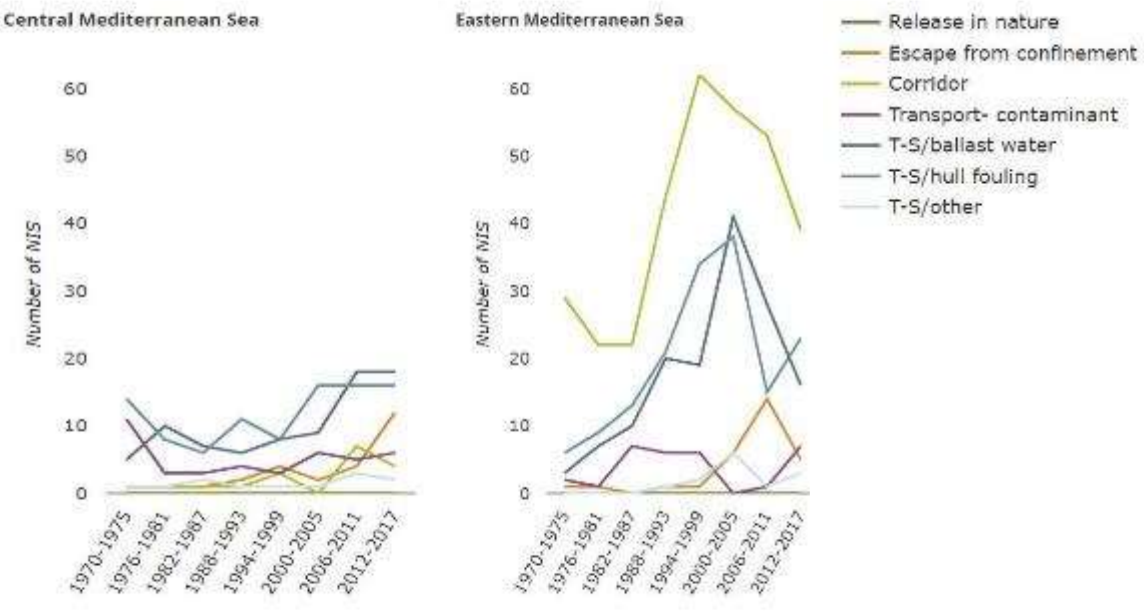

Figure 135 Temporal variability of NIS introduction associated with each pathway between 1970 and 2017y in Mediterranean marine subregions. Transport stowaway: moving of live organisms by maritime transport via various vectors: ballast water and sediments (T-S/ballast water), bio-fouling of ships, boats, offshore oil and gas platforms and other water vessels (T-S/hull fouling) and dredging, angling or fishing equipment (T-S/other). Release in nature: intentional introduction of live alien organisms (e.g. for fishing or hunting in the wild). Escape from confinement: movement of (potentially) invasive alien species from confinement (e.g. aquaculture). Transport contaminant: unintentional movement of live organisms as (e.g. pests, through international trade). Corridor: movement of alien organisms via transport infrastructure (e.g. canals). Source: Hellenic Centre for Marine Research (HCMR) https://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species-1/assessment accessed in June 2020.

Common Hull Fouling Invasive Species

Biofouled hulls are an ancient and significant vector of introduction of aquatic organisms (Hewitt and Campbell 2007). Their major role in marine introduction has been recognized since the 1970s. The table below provides a list of high-profile Invasive Aquatic Species that are capable of being translocated via biofouling. This list is indicative and there are numerous other species involved in serious invasions which have been recorded around the world.

Table 30 Species capable of being translocated via biofouling (Source: Imo Web Site).

Name	**Native to**	**Introduced to**	**Impact**
Asian paddle crab *Charybdis japonica*	Ranges from the North-west Pacific (China, Japan, Korea) to the east Asian Seas (Thailand, Malaysia)	New Zealand; detected but not established in Australia	May carry the White Spot Syndrome virus which can affect crustacean mariculture. Can affect biodiversity through either predation or by indirectly altering trophic levels.

Name	Native to	Introduced to	Impact
Colonial tunicate *Didemnum vexillum*	North-west Pacific	North-east and north-west Atlantic, north-east Pacific, New Zealand	This species is an aggressive invader and is able to reproduce sexually or asexually. Fragments of the species are able to disperse, reproduce, reattach and thrive. This species fouls hydrotechnical constructions, ships, aquaculture infrastructure and cultured molluscs. It affects the biodiversity of existing communities as it outcompetes for habitat or simply grows over or smothers existing species.
North Pacific seastar *Asterias amurensis*	North-west Pacific	North-east Pacific, Southern Australia	This species is a voracious carnivorous feeder. They are prolific breeders and are able to quickly establish large populations in new areas. The species is a serious pest to native species, such as the endangered spotted handfish (*Brachionichthys hirsutus*), as the seastar preys on the fish's egg masses. The species preference for mussels, scallops and clams ensures that it impacts mollusc aquaculture and wild fisheries.
Asian green mussel *Perna viridis*	Occurs from the Persian Gulf through to the Philippines, throughout the East Asian Seas and up to eastern China	The Caribbean, South Atlantic, South Pacific; detected in far North Queensland, Australia but not established	Tolerates wide fluctuations of salinity and temperature and reaches high densities. This species fouls hydrotechnical constructions, ships and aquaculture infrastructure. It affects the biodiversity of existing communities and can alter trophic levels.
Black striped mussel *Mytilopsis sallei*	North-west Atlantic, the Caribbean and South Atlantic	India, East Asian Seas (Malaysia, Singapore), South Pacific, North-west Pacific (Japan, Taiwan, Hong Kong); was detected in Darwin, Australia but eradicated	Tolerates wide fluctuations of salinity and temperature. Highly fecund, grows and reaches maturity rapidly. This species is capable of forming dense aggregations, impacting biodiversity as they exclude most other species. The fouling of hydrotechnical constructions, ships and aquaculture infrastructure with this species causes corrosion, technical problems and loss of efficiency.
European fan worm *Sabella spallanzanii*	North-east Atlantic, Mediterranean	South-west Atlantic, Southern Australia, New Zealand, North-west Pacific	This species is highly fecund and is able to form mat-like, dense populations on the seafloor. The species can tolerate wide ranges in salinity and successfully fouls artificial structures such as hydrotechnical constructions, vessels and aquaculture infrastructure. The species competes with native filter-feeding organisms for habitat and food. It is possible that dense formations alter water flow, sediment stability and bacterial communities due to their efficiency filtering particulate matter from the water column.

Name	Native to	Introduced to	Impact
Bay barnacle *Amphibalanus improvisus*	Thought to be the east coast of North-east and North-west Atlantic	South-west Atlantic, Caribbean Sea, Atlantic, Baltic Sea, Black Sea, Caspian Sea, North-west Pacific, East Asia Seas; detected but not established in Australia and New Zealand	This species is fast growing and gregarious. It has high reproductive potential; being able to re-produce sexually and asexually. Tolerates wide fluctuations of salinity and temperature. The fouling of hydrotechnical constructions, ships and aquaculture infrastructure with this species causes corrosion, technical problems and loss of efficiency. Able to affect biodiversity, change community structures and alter trophic levels.
Wakame seaweed *Undaria pinnatifida*	North-west Pacific	Mediterranean, North-east Atlantic, South-west Atlantic, North-east Pacific, South-east Australia, New Zealand	This species is able to rapidly colonise temperate regions; it can colonise any hard surface and is therefore able to foul hydrotechnical constructions, ships and aquaculture infrastructure. Able to affect biodiversity, change community structures and alter trophic levels.
European shore crab *Carcinus maenas*	North-east Atlantic, The Baltic Sea	West Africa (Mauritania to South Africa), Mediterranean, North-west Atlantic (Delaware to Nova Scotia), South-west Atlantic (Panama to Argentina), East Africa (Red Sea to South Africa; including Madagascar), North-west Pacific (Japan), North-east Pacific (South-east Alaska to California), East Asian Seas (Burma), Central Indian Ocean (Sri Lanka), South Pacific, South-eastern Australia	The adult specimens of this species are able to withstand wide ranging temperature and salinity fluctuations. It is able to reside in damp air exposed environments for up to 10 days and tolerate up to 3 months of starvation. However, when able to feed, this species is a voracious predator, preying on molluscs and other crustaceans, including commercially important species. Apart from impacting on native species through predation, this species disrupts existing community structures through competition (habitat and food) and behavioural activities (burrowing).

3.5.3 Environmental impacts

Human-mediated introduction of marine species to a region outside their natural range of distribution is widely considered to be the major threat to indigenous species diversity and community structures (Rotter et al., 2020) [36]. This can cause habitat modifications, changes in ecosystem functioning, introduction of new diseases and parasites, and genetic modifications, such as hybridization with the native taxa (Cook et al., 2016) [38]. NIS, and especially marine Invasive Alien Species (IAS), have an overall impact on the provisioning, regulating, cultural, and supporting ecosystem services (Kettunen et al., 2008) [39]. Some studies have argued that the overall impact of invasive species is first related to the degree of biological diversity of the recipient habitats, which assumes that the higher the biodiversity, the lower the level of vulnerability of a habitat to NIS invasion (Occhipinti-Ambrogi and Savini, 2003 [40]; Bulleri et al., 2008 [41]). However, the overall ecological impact of NIS on the Mediterranean Sea remains relatively difficult to quantify, and is mainly qualitative; nevertheless, there have been some good attempts at quantification (Katsanevakis et al., 2014 [42], 2016 [47]; Gallardo et al., 2016 [48]). In particular, the analyses of Katsanevakis et al. (2014) [42] have led to the conclusion that the majority of the recognized invasive species in the European seas (72%) have both positive and negative impacts on the native biota. Few have only positive effects (8%), while more (~20%) have only negative effects on the host environment.

For example, invasive macroalgae have the highest impact among all of the taxonomic groups, with Caulerpa cylindracea Sonder, *Womersleyella setacea* (Hollenberg) R.E. Norris, and *Lophocladia lallemandii* (Montagne) F. Schmitz indicated as the most invasive in the Mediterranean Sea (Katsanevakis et al., 2016) [32]. The green alga C. cylindracea is considered highly invasive also in the Adriatic Sea (for review, see Orlando-Bonaca et al., 2019), and specifically along the eastern Croatian coast. This seaweed was reported to have smothered live colonies of

Mediterranean stony coral [*Cladocora caespitosa* (L., 1767)] in the Mljet National Park, which caused complete retraction of the corals, thus leaving the calyx rims deprived of tissue cover (Kružić et al., 2008) [43].

Among the animal NIS, it appears that the invasive American comb jellyfish, Mnemiopsis leidyi A. Agassiz, 1865, is one of the invertebrates that is still spreading, and has not yet reached its maximum possible extension (Malej et al., 2017) [44]. M. leidyi was first detected in the Black Sea in the 1980s (Vinogradov et al., 1989), from where it has spread to diverse marine and transitional Mediterranean areas (Shiganova et al., 2004; Boero et al., 2009 [45]; Galil et al., 2009) [46]. From 2016, M. leidyi has been observed in several northern Adriatic areas, where it was also reported to successfully reproduce, which confirms its status as a successful invader (Malej et al., 2017).

In the Mediterranean the impact of *Caulerpa* species on coastal habitats has been widely studied. In particular, the impact of *Caulerpa* on *Posidonia* has been a subject of controversy, because the seagrass meadows were in decline before their spread, and experimental and observational investigations failed to provide clear conclusions as to the reason for decline (e.g. Bulleri and Piazzi 2015 [49]).

In the eastern Mediterranean algae-dominated rocky habitats, including *Cystoseira* meadows, have been decimated by large populations of herbivorous fish introduced through the Suez Canal. The two voracious grazers, the Erythraean rabbitfish *Siganus luridus* and *S. rivulatus*, transformed lush rocky reefs into “barrens” (Sala et al. 2011 [50]; Giakoumi 2014 [51]; Vergés et al. 2014 [52]).

Commercial exploitation of NIS has also had an impact: the fishing of cultivated Manila clams by vibrating rakes began in the late 1980s and expanded greatly in the mid-1990s (Canu et al. 2011) [53]. It has altered the physical structure, nutrient cycling and biological processes of the Northern Adriatic Lagoons

For the greatest majority of NIS, mainly medium to small sized invertebrates, no information exists as to their ecological impacts; even basic information on the biology and ecology of some widespread NIS is lacking (Cardeccia et al. 2017) [54].

A recent study of commercial trawl hauls off the Israeli coastline, based on examination of more than 200,000 fishes belonging to 111 species, revealed that Erythraean NIS comprised 54% of individuals and 70% of the biomass at 20 m depth and 67% of individuals and 45% of the biomass at 40 m (Goren et al. 2016). The increase of Erythraean NIS in fishery landings is not an unalloyed gain. Some of the most commercially important NIS (e.g. the fishes *U. moluccensis*, *S. lessepsianus*, *Siganus* spp., the shrimp *P. pulchricaudatus* and the crab *P. segnis*) have replaced native species, while some, like *P. segnis* and *Lagocephalus* spp., interfere with local artisanal fisheries, damaging gear and spoiling already netted catch (J. Ben Souissi pers. com.). Other Erythraean NIS are simply nuisance species (Galil et al., 2018) [26].

A handful of the NIS occurring in the Mediterranean Sea are venomous or poisonous and pose a threat to human health (Table 2.1). They comprise recent records (e.g. the striped eel catfish *Plotosus lineatus* , silverstripe toadfish *L. sceleratus*, long-spined sea urchin *Diadema setosum* , stonefish *Synanceia verrucosa*), or species that have greatly increased their spread in the last decade (e.g. the lionfish *Pterois miles* and jellyfish *Rhopilema nomadica*) (Galil et al., 2018) [26].

Table 31 Species with impact on human health introduced to the Mediterranean Sea. Source: Galil et al. (2018) [26]

Species	**Phylum**	**First Mediterranean record**	**Country of first record**	**Number of Mediterranean countries reported from (June 2017)**
Rhopilema nomadica	Cnidaria	1976	Israel	10
Macrorhynchia philippina	Cnidaria	1991	Lebanon	3
Diadema setosum	Echinodermata	2006	Turkey	4
Lagocephalus sceleratus	Chordata	2003	Turkey	13
Plotosus lineatus	Chordata	2001	Israel	5
Pterois miles	Chordata	1991	Israel	7
Synanceia verrucosa	Chordata	2010	Israel	3

NIS can also negatively affect the industry through biofouling of hulls, increasing fuel consumption. Organism assemblages attached to the underwater surfaces of ships (biofouling) significantly reduce propulsion efficiency through increased drag, leading to increased fuel consumption and emissions. A significant portion of this fuel is used to overcome the frictional resistance between the ship's hull and the water, and this can be as high as 40–80% of the total fuel consumption of a given ship. Antifouling paints and coatings that help to control biofouling of ships hulls have thus been in use for many decades (Fernades et al., 2016) [54].

3.5.4 Measures

The UN Convention on the Law of the Sea (Article 196) provides the global framework by requiring States to work together to prevent, reduce and control pollution of the marine environment including the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto.

In 1991 the MEPC adopted the International Guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediment discharges (resolution MEPC.50(31)); while the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, recognized the issue as a major international concern.

In November 1997 the IMO assembly adopted (resolution A.868(20) the Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens, inviting its Member States to use these new guidelines when addressing the issue of IAS.

The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) was adopted on 13 February 2004 and entered into force on 8 September 2017. The Convention requires all ships to implement a ballast water management plan. All ships have to carry a ballast water record book and are required to carry out ballast water management procedures to a given standard. 14 sets of Guidelines, the last one being adopted by resolution MEPC.173(58) in October 2008 and other relevant guidance documents have been developed to support the implementation of the BWM Convention (Source: IMO Web Site).

Regulation D-3 of the BWM Convention requires that ballast water management systems used to comply with the Convention must be approved by the Administration taking into account the Guidelines for approval of ballast water management systems (G8). The Guidelines (G8) have been revised in 2016 and converted into a mandatory Code for approval of ballast water management systems (BWMS Code), which was adopted by MEPC 72 (April 2018) and entered into force in October 2019 (Source: IMO Web Site).

Regulation D-3 also requires that ballast water management systems which make use of Active Substances to comply with the Convention shall be approved by IMO in accordance with the Procedure for approval of ballast water management systems that make use of Active Substances (G9). Procedure (G9) consists of a two-tier process – Basic and Final Approval – to ensure that the ballast water management system does not pose unreasonable risk to the environment, human health, property or resources (Source: IMO Web Site).

IMO's initiatives also included the development of the GloBallast Programme, a technical cooperation project financed by the Global Environment Facility (GEF), along with co-financing from countries and other international partners, implemented by the United Nations Development Programme (UNDP) and executed by the IMO through the Programme Coordination Unit (PCU) within the IMO’s Marine Environment Division (MED). This Programme aims at assisting the GEF's eligible countries to acquire the necessary knowledge and tools to integrate into their national systems measures related to preventing and controlling invasive species introduction via ships' ballast water and sediments.

The GloBallast Programme included a pilot phase addressing the issue in six Pilot Countries (2000-2004). This pilot phase was followed by a second phase entitled “GloBallast Partnerships” (2008-2012), which has been implemented in six priority regions, including the Mediterranean. Although initially planned as a five-year project, it was first extended to the end of 2014 and then to September 2016 to take advantage of the significant co-financing that the Project has mobilised over the last few years and to continue to support the efforts of the Lead Partnering Countries (LPCs) and the project outreach activities with a view to preparing for the implementation of the BWM Convention.

The IMO´s MEPC adopted the 2011 Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species, while requesting Member States to take urgent action in applying the Guidelines when adopting measures to minimise the risk of introducing invasive aquatic species via biofouling. These Guidelines are intended to provide a globally consistent approach to the management of biofouling. As scientific and technological advances are made, the Guidelines will be refined to enable the risk to be more adequately addressed. Port States, flag States, coastal States and other parties that can assist in mitigating the problems associated with biofouling should exercise due diligence to implement the Guidelines to the maximum extent possible.

The Guidelines were further supplemented by the Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft, approved by MEPC at its sixty-fourth session in October 2012 and circulated as MEPC.1/Circ.792. This Guidance is for use by all owners and operators of recreational craft less than 24 metres in length, which may constitute an important vector for the transfer of invasive aquatic species due to their large numbers and their operating profile that may make them particularly susceptible to biofouling.

To support the implementation of the Biofouling Guidelines, the IMO Secretariat is implementing technical cooperation activities under its Integrated Technical Co-operation Programme (ITCP) focusing on the issue of biofouling and the Biofouling Guidelines. The aims of these activities are, on the one hand, to raise awareness of the aspects and implications of the transfer of invasive aquatic species through ships' hull fouling and, on the other hand, to enhance the familiarity and understanding of the Guidelines in order to facilitate their global implementation and the minimization of species invasions. In addition, IMO initiated the GloFouling Partnerships project in 2017. This project aims to build capacity in developing countries to implement the Biofouling Guidelines and protect marine ecosystems. The project is a collaboration between the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the IMO and will address the transfer of aquatic species through bio-fouling. Implementation is planned from September 2018 for a period of five years.

At European level, the Marine Strategy Framework Directive (MSFD) [DIRECTIVE 2008/56/EC] came into force in 2008. Of the 11 high level descriptors of 'good environmental status' outlined in the Directive, the second states "Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems." MSFD is the single most important policy measure taken by the European Union concerning marine NIS. In fact, the EU Regulation 1143/2014 on the prevention and management of the introduction and spread of invasive alien species (IAS Regulation), entered into force in 2015, does not include marine species. The Regulation lays down rules to prevent, minimize and mitigate the adverse impacts of the introduction and spread, both intentional and unintentional, of a subset of IAS of 'Union concern' (49 species to date, none marine) on biodiversity and the related ecosystem services.

A 'European code of conduct on recreational boating and invasive alien species' was recently presented to the Council of Europe.

At Mediterranean level, in the framework of the Barcelona convention, the Mediterranean Strategy on Ships' Ballast Water Management (BWM), including its Action Plan and Timetable as well as the "General Guidance on the Voluntary Application of the D1 Ballast Water Exchange Standard by Vessels Operating between the Mediterranean Sea and the North-East Atlantic and/or the Baltic Sea" was adopted by the Contracting Parties to the Barcelona Convention in 2009 (Decision IG.20/11). The Mediterranean Strategy is consistent with the requirements and standards of the BWM Convention: according to the BWM Convention, when travelling within the Mediterranean, ships should undertake ballast water exchange as far from the nearest land as possible, and in all cases in waters at least 50 nautical miles from the nearest land and in waters of at least 200 meters depth (Figure 136)

The Mediterranean BWM Strategy's Action Plan identifies eight (8) main measures to be taken at regional level, sub-regional or national level in accordance with the Strategic Priorities, as follows:

- Action 1 – Ratify the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention);
- Action 2 – Adopt harmonised arrangements for ballast water exchange in the Mediterranean region;
- Action 3 – Establish a solid Compliance, Monitoring and Enforcement (CME) system in the Mediterranean region;
- Action 4 – Establish a survey, biological monitoring and risk assessment system for Mediterranean ports;
- Action 5 – Enhance expertise; facilitate knowledge transfer and capacity building in the Mediterranean region;
- Action 6 – Enhance public awareness on ships' ballast water and invasive alien species issues;
- Action 7 – Set-up a web-based Mediterranean mechanism for exchanging information; and
- Action 8 – Incorporate the Action Plan evaluation within the Barcelona Convention reporting system and procedure.

The Mediterranean Strategy on Ships' Ballast Water Management (BWM) is currently under review.

As regards the implementation of the GloBallast Partnerships Project in the Mediterranean region, REMPEC was identified by the IMO as the Regional Coordinating Organization (RCO) to lead the implementation of the project in the region, in consideration of the direct relevance of the Partnership's objectives to the mandate of the Centre. REMPEC coordinated the implementation of the project in collaboration with the UNEP/MAP's Regional Activity Centre for Specially Protected Areas (RAC/SPA). At the beginning of the Project, Croatia and Turkey volunteered to act as LPCs in the implementation of the Project in the Mediterranean region. The GloBallast Partnerships

Project has implemented, during the reporting period, a number of activities at global, regional and national levels to accelerate the legal, policy and institutional development in the LPCs and Partnering Countries (PCs) with a view to preparing for the implementation of the BWM Convention.

In addition, the Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021) (UNEP(DEPI)/MED IG.22/28) included in the its expected results: the application of the 2011 Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species, with medium priority, when adopting measures to minimise the risk of introducing such species via biofouling, and any experience gained in their implementation is reported to IMO; the dissemination of the Guidelines to the shipping industry and other interested parties, which are requested to cooperate in minimising the risks involved; to provide advice and assistance to Mediterranean coastal States in the application of the Guidelines.

In recent years there has been a strong interest from the scientific community and international organisations, such as UNEP/MAP, in monitoring biological invasions in the Mediterranean Sea, assessing their impact on biodiversity and ecosystem services, investigating their pathways and gateways of introduction, and proposing management measures.

To this end, the Mediterranean countries adopted since 2003 and update it in 2016 in the framework of the implementation of the framework of the Protocol concerning Specially Protected Areas and biological diversity in the Mediterranean (SPA/BD Protocol), the Action Plan Concerning Species Introductions and Invasive Species in the Mediterranean Sea as an effective way of guiding, coordinating and stepping up the efforts made by the Mediterranean countries to safeguard the region's natural heritage. The updated Action plan will promote the development of coordinated efforts and management measures throughout the Mediterranean region in order to prevent as appropriate, minimize and limit, monitor, and control marine biological invasions and their impacts on biodiversity, human health, and ecosystem services, particularly strengthening the capacity of the Mediterranean countries to deal with the issue of alien species, within the framework of the EcAp

Within this framework, two important tools were elaborated the "Guidelines for Controlling the Vectors of Introduction into the Mediterranean of Non-Indigenous Species and Invasive Marine Species[25]" and the "Guide for Risk Analysis assessing the Impacts of the Introduction of Non-Indigenous Species[26]".

As provided for by the Action Plan concerning species introduction and invasive species in the Mediterranean Sea, a first version of a regional system for the collection, analysis and dissemination of information on alien and invasive species was developed. The online database on marine invasive species in the Mediterranean Sea (MAMIAS; www.mamias.org) gives information on invasive non-indigenous species in the Mediterranean (list of alien species, list of marine invasive species, list of vectors, etc) and allows the use of different filters to find required data and retrieve statistics at regional and national level about aliens and invasive species. Actually, the MAMIAS is offline because it is under final testing before final release and could be accessed at www.mamias.org.

At their 19th Ordinary Meeting (COP19, Athens, Greece,9-12 February 2016), the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) adopted a novel and ambitious Integrated Monitoring and Assessment Programme and related Assessment Criteria (IMAP). IMAP is a key achievement for the Mediterranean region, which will enable for the first time a quantitative, integrated analysis of the state of the marine and coastal environment, covering pollution and marine litter, biodiversity, non-indigenous species, coast, and hydrography, based on common regional indicators, targets and Good Environmental Status (GES) descriptions.

The common indicator in relation to NIS is: COMMON INDICATOR 6: Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas (EO2, in relation to the main vectors and pathways of spreading of such species in the water column and seabed, as appropriate);

Non-indigenous species monitoring in the Mediterranean is a trend monitoring, where it is key to establish reliable, long-term data-sets as a first step of monitoring. Following the risk based approach, it needs to be focused on the invasive alien species (IAS) in IAS introduction "hot spots" (e.g. ports and their surrounding areas, docks, marinas, aquaculture installations, heated power plant effluents sites, offshore structures). In addition, areas of special interest such as marine protected areas or lagoons may be selected on a case by case basis, as appropriate, depending on the proximity to alien species introduction hot spots. As the most effective monitoring method a Rapid Assessment Survey (RAS) will be carried out, at least yearly by the Contracting Parties in hot-spot areas.

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[25] https://www.rac-spa.org/sites/default/files/doc_alien/ld_controle.pdf
[26] https://www.rac-spa.org/sites/default/files/doc_alien/ld_analyse.pdf

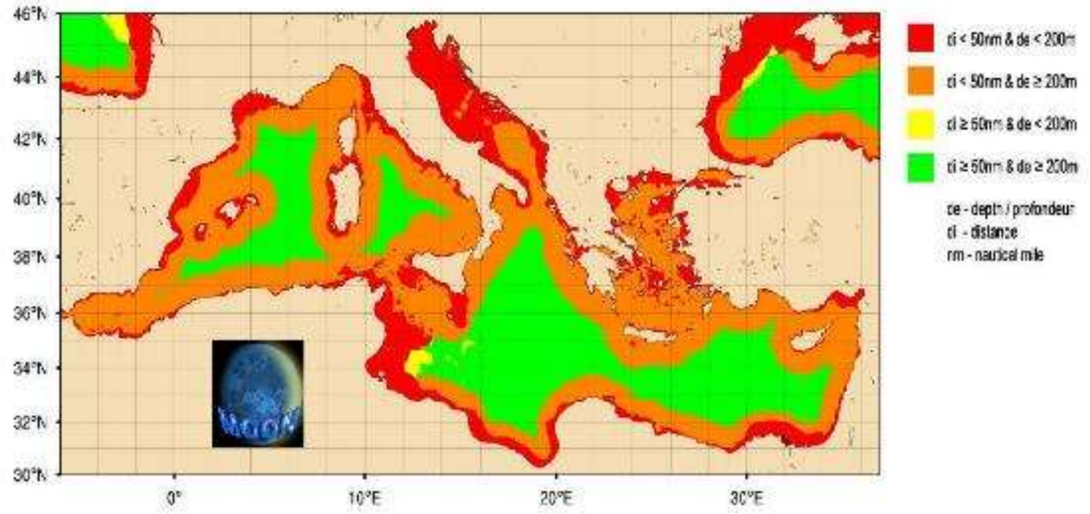

Figure 136 Areas in the Mediterranean Sea meeting the requirements set out in Regulation B-4.1.2 of the Ballast Water Management Convention (at least 50 nautical miles from the nearest land in waters of at least 200 meters depth). Source: Mediterranean Strategy and Action Plan on Ships' Ballast Water Management. UNEP(DEPI)/MED IG 20/8 Annex II.

3.5.5 References

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3.6 Underwater noise

3.6.1 Overview

Over the last century, human activities such as shipping, recreational boating, seismic surveys and low-frequency navy sonars and energy exploration have increased along the coasts, offshore, and deep ocean environments. Noise from these activities travel long distances underwater, leading to increases and changes in ocean noise levels. Rising noise levels can negatively impact ocean animals and ecosystems. These higher noise levels can reduce the ability of animals to communicate with potential mates, other group members, their offspring, or feeding partners. Noise can also reduce an ocean animal's ability to hear environmental cues that are vital for survival, including those key to avoiding predators, finding food, and navigating to preferred habitats.

Noise pollution from this activities problem often neglected by reviews of marine pollution, yet low frequency noise has doubled every decade since 1950 (ASCOBAMS, 2009) [1].

Sea ambient noise affects many marine species for which sound is the basis of survival; in particular those marine animals which use hearing as their primary foraging and communication sense. While most interest in anthropogenic noise and its mitigation has focused on marine mammals (mainly cetaceans and pinnipeds) and a few other vertebrates (such as sea turtles), there is increasing concern regarding the impact of such noise on fish, aquatic birds and marine invertebrates (Abdulla & Linden, 2008) [2]. Long-term exposure to intensive sound results in modification of behaviour and use of habitat in some fish species (Bass & McKibben, 2003 [4]; Slabbekoorn et al., 2010 [5]).

Marine animals rely on the acoustic scene for collecting information of biotic or abiotic origin. The exposure to increasing levels of underwater noise pollution cause adverse effects on marine organisms over different timescales (acute vs. chronic effects) and extents, ranging from temporary reduction in hearing sensitivity and behavioural effects to more dramatic effects such as death (Slabbekoorn et al., 2010 [5]; Radford et al., 2014 [6]).

Sources of marine noise pollution include ship traffic, oil and gas exploration and exploitation, industrial and military sonar use, the use of experimental acoustic sources, undersea explosions, and offshore and inshore industrial construction works. In particular, ship traffic can be seen as a worldwide network of moving noise sources with variable characteristics. Noise from shipping is primarily produced by cavitation with most of energy in the low frequencies, i.e. less than 1 kHz (Leaper and Renilson, 2012 [7]). As low frequency sound can travel over long distances (Tasker et al., 2010 [8]; Van der Graaf et al., 2012 [9]; Dekeling et al., 2014 [10]), shipping noise contributes to raise background noise levels. At a global scale, shipping is the dominant source of underwater ambient noise at frequencies below 300 Hz (Andrew et al., 2011 [11]; Hildebrand, 2009 [12]), and for the Mediterranean case, even for frequencies up to 500 Hz (Pulvirenti et al., 2014 [13]).

3.6.2 Underwater noise pollution: status and trends

Background noise levels in the Mediterranean are higher than in any other ocean basin (Ross, 2005) [3], with ship noise and seismic surveys being among the primary sources of noise (Abdulla and Linden, 2008) [2]. Within the Mediterranean, the Adriatic Sea, and especially its northern part, is characterized by high levels of underwater noise as documented in Trieste (Italy) (Codarin & Picciulin, 2015) [8], Monfalcone (Italy) (Picciulin et al., 2011) [14], Venice (Italy) (Bolgan et al., 2015) [15] and Cres-Losinj (Croatia) (Rako et al., 2013) [16]. The primary cause of anthropogenic noise in the Adriatic Sea is maritime transport Rako et al., 2012) [17].

In the Trieste Gulf (Codarin & Picciulin, 2015) [8] the reported underwater noise levels were about 100 dB re 1 µPa for 63 and 125 1/3 octave bands and about 125 dB re 1 µPa once considering the entire wideband. These values are similar to the ones obtained in previous local studies: the underwater noise measured in 2006–2007 at the WWF-Natural Marine Reserve of Miramare (Trieste) was ranging from 97 to 127 dB re 1 µPa in the wideband of 40 Hz–20 kHz (Picciulin and Codarin, 2007 [18]; Codarin, 2008 [19]; Codarin et al., 2009 [20]; Picciulin et al., 2010 [21]) and it was ranging from 81 to 110 dB re 1 µPa and from 89 to 110 dB re 1 µPa in the 63 and 125 1/3 octave bands, respectively (Picciulin, unpublished data). High values have also been previously found at the main entrance of the portal area of Monfalcone, where the recorded sea ambient noise was about 124 dB re 1 µPa (wideband; Picciulin et al., 2011 [14]). In the Slovenian part of the Trieste Gulf about 130 dB re 1 µPa, wideband, were recorded (Ferdinand Deželak, pers. com. in Codarin & Picciulin, 2015 [8]), likely due to a similar vessel traffic both in the open waters and around the harbour of Koper. Similar Sound Pressure Levels (average of about 125 dB re 1 µPa, wideband) have also been detected in the closely located Venice city and Venice lagoon (Northern Adriatic Sea, Italy) (Bolgan et al., 2015 [15]), with more intense noise in the Malamocco tide inlet and in the ‘Bacino San Marco’ (in the inner city) due to the heavy ship traffic (public transports, merchant and passenger ships). Underwater noise levels of about 130 dB re 1 µPa for the wideband frequency range (63 Hz–20 kHz) have been reported for the Cres and Losinj archipelago (Croatia) by Rako et al., 2013 [16]. All together these data indicate that the North Adriatic sub-region experiences high noise pressure in the marine waters, which is not surprizing given the shallow water and the high vessel traffic that characterize the area (Codarin & Picciulin, 2015) [8].

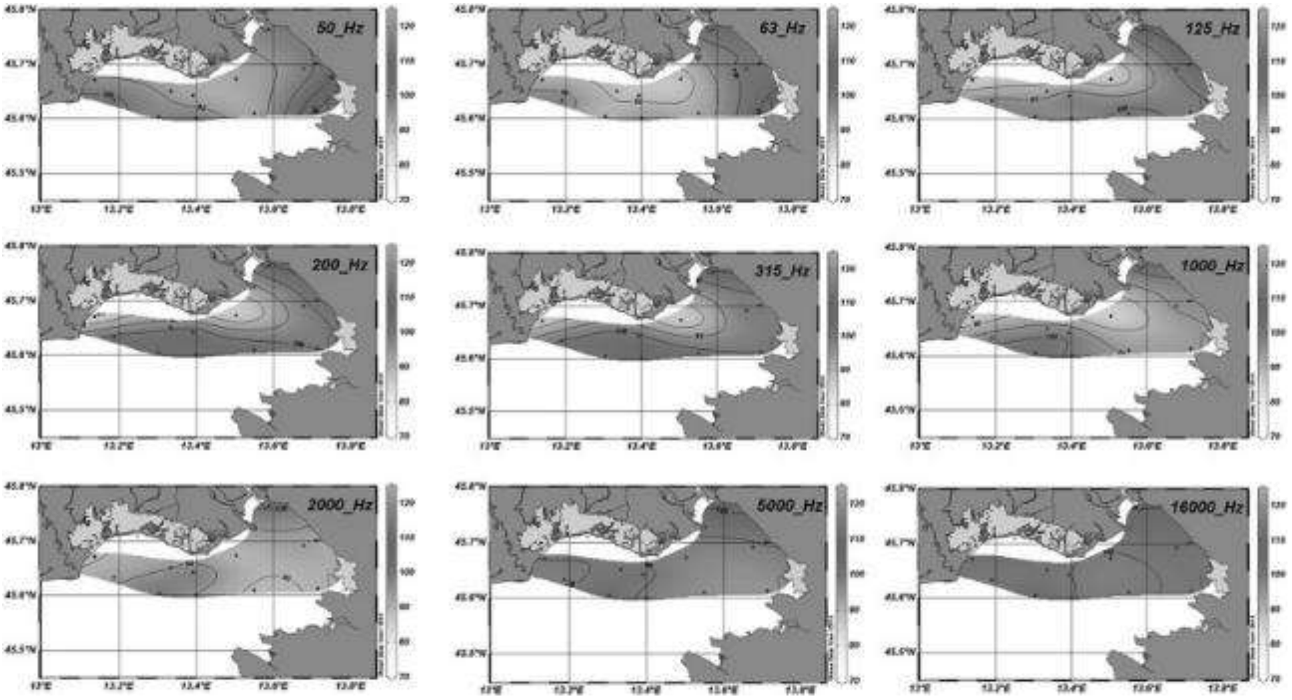

Figure 137 Annual underwater noise distribution maps for some of the 1/3 octave bands (50 Hz, 63 Hz, 125 Hz, 200 Hz, 315 Hz, 1000 Hz, 2000 Hz, 5000 Hz and 16,000 Hz). The maps were processed using the Data-Interpolating Variational Analysis gridding (DIVA). The resulting maps are a graphical representation of the data collected; no acoustic models for interpolation were applied to the data. Source: Codarin & Picciulin, 2015 [8].

In a coastal area of the northern Tyrrhenian Sea (Port of Civitavecchia, Italy) spatial and temporal variations in the noise level, and the type and number of ships sailing through the port were recorded using short-term recordings (Cafaro et al., 2018) [18]. A significant correlation was found between ferry boats and sound pressure levels, indicating their role as a prevalent source of low frequency underwater noise in the project area. Overall, maritime traffic can be considered to be the main source of anthropogenic noise in this area. The results of the broadband SPLs obtained using 60-second recordings, show highly varied values with a minimum and a maximum recorded in May and August, respectively. During August, the large presence of recreational boating linked to the Riva di Traiano marina (located on south side of Civitavecchia) could influence the high noise levels recorded.

In the Gulf of Naples (Italy) (Pieretti et al., 2020) [22], the investigated area was also characterized by a high anthropogenic noise pressure. Ambient noise levels here were principally driven by shipping noise and biological sounds of invertebrates (e.g., snapping shrimps). Shipping was the main source of lower-frequency underwater noises (<1 kHz) at both sites. This activity induced a constant rise in noise levels in the acoustic environment and produced temporarily unpredictable variations due to close-by passages of ships. Daily hours experienced higher sound pressure levels, though relatively high levels were documented at night when biological signals predominately occur in the Mediterranean Sea.

Maglio et al. (2015) [23] studied the Ligurian Sea in 2012 and pointed out that in most of the study area mean SPL broadband levels calculated at 80 m depth are higher than 100 dB, whereas natural ambient noise is expected to be found between 60 and 80 dB (Wenz, 1962) [24]. Figure 138 shows that 120 dB are exceeded 5 % of time along the central and eastern French Riviera and in the NE of Corsica, while almost the whole area is found at levels higher than 100 dB 5 % of time. All noise maps highlight the coastal zone among Monaco and Saint-Tropez (French Riviera) as an area characterized by constantly higher noise values than the rest of the study area. On the other hand, a greater variability is associated to Corsican waters. All eastern Corsican waters appeared as being less affected by shipping noise, highlight the NE part as being as noisy as the French Riviera. This variability could be associated with the heavier ferry traffic possibly occurring during the "high season" in the summer period. Also, the contribution of recreational craft to the whole noise picture should be assessed, especially in the coastal waters of the French Riviera, an area known to be heavily exploited by such navigation.

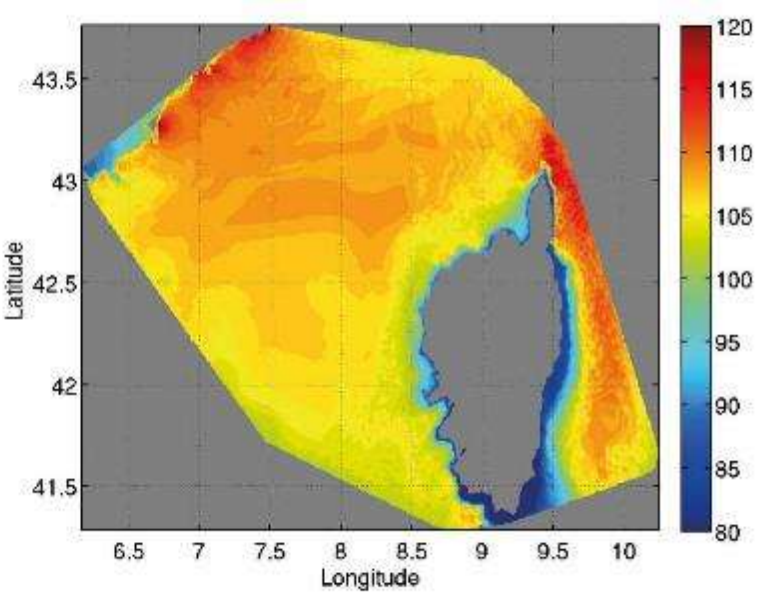

Figure 138 Levels of noise exceedance in percentile (or Exceedance levels). The map represents levels exceeded 5 % of time. Source: Maglio et al. (2015) [23]

As shown in Figure 139, multiple continuous noise sources (ships) create sound fields propagating for tens to hundreds of km, overlapping each other, and finally resulting in diffused increase of ambient noise levels. This increase represents a modification of the natural acoustic conditions of marine organisms.

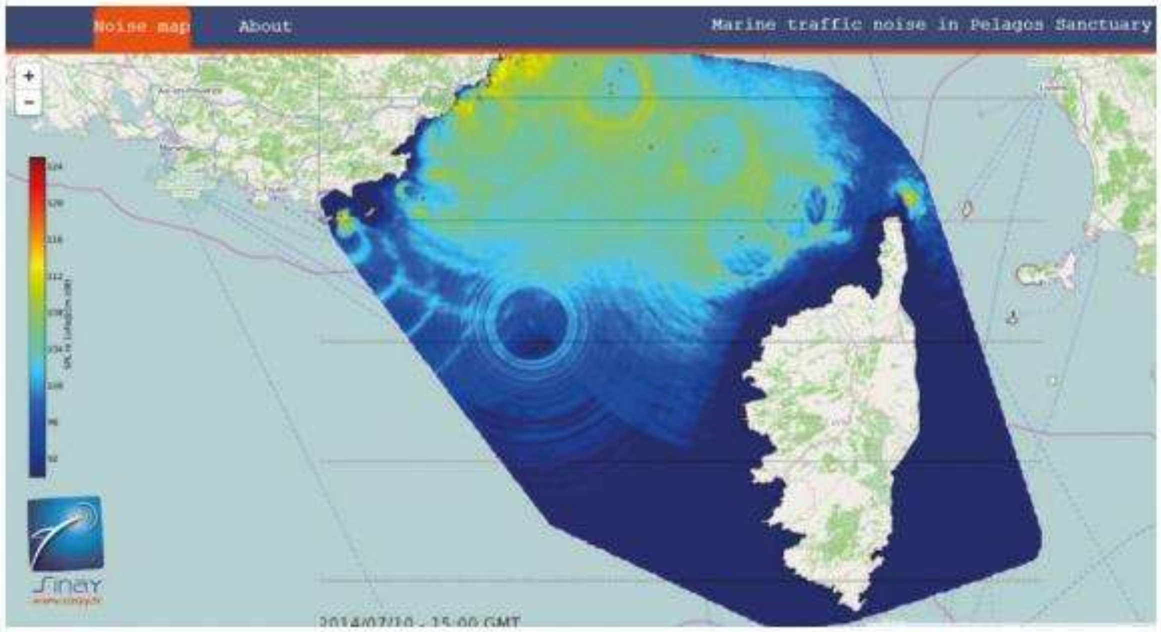

Figure 139 Levels Overlapping sound fields created by multiple ships navigating in the Ligurian Sea. Depth layer is 80 meters; date/hour: October 10th, 2014 at 15:00 GMT (Greenwich Meridian Time). In this picture, 22 ships are simultaneously navigating in the area. Dark red points represent noise levels exactly downward the position of ships. Concentric circles are zones of higher noise far from the source due to the sinusoidal propagation of sound waves. Source: Maglio et al. (2015) [23].

Recently a report commissioned by the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) presented a basin-wide map that shows the density of the main anthropogenic impulsive (i.e. not considering shipping) noise sources in the Mediterranean Sea (Maglio et al., 2016) [24]. The report is drawn from a dataset covering 1,446 harbours and marinas, 228 oil drilling platforms, 830 seismic explorations, 7 million ship positions, 52 wind farm projects, as well as publicly available information regarding military activities for the period 2005 to 2015. Together with increasing maritime traffic, the increase in seismic activities, especially for oil and gas exploration, is particularly striking. While in

2005 airgun use, sending loud impulsive noise of up to 260 decibels towards the sea floor, affected 3.8% of the Mediterranean's surface, this share increased to 27% in 2013. The report's mapping reveals that noise hotspots overlap with protected areas and/or with areas that are of particular importance to noise-sensitive marine mammal species. These include the Pelagos Marine Mammal Sanctuary in the Ligurian Sea, the Strait of Sicily, parts of the Hellenic Trench, as well as the waters between the Balearic Islands and continental Spain where noise-producing activities accumulate.

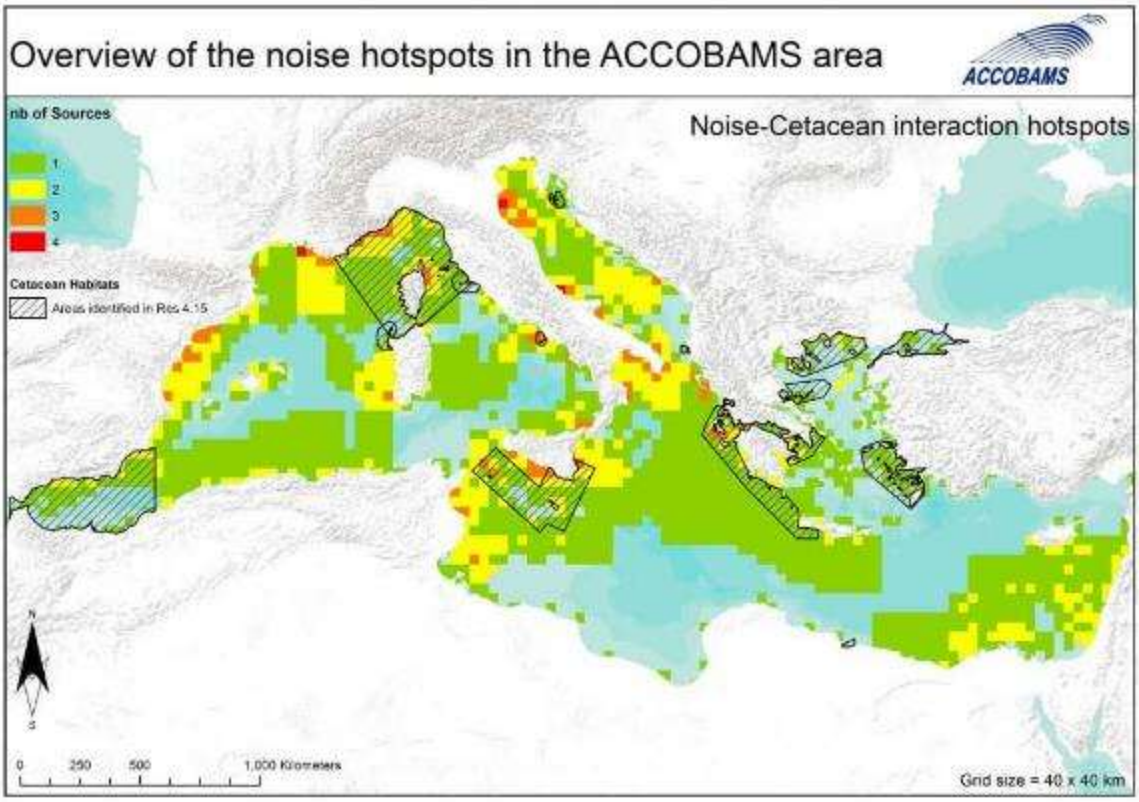

Figure 140 Overview of noise impulsive hotspots in the ACCOBAMS area. The noise sources include harbours, O&G drilling sites, offshore windfarms, seismic surveys, military areas. Source: Maglio et al. (2016) [24].

3.6.3 Environmental impacts

Anthropogenic underwater sound can have various impacts on marine species, ranging from exposures causing no adverse impacts, to behavioural disturbances, to loss of hearing, to mortality. Potential effects depend on various factors, including overlap in space and time with the organism and sound source, duration, nature and frequency content of the sound, received level (sound level at the animal), and context of exposure (i.e., animals may be more sensitive to sound during critical times, like feeding, breeding/spawning/nesting, or nursing/rearing young). In areas with high levels of anthropogenic noise, listening horizons are significantly reduced by elevated background sound levels. Many populations of whales and fish have been reduced in abundance by commercial whaling and fishing (JRC, 2010) [25]. This reduction in abundance may have increased the separation between individual animals at the same time that noise may have reduced the range of communication. It is possible that these effects could affect the ability of these populations to recover. The issue of noise exposure is complex with a wide variety of anthropogenic sound sources in the environment, numerous species inhabiting these environments, varying overlap in space and time between sources and receivers, and a range of potential impacts from exposure to noise, ranging from minor to severe (JRC, 2010) [25].

Ambient noise is defined as background noise without distinguishable sound sources (JRC, 2010) [25]. It includes natural (biological and physical processes) and anthropogenic sounds. Research has shown increases in ambient noise levels in the past 50 years mostly due to shipping activity (JRC, 2010) [25]. This increase might result in the masking of biological relevant signals (e.g. communication calls in marine mammals and fish) considerably reducing the range over which individuals are able to exchange information Figure 141). It is also known that marine mammals alter their communication signals in noisy environments which might have adverse consequences. It is further likely that prolonged exposure to increased ambient noise leads to physiological and behavioural stress. Thus chronic exposure to noise can permanently impair important biological functions and may lead to consequences that are as severe as those induced by acute exposure.

Figure 141 Typical frequency bands of sounds produced by marine mammals and fish compared with the nominal low-frequency sounds associated with commercial shipping. Note that some organisms are sensitive to frequencies beyond those that they produce. Source: (JRC, 2010) [25].

Depth sounding sonar systems on small vessels typically use frequencies between 50 and 200 kHz. Sonar usage, particularly on leisure boats, is increasing and is unregulated. These vessels tend to operate in coastal areas throughout the EU; these waters are often important for some marine mammals. These animals use frequencies up to about 180 kHz for communication and thus there is an overlap in frequency usage. There has been little research on the effects of these sonar systems and the scientific evidence for adverse effects is limited. However, the sounds are similar to those used in acoustic alarms (pingers) that are designed to scare away small cetaceans from gill and tangle nets used in the fishery (JRC, 2010) [25].

A study conducted at five sites in the Western Mediterranean Sea region (Strait of Gibraltar, Alboran basin, Balearic basin, and Provençal basin) and the adjacent NE Atlantic region (Azores archipelago) from August 2006 to January 2009 (Castellote et al., 2012) [26] provided evidence that male fin whales from two different subpopulations modify song characteristics under increased background noise conditions, These results show that the measured temporal and spectral features of fin whale 20-Hz song notes from two subpopulations, at both small and large spatial scales, decrease under both types of anthropogenic noise: high shipping noise levels and airgun noise from a seismic survey.

Underwater noise generated by industrial (oil and gas prospecting through seismic surveys) and naval sonar operations, as well as illegal dynamite fishing, all known to be highly disruptive of cetacean behaviour (Weir, 2008), has been a source of concern for causing disturbance to, and even potentially atypical mass strandings of sperm whales in the Mediterranean for at least two decades (Notarbartolo di Sciara and Gordon, 1997).

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A relationship between noise and cetacean reactions has been identified also for ship noise and beaked whales (Aguilar de Soto et al., 2006 [27]; Pirotta et al., 2012 [29]). Finally, based on recent IUCN assessments, several cetacean species are experiencing a decreasing population trend, e.g. the bottlenose dolphin and the sperm whale (Notarbartolo di Sciara et al., 2014 [26]; Bearzi et al., 2012 [29]).

The effect of boat noise was also demonstrated on the behaviour of bluefin tuna Thunnus thynnus in the Egadi Islands (Sarà et al., 2007 [30]). The study showed that local noise pollution generated by boats produced behavioural deviations in tuna schools. Schooling enhances tuna homing accuracy during their spawning migration, and an alteration in schooling behaviour can affect the accuracy of their migration to spawning and feeding grounds. In the absence of boat noise, tuna assumed a concentrated coordinated school structure with unidirectional swimming and without a precise shape. When a car ferry approached, tuna changed swimming direction and increased their vertical movement toward surface or bottom; the school exhibited an unconcentrated structure and uncoordinated swimming behaviour. Hydrofoils appeared to elicit a similar response, but for shorter periods. Agonistic behaviour was more evident when exposed to sounds from outboard motors of small boats.

Nautical traffic has been also recognized as a source of anthropogenic noise for zooplankton in the MPA of Capo Gallo and Isola delle Femmine, (Sicily, Southern Mediterranean, Italy) (Bracciali et al., 2012 [31]). Feeding frequencies, escape reaction and school density of damselfish (Chromis chromis) were studied. C. chromis is the most common and most abundant zooplanktivorous species in the marine coastal ecosystems of the Mediterranean Sea. A significant modification of the daily foraging habits of C. chromis due to boat noise was observed, which was slightly buffered by no-take zones established within the MPA. Greater traffic volume corresponded to lower feeding frequencies. The escape reaction was longer in duration (>1 min) when boat passed nearby, while moored boats did not induce an escape response.

Perez et al. (2000) [32] investigated the effects of the acoustic pollution produced by a heavy maritime traffic (mostly commercial ships, then fishing fleets and pleasure boats) in the Alboran Sea. They used both acoustic (estimating intensities of ship noise and cetaceans sounds on a scale of 0- 5) and visual (recording simultaneously numbers of boats and cetaceans) methods. Visual results demonstrated that cetaceans do not completely avoid passing vessels. However, they found a negative correlation between cetaceans clicks and whistles and ship noise, what can be interpreted either as a response by small cetaceans to shipping noise, or as ship noise masking the analyst’s ability to detect cetaceans sounds. In the two cases, they concluded that cetaceans possibilities to explore their environment through sound production (in the first case by a decrease of their calls) and reception (in the second case by masking of sounds to be received) could be greatly reduced.

3.6.4 Measures

Measures defined at international level

In 2008, the IMO Marine Environment Protection Committee (MEPC) agreed to develop non-mandatory technical guidelines to minimize the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life (Source: IMO Web Site).

In 2014, IMO approved guidelines on reducing underwater noise from commercial shipping, to address adverse impacts on marine life. The document intended to provide general, not mandatory advice to designers, shipbuilders and ship operators for the reduction of underwater noise from commercial shipping, having short term and long-term negative consequences on marine life, especially marine mammals. Given the complexities associated with ship design and construction, the Guidelines focus on primary sources of underwater noise, namely on propellers, hull form, on-board machinery, and various operational and maintenance recommendations such as hull cleaning. Main recommendations suggested are:

- Use computational models to estimate the total predicted noise level and to identify mitigation measure;
- Use standards and references: (i) to measure underwater noise (e.g. ISO/PAS 17208-1, ISO/DIS 16554); (ii) to design new commercial ships, according to international noise specification.
- Adopt design considerations, especially for new ships (propellers and hull design reducing cavitation) and additional technologies for existing ships;
- Select proper onboard machinery along with appropriate vibration control measure
- Enact operational modification and maintenance measures (propeller cleaning, underwater hull surface smoothing, selection of ship speed, re-routing and operational decisions to reduce adverse impacts on marine life.

Much of the underwater noise is caused by propeller cavitation (the formation and implosion of water vapour cavities caused by the decrease and increase in pressure as water moves across a propeller blade - cavitation causes broadband noise and discrete peaks at harmonics of the blade passage frequency in the underwater noise spectrum). On-board machinery and operational modification issues are also relevant.

The Guidelines also include definitions and underwater noise measurement standards. When adopting the Guidelines, it was noted that there were still significant knowledge gaps, and that sound levels in the marine environment and the contribution from various sources was a complex issue, so setting future targets for underwater sound levels emanating from ships was premature and more research was needed, in particular on the measurement and reporting of underwater sound radiating from ships. The Committee invited interested Member Governments to submit proposals to a future session (Source: IMO Web Site).

Particularly Sensitive Sea areas and routeing measures.

The issue of underwater noise and its effects on marine life is also considered through IMO adopted “Particularly Sensitive Sea Areas” (PSSAs). These are areas considered to deserve special protection, due to their recognized ecological or socio-economic or scientific significance, and which may be vulnerable to damage by ships. Ship routeing measures can be proposed for adoption in connection with a PSSA, to protect marine life. IMO has also adopted a series of routeing measures to protect whales and other cetaceans from ship strikes during breeding seasons, by keeping ships away from specified areas. These measures may also have a positive effect in terms of reducing the impacts of underwater noise.

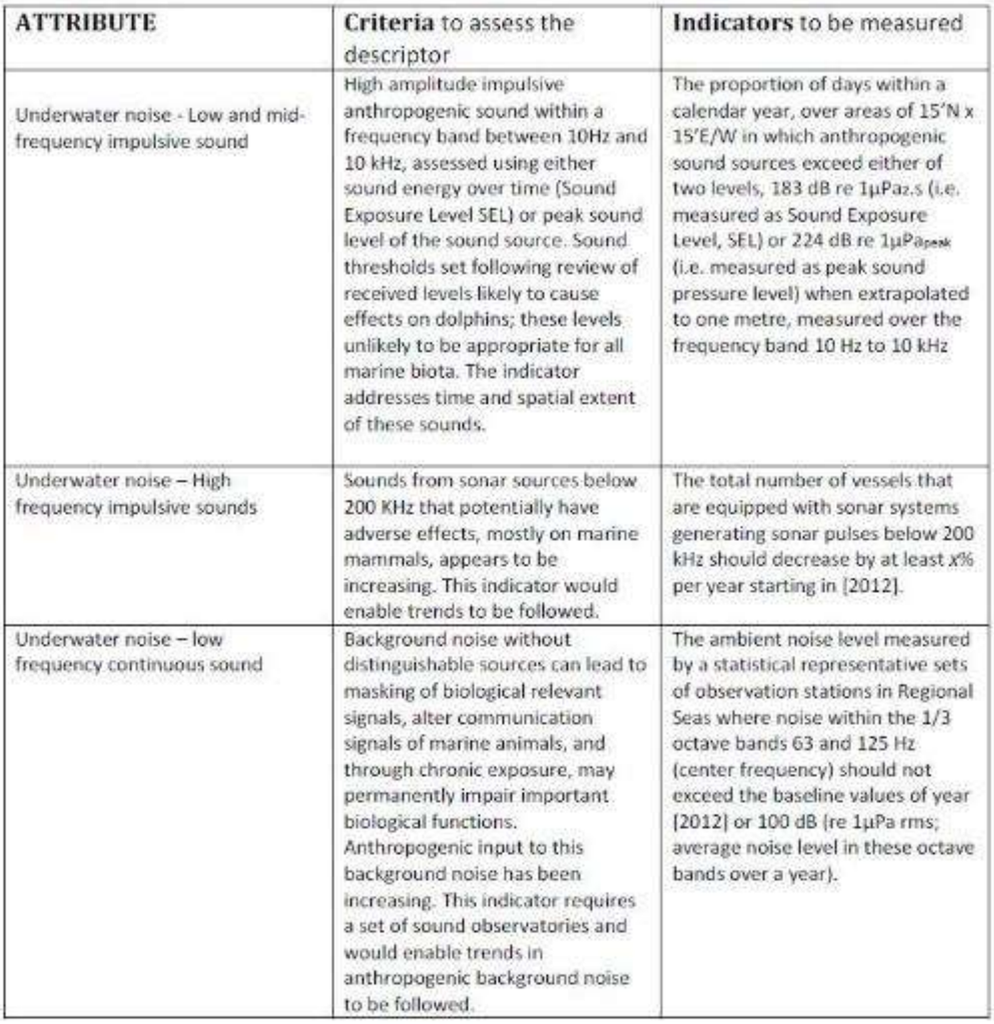
Noise from dredging.

Noise has also been discussed in the context of the work of the London Convention and Protocol on the protection of the marine environment from pollution from dumping of wastes and other matter. Dredging activities – dredged material is the main source of permitted wastes dumped at sea under these treaties - are also a source of anthropogenic noise. The World Dredging Association (WODA) has submitted technical guidance on underwater sound in relation to dredging activities to the London Convention and Protocol Scientific Groups, providing advice to decision-makers, stakeholders and scientists on how to manage impacts of underwater sound, primarily from dredging.

At European level, the introduction of the Marine Strategy Framework Directive (MSFD) (2008/56/EC, EU, 2008) directs European Union Member States "with a view to ensuring a high level of protection of the marine environment, especially species and habitats, environmental impact assessment and screening procedures for projects in the marine environment should take into account the characteristics of those projects with particular regard to the technologies used (for example seismic surveys using active sonars).

With the Directive and the Commission Decision of September 2010 (2010/477/EU, regarding the criteria and methodological standards on Good Environmental Status, GES), underwater noise has been recognized as pollution and included in the qualitative high-level descriptors to achieve GES. To assist MSFD implementation, the Task group 11 addressed "Underwater noise and other forms of energy" and issued its first report in April 2010. Much work has been dedicated to the development of common indicators to be used to monitor underwater noise (Table 32).

Table 32 Indicators proposed in the Task Group 11 Report of April 2010 (JRC, 2010) [25].



ATTRIBUTE	**Criteria** to assess the descriptor	**Indicators** to be measured
Underwater noise - Low and mid-frequency impulsive sound	High amplitude impulsive anthropogenic sound within a frequency band between 10Hz and 10 kHz, assessed using either sound energy over time (Sound Exposure Level SEL) or peak sound level of the sound source. Sound thresholds set following review of received levels likely to cause effects on dolphins; these levels unlikely to be appropriate for all marine biota. The indicator addresses time and spatial extent of these sounds.	The proportion of days within a calendar year, over areas of 15'N x 15'E/W in which anthropogenic sound sources exceed either of two levels, 183 dB re $1\mu Pa_{2.s}$ (i.e. measured as Sound Exposure Level, SEL) or 224 dB re $1\mu Pa_{peak}$ (i.e. measured as peak sound pressure level) when extrapolated to one metre, measured over the frequency band 10 Hz to 10 kHz
Underwater noise – High frequency impulsive sounds	Sounds from sonar sources below 200 KHz that potentially have adverse effects, mostly on marine mammals, appears to be increasing. This indicator would enable trends to be followed.	The total number of vessels that are equipped with sonar systems generating sonar pulses below 200 kHz should decrease by at least *x*% per year starting in [2012].
Underwater noise – low frequency continuous sound	Background noise without distinguishable sources can lead to masking of biological relevant signals, alter communication signals of marine animals, and through chronic exposure, may permanently impair important biological functions. Anthropogenic input to this background noise has been increasing. This indicator requires a set of sound observatories and would enable trends in anthropogenic background noise to be followed.	The ambient noise level measured by a statistical representative sets of observation stations in Regional Seas where noise within the 1/3 octave bands 63 and 125 Hz (center frequency) should not exceed the baseline values of year [2012] or 100 dB (re 1µPa rms; average noise level in these octave bands over a year).

As reported in the Monitoring Guidance of Underwater Noise (Dekeling et al., 2014) [33], Indicator 11.2.1 assessed the issue of marine life chronic exposure to low frequency ambient noise, of which the main contributor is commercial shipping noise. This Indicator requests monitoring of the ambient noise level trend within the 1/3 octave bands 63 Hz and 125 Hz (center frequency; re 1 µPa RMS, the average noise level in these octave bands over a year), measured at different observation stations.

Measures and initiatives defined at Mediterranean level

The Integrated Monitoring and Assessment Program (IMAP), established in the framework of the Barcelona Convention, includes an Ecological Objective (EO11) and 2 Candidate Indicators (CI 26 and 27) related to underwater noise. Even though at this stage the monitoring of this EO it is not mandatory, and most of the data currently available for the region is from other sources (ACCOBAMS, QuietMedII project, see below), the existence of this EO demonstrates the recognized importance of underwater noise as an issue for the Mediterranean ecosystems.

The European project quietMED aims to get better coordination among Member Stas that share marine regions and sub-regions to increase the protection level and the conservation status of the marine spaces of the Mediterranean Sea against the damages caused by underwater noise resulted from anthropogenic activities. The project aims to improve the level of coherence and the comparability as regards Descriptor 11 (underwater noise) by enhancing cooperation among Mediterranean Sea Basin countries within the implementation of the second cycle of the Marine Strategy Framework Directive.

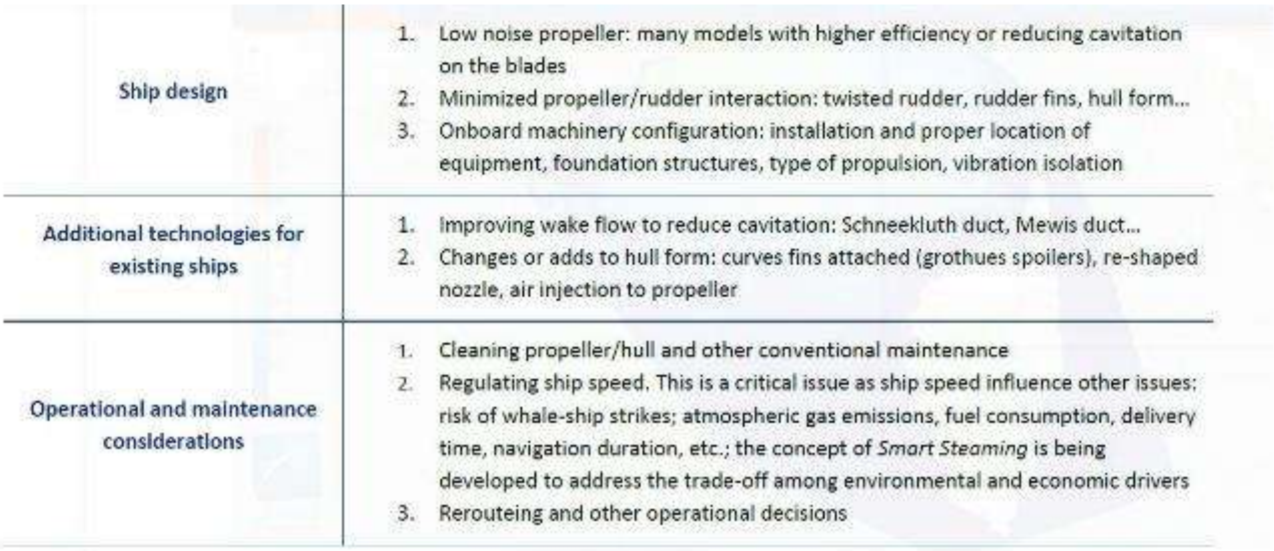
The Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) has addressed the impact of underwater noise on cetacean species through a varied range of actions. On the policy side, Resolution 2.16 (2004), 3.10 (2007), 4.17 (2010), 5.13 (2013) and 6.17 (2016) are juridical tools promoting the adoption and the dissemination of mitigation measures to stakeholders of each Contracting Party. "Resolution 5.13: Conservation of Cuvier's beaked whales in the Mediterranean" and "Resolution 5.15: Addressing the impact of anthropogenic noise" reinforce the commitments made in "Resolution

4.17: Guidelines to Address the Impact of Anthropogenic Noise on Cetaceans in the ACCOBAMS Area“ that urges ACCOBAMS Parties to: “recognize that anthropogenic ocean noise is a form of pollution, caused by the introduction of energy into the marine environment, that can have adverse effects on marine life, ranging from disturbance to injury and death”). This Resolution also encourages ACCOBAMS Parties to: “address fully the issue of anthropogenic noise in the marine environment, including cumulative effects, in the light of the best scientific information available and taking into consideration the applicable legislation of the Parties, particularly as regards the need for thorough environmental impact assessments being undertaken before granting approval to proposed noise-producing activities”.

In 2013 ACCOBAMS prepared a Methodological Guide reviewing practices and existing technologies that should be used during or instead conventional maritime activities producing impulsive underwater noise. The Guide also provide references for those technologies which are very likely to become increasingly used (and market available) in the next future. The major sources of impulsive underwater noise were considered as the following: Seismic surveys (airgun); offshore construction (pile driving); Military Sonar; Use or disposal of explosives. The recent, updated ACCOBAMS Noise Guidelines (ACCOBAMS, 2019) [34] provide further comprehensive detail relating to each of the marine noise producing activities. This third version of the guide addresses both continuous and impulsive noise sources as these are equally concerning with regards to marine life. It is thought to outline practices and technologies that should be used during or instead conventional maritime activities producing underwater noise. References are also included for those technologies which are very likely to become increasingly used (and market available) in the next future.

Regarding shipping the Guidelines suggest shipping noise should be controlled through appropriate management measures.

Table 33 Mitigation tools for shipping (non exhaustive list). Source: ACCOBAMS (2019) [34] (adapted from IMO/MEPC Circ. 883 and Renilson Marine Consulting Pty Ltd 2009).



Ship design	1. Low noise propeller: many models with higher efficiency or reducing cavitation on the blades 2. Minimized propeller/rudder interaction: twisted rudder, rudder fins, hull form... 3. Onboard machinery configuration: installation and proper location of equipment, foundation structures, type of propulsion, vibration isolation
Additional technologies for existing ships	1. Improving wake flow to reduce cavitation: Schneekluth duct, Mewis duct... 2. Changes or adds to hull form: curves fins attached (grothues spoilers), re-shaped nozzle, air injection to propeller
Operational and maintenance considerations	1. Cleaning propeller/hull and other conventional maintenance 2. Regulating ship speed. This is a critical issue as ship speed influence other issues: risk of whale-ship strikes; atmospheric gas emissions, fuel consumption, delivery time, navigation duration, etc.; the concept of *Smart Steaming* is being developed to address the trade-off among environmental and economic drivers 3. Rerouteing and other operational decisions

Further, this guide reviews information on areas where spatial mitigation measures should be applied in the Mediterranean Sea, i.e. areas where activities having an acoustic impact on cetaceans should be avoided.

The ACCOBAMS Resolution 5.13 “Conservation of Cuviers’s Beaked Whales in the Mediterranean” points out that the concept of areas of special concern in which noise would be mitigated should be enhanced and include in mitigation requirements dedicated surveys and monitoring efforts of all potential beaked whale habitats with buffer zones around planned noise activities.

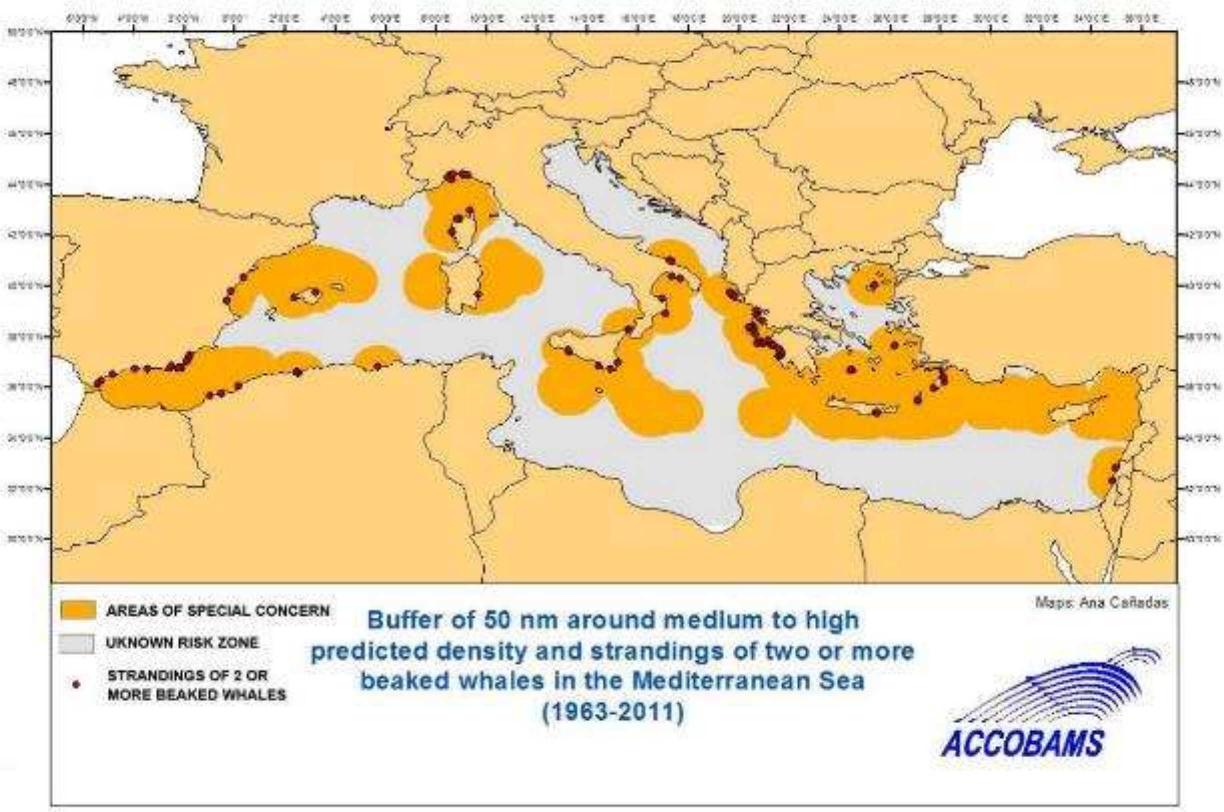


Figure 142 Areas of special concern for Beaked whales. Source: ACCOBAMS.

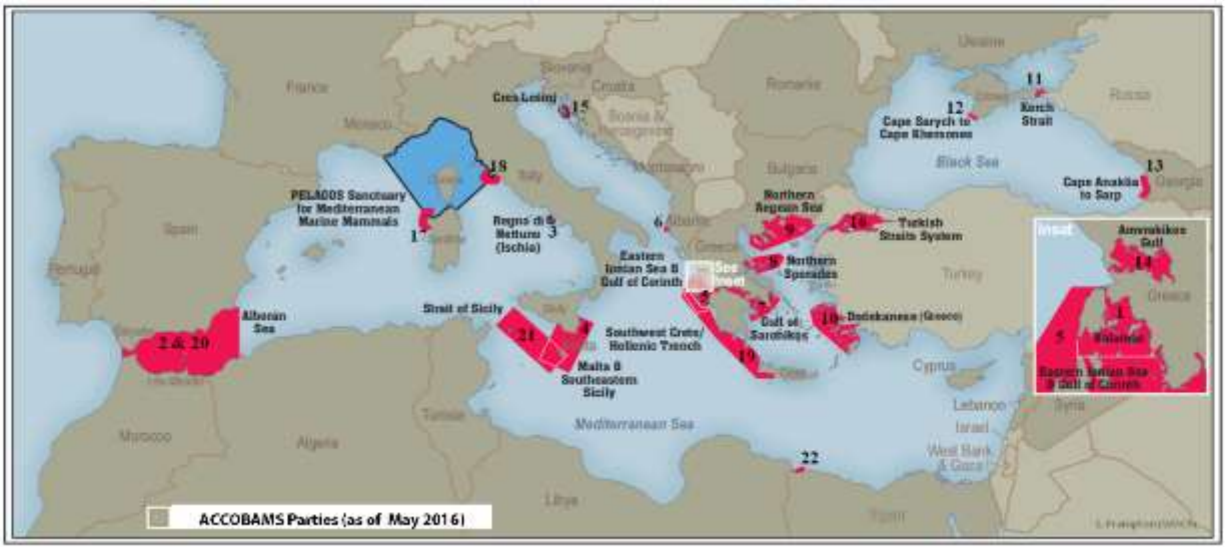


Figure 143 Cetaceans Critical Habitats (red areas) and Pelagos Sanctuary for marine mammals (blue area). Source: ACCOBAMS.

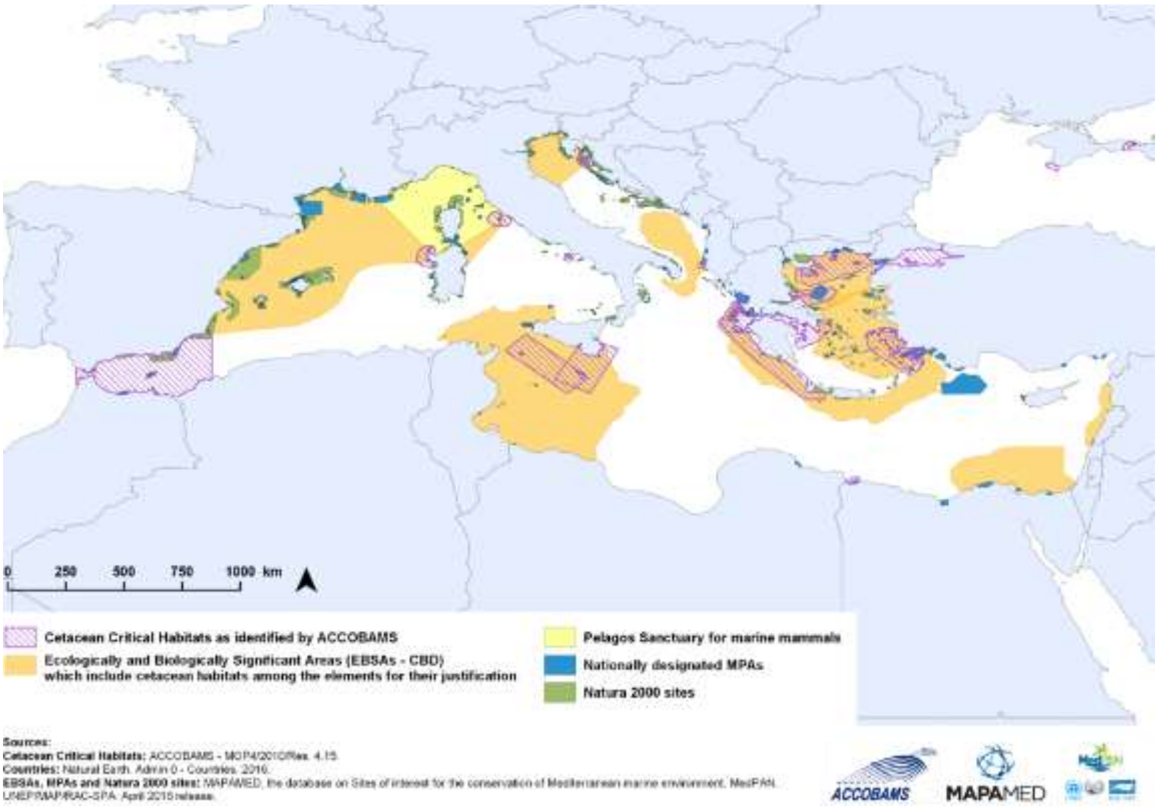


Figure 144 Cetaceans Critical Habitats and other conservation areas relevant for cetaceans. Source: ACCOBAMS.

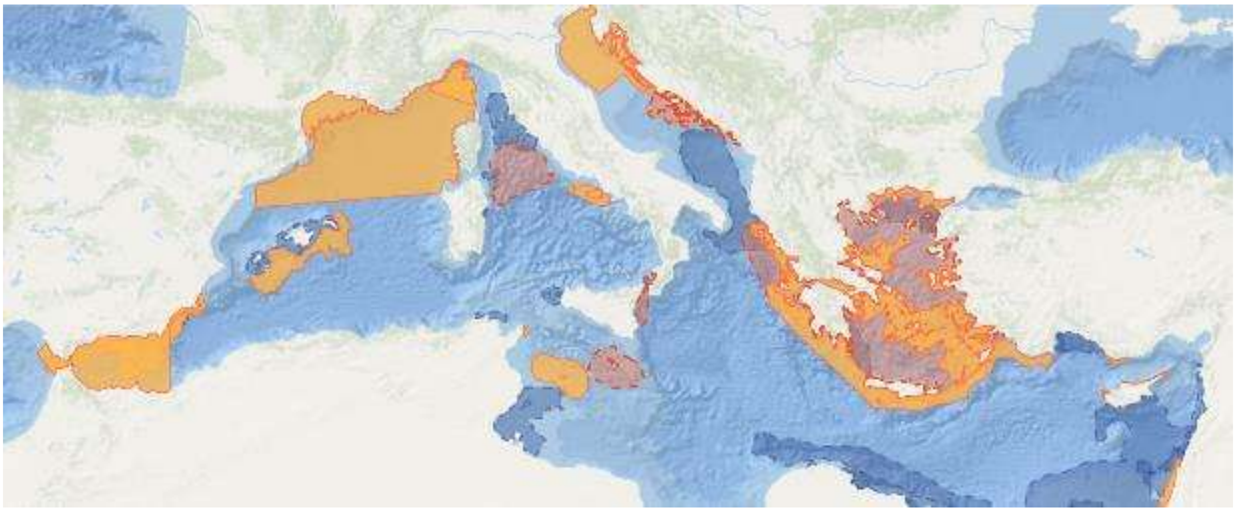


Figure 145 Important Marine Mammals Areas (IMMAs, in orange), Candidate IMMAs (cIMMAs, in red), and Areas of Interest (AOI, in blue). Source: Marine Mammals Protected Areas Task Force www.marinemammalhabitat.org.

ACCOBAMS also proposed establishment of “quite zones” at the 10th Meeting of the ACCOBAMS Scientific Committee, as possible solution to mitigate negative impacts of anthropogenic noise to some of the most sensitive species (Lüber et al, 2015) [35]. In order to ensure functionality of “quite zones”, it was recommended to establish four Specially Protected Areas of Mediterranean Importance under Barcelona Convention (SPAMI), covering critical habitats of the Cuvier’s beaked whale and monk seal in the Mediterranean Sea.

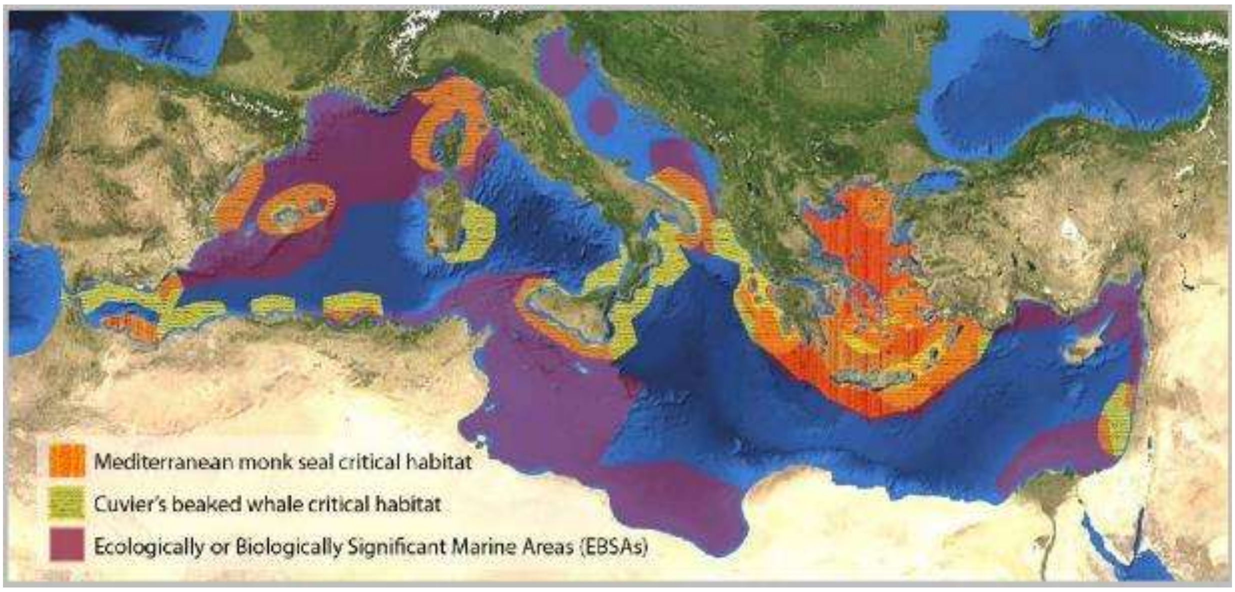


Figure 146 Proposed "quite zones" in the Mediterranean Sea. Source: Lüber et al. (2015)

Finally, ACCOBAMS has also developed a Noise Register for the Mediterranean. This is a database recording data on the temporal and spatial distribution of human activities generating loud impulsive acoustic signals in the low to mid-frequency range. Concerning the implementation of the regional register for the Mediterranean Sea, a Memorandum of Understanding define since 2016 the cooperation between ACCOBAMS and the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean.

In the framework of the Barcelona convention, the Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021) (UNEP(DEPI)/MED IG.22/28) included in the its expected results: to prepare an EcAp Monitoring Programme, and to integrate EcAp in the overall work of UNEP-MAP/Barcelona Convention, the reduction of marine noise from human activities being one of the ecological objectives. The Regional Strategy recognizes that IMO Member States have raised concern over the years that a significant portion of the underwater noise generated by human activity may be related to commercial shipping and the international community recognises that underwater-radiated noise from commercial ships may have both short and long-term negative consequences on marine life, especially marine mammals. Subsequently the Regional Strategy stresses the importance of supporting the implementation of the IMO Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life and invited Member Governments to use the Guidelines.

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4 STATE AND OUTLOOK OF MARINE POLLUTION FROM SHIPS AND OFFSHORE ACTIVITIES IN THE MEDITERRANEAN: KEY MESSAGES AND RECCOMENDATIONS

Maritime traffic and offshore O&G exploration and production are key maritime activities in the Mediterranean. While the Mediterranean, compared to other regions, can be considered a relatively small producer of offshore O&G, it represents a hotspot for maritime traffic. This is due to its strategic position at the interface of three continents, Africa, Asia and Europe, and at the crossroad of three main maritime passages, the Strait of Gibraltar, the Suez Canal and the Strait of Bosporus.

Maritime traffic and offshore O&G activities are important drivers of marine pollution in the basin. The environmental impacts and the risks they generate pose threats to the marine ecosystems and biodiversity, as well as to other maritime and coastal human activities that can be impacted (e.g. mariculture, tourism). These activities generate a variety of different pressures on the marine environment: loss or discharge of solid wastes contributing to marine litter pollution, emissions of gaseous pollutants and particulate into the atmosphere, emissions of continuous and impulsive underwater noise and vibrations, release of oil and other contaminants in the marine waters, introduction of invasive species though ballast water and hull fouling.

These pressures are only a part of the pressures exerted on the Mediterranean Sea. In some cases, important contributions to the same type of pressures determined by maritime traffic are also generated by other activities carried out on land: the general prevalence of land-based sources of marine litter pollution is an example of this. The difficulty in understanding the origin of pollution makes the identification of prevention measures even more challenging, as well as the evaluation of their effectiveness.

Maritime traffic and offshore O&G activities determine a number of impacts on the marine environment, at all organizational levels, from individuals to ecosystems. Impacts have been demonstrated both locally and at more general spatial scale. Oil spills, vessel strikes on endangered cetaceans and sea turtles entangled by fishnets are perhaps the most visible ones but underwater noise, chemical contamination, introduction of alien species and air pollution are also associated with these sectors. Being responsible of different type of pressures, maritime traffic can determine multiple, cumulative impacts: cetaceans are an example of particularly impacted species, though collisions with vessels, plastic ingestion, exposure to underwater noise and water pollution.

Based on the evidences presented in this study there is generally a good correspondence between the intensity of maritime traffic and the different pollution pressures generated. To help identification of hotspots for pressure from maritime traffic, a synthetic representation is provided in Figure 147, showing the distribution of vessel density (2018) and the areas of conservation in place in the Mediterranean. This map updates the one prepared by Randone et al, (2019) [5].

The map shows a significant overlapping between some of the areas with the highest vessel density and some conservation areas. Some relevant examples are provided herein. The Cetacean Critical Habitat (CCH) area identified by ACCOBAMS in the extreme Western Mediterranean intersects with the main shipping corridor used by commercial ships entering or leaving the Strait of Gibraltar. The recently established (2019) Cetacean Migration Corridor identified between the Balearic Islands and the Spanish mainland (provinces of Valencia and Catalonia), and formally approved as Specially Protected Area of Mediterranean Importance (SPAMI), also locates in an area impacted by maritime traffic, especially passenger traffic. The Pelagos Sanctuary for Marine Mammals represents an area where maritime traffic has been identified as of the most relevant pressures (for ship strikes, underwater noise emission, greenhouse gas and other air pollutant emissions). The Sicily corridor is another hotspot of interaction between maritime traffic and conservation areas with two CCH areas and the Central Mediterranean EBSA intersecting the main cross-Mediterranean shipping corridor and also some areas of intense short-distance routes between Sicily, the other Italian islands and archipelagos, and Malta. In the Adriatic Sea, hotspots of maritime traffic overlap with the EBSA in the Northern Adriatic and with the FRA in the Central Adriatic. The most Eastern edge of the Mediterranean represents again a hotspot of interaction with the CCHs of the Bosporus Strait, of the Northern Aegean Sea (in front of the Greek province of Central Macedonia), and of the Eastern Aegean Sea (in front of the Turkish coast). The EBSA in the Southern Levantine Sea, in front of Israel and Egypt is also located in an area of intense maritime traffic.

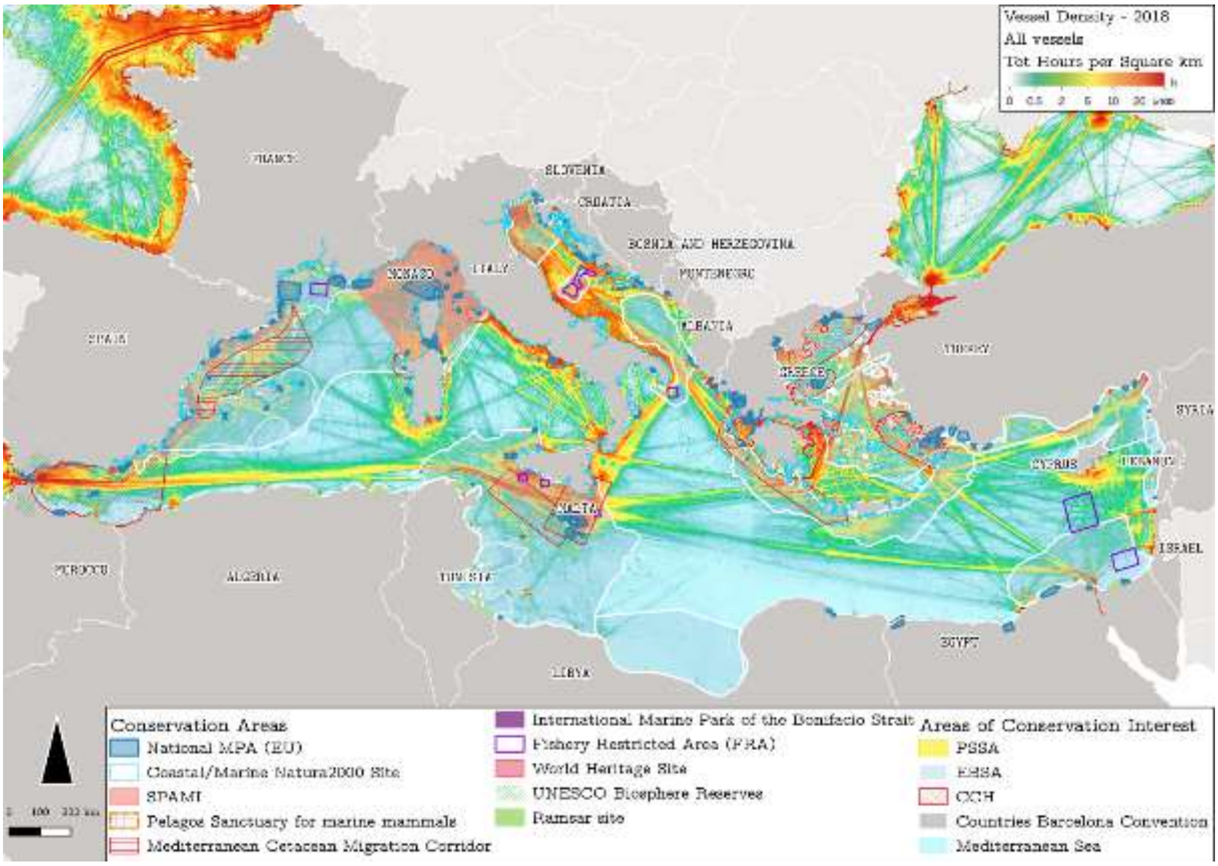


Figure 147. Annual density (2018) of vessels transiting in the Mediterranean. Data sources for vessel density and ports: EMODnet Human Activities portal (data retrieved on 02.06.2020).

Huge efforts towards reduction of pollution from shipping have been made under the International Convention for the Prevention of Pollution from Ships (MARPOL). The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes. The Mediterranean Sea is recognized as Special Area with strict controls under Annex I (pollution by oil) and V (pollution by garbage). Its recognition as Special Area under Annex VI is under evaluation. Many initiatives have been put in place under the Barcelona convention, particularly trough REMPEC, to support and facilitate implementation of international measures for shipping pollution reduction and prevention by the Mediterranean states.

In this report we have compiled knowledge about maritime traffic and offshore O&G activities as drivers of change for marine pollution in the Mediterranean and their impacts on the marine environment, focusing on four main aspects: pollution from oil and chemicals, marine litter, air pollution, non-indigenous species (NIS) and underwater noise. Main facts and figures about drivers, impacts and response measures are given here below in paragraph 4.1.1. The Driver-Pressure-State-Impact-Responses (DPSIR) scheme presented in *Figure 148* provides an extreme synthesis of the study findings.

Being maritime traffic in the Mediterranean a growing sector and offshore O&G activities stable/slightly decreasing, the overall pressure on the marine environment is expected to grow. But, at the same time, targeted policies, technological progress and advances in science and research are offering more and more valuable solutions for improving the situation. Despite few evidences are presently available documenting the effectiveness of the measures in place, some considerations concerning the expected evolution of marine pollution are given in paragraph. Knowledge gaps and recommendations for future actions are identified in paragraph 4.1.3.

4.1.1 Main facts and figures

MARITIME TRAFFIC

The Mediterranean Sea covers less than 1% of the world oceans. However, this sea basin is strategically located at the interface of the three continents of Asia, Europe and Africa and at the crossroads of three maritime corridors. The Mediterranean Sea is one of the busiest seas in the world, harvesting in 2019, 24% of the global fleet of ships calling ports or passing through the Mediterranean, including container ships, gas tankers and oil and chemical tankers representing 36.5%, 32.6%, and 27% of the word fleet, respectively . Moreover, the Mediterranean is the second largest market globally (after Caribbean) for cruising, accounting for 17.3% of worldwide cruises in 2019.

Notwithstanding its limited size, the Mediterranean is significantly affected by both commercial and passenger traffic. More than half of the Mediterranean commercial traffic is internal (about 58%). However, the basin also plays an important role for international merchant shipping, travelling along the Suez-Gibraltar route and entering the basin from the Bosporus Strait, as well as for the Mediterranean seaborne traffic, i.e. ship movements between a port within the Mediterranean and a port outside the basin.

The Western Mediterranean, the Aegean Sea, the Levantine Sea and the Adriatic and Ionian Seas are the busiest areas for maritime traffic. Passenger traffic is quite exclusively concentrated in the northern countries of the Mediterranean basin. Major routes crossing the Mediterranean are dominated by cargo and tanker maritime traffic. Large container ships mostly take the route from east to west Mediterranean to then continue to the Northern European ports, while smaller cargos are directed to Mediterranean ports, which are reached also by trans-shipment. The east-west route and the one coming from the Black Sea are also used to convey oil from production areas (Persian Gulf, Black Sea and Middle East).

In 2019, there were 14,403 ships in the Mediterranean Sea which made about 453,000 port calls. Moreover, activity of vessels passing through the Mediterranean Sea without calling a port in 2019 counted 5,251 vessels with a total dwt of 510 million; these were mainly larger vessels. A little more than 24% of the global fleet of ships called ports or passed through the Mediterranean in 2019. The majority of ships sailing in the Mediterranean have been built the last 15 years, but there is a significant number of old ships. Overall, the fleet sailing in the Mediterranean is younger than the global fleet.

In the period 2010-2019, seaborne trade to and from countries in the Mediterranean has increased by 284 million tonnes. Dry bulks have grown the most in tonnes, while containerized cargos have grown the most in relative terms. Liquid bulks have only grown marginally (3%), while non-containerized general cargo has declined.

Port calls in the Mediterranean increased significantly in the same period (+74.5%). The growth was particular evident for passenger vessels (1.6 times); this might be also due to an improved ability to adequately capture the highly frequent parts of the ferry traffic since 2010. The number of port calls increased strongly for all merchant vessel typologies, with the exception of container ships which show a lower increase between 2010 and 2019 (11.4%) and a decrease since 2016. The average vessel size and related carrying capacity of container ships has significantly increased worldwide over the years and the enlargement of the Suez Canal has allowed larger ships entering the Mediterranean. This have likely contributed to a reduction in port calls but not to a decrease in transported volumes.

Globally, commercial maritime traffic is expected to increase by 3.4% in the period 2019-2024. Mediterranean merchant transport will also grow, driven by two major factors: the quite recent doubling of the Suez Canal and Belt and the 21st Century Maritime Silk Road, part of the Belt and Road Initiative of the Chinese government, aimed at further improving the maritime connection between China and Europe. Both commercial and passenger traffic are expected to increase, including in the first case the strengthening of the already occurring shift towards mega container ships, and in the second the continuous growth of the cruising sector.

Overall, seaborne trade in the Mediterranean is expected to increase also by both scenarios developed by REMPEC (2020) [1]. The first scenario assumes a higher economic growth, a later peak in energy consumption and a slower decline in oil and coal consumption than scenario 2. Both scenarios consider a growth in the Mediterranean seaborne trade. In scenario 1, dry bulk seaborne trade will show the strongest growth in tonnes while containerized trade will grow the fastest. The growth in liquid bulk trade will slow down but will recover towards the end. Under scenario 2, the seaborne trade is expected to grow less: while trade of dry bulks and containers are expected to increase (as in scenario 1), those of general cargo and in particular of liquid bulk would decrease. The total number of port calls is expected to decrease by both scenarios, more consistently in scenario 2 (-20.1% by 2050) than in scenario 1 (-11.2% by 2050). On the contrary, the number of vessels transiting along the Mediterranean without making a port call is projected to increase: +38.2% by 2050 for scenario 1 and +6.8% by 2050 for scenario 2.

OIL AND GAS PRODUCTION

Compared to the other regions, the Mediterranean Sea is a small producer of offshore oil and gas. Extraction is mainly concentrated in four areas: the Levantine basin (mainly for gas), the Channel of Sicily, the Gulf of Gabès and the neighbouring Libyan marine area, and the Northern Adriatic (mainly for gas). Libya and Egypt are the main producers of offshore oil. Egypt is also the main actor for offshore gas production; with the recent discovery of large gas fields in the Levantine basin. Israel has also emerged as an important player in this sector. The majority of known fields concentrate in shallow waters (depth <500 m). Recent discoveries in the Levantine Sea expanded gas offshore extraction to deepwater and even ultra-deep-water.

Contrarily to the development of offshore gas, there have been no major discoveries of offshore oil fields after 2010 and the number of deep water and ultradeep water fields are in general very limited. The historical evolution of offshore oil production shows a variable trend in the period 1980-2019, with a peak in early 1990s and a decrease since. In the same period, offshore gas production has significantly increased.

Offshore exploration has expanded in recent years and novel countries are expected to enter into the market (e.g. Cyprus, Malta, Montenegro and Lebanon). Not all explorations will lead to actual exploitation of fields, as this depends on other economic, regulatory, environmental and geopolitical factors. Offshore oil production is projected to slightly decrease in the Mediterranean, while gas extraction is expected to significantly increase due to the expansion of the sector in the Eastern Mediterranean.

In the Mediterranean Sea, oil is mainly shipped through tankers, while gas is mainly transported through pipelines. New pipelines are planned to improve gas supply to the increasing European market.

A number of old offshore platforms are approaching the end of operational lifetime. Their decommissioning is a challenge to be addressed in the near future, which has also environmental implications. At the end of their productive life, offshore platforms are generally removed completely and disposed of onshore. Alternative options include partial removal, reuse for other purposes (also in a multi-use perspective) and nearby relocation. Decommissioning of offshore platforms is context and site specific and the selection of the preferable option must be based on a multi-criteria analysis.

OIL AND CHEMICAL POLLUTION

Operational pollution from ships is a major source of oil pollution in the Mediterranean region. Up to 1,500-2,000 events of operational oil spill are estimated to occur yearly in the basin. The distribution of oil spills is well correlated with major shipping routes, crossing the Mediterranean from east to west and linking major ports.

Oil spills can seriously affect the marine environment both as a result of physical smothering and toxic effects. The severity of impact depends on the quality and type of oil spill, the ambient conditions (including meteorological ones affecting the dispersion of the spilled substances) and the sensitivity of the affected organisms and their habitats to the oil.

Incidents

Most of the larger oil spills due to shipping accidents occurred in the Mediterranean before 2000. Innovation in shipping construction and improvement in maintenance, operation and routing have reduced the occurrence of these events in the basin and worldwide.

Causalities causing the spill of small quantities of oil and other hazardous substances are still numerous. There is the need to further strengthen monitoring and reporting of incidents, including small ones, to evaluate the evolution their evolution and related impacts on the marine environment.

Most of the maritime incidents occur near the coasts and in particular close to major ports. Mediterranean areas characterised by the higher occurrence of incidents include the Bosporus Strait, the Aegean Sea and the Strait of Gibraltar.

Illicit discharges

While major accidental pollution has drastically decreased, illicit discharges of oil, oil mixture and other HNS from ships remain a problem of concern for the Mediterranean.

Quantitative estimations of spilled volumes due to illicit discharges in the Mediterranean is highly uncertain, due to the lack of systematic data. Kostianoy and Carpenter (2018) suggests 50,000-100,000 tons per year as possible estimation of volume of oil illicitly discharged every year.

Numerous measures are available to contrast oil pollution in the Mediterranean, policy prevention measures are in place under IMO/MARPOL, the Barcelona Convention and EU regulations. Pollution preparedness and response measures are available at national and sub-regional level and are coordinated, promoted and supported by

REMPEC. Many operational tools numerical models, guidelines for response actions, decision support tools are available.

MARINE LITTER

A specific estimation of litter originating from ships in the Mediterranean Sea is not yet available. With an evaluation of inputs from ships at 6 million tons worldwide and 30% of the maritime traffic worldwide occurring in the Mediterranean Sea, it has been estimated a million tons of garbage coming from ships to the Mediterranean.

Site specific data showed quite a range of variation of marine litter source distribution. The highest densities of surface man-made litter were found along the main shipping corridor used by ships entering or leaving the Strait of Gibraltar runs exactly along the Algerian slope.

Despite the scarcity and inconsistency of derelict fishing gear related data, this has been recognized as an issue of major concern in the Mediterranean. Fishing related marine litter has been showed to be predominant in areas characterized by intense fishing activities, such as the western Mediterranean Sea, the Sicily channel and the northern African coasts.

Marine litter trends for the Mediterranean are not clear.

Marine litter impacts organisms at different levels of biological organization and habitats in a number of ways, namely through entanglement in, or ingestion of litter items by individuals, through chemical transfer, as a vector for transport of biota and by altering or modifying assemblages of species e.g. by providing artificial habitats or through smothering.

Measures to prevent marine litter pollution from ships are in place at international level under MARPOL, at European level and at Mediterranean level, under the Barcelona Convention.

AIR POLLUTION

Ship emissions contribute significantly to air pollution in the Mediterranean Basin. Up to 57% of all emissions from international shipping in Europe occur in the Mediterranean Sea. In the Mediterranean Sea, about two thirds of emissions originate from the EU waters where the majority of maritime traffic are concentrated.

Despite in-port ship emissions represent only a small fraction of the global emissions associated with shipping, they can have important environmental effect on coastal regions of the Mediterranean Sea, which often have harbours located near urban and industrial centres.

The health impacts (including premature mortality and cardiovascular and respiratory illness) from long-term exposure to shipping emissions, have been demonstrated for Mediterranean coastal cities.

Measures are in place under MARPOL/IMO. Particularly the establishment of a Mediterranean SOX ECA would result in the following outcomes:

- emissions would be lowered by 78.7% for SOx and 23.7% for PM2.5, when comparing to the IMO sulphur cap (0.5%).
- the potential to avoid 1,000 premature deaths, more than 2,000 cases of childhood asthmas.
- acidification impacts on aquatic systems by wet sulphate and dry sulphate depositions would be reduced by 1.16% and 1.95% respectively, while the maximum percent decreases could reach 14.23% and 48.13% respectively in certain parts of the region.
- a reduction in haze with improved visibility, which would be notably felt over the Straits of Gibraltar and northern Morocco and Algeria, and along the main shipping lane connecting the Straits of Gibraltar, Malta, and towards the Suez.

Some elements supporting the effectiveness of the measures already undertaken area available in terms of decreasing trends in pollutant concentrations in some areas.

NON-INDIGENOUS SPECIES

Over the last two decades, changes in the Mediterranean marine biodiversity related to introduction of NIS have been reported as the consequences of a number of specific activities: intense maritime traffic, opening of artificial channels and aquaculture farming.

In the last decade, the species richness of marine organisms in the Mediterranean Sea has been reported to have reached ~17,000 taxa, among which some 820 can be considered NIS.

Corridors are the most important pathways of new introductions in the Mediterranean, followed by shipping and aquaculture. Vessel-introduced NIS represent the 26% in the Mediterranean and the 80% and 77 % in Baltic and Western European margin, respectively (considering post-1990 widespread NIS) (Galil et al., 2014) [17].

Ships' ballast water is of concern as a vector of introduction of invasive alien species in the Mediterranean Sea because of the large quantities of ballast water coming from different marine environments around the world being discharged at Mediterranean ports.

Despite the moderate number of propagules transported, in comparison with the ballast water vector, biofouling on ships' hulls is a relevant vector for NIS introduction.

Different countries of the Mediterranean show different trend of introduction of NIS, according to the likely vector of introduction. The 46% of NIS has been recorded in the East Mediterranean (SPA/RAC – MAMIAS, 2020) [18].

While NIS introductions still occur, the rate of NIS introductions has been observed decreasing for the first time in the time period 2006-2017 (Galil et al., 2018) [26]. The decreasing trend can be assigned to polices effectiveness as well as to other reasons, such as decreasing pool of potential NIS species, variations in sampling effort or available expertise.

Impacts of NIS in the Mediterranean are recognized and include also impacts on human health and to human activities. However, the overall ecological impact of NIS on the Mediterranean Sea remains relatively difficult to quantify, and is mainly qualitative. At European level, the majority of the recognized marine invasive species (72%) have both positive and negative impacts on the native biota. Few have only positive effects (8%), while more (~20%) have only negative effects on the host environment.

Mitigation measures are in place at international level under IMO/MARPOL and at Mediterranean level, under the Barcelona Convention.

UNDERWATER NOISE

Background noise levels in the Mediterranean are higher than in any other ocean basin with ship noise and seismic surveys being among the primary sources of noise. Within the Mediterranean, the Adriatic Sea, and especially its northern part, is characterized by high levels of underwater noise. The primary cause of anthropogenic noise in the Adriatic Sea is maritime transport.

Correlation has been found in many Mediterranean ports and coastal areas between underwater noise and maritime traffic, including passenger traffic (ferries) and leisure boating.

Some significant noise hotspots overlap with protected areas and/or with areas that are of particular importance to cetaceans.

Anthropogenic underwater sound can have various impacts on marine species, ranging from exposures causing no adverse impacts, to behavioural disturbances, to loss of hearing, to mortality. Potential effects depend on various factors, including overlap in space and time with the organism and sound source, duration, nature and frequency content of the sound, received level (sound level at the animal), and context of exposure (i.e., animals may be more sensitive to sound during critical times, like feeding, breeding/spawning/nesting, or nursing/rearing young). Several cases of impacts were documented for the Mediterranean.

Mitigation measures are in place under IMO, at European level and at regional level under ACCOBAMS.

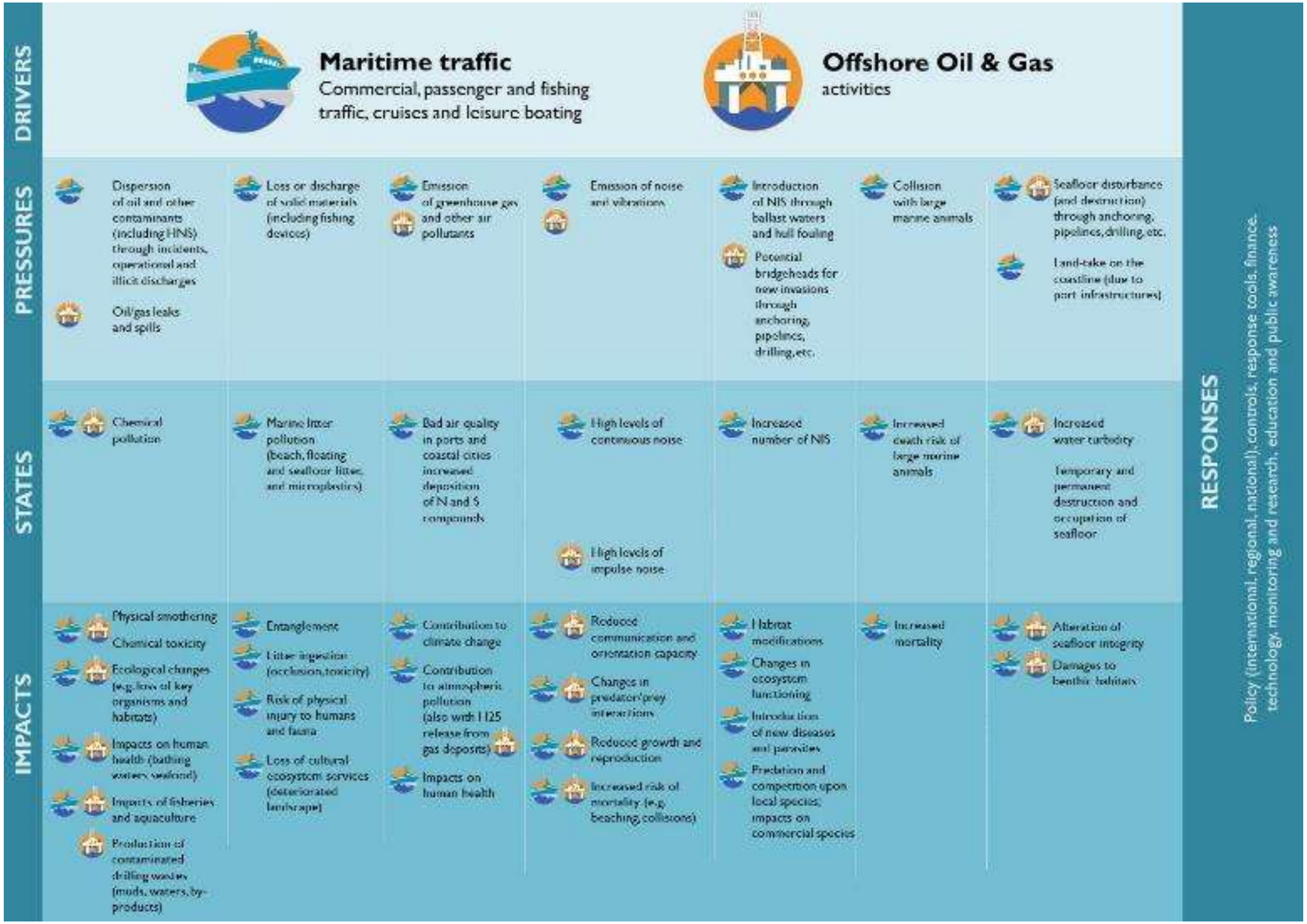


Figure 148. Driver-Pressure-State-Impact-Response (DPSIR) scheme for maritime traffic and O&G activities in the Mediterranean.

4.1.2 Outlook

Globally, commercial maritime traffic is expected to increase by 3.4% in the period 2019-2024, driven by international trading and the globalisation process. Mediterranean merchant transport will also grow, driven by two major factors: the quite recent doubling of the Suez Canal and the 21st Century Maritime Silk Road, part of the Belt and Road Initiative of the Chinese government, aimed at further improving the maritime connection between China and Europe.

Both commercial and passenger traffic are expected to increase in the Mediterranean, including in the first case the strengthening of the already occurring shift towards mega container ships, and in the second the continuous growth of the cruising sector. 2019-2050 scenarios project an initial increase of seaborne trade of crude oil and petroleum products and a decrease after the peak (2025-2030, depending on the considered scenario) .

However, future projections of maritime traffic evolution are highly uncertain, being affected by a wide range of geo-political factors, trading policies and socio-economic crisis. The recent and rapid spread of COVID-19 has demonstrated the vulnerability of the sector. Such crisis has significantly affected global shipping markets, decreasing the demand for goods from China, with ripple effects on any maritime transport, from container ships to oil tankers.

Offshore oil production is projected to slightly decrease in the Mediterranean, while offshore gas extraction is expected to significantly increase due to the expansion of the sector in the Levantine basin, involving also deep and ultradeep waters. The eastern Mediterranean resources are only partially exploited (by Egypt and Israel), and will likely attract the other countries of the region.

Regarding oil and chemical pollution, a sharp decreasing trend in major incidents has been documented in the last decades worldwide and in the Mediterranean as well. It can be concluded that the impact of the international regulatory framework adopted through the IMO as well as technical cooperation activities undertaken at regional level is very positive, especially as far as prevention of accidental pollution is concerned (UNEP(DEPI)/MED IG.23/23). It is reasonable to expect that this situation will stabilize, if not improve further, in the future and an even lower occurrence of large oil spills due to incidents can be expected.

Instead, numerous incidents of minor dimension are still reported, particularly in the vicinity of ports. In a scenario of increased maritime traffic, a decrease in occurrence of such events is improbable, even with growing attention to safety procedures. But improved preparedness and availability of operative intervention measures are expected to contribute reducing impacts, both in magnitude and in spatial extension. Regarding illicit discharges, improved surveillance and rapidity of sanctions would help reducing this practice. While enhanced effectiveness and rapidity of detection can be assumed for the future, also thanks to on-going research and innovation (e.g. on the use of satellites), it is not possible to say whether the sanction systems would evolve and if it would yield a better prevention of pollution.

As documented in this study, identification of sources for marine litter is a difficult topic, being possible to attribute the same type of litter to different sources (sea-based and land-based). Quantification of the shipping contribution to marine litter pollution is not an easy task and this makes the assessment of effectiveness of prevention measures even more complicated. The recently adopted (2018) IMO Action Plan addressing marine plastic litter from ships aims, *inter alia*, at improving availability and adequacy of port reception facilities, at facilitating the delivery of retrieved fishing gear to shore facilities, and at considering the establishment of a compulsory mechanism to declare loss of containers at sea. The implementation of the Action Plan is supported by various initiatives, including the GloLitter Partnerships Project, aiming to prevent and reduce marine plastic litter from shipping and fisheries. In addition, it is expected that the many available pilot experiences of fishing for litter would result in improved availability of port facilities across the Mediterranean, improved national legislations and resolution of present bureaucratic obstacles related to the collection of waste in ports. Based on the existence of these measures, recently put in place, one can expect the quantity of waste discharged from shipping and fishing activities would be reduced in the next future and this pollution pressure on the Mediterranean marine environment will decrease.

Gaseous and particle emissions from shipping are expected to growth, at least in the short term, with increased maritime traffic in the Mediterranean. Regarding GHG, on the medium/long term, the effect of the implementation of the recent (2018) IMO Strategy for GHG Emissions from Ships is expected to become tangible. Aim of the Strategy is to achieve a yearly reduction of CO_2 emissions from shipping at global level of 40% by 2030 and an overall GHG reduction of emissions of 50% by 2050. This will sum up with the efforts at European level, in the framework of the 2019 European Green Deal, including measures the maritime transport sector's contribution to the fight against climate change.

From the 1st of January 2020, the IMO Global Sulphur Cap has come to its full extent (with a sulphur content of fuel permitted outside the Emission Control Areas of 0.5%). MARPOL VI standards are expected to reduce SO_x emissions by approximately 75% from typical operations using residual fuels. In addition, the possible designation of the Mediterranean Sea as an Emission Control Area for sulphur oxides (Med SO_x ECA, sulphur content of fuel

0.1%) has been estimated to be able to lower the emissions in the Mediterranean by additional 78.7% for SO_x and 23.7% for PM2.5, when comparing to the implementation of the IMO Sulphur Cap. Thanks to these measures one can expect the emissions from the shipping sector in the Mediterranean will be reduced in the medium/long term. This would not completely prevent critical situations of air pollution to still occur in main ports, representing hotspots for traffic concentration.

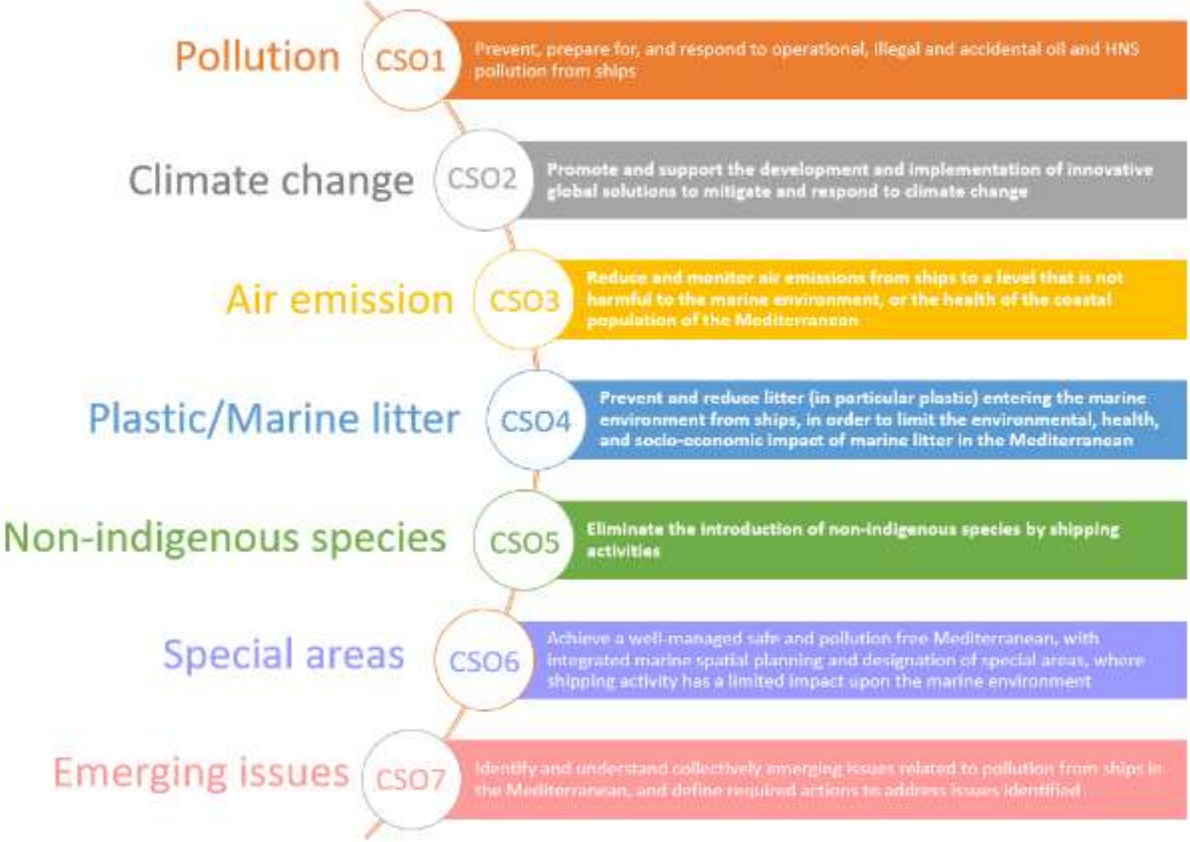
An increasing trend of NIS introduction has been observed in the Mediterranean for a century with decreasing incremental introductions since 2006-2017. This can be can be ascribed to the effective implementation of policies (including the Mediterranean Strategy on Ships' Ballast Water Management, 2012) as well as to other reasons, such as decreasing pool of potential NIS species or variations in sampling effort or available expertise. Given corridors represent the main vector for NIS introduction in the Mediterranean, followed by vessels, it is not possible to estimate whether and when the implementation of measures preventing NIS introduction by ships would result in tangible results at regional scale.

Despite the availability of locally collected data, integrated knowledge on underwater noise at Mediterranean regional scale is still limited, when considering measured levels and impacts. Instead, main sources of noise emissions in the region have been recently mapped. Measures in place under IMO and ACCOBAMS will contribute to limit underwater noise emissions in the future. Research and technology development provide several technical solutions to minimize noise emission from ships: these include ship concept and power requirements, deduction of propeller noise and reduction of machinery noise, as well as measures that can be taken at operational and ship traffic control level. Based on the presently available data it is not possible to estimate a future evolution for noise levels in the Mediterranean. The implementation of the full portfolio of policy and innovative technological measures could decrease underwater noise impacts, while the expected increase in the Mediterranean maritime traffic is expected to increase the pressure.

4.1.3 Gaps and recommendations

Based on the evidences presented in the study, some knowledge gaps and actions gaps, and related recommendations can be identified.

The recommended actions fit into the framework of the Draft Mediterranean Strategy for the Prevention of, and Response to Marine Pollution from Ships (2022-2031) which is still under review. The Strategy identifies seven Common Strategic Objectives (CSO) (Figure 149).



Prevent, prepare for, and respond to operational, illegal and accidental oil and HNS pollution from ships

Promote and support the development and implementation of innovative global solutions to mitigate and respond to climate change

Reduce and monitor air emissions from ships to a level that is not harmful to the marine environment, or the health of the coastal population of the Mediterranean

Prevent and reduce litter (in particular plastic) entering the marine environment from ships, in order to limit the environmental, health, and socio-economic impact of marine litter in the Mediterranean

Eliminate the introduction of non-indigenous species by shipping activities

Achieve a well-managed safe and pollution free Mediterranean, with integrated marine spatial planning and designation of special areas, where shipping activity has a limited impact upon the marine environment

Identify and understand collectively emerging issues related to pollution from ships in the Mediterranean, and define required actions to address issues identified

Figure 149. Common Strategic Objectives (CSO) of the Draft Mediterranean Strategy for the Prevention of, and Response to Marine Pollution from Ships (2022-2031)

Knowledge gaps and recommendations:

Integrated maritime data with a specific focus on the Mediterranean Sea remains scarce. Economic and shipping data (such as UNCTAD data or Eurostat data and other databases and data analysis) often do not consider the Mediterranean as a whole. In most cases, Mediterranean coastal States are distributed among different geographical groups (Europe; Africa; Middle East) or are classified in groups according to their level of economic development.

> → Actions are recommended to ensure to the Barcelona Convention system integrated data availability on maritime traffic in the Mediterranean basin

Little information is available on the impact of pollution events caused by shipping on biota and habitat. This is due to the fact that ship generated pollution impact is usually considered from a response perspective (protection of sensitive areas and facilities) and there is no obligation for countries to carry out environmental surveys of sea and shorelines affected by a spill (UNEP(DEPI)/MED IG.23/23).

> → Further strengthen of monitoring and reporting of incidents, including small ones, is needed in order to evaluate their evolution and the related impacts on the marine environment.

> → Environmental surveys of sea and shorelines affected by a spill should be carried out to evaluate impacts from acute pollution events. There is the need to define conditions when monitoring of post-spill impacts should be carried out (e.g. spatial extent of the pollution and volumes discharged).

Surveillance, monitoring and reporting of illicit discharges remain a critical gap. As these are illegal operations by nature (when not within the limits set by MARPOL), it is extremely difficult to get information on occurrences and extent of spills. Marine surveillance requires aerial means and equipment (planes, airborne radars and sampling sets) or special technology such as the use of satellite images. There is no regionally centralised system for surveying the Mediterranean waters as defined in the Barcelona Convention. The CleanSeaNet platform, the European satellite-based oil spill monitoring and vessel detection service, is a good resource, but only available in principle to countries that are Members States of the European Union (UNEP(DEPI)/MED IG.23/23).

> → In addition to surveillance by aircraft and patrol boats, cooperation and exchange of information on satellite surveillance should be enhanced for improving the detection of illicit discharges in the entire Mediterranean region. In fact, there has been consistent progress on the use of satellite images for the detection of oil spills. Innovation needs to be operationalised in a service covering the entire Mediterranean.

Comprehensive/integrated regional knowledge about some key shipping related pollution factors – namely air pollution trends (e.g. in the Mediterranean ports), marine litter pollution and underwater noise level – is missing.

> → Full implementation of IMAP and related reporting is needed. Integration with data regarding air pollution could be considered. In parallel, preparation of studies compiling and integrating existing data (from sources other than IMAP) at regional scale is recommended.

Understanding of the contribution of shipping and offshore O&G activities to marine litter pollution is limited and not comprehensive at regional scale.

> → Monitoring strategies should be encouraged at regional level based on harmonized and standardized monitoring and assessment methods, thus contributing to the global process through the IMO Action Plan to address marine plastic litter from ships. More specifically, Contracting Parties to the Barcelona Convention and relevant international or regional organizations that have conducted any scientific research related to marine litter in the Mediterranean are encouraged:
> - to share the results of such research, including any information on the areas contaminated by marine litter from ships in the Mediterranean;
> - to contribute to the IMO study on marine plastic litter, including macro and microplastics, from all ships; and
> - to undertake studies to better understand microplastics from ships in the Mediterranean.

Regular, dedicated NIS monitoring and quantitative estimation of their impacts are missing.

> → A stronger base for quantitative estimation of the impacts from NIS should be provided, also through experiments or ecological modelling; regular dedicated monitoring and long-time series to provide information on trends should be ensured; NIS identification capacity should be strengthened, also by the use of molecular

approaches including bar-coding, besides traditional species identification. These recommendations are included in the decision UNEP(DEPI)/MED IG.23/23 and are confirmed by the results of this study.

→ There is a need for better coordination at national and sub-regional level on NIS monitoring.

Few information is available about pressures and impacts exerted by offshore installations and activities on the marine environment. Comprehensive, regional knowledge is missing.

→ Monitoring procedures and programme for offshore installations and activities should be set up in the framework of the Med Offshore Action Plan (under Specific Objective 9). Any CI of the IMAP system should be integrated/updated as required.

Action gaps and recommendations:

Additional measures to minimize operational pollution and to combat illicit discharges are needed.

→ In addition to existing operations (e.g. Oscarmed, supported by RAMOGE) controls of the oil registers of ships by the port authorities would limit their number and would encourage the use of reception facilities.

Due to continuous growing of vessel size (container and cruise ships) response capacity need to be adjusted.

→ Strengthening response capacity to incidents involving large container vessels or cruise ships is recommended for example through improving the characteristics of offshore tugs.

Implementation of national IMAPs is still partial and limited.

→ UNEP/MAP IMAP Ecosystem Approach and the IMAP monitoring and assessment conducted as part of it are aimed to enable informed decision making and to help identify further actions and measures needed to achieve the Good Environmental Status of the Mediterranean. Some of the IMAP Ecological Objectives and Common Indicators (EO2 - CI 6, EO3 - CI 19, EO10 - CI 22 and 23, EO11 – Candidate indicators 26 and 27) are specific for the scope of this study and can be considered as operative measures to combat marine pollution from shipping and O&G activities. Therefore, we can conclude there is the need to enforce the implementation of national IMAPs to ensure better monitoring and future assessment of the issues identified in the report.

Despite the effort of the Secretariat to facilitate reporting obligation, the majority of the 22 Contracting Parties, with few exceptions of four (4), are still in non-compliance with their reporting obligation under Article 9 of the 2002 Prevention Protocol. A similar observation can be made with regard to the reporting obligation defined by IMO Circular MEPC/Circ.318. This has an impact on the monitoring of the CI19 and on the assessment of the progress made regarding EO9.

→ The Compliance Committee under the Barcelona Convention and its Protocols, recommended through Decision IG.24/1:

- to foster the collection of data on pollution incidents through a user friendly and simple online system.
- to encourage Contracting Parties to report pollution incidents under the online Barcelona Convention Reporting System (BCRS).
- to support the Secretariat in carrying out (at international and regional level) a comparative exercise between already existing reporting procedures and formats.

The comparative analysis of reporting obligations on marine pollution from ships, due by the Mediterranean countries highlighted opportunities to minimize overlapping, improve coherence among different reporting systems and fill some reporting gaps.

→ Overlapping in reporting obligations on marine pollution from ships should be minimized, coherence in reporting system improved and reporting gaps filled. This particularly applies to reporting of shipping incidents which may result in a discharge of oil or hazardous and noxious substances; reporting on dumping; reporting on accidental loss or discharge of fishing gears.