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Mediterranean Sea and Coasts – Transboundary Diagnostic Analysis

TDA 2023

Pollution & Ecosystems

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Executive Summary

This GEF TDA Report update 2023 provides an opportunity to revise and update the science related to pollution issues and ecosystems concerns in the Mediterranean LME since its last edition in 2005. This new Mediterranean Sea TDA was undertaken by applying the global GEF TDA/SAP methodology (October 2020)1 and by adapting the TDA report outline and content to the environmental and multiculturality characteristics present in the Mediterranean LME. The GEF TDA report chapters are detailed in the description of the chapters below.

The CHAPTER 1: Introduction, firstly, highlights the importance of the international scope of the TDA reports under the GEF International Waters (IW) Focal area since its origin and initial developments within the world Large Marine Ecosystems (LMEs) framework, as well as describing the two-step IW GEF reporting process (GEF TDA/SAP methodology) until the latest updates and tools provided by IW:LEARN. The Mediterranean Sea environmental concerns with the current execution of the GEF MedProgramme (2020-2025) and recent UNEP/MAP achievements are mentioned to introduce the particularities and demands of this multicultural region where riparian countries under the UN Barcelona Convention cooperate for over 40 years. Finally, the alignment with the UNEP/MAP (Mediterranean Action Plan) current activities and mid-term strategic program is considered to place the TDA update report in the current framework regarding environmental policy in the region.

CHAPTER 2: TDA Approach describes both the building of the structure of the report and the collaborative process undertaken with multinational stakeholders, including the partner countries participating in the Child Project 1.1., to deliver an innovative and coherent TDA update. In first place, the approach for: the overall methodology, identification of priorities, causal chain analysis (CCA) exercises, thematic assessments, stakeholder analysis, governance analysis, scenario analysis, and for an indicator based TDA/SAP implementation, as well as the findings for the SAP. The approach for each is justified by explaining the differences with the TDA 2005 version and the adaptation needs through conceptualizing and enlarging the ecosystem concepts used in the earlier version to interlink them with the current implemented Ecosystem Approach (EcAp) in the Mediterranean Sea. For example, using the word ‘ecosystem’ (e.g., marine ecosystem) through the text instead of the simple use of ‘water quality’ as a concept, such as in 2005, to diagnose and analyze the situation of the coastal and marine (water) systems in the Mediterranean LME. Similarly, describing fisheries as a part of the whole biodiversity loss concerns, along other habitats and species within recent years have been impacted at transboundary level (i.e., benthic habitats degradation, Pinna nobilis mortality events); and therefore, towards a more holistic approach of the marine ecosystem as it is now required given the larger growing complexity of environmental problems.

It is worth to mention here that pollution (e.g., chemicals) still the focus of the Mediterranean TDA reports within the coastal and marine systems (e.g., ecosystems) under MEDPOL/UNEP/MAP, and later on, with a transversal analysis of the problems, impacts and causes, including relationships with other transboundary concerns (e.g., seawater aquifer intrusions) are also considered aiming at the TDA report

[1] https://iwlearn.net/resolveuid/2cc6db95-cc24-46e6-8f18-8c894c156a27

integration. Further, the intense coordination work over the two years together with CP1.1. Component 2, GEF MedProgramme and partner countries and other different national stakeholders (involved through the participation in the organized national TDA Stakeholder Workshops) are described in this Chapter. Five out of nine country partners were engaged through UNEP/GEF legal instruments, namely Small-Scale Funding Agreements (SSFA): Albania, Bosnia and Herzegovina, Lebanon, Montenegro and Morocco, to deliver National TDA thematic assessments (composed of 6 synthesis reports), whilst updating on environmental sciences-policies (i.e., environmental law) achievements, as well as provide their particular transboundary perspectives of environmental Mediterranean (either transboundary or shared concerns).

The updates on the Mediterranean Sea region can be found in CHAPTER 3: Baseline information on the Mediterranean, with the known and new scientific insights regarding the LME functioning, environmental and socioeconomic changes at regional level. The Chapter is based in the classical description structure of environmental and socioeconomic terms of the Mediterranean basin, namely, geographical scope (of the basin and sub basins), environmental characteristics (with clear references to the water systems under concern), climatic features (related to climate change observed variabilities), and natural resources (with reference to natural resources both renewable and non-renewable), whilst focusing on socio-economy. The socioeconomic update and facts on selected well-known sectors in transition and blue economy sectors in expansion in the Mediterranean Sea are presented (i.e., tourism, fisheries, aquaculture, maritime transport, energy, marine mining, water abstraction, wastewater technologies, maritime infrastructures, and coastal development).

With regard the Mediterranean LME characteristics the subsection in Chapter 3 aimed to consider the relevant water systems and related ecosystems and processes involved. In this way, the subsection enumerates the hydrological cycle and their water related fluxes: the watersheds and catchment areas (with mainly focus on rivers and lakes in the coastal area), the role of the forest, groundwaters (coastal aquifers), marine and coastal wetlands, marine ecosystems, and the atmosphere. Regarding Natural resources these are explained in terms of renewable and non-renewable resources, coastal and marine resources, offshore energy production, and ecosystem services. Regarding to Climatic features, two indicators temperature and precipitation are described within the well-known Mediterranean climate, as recent investigations and evidence allow to refine the earlier knowledge. However, readers are pointed to the recent and first MAR1 Report from MedEEC that was published in 2020 and contained information on climate change aligned with the IPCC. It is worth to mention here for the latter, that the socioeconomic update has been limited majorly for the issues during the period 2019 until 2022, and therefore, the beginning and end of the COVID-19 pandemics, thus reflecting on the global and regional effects and measures taken. The socioeconomic update was done in collaboration with Plan Bleu who published the SOED 2020 Report containing the diagnostic and trends in the Mediterranean region up to 2019 before the pandemics. To this regard, the new data after COVID-19, clearly shows both breakpoints and step changes in time trends, however, its effects are treated as a one-off event regarding the changes and challenges ahead. The content of this Chapter is majorly detailed and used in the report as a basis to develop the CCA methodology in Chapter 4.

The core chapter of the TDA Report is the CHAPTER 4: LME Transboundary changes and challenges. The changes (environmental problems and impacts) and challenges (socioeconomic transformations, including research and technology) known at a transboundary level in the region were initially listed and provided as a starting point for the update and coordination of the TDA update work, and aligned with the existing known UNEP/MAP activities and strategies, the nature of the GEF MedProgramme, and other regional organizations programmes of work in the Mediterranean region (e.g., GFCM, UNESCO-IHP, GWP-Med, etc.) dealing with transboundary environmental problems at present, as well as the revision of the concerns identified in the previous TDA 2005 version.

Chapter 4 approach then, operated based on initially 'a priori' transboundary known problems (environmental changes and issues) and social and economic context (challenges) gathered from an initial knowledge pooling phase (see Table 1) classified as, 4.1. Reversing pollution, 4.2. Stopping litter, 4.3. Enhancing nature, 4.4. Fighting climate, 4.5. Sustaining assets, 4.6 Switching livelihoods, 4.7. Integrating knowledge, 4.8. Boosting digitalization, and 4.9. Long-term LME regulation. Later on, 'a posteriori' judgement on the highlighted and relevant issues was undertaken (see Section 5), through expert discussions, national TDA workshops and considering the current regional agendas and perspectives of many other countries and stakeholders. These were developed and updated with the support of a team of international consultants (ca. experts on pollution, biodiversity and fisheries and climate change) and a number of contracting parties (ca. CP1.1. Partner countries) from the Adriatic Sea (Bosnia and Hercegovina, Montenegro and Albania), the Eastern Mediterranean (Lebanon) and the southern part of the Mediterranean (Morocco, Algeria, Tunisia, Libya and Egypt) through developing national TDA perspectives reports. Further, within the UNEP/MAP system, the Secretariat EcAP-QSR Unit, SPA/RAC and Plan Bleu RAC were also supporting the TDA Process under CP1.1., led by MEDPOL/UNEP/MAP. Further, after an initial study on the prioritization of the transboundary long-term LME regulation undertaken by Plan Bleu from an exosystemic point of view, the initial suggested transboundary changes and challenges were worked out by the lead and regional consultants through joint CCA sessions to develop the Causal Chain Analysis (see Section 4). As a result, the subsections in Chapter 4 depict the transboundary environmental problems and their impacts along the elucidation of their causes through the Causal Chain Analysis (CCA), including diagrams; and therefore, with the purpose to analyze the transboundary/shared environmental impacts and diagnose both the immediate, underlying, and root causes for each issue, as well as the socio-economic and environmental consequences.

An overview on gender equality related to the environment can be found in a specific chapter entitled CHAPTER 5: Gender Assessment. The regional data obtained from high level UN Women programmes and standards was attempted to be complemented with newer national statistics or case studies from the partner countries with low success. The gender data to monitor progress regarding gender equality in relation to the environment and its socioeconomic links is not available nor exists despite gender policies are considered beyond TDA activities. For this reason, the requirements from GEF in terms of gender indicators have been difficult to fulfill. Some information is presented, including case studies through reports recently published by FAO on gender in the Mediterranean region.

The next two chapters within the report, CHAPTER 6: Stakeholder Analysis and CHAPTER 7: Governance Analysis, to illustrate the present-day public national and regional governance and current strategies in the Mediterranean Sea LME for assessment, protection, and conservation, including the UNEP/MAP system with its Regional Activity Centers (RACs). Further, the type of associated regional and sub regional organizations supporting, promoting and executing the programmes and policies at all levels in the region are also mentioned.

The CHAPTER 8: Scenario Analysis presents the approach in the Mediterranean region and within the UNEP/MAP context with a few descriptive examples of the potential near future concerns in the Mediterranean LME by showing some scientific opinions on both natural and related to ecosystem services consequences of transboundary concern. Within the UNEP/MAP system, the scenario analysis and foresight is a process lead by Plan Bleu, as it was in the TDA 2005, and currently under its Med2050 framework, which offered the introduction to this Chapter. Though, there are no direct references to the future climate change concerns in the Mediterranean region and readers are redirected to consult the recent and first MAR1 report (MedECC, 2020) which depicts the future scenarios to this regard.

With reference to the growing ecosystem indicator-based management (and integrated) approaches CHAPTER 9: TDA and SAP indicators (linked to SDGs) describes some of the existing frameworks at regional level (i.e., of transboundary concern, MSCD), and linked the Global SDGs. Discussion is provided with regard the future gaps and challenges for the effective implementation of indicator frameworks in the Mediterranean LME linked to the GEF TDA/SAP global methodology.

Finally, CHAPTER 10: Findings for the Strategic Action Program (SAP) and CHAPTER 11: Summary, conclusions, and recommendations presents LME analysis on the prioritized transboundary issues and the way forward to be considered for the elaboration of a Pollution focus SAP to halt the identified transboundary changes and challenges, and surely through Mediterranean states transboundary cooperation. To conclude, two relevant Annexes are included: Annex A, which attempt to compare the action’s list proposed under the main and recent reporting processes in the Mediterranean region, and Annex B listing the EU links to the information layers for the Mediterranean Sea under EMODnet platform.

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List of acronyms and abbreviations

BD	Biodiversity
CC	Climate Change
CCA	Causal Chain Analysis
cca	Capital consumption allowance
Chl-a	Chlorophyll a
COP	Conference of the Parties
CU	Coordinating Unit of the Mediterranean Action Plan
CW	Chemical and Waste
DPSIR	Drivers/Pressures/Status/Impacts/Response
EcAp	Ecosystem Approach
EEA	European Environment Agency
EMSA	European Maritime Safety Agency
EO	Ecological Objective
GEF	Global Environmental Facility
GDP	Gross Domestic Product
H2020	Horizon 2020
HNS	Hazardous and Noxious Substances
IMAP	Integrated Monitoring and Assessment Programme
IMO	International Maritime Organization
IW	International Waters
LBS	Land Based Sources
LME	Large Marine Ecosystem
MBES	Mediterranean and Black Sea Earth System

MBMS	Mediterranean and Black Sea Marine System
MCSD	Mediterranean Commission on Sustainable Development
MedECC	Mediterranean Experts on Climate and environmental Change
MED POL	Mediterranean Pollution Control and Assessment Programme
MedProgramme	Mediterranean Sea Programme
MHW	Marine Heat Waves
MME	Marine Mortality Events
MMB	Mediterranean Magreb Basin
MPA	Marine Protected Areas
MWD	Mediterranean Water Deficit
NBB	National Baseline Budget of Pollutants
NIS	Non-Indigenous Species
QSR	Quality Status Report
RAC	Regional Activity Center
REMPEC	Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
SAP	Strategic Action Programme
SAPBIO	Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region
SDG	Sustainable Development Goals
SEMC	Southeast Mediterranean Countries
SoED	State of the Environment and Development Report
SST	Sea Surface Temperature
TDA	Transboundary Diagnostic Analysis
UNEP/MAP	United Nations Environment Programme /Mediterranean Action Plan
WWTP	Wastewater Treatment Plant

CHAPTER 1. Introduction

1.1. Context

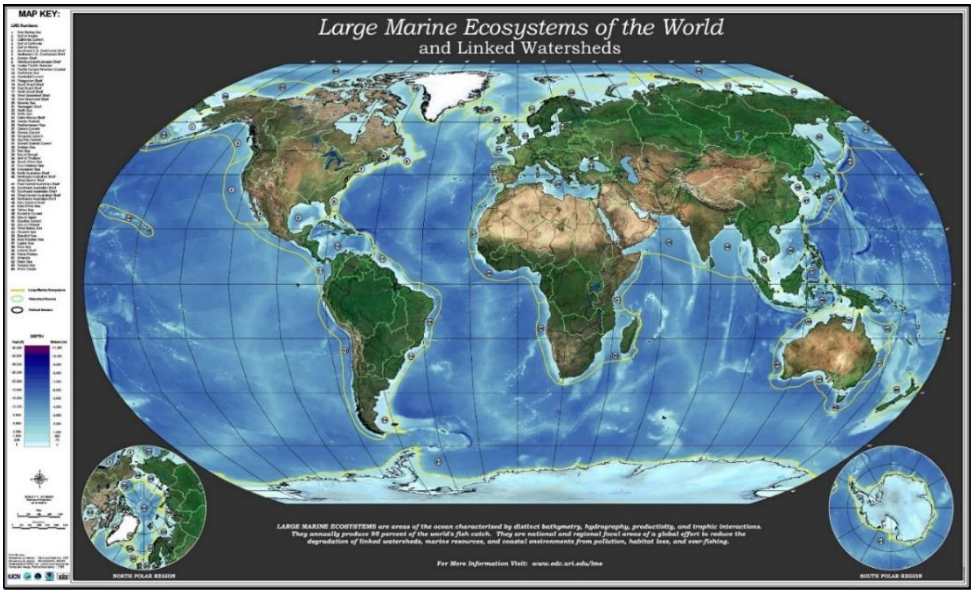
Science have identified 64 LMEs worldwide (
Figure 1) since the mid-1980s, after Dr. Kenneth Sherman of NOAA's National Marine Fisheries Service and Dr. Lewis Alexander of the University of Rhode Island pioneered the concept of Large Marine Ecosystems (LMEs). LMEs relates to a higher interlinked functioning of different parts of the coastal oceans and seas, of transboundary nature (ca. cross-border); that is, larger marine ecosystems units. In addition, these LMEs are defined in terms of being highly productive and valuable ecosystem services, such as fisheries. Contrarily, anthropogenic factors such as overexploitation of living resources, habitats deterioration and pollution threaten the varying productivity (ca. exploited resources) and long-term conservation of these large-scale transboundary ecosystems.

The actual conceptualization and global growing practice of the ecosystem-based management approaches are not far from the original idea for the strategic management of these LMEs, primarily, directed to protect ecosystem services, including both exploited renewable (i.e., fisheries) and non-renewable marine resources through sustainability practices and conservation strategies in the long-term. Both approaches are increasingly relevant at global scale as ecosystem services provided by the marine environments are under pressure or in decline. The LME management approach requires from different disciplines, from natural science to social and economic sciences and law, to develop today under GEF International Waters (IW) portfolio, the LME Transboundary Diagnostic Analysis (TDA) and LME Strategic Action Program (SAP).

The original objective of the LME report studies was transboundary both by nature and definition. The purpose was to understand the variability of these large ecosystems and how to manage the oceans' living resources for sustained (fisheries) productivity. In words of Sherman and Alexander:

"*The LME approach brings multidisciplinary marine studies to bear on regional-scale concepts of resource sustainability by examining the causes of variability in the productivity of those regions around the margins of the world's oceans from which 95% of the annual yields of usable fisheries biomass is harvested. Emphasis is placed on identification of the primary, secondary, and tertiary driving forces controlling the large-scale variability of biomass yields within and among LMEs.*"
(From Large Marine Ecosystems: Stress, Mitigation, and Sustainability, 1993)

Almost after four decades, despite the original objective of the LME approaches by science was to ensure the preservation of fisheries by elucidating the causes (ca. forces) affecting the stocks variability and to both understand and develop management strategies, the LME concept has been modernized targeting the transboundary concerns of the large ecosystems as a unit and extending ecosystem services beyond fisheries and interlinked with a full spectrum of anthropic pressures in larger interconnected diverse marine ecosystems. The LME concept adopted by GEF IW promotes the regional transboundary water systems cooperation by funding projects related to continental water systems (e.g., rivers) and marine (LMEs). In particular, the GEF TDA reports are scientific and technical assessments of the water related ecosystems mainly in terms of anthropogenic causes and effects towards developing regional (transboundary) actions and cooperation (SAP). The GEF TDA/SAP methodology is a highly collaborative process consolidated as a major strategic planning tool by GEF IW Projects over almost three decades. It is important to consider the evolution of the ecosystem management theories and approaches, including LMEs, over these decades to understand the new needs and science policy interface challenges. Since the Rio and later Rio+20 conferences the threats to the global environment, including the marine environment, are worsening (e.g. marine litter, climate change) with complex solutions and difficulties of implementation.



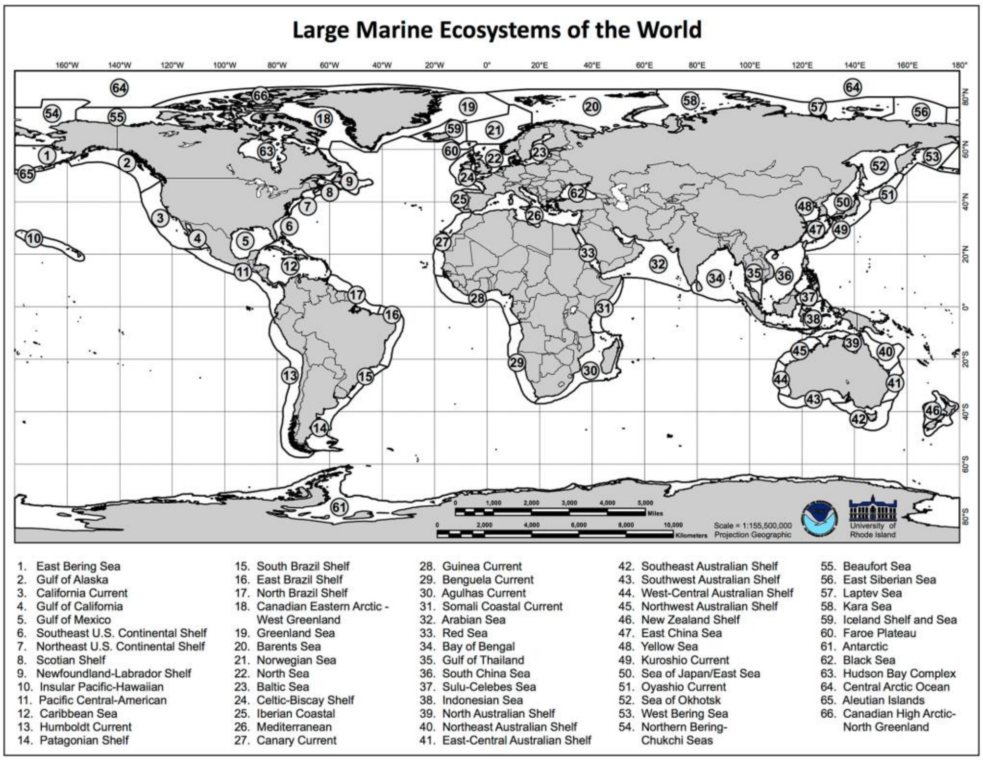


Figure 1. Two global maps showing the Large Marine Ecosystems (LMEs). Credit: NOAA (NOAA 200th: Top Tens: Breakthroughs: Large Marine Ecosystems: Map).

Online access to current LMEs: [IW:LEARN | LME:LEARN -> Services -> LME HUB (iwlearn.net)]

1.2. The Mediterranean LME

The location between continents and enclosed characteristics of the Mediterranean Sea are distinctive, including the highly diverse ecosystems on land and at sea. The Mediterranean LME have been acknowledged by many authors as one of the earth's hot spots in terms of biological diversity. Recently, Pirodi et al. (2020)[2] reviewed the basic description of the Mediterranean LME in the introduction to their study and stated the major attributes of the basin, namely, area (2 522 000 Km2), geographical location (from 30◦N to 45◦N and from 6◦W to 36◦E), and depth (average 1460 m, maximum 5267 m). The LME is 4000 km wide and 800 km long with about 46000 km of coastline. In **Figure 2**, the Mediterranean Sea LME with the divisions according to the FAO-GFCM fisheries areas are shown, including the total catches from 1970 to 2017, from both reported (dotted-line) and reconstructed adding other database sources (e.g., discards estimations, recreational) and input of local experts (in Pirodi et al. 2020).

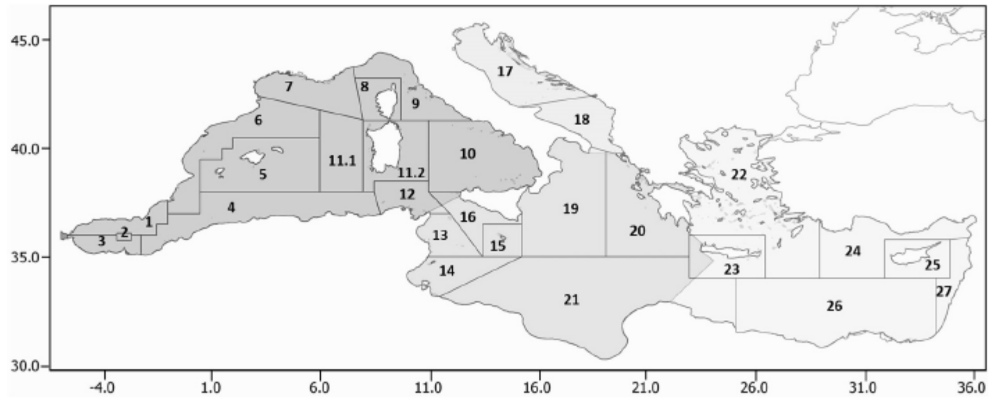


Fig. 1. The Mediterranean Sea LME (Med-LME) with the four main divisions accordingly to the European Marine Strategy Framework Directive (MSFD; 2008/56/EC): Western Mediterranean Sea (dark grey); Adriatic Sea (light grey); Ionian and Central Mediterranean Sea (grey); Aegean and Levantine Sea (white), and the twenty seven FAO-GFCM Geographical Sub-Areas (GSAs): Northern Alboran Sea (1); Alboran Island (2); Southern Alboran Sea (3); Algeria (4); Balearic Islands (5); Northern Spain (6); Gulf of Lions (7); Corsica Island (8); Ligurian and North Tyrrhenian Sea (9); South Tyrrhenian Sea (10); Sardinia (west: 11.1); Sardinia (east:11.2); Northern Tunisia (12); Gulf of Hammamet (13); Gulf of Gabes (14); Malta Island (15); South of Sicily (16); Northern Adriatic (17); Southern Adriatic Sea (18); Western Ionian Sea (19); Eastern Ionian Sea (20); Southern Ionian Sea (21); Aegean Sea (22); Crete Island (23); North Levant (24); Cyprus Island (25); South Levant (26); Eastern Levant Sea (27).

C. Piroddi et al. *Environmental Development 36 (2020) 100555*

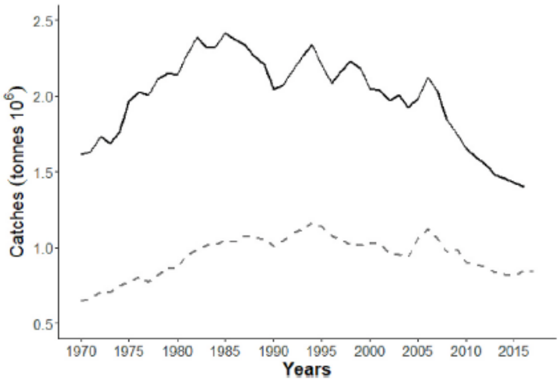


Fig. 2. The Mediterranean Sea LME catches reported to FAO (dotted line) and reconstructed catches (black line) for the 1970–2017 period. Reconstructed catches were estimated using a catch-reconstruction approach (Pauly et al., 2014; Pauly and Zeller, 2016) which looked at all types of fisheries removals: from reported and unreported catches (from both industrial and artisanal fisheries) to recreational catch and discards, using official statistics and data from peer-reviewed and grey literature and input of local experts.

Figure 2. Geographical scale and fisheries trends of the Mediterranean Sea LME (in Priodi et al. 2020).

[2] *Piroddi et al. (2020). The living marine resources in the Mediterranean Sea Large Marine Ecosystem*

The information from several sources, including FAO-GFCM, evidences the worsening trends in total commercial fish stocks reported, and consequently, the progressive decline of the economic sector since the 90s, in this case supported by the specialized databases covering the full geographical region. The agreement between scientific authors and evidence are clear for many years with regard the Mediterranean LME, in terms of the primary conservation objective (ca. fisheries) behind the LME concept, and this latest scientific work from Pirodi et al. (2020) continues reflecting that the issue still a transboundary concern in the Mediterranean Sea. In addition, the current scientific and technical programs and governance structures also evidences that the Mediterranean Sea marine environment is threatened for decades, and for some sectors such as fisheries (ca. biodiversity loss) and tourism (ca. coastal artificialization, habitats deterioration and pollution), can be considered an ecosystem in decline and loss in many parts at the subregional and regional levels.

Beyond fisheries concerns, the Mediterranean Sea LME is highly complex with a spatial variety of ecosystems and functioning regimes, as it has been also established by may authors and it can be observed in

Figure 3 (Coll, 2010)[3]. The Mediterranean Sea LME has multiple dimensions that govern the large marine ecosystem itself and influences the socio-cultural and economic systems. Within these complexities, the causes affecting the environmental deterioration within a TDA report must be elucidated through a cause and effects analysis (ca. Causal Chain Analysis, CCA).

The CCA is the core methodology of the GEF TDA LME reports and has focused on four main dimensions: Pollution and Health, Fisheries, Socioeconomics and Governance. These are the original and basic dimensions used to approach the study of the LMEs. The fisheries concept, despite the socioeconomic sectoral links and fundamental importance for food security today has evolved towards a concept focusing its biodiversity role (ca. fish of targeted and non-targeted commercial species as an ecosystem component) and enlarging the concern towards the protection and conservation of the species and habitats and reflecting the biodiversity loss rather than the economic loss in the Mediterranean Sea. The governance and socioeconomic dimensions, despite these are not directly related to environmental sciences reproduce the socioeconomic models in the region and are fundamental to understand the LME management frameworks in terms of ecosystems and economy relationships, as well as environmental law and policies regarding the transboundary concerns. Concerning the Pollution and Health dimension, reflects widely the anthropogenic transboundary concerns and status of the Mediterranean LME and their marine and water-related systems.

These four Mediterranean LME dimensions need a full perspective today, to capture the most relevant and interlinked elements in the Mediterranean region:

- Pollution and Health as pollution, environmental water-systems (both coastal and marine) and social concerns relationships, including climate variability.
- Fisheries as a multilayer biodiversity concern in the LME.
- Governance meaning the multilevel governance structures and LME essential long-term.
- Socioeconomic as primarily demography and socioeconomic models in the LME.

[3]*Coll (2010). The biodiversity of the Mediterranean Sea: Estimates, Patterns and Threats.*

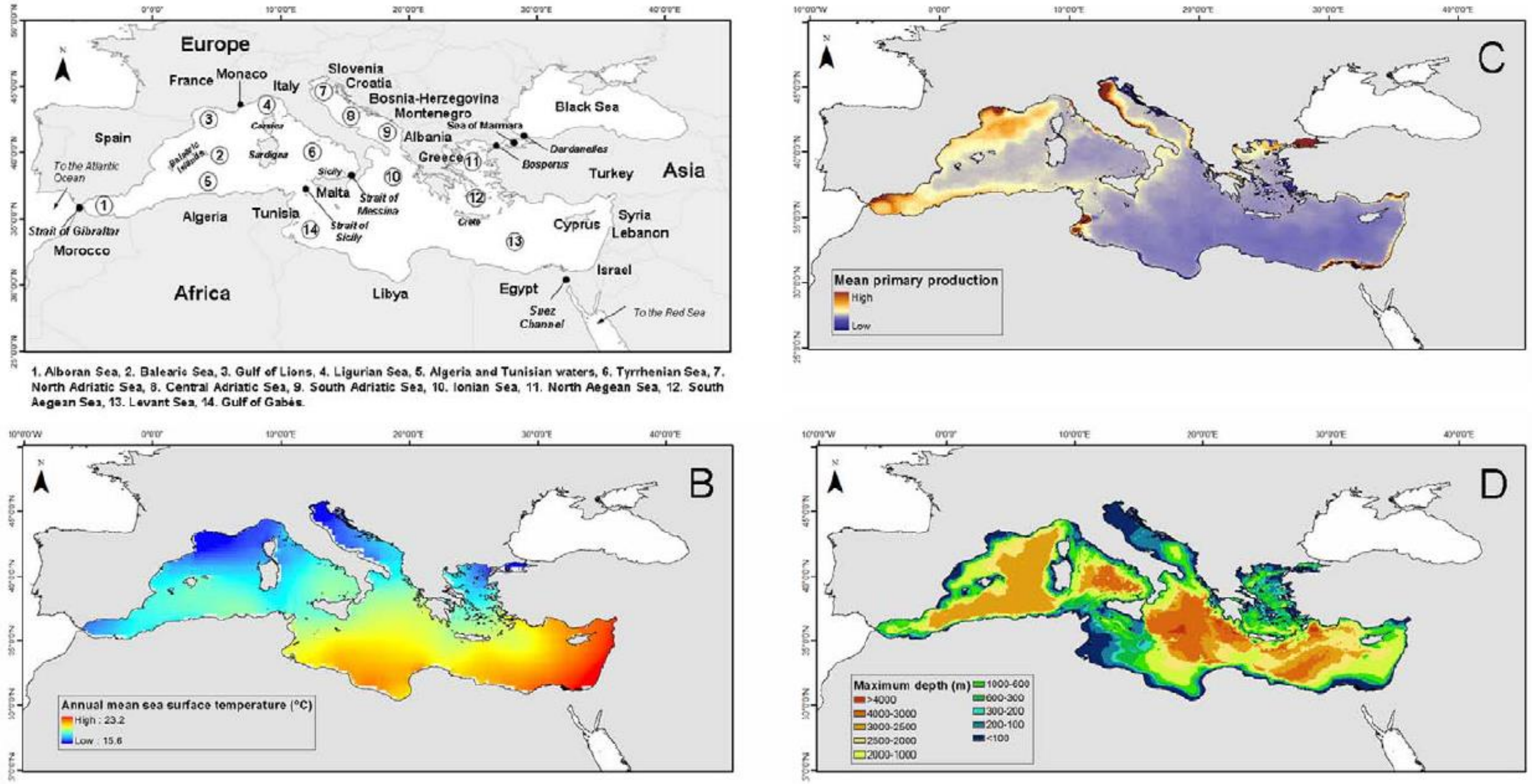


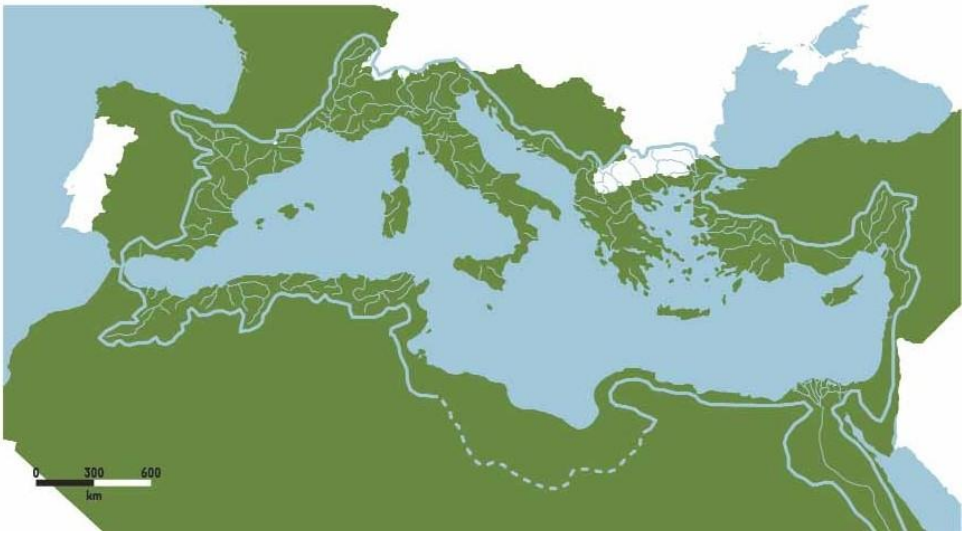
Figure 1. Biogeographic regions and oceanographic features of the Mediterranean Sea. (A) Main biogeographic regions, basins, and administrative divisions of the Mediterranean Sea, (B) Annual mean sea surface temperature (°C) (2003, NOAA), (C) Annual mean relative primary production (2002, Inland and Marine Waters Unit, Institute for Environment and Sustainability, EU Joint Research Centre, Ispra, Italy), and (D) maximum average depth (m) (NOAA).
doi:10.1371/journal.pone.0011842.g001

Figure 3. Biogeographic regions and oceanographic features of the Mediterranean Sea (in Coll (2010).

1.2.1. A ‘practically’ closed freshwater and marine system

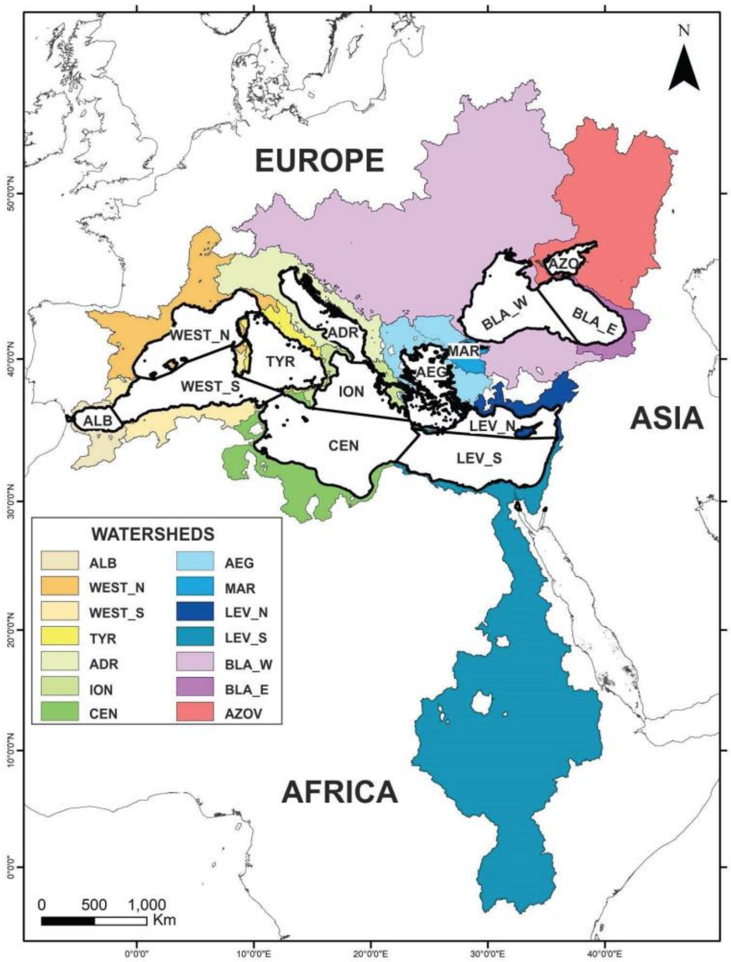
In relation to Pollution and Health issues it is imperative the use of the ecosystem approach to study water-systems of transboundary nature (on land, seawards and marine, including coasts). The enclosed morphology of the Mediterranean Sea is responsible for the higher salinity (approximately 38 psu) compared to the Atlantic Ocean waters (approximately 35 psu). The evaporation process dominates in the basin exacerbated in the eastern part, and therefore, the dependency on the water systems to maintain the LME balance is very relevant (ca. hydrological cycles, particularly the freshwater-continental flows). The watersheds and main water systems (e.g., rivers and groundwaters) flowing into the coastal and marine waters of the Mediterranean Sea are shown in Figure 4 as shown in the TDA 2005, in EMODnet database, in Poulos (2019), and related to the groundwaters and Mediterranean aquifers by UNESCO/IHP Program. Recent scientific publications on Mediterranean river flows (flows m3/s) and discharges have been updated for the major rivers, whilst the rivers and catchments <10,000 km2 are less well studied (Poulos 2019, 2020).

Visual LME GEOMAP n°1

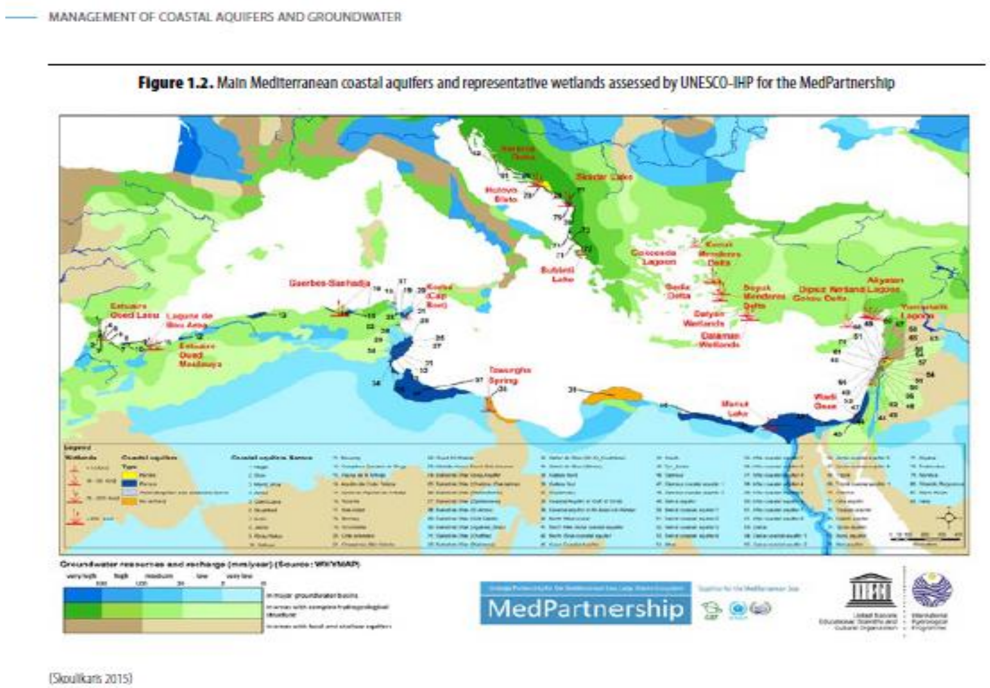


Map A. Watersheds flowing into the Mediterranean coastal and marine ecosystems (in TDA 2005).

Map B. Major rivers in the Mediterranean Sea. Extracted from EMODnet.
https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas



Map C. Mediterranean Watersheds. Poulos (2019)



Map D. Mediterranean coastal aquifers and groundwater resources. UNESCO/IHP, 2015.

Figure 4. The freshwater (continental) and marine water systems of the Mediterranean LME.

The figure above includes the groundwater and aquifer's locations (Map D) from an study by IHP-UNESCO[4] and elaborated during the GEF MedPartnership Programme (2009-2015) to support the Mediterranean LME understanding on transboundary water systems, particularly groundwaters (ca. coastal aquifers). The complexity of the international waters and transnational flows is large and includes wetlands and other coastal morphologies in the Mediterranean region as well, with a number of characteristic habitats features at regional and subregional basins.

The regional complexity is evident from many potential nested spatial assessments of water-related ecosystems in the Mediterranean LME. To this regard, for example, it should be mentioned and earlier study in the Drin River basin, the GEF Drin Basin Project to assess the transboundary river water-flows discharging into the Adriatic Sea (i.e., one of the four ecoregions of the Mediterranean Sea). The GEF Drin Project, entitled "Enabling Transboundary Cooperation and Integrated Water Resources Management in the Extended Drin River Basin" was implemented by the United Nations Development Programme (UNDP) and executed by GWP-Mediterranean (GWP-Med) in cooperation with UNECE. More recently, the GEF Adriatic Project (2018-2020), could be also considered a higher resolution study in the central part of the Adriatic Sea.

It should be highlighted here, the conceptual approach followed by Poulos (2019) for the study of the Mediterranean region which consider the Mediterranean Sea LME connected *de facto* to the Black Sea LME and not only to the continental freshwater watersheds around the Mediterranean region. The seawater and brackish water (approximately 18 psu) exchanges between the Mediterranean Sea and the Black Sea, respectively, constitute a fundamental flow into the Mediterranean Sea (see also Chapter 3). As well, the Mediterranean Sea is through the Gibraltar Strait connected to the Atlantic Ocean and through the Suez Canal (man-made) to the Red Sea (ca. Indic Ocean), and therefore, surrounded by Europe, Africa, and Asia.

1.2.2. Pollution, water-related ecosystems and governance scales

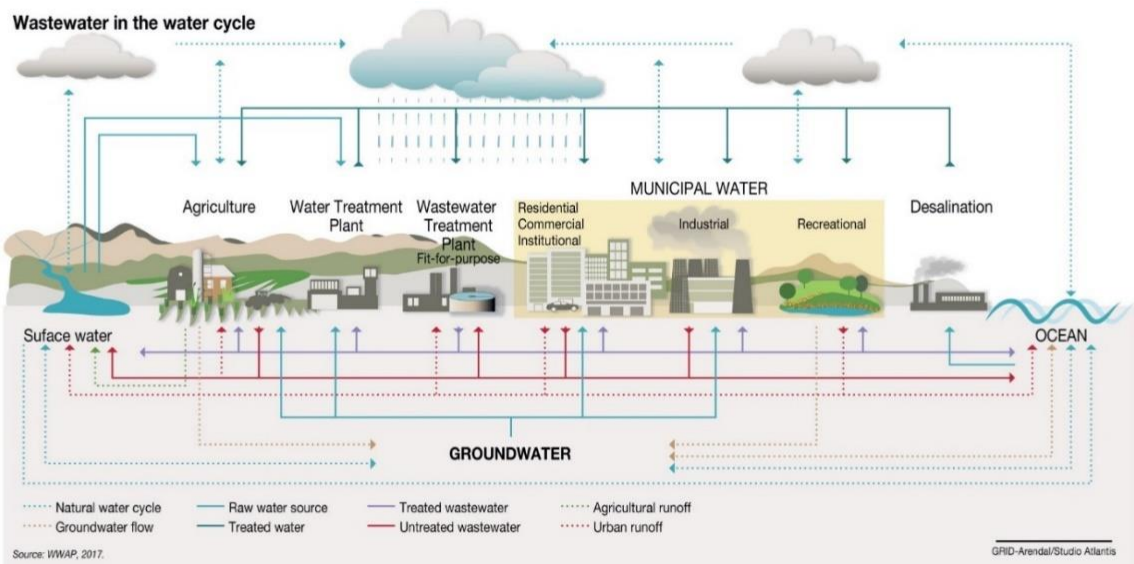
The land-based sources of pollution still the primary identified concern in the Mediterranean Sea region in relation to the coastal and marine pollution issues (i.e., regionally ruled via the Barcelona Convention and its Land-Based Sources (LBS) Protocol). The continental and transitional water systems are the vehicle for chemicals and litter discharges into the coastal and marine areas provoking chronical contamination and pollution and contributing to the biodiversity and habitats loss. In turn, ecosystems are exposed to the climate change variability and intensified in the Mediterranean region. This is the primary frame to describe the main environmental concerns of the Mediterranena LME (see **Figure 5**) from an anthropogenic perspective in different transitional water-systems. This approach is highly focused on the transboundary (and national) water-systems providing a clear picture of the environmental concerns in terms of water resources and pollution (transitional rivers, WWTPs, sea discharges, groundwater and atmospheric inputs), which could be either transboundary, subregional or national in nature; however, these concerns are regionally shared by the Mediterranean countries who provide and define the relevance and actions nedeed for the development of futher environmental law and governance at all

[4] Hydrology (IHP) (unesco.org)

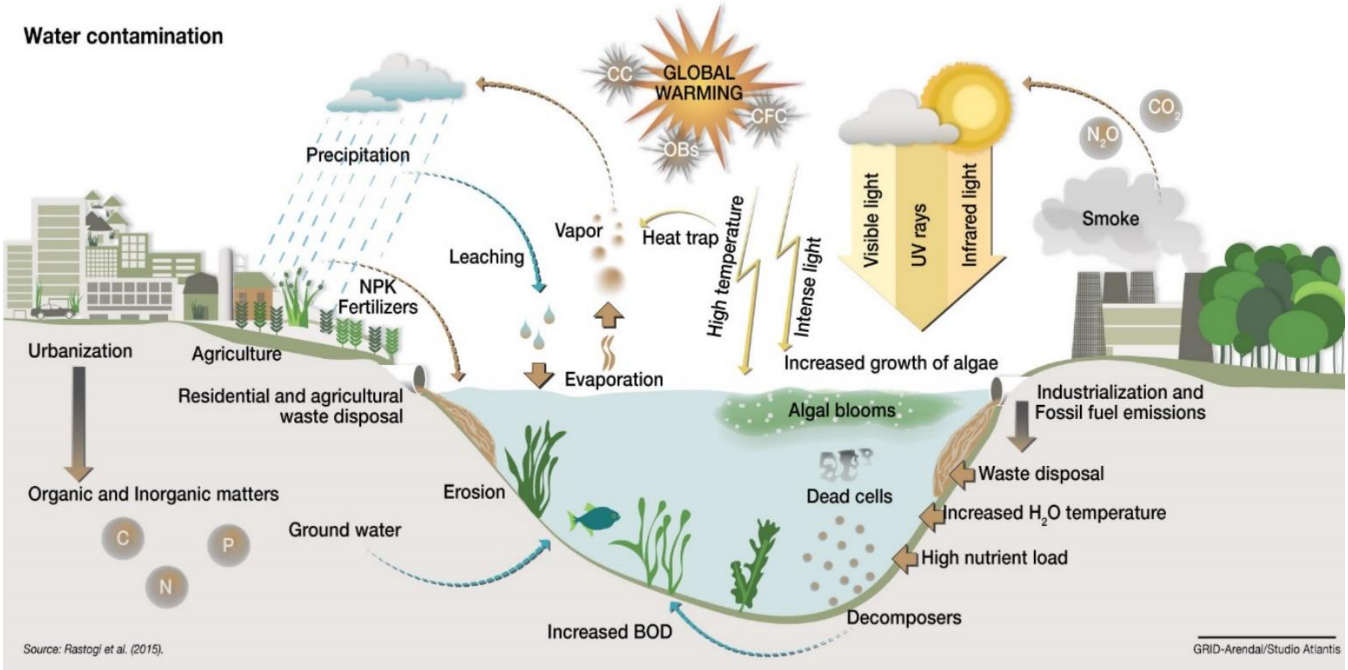
levels (e.g., the Barcelona Convention, the Mediterranean Action Plan and MEDPOL Programme, the European Union, the Contracting Parties, etc.).
As this, a TDA study related to pollution must consider the known and current concerns under scientific research and related to different ecosystem components which affects transboundary ecosystem services and resources, such as chemical contamination of water flows and their biological effects in explotable and non-explotable resources and habitats; the microbial pollution and the ecosystem recreational services in terms of bathing waters quality to mention a few. Secondly, it is imperative to revise the evidences and the relationships with current environmental concerns with studies from other scientific disciplines (ca. biology, geology, chemistry, etc.) and mixed disciplines (ca. oceanography, climatology, etc.); to update the knowledge in topics such as pollution and fisheries, pollution and climate variability, etc. In addition, there are other environmental concerns at a transboundary level arising from socio-economy, for example, coastal artificialization, sustainable blue economy and existing economic sectors, etc. which are a main environmental threat to the LME as well in the Mediterranean region.

The anthropogenic pressures in the Mediterranean Sea marine ecosystem still high, although a relevant policy deployment was initiated in the 70s regarding majorly to chemical pollution concerns with success (e.g., phosphate (detergents) use ban, tin-based (antifouling paints) products ban, pesticides (agriculture) use ban, etc.), as well as the first marine protected areas (e.g., Port-Cros MPA, Hyères, France). These science-policy interface continues among other stakeholders in the region as well (e.g., Mediterranean IMO Sulphur Emission Control Area-SECA in 2022) at different spatial and temporal scales and according to the existing socioeconomic models which differ among the riparian Mediterranean countries, and therefore, the human-related environmental and economic impacts. Several recent studies, such as Micheli et al., 2013, attempt to assess the cumulative pressures occurring through multiple stressors in the Mediterranean Sea and being most of them of transboundary concern (e.g., demersal fisheries, diffuse pollution sources, maritime traffic to mention a few). These are stressors related directly or indirectly to transboundary impacts with high concern for coastal and marine ecosystem management at national level. The **Figure 6** represents the zonation of the cumulative impacts and consequences in the Mediterranean (and Black Sea) assessed through the study of 22 drivers and 17 marine ecosystems.

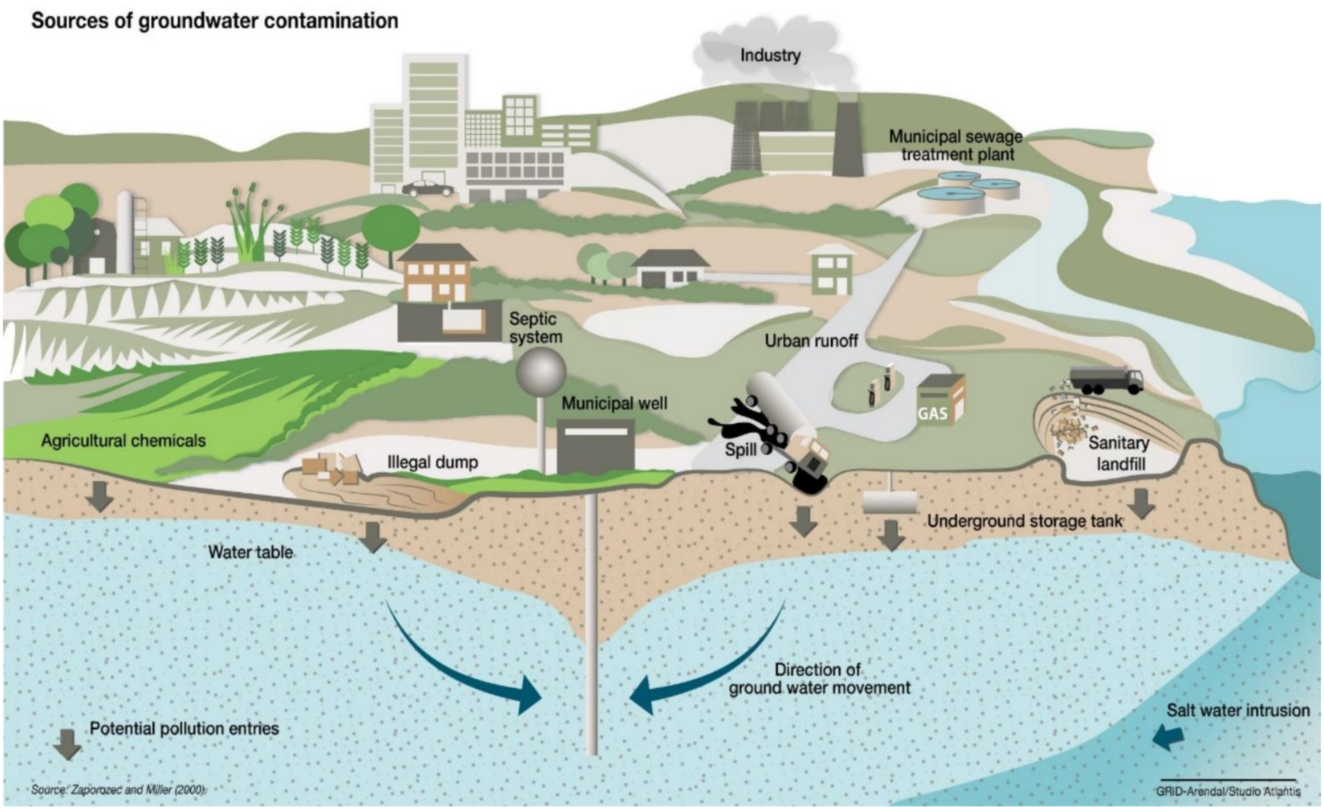
A. TRANSITIONAL WATER SYSTEMS AND WASTEWATER FLOW AND TREATMENTS



B. WETLANDS (COASTAL LAGOONS)



C. GROUNDWATER



C. SEAWARDS FLOWS OF POLLUTANTS AND WASTE

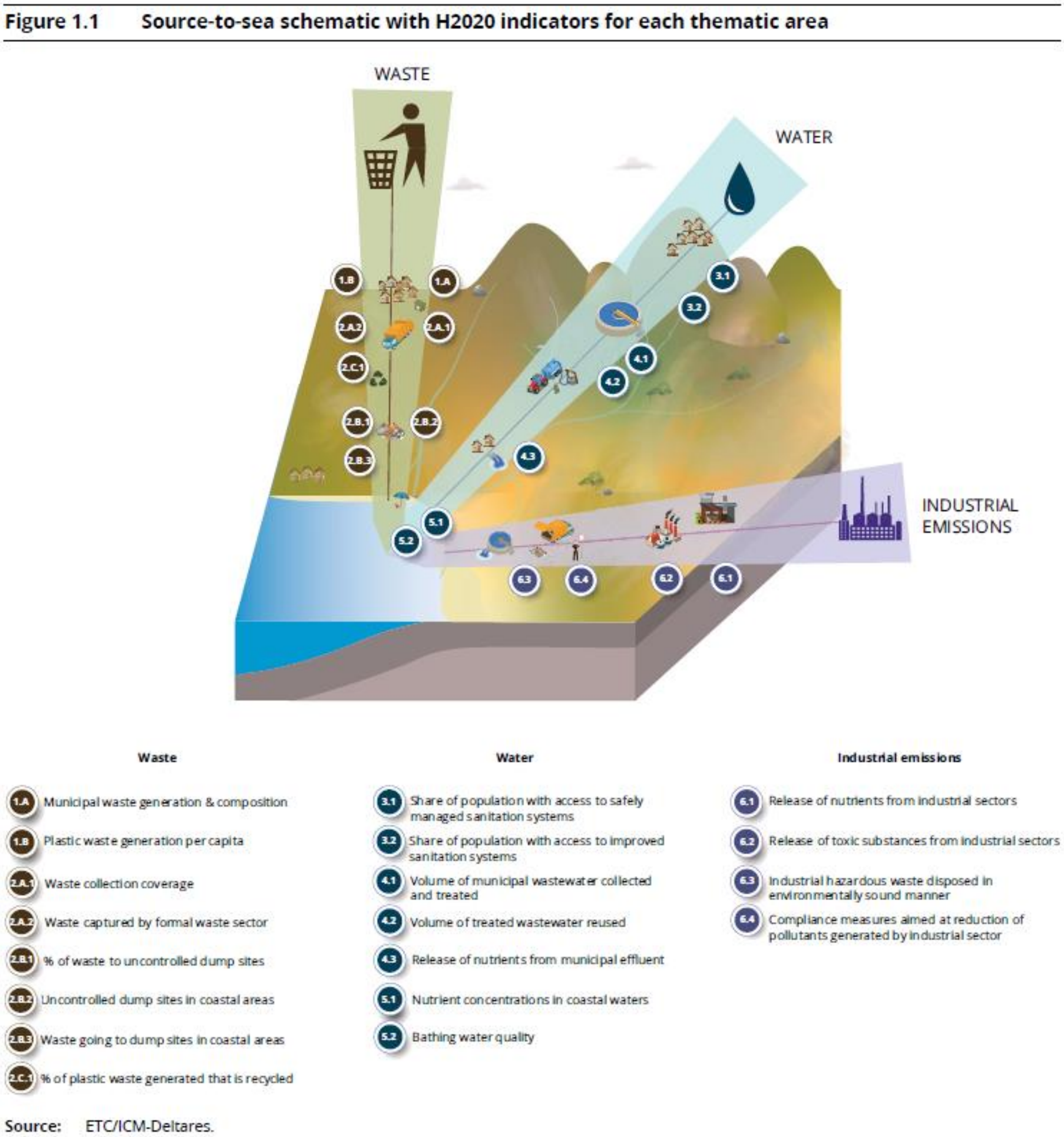


Figure 5. Infographics reflecting on the main current pollution concerns in the LME and their relationships with national or transnational water bodies. Source: GRID-Arendal (A, B, C top) and H2020 report (D, down).

However, it should be observed in Figure 6 graphs that the scores related to socioeconomic pressures (ca. environmental impacts from pollution and biodiversity) have lower impact scores compared to the basic ecosystem state indicators. Thus, the climate related characteristics studied by Micheli et al. (2013), namely, pH decrease, SST increase, and UV increase dominate the result of their assessment. These ecosystem factors mainly indirectly measured and assessed would have certainly a major contribution to the stability of the Mediterranean Sea ecosystem and are highly transboundary-scale relevant, despite their larger temporal scales and complex governance limiting the direct policy action compared to the current pollution and biodiversity concerns at regional and subregional scales. An ecosystem approach vision (at any spatial scale) requires more than ever, in a global environmental emergency, the cumulative study of pressures and the classification of drivers to be performed by methodologies resulting in conceivable responses (ca. policy), such as the Causal Chain Analysis (CCA) and the core methodology of this TDA report (see Chapter 4). Additionally, the subsequent geographical lower levels down to countries, municipalities, etc. (i.e., high-resolution subdivisions) rather than the wider LME are also needed to effectively address large transboundary effects and cumulative pressures concerns. To this regard, the multilevel and cross-border stakeholder engagement is fundamental for the transboundary cooperation.

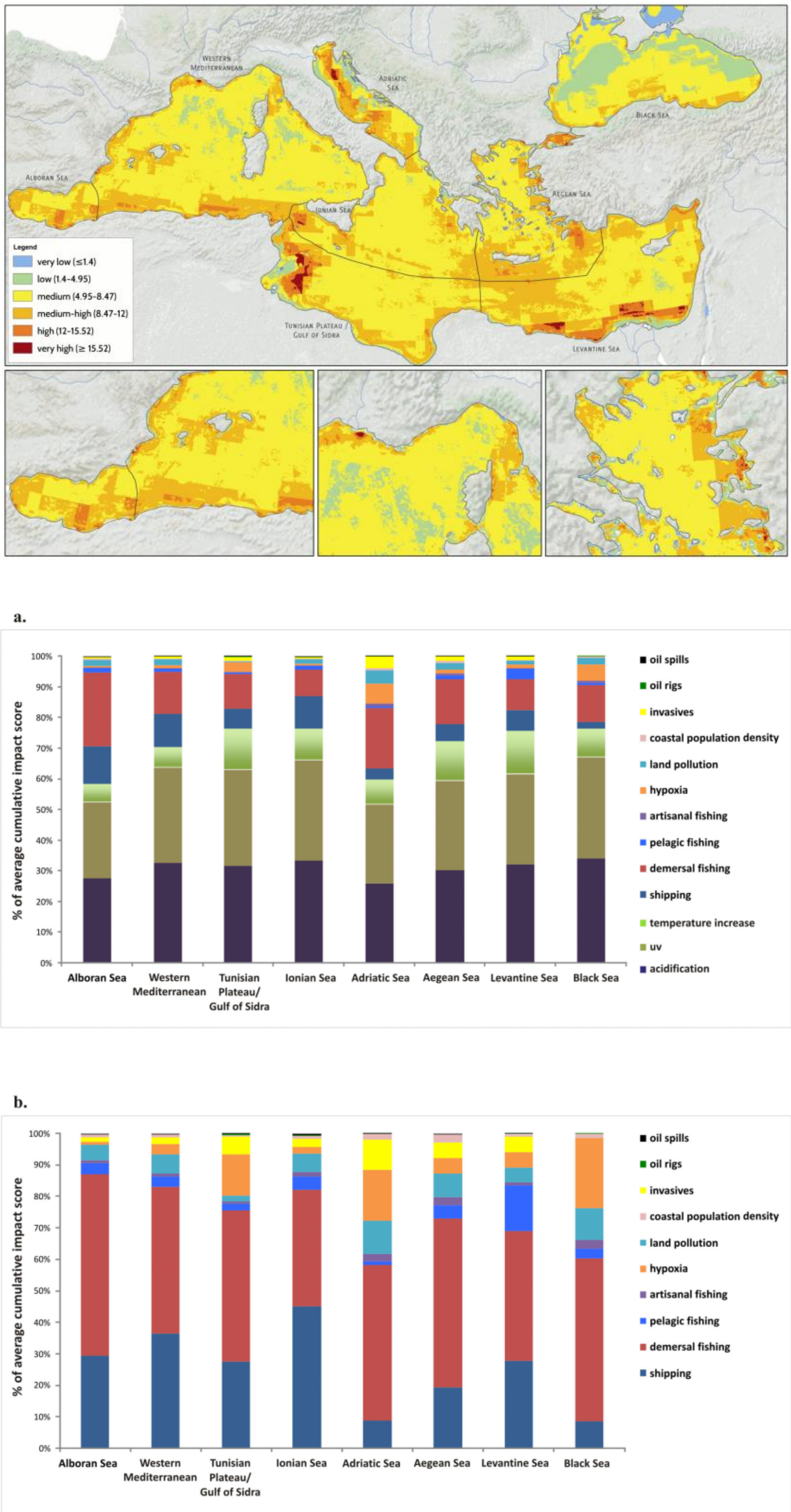


Figure 6. The Mediterranean and Black Seas cumulative pressures and geospatial coincidences around the Mediterranean region (top) and related drivers and pressures (down) (Micheli et al., 2013).

The Mediterranean LME has a strong governance structure lead by the 21 riparian countries and the European Union under the leadership of the UNEP Barcelona Convention Secretariat and Mediterranean Action Plan (MAP) Coordination Unit and its Regional Activity Centres, namely the UNEP/MAP System, since the late 70s. This is important to be cited here, as in the long-term, the institutional governance structure reflect *de facto* linked to the ecosystem regulation potential in the region from local to regional levels. The figures below (Figure 7) show two examples of the scientific work (Coll et al., 2012 Micheli et al., 2013) interlinking the environmental scientific disciplines with the governance strategies.

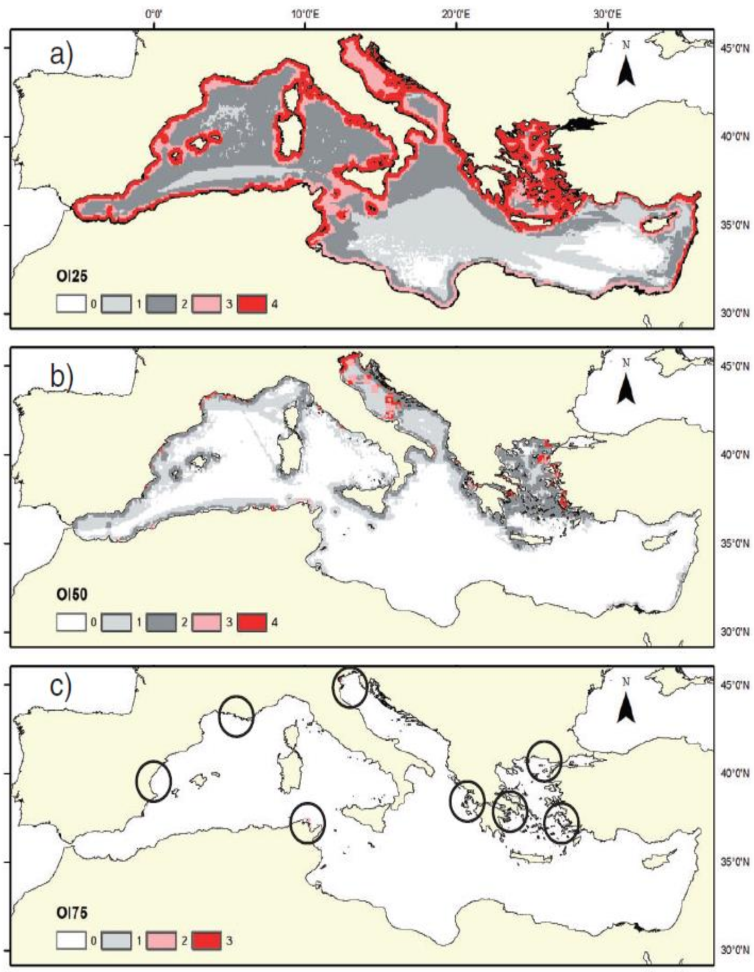


Figure 6 Global areas of conservation concern in the Mediterranean Sea where high biodiversity of invertebrates, fishes, marine mammals and turtles, and seabirds, and high threats overlap. The overlap index (*OI*) indicates areas where both species diversity and intensity of cumulative threats were: (a) ≥ 25% (OI_{25}), (b) ≥ 50% (OI_{50}) and (c) ≥ 75% (OI_{75}). 0 = no groups (of the four biodiversity groupings studied: invertebrates, fishes, marine mammals and turtles, and seabirds) show high diversity and high cumulative threats; 1 = only one group shows high diversity and high threats; 2 = two groups of the four show high diversity and high threats; 3 = three groups of the four show high diversity and high threats; and 4 = all groups show high diversity and high threats. Black circles indicate cells with data.

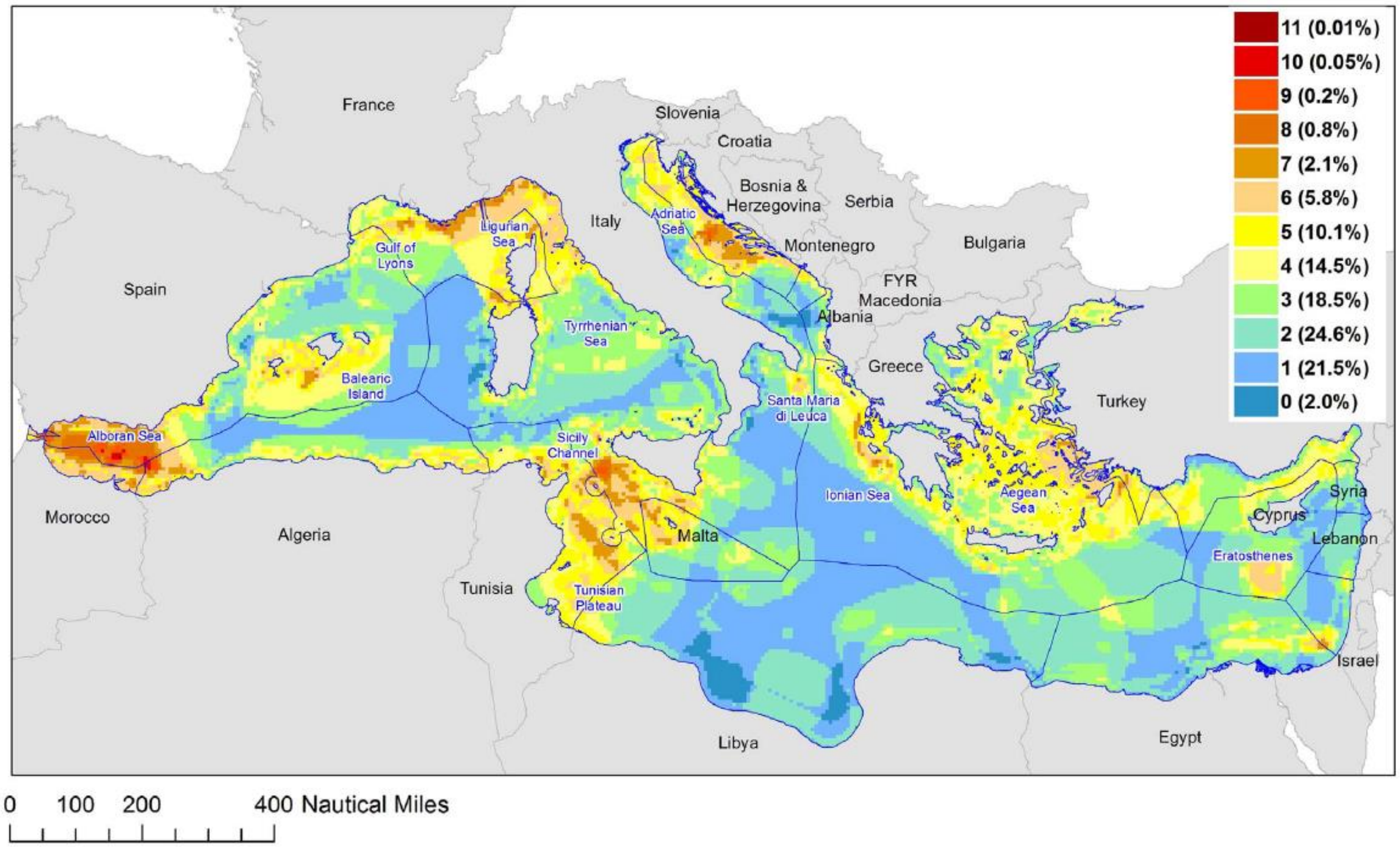


Figure 5. Frequency of inclusion by proposed conservation plans. The number of schemes including a particular area and the total % included are reported in the legend.

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Figure 7. Examples of science to policy interface related to biodiversity in the Mediterranean Sea (Coll et al., 2012-top; Micheli et al., 2013-bottom)

However, it is important to signal that environmental governance is founded in applied science and technologies, and therefore, the existing governance structures reflect the past concerns and solutions but might not reflect necessarily the present or predicted ones (e.g., climate variability is highly relevant for the past few decades but the first regional science-policy interface study in the Mediterranean was published in 2020) calling for a science-policy dialogues towards sustained and effective governance.

1.2.3. Demography, socioeconomy, and development

The UN DESA[5] Population Division (2022) shows the population in the Mediterranean countries increased by close to 82 million since the publication of the TDA Report in 2005, thus reaching 531.7 million in 2021, and up to 540.6 million in latest 2023 statistics[6]. The overall increase of 41.4% was recorded between 1990 and 2021, while decade-on-decade growth accelerated (from a rate of 12.5% between 1990 and 2000, to 13.5% between 2000 and 2010 and 17.2% for the last decade), whilst upward and downwards trends are observed for different countries (UN DESA, 2022).

The most populous countries are Egypt (109.3 million in 2021) followed by Turkey (84.8 million), France (64.5), Italy (59.2) and Spain (47.5). Montenegro, Malta and Monaco have populations of less than a million. Monaco is at the same time the most densely populated country with 24,622 inhabitants/km2 (from 18,149 to 24,622 depending on the sources and with about 2% more land extended to the sea since 2020. Other densely populated countries are Malta and Italy and eastern countries (Egypt, Palestine, Lebanon and Israel). On the contrary, low population density (of 100 or less inhabitants per km2) are found in some parts of Spain, Morocco, Greece, Tunisia, Croatia, Bosnia and Herzegovina, Montenegro, Algeria (18 inhabitants/km2) and Libya (4 inhabitants/km2). The Figure 8 illustrates the demography status in the Mediterranean region.

Visual LME GEOMAP n°2

Table 1. Key demographic data, 2021.

Countries	Median age of population (years)	Population change prev. yr., (in 000)	Population density (inhab./ km^2)	Total population (in 000)	Popul. % change ‘21/’01	Total net-migration (in 000)	Life expectancy at birth (years)
AL	37.27	-13.71	104.19	2,854.71	-9.5	-10.61	76.46
DZ	27.80	731.25	18.55	44,177.97	41.6	-18.80	76.38
BA	41.82	-49.80	63.89	3,270.94	-22.0	-25.87	75.30
HR	43.73	-37.93	72.64	4,060.14	-9.9	-10.40	77.58
CY	37.59	5.78	134.65	1,244.19	29.0	2.00	81.20
EG	23.94	1,741.26	109.76	109,262.18	50.0	-32.37	70.22
FR	41.59	58.20	117.04	64,531.44	9.3	20.61	82.50
GR	44.74	-71.51	79.85	10,445.37	-5.7	-14.81	80.11

[5] UN Department of Economic and Social Affairs
[6] World Population Review 2023

IL	29.04	141.35	411.22	8,900.06	42.7	16.86	82.26
IT	46.83	-241.86	200.15	59,240.33	3.9	28.02	82.85
LB	28.27	-77.39	546.69	5,592.63	27.4	-115.12	75.05
LY	26.27	78.84	4.02	6,735.28	27.7	-0.70	71.91
MT	39.01	11.25	1,672.22	526.75	31.0	10.41	83.78
MC	54.52	-0.25	24,621.48	36.69	13.1	0.21	85.95
ME	38.19	-0.69	45.46	627.86	-0.8	-0.10	76.34
MA	28.67	375.77	83.08	37,076.59	28.2	-46.24	74.04
SI	43.20	0.76	105.24	2,119.41	6.9	4.57	80.69
ES	43.88	178.55	94.53	47,486.94	15.9	275.02	83.01
PS	19.21	113.15	852.72	5,133.39	58.9	-12.37	73.47
SY	20.94	530.44	116.08	21,324.37	27.5	212.19	72.06
TN	31.74	91.50	78.90	12,262.95	22.7	-9.19	73.77
TR	30.93	632.46	110.15	84,775.40	30.3	-69.73	76.03
TOTAL MED				531,685.56	24.3		

Source: UN DESA, Population Division (2022); own calculations

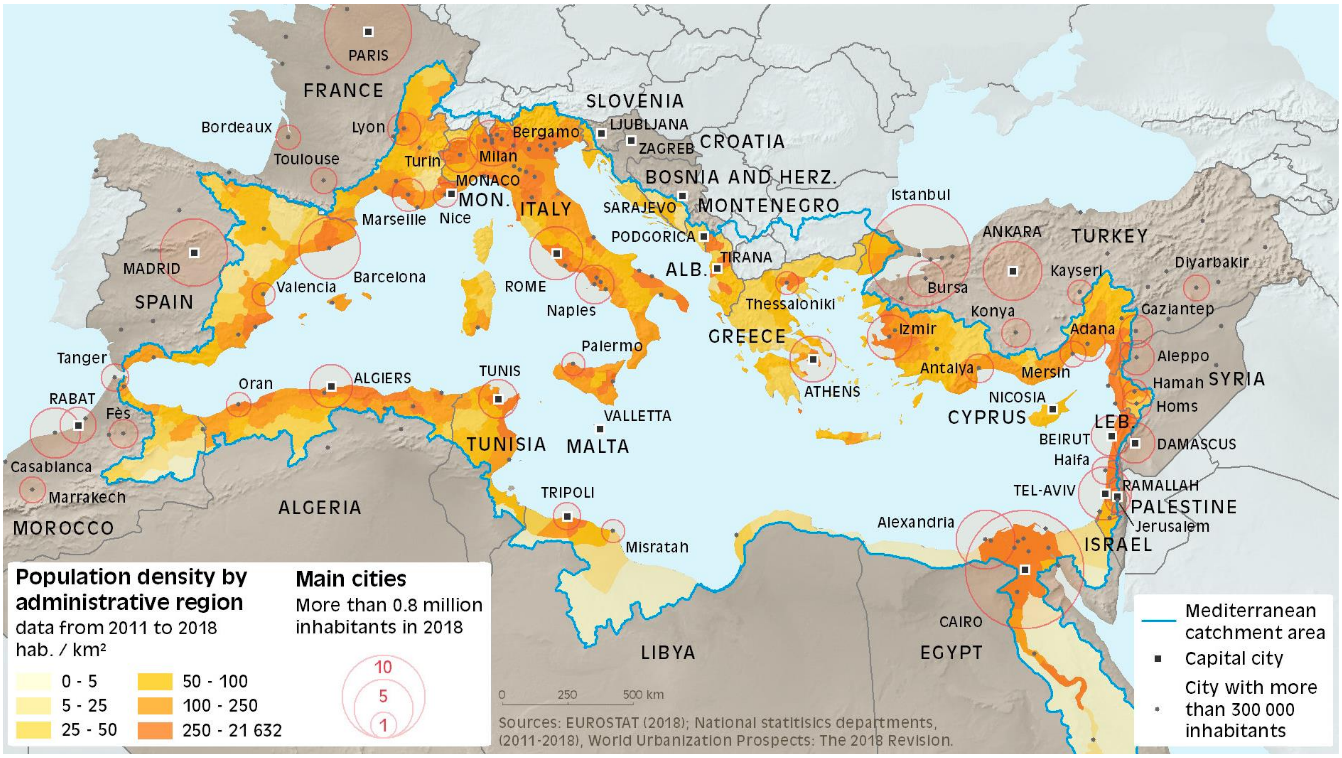


Figure 8. Demography characteristics in the Mediterranean Sea region. UN DESA data table (updated 2022) and SoED map (2020 with 2018 mixed datasets).

The decreases in population, on a year basis, have been observed up to the entire period starting since 2000 in about half the Mediterranean countries. The downward population trend has been most consistent in Albania, Bosnia and Herzegovina (since 2002), Croatia, Greece (since 2005) and Montenegro (almost all years in the observed period). Periodic population decreases during the last 20 years also characterize a few SEMC (Lebanon, Libya and Syria) and can be correlated with periods of conflicts and crises. Negative population growth rates were also seen in Italy (since 2014), Spain (in the period 2012 – 2015) and Monaco. In other Mediterranean countries, annual population changes during the past two decades were positive.

Countries with prevailing negative net migration (numbers of emigrants exceeding the numbers of immigrants, that is, negative immigration) are Albania, Algeria, Bosnia and Herzegovina, Croatia, Greece, Lebanon (since 2015), Montenegro, Morocco, Palestine, Syria (2008 – 2018) and Tunisia. Intermittent negative net migration (ca. emigration) has been recorded in Egypt (between 2005 and 2010, as well as since 2017, but with markedly contrasting tendencies in 2011 and 2013) and Turkey (in the period 2017-2019). Cumulative change rates 2001 – 2021 indicate population declined in Bosnia and Herzegovina (-22%), as well as in Croatia, Albania, Greece and Montenegro (by less than 10% and in the case of Montenegro by less than 1%). Countries with the highest population growth (around 60% to 40% respectively) were Palestine, Egypt, Israel and Algeria, whilst growth rates above the Mediterranean average (of 24.3%) were also recorded in Malta, Turkey, Cyprus, Morocco, Libya, Syria and Lebanon. The youngest population lives in Palestine, Syria, Egypt, Libya, and Algeria, where median age of population ranges between 19 and 28 years (ca. at least half the population in these countries are below these ages). On the other hand, median age population of 40+ years are found in most of the EU Mediterranean countries (except for Cyprus and Malta that have somewhat younger inhabitants) and Bosnia and Herzegovina. With the median age of 54.5, Monaco has the eldest population in the Mediterranean. Overall, life expectancy ranges between 70.2 years in Egypt and 86 in Monaco, whilst in the EU Mediterranean countries life expectancy is 80+ years.

The Mediterranean countries' economy grew less than the world average in the past two decades, leading to a decreasing share of the Mediterranean region in the world GDP: from 12.9% in 2000 to 11% in 2010 and 9.8% in 2017 (UNEP/MAP and Plan Bleu, 2020). During the same period, the Mediterranean population made around 7% of the total global population. In the past few years, the Mediterranean contribution to the global GDP remained at the same level, with slight decreases to 9.7% in 2019, and 9.5 and 9.4% in the years 2020 and 2021, respectively, following the COVID-19 outbreak (World Development Indicators, World Bank, 2022); and similarly, the Mediterranean population made around 6.7% of the world's total (UNE DESA, 2022). The impacts of COVID-19 crisis manifested in different way across the region, with most countries recording a loss of 5 – 10% of their GDP in 2020 (compared to 2019). Economies that showed better resistance include Israel, Bosnia, Algeria, Albania, Cyprus and Slovenia, where GDP declined by less than 5%; exceptionally, Turkish economy grew by 1.8% (World Development Indicators, World Bank, 2022).

Overall, Mediterranean economy was more affected than the world's (-4.7% compared to -3.2% on global level in 2020), but also with a much stronger recovery in 2021, with a growth rate of 11.7% (compared to +4.7% globally). The EU Mediterranean countries account for 60% of the total GDP generated in the region. In 2017, the average GDP per capita in SEMC was three times lower than the average income in the EU Mediterranean countries (UNEP/ MAP and Plan Bleu, 2020). According the to the World Bank's country data (World Bank, 2022), per capita GDP (in current USD) in the Mediterranean in 2021 ranged from USD 1,266 and 2,670 in Syria and Lebanon, respectively, to more than USD 50,000 in Israel and close to 174,000 in Monaco. This reiterates the region's development disparities that have a historic background but have been also exacerbated by recent conflicts and economic and health crises. The war-shattered Syrian and struggling Lebanese economies, for example, generate by far (15 to 40 times) lower GDP compared to the Mediterranean EU Member States and Israel (the richest countries, not counting Monaco). North African countries had a per capita GDP of USD 3,500 and 4,000 (except for Libya at cca USD 6,000), while Western Balkan countries plus Turkey had GDPs between USD 6,500 and 10,000. Total economic output in the region's EU countries and Israel was in the range of USD 17,000 – 51,000 per capita. The picture somewhat changes when GDP figures are adjusted for Purchasing Power Parity (PPP), whereas Turkey moves to the group of 10 countries with the highest GDP per capita (besides the EU and Israel). On the other hand, the lowest per capita GDP of less than 15,000 (PPP, international USD) is found in Morocco, Lebanon, Tunisia, Algeria and Egypt. Albania, Bosnia, Montenegro and Libya belong to a group of countries with mid-range per capita GDP (15,000 – 30,000) expressed in PPP.

According to SoED 2020 Report (UNEP/MAP and Plan Bleu, 2020), in addition to demographic differences and disparities in economic wealth among the Mediterranean countries (or country groups), other socioeconomic inequalities and issues such as human development and gender, governance and environmental management, affect the region's development prospects significantly, such as chronic human development disparities (aggravated by conflicts and crises), gender gap, unemployment (in particular for women and youth) and unequal opportunities for growth (amidst further tertiarization of economies). Further, the Mediterranean socioeconomic system is characterized as unsustainable, relying highly on resource consumption and fossil fuels (SoED, 2020); even though, a trend of decoupling national economies from energy use and material consumption is evident in many countries, the ecological footprint in the Mediterranean remains above the world average exceeding the region's biocapacity (Global Footprint Network, 2023).

1.3. Objectives of the TDA

The TDA update provide a factual basis towards contributing to the formulation of the next SAP for the Mediterranean Sea and Coasts that will through strategically planning, negotiations and expected follow-up activities, set priorities for the time horizon beyond 2025 to address the priority transboundary problems identified.

The updated TDA will be undertaken by identifying and prioritizing the transboundary problems gathering and interpreting information on the environmental impacts and socio-economic consequences; and analyzing the immediate, underlying, and root causes for each problem, and in particular identifying specific practices, sources, locations, and human activity sectors from which environmental degradation arises or threatens to arise.

CHAPTER 2. TDA Approach

2.1. TDA Methodology

The elaboration and publication of a Mediterranean Sea and Coasts TDA Report should be seen as a follow up of the earlier edition in 2005. Four main phases of different duration between 2021 and 2023 were envisaged aimed to establish a highly collaborative framework as follows:

Phase 1. Set up, structure, and stakeholders' engagement.

Phase 2. Development, analysis, and diagnostic

Phase 3. Review of the TDA pre-publication report

Phase 4. Final layout, multimedia, and publication

Within this Chapter the main steps involved mainly in Phases 1 and 2 (2021-2023) are described. These phases followed the guidelines of the GEF IW TDA/SAP Methodology (October 2020) published by GEF IW:LEARN to undertake the TDA/SAP approach. Here, it is important to mention that the last Phases 3 and 4 for the report review and publication, respectively, was a significant period to be considered and depended basically on the number of stakeholders involved, the LME previous experience (ca. reports) and number of revisions, as well as several financial and managerial administrative tasks. The main timeline approach for the building of the updated Mediterranean TDA Report by 2023 was followed according the CP1.1. Component 2, TDA Update 2.1. workplan to deliver this report.

The Phase 1 (Set up, structure, and stakeholders' engagement) was initiated in March 2021 with the objective to set up the TDA Core Team, as well as the TDA report roadmap (i.e., TDA objectives, milestones and workplan), including the stakeholders engagement strategy. This phase had a duration of about 7 months and included the basic knowledge pooling and first report on prioritization of the transboundary Mediterranean LME concerns (by Plan Bleu). The outcome of the discussions among the TDA Core Team, the MEDPOL, the UNEP/MAP Secretariat and the MedPCU, and the Partner countries concluded at the 1st TDA Steering Committee (SC) Meeting held on the 4th November 2021 with the approval of the roadmap, and therefore, resulted in the initiation of Phase 2.

The Phase 2 (Development, analysis, and diagnostic) period started in November 2021 until March 2023, thus, a total of 17 months. This phase developed all the elements designed and considered relevant for the delivery of a successful Mediterranean TDA Report to fulfil its objective towards the development of a SAP contributing to the Mediterranean LME management beyond 2025. In brief, these were both technical and managerial activities at the same time, namely, the regional consultancies contributions, the UNEP/MAP Plan Bleu Regional Activity Center contributions, the signature and follow up of the SSFA from partner countries, the organization and development national stakeholders' workshops, and the preparation of the TDA Prepublication copy by the end of the phase (March 2023). During the Phase 2 a number of meetings and workshop activities were sequentially undertaken as follows;

• 1st TDA Steering Committee (SC) Meeting, 4 November 2021

• 3x Joint Regional Consultants CCA Meetings (October-December 2022)

• 2nd TDA Steering Committee (SC) Meeting, 13 December 2022

• SSFA TDA Stakeholder Workshops (Albania, Bosnia, Montenegro, Lebanon, Morocco) (December 2022-February 2023)

• PB PCA's Workshop on Climate change Indicators (30 January 2023)

• 3rd TDA Steering Committee (SC) Meeting, 15 February 2023

Finally, the Phases 3 and 4 (Review and Publication, respectively) were initiated in April 2023, and both received the approval of stakeholders involved as well as the UNEP Publication Board, whilst finalized with the Mediterranean TDA Publication (by UNEP/MAP, GEF with Partner Countries contributions) by 2024. The subsections in this chapter describe the main activities achieved related to Phase 1 and 2.

2.1.1. Identification of priority transboundary problems

There was a need to review the TDA published in 2005 as a first stop for developing an updated version for the Mediterranean Sea, however, the follow up context of the environmental governance changes and structures since 2005 were as well useful to identify well-known priority transboundary problems. In parallel, there was both a scientific and policy knowledge pooling phase which focused on recent scientific advancement and programs, including policy achievement to some extent, namely, significant, and relevant progresses with regard the Mediterranean LME to identify the current transboundary problems (ca. 'a priori'). This work was carried over during Phase 1.

The table below indicates the 'a priori' selection of updated transboundary and shared themes in the LME initially developed, divided between transboundary changes (environmental concerns) and challenges (socioeconomic transitions), to allow structuring the TDA process and report and to build an innovative TDA. Further, the new needs for an innovative TDA Report in accordance with current and facts and demands, such as ecosystem integration approaches, gender perspective, marine literacy and digital transitions, sustainable blue economy to mention a few were considered as potential factors (ca. causes) within the 'a priori' transboundary concerns to further depict the LME analysis and diagnostics later on.

The "a posteriori" judgement on the relevant issues was undertaken, through expert discussions; national TDA workshops; also considering the current regional agendas and perspectives of other countries and stakeholders. The linkages between 'a priori' transboundary and shared Mediterranean concerns (ca. environmental changes and challenges) for the elaboration of the TDA 2023 Update Report are explained in Table 3.

Table 2. Linkages between 'a priori' transboundary and shared Mediterranean concerns (ca. environmental changes and challenges) for the elaboration of the TDA 2023 Update Report and relationships with ongoing regional and global environmental governance.

Issues	TDA/SAP changes and challenges in the Mediterranean LME	Related Section in the TDA Chapter 4 report related to the Transboundary Issues	Related CU/RACs	GEF Focal Areas	IMAP related EOs	UNEP MAP MTS 2022-2027	UNEP "Triple crisis"	Green/blue transition targeted pillars
Environmental transboundary issues (changes)	1. Reversing Pollution	4.1. on Land and sea-based chemical, biological and physical pollution in transitional waters, coasts and offshore	CU, MED POL, REMPEC	CW and IW	EO5, EO9, EO10, EO11	1, (6)	Pollution	Environmental
	2. Stopping Litter	4.2. Sources and fate of litter and waste pollution, including coasts and offshore seafloor	CU, MED POL, SCP/RAC (MedWaves)	CW, IW	EO9, EO10	1, (6)	Pollution	Environmental
	3. Enhancing Nature	4.3. on Nature value loss, focusing in marine habitats, biodiversity and ecosystems	SPA/RAC	BD	EO1, EO2, EO3, EO4, EO6	2, (6)	Biodiversity	Environmental
	4. Fighting Climate Change	4.4. on Climate change adaptation, mitigation and socio-ecological resilience	Plan Bleu	CC	EO7, EO8	3	Climate change	Environmental
Welfare transboundary issues (challenges)	5. Sustaining Assets	4.5. on Coastal belts degradation, sustainability and restoration	PAP/RAC	-	(EO8)	4, (6)	-	Social and economic
	6. Switching Livelihoods	4.6. on Socio-economic drivers of transformation, green recovery and sustainable blue finance	SCP/RAC	-	-	1, 4	-	Social and economic
	7. Integrating knowledge	4.7. on Observing infrastructures, including joint IMAP national monitoring data flows, regional and global indicators	CU, MED POL, REMPEC, SPA/RAC, PAP/RAC, Plan Bleu, Info/RAC	CW, IW, BD and CC	All	(6)	All	Social
	8. Boosting Digitalization	4.8. on Environmental digitalization, marine literacy and forecasting research	PAP/RAC, Info/RAC	-	-	(7)	-	Social
	9. Preventing Crises	4.9. on Long-term global regulation affecting the Mediterranean LME	CU Plan Bleu	-	-	5, (6), (7)	-	Social and economic

2.1.2. Causal chain analysis (CCA)

The CCA is the core element of a TDA report (GEF IW TDA/SAP Guidelines, October 2020). To develop the analysis of the causes (ca. a linear sequence of causes) and effects (ca. environmental and economic impacts) of each transboundary environmental concern three joint sessions among the TDA Team, namely the regional consultants, were organized during Phase 2. Initially, included the harmonization of the CCA framework among multicultural expert profiles to ensure the understanding and purpose of the CCA methodology (Figure 9). The transboundary issues identified discussed among regional consultants during 3 joint sessions over October and November 2022 served as an initial framework together with the past, present and future work within the UNEP/MAP system (particularly, MEDPOL) which was a reference for discussions and the elaboration of the CCA diagrams by the regional consultants on pollution, biodiversity, and climate change, with the support of the socioeconomic regional consultant and lead TDA consultant. Together with the Plan Bleu's prioritization report outcome and during the national TDA stakeholder workshops the prioritization of transboundary and shared issues were further consolidated.

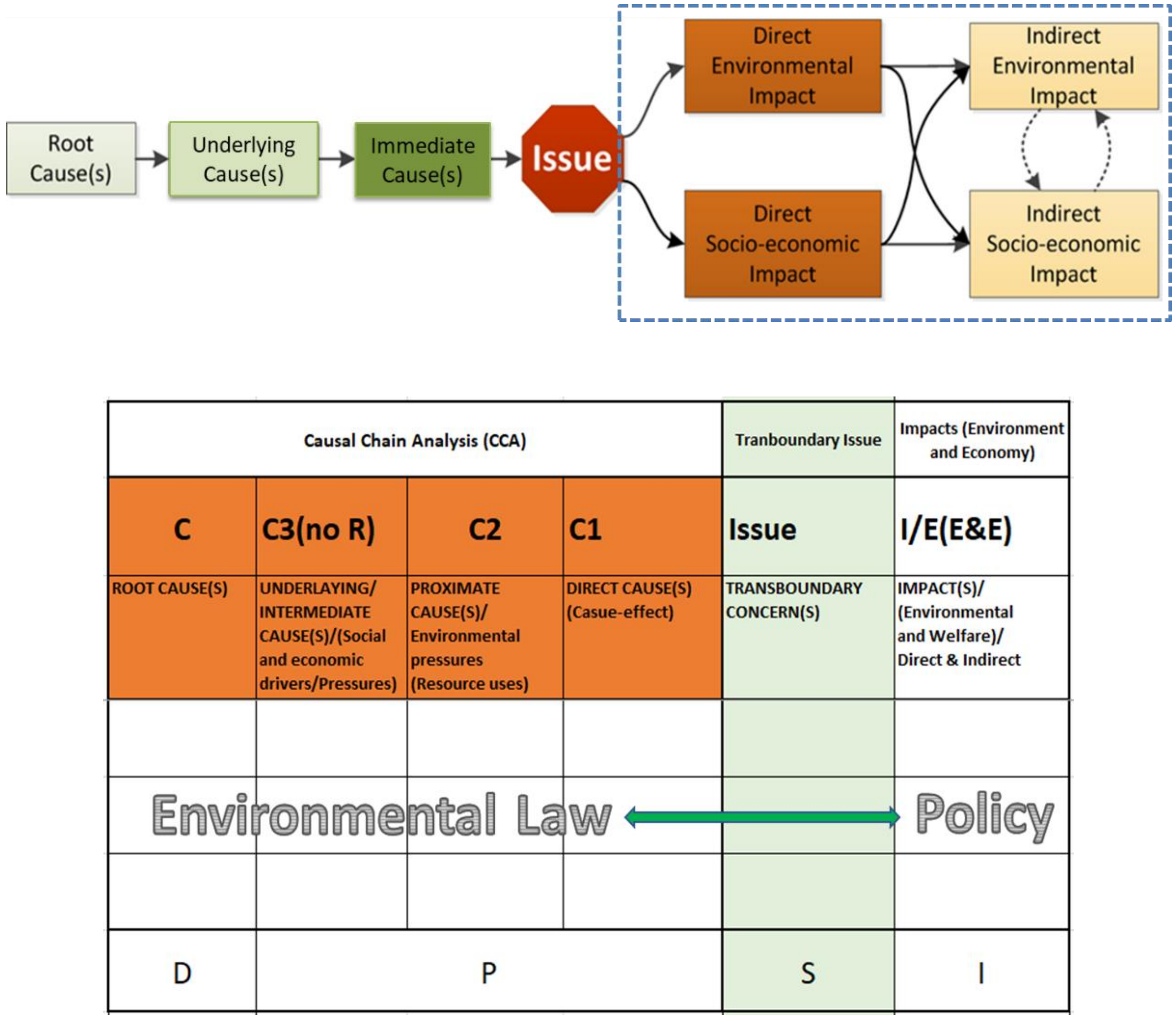


Figure 9. Two simplified schemes of the CCA target elements and relationships of the CCA methodology used in the TDA type-report and comparison with the DPSIR model used mostly in Europe (bottom).

It is worth to mention the slight difference between the DPSIR and the CCA models, which pursue the same objective despite the different methodology and timeline of both processes. Conceptually, the CCA method considers a sequence of causes (e.g., direct, underlaying, root) instead of 'one by default' when compared to the DPSIR, and therefore, providing a more robust cause-effect framework between the so-called Drivers and Pressures in the DPSIR model. This approach in turn, provides a causality path useful in terms of establishing environment law developments and policy actions.

The Figure 10 below shows the CCA practical value. As it can be observed, establishing the balance between different 'environment' issues such as transboundary pollution, biodiversity and climate change concerns and their direct causes, underlaying causes and root causes linked to 'welfare', as well as their relative importance, under a TDA report is a practical way to further elucidate or approximate the most accurate SAP for action. Therefore, through CCA, the TDA is the starting point to develop and depict prioritized transboundary issues towards setting the equilibrium based on risk-based approaches and countries priorities for a SAP implementation (ca. strategic actions).

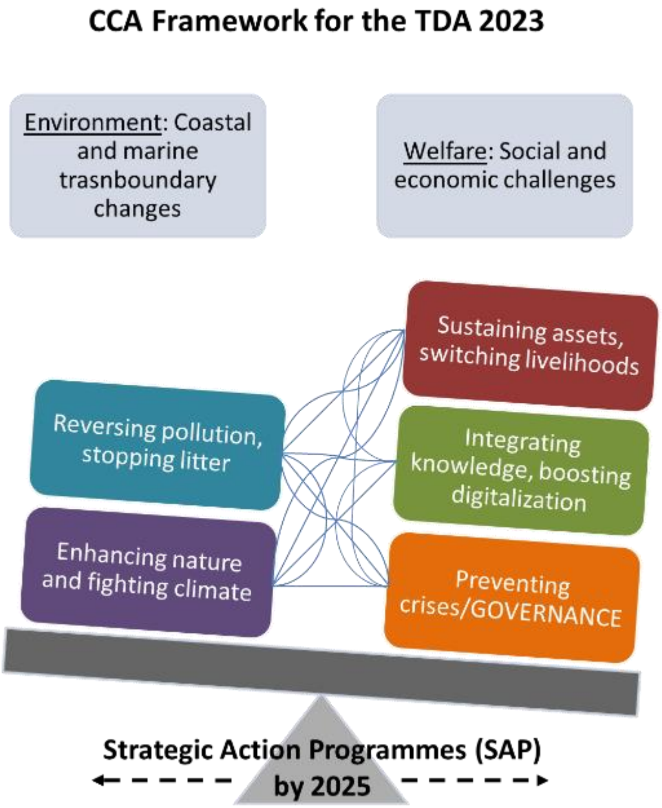


Figure 10. Relationships (CCA-TDA) and balance (SAP) outcomes of the TDA/SAP methodology.

2.1.3. Thematic Assessments

Thematic assessments, at regional and national scales, were undertaken by regional consultants and partner countries of the GEF CP1.1. Child Project under Component 2, respectively. The regional consultants were engaged to develop thematic assessments on pollution, biodiversity, climate change and socioeconomic analysis providing the substantial contribution update of the scientific knowledge at the transboundary level. On the other hand, the partner countries provided their points of view on the '*a* *priori*' transboundary issues by preparing a National Transboundary Assessment Perspectives Reports containing the 6 following synthesis:

1. Land and sea-based chemical, biological and physical pollution in transitional waters, coastal and offshore (Thematic Assessment A)

2. Sources and fate of litter and waste pollution, including coasts and offshore seafloor (Thematic Assessment B)

3. Nature value loss, focusing on marine habitats, biodiversity and ecosystems (Thematic Assessment C)

4. Climate change adaptation, mitigation and socio-ecological resilience (Thematic Assessment D)

5. Coastal belts degradation, socio-economic drivers and restoration (Thematic Assessment E)

6. Observing infrastructures (regional and global indicators), digitalization and marine literacy (Thematic Assessment F)

The countries voluntarily benefited from legal instruments (Small Scale Financial Agreement, SSFA), established to provide the national perspective on the above which included a national stakeholder's workshop organization and participation. The SSFAs were successfully signed by five out of eight countries (Albania, Montenegro, Bosnia and Hercegovina, Lebanon and Morocco) with UNEP/MAP (Implementing Agency of the GEF MedProgramme); whilst for three countries Argelia, Libya and Tunisia was not achieved. More, the information exchanges with Libya were effective over the process, despite the unsuccessful signature and implementation of an SSFA.

2.1.4. Stakeholder analysis

The analysis of stakeholders in the Mediterranean region followed a two-fold approach, namely, within the GEF MedProgramme and the initial knowledge management work (including during the preparation phase of the GEF MedProgramme), as well as during the elaboration of the TDA during Phase 2 and arising mainly from the UNEP/MAP system. As well, at national level, countries revised their networks to prepare of the national TDA stakeholder's workshops. However, the stakeholder's analysis was not meant to be exhaustive but functional primarily, and therefore, the representative organizations and government administrative units were involved.

2.1.5. Governance analysis

Though the UNEP/MAP Secretariat activities for almost five decades, the Contracting Parties of the Barcelona Convention have implemented governance structures for the environmental management of the Mediterranean Sea. These have been refined over time such as in recent years for the implementation of the IMAP framework (the Integrated Monitoring and Assessment Program of the Mediterranean Sea and Coasts). As this, the main regional structure of the UNEP/MAP is included in the present report. Updates on the Mediterranean Sea governance were discussed with the governance unit at the UNEP/MAP Secretariat to provide an overview of the governance structure in the region, as well as the future recommendations to accommodate the effective implementation of the regional programs under the leadership of UNEP/MAP mandated by Contracting Parties.

2.1.6. Prospective studies and scenario analysis

The work under the prospective studies and scenario analysis for the Mediterranean LME was based mainly on scientific conclusions from studies highlighting different potential scenarios related to the transboundary ecosystem changes in the long-term time scale. However, the climate change scenarios were not specifically included as these are well documented in other reports arising from other reports. We suggest the readers interested in deepening on Mediterranean climate change scenarios to follow up on the IPCC[7] (regional) Reports, as well as the MAR1-MedDEEC[8] Report (2020) recently published and dedicated exclusively to the Climate Change and Environment in the Mediterranean region. Similarly, for the socioeconomic scenarios and foresight we suggest the readers to consult the UNEP/MAP Plan bleu SOeD 2020 Report[9]. Within the UNEP/MAP system, the scenario analysis and foresight is a process lead by Plan Bleu, as it was in the TDA 2005, and currently elaborated under its Med2050 framework, which offered an introduction to this Chapter.

2.1.7. Indicators for data driven TDA and SAP implementation

The elaboration of the indicators analysis for the TDA and SAP purposes was undertaken, as it could not be differently, was based on the existing and ongoing UNEP/MAP work to this regard to streamline the outcomes of the TDA report, if possible. There are different indicators sources at different level and for different matters in the regional context primarily driven by the global indicator frameworks implementation, namely the Sustainable Development Goals (SDGs) and the 2030 Agenda, which includes some marine environment indicators under Goal 14. For the Mediterranean Sea, apart from the Integrated Marine and Assessment Programme (IMAP) with 11 Ecological objectives and 27 Common Indicators to describe the status of the coastal and marine environment (except for the climate change and the marine environment relationship), there are also a number of Regional Plans containing indicators, such as the Regional Plan on Sustainable Consumption and Production. Further, on the next level the Mediterranean Strategy for Sustainable Development (MSSD) 2016-2025 provides an integrative policy framework, including a dashboard of fit-for-purpose Mediterranean indicators, to translate the 2030 Agenda for Sustainable development and its 17 goals and the UN SDG Global Indicators Framework to both contribute and align regional and global strategies. A mention was included on the UN WESR (World Environmental Situation Room) initiative, as well as different networks reporting on SDGs in the Mediterranean[10]. Therefore, the indicator frameworks allowed to evaluate the options for the Mediterranean TDA indicators framework considering the ongoing processes and the reality in data availability, management and achievements in the Mediterranean region.

[7] IPCC — Intergovernmental Panel on Climate Change
[8] 1st Mediterranean Assessment Report (MAR1): main results - MedECC
[9] SoED 2020 : State of Environment and Development in Mediterranean - Plan-bleu : Environnement et développement en Méditerranée (planbleu.org)
[10] Documents – SDSN Mediterranean (unisi.it)

CHAPTER 3. Baseline information on the Mediterranean region

3.1. Geographical scope

3.1.1. Mediterranean region

The Mediterranean Sea was delimited internationally as composed of two main basins, as early as mid-20th century by the International Hydrographic Office (IHO) who established the specific geographical coordinates that divides the Western and Eastern Mediterranean Sea basins along other internal basin delimitations, such as the Alboran Sea, the Adriatic Sea or the Ionian Sea (IHO, 1953). These geographical divisions evolved whilst turning regarding environmental affairs into four main sub-basins or ecoregions (ca. Western, Adriatic, Central and Aegean-Levantine basins) in the Mediterranean Sea, beyond navigation purposes, for the accommodation of the science-policy marine matters over the last quarter of the 20th century under the work of UNEP/MAP and continues until today supporting the environmental governance in the Mediterranean Sea (Figure 11).

Visual LME GEOMAP n°3 (Figures 11, 12, 13, 14 and 15)

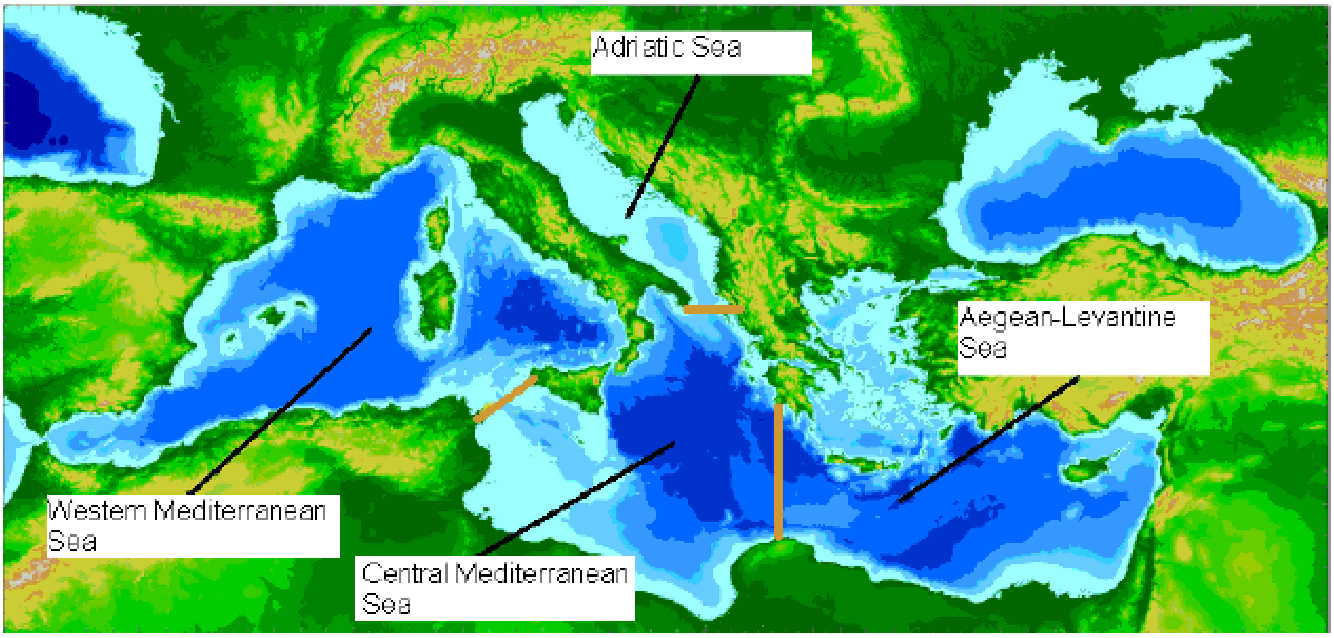
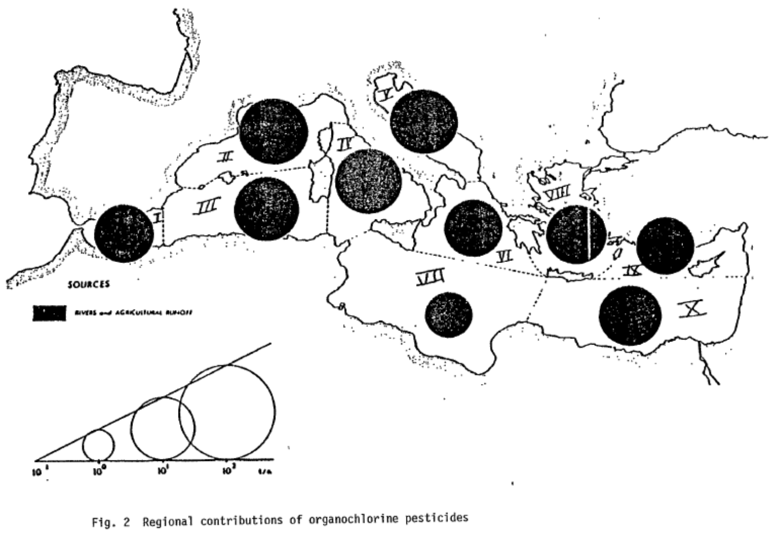
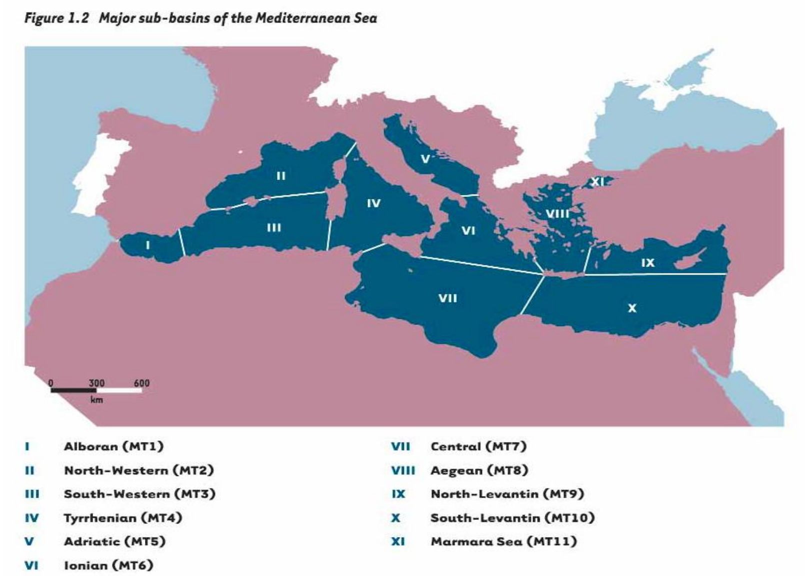


Figure 11. Four main ecoregions by UNEP/MAP

This TDA report continues to consider the subdivisions of the previous TDA published in 2005 which followed the MEDPOL divisions used in the pollution assessments since the 90s (MTS, 1990) (Figure 12). This subdivisions within the four ecoregions have been used as well in research publications, regional studies and policy assessments which required a higher resolution geographical scale perspective to allow effective environmental regional management (ca. nested approach).



Map A. The 10 MEDPOL subregions in the Mediterranean Sea (Source: UNEP/FAO/WHO/IAEA, 1990).



Map B. The TDA 2005 Mediterranean subdivisions presented (including the Marmara Sea).

Figure 12. MEDPOL subdivisions of the Mediterranean ecoregions (UNEP/MAP) since the 90s (A) and used in the TDA 2005 (B) and in the present report (Mediterranean Pollution Program, UNEP/MAP)

From a closer marine sciences perspective using a combination of the oceanographic features, biodiversity distributions and ecosystems within the coasts, nearshore and offshore areas (e.g., circulation patterns, climatic features, related habitats and species, etc.), the geographical scope of the Mediterranean Sea can be further divided in different sub-basins (ca. seas) or ecoregions. There have been refinements of the above UNEP/MAP 4 ecoregions of the Mediterranean Sea (Figure 11) in 7 ecoregions (Spalding et al., 2007), 8 ecoregions/biogeographic regions (Notabartolo di Sciara and Agardy, 2010; Giakoumi et al., 2013, Figure 13), and so on; however, it is important to state that in the majority of cases, disregarding the variables under study, the UNEP/MAP 4 ecoregions model of the Mediterranean Sea or the 10 MEDPOL divisions are always present within newer both science and policy research and assessments, respectively. A few exceptions exist for specific investigations or purposes, such as in Ciavatta et al. (2019) which presented an ecoregions model based on a reanalysis study of different phytoplankton functional sizes proposing a different regional division model for the Mediterranean Sea. In the same line, the FAO-GFCM divisions in the Mediterranean Sea corresponding to economic and statistical purposes (ca. fishing areas and catches) has been also a formal fit-for-purpose regional division of the Mediterranean basin (Figure 2, Chapter 1). There have been no substantial revisions or proposed amendments disregarding a few specific studies.

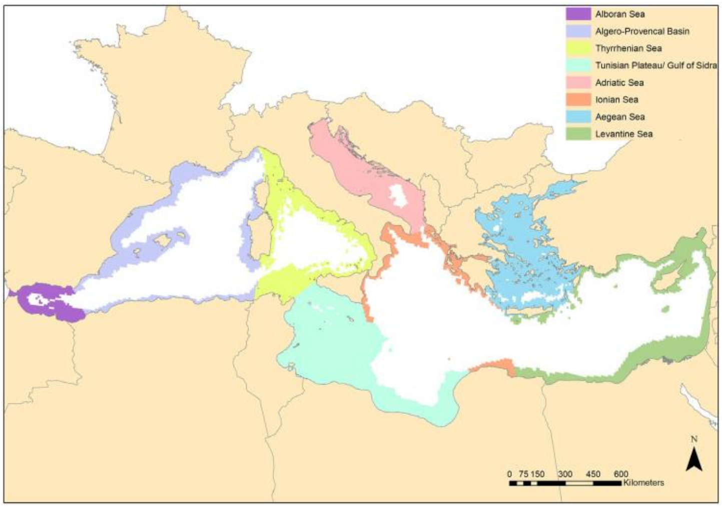


Figure 13. Biogeographic subdivisions of the Mediterranean Sea (in: Giakoumi et al. 2013, and references therein). It can be observed the 8 regions match with the proposed MEDPOL divisions for pollution studies, excluding the Northwestern Mediterranean and the Levantine Seas north-south split up which is not present, and therefore, 8 regions instead of 10.

In fact, the original 10 MEDPOL subdivisions of the Mediterranean basin are well in accordance with some recent authors that reviewed the chemical pollution with investigations mainly related to legacy pollution sources and their occurrences allowing to establish correlations between causes and effects of land-based sources of anthropogenic pollution (Merhaby et al. 2019). Further, the anthropogenic pollution in the Mediterranean Sea region can be clearly differentiated between coastal and offshore areas, where there is a greater variability for the former in terms of the main rivers discharges, subregional and climate characteristics, coastal morphologies, etc. In Merhaby et al. (2019) the authors used the 10 subdivisions of the Mediterranean Sea (Figure 14) pairing the MEDPOL divisions in the 90s also used in the Mediterranean TDA 2005 as seen above.

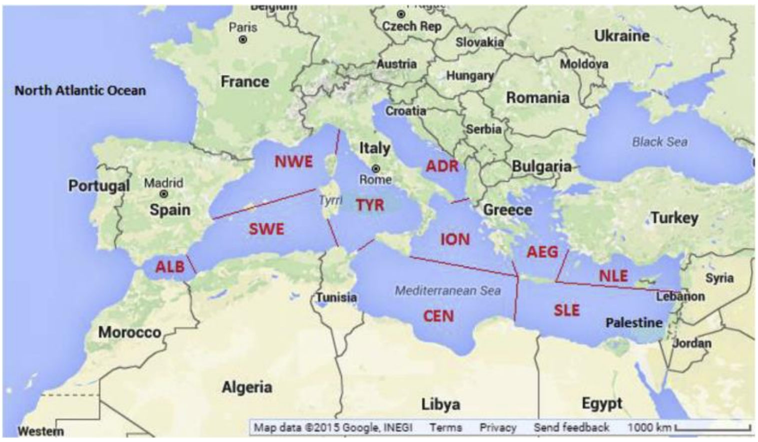


Figure 14. UNEP/MAP/MEDPOL divisions spawn over three decades for pollution and environmental studies in the Mediterranean Sea (in Merhaby et al. 2019)

As this, the 4 UNEP/MAP ecoregions used for the science-policy matters have embedded the 10 subregions (ca. MEDPOL divisions) and allow lower scales (ca. high resolution studies) whilst keeping a nested approach. For example, the Adriatic Sea is also commonly subdivided in three zones: the North, Central and south Adriatic Sea. Similarly, the Central Mediterranean subregion in two: the Tunisian Plateau (Gulf of Gabes) and the Gulf of Sidra, and so on, and these all fit with the current UNEP/MAP ecoregions.

Concluding, the regional geographical scope within this updated TDA report covers the entire basin, and utilized the 10 MEDPOL subdivisons of the Mediterranean Sea as in the previous TDA publication in 2005, which in turn respects the 4 UNEP/MAP ecoregions divisions acknowledged by the European Union-EEA (Figure 15) and the UNEP/MAP-Barcelona Convention system providing a nested approach necessary to effectively manage and conserve the environmental resources according to the policy strategies and governance structures agreed in the region (note a slight difference between the EU and UNEP/MAP divisions is the trace from Libya to Crete instead of the trace to the sourthen Greek coast (parallel to meridians). Despite this might seem not very relevant, the clarity and consensus to this regard is fundamental to maintain the alignment of the science, socioeconomic and environmental understanding, knowledge, and policy actions; not to mention the upcoming full implementation of the marine spatial planning (MSP) in the Mediterranean Sea.

Figure 3.4.1 The Mediterranean Sea region with four sub-basins.

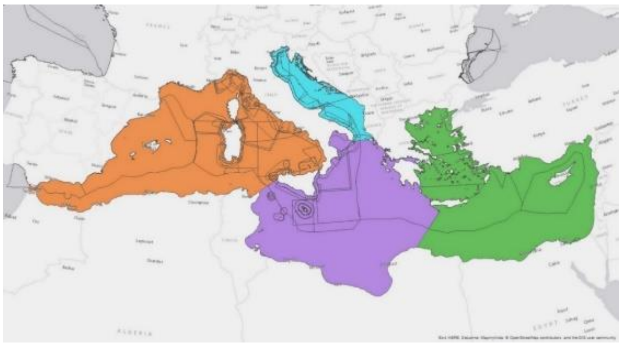


Figure 15. The European Union area (colored left) and subdivisions of the Mediterranean Sea (colored right) under the EU MSFD.

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Notarbartolo di Sciara and Agardy, 2010. Overview of scientific findings and criteria relevant to identifying SPAMIs in the Mediterranean open seas, including the deep sea. Tunis: UNEP-MAP. 1–71 p.

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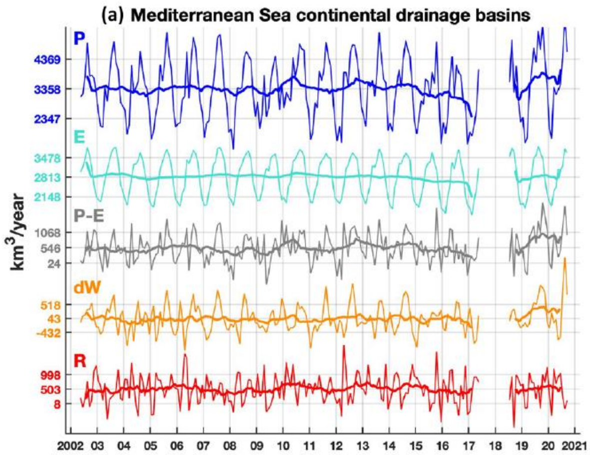
Merhaby et al., 2019. Overview of sediments pollution by PAHs and PCBs in 50rea50onment50l basin: Transport, fate, occurrence, and distribution. Marine Pollution Bulletin, 149. https://doi.org/10.1016/j.marpolbul.2019.110646

3.2. Characteristics

3.2.1. Hydrological cycle (atmospheric and marine systems)

The hydrological cycle and water balances in the Mediterranean region responds to the combined dynamics of the atmospheric, continental, and marine systems in a steady-state equilibrium with a great external influence of the North Atlantic Oscillation (NAO), and the Atlantic Meridional Overturning Circulation (AMOC) (García-García et al., 2022), in the northwestern part of the Mediterranean area. These results in a very well established yearly seasonal cycles, and variability, in the Mediterranean Sea basin. The marine component (ca. marine ecosystem) of the hydrological cycle is highly dependent on the input through the Gibraltar Strait, followed by the continental water flows into the basin (ca. rivers), and the Black Sea flow into the Mediterranean Sea in third place. Despite, discrepancies among authors to estimate the net water flux exiting the basin point to different air-sea fluxes parametrizations (Mariotti, 2002 and references therein), and ranging from 650 mm/yr up to 1230 mm/yr rates for the so-called Mediterranean Water Deficit (MWD) caused by evaporation (plus the atmospheric moisture divergence), which has been estimated approximately equal to the water flux at the Gibraltar Strait. Recently, according to García-García et al., (2022), the MWD is only about 60% of the water flow input through the Gibraltar Strait being the total river discharges into the Mediterranean Sea estimated at 504±36 km3/yr (Figure 16, P (Precipitation), E (Evaporation), P-E (PE Balance), dW (water mass budget variations), R (G (Mediterranean Sea inflows)). The climatological (ca. decadal) river discharges into the Mediterranean Sea have been largely studied using models, such as the Mediterranean Hydrological Cycle Observing System (MED-HYCOS) and the Global Runnoff Data Center (GRDC) models for the 67 rivers altogether covering a 76% of the catchment area in the Mediterranean basin, approximately, as early as in the 90s. Despite variable total river water flow inputs, the trend of the overall MWD is estimated to have increased up to a 24% considering the longer period dataset of 50 years from 1948-98 (Mariotti, 2002).



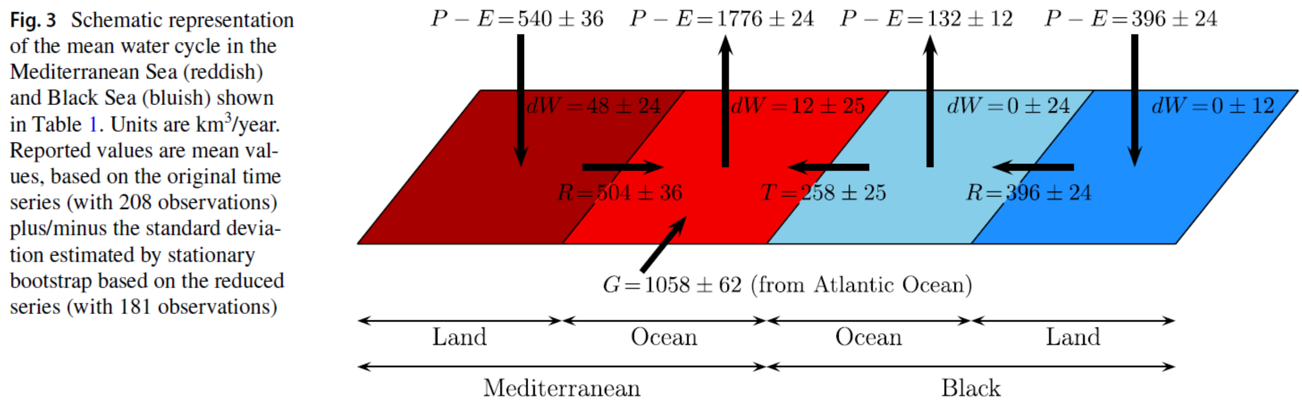


Figure 16. Mediterranean water flux balances and related parameter trends (García-García et al., 2022).

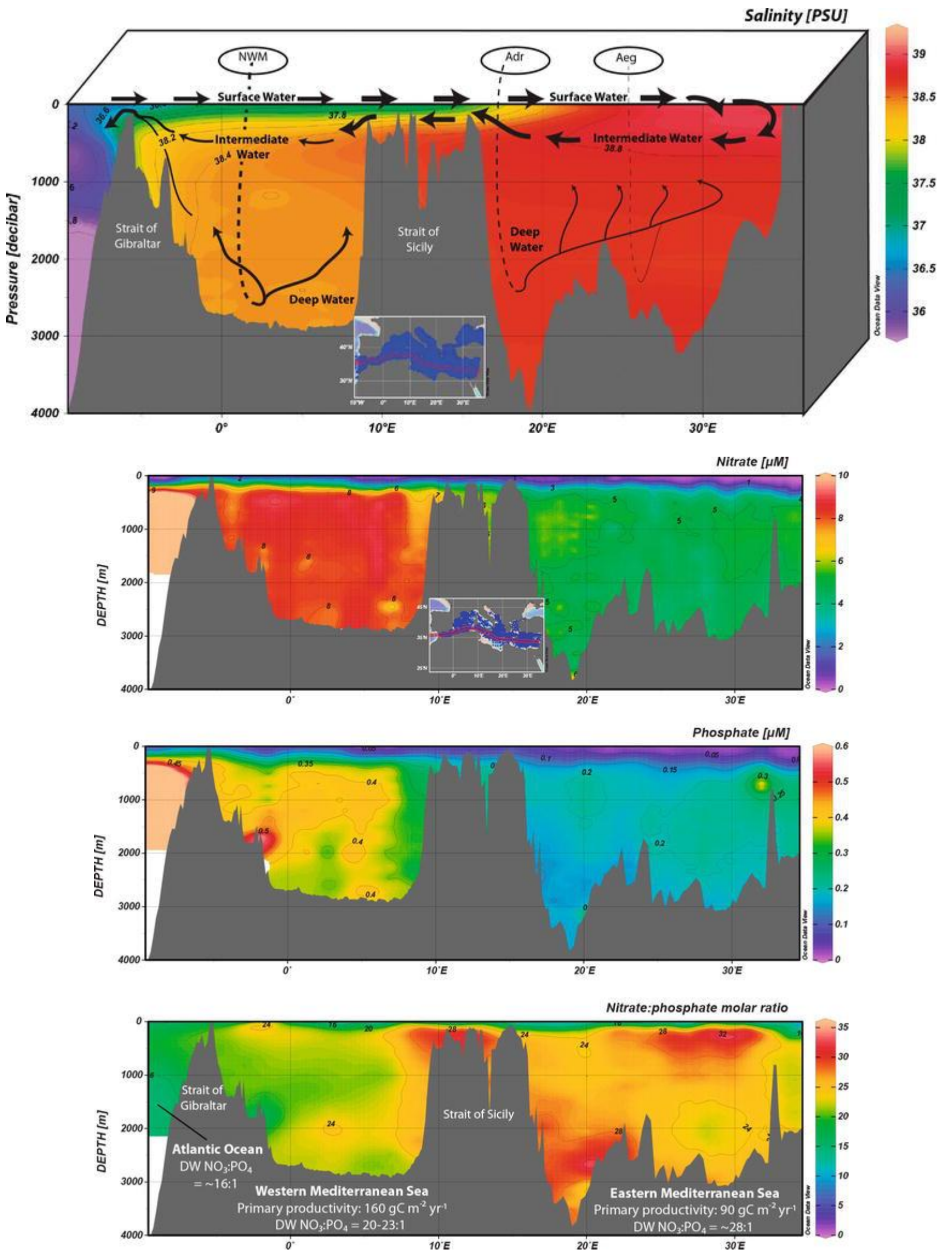


Figure 17. Natural biogeochemical characteristics of the Mediterranean Sea with contribution of the oceanographic processes and showing the nitrate: phosphate larger ratios 20-30:1 (the so-called Redfield standard 16:1 ratio) and primary productivity (Powley et al., 2017).

The hydrological cycle over the Mediterranean examined from a holistic perspective, and therefore, including all the ecosystems in the region, namely within terrestrial, atmospheric, coastal and marine areas as described above, are the main components of the biosphere that outline the characteristics of the Mediterranean region, and thus, the biogeochemical and essential composition characteristics of the Mediterranean Sea. The Figure 17 (Powley et al., 2017) show the main features in terms of essential chemical compounds (ca. nutrients) for the two main Mediterranean basins (Western and Eastern) and from surface to deep waters.

Contrarily to the most known marine environments the Redfield ratio in the Mediterranean Sea is higher, up to 28:1 ($NO3:PO4$) in the Eastern basin, and therefore, the Mediterranean Sea is known to be limited by phosphates rather than nitrates (Lazzari et al., 2016), except for the area closer to the Atlantic Ocean (as shown in Figure 17). The marine geochemistry of the Mediterranean Sea which sustain its marine biodiversity and ecosystems in first place is dependent on the maintenance of the correct balances among the different natural environments surrounding the basin which are subject to multiple pressures from an anthropogenic origin (e.g., environmental degradation caused by pollution, intensive agriculture and land-use changes, marine resources overexploitation to mention a few), as well as incidents from natural origin (e.g., fires and volcanic activity).

Beyond the relevance and functions of the atmospheric processes in the hydrological cycle functioning across the Mediterranean region with a clear precipitation pattern over land and sea, the atmosphere maintains the larger weather conditions and characteristics at subregional level, and therefore, the atmospheric phenomena (e.g., mesoscale winds), beyond the climatic features. To this regard, it is important to mention the southern dry winds over the north African continents which are well known due to their transport of atmospheric dust and dry deposition processes in the northern regions which is clearly a transboundary mechanism. The fact that the atmospheric dust concentrations are transported far away from their sources implies that the concentration of potentially harmful substances is equally transported, as anomalies have been observed in monitoring coastal station in Corsica and Sardinia. In Figure 18 and Figure 19, two examples illustrate the transboundary concerns of the atmospheric system over the Mediterranean Sea coastal and marine atmosphere, namely the aeolian dust transport (Kotinas and Poulos, 2021) and radioactive particle transport (Thébault et al., 2008), respectively.

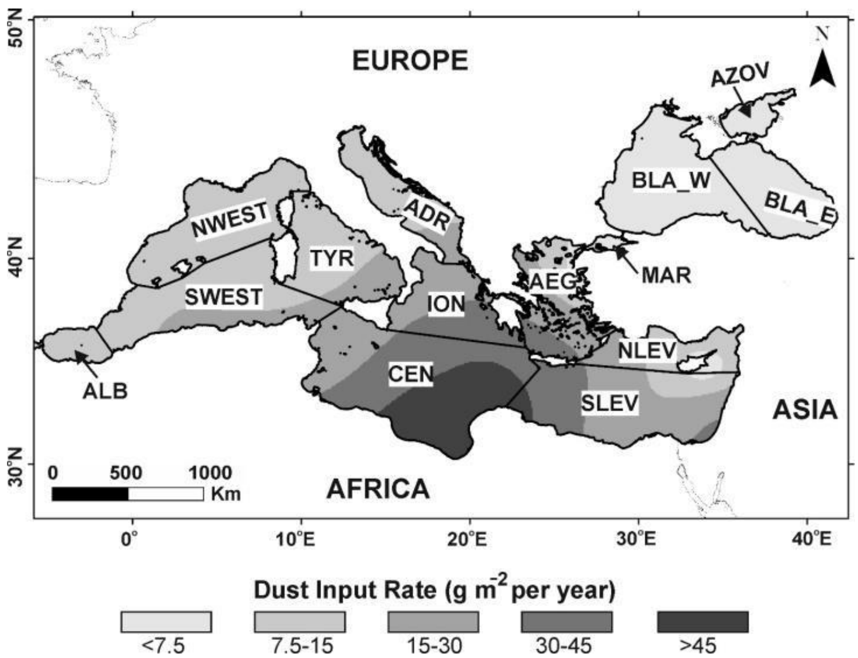


Figure 18. Fluxes of atmospheric dust inputs in the Mediterranean basin (Kotinas and Poulos, 2021).

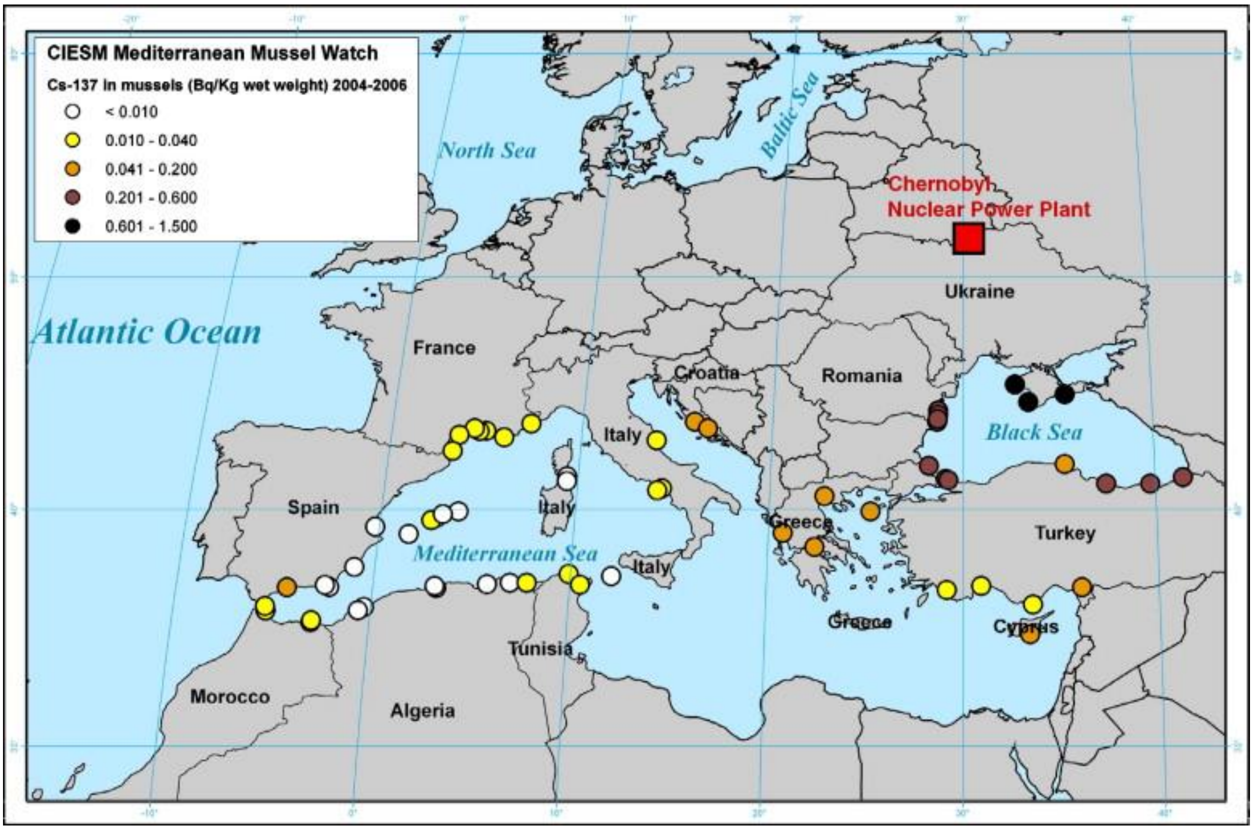


Figure 19. Small Cesium 137 activity (after Chernobyl incident) recorded in a large-scale study in the Mediterranean Sea years after the incident (Thébault et al., 2008).

3.2.2. Watersheds (drainage basins) and surface water flows

Wang and Polcher (2019) have recently examined the continental water flows into the Mediterranean Sea (569±149 km3/yr) with datasets from 1980-2013 using the land surface FOG model and pointed to earlier underestimated discharges of continental water flows as result of a large number of unmonitored coastal basins and groundwater discharges. Historically the total flow into the Mediterranean Sea ranged between 256 to 328 (km3 per year) by Mariotti (2002) to over the approximate value of 500 km3/yr; for example, 550 km3/yr (Poulos, 2011) and 504±36 km3/yr (García-García et al., 2022). However, Margat and Treyer which accounted also for submarine groundwater discharges (UNEP/MAP, 2004) and a few other authors had similar flow estimations as recently published in Wang and Polcher (2019) (Table 4). Noticeably, Wang and Polcher (2019) assessed the mean freshwater flows and trends at the 10 Mediterranean subdivisons in this report and including the Black Sea (Table 4).

However, the uncertainties remain related to the hydrological cycle in the Mediterranean and the river water flows as the monitoring stations in land, cover the major drainage basins but disregard minor rivers, which in turn are markedly more affected both by anthropogenic pressures (e.g., water abstraction) and climate change variability. Further, the current variable climatological patterns and the decreasing availability of river flow monitoring datasets (Mariotti, 2002) could make the mathematical uncertainties increase, and therefore, posing a high risk for the mismanagement of the watersheds and surface water flows as a whole.

Table 3. Mean freshwater inflow and decadal trends (including climatic trends considerations) into the 10 Mediterranean basins subdivisions with the Black Sea. Wang and Polcher (2019).

Basin	Mean freshwater inflow [km^3/y]	Total trend [$km^3/y/10y$]	Climatic trend [$km^3/y/10y$]	Non-climatic trend [$km^3/y/10y$]
Alboran (ALB)	14 ± 4	**1.77 (24/30)**	1.60	**0.18** (2/30)
South Western (SWE)	32 ± 20	0.80 (6/30)	0.75	0.05 (2/30)
North Western (NWE)	117 ± 51	−2.99 (6/30)	−4.46	1.37 (3/30)
Tyranian (TYR)	57 ± 11	−0.38 (0/30)	−0.33	**−0.05** (6/30)
Adriatic (ADR)	125 ± 31	**−8.02 (19/30)**	−5.53	−2.49 (7/30)
Ionian (ION)	46 ± 5	1.09 (0/30)	−1.10	−0.01 **(20/30)**
Central (CEN)	28 ± 0.3	−0.24 (0/30)	−0.21	**−0.03** (3/30)
Agean (AEG)	70 ± 18	0.91 (0/30)	1.03	**−0.12 (30/30)**
North Levantine (NLE)	54 ± 3	−3.15 (2/30)	−0.99	**−2.17 (26/30)**
South Lenatine (SLE)	25 ± 6	−0.22 (0/30)	−0.195	**−0.02** (4/30)
Black Sea (BLS)	367 ± 61	0.56 (0/30)	3.88	−3.32 (7/30)

Table 2. Mean freshwater flux and its trend over the 11 sub-basins from 1980 to 2013. The underlined bold numbers indicate a significant trend in FOG at the 5% confidence level for the Mann-Kendall test. The numbers in parentheses indicate the numbers of the ensemble members in which a significant trend is detected. A bold font is used when FOG displays a significant trend or a majority of the members are in this case.

The Mediterranean watersheds and their water systems flowing seawards (e.g., lakes, rivers, transitional waters through coastal lagoons, aquifers, wetlands, and marine water bodies) are key to maintain the biogeochemical cycles in the coastal and marine environments. Further, the formation and evolution of many of the coastal zones are basically dependent on the external geophysical processes occurring by means of water flows and sediment fluxes, namely sediment transport and both deposition and erosion processes combined with the marine climate dynamics. A clear example of these morphologies and ecosystems are deltas (e.g Ebro delta, Nile delta, etc.).

At molecular level the importance of the water flows are the distribution and transport of substances (ca. essential nutrients and microelements) from the major continental ecosystems to the marine system according to their physicochemical characteristics. This is fundamental to sustain different habitats, trophic levels and species. It is worth to point out to this regard the long known and assessed impact of river damming in the continental water systems in the Mediterranean region which have estimated a reduction by 40% of the freshwater fluxes in the past decades (Poulos, 2011 and Poulos, 2020) and is also expected the total freshwater discharges to be further affected due to climate change effects.

The recent study of Poulos (2019) investigates the riverine freshwater, suspended and dissolved sediment loads and provides a knowledge update for the Western, Central (including the Adriatic Sea) and Eastern subregions of the Mediterranean Sea, whilst describing both the catchment and marine areas of the 10 subdivisions of the Mediterranean Sea, including the Black Sea (Table 5, Figure 20). The so-called Mediterranean Sea and Black Sea Earth System (MBES) or Marine System (MBMS) is a single unit in this author's update as there is a clear link between the two seas connected through the Marmara Sea (Poulos, 2019 and 2020), as well as recently considered in the Mediterranean water flux balances (García-García et al., 2022) which also included the Black Sea as a fundamental water source to the Mediterranean Sea.

Table 4. Areas of the catchments and marine surface for each division. Poulos (2019).

Table 1. Sea surface area (SSA) and catchment area (CA) for all the marine regions of the MBES (for acronyms see text).

		SSA (km^2)	CA (km^2)
ALB		54,173	90,000
	WEST_N	*258,300*	*303,000*
	WEST_S	*316,727*	*185,000*
WEST		575,027	488,000
TYR		212,500	74,000
WMED		841,700	652,000
ADR		140,320	229,000
ION		197,980	70,400
CEN		**573,990**	306,000
CMED		912,290	605,400
	LEV_S	*420,000*	*3,045,000*
	LEV_N	*140,588*	*114,600*
LEV		560,588	3,159,600
AEG		**192,026**	240,000
MAR		**11,887**	40,000
EMED		764,501	3,439,600
MED		**2,518,491**	**4,697,000**
	BLA_E	*161,340*	*83,615*
	BLA_W	*260,895*	*1,724,385*
BLA		**422,235**	1,808,000
AZOV		**41,274**	590,000
BLS		**463,509**	**2,398,000**
MBES		**2,982,000**	**7,095,000**

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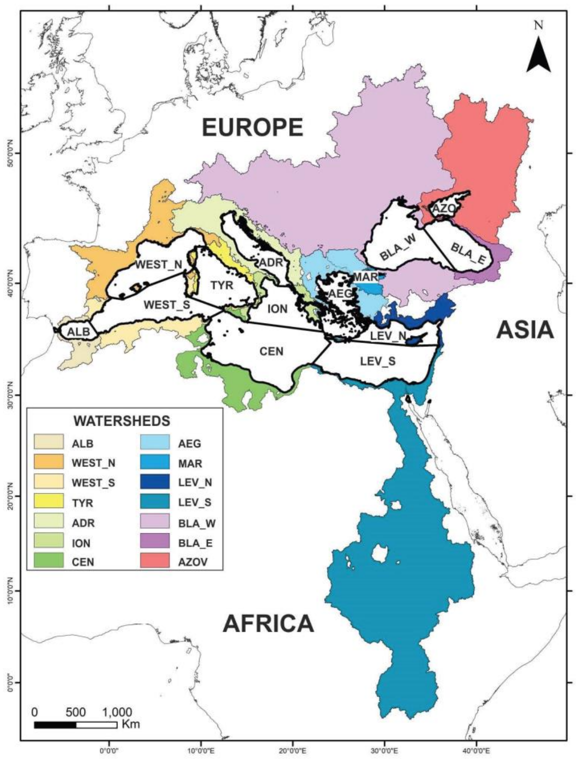
There are 27 major water river systems flowing into the Mediterranean Sea as shown in Figure 20 with catchments larger than 10E4 km2 and 12 in the Black Sea (Poulos, 2019). It is important to mention as seen earlier that the Mediterranean and Black Seas form a unique water system regarding the water balance. Poulos (2019 and 2020) consider the Mediterranean and Black Seas Earth System or Marine System (MBES or MBMS) to highlight the geographical scale and connection of the two basins, where there is a net flow from the Black Sea to the Mediterranean Sea of 255± 25 km3/yr (García-García et al., 2022).



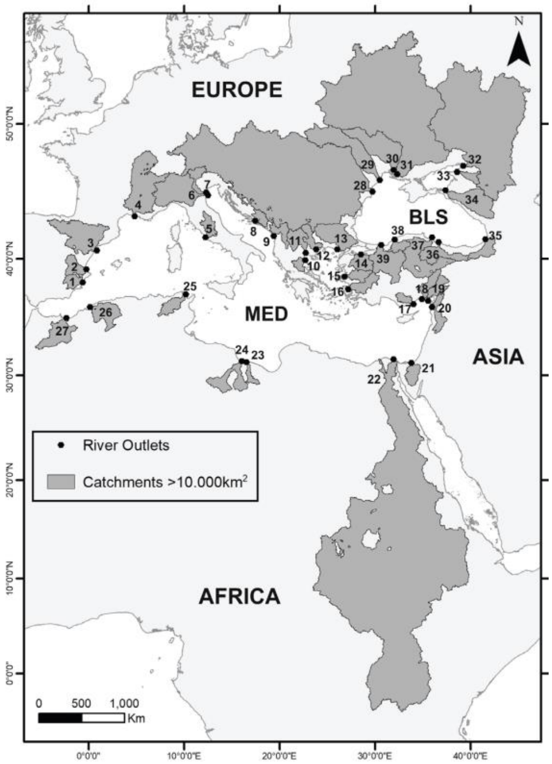


Figure 20. MBES/MBMS watersheds (top) and those extending to more than 10,000 km2 (bottom).

(1: Segura; 2: Jucar; 3: Ebro; 4: Rhone; 5: Tiber; 6: Po; 7: Antige; 8: Neretva; 9: Drin; 10: Pinios; 11: Axios; 12: Strimonas; 13: Evros; 14: Simav; 15: Cediz-Nehri; 16: Büyükmenderes; 17: Goksu; 18: Seyhan; 19: Ceyhan; 20: Asi (Orontes); 21: Wadi el Arish; 22: Nile; 23: Wadi Tamit; 24: Wadi Baey al Kabir; 25: Mejerda; 26: Moulouya; 27: Chelif; 28: Danube; 29: Dniester; 30: Southern Bug; 31: Dnieper; 32: Don; 33: Rioni; 34: Kuban; 35: Chorokhi (Goruh); 36: Yesilirmak; 37: Kizilirmak; 38: Filyos; 39: Sakarya). (Poulos, 2019). More recently, Poulos (2020) presented recently the most comprehensive update on the major catchment basins with rivers flowing into the Mediterrranean Sea (catchments larger than 10E4 km2) along their estimated sediment fluxes and showing including the reduction in flows after damming (Table 3.2.4).

Table 5. Annual estimated freshwater and sediment fluxes into the Mediterranean and Black Seas (Poulos, 2019).

Appendix A

Table A.1
Rivers with catchment basins > 10^4 km^2 and their annual natural freshwater and sediment fluxes into MBMS; reduced inflows after damming are shown in parentheses.

	River – Country of river mouth	Catchment Area (km^2)	Water flux (km^3/year)	Suspended Sediment Load (x 10^6 tons)	Dissolved Sediment Load (x 10^6 tons)
Mediterranean basin					
1	Segura (ES) [1,2]	19,525	3.1	1.1	n/a
2	Jucar or Xïquer (ES) [3,1,4]	22,084	4.5 (1.2)*	0.8	1.0
3	Ebro (ES) [1,4,2]	85,835	50 (17)*	18 (1.5)*	9.0
4	Rhone (FR) [4,1,2]	96,000	54	59 (6.2)*	17.0
5	Tevere or Tiber (IT) [4,1,2]	17,000	7.4	7.5 (0.33)*	5.9
6	Po (IT) [1,2]	54,290	46	15 (10)*	15.2
	Adige (IT) [1,2]	17,000	7.3	1.6	1.6
7	Neretva (HR) [1,2]	13,000	12	13.6	5.3
8	Drin (AL) [4,1,2]	19,582	21.4	21/2.1	n/a
9	Pinios (GR) [4,11,5]	10,750	3.8/2.4	n/a	n/a
10	Axios (Vardar) (GR) [4,1,10,5]	23,747	5.3/7.7	11	1.7
11	Strimonas (GR) [2,1,5,11]	16,816	5.2/2.8	4.0	1,5
12	Evros or Meric (GR-TR) [6,1,5,7]	53,025	8.12	8.5	2.6
13	Simav (TR) [8,9]	23,765	4.55 (3)*	0.88 (0.44)*	1.2
14	Cediz-Nehri (TR) [1,2]	18,000	2.3	1.3	3.7
15	Büyükmenderes (TR) [1,2]	25,000	4.7	0.8	3.4
16	Goksu (TR) [6,1,2]	10,561	4.7 (3.1)*	2.5	n/a
17	Seyhan (TR) [1,4]	22,000	8	5.2 (0.1)*	1.3
18	Ceyhan (TR) [1,4]	21,000	7	5.5 (4.8)*	2.0
19	Asi or Orontes (TR-SY) [1]	23,000	2.7	19 (0.36)*	1.0
20	Wadi el Arish (EG) [1]	19,000	n/a	n/a	n/a
21	Nile (EG) [1]	2880,000	90.3 (30)*	120 (0.2)*	6.1
22	Wadi Tamit (LY) [1]	18,000	n/a	n/a	n/a
23	Wadi Baey al Kabir (LY) [1]	36,000	n/a	n/a	n/a
24	Medherda (TN) [1,4,2]	22,000	0.9	9.4	15.1
25	Moulouya (MA) [4,1,2]	51,000	1.6 (0.2)*	12.0 (0.8)*	12.8
26	Cheliff (DZ) [1,4]	44,000	1.3	4.0	n/a
Black Sea basin [12,1]					
27	Danube (RO)	817,000	200	87.8 (51.2)*	80.0
28	Dniester (UA)	72,100	10.2 (9.1)*	2.5 (1.7)*	6.1
29	Southern Bug (UA)	63,700	2.2	0.2	n/a
30	Dnieper (UA)	503,000	53 (43.5)*	2.1 (0.8)*	15.0
31	Don (RU)	422,000	28	7.8	12.0
32	Kuban (RU)	63,500	12.8	8.4	n/a
33	Rioni (GE)	13,400	9.6	3.4	2.8
34	Chorokhi or Goruh (GE)	22,100	8.7	8.4	n/a
35	Yeshil Irmak (TR	36,100	5.3	12.5 (0.3)*	1.0
36	Kizil Irmak (TR)	78,600	5.9	16.7 (0.4)*	5.5
37	Filyos (TR)	13,100	2.9	3.7	n/a
38	Sakarya (TR)	56,500	5.6	4.6 (3.8)*	2.9

References. 1: Milliman and Farnsworth (2013) and references herein; 2: UNEP/MAP/MED_POL (2003); 3: Eurosion (2004); 4: Poulos and Collins (2002) and references herein; 5: Skoulikidis (2018); 6: Skoulikidis and Kondylakis (1997); 7: Karditsa and Poulos (2013); 8: CIESM (2006); 9: Okay and Ergün (2005); 10: Med-Hycos (2001); 11: Poulos et al. (1996); 12: Jaoshvili (2002) and references herein.
Country's abbreviations. ES: Spain; FR: France; IT: Italy; HR: Croatia, GR: Greece; AL: Albania; BG: Bulgaria; RO: Romania; UA: Ukraine; RU: Russia; GE: Georgia; TR: Turkey; SY: Syria; EG: Egypt; LY: Libya; TN: Tunisia; DZ: Algeria; MA: Morocco.
*values after damming

The Mediterranean watersheds are characterized by the presence of the megasized Nile River and the absence of very large (10E5-10E6 km2) river catchments (Poulos, 2019 and 2020). Nevertheless, it is noticeable a data gap related to the total water flows into the Mediterranean arising from the Mediterranean catchments lower than 10.000 km2 which represents about 15.6% of the total catchment area of the Mediterranean region and up to a 41%, excluding the Nile River catchment from the calculations (Poulos, 2011 and references therein). Therefore, there is a non-accounted surface water from a regional management perspective with an unknow yearly flow input of potential transboundary interest (Figure 21). The majority of these rivers are monitored at national level and are not included in the total accounts of both the hydrological and biogeochemical cycles in the Mediterranean Sea at regional scale, despite these are largely distributed and exposed to the current socioeconomic demands.

Figure 21. Layers for rivers (AQUASTAT. Assessments are majorly made for only the 85% of the larger catchment areas, inlcuding the Nile River catchment.

The unknows regarding lower catchments surfaces are being investigated at high resolution (ca. local studies) because there is an increasing pressure on freshwater resources and these are predicted to worsen due to climate change effects, such as in the Maghreb region. In a recent research publication by Sadaoui et al. (2018) in the Mediterranean Maghreb Basin (MMB) shared between Morocco, Algeria and the north of Tunisia many rivers and their dams and reservoirs have been (manually) integrated to model the dynamics of the sediment transport into the MMB by means of a novel methodology and using geospatial tools (Figure 22) . This is a pioneering and highly multidisciplinary work to understand and towards effective management an incorporates the use of digital technologies (Sadaoui et al. 2018).

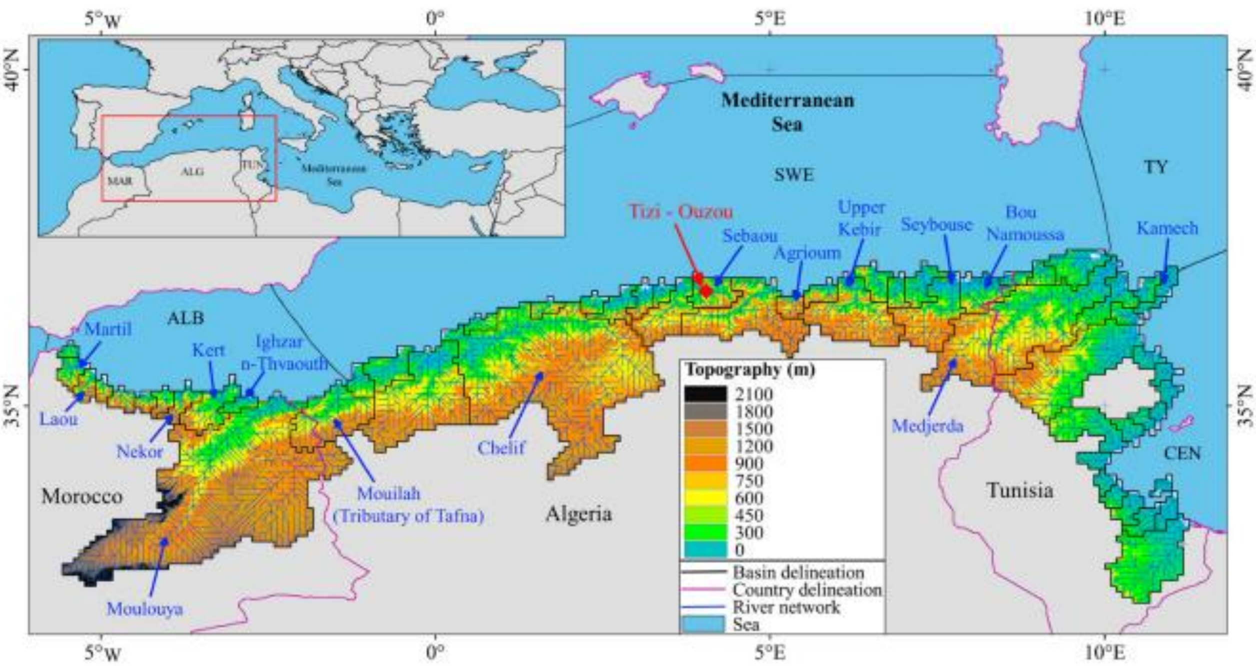


Figure 1. Location map of the Mediterranean Maghreb Basin (MMB) and delimitation of its drainage basins at a spatial resolution of 5 arc-minutes. Topography was extracted from the digital elevation model of [16]. All rivers and locations which are mentioned in the text have been included in this figure. Abbreviations: ALB: Alboran sub-basin, CEN: Central sub-basin, SWE: Southwestern sub-basin, TY: Tyearrhenian sub-basin.

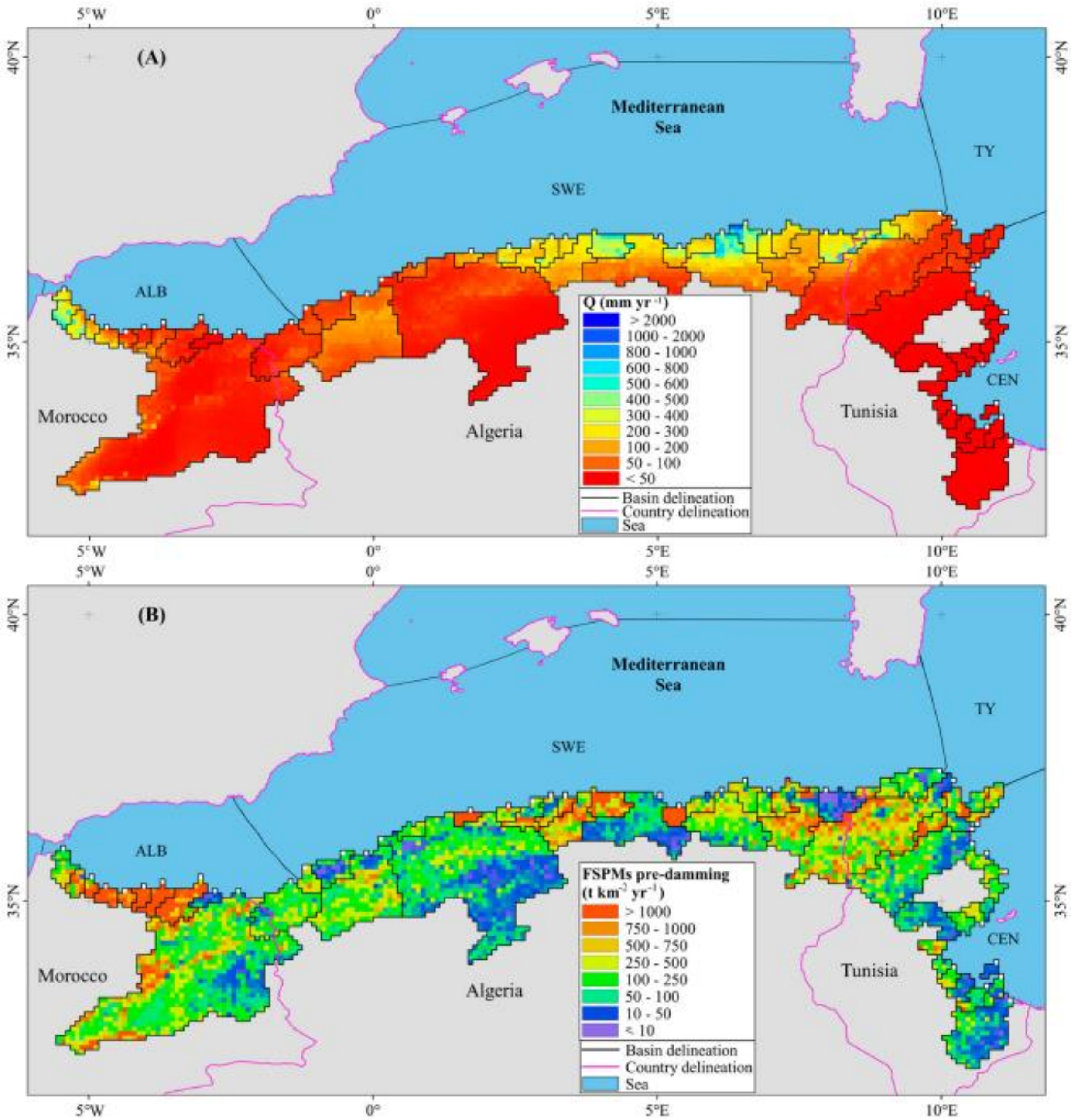


Figure 3. Spatial distribution of (**A**) specific riverine water discharge (Q-mod) and (**B**) specific suspended particulate matter fluxes (FSPMs pre-damming) in the Mediterranean Maghreb Basin according to the study of [7].

Figure 22. Plots of the studies in the Mediterranean Maghreb Basin (MMB) in Sadaoui et al. (2018).

3.2.3. Underground water flows and coastal aquifers

Groundwater flows and reservoirs represents another component of the hydrological cycle in the Mediterranean. Particularly the pressures to these compartments can have a transboundary nature, namely water fluxes through coastal karstic aquifers where the density of coastal aquifers are increased in coastal areas limiting between countries (e.g., Croatia, Bosnia and Hercegovina, Montenegro and Albania), as well as those connected landwards in balance with the surface water flow systems. Different pressures affect water quality and quantity loss, including legacy pollution, seawater intrusion, such as in the Apulian coastal groundwater belt (ca. 800 km long) in Italy (Polemio, 2016), whilst examples are found also in Albania and Montenegro. Further, the impacts of climate change are also expected to affect seriously the groundwater reservoirs used for irrigation and high-quality drinking-water both in terms of hydrological cycle variability and due to freshwater demands despite regional and local regulations exist for groundwater management. In the surface the regions where coastal aquifers are found several wetlands coexist as it can be observed in the Figure 3.2.7 in both north and south shores of the Mediterranean Sea, and where the balances are interlinked. Pollution and salinization are the two impacts affecting water quality and quantity of these freshwater reservoirs of water unmanaged pressures, larger than the continental surface flows despite less renewable (Polemio, 2016).

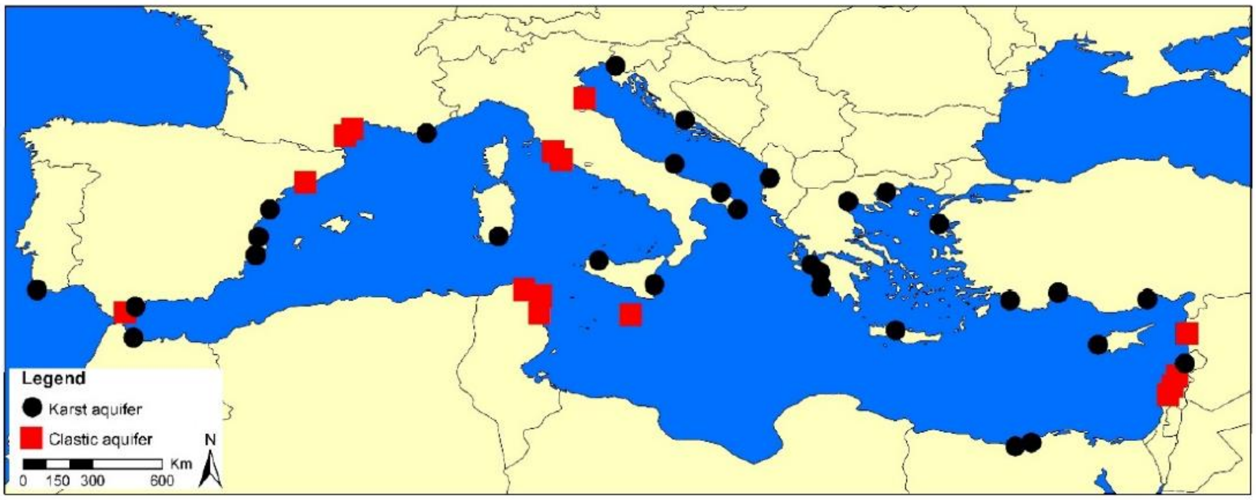


Figure 2. The main Mediterranean coastal aquifers highly affected by groundwater quality degradation due to seawater intrusion and anthropogenic contamination.

MANAGEMENT OF COASTAL AQUIFERS AND GROUNDWATER

Figure 1.2. Main Mediterranean coastal aquifers and representative wetlands assessed by UNESCO-IHP for the MedPartnership

(Skoulikaris 2015)

Figure 23. Coastal aquifers and wetlands (top, Polemio (2016) and bottom UNESCO-IHP) showing the complexity of both surface and groundwater equilibriums, including habitat features in the Mediterranean basin and subasins.

3.2.4. Forest, coastal wetlands and lagoons features

The Mediterranean region accounts for many wetland morphologies. Coastal and marine wetlands are homogeneous, flat and geodynamical stable surfaces infiltrated water systems at the sea level by either continental or marine (or both). The wetland morphologies are classified in three main categories according the Ramsar Convention (1971) which holds the records of the designated wetland sites across the world (the "Wetlands Convention"): Inland (continental), Marine or coastal wetlands and Artificial wetlands. There are different types of marine and coastal wetlands which applies in the Mediterranean Sea (Table 7), as classified by the Ramsar Convention:

Table 6. Wetlands classification.

Marine and coastal wetlands (RAMSAR world classification)	Sand, shingle, or pebble shores
	Permanent shallow marine waters
	Intertidal marshes*
	Intertidal mud, sand or salt flats*
	Coastal brackish / saline lagoons
	Marine subtidal aquatic beds (Underwater vegetation) *
	Rocky marine shores
	Coastal freshwater lagoons
	Karst and other subterranean hydrological systems
	Bivalve (shellfish) reef*

*The Mediterranean region is considered a microtidal environment and therefore these type of wetlands does not clearly apply. Edited from RAMSAR website.

Human-made wetlands (RAMSAR world classification)	Canals and drainage channels or ditches
	Seasonally flooded agricultural land*
	Water storage areas/Reservoirs
	Irrigated land*

*The Mediterranean examples of these categories in the coastal belt are rice fields and salines present in the Mediterranean region since Roman times. Edited from RAMSAR website.

The Mediterranean wetlands could locate at the land-sea interface within the coastal belt (i.e. coastal and marine wetlands). Despite is not a characteristic coastal feature wetlands cover 18.5 million hectares in the Mediterranean region, between 1.7 and 2.4% of the total area of the 27 Mediterranean countries representing up to a 2% of the wetland areas in the world (Taylor et al., 2021 and Tour de Valat, website), however, in terms of biodiversity benefits, although they occupy a low percentage area of the basin are home to more than 30% of vertebrate species (Mediterranean Wetland Outlook2; Mediterranean Wetland Observatory, 2018).

Therefore, due to the biodiversity hotspots value that wetlands represent globally, in the Mediterranean region these are not an exception and are as well under threat due to industrialization, intensive agriculture, urbanization and different human-induced pressures (e.g., urban development and roads) leading to increased pollution, invasive species, flow diversions to mention a few. The wetlands are linked to the known watersheds and water flows in the Mediterranean region, and therefore, are affected by the pollution stressors (e.g., nutrients, chemical pollution, macro and microliter, etc.) originated within the watershed. Recently Taylor et al. (2021) have revised the problematics around the wetlands in the

Mediterranean region. The Figure 24 is a comprehensive plot of the distribution and characteristics of the marine and coastal wetlands in the Mediterranean region.

Visual LME GEOMAP n°4 (Figures 24)

Fig. 1 Overview of the extent of Mediterranean wetlands; note that these data are illustrative only and do not exactly match the scope of our horizon-scanning and question-setting exercise (cf. Fig. 2). The area of each circle is proportional to wetland area. *Yellow-orange-red circles* represent continental surface wetlands; *shading* indicates the percentage of each country covered by wetlands. *Blue circles* represent marine wetlands (< 6 m water depth at low tide) on the Mediterranean coast of each country, plus Atlantic coasts for Morocco and Portugal. Data from Perennou et al. (2012) and MWO (2018). Data for Andorra, Gibraltar, San Marino and Vatican City not available

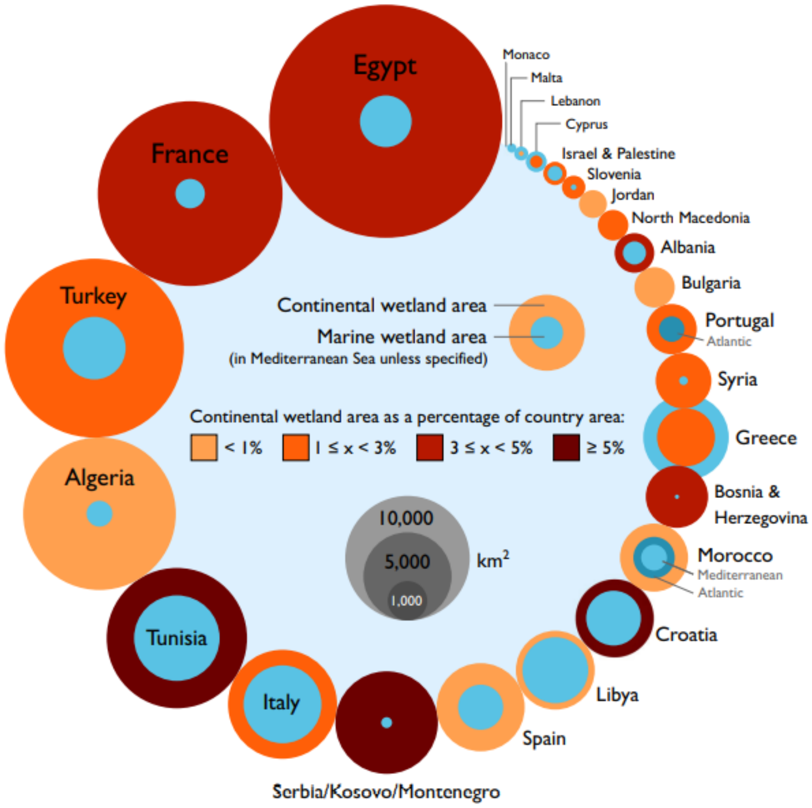


Figure 24. Overview of the extent of Mediterranean wetlands.

The Figure 25 presents a case study of the Tanta catchment changes over time (ca. wetland characteristics) inside the Nile Delta in Egypt. The authors (Abu-Hashim et al., 2015) studied the changes in the soil organic carbon pool (SOCP) related to the changes in the usage of the land, namely anthropogenic factors, which exemplifies the common continued trend in wetland area use changes and evolution under human-induced alterations. Similar studies related to wetland mapping, management, conservation, and protection have been published the Mediterranean basin due to the fragility and importance of these ecosystems (Martínez-López et al., 2013, Sánchez et al., 2015 and Geijzendorffer et al., 2019).

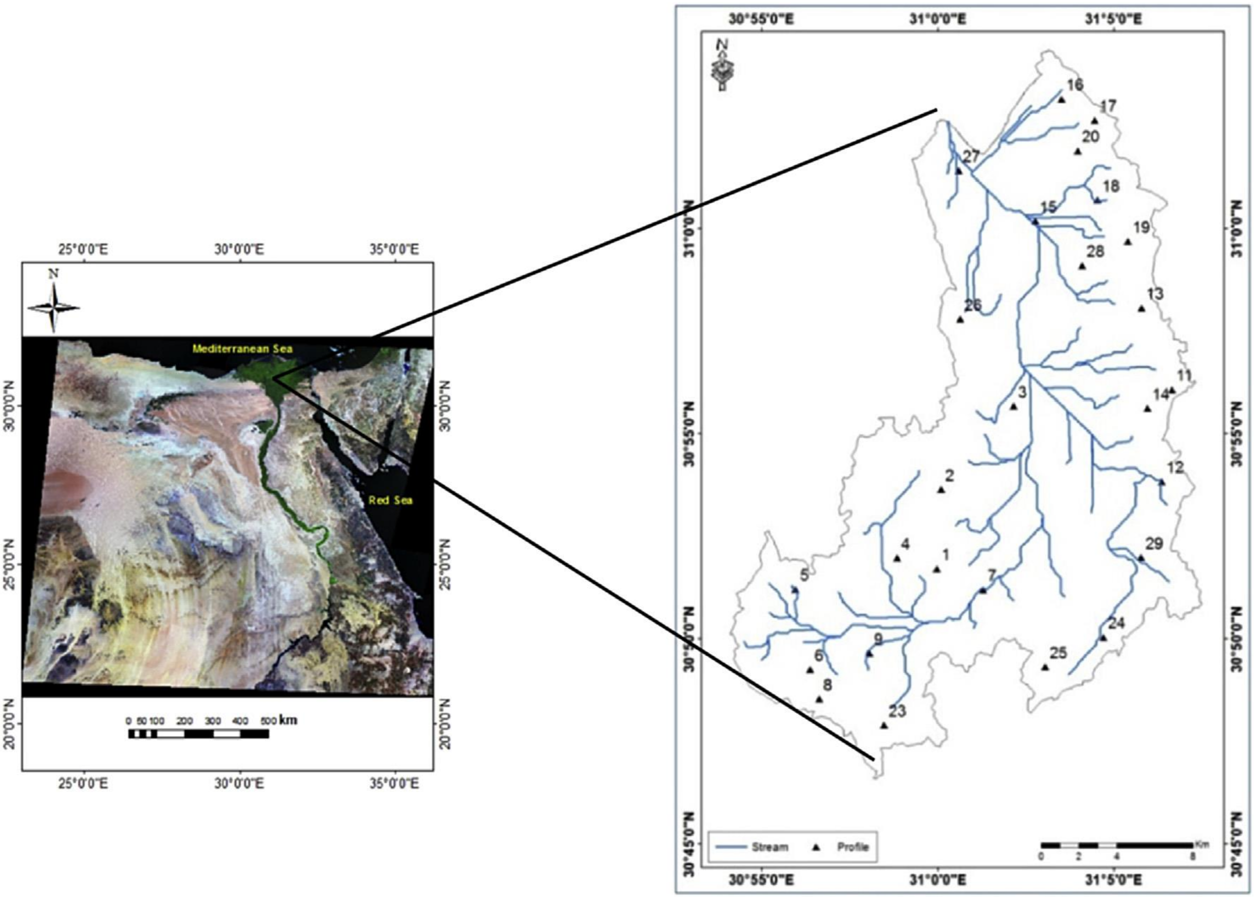


Table 1
Land-use changes of Tanta catchment area in 1990 and 2015.

Land-use	1990 (ha)	2015(ha)	Change (ha)	Change (%)
Cropland	25,810.36	20,510.06	5300.3	−15.31
Bare soil	1370.62	1786.66	416.1	1.20
Fallow	5315.29	9442.29	4127.0	11.92
Urban area	2028.11	2765.88	737.8	2.13
Water	104.68	124.17	19.49	0.06

Figure 25. A case study of the Tanta catchment inside the Nile delta (Egypt) changes over time (Abu-Hashim et al., 2015).

Similarly, to the highly rich areas of diverse wetland types and their linkage to the water cycles, the Mediterranean forests also play a role maintaining and adapting the heat and water balances in the region being subject both to human-induced (i.e. forest fires) and natural changes. Therefore, the ecohydrological knowledge is necessary to manage the limited forest particularly in arid areas (Sabater et al., 2021) where droughts are expected to increase due to climate change effects. Further, water is a critical factor influencing forest distribution and, thereby, has strong influence on carbon sequestration at regional and global scales, and in turn, vegetation is one of the major derivers of watershed hydrology components such as evapotranspiration, runoff and soil–water interaction. Donmez and Berberoglu (2016) elaborated a comparative assessment of the catchment runoff generation and forest productivity in a semi-arid environment (ca. Eastern Mediterranean) to understand the interactions between forest ecosystems and water in the Mediterranean region. The analysis and modelling results shown that temperature was a primary factor in the forest net primary productivity (NPP), and secondly, that the catchment runoff dynamics was influenced by elevation, precipitation and forest cover. These factors are all related with the climatic parameters, and viceversa, at regional scale.

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3.3. Climatic features

3.3.1. Temperature and precipitation

The Mediterranean region main climatic features (e.g., temperature and precipitation) are characterized by mild winters and hot and dry summers and need to be considered from the interactions and feedbacks both within the limits of the basin (ca. weather conditions) and beyond. From the West, the Atlantic Ocean regimes, the North Atlantic Oscillation (NAO) have a great intra-seasonal and interannual variability influence in the Mediterranean reaching mainly the north-northeast part of the Mediterranean land and sea, whilst the Eastern and Southern climatic regimes provide the characteristics of the southern Mediterranean areas, particularly the north part of the eastern Mediterranean basin. Therefore, the climatic features in the Mediterranean Sea region responds both to the internal and external atmospheric, land and sea processes (ca. transboundary nature) and defines the observed and well-known characteristics (Figure 26) providing the ecosystem divisions and species distribution patterns in land (e.g. vegetation), as well as in the sea.

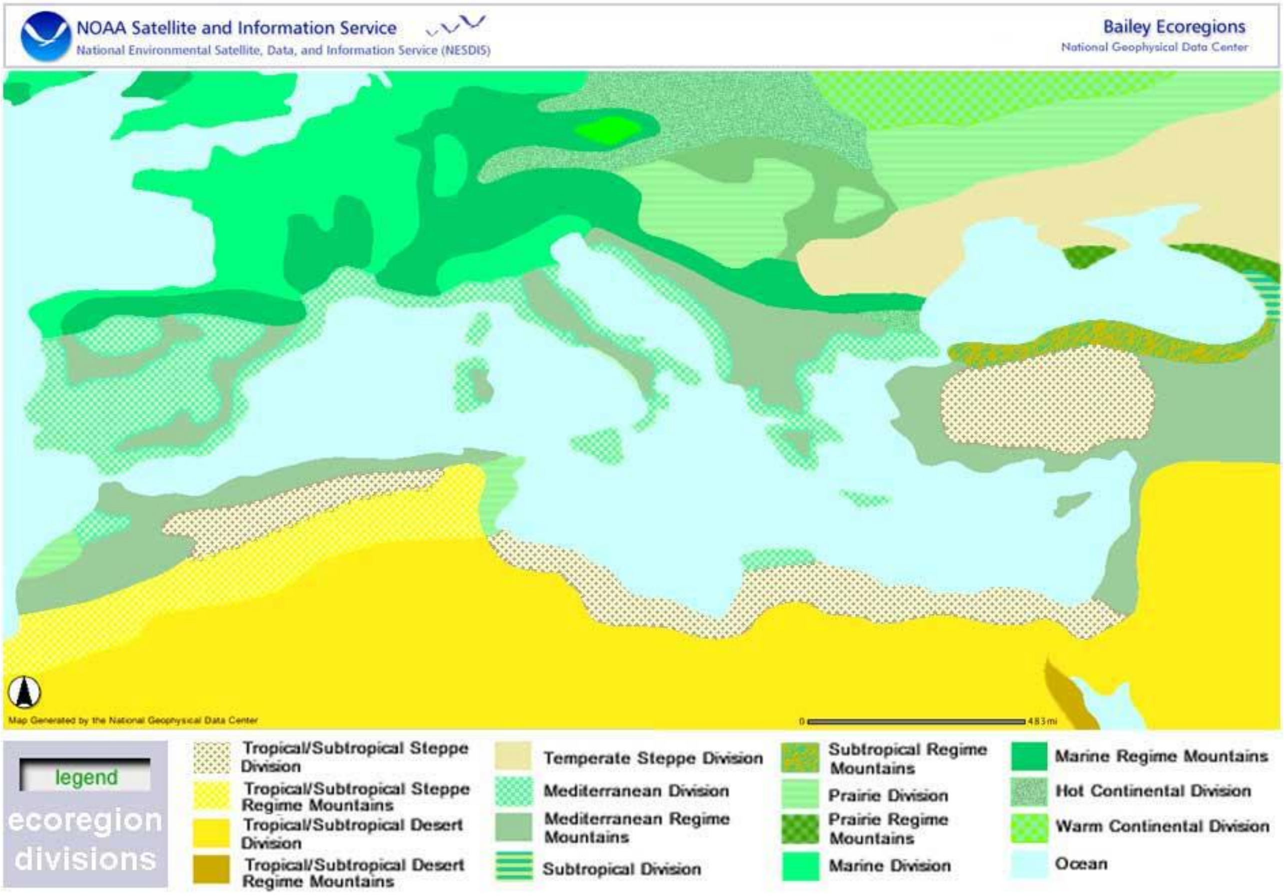

Figure 26. Mediterranean Basin : Bailey ecoregion divisions map (Source: NGDC, US)

The latest studies of the Mediterranean Sea basin have considered both the European and African geographical scales, due to its contrasting climatic-based ecosystem divisions, thus being at the boundary between the two continents reflecting the high complexity and contrasts between the northern and southern part of the basin (Figure 26), and therefore, the limitations in the Mediterranean climatic understanding and differential effects of climate change (IPCC, 2021 [Atlas | Climate Change 2021: The Physical Science Basis (ipcc.ch)]).

Therefore, researchers have considered for regional studies the interconnections between the northern and southern traits, as well as including the Black Sea (Figure 27), thus the so-called Mediterranean and Black Sea Earth System (MBES watershed) by Poulos (2019), for two main climatic parameters: precipitation and temperature.

Visual LME GEOMAP n°5 (Figures 27, 28 and 29)

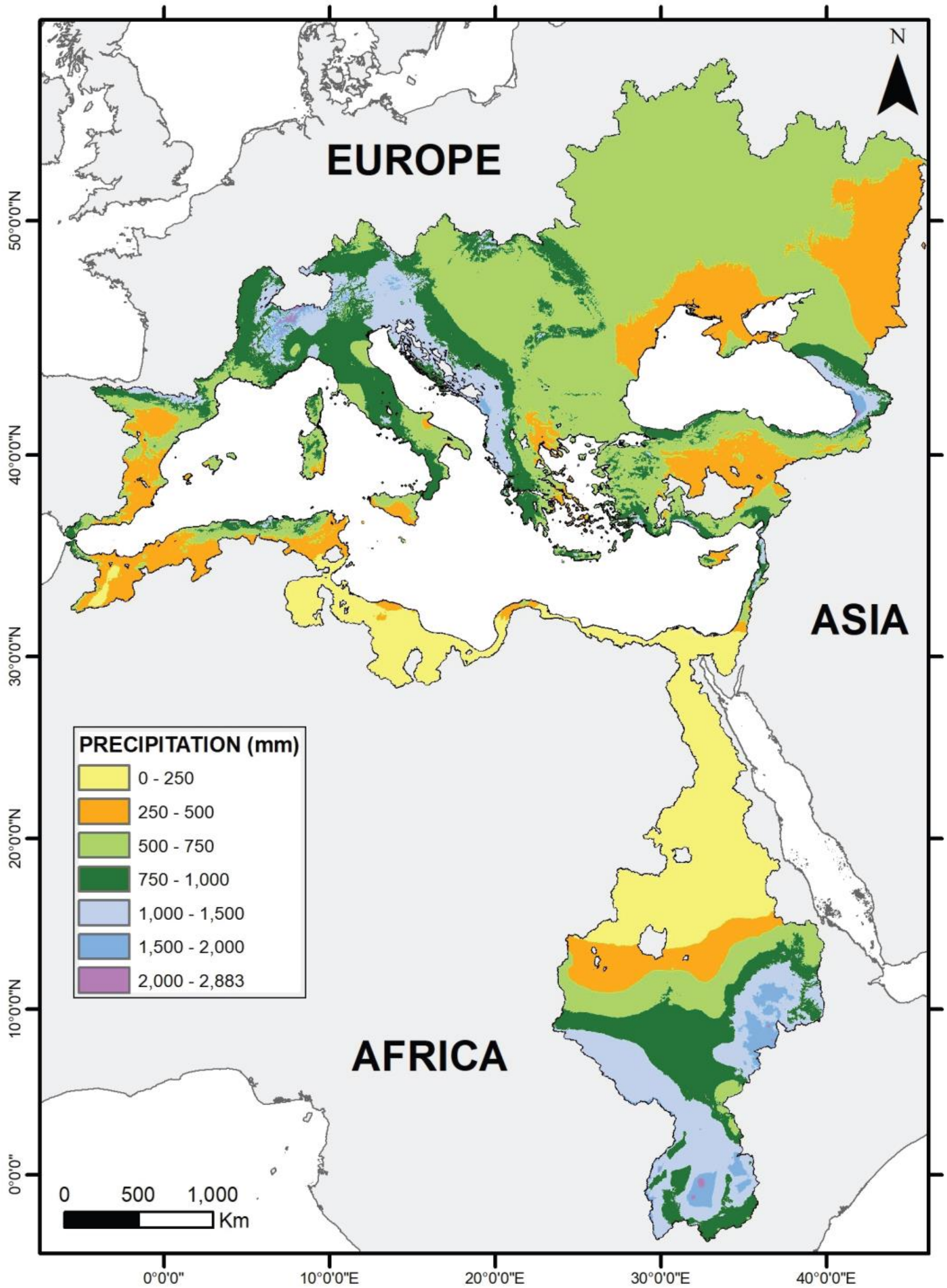

Figure 27. The spatial precipitation pattern within the MBES watershed (WORDCLIM2 dataset). (Poulos, 2019)

It is worth to mention that the internal Mediterranean climate is highly typified and their features are known to occur in four other relatively smaller areas around the planet as well: central Chile, the Cape region of South Africa, southwestern and southern Australia, and southern California and northern Baja

California (Table 8) (Cid et al., 2017). The main characteristic is a regime of hot and dry summer and mild winter with rains (Figures 28 and 29).

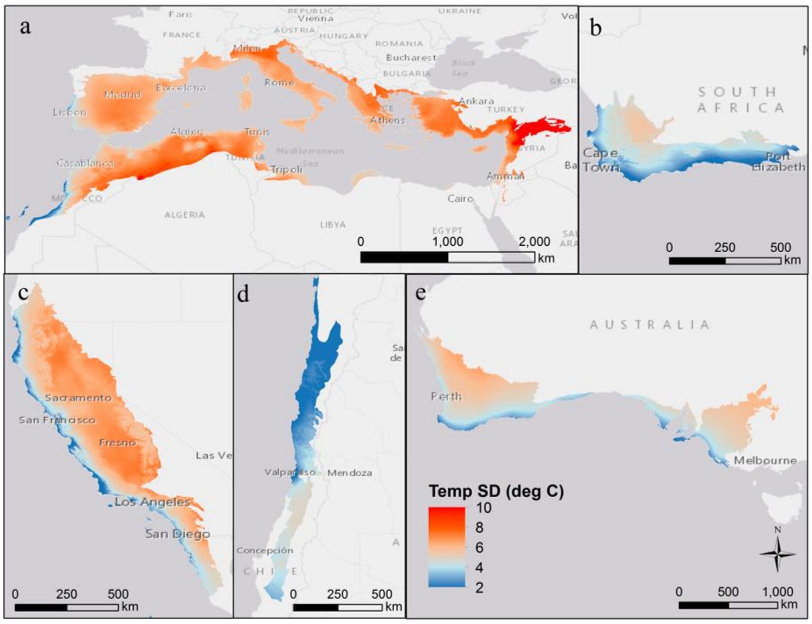

Figure 28. Seasonal variation in mean monthly temperatures (SD) for the five Mediterranean regions in the world (Cid et al., 2017): Mediterranean Basin (a); South Africa (b); California (c); Chile (d); and Australia I. Data source: WorldClim Database, v1.4 [29]. Records correspond to the period 1960–1990.

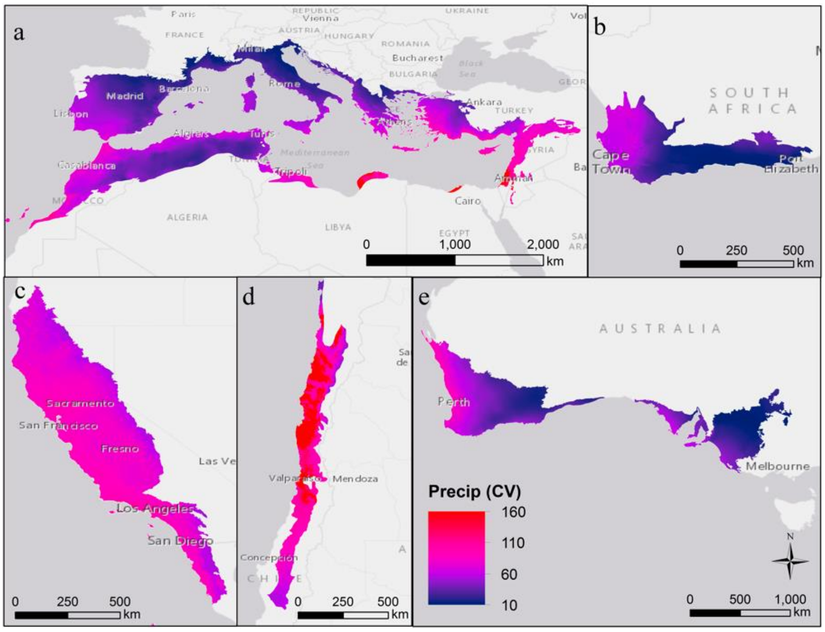

Figure 29. Seasonal variation in mean monthly precipitation (SD) for the five Mediterranean regions in the world (Cid et al., 2017): Mediterranean Basin (a); South Africa (b); California (c); Chile (d); and Australia I. Data source: WorldClim Database, v1.4 [29]. Records correspond to the period 1960–1990.

Table 7. Features of the Mediterranean climate locations in the world. Climatic features (temperature and precipitation, 1960-1990) in the five so-called Mediterranean areas in the world (Cid et al., 2017). (Source: Water 2017, 9, 52; doi:10.3390/w9010052 – High Variability Is a Defining Component of Mediterranean-Climate Rivers and Their Biota)

Table 1. Elevation and climate characteristics for the five Mediterranean climate regions from the world, derived from the SRTM 90 m Digital Elevation Database, v4.1 [28] and Worldclim Database, v1.4 [29]. For each variable, the mean value and standard deviation (SD) of values from all data points within a region are reported. The temperature and precipitation records are from the period 1960–1990.

Region	Mediterranean Basin	California	Chile	Australia	South Africa
Area (km^2)	2,137,100	324,900	148,400	791,300	123,100
Elevation (mean ± SD m.a.s.l.)	640 ± 490	800 ± 580	980 ± 580	200 ± 185	530 ± 461
Mean temperature (mean ± SD °C)	15 ± 3	13 ± 4	13 ± 3	17 ± 2	16 ± 2
Mean min. temperature [1] (mean ± SD °C)	2 ± 3	0 ± 4	3 ± 4	5 ± 1	4 ± 2
Mean max. temperature [2] (mean ± SD °C)	31 ± 4	30 ± 5	24 ± 4	32 ± 3	28 ± 3
Annual precipitation (mean ± SD mm)	560 ± 250	700 ± 410	420 ± 520	390 ± 165	430 ± 200

Notes: [1] Minimum temperature of coldest month; [2] Maximum temperature of warmest month.

Nowadays, the external influence of the Mediterranean climatic regimes beyond the basin, and viceversa, (ca. desertification, droughts, rainfall variability, extreme events, etc.) determines the present and the future climatic features and changes within the region. Within the Mediterranean basin, the relevant climate related UN IPCC regions over land and over sea were subdivided and determined in the MedECC report (Figure 30) matching the Baley's map that reflects the climatic vegetation features (Figure 26), whilst for the sea differs from the UNEP/MAP ecoregions (ca. based on Spalding et al., 2007), but responding to climate purposes notably with the know minimum precipitation annual average in the region in both EM and LE areas (Figure 30).

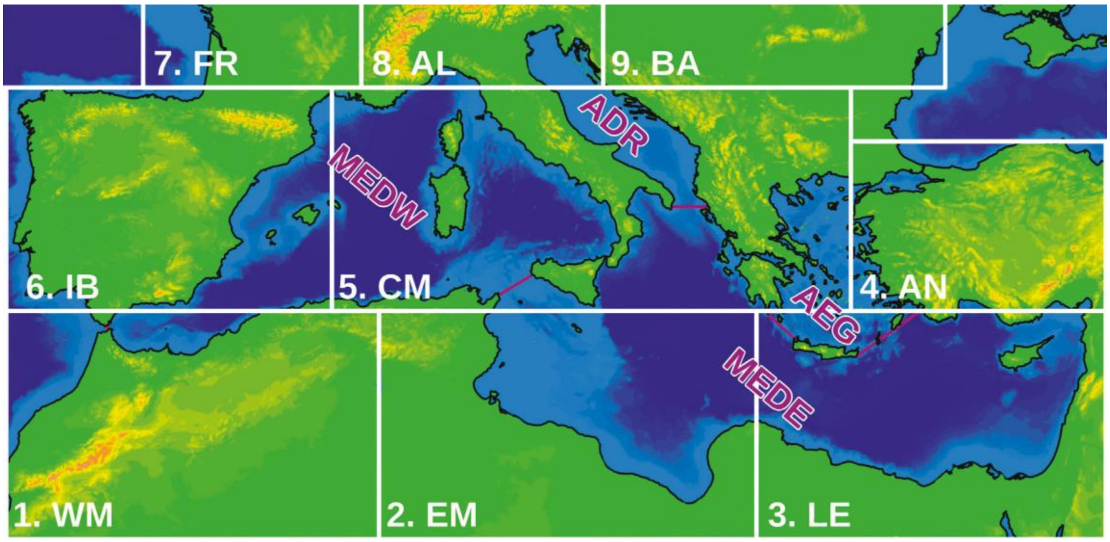

Figure 30. The MedECC report (2020) Mediterranenan climate related box subregions definition (West Maghreb (WM), East Maghreb (EM), Levant (LE), Anatolia (AN), Central Mediterranean (CM), Iberia (IB), France (FR), Alps (AL) and Balkans (BA)).

The MedECC report was the first regional climate and environmental change assessment report in the Mediterranean region and looking at the future scenarios and based on the IPCC global work and regionally assessed through a network of Mediterranean experts. An outcome of the report are the focus on the potential main climatic features scenarios (ca. temperature and precipitations) in the region as shown in Figure 31.

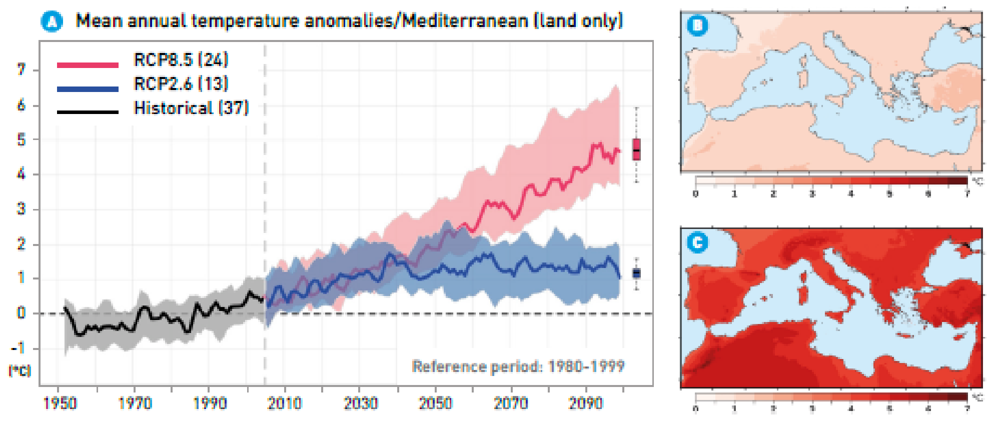

Figure SPM.2 | Projected warming in the Mediterranean Basin over land. Projected changes in annual temperature relative to the recent past reference period (1980-1999), based on the EURO-CORDEX 0.11° ensemble mean, A: simulations for pathways RCP2.6 and RCP8.5, B: warming at the end of the 21st century (2080-2099) for RCP2.6, C: idem for RCP8.5.

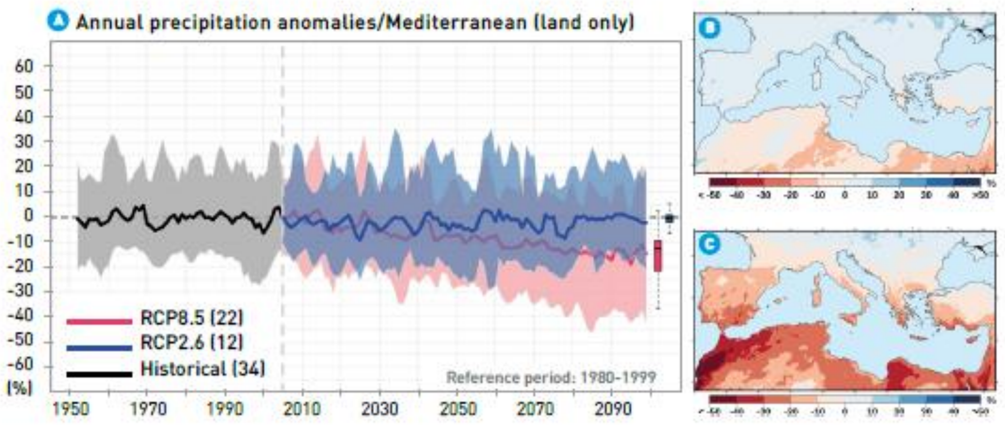

Figure SPM.3 | Projected rainfall change in the Mediterranean Basin. Projected changes in annual rainfall relative to the recent past reference period (1980-1999), based on the EURO-CORDEX 0.11° ensemble mean, A: simulations for pathways RCP2.6 and RCP8.5, B: rainfall anomalies at the end of the 21st century (2080-2099) for RCP2.6, C: idem for RCP8.5.

Figure 3.3.6

Figure 31. Estimations of temperature and precipitation changes over the Mediterranean basin (MedEEC, 2002).

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3.4. Natural resources

The Mediterranean LME provides natural resources and trade for millennia. The natural resources exploited from the sea are many, but fisheries for seafood consumption is the most exploited until today (and a basic component of the well-known 'Mediterranean diet'); however, there are a more recent resources and benefits (bathing waters, landscapes, cultural heritage, wind energy production areas, desalination, salt production, etc.), either renewable or non-renewable which, ultimately, directs to the protection and conservation of the Mediterranean Sea and coasts, as different economic models have been built over centuries and our societies and national economies are dependent on them. As this, the sustainability of the natural resources is a key element for the continued development of the Mediterranean countries. The natural resources and benefits provided by the Mediterranean Sea are related to the most known economic sectors, such as materials (e.g. seafloor mining, seawater desalination, salines) and energy (ca. offshore wind generation). The classification and differentiation between the geographical locations of the resources within the marine ecosystems (e.g., coastal and offshore), as well as the indirect ecosystem services (ca. exploited or built-in economic sector) need to be also acknowledged within the concept of natural resources. This section introduces the main renewable and non-renewable marine resources to elaborate in the following ones those in terms of economic sector (ca. blue economy sectors).

3.4.1. Renewable resources

The fisheries in the Mediterranean Sea have been largely overcome their biological limits for most of the species (see Section 1.1), whilst the aquaculture as an alternative is in expansion (see Section 3.5). These are renewable natural resources within their own time scales not aligned with the socioeconomic needs and therefore a rapid overexploitation is leading to the loss of traditional commercial fisheries and species stocks collapse. The governance of the fisheries and aquaculture sectors in the Mediterranean Sea has been led by the FAO GFCM, which oversees the accounts reported by countries developing fisheries statistics, modelling tools and national/international policy reporting (Figure 32). There is still a need to effectively implement a holistic policy in the Mediterranean, based on stock assessments and ecosystem-based modelling approaches to be adopted in support of the management and conservation strategic measures for the preservation and sustainability of the fisheries in the Mediterranean LME. In Section 1.1. it was described the observed a decreasing trend in the total catches since the 90s in the Mediterranean Sea. Further, total catches in the Mediterranean have been also studied and reconstructed for the period 1970-2017 (Piroddi et al. 2017) in the four UNEP/MAP ecoregions (Figure 32).

Disregarding the medium and large fleets operating in the Mediterranean Sea, the artisanal fishing has been the landmark in the fisheries sector in the basin. Similarly, the sustainability of this coastal resource is damaged and new models of co-management are being tested in different zones as a long-term tool to provide the restoration of stocks and avoid environmental and socioeconomic impacts. However, beyond fisheries, a few other emblematic renewable resources continue to be exploited in the Mediterranean Sea of transboundary nature, namely seawater desalination for consumption to supply the increasing demand particularly in the eastern and southern coast of the Mediterranean Sea. Further, offshore wind energy production and desalinization are two other forms of exploited renewable natural resources (Figure 33).

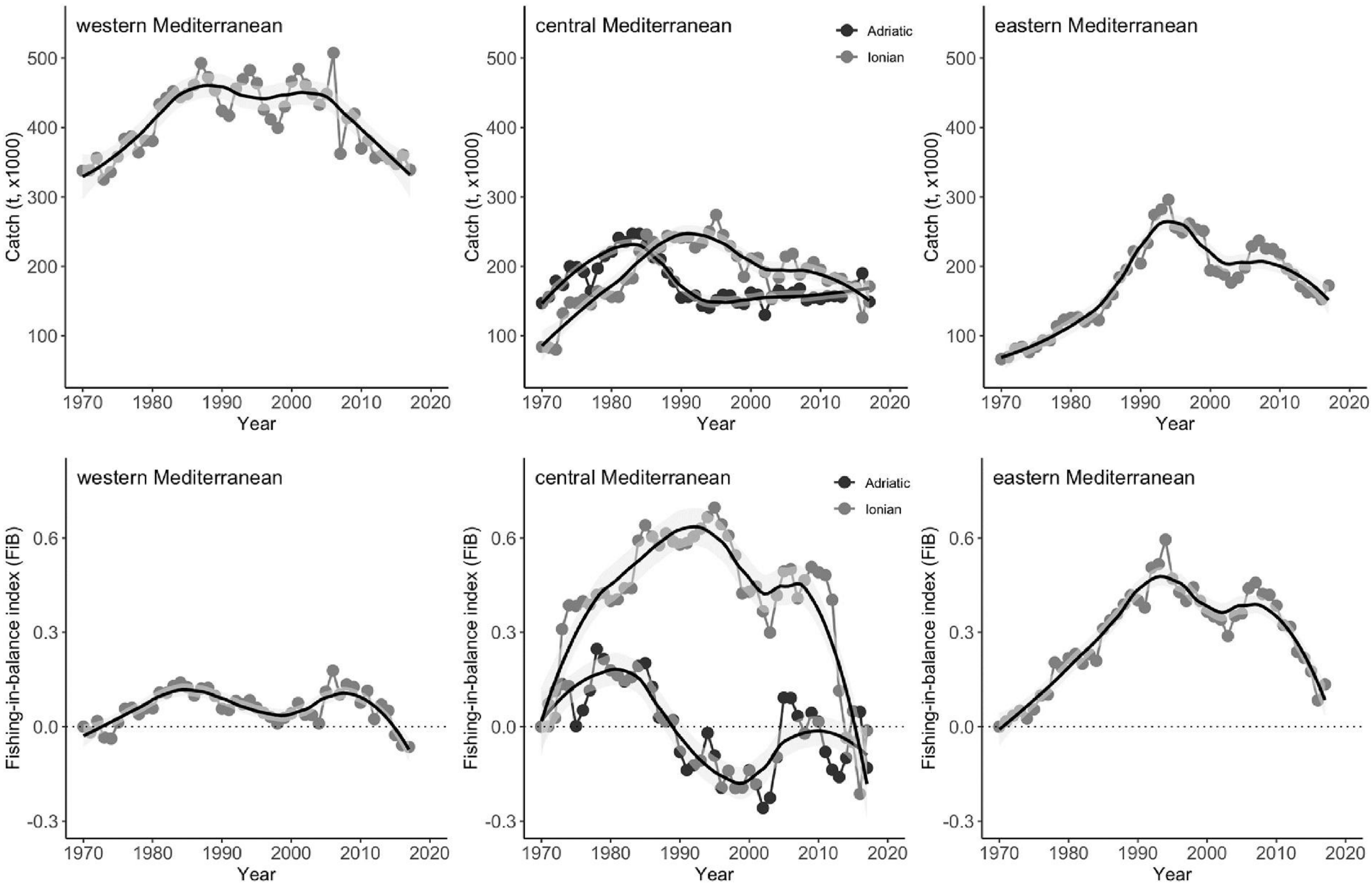
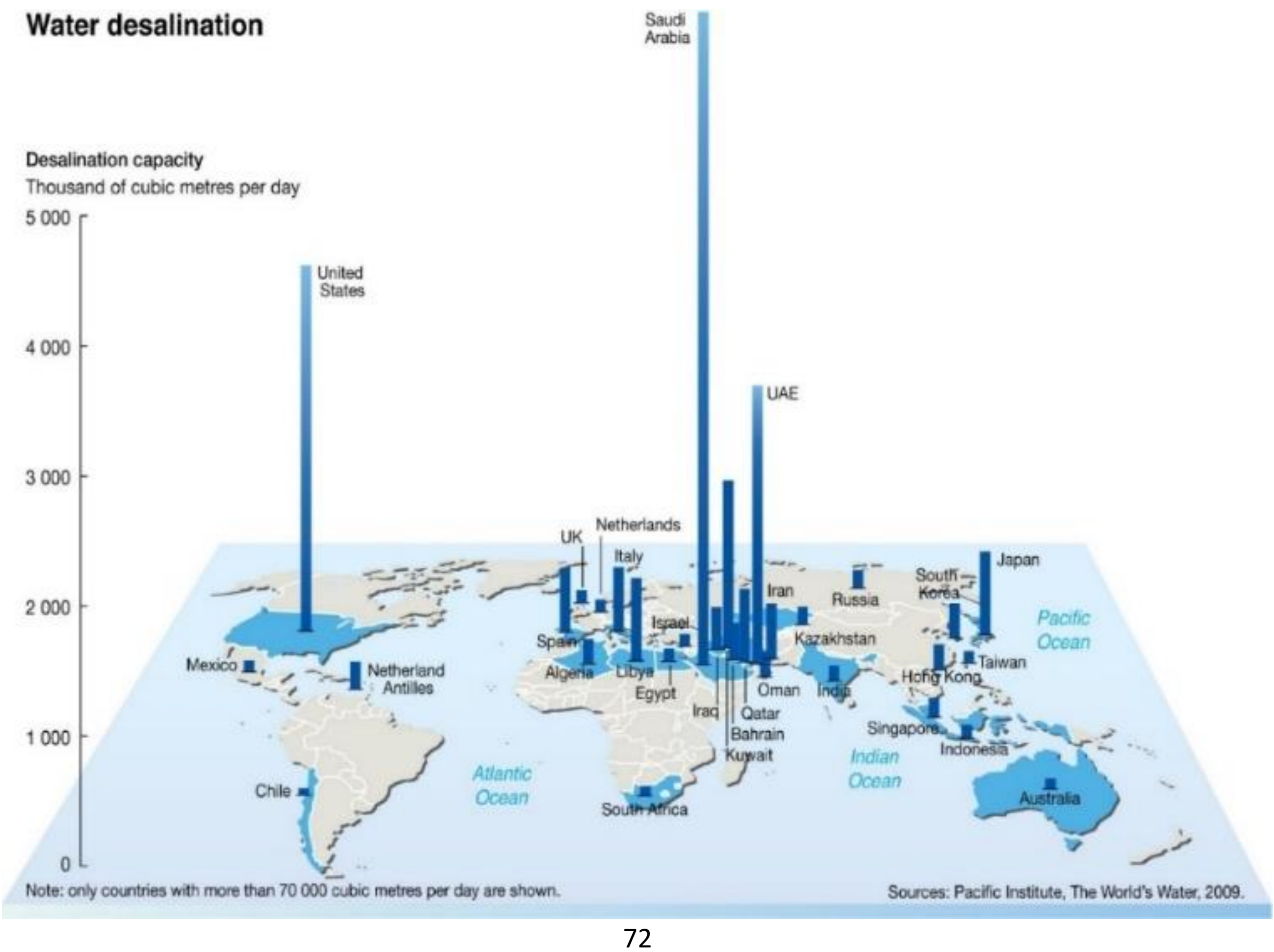
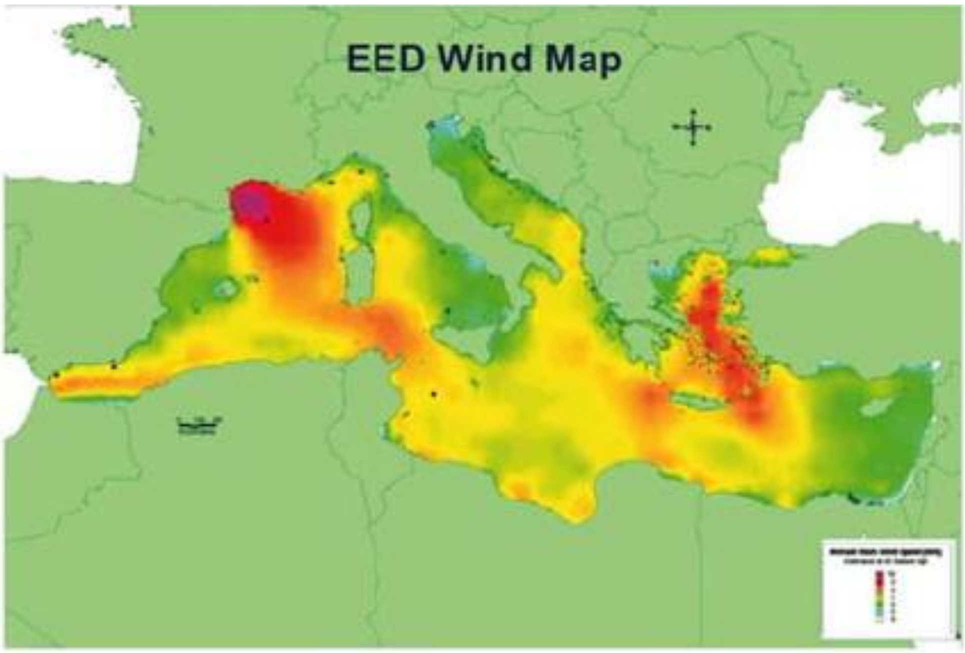


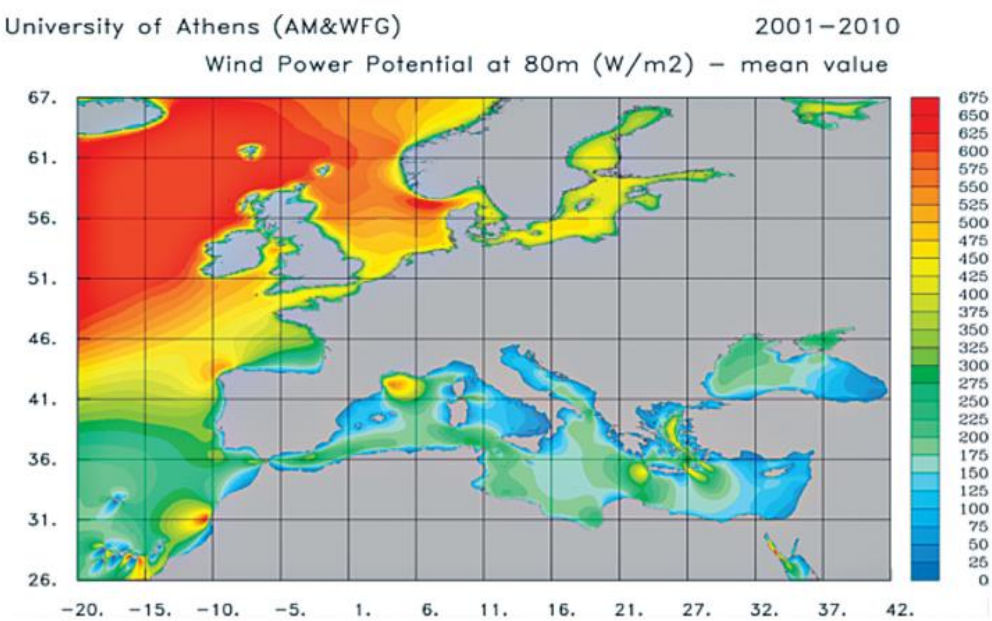
Figure 32. Total reported catches (thousands of tons) and fishing-in-balance index (FiB) in the western, central (Adriatic and Ionian Seas) and eastern basins of the Mediterranean LME (top and bottom, respectively). The western and central areas are the result of overexploitation. (Piroddi et al., 2020 and references therein).



MAP A.



MAP B.



MAP C.

Figure 33. Regional maps of renewable resources of the Mediterranean Sea for Water desalination and Potential for offshore wind development (Gaudiosi and Borri, 2010) in the Mediterranean region (red shows the geographical areas with higher potential due to wind favourable conditions). MAP C. in: Mongoos strategy.

3.4.2. Non-renewable resources

The coastal and offshore marine environments contain non-renewable resources which are being exploited. On one side, there is no doubt that both the Mediterranean landscapes and the coastline ecosystems (both surface and underwater) are by themselves natural non-renewable resources and are increasingly recognized and exploited, despite not consumed (ca. tourism). As such, the preservation and the sustainability of such natural capital cannot be dismissed. The protection, conservation, and environmental accounting of these forms of natural capital (ca. natural resources) need to be considered as the fundamental pillar for the development over the last 50 years of the tourism in the Mediterranean.

On the other hand, there are classical non-renewable resources (ca. energy production), with an exploitation potential in the offshore areas of the Mediterranean Sea, namely, oil and gas exploitation. The Figure 34 shows the current framework and capabilities to both explore and exploit these non-renewable natural resources.

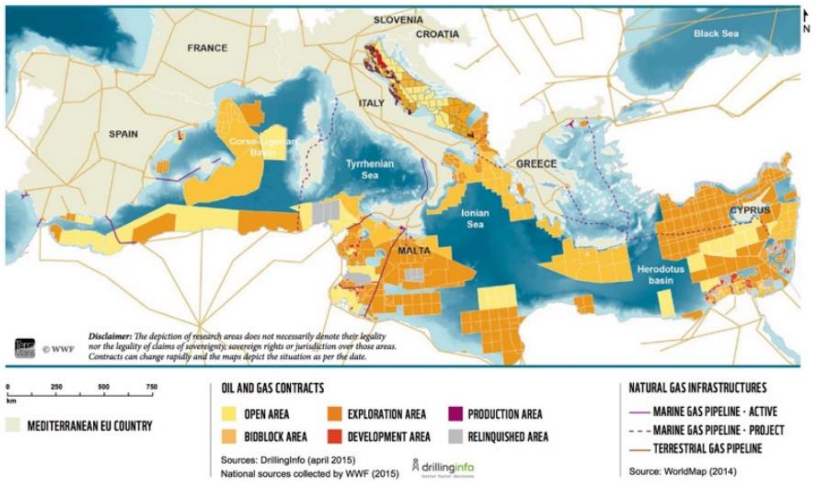


Figure 16. Current offshore oil and gas exploration and production contracts in the Mediterranean Sea (depicted as broad areas), and active and projected gas pipelines (depicted as lines). Image from Piante and Ody (2015).

http://www.merces-project.eu/sites/default/files/MERCES_D1.2_Pressures_Final_25052017.pdf

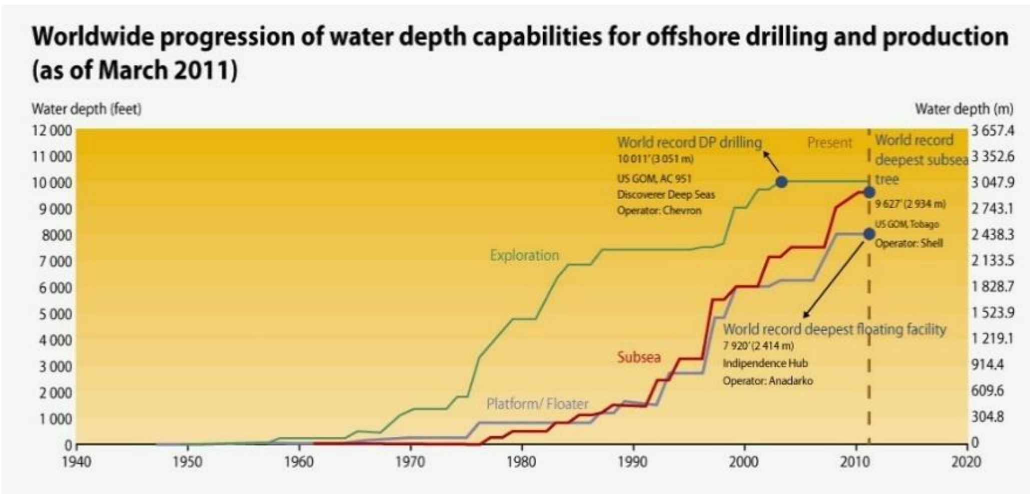


Figure 34. Mediterranean oil and gas exploration (Piante and Oddy, 2015) and worldwide offshore drilling capabilities increase 1950-2011.

References

Piroddi et al., 2020. The living marine resources in the Mediterranean Sea Large Marine Ecosystem. Environmental Development, 36, 100555. https://doi.org/10.1016/j.envdev.2020.100555

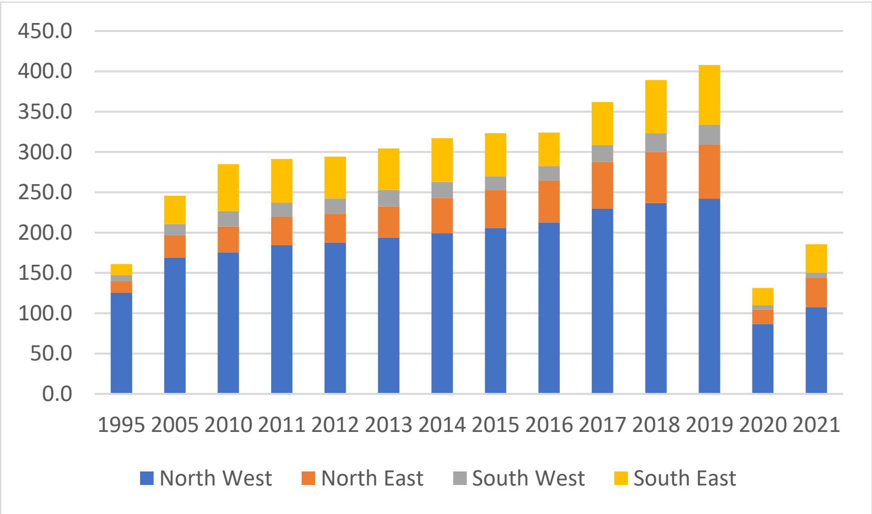
Gaudiosi and Borri, 2010. Offshore wind energy in the 74rea74onment74l countries. Revue des energies renouvelables SMEE'10 Bou Ismail Tipaza (2010).

3.5. Socio-economic situation

3.5.1. The main drivers of environmental change

3.5.1.1. Tourism

The Mediterranean Sea is one of the leading tourism destinations in the world (UNWTO, 2015; UNEP/MAP and Plan Bleu, 2020). Over the time, Mediterranean destinations developed a rich and diverse set of tourism products, services and experiences, whereas the traditional sun and sea attractions were complemented with health, sports, nature and culture as well as cruise and meetings tourism.



Sources: Based on UNWTO 2022 and 2022b

Figure 35: International Tourist Arrivals (ITAs) in the Mediterranean (in millions)

The overall number of ITAs in the Mediterranean reached 408 million in 2019, as a result of the sector's strong growth seen in the region throughout much of the last 50 years. During the past decade (2010 – 2019) alone, an average annual increase of 13.7 million of ITAs (4.1% year-on-year) was recorded. While the contribution from the established Northwest Mediterranean destinations (primarily France, Spain and Italy) remained predominant, their relative share in the total numbers of visits decreased by nearly 20 percentage points between 1995 and 2019. On the other hand, the share of fast-growing destinations from Southeast and Northeast (in particular Turkey, but also countries like Albania, Croatia and Montenegro) in the overall number of tourists in the region has increased considerably, in particular during the past 15 years. The share of ITAs to Northeast Mediterranean countries, for example, increased from 11.4% in 2005 to 16.4% in 2019. Despite significant potential, the contribution of Southwest destinations to the overall Mediterranean ITAs remained modest (5 to 6%). In 2019, the Mediterranean earned close to USD 308 billion in international tourism receipts, which is approximately at the level of Egypt's GDP for the same year, or 1.5 times higher than the GDP of Greece.

Table 8. NOTE: Data from the table to be mapped, if possible, showing 2019 ITAs per capita at destination; available data on per capita receipts could be also shown

Country code	ITAs p.c.	Receipts from tourism p.c. (in USD)
AL	2.07	805.8
DZ	0.06	2.3
BA	0.36	363.5
HR	4.28	2,902.6
CY	3.34	2,753.3
EG	0.13	129.5
FR	1.35	944.3
GR	2.92	1,902.7
IL	0.51	839.4
IT	1.08	830.4
LB	0.28	1,254.4
LY	-	-
MT	5.55	3,769.4
MC	10.01	-
ME	4.02	1,929.2
MA	0.35	224.8
PS	0.23	85.4
SI	2.25	1,532.3
ES	1.77	1,690.9
SY	0.14	-
TN	0.80	179.6
TR	0.61	357.2
MED	*0.79*	*593.3*

Sources: Based on UNWTO 2022 and 2022b; World Bank, 2022

Colour codes

≥ 10 ITAs p.c		
5 – 10		
2 – 5		
0.5 – 2		
≤ 0.5		

Armed conflicts in the region and security concerns as well as political instability (including Arab spring) alongside with deteriorating social and economic conditions resulted in tourism downturns and/ or serious disruptions in some of the Eastern shores and North African countries in the period since 2010, affecting in particular Syria (with 8.1 million ITAs in 2010 and only 2.4 million in 2019), Libya, Egypt and Tunisia. Egypt experienced a rapid tourism growth in the past – from 2.9 million arrivals in 1995 to a record of 14 million in 2010. Following the 2011 instability and related events, ITAs went down considerably and remained below 10 million for several years, to start rising again in 2018 and 2019.

The COVID-19 pandemic brought the total number of international arrivals down to 131.4 million in 2020 (-67.8% compared to 2019), well below the 1995 level of 161 million. Receipts also plummeted from USD 308 billion in 2019 to USD 110 billion in 2020 (- 64.3%). The losses were not spread evenly across the region: Monaco and France recorded lowest decreases in ITAs (of 50% and 54% respectively), while several countries experienced a contraction of more than 80% of the 2019 arrivals. Cyprus was the most affected (-85%), followed by Montenegro (-84%), Bosnia and Herzegovina (-83.3%), Israel (-82.6%) and Palestine (-81.8%). Signs of recovery were visible already in 2021, with the total number of ITAs reaching 45.5% of the 2019 level, representing a remarkable increase of 41.3% compared to 2020, whereas receipts increased by even larger margin (56.7%). The strongest recovery trends were recorded in France, Turkey, Montenegro and in particular in Albania (where 2021 ITAs reached almost 90% of the 2019 level), while negative trends worsened in Algeria and Israel. Mediterranean tourism seems to be recovering faster than the global, with global 2021 ITAs at 30.4% of the 2019 level, as compared to 45.5% in the Mediterranean.

Moreover, regional ITAs made up as much as 41.6% of the world tourism in 2021, compared to 27.8% in the pre-pandemic 2019. Such trends are likely to continue as Europe and the Middle East regions showed the fastest recovery in the period January – July 2022, with arrivals reaching 74% and 76% of 2019 levels, respectively (UNWTO, 2022a). Global tourism arrivals are expected to rise by 60% in 2022 and by further 30% in 2023, but the full recovery to pre-pandemic levels is only projected for 2024 (EIU, 2022). Taking into account past growth rates and recovery projections, the scenario of 500 million Mediterranean ITAs by 2030 is still likely. The future of Mediterranean tourism will however depend on many factors, including the pace of post-COVID recovery of the global economy, effects of the ongoing conflicts affecting important source markets (for example, war in Ukraine), geo-political instabilities and climate crisis, and most importantly – on resolution of conflicts and stability in the region.

According to the available estimates, almost half (47.2%) of all the ITAs to the 22 Mediterranean countries in 2017 were linked to coastal areas (UNEP/MAP and Plan Bleu, 2020). Shares of coastal tourism varied markedly between different groups of countries, reaching for example 85% in the Northeast Mediterranean countries while remaining below 40% in Northwest and Southeast; the estimated share of coastal tourism in the South West Mediterranean was around 62%. In the Mediterranean EU countries in 2019, coastal areas accounted for a very high share of the total nights spent in tourist accommodation in Malta (100%), Cyprus (97%), Greece (96%), Spain (96%), and Croatia (93%); in Italy, 53% of the total number of nights spent in tourist accommodation were linked to the coastal areas (European Commission, 2022). Taking into account all the EU countries, nights spent in coastal regions in 2018 represented 42% of the total; at the same time, coastal regions had the highest tourism intensity[11] with 12.3 nights-spent per inhabitant (Batista e Silva et al., 2020).

According to the WTTC data[12], travel and tourism GDP in the Mediterranean reached USD 943.4 billion in 2019, with 18.4 million jobs. Following a loss of more than USD 503 billion in 2020, the sector's

[11] Compared to other types of tourism such as mountains and nature, cities, urban mix, and rural.
[12] Refer to direct and indirect GDP/ jobs.

contribution to GDP increased by 47% in 2021, reaching USD 647.4 billion or some 69% of the 2019 level. The impact of COVID-19 crisis on employment was less severe: following a loss of 3.1 million jobs across the region in 2020 (a decline of 17.1% compared to 2019), total employment in 2021 was 16.8 million (representing a decline of 8.8% in relation to 2019).

Table 9. NOTE: Data from the table to be mapped, if possible, showing small bar graphs for 2019, 2020 and 2021 with GDP shares by country, alongside with data on 2019 jobs

Countries	Tourism and travel GDP (share of total)			Tourism and travel 78rea (000)		
	2019	2020	2021	2019	2020	2030
Albania	20.3	10.5	17.4	243.8	178.6	226.1
Algeria	5.5	3.2	4.3	629.2	484.6	542.5
BA	9.7	5.0	6.6	87.9	63.5	71.2
Croatia	24.8	13.2	16.1	393.7	325.1	333.5
Cyprus	13.7	3.7	9.3	56.5	46.8	53.7
Egypt	8.5	4.3	5.1	2,420.0	1,890.0	2,160.0
France	8.4	5.0	6.5	2,680.0	2,430.0	2,600.0
Greece	20.7	9.2	14.9	819.8	707.8	781.6
Israel	5.7	2.6	2.9	236.0	215.1	221.2
Italy	10.6	6.1	9.1	2,850.0	2,410.0	2,640.0
Lebanon	19.1	4.9	2.5	422.3	296.6	335.8
Libya	2.3	1.7	1.4	47.2	34.4	42.5
Malta	15.0	4.9	6.7	53.8	47.3	51.1
Monaco						
Montenegro	30.8	7.7	25.5	64.8	39.0	45.2
Morocco	12.0	6.8	6.9	1,340.0	1,160.0	1,180.0
Palestine						
Slovenia	10.8	7.2	7.7	100.3	96.3	97.7
Spain	14.0	5.9	8.5	2,840.0	2,290.0	2,510.0
Syrian AR	8.3	3.2	4.4	165.1	133.5	145.4
Tunisia	13.2	6.0	8.3	383.9	294.1	345.5
Turkey	11.0	5.1	7.3	2,590.0	2,130.0	2,420.0

Tourism is a very important part of national economy in many Mediterranean countries. In Albania, Croatia, Greece, Lebanon and Montenegro, for example, one fifth (or more) of the national GDP is assessed to have come from tourism and travel in 2019. Countries highly dependent on tourism were amongst the most affected following the outbreak of COVID-19. In 2020, Cyprus, Greece, Lebanon, Malta, Montenegro and Syria lost some 60 to 80% of the 2019 travel and tourism GDP. In Albania, Croatia, Israel, Tunisia and Turkey, travel and tourism GDP declined by some 50 – 60%, while other major destinations also suffered significant but less prominent losses (of less than 50%). France, Israel and Slovenia were among the most effective countries in preserving tourism and travel jobs amidst COVID-19 crisis, keeping the 2020 losses at the levels of less than 10%.

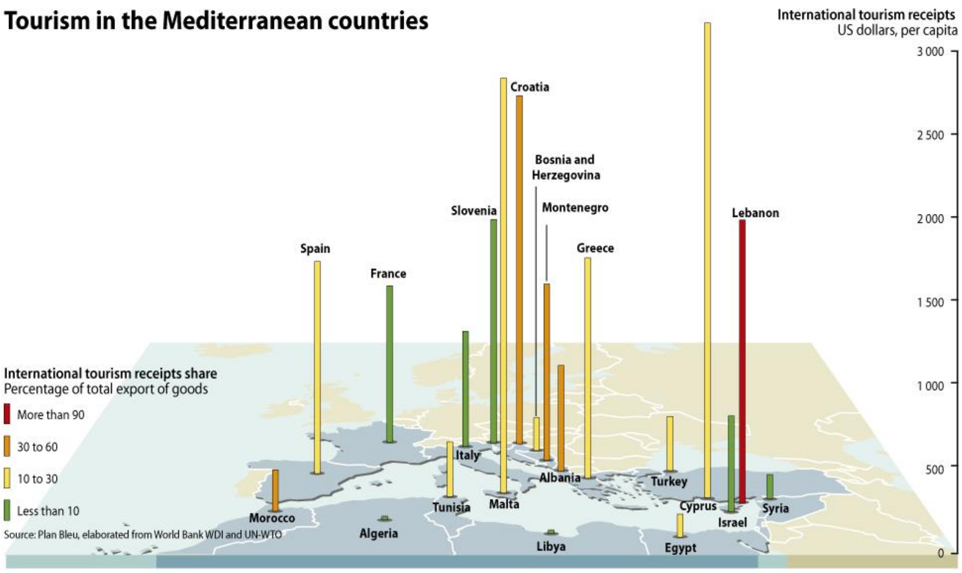
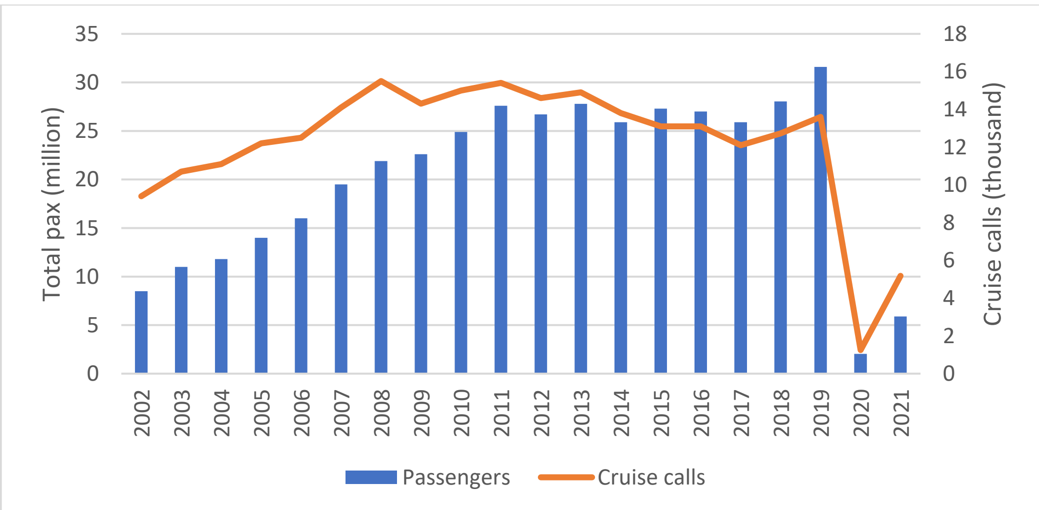


Figure 36. Tourism parameters evaluation in the Mediterranean region (Illustrated by GRID-Arendal).

The Mediterranean is the second biggest cruise region in the world, deploying some 15 – 20% of the global cruise fleet in recent years (MedCruise 2018, 2019 and 2022).

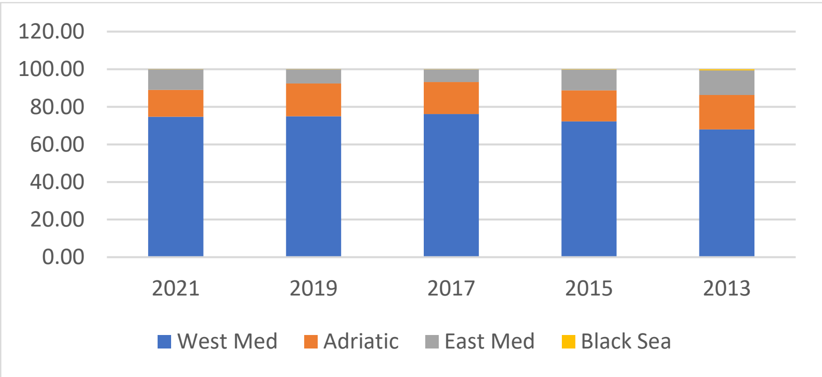


Sources: MedCruise 2018, 2019 and 2022

Figure 37: Cruise passenger movements and cruise calls in the Mediterranean, 2022 – 2021

Cruise industry has developed rapidly over the past twenty years, with the total number of passengers almost quadrupling between 2002 and record 2019, reaching 31.6 million; over the same period, total number of cruise calls in the MedCruise ports increased by around 45%. In 2008, a single Mediterranean port for the first time hosted more than a million passengers from cruise ships, in 2008 a 2 million record was set and in 2018, the port of Barcelona hosted more than 3 million passengers. Cruising was badly affected by COVID-19 pandemic and related restrictions, as evidenced by more than 90% drops in both the number of passengers and cruise calls in 2020 compared to 2019 (Figure 37: Cruise passenger movements and cruise calls in the Mediterranean, 2022 – 2021).

In terms of total passenger movements, the main cruise ports in the Mediterranean include Barcelona, Civitavecchia/ Fiumicino/ Gaeta, Balearic Islands, Genoa/ Savona, Marseille, Venice, Naples/ Salermo/ C. di Stabia, Tenerife Ports and Piraeus. Considering the number of calls, the ports of Dubrovnik, Kotor and Corfu also rank among the top ten ports. Nearly two thirds of the total cruise calls take place in Italian, Spanish and Greek ports. An overview of the cruise passenger movements since 2013 per sub-region (Western Mediterranean, Adriatic, Eastern Mediterranean and Black Sea) is shown in Figure 38: Cruise passenger movements per sub-region, indicating a slight increase in the visits to the West Med cruise ports, a decreasing share (from cca 18.3 to cca 14.3%) for the Adriatic and a stable trend for East Med; the share of Black Sea ports is negligible (below 0.6%).



Sources: MedCruise 2018, 2019 and 2022

Figure 38: Cruise passenger movements per sub-region

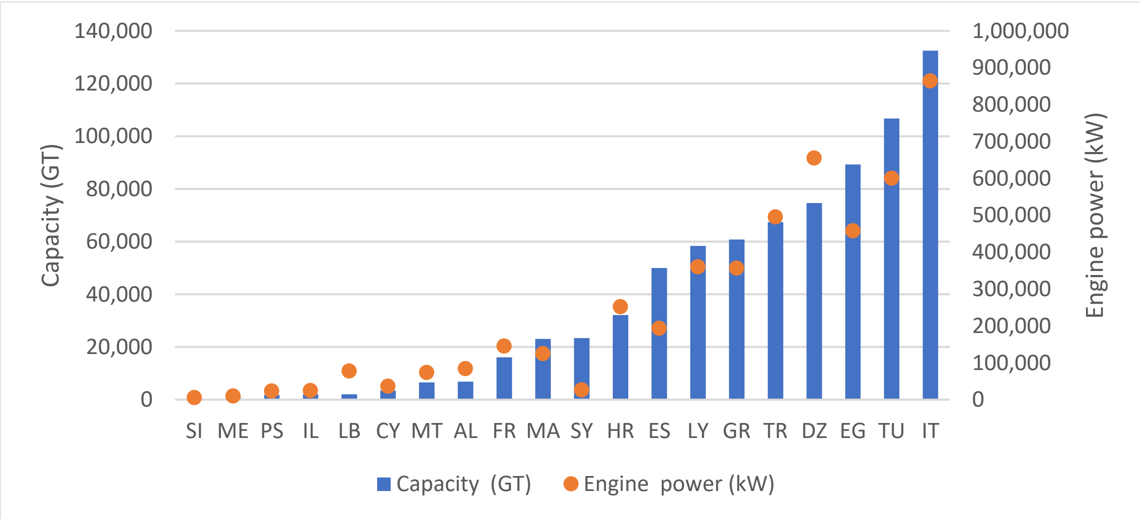
While tourism had a strong positive economic impact across the region and has emerged as a pillar of many national economies in the Mediterranean, the benefits associated with tourism came at significant environmental and social costs. The negative impacts of tourism have been widely recognized and documented, whereas there is a growing set of recommendations, policies and projects aiming at the development of sustainable tourism in the Mediterranean.

The main pressures of the tourism sector on the marine environment are marine litter, coastal land take, habitat degradation, air emissions, water consumption and sewage generation, and proximity to natural sensitive areas (UNEP/ MAP and Plan Bleu, 2020).

3.5.1.2. Fisheries

Variety of capture fisheries gears and aquaculture techniques are employed across the Mediterranean at different scales, including industrial, semi-industrial and small-scale fisheries, as well as industrial and small-scale farming. Capture fisheries exploit a variety of benthic and pelagic fish stocks, molluscs and crustaceans. *Aquaculture production includes extensive aquaculture in pond or lagoon areas and small family farms cultivating mussels, but also more intensive offshore finfish cage farms.* According to SoED (UNEP/ MAP and Plan Bleu, 2020), fishery and aquaculture represent a relatively small sector of the Mediterranean blue economy (both in terms of GVA – less than 5%, and job creation – less than 10%)13, nevertheless with an important socioeconomic and cultural function in terms of food production, revenue, employment and preservation of traditional activities.

According to the latest available data (as reported to the GFCM Secretariat and/ or estimated), a total of 76,280 vessels were operating by 2019 in 20 Mediterranean countries14, with the total capacity of around 758,000 GT15. These figures should be considered as approximate and most likely as an underestimate of the real size of the fleet, given the lack of data from some countries, especially on small-scale vessels (FAO, 2020).



Source: FAO, 2020; own estimate

Figure 39. Capacity of the fishing fleet operating in the Mediterranean basin by country, 2019

In terms of capacity (expressed in GT), more than 62% of the fishing fleet is operated by five countries: Italy (17.5%), Tunisia (14.1%), Egypt (11.8), Algeria (9.8%) and Turkey (8.9%16). Greece's fishing fleet

[13] Union for the Mediterranean (UfM) 2017 report *Blue economy in the Mediterranean,* https://ufmsecretariat.org/wp-content/uploads/2017/12/UfMS_Blue-Economy_Report.pdf based on earlier Plan Bleu analyses (e.g. 2014 report *Economic and social analysis of the uses of the coastal and marine waters in the Mediterranean*, https://planbleu.org/sites/default/files/publications/esa_ven_en.pdf)

[14] Data for Turkey refers to the number of vessels operating in the Mediterranean, whereas capacity of these vessels was estimated based on an assumption it mirrors the share (39.3%) of the total number of vessels reported for the Mediterranean and Black Seas. Bosnia and Herzegovina and Monaco informed the GFCM Secretariat they had no operating fishing fleet in the last reporting period.

[15] The overall number of vessels reported and/ or estimated (by FAO, 2020) for Mediterranean and Black Sea was 87,641 (903,270 GT).

[16] Taking only into account 6,026 vessels that operate in the Mediterranean. Turkey' total fishing fleet operating in Mediterranean and Black Seas was reported to include 15,352 vessels (with capacity of 171,785 and engine power of 1,261,241 kW).

makes 16.8% of the total number of vessels, but only 8% of the total capacity, indicating that small-scale fisheries are prevalent. Besides Greece, small-scale fishing vessels account for 90% or more of the total fleet in Lebanon, Cyprus, Turkey, Tunisia and Croatia. Four out of five fishing vessels in the Mediterranean are small-scale vessels17 which are predominant fleet segment in all the Mediterranean fishing sub-regions, in particular in Eastern and Central Mediterranean. Another important fleet segment are trawlers and beam trawlers, accounting for 7.9% of the total, predominantly used in Western Mediterranean and the Adriatic; purse seiners and pelagic trawlers make up 5.5% of the fleet.

Table 10. Mediterranean fishing fleet by country and segment

NOTE: Data from the table to be mapped, with structure of the fleet represented by pie charts the size of which should correspond with the overall fleet size by country. If possible, the map should indicate GFCM fishing sub-regions (Western, Central and Eastern Med, and Adriatic Sea)

Country code	No of vessels	Share (%) of operating vessels by fleet segment				
		Small-scale	Trawlers, beam trawlers	Purse sein., pelagic trawl.	Other segments[18]	Unallocated
AL	445	67.0	27.0	5.2	0.9	0.0
DZ	5608	61.8	9.9	28.4	0.0	0.0
HR	6211	91.2	5.5	2.7	0.5	0.0
CY	774	94.4	1.0	0.0	4.5	0.0
EG	3945	44.6	24.0	5.3	26.1	0.0
FR	1418	88.9	6.0	1.1	3.9	0.0
GR	12807	95.4	1.8	1.7	1.2	0.0
IL	336	79.8	5.7	3.0	11.6	0.0
IT	10909	69.7	18.6	4.1	7.6	0.0
LB	2084	95.0	0.0	4.4	0.7	0.0
LY	3974	73.3	2.0	3.1	17.8	3.7
MT	682	77.6	2.9	0.6	18.9	0.0
ME	224	85.3	5.8	8.9	0.0	0.0
MA	3496	87.0	4.3	7.0	1.7	0.0
SI	72	87.5	12.5	0.0	0.0	0.0
ES	2056	51.2	28.0	10.7	10.1	0.0
PS	613	65.9	2.0	32.1	0.0	0.0
SY	1300	0.0	0.0	0.0	0.0	100.0
TU	13300	92.7	3.6	3.4	0.3	0.0
TR	6026	93.9	3.8	1.0	1.4	0.0

[17] Including small-scale vessels 0–12 m with engines using passive gear; polyvalent vessels 6–12 m; and small-scale vessels 0–12 m without engines using passive gear. Polyvalent vessels are all vessels using more than one gear type, with a combination of passive and active types of gear, none of which are used for more than 50 percent of the time at sea during the year.

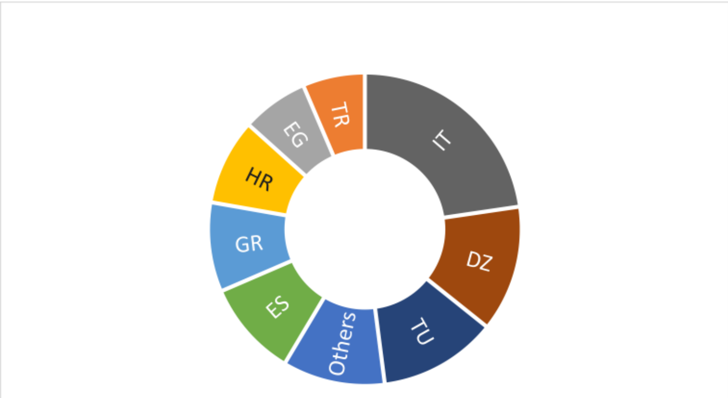
[18] Includes polyvalent vessels 12–24 m, longliners 12–24 m, dredgers 12–24 m, and longliners > 6 m.

Med total	76,280	80.5	7.7	5.4	4.5	1.9

Source: FAO, 2020

Total capture fisheries production in the Mediterranean and the Black Sea peaked during 1980s reaching 1,788,000 tonnes in 1988. Contribution of the Mediterranean and Black Sea fisheries to the global marine capture ranged from 2.55% during 1980s to 1.55% in 2020 (FAO, 2022). In the Mediterranean Sea, total landings were rising until 1994, reaching 1,087,000 tonnes. From mid-1990s, landings declined irregularly to 760,000 in 2015, with production increasing again over the following three years to 805,700 tonnes in 2018. The average landings over the 2016-2018 period were 787.830 tonnes (a 3% increase compared to the average for the period 2014-2016).

From 2016 to 2018, Italy continued to be the main producer (22.7% of the total Mediterranean landings), followed by Algeria (13.1%), Tunisia (12.2%), Spain (10%), Greece (9.3%), Croatia (8.9%), Egypt (6.9%), and Turkey[19](6.4%). The remaining 12 countries[20] accounted for less than 4% individually; added together, their landings represented 10.6% of the Mediterranean total. Compared to the previous period (2014-2016), total landings increased the most in Turkey (by 20.4%), while as the most substantial decrease (-10.6%) among major producers was recorded in Morocco; in Slovenia and Israel average landings decreased by 30.5 and 22.2% respectively.



Source: FAO, 2020

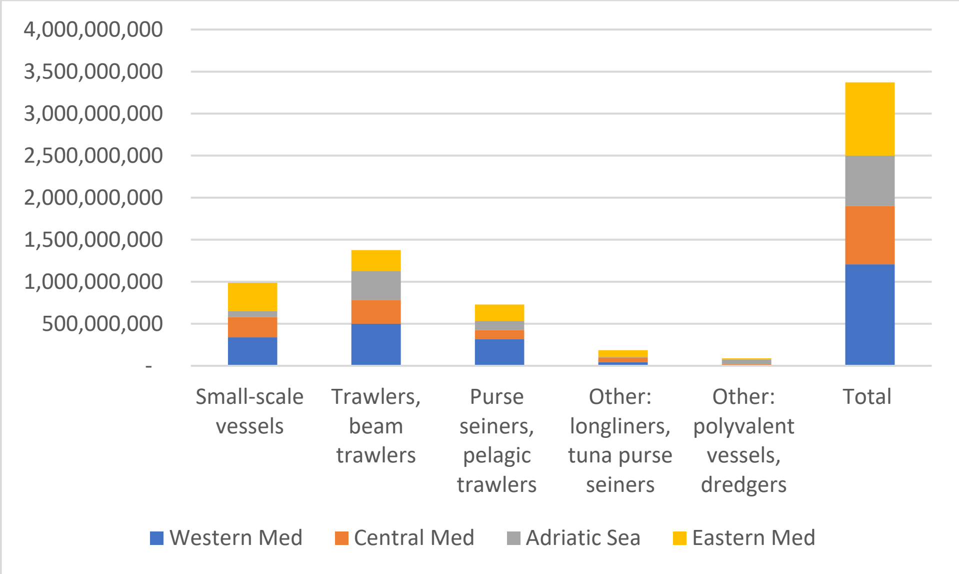
Figure 40: Distribution of landings, average 2016-2018

In the period 2016-2018, the main species and their contributions to the total catch were as follows: sardine (23%); European anchovy (14.1%); Sardinellas nei (5.8%); marine fishes nei (4.6%); jack and horse mackerels nei (2.8%); deep-water rose shrimp (2.8%); bogue (2.6%); and Europan hake (2.5%); other species' individual contributions were below 2%.

During the period (2013-2018), total revenues in the GFCM area (including Black Sea) were between 3.2 and 3.6 billion (in constant 2018 USD). Total revenue/ value at first sale[21] from marine capture fisheries

[19] Average landings 2016-2018 for the Mediterranean Sea equalled 50,772 tonnes; average total landings (including Black Sea) were 273,977.
[20] Total landings by Bosnia and Herzegovina and Monaco are negligible.
[21] Revenue is estimated as the value at first sale of fish from vessel-based marine capture, prior to any processing or value-addition activities.

in the Mediterranean is estimated at USD 3.4 billion in 2018. When different fleet segments are considered, the highest revenues are generated by trawlers, followed by small-scale vessels and purse seiners/ pelagic trawlers. As regards the fishing sub-regions, predominant shares of total revenues are generated in Western and Eastern Mediterranean (FAO, 2020).



Source: FAO, 2020

Figure 41: Revenue by fleet segment and sub-region (constant 2018 USD)

The wider economic impact of fisheries along the value chain in the region, including direct and indirect and induced effects, is estimated to be 2.6 times the value at first sale (FAO, 2018). In the Mediterranean, revenue from small-scale fisheries makes 29% of the total; however, in some countries (e.g. Cyprus, France, Greece, Lebanon, Morocco, Slovenia), small-scale fisheries account for as much as 50% of the total revenue (FAO, 2020).

According to FAO (2020), total employment onboard fishing vessels in the Mediterranean was near 202,000 in 2018. Approximately one third of these jobs are linked to fishing in each the Western and Eastern Mediterranean sub-regions; Central Mediterranean accounts for 24% of the total number of jobs, and Adriatic Sea sub-region for 9%. Estimates from the previous analyses (for example by the World Bank, FAO and WorldFish) suggest that non-vessel-based jobs employ almost 2.5 times as many people as those onboard vessels. On average, employment onboard fishing vessels represents around 0.1% of total coastal populations (i.e. approximately one fisherman per 1,000 coastal residents), but is six to 11 times higher in countries like Morocco, Croatia and Tunisia. Small-scale fisheries account for 55% of the total employment onboard fishing vessels (but the share can go to as much as 70 – 90% in some countries).

A study conducted in the EU Member States fishing in Mediterranean and Black Sea basins concluded that due to the lack of systematic collection of gender disaggregated data, women in the fisheries sector were largely invisible. It was assessed that women represented between 1 and 6% of the capture fisheries workforce. In processing, women either represent the majority of workers or are in the same numbers as men. As regards fisheries-related activities, women are considered to play a vital role in the sale of fish,

pesca-tourism and gastronomic activities. Where available, disaggregated data showed women were predominantly found in lower-level jobs with less pay than men (EC, 2019).
The analyses (GFCM, 2020; FAO, 2020) showed that Mediterranean and Black Sea fisheries were fiercely affected by the COVID-19 pandemic. A reduction in operating vessels of up to 80% was observed in some countries, with a decrease in production of some 75% during the first months following the outbreak. Fish market prices decreased between 20 and 70%, particularly for species typically destined to the hotel, restaurant and catering sector. Due to sector's adaptability and measures put in place by governments, the dramatic early impacts began fading towards summer of 2020, with production returning to pre-crisis levels in many countries. Nevertheless, demand has remained volatile throughout 2020. Considering the strong reduction in fishing effort in the early phase of the pandemic, some hypothesized that it may have (at least temporarily) reduced pressure on resources and the environment. Longer-term COVID-19 impacts on the fisheries are yet to be analysed. Data from the latest FAO report on the state of world fisheries and aquaculture (2022) indicate that total marine captures in the Mediterranean and Black Sea decreased by 14.4% in 2020 compared to 2019, i.e. by 9.2% compared to the average annual production during 2010s.

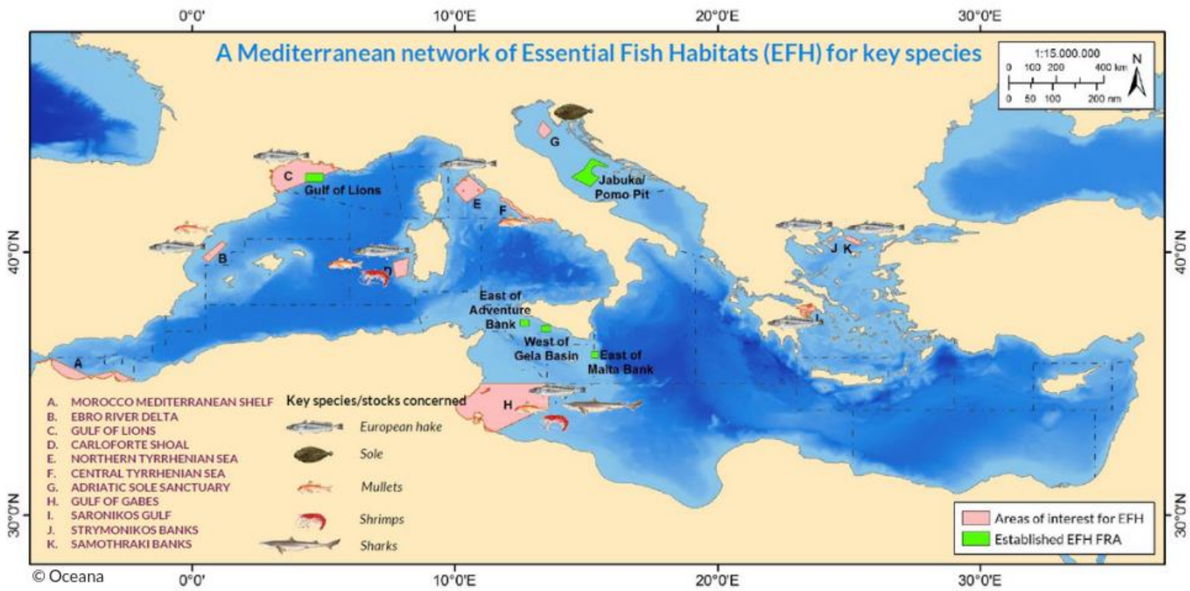
Despite positive trends during the past couple of decades, fisheries in the Mediterranean and Black Sea remain highly threatened by overfishing, pollution, habitat degradation, invasive species and climate change (UNEP/MAP and Plan Bleu, 2020). The latest FAO report on the state of world fisheries and aquaculture (FAO, 2022) concludes that among FAO's 16 Major Fishing Areas in 2019, the Southeast Pacific had the highest percentage (66.7) of stocks fished at unsustainable levels, followed by the Mediterranean and Black Sea with 63.4%.

While most stocks remain in overexploitation, the number of stocks in overexploitation has further decreased, as has the overall exploitation for the whole Mediterranean and Black Sea region. For the stocks for which validated assessments are available, a notable decrease of stocks in overexploitation has been assessed in recent years: from 88% in 2014, to 75% in 2018. This dynamic is reflected in marked improvements for a number of demersal species in terms of fishing mortality and, in some cases, of biomass too (FAO, 2020).

Nevertheless, the GFCM estimates the overall fishing mortality for all resources combined is nearly 2.5 times higher than sustainable reference points. A clear (although not significant) decreasing trend has been seen in the average exploitation ratio (current fishing mortality over target fishing mortality, F/FMSY) since 2012. Based on available information (for 62 stocks covering 20 geographical subareas and 14 species), 36% of Mediterranean stocks are assessed to have low biomass levels, 19% intermediate and less than a half (46%) high biomass level (FAO, 2020).

In addition to its negative environmental impact, bycatch from fishing activities – including discards and incidental catch of vulnerable species – has significant implications for the sector, including from economic, regulatory and public perception perspectives. Sea turtles (around 89%) and elasmobranchs (around 8%) continue to represent the highest share of reported incidental catch of vulnerable species; seabirds and marine mammals together account for the remaining 3% (FAO, 2020). According to SoED, discards represent a window for improvement in the fishing sector as 18% of total catches are discarded (UNEP/MAP and Plan Bleu, 2020, based on the FAO's The State of Mediterranean and Black Sea Fisheries 2018).

Small-scale fisheries are generally considered to have less ecological impact than industrial fisheries, and are usually seen as more sustainable, but can still have significant impacts that need to be addressed (Piante et al., 2019).



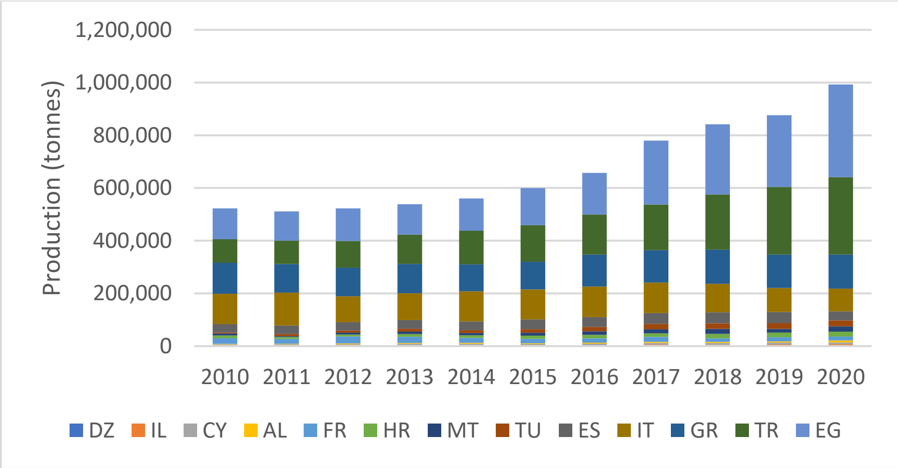
Note: The NGO Oceana claim UN and EU's failure to protect areas for young fish in the Mediterranean, the world's most overfished sea. [Oceana criticizes UN and EU's failure to protect areas for young fish in the Mediterranean, the world's most overfished sea | Oceana Europe]

3.5.1.3. Marine Aquaculture

According to SoED, total aquaculture production in Mediterranean States, considering all species and all environments (marine, brackish and freshwater), has increased substantially over the past decades: it more than doubled by 2006 (from slightly over half a million tonnes in 1996), and continued to grow until 2016 at an average annual rate of more than 7% (UNEP/MAP and Plan Bleu, 2020).

Strong growth over the period 2010 – 2020 is also evident when marine aquaculture production in the Mediterranean (excluding freshwater, including Turkey's Black Sea production) is considered. Total production approached one million (994,623) tonnes in 2020; average annual growth rates were at the level of 6.8%, cumulative increase (2020 compared to 2010) was around 90%. The most extensive growth was recorded in Palestine and Algeria, where production increased by a factor of 15 to 30. In the same period, production increased by several folds in Tunisia, Albania, Turkey, Egypt and Malta. Negative growth rates were recorded in France and Italy, as well as in Bosnia and Herzegovina and Lebanon. Marine aquaculture output was not negatively affected by COVID-19 pandemic: production in 2020 increased by 13.2% compared to 2019.

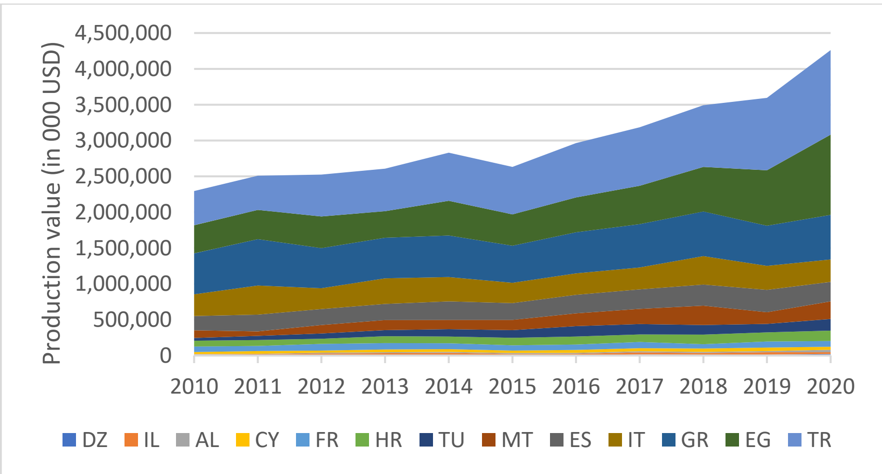
The biggest producers are Egypt, Turkey, Greece and Italy. Taking into account the average annual production (2010-2020), Egypt and Turkey accounted for 27.2 and 23.4% of the total respectively; due to high growth rates in these two countries, their relative shares in the overall production increased by 2020 approaching and/or slightly exceeding one third of the total (35.4% for Egypt and 29.5 for Turkey). Egypt is a globally significant producer, where total aquaculture output (including freshwater) grew from less than half a million tonnes in early 2000s, to 1.6 million tonnes in 2019, making more than 80% of the total – capture fisheries and aquaculture – production in the country (FAO, 2022).



Note: countries with production of more than a thousand tonnes in recent years (cumulatively accounting for more than 99% of the total) shown in the graph
Source: FAO, 2022a, FishStatJ database accessed November 2022

Figure 42: Aquaculture output 2010-2020: contribution of the main producers

In 2019, production of less than one thousand tonnes was recorded in Slovenia (914), Palestine (560), Morocco (465), Montenegro (379), Bosnia and Herzegovina (176) and Lebanon (19). Among the top five producers, stable output trends were recorded in Greece and Spain, while in Italy production dropped by a quarter in 2020 compared to 2010 (mainly due to reduced shellfish production). High growth rates characterize production in Turkey and Egypt, especially as of 2016. Value of production increased from USD 2.3 billion in 2010 to USD 4.3 billion in 2020. In 2018, aquaculture production value (USD 3.5 billion) slightly exceeded total revenue from capture fisheries (USD 3.4 billion)[22]. Highest production values in 2020 were recorded in Turkey, Egypt. Greece, Italy, Spain and Malta (accounting for some 88% of the total).



Source: FAO, 2022a, FishStatJ database accessed November 2022

[22] It should be noted that aquaculture production value includes Turkey's Black Sea production (while as capture fisheries revenue refers only to the Mediterranean fishing area).

Figure 43: Aquaculture production value, main producers 2010-2020

Mediterranean marine aquaculture is dominated by finfish, accounting for 83% of the total production; molluscs account for 16% of the overall output. Gilthead seabream (Sparus aurata) and European seabass (Dicentrarchus labrax) are the most commonly farmed species, at 464,000 tonnes and USD 2.24 billion in 2019. More than 95% of the world's seabream and seabass production comes from aquaculture, of which 97% is produced by Mediterranean countries. In terms of quantity, other important farmed species are mullets and mussels. With production of 99,200 tonnes in 2019, Mediterranean mussel (Mytilus galloprovincialis) is the fourth most farmed species in the region, with Italy (62% of the region's production) and Greece (24%) as the main producers (Carvalho and Guillen, 2021). Bluefin tuna, despite is not yet a complete life-cycle aquaculture species, are also raised in some locations (e.g., Spain).

As far as shellfish farming is concerned, total production decreased by nearly a quarter (-23%) between 2000 and 2010, and then stabilised through to mid-2010s. The decrease in production is mainly related to the loss of space suitable for shellfish farming, along with important changes in Mediterranean coastal waters on the level of nutrient availability, extreme events23, marine pollution and biotoxins. Most of these changes were due to anthropogenic pressures and climate change (Bolognini et al., 2019).

Data on aquaculture jobs are less available than for capture fisheries. One of the recent estimates suggest that Mediterranean aquaculture offers employment to 313,000 persons, taking into account both direct and indirect jobs (Bolognini et al., 2019). Like fisheries, aquaculture is also a sub-sector dominated by male workers in the EU Member States, with women representing 7% to 26% of the workforce, but with more opportunities being provided for women (EC, 2019). In this sub-sector, there is also an unreported number of "invisible" female workers, particularly in small-scale freshwater aquaculture and shellfish farming.

Aquaculture made around half the total fishery output in the Mediterranean in recent years, and is expected to continue growing, in line with global trends. Its environmental effects depend on the size of the farms, the production systems and management methods used, as well as on the marine habitats in which they're located; aquaculture may harm the marine environment, and at the same time it may be seriously affected by other factors that cause water quality and habitat degradation (Bolognini et al., 2019).

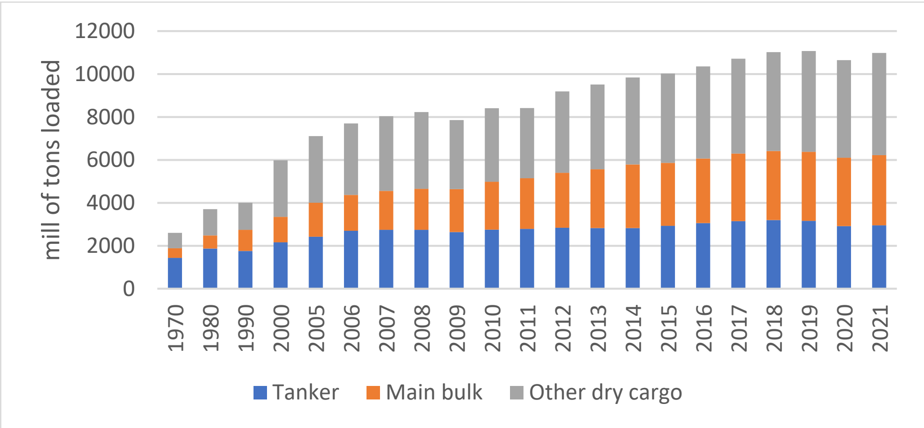
According to SoED, growth in aquaculture production in the Mediterranean is accompanied with high dependency on fish meal from sea catches, large nitrate and phosphorus effluents, as well as genetic modification of natural fish stocks (UNEP/ MAP and Plan Bleu, 2020). Some of the priority issues related to sustainable aquaculture development in the Mediterranean and Black Sea (as identified by Massa et al., 2017) include integration of aquaculture into coastal zone management and sea use planning,

[23] An example presented in the SoED refers to Thau lagoon (close to Montpellier on the French Mediterranean coast). In August 2018, unusually high water temperatures over an extended period (exceeding 29°C over eight days) combined with no wind causing radically reduced oxygen levels (anoxia) led to high mortality of shellfish farmed in the lagoon. Mortality rates for oysters reached 30% to over 60% depending on the zone in the lagoon, and 100% for farmed mussels. Losses of 2,703 tonnes of oysters (worth EUR 4.73 million) and 1,218 tonnes of mussels (worth EUR 1.22 million) were recorded (UNEP/ MAP and Plan Bleu, based on information from Prefecture of the Hérault Department, France, 2018).

improvements in site selection and licensing procedures, enhancement of aquaculture-environment interactions and implementation of environmental monitoring, and similar.

3.5.1.4. Marine transport

Maritime transport is the backbone of international trade and the global economy. Around 80% of global trade by volume and more than 70% by value is carried by sea (Randone et al., 2019). World maritime trade more than quadrupled since 1970, approaching 11 billion of tons loaded in 2021; minor bulk commodities, containers and residual general cargo (other dry cargo) represent the the most signficant and the fastest growing cargo segment.



Notes: Tanker includes crude oil, refined petroleum products, gas, and chemicals

Main bulk includes iron ore, grain, coal, bauxite/alumina and phosphate. Starting in 2006, "Main bulk" includes iron ore, grain, and coal only. Data relating to bauxite/alumina and phosphate are included under "Dry cargo other than main bulk".

Other dry cargo includes minor bulk commodities, containerized trade, and residual general cargo.

Sources: UNCTAD, 2021 and 2022

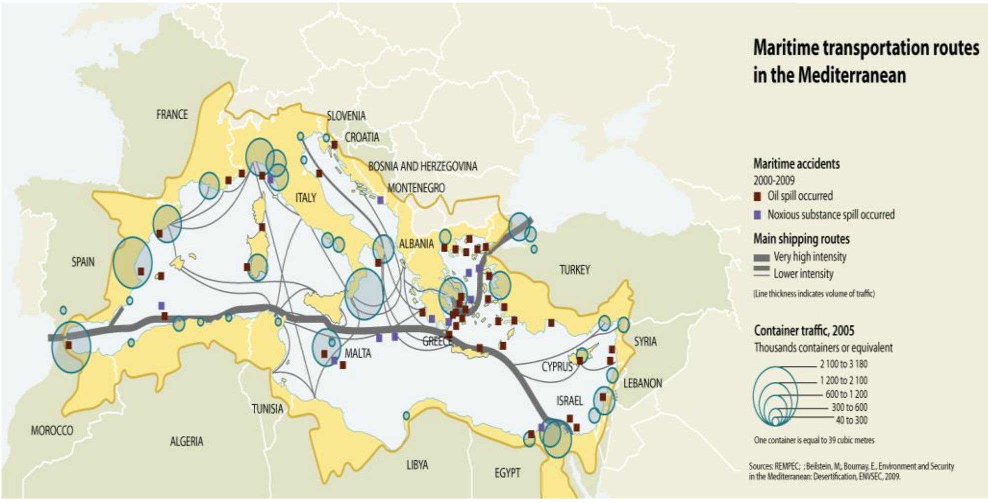
Figure 44: International maritime trade, 1970-2021

The impact of COVID-19 pandemic on international maritime trade was not as dramatic as initially feared24. Growth had already been weak in 2019 at 0.5%, and in 2020 total maritime trade declined by 3.8%. As the global economy started to recover, there was a rebound in 2021 when a 3.2% growth was recorded brining global maritime trade to only slightly below the pre-pandemic level. However, the recovery was uneven: containerized cargo, gas, and dry bulk shipping expanded, while shipments of crude oil declined (UNCTAD, 2021 and 2022).

[24] A study (March et al., 2021) looking at the COVID-19 impacts in, *inter alia* the Western Mediterranean, found out that the number of vessels sharply decreased in the first days of mobility restrictions (starting from March 2020) compared to pre-disturbance baselines (i.e. equivalent periods of 2019), reaching an overall median drop of 51% during the initial national lockdowns (lasting approximately until 22 June 2020). Maximal reductions ranged from 22.2% (tankers) to 93.7% (recreational boats), with a maximal overall drop across all categories of 62.2% during mid-April.

The Mediterranean Sea is located at the crossroads of three major maritime crossings: Strait of Gibraltar, opening into the Atlantic Ocean and the Americas; the Suez Canal, a major shipping gateway which connects to Southeast Asia via the Red Sea; and the Bosphorus Strait, leading to the Black Sea and Eastern Europe/ Central Asia. With such a strategic location, it is an important transit and trans-shipment area for international shipping, as well as a realm for Mediterranean seaborne traffic (movement between a Mediterranean port and a port outside the Mediterranean) and short sea shipping activities between Mediterranean ports (UNEP/MAP and Plan Bleu, 2020).

Despite covering less than 1% of the world's oceans, the Mediterranean Sea accounted for more than a fifth (21-22%) of global shipping activity measured by the annual number of port calls, and around 9% of the annual container port throughput in recent years (Randone et.al, 2019; own calculations based on UNCTAD, 2022a). Approximately 18% of global seaborne crude oil shipments take place within or through the Mediterranean. According to the Plan Bleu's analyses referring to early 2010s, direct employment in Mediterranean countries' maritime transport was around 550,000 people, while as the sector generated a Gross Value Added (GVA) of € 25 billion (Plan Bleu, 2014). In some of the EU Mediterranean Member States (Croatia, Cyprus, Greece, Italy, Malta, Spain) in 2019, maritime transport (including port activities and shipbuilding and repair) accounted for between 0.4 and 1.3% of the total employment, and between 0.6 and 2.1% of the national GVA. The Western Mediterranean and the Aegean-Levantine Sea are the busiest parts of the basin (Randone et al., 2019).



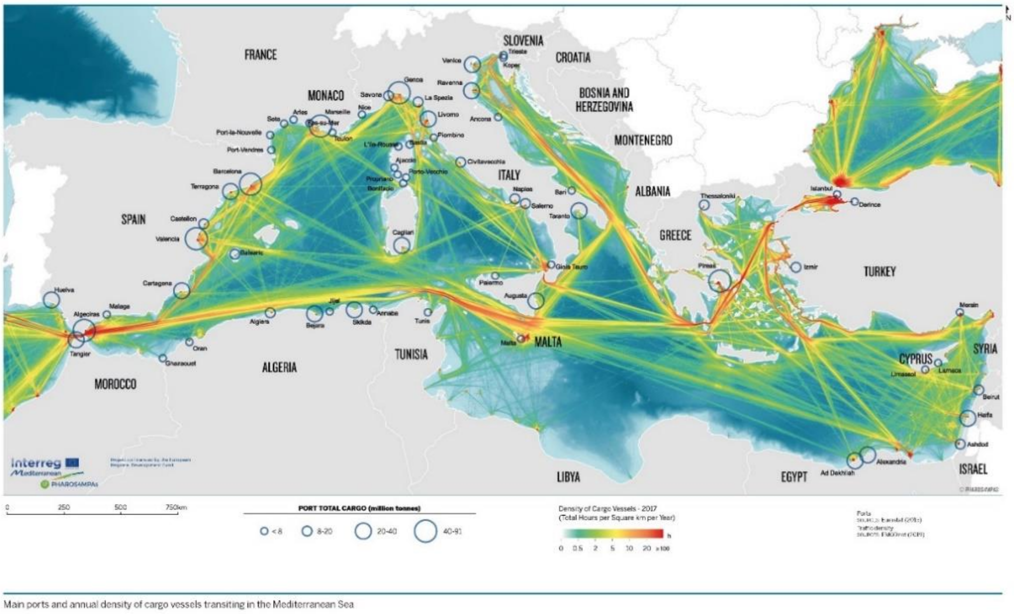
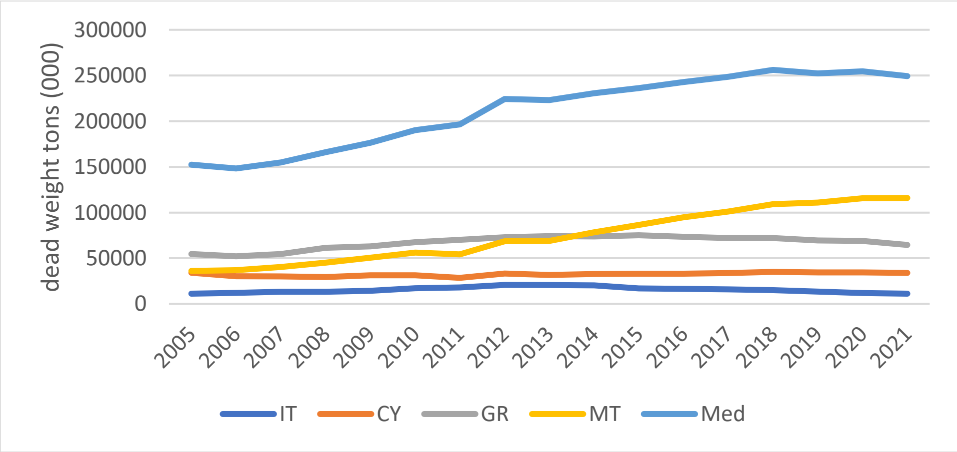


Figure 45: Main ports and annual density of cargo vessels in the Mediterranean (Sources: by GRID-Arendal (top), PHAROS4MPAs Project (middle) and Maritime traffic (bottom).

The Mediterranean's passenger transport represents a major component of maritime traffic in the region, especially in the Aegean Levantine Sea (Plan Bleu, 2014). Italy and Greece had the highest numbers of seaborne passengers in Europe, accounting for one third of all passengers embarking and disembarking in EU ports. A significant decrease in maritime passenger transport was seen as new alternatives (including bridges, tunnels and low-cost flights) were becoming available: in Italy and Greece, for example numbers of seaborne passengers decreased by 21.8 and 27.8% respectively over the decade 2006 – 2016 (Randone et al., 2019).

Over the period 2015 – 2021, merchant fleet registered in 20 Mediterranean countries25 encompassed a total of 9,300 – 9,400 vessels, with 245.3 million dead-weight tons in 2021. Total carrying capacity increased by 63.5% (from 152.9 million) in comparison with 2005. Four countries (Malta with 46.5%, Greece with 25.9%, Cyprus with 13.7% and Italy with 4.5%) account for 90% of the total merchant fleet carrying capacity (UNCTAD, 2022a).

[25] No data for Bosnia and Herzegovina and Palestine.



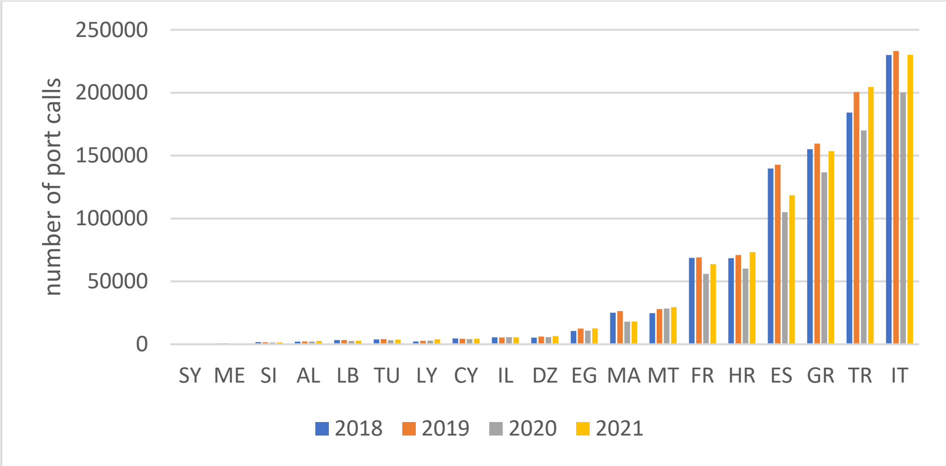
Source: UNCTAD, 2022a. http://stats.unctad.org/fleet Accessed November 2022

Figure 46: Carrying capacity of the merchant fleet registered in the Mediterranean (top four countries and total), 2005-2021

As regards ownership of the world fleet (by carrying capacity expressed in dead-weight tons) in 2021, five Mediterranean countries were among top 35 world economies: Greece (4,705 vessels in total, 620 under national flag) with 17.6% of the world total; Monaco (478 vessels, none under national flag), accounting for 2.1% of the total; Turkey (1,541 vessels, 429 under national flag), 1.3%; Italy (651 vessels, 481 under national flag), 0.8%; and Cyprus (311 vessels, 134 under national flag), with 0.6% of the carrying capacity of the world's fleet (UNCTAD, 2021).

The Mediterranean has more than 600 commercial ports and terminals (Plan Bleu, 2014). Nine of these are among the 20 largest cargo ports in the European Union: Algeciras and Valencia (Spain), Marseille (France), Genova and Trieste (Italy), Piraeus (Greece), and Aliaga, Izmir and Botas ports (Turkey). Important ports in the southern Mediterranean with more than 1 million TEU include Port Said and Alexandria (Egypt), Tangier (Morocco), Beirut (Lebanon) and Haifa (Israel) (Randone et al., 2019, and Grifoll et al., 2018).

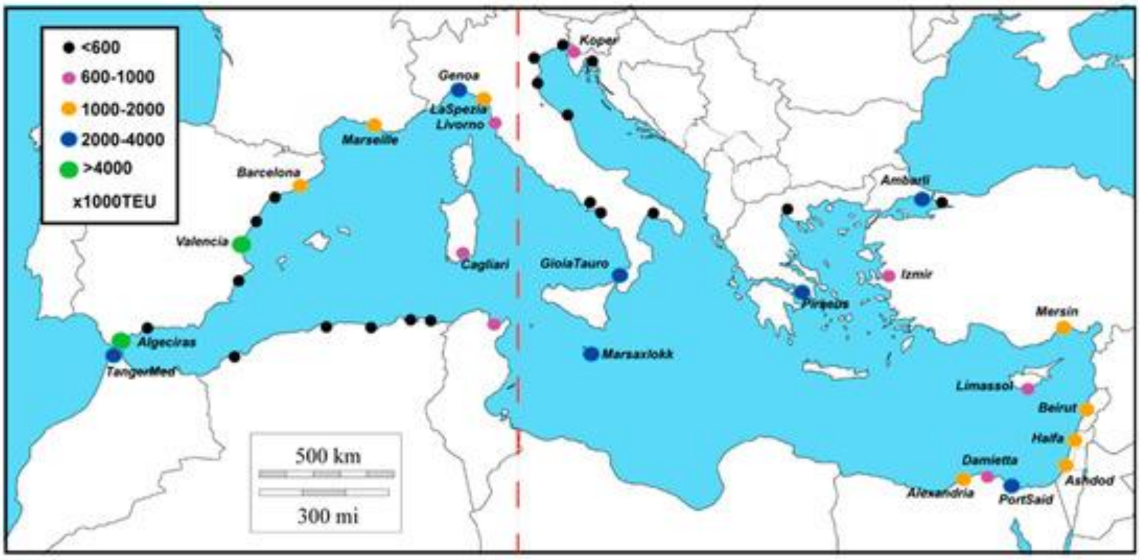
With nearly one million (935,649) port calls in 2021, volume of maritime transport reached 96% of 2019 level in the Mediterranean countries. Italy's ports accounted for one quarter of the total port calls in 2021, Turkey's for one fifth, followed by Greece (16.4%), Spain (12.7%), Croatia (7.8%), France (6.8%) and Malta (3.2%). Share of passenger ships in total port calls in 2019 exceeded 75% in Croatia, Malta, Italy, Greece and Turkey; cargo ship calls were predominant (accounting for 75% of the total or more) in Tunisia, Cyprus, Algeria, Slovenia and Israel. COVID-19 impact (measured by the number of port calls) was the lowest in Albania (-3% in 2020 compared to 2019), the highest in Montenegro (reduction of nearly 52%); in the countries with largest annual numbers of port calls, reduction was around 15% (UNCTAD, 2022a). Passenger ports were most affected, with numbers of passengers dropping by 8 to 61% in the top twenty EU passenger ports in 2020 compared to 2019; the number of seaborne travellers within the EU decreased the most in Cyprus, Spain, France and Croatia, flowed by Greece, Malta and Italy (EC, 2022).



Source: UNCTAD 2022a. [http://stats.unctad.org/portcalls_number_a Accessed November 2022](http://stats.unctad.org/portcalls_number_a)

Figure 47: Number of port calls by country, 2018-2021

Container port throughput in Mediterranean countries[26] increased from 50.6 million in 2010 to 72.9 million TEU in 2019, with an average annual growth rate of 4.2% and the overall increase of 44; the throughput declined by 1.8% in 2020. Countries with annual throughput of more than 2 million TEU in 2020 were Malta (accounting for 3.4% of the total Mediterranean throughput), Israel (4.18), France (7.1%), Greece (8%), Egypt (8.3%), Morocco (9.8%), Italy (13.7%), Turkey (16.3%) and Spain (24.3%) (based on UNCTAD, 2022a). Major ports (in terms of container throughput) are shown in figure below.



Notes: For clarity, only the names of the ports with > 200,000 TEU appear on the map. The red dashed line denotes the division (East and West Mediterranean) used in the analysis.

Source: Grifoll et al., 2018

Figure 48: The main Mediterranean ports by container throughput for 2015 (in 000 TEU)

[26] UNCTAD statistics database http://stats.unctad.org/maritime did not contain data for Albania, Bosnia and Herzegovina, Libya, Monaco, Montenegro, Palestine and Syria.

In recent years, significant shipbuilding activities are present in several Mediterranean countries (Egypt, Greece, Spain, Croatia, Turkey, France and Italy) but they represent a very small share of the global shipbuilding: with a share of 0.6 to 0.9% since 2016, Italy was the lead Mediterranean country. Turkey is a globally significant provider for ship recycling, with 9.2% (or 1.6 million gross tons) of the total reported tonnage sold for ship recycling in 2020 (UNCTAD, 2021).

In line with the global expansion of seaborne trade, shipping activity in the Mediterranean basin is expected to increase in the coming years, in terms of both number of routes and traffic intensity. Doubling of the Suez Canal capacity[27] – from 50 to 100 ships per day – was expected to nearly double the number of shipping of containers which pass through the Mediterranean (Girin and Carpenter, 2017). The Mediterranean is also expected to become busier as a result of the Belt and Road Initiative (also referred to as the new Silk Road) – the Chinese government's vast investment plan aimed at improving connectivity between China and Europe, with the Chinese-owned port of Piraeus playing an important role and with new investments in port areas and inland logistic and industrial facilities (Randone et al., 2019).

According to SoED, the main pressures from maritime transport on the environment include: potential accidental and illicit discharges of oil and hazardous and noxious substances (HNS); marine litter; water discharge and hull fouling; air emissions from ships; underwater noise; collisions with marine mammals; land take through port infrastructure; and anchoring (UNEP/ MAP and Plan Bleu, 2020). Some of the key findings of the European Maritime Transport Environmental Report 2021 (EEA and EMSA, 2021) of relevance for understanding the maritime pressures and impacts in the Mediterranean include:

- In 2018, emissions from maritime transport made up 13.5% of the EU's total greenhouse gas emissions from transport sector (following road transport with 71% and aviation with 14.4%);
- In 2018, the maritime transport produced nearly a quarter (24%) of all NOx and SOx emissions, and 9% of all PM2.5 emissions; this is of concern for coastal communities, with approximately 40% of total population in the EU living within 50 km from the sea;
- It is estimated that between 2014 and 2019, the total accumulated underwater radiated noise more than doubled in EU waters; container ships, passenger ships, and tankers generate the highest noise emissions from propeller use;
- The total amount of accidental oil spills has been constantly declining: over the 2010-2019 period, five out of 44 global medium size oil spills were in European seas; for large oils spills, three out of 18 happened in the EU.

3.5.1.5. Energy

The Mediterranean region is a net importer of energy: in 2018, total consumption exceeded total production by 39%. If the current trends continue, import dependence is projected to grow over the next decades, exacerbating the tensions in the region (OME, 2021). On the other hand, it is assessed that implementation of energy transition policies could turn the region into a net exporter by 2050; extensive

[27] Following the expansion i.e. opening of the new side channel in 2016, the number of transiting ships in 2018 increased by around 18,000, while transported cargo increased by almost 1 billion tons (Randone et el., 2019).

deployment of renewable sources in the South Mediterranean[28] countries are seen as pivotal factor for materialising such a change.

Primary energy demand

Total primary energy demand (Table 12) in the Mediterranean equaled 1,021 Mtoe[29] in 2018 and 1,030 Mtoe in 2019, with an overall increase of 43 – 45% compared to 1990. According to MedECC, 2020, annual increases over the period 1980 – 2016 were on average at the level of 1.7% and were mainly driven by changes in demographic, socio-economic (lifestyle and consumption) and climate conditions. In 2020, a decrease of around 9% was recorded due to the effects of the COVID-19 pandemic, bringing primary energy demand down to 938 Mtoe.

Table 11: Primary energy demand in the Mediterranean

	1990		2018		2020	
	Mtoe	Share (%)	Mtoe	Share (%)	Mtoe	Share (%)
Coal	106	14.9	105	10.3	95	10.1
Oil	350	49.1	369	36.1	322	34.3
Gas	108	15.2	303	29.7	284	30.3
Nuclear	97	13.6	124	12.1	99	10.6
Hydro	16	2.3	24	2.4	24	2.6
Renewables	35.5	4.9	96.1	9.4	113.6	12.1
TOTAL	712.5		1021.1		937.6	

Source: OME (2021), Mediterranean Energy Perspectives to 2050, edition 2021

Shares of coal and oil in the total primary energy demand had a downward trend over the past three decades, with particularly pronounced decrease for oil (accounting for about half the energy demand in 1990, going down to around one third in 2020); shares of nuclear sources and hydro energy were relatively stable (Table 12). Major changes in the primary energy mix were seen for gas (doubling of the share in 2020 compared to 1990) and renewables (increase of 2.4 times between 1990 and 2020). Demand for renewables proved resilient to the effects of COVID-19 crisis, with a recorded increase of some 18% in 2020 (compared to 2018).

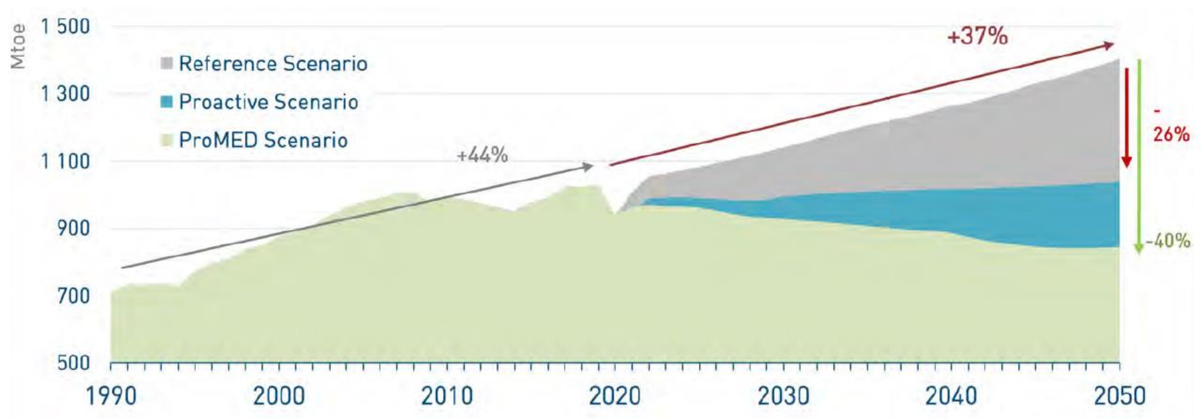
The OME report (Mediterranean Energy Perspectives to 2050, edition 2021) examines possible changes in energy demand in the Mediterranean under three scenarios: the Reference Scenario (RS) or baseline/ BaU scenario based on past trends, current policies and ongoing projects; the Proactive Scenario (PS)

[28] The Observatoire Méditerranéen de l'Energie (OME) report Mediterranean Energy Perspectives to 2050 (2021 edition) used the following country groups for the analysis: a) North Mediterranean countries – Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, Slovenia and Spain, and other North Mediterranean countries – Albania, Bosnia Herzegovina, North Macedonia, Montenegro and Serbia; and b) South Mediterranean countries (North Africa and South-East sub-regions) – Algeria, Egypt, Libya, Mauritania, Morocco, Tunisia, Israel, Jordan, Lebanon, Palestine, Syria, and Turkey.

[29] Million tonnes of oil equivalent

that takes into account strong energy efficiency programmes and energy mix diversification based on submitted NDCs (Nationally Determined Contributions); and the ProMED "Near Zero Carbon" Scenario (PM), taking into account more ambitious measures for energy efficiency and diversification of the energy mix, as well as significant development of technologies for curbing carbon dioxide (CO_2) emissions. Figure 49: Mediterranean primary energy demand by scenario, 1990 – 2050 presents the key findings of the OME report concerning possible evolution of the primary energy demand under the three scenarios. Compared to the current level, total primary energy consumption in 2050 is expected to increase by 37% under the RS, remain at more or less the same level under the PS, and decrease by around 18% under the PM. In relation to Business- as-Usual (the Reference Scenario) pathway, PS and PM are expected to lead to reductions in primary energy demand of 26% and 40% respectively.

There are marked differences in the primary energy consumption across the Mediterranean, with the South Mediterranean countries currently accounting for 40% of the region's total, while per capita energy demand in the South is less than half that in the North. Disparities are also pronounced as regards energy transition. Despite recent investments, some eastern and southern rim countries lag behind the Northern Mediterranean in energy mix diversification, energy efficiency improvements and in increasing the share of renewable energies (MedECC, 2020). In all three scenarios analysed in the OME 2021 report, energy demand by 2050 is expected to grow in the South and decrease further in the North Mediterranean countries, with the demand in the South overtaking the North Mediterranean demand by early 2030's.



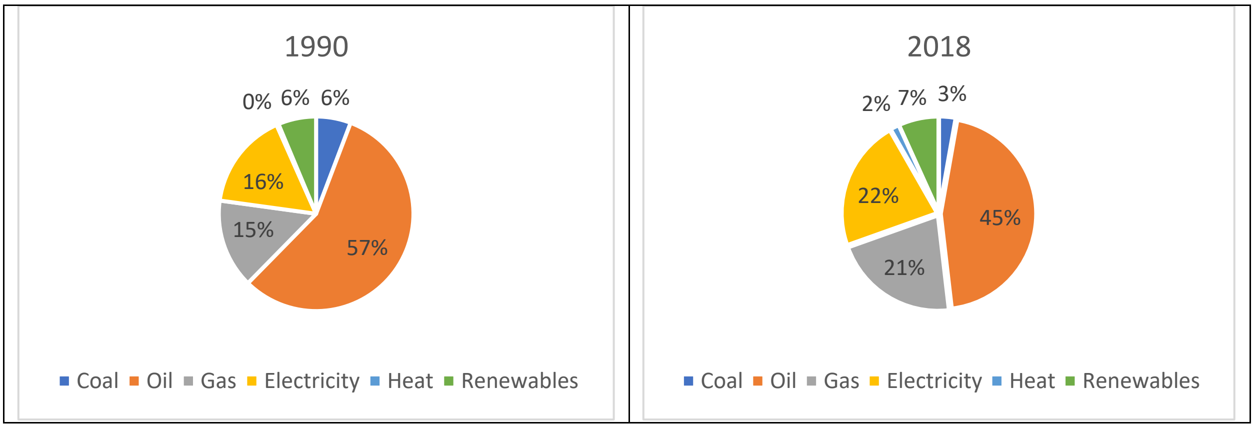
Source: OME (2021), Mediterranean Energy Perspectives to 2050, edition 2021

Figure 49: Mediterranean primary energy demand by scenario, 1990 – 2050

In 2018, primary energy intensity[30] in the Mediterranean was 0.095 toe per EUR 1,000 of GDP (2015 PPPs[31]) – a 25% decrease compared to 1970. The figure mainly reflects the trends in the North Mediterranean countries (which account for 60% of both Mediterranean GDP and total primary energy demand), thus masking significant variations between sub-regions and countries. A sub-regional perspective shows the energy intensity decreased by 35% in the North (1970 – 2018) due to structural shifts in the economy and, in recent years, due to rising energy prices and energy efficiency/ emissions reduction policies. Conversely, energy demand has been increasing faster than GDP in the South, leading to an overall 40% increase in energy intensity over the same period (1970 – 2018), and as much as 140%

[30] The amount of energy needed to produce a unit of GDP
[31] Purchasing Power Parities

increase in North Africa (OME, 2021). Under the Reference Scenario, a 35% reduction in energy intensity is expected by 2050; reduction under the Proactive Scenario is projected at 55%.



Source: OME, 2021

Figure 50: Final energy consumption in the Mediterranean, 1990 and 2018

Final energy consumption

In 2018, final energy consumption in the Mediterranean stood at 704 Mtoe. Between 1990 and 2018, significant decreases in the shares of oil (from 57% to 45%) and coal (from 6% to 3%) in the final energy mix were recorded. At the same time, shares of electricity and gas increased by 6 percentage points each (Figure 50). As regards the end-use sectors, buildings accounted for 34% of the total final energy consumption in 2018. Transport was the second highest energy consuming sector with a share of 32% of the region's energy consumption, followed by industry with 27%.

The transport sector has a strong dependency on fossil fuels (with oil accounting for 94% of total energy consumption in 2018) and is one of the largest contributors to GHG emissions in the Mediterranean. Terrestrial transport, and road transport/ private vehicles in particular, are the principal source of GHG emissions; maritime and air traffic contributions are much lower. In addition to GHG emissions, transport also causes significant air pollution and represents an important threat to human health, in particular in cities (OME, 2021, and UNEP/MAP and Plan Bleu, 2020).

Electricity

Total electricity generation in the Mediterranean region nearly doubled between 1990 and 2018 – from 1,114 to 2,135 TWh. In 2018 and 2020, non-hydro renewables accounted for 13% and 17% of the total generation – a prominent expansion from less than 1% in 1990. With an installed capacity of 177,849 MW (26% of the total) in 2020, renewables represented the second largest electricity generation source (after gas with the share of 33%) and have surpassed hydroelectric sources (17% of the installed capacity)32.

Electricity consumption is expected to grow at faster pace in the South and East Mediterranean, due to demographic trends, urbanisation, electrification of the economy and anticipated stronger GDP growth compared to the North. Under the Reference Scenario, electricity consumption is expected to grow up

[32] Data from OME, 2021.

to 20500 at an average annual rate of 3% in the South; growth rates under Proactive and ProMED Scenarios are projected at 2.1% and 2.5% respectively, taking into account effects of energy efficiency measures. In the North, average annual growth rates are expected to remain below 1% under all scenarios (OME, 2021).

According to OME, future investments in power generation across the Mediterranean are expected to be predominantly linked to various renewables and to a lesser extent to natural gas. Renewables (excluding hydro) should account for 56% (under Reference), 67% (Proactive) and near 70% (ProMED Scenario). In case of ProMED Scenario, 93% of total Mediterranean power generation would be from non-carbon sources (90% in the South and 98% in the North).

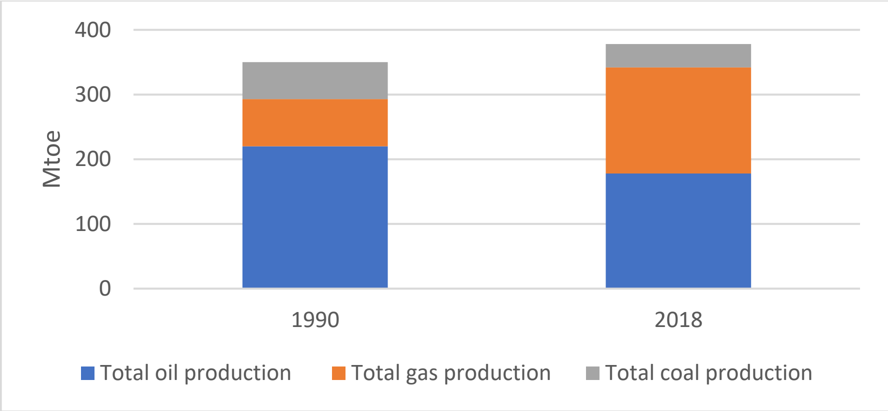
3.5.1.5.1. Oil and gas

Although shares of fossil fuels in the total primary energy are slowly declining, reliance on these energy sources is still very high across the Mediterranean, with coal, oil, and gas accounting for three quarters of the region's primary energy demand in 2020. Fossil fuels subsidies are widely applied, reaching the levels of 2% to nearly 6% of GDP in some Mediterranean countries in 2020; exceptionally, fossil fuels subsidies in Libya were at the level of 17% of GDP (IEA, 2020)[33]. According to International Energy Agency (IEA), fossil fuel subsidies *inter alia* distort markets, send the wrong price signals to users and discourage the adoption of cleaner renewable energy sources.

The Mediterranean region has less than 5% of the world's proven oil, gas and coal reserves. The region is estimated to hold substantial undiscovered resources, in particular in the unexplored/ underexplored areas in the South (including offshore areas). Overall, the Mediterranean oil and gas resources are assessed at close to 7% of oil and over 9% of the world's conventional gas resources (OME, 2021). The SoED (UNEP/MAP and Plan Bleu, 2020) analyses indicated that more than two hundred offshore oil and gas platforms were active in the Mediterranean in the second half of 2010s. With recent explorations (in the Levantine Basin, in Lebanon and the Syrian Arab Republic, as well as in the Nile Delta Basin and the Aegean Basin) and new discoveries of large fossil fuel reserves[34], the number is expected to increase, with potential transformative effects for ecosystems and economies, in particular in the Eastern Mediterranean. In recent years, resurgence of interest in exploration has been recorded in the Adriatic, in the areas south-west and west of Crete, and in the Ionian Sea (OME, 2021).

[33] The IEA data shows that the fall in fossil fuel prices and overall energy use (caused by COVID-19 pandemic) brought the global value of fossil fuel consumption subsidies down to a record low of about USD 180 billion in 2020 (a 40% decrease compared to 2019 levels). In 2021, however, the subsidies surged to USD 440 billion as energy prices and use rebounded, and as policy makers were reluctant to reform subsidy schemes amidst uncertain economic recovery.

[34] According to OME, 2021, one of the most important recent (2015) natural gas discoveries was the super-giant Zohr field offshore Egypt with 850 bcm of gas in place, confirming the substantial hydrocarbons potential in the Mediterranean Sea and the region's significance in the global fossil fuels exploration and production industry.



Source: OME, 2021

Figure 51: Total production of fossil fuels in the Mediterranean (in Mtoe), 1990 and 2018

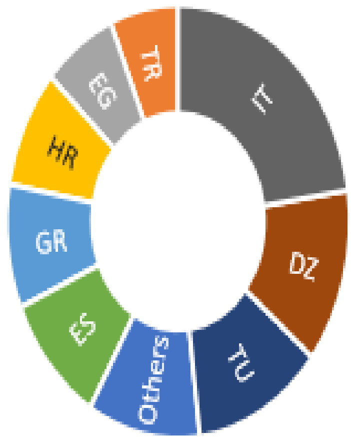
Between 1990 and 2018, total production of fossil fuels in the Mediterranean increased by 8.3% (from 349 to 378 Mtoe), whereas oil and coal productions shrank and gas production more than doubled. According to the Mediterranean Energy Perspectives to 2050 (OME, 2021), the key trends and outlook for the main fossil fuels are as follows:

Oil production decreased significantly since early 2010s to less than 3 million barrels a day (mb/d) in 2020. The drop can be mainly attributed to lower production in Libya (due to political situation). Over the next couple of decades, production in the Mediterranean is expected to grow slightly to reach 3.9 mb/d by 2040, and then decline to 3.8 mb/d in 2050.
Natural gas production increased by 120% between 1990 and 2008, declined till 2015 and rebounded to 196 billion cubic metres (bcm) in 2020. Production is expected to peak at 325 bcm in early 2040s and to remain for a while above 300 bcm before it declines to 290 bcm by 2050. Algeria and Egypt will remain the largest producers.

Coal production dropped by almost a quarter between 1990 and 2020. Production peak of around 210 million tons (Mt) is expected in the early 2030s, followed by a period of stagnation and eventually a decline to 160 Mt in 2050. Turkey will remain the largest producer in the Mediterranean.

Green gases were not used to a significant extent in the past. However, “greening” of the natural gas sector has started through the development and use of gases such as biomethane from organic sources, bio-LNG and synthetic natural gas, or by blending hydrogen[35] into existing natural gas networks (OME, 2021).

[35] Green hydrogen produced from water using renewable electricity or blue hydrogen produced from natural gas supported with Carbon Capture, Utilisation and Storage (CCUS).



http://www.merces-project.eu/sites/default/files/MERCES_D1.2_Pressures_Final_25052017.pdf

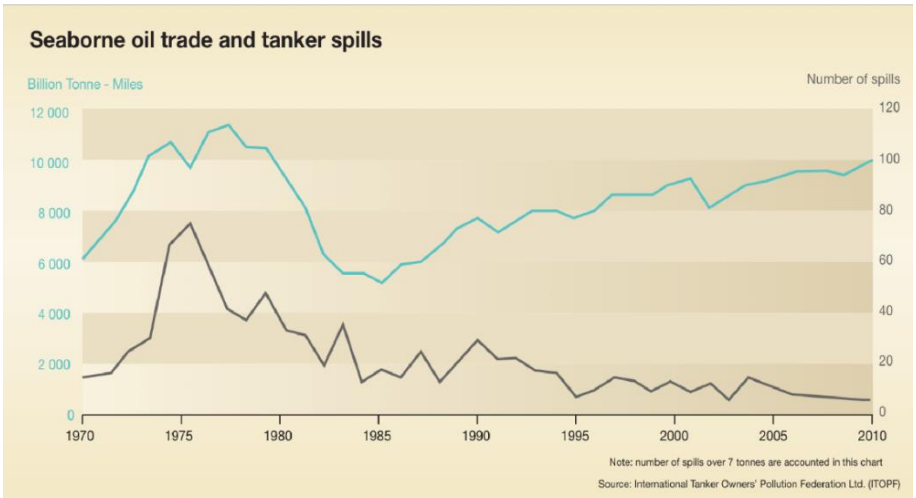


Figure 52. Mediterranean oil and gas exploration (in Piante and Oddy, 2015)

3.5.1.5.2. Renewable energy (offshore)

The OME analyses have shown that over the past 15 years, renewable energy supply doubled (from 65 Mtoe in 2005 to 130 Mtoe in 2020), accounting for some 15% of the energy mix in the Mediterranean region as a whole. The most significant progress with the uptake of renewables has been recorded in power generation, while as the share of renewable sources is still very low in end-use sectors, especially in industry and transport. In 2020, renewable energy technologies made 43% (686 GW) of the total power generation capacity, deployed predominantly in the North Mediterranean countries. Nevertheless, worth noting is that development of renewable capacity was very fast in the South and East where it nearly tripled over the period 2005 – 2020.

Renewables are projected to grow by an average 2.7% per year in the Reference and 3.8% in the Proactive Scenario, making up, respectively, 19% and 35% of the energy mix in 2050; sustained growth is expected both in the North and South Mediterranean sub-regions.

Biomass and waste had a dominant share (59.3%) in the structure of renewables in 2020, followed with geothermal (14.6%), wind (14.4%) and solar (11.5%); share of tide, wave and ocean energy was below 1%. Photovoltaics were the main contributor to solar energy demand in 2020, accounting for 58.6% of the total, followed with solar heating and cooling (25%) and concentrated solar power (16.3%). The fastest growing renewables are wind and solar: demand for wind energy reached 16.36 Mtoe in 2020 while it was non-existent in 1990; demand for solar energy increased from 0.54 Mtoe in 1990 to 13.11 Mtoe in 2020 (data from OME, 2021).

One of the factors that has significantly contributed to the so far development of renewable energy is sharp decline in the costs for various renewables: during the past decade (2009 – 2019) alone, costs of generating a megawatt hour from onshore wind installations and photovoltaics dropped by as much as 70 – 90% (Table 13).

Table 12: The cost of renewable energy 2009 – 2019

Energy source	Levelized cost of energy (USD/ MWh)		Difference
	2009	2019	
Solar photovoltaic	359	40	-89%
Onshore wind	135	41	-70%
Gas (combined cycle)	83	56	-33%
Coal	111	109	-2%
Solar 101rea101o power	168	141	-16%
Nuclear	123	155	26%
Gas peaker	275	175	-36%

Source: Roser, 2020, https://ourworldindata.org/cheap-renewables-growth

Offshore wind installations, as well as wave, tide-current and thermal gradient energies are in the early stages of development in the Mediterranean. The offshore wind sector is expected to grow in the coming decades, inter alia due to new developments in floating platform constructions making them more suitable to deep waters. In the EU Mediterranean countries, production of electricity by offshore wind farms could reach 12 gigawatts (GW) in 2030 (UNEP/MAP and Plan Bleu, 2020).

Note: Sustainability of the Renewable Energy Extraction Close to the Mediterranean Islands by Vincenzo Franzitta and Domenico Curto. Department of Energy, Information and Mathematical models, University of Palermo (UNIPA), 90128 Palermo, Italy. *Energies* 2017, *10*(3), 283; https://doi.org/10.3390/en10030283

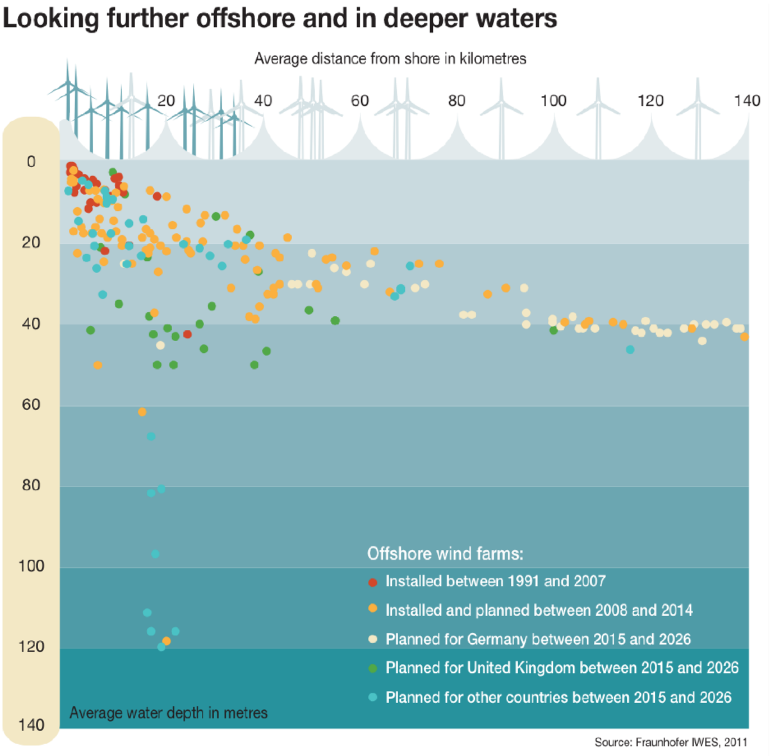


Figure 53. Offshore wind farming technologies.

3.5.1.6. Marine mining

Note: statistical data on marine mining in the Mediterranean could not be retrieved; written summary from the relevant sources is presented below

Marine and seabed mining is defined by OECD as the production, extraction and processing of non-living resources in seabed or seawater (OECD, 2016). This, for example, includes extraction of minerals and metals from the seabed (in shallow waters or at the deep sea), marine aggregates (limestone, sand and gravel) and minerals dissolved in seawater. The analyses conducted in the framework of the European Maritime Spatial Planning Platform (Pascual and Jones, 2018) offered the following definitions/ assessments:

- Marine mining refers to exploration, exploitation and extraction of marine minerals, such as iron ore, tin, copper, manganese and cobalt; the sector is characterized as growing.
- Deep-sea mining is done at depths from 800 to 6,000 m, primarily targeting deposits of polymetallic nodules, manganese crust and sulphides, and is in early stages of development – characterised as an emerging sector;

- The marine aggregates is a mature sector that refers to exploration, exploitation, extraction and dredging of sand and gravel from the seabed, primarily for the purpose of construction and beach nourishment.

- At a longer time scale, Rare Earth Elements (REE) that are present in deep-sea mud may also become strategic mining targets as land-based reserves become progressively less accessible (Piante and Ody, 2015).

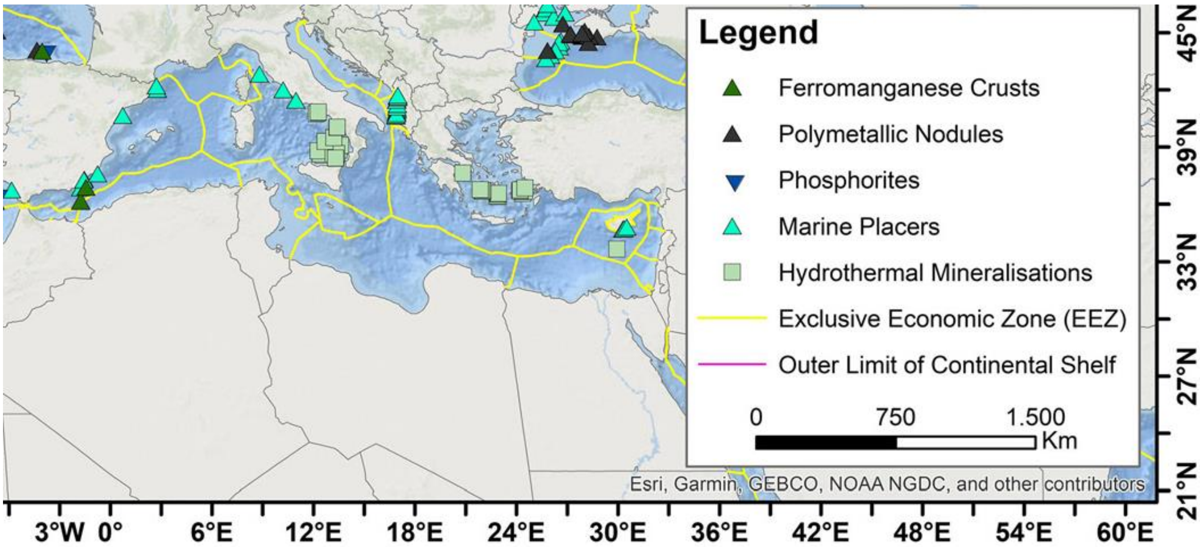
According to the EEA (2015), mining of aggregates had an estimated gross value added (GVA) of EUR 625 million and provided 4,800 jobs in Europe. Based on the technical assessments that preceded it, the EC Blue Growth Communication from 2012 estimated that 5% of the world's minerals, including cobalt, copper and zinc, could come from the ocean floors by 2020, with expected further rise to 10% by 2030; seabed mining was identified as one of the five "priority areas" of blue growth (EC, 2012).

According to the WWF report (Piante and Ody, 2015), potential areas for seabed mining have been identified in the Mediterranean Sea, with sulphide deposits identified along the Italian and Greek coastlines. Results of the EC funded project GeoERA-MINDeSEA[36] (Figure 54) revealed promising prospects in placer deposits in the eastern Mediterranean – Greece and Cyprus – coasts (Sakellariadou et al., 2022).

While economic potential of deep-sea mining is assessed as significant, the Mediterranean is not considered a priority area for these activities. The UfM Blue Economy report concluded there were no projects that have been granted a mining license in the Mediterranean and no deep-sea activities by 2017, with the exception of the 2007 exploration project in the Tyrrhenian Sea in Italy. The slow development of deep-sea exploitation in the Mediterranean can be partially attributed to low technological development in the region and the lack of regulatory system (UfM, 2017).

Potential environmental issues linked to deep-sea mining are not well known, which questions the sustainability of such a practice; the main pressures (with potential to cause harmful environmental consequences) are linked to extractive techniques, underwater noise and light, and water discharges (UNEP/ MAP UNEP/MAP and Plan Bleu, 2020). An attempt to identify and understand better potential environmental impacts from deep-sea mining undertaken within the MIDAS project (Managing Impacts of Deep-seA exploitation project, partly funded by the EU, implemented over the period 2013 – 2016) resulted with a set of recommendations and best practices for ensuring relative sustainability of the industry, including creation of conservation zones where mining activities would be prohibited; these recommendations were taken into account for the regulations of the EU Member States for areas located in their Exclusive Economic Zones, as well as for the regulations of the International Seabed Authority for international waters (UfM, 2017).
In the EU Communication on Blue Economy (EC, 2021) it is emphasized that marine minerals in the international seabed area cannot be exploited before the effects of deep-sea mining on the marine environment, biodiversity and human activities have been sufficiently researched, the risks understood and before it is demonstrated that the technologies and operational practices do not cause serious harm to the environment (EC, 2021).

[36] Launched in 2018 to map and to establish the metallogenic context for different seabed mineral deposits with economic potential in the pan-European setting.



Source: (Sakellariadou et al., 2022)

Figure 54: Excerpt from the MINDeSEA compilation map referring to the Mediterranean

The EU blue economy statistics (EU, 2022) noted a downward trend (a GVA drop of 68% in 2019 compared to 2009) in the sector of *Non-living resources*, comprising, besides oil and gas, exploitation of marine aggregates and other minerals[37]; the decline is due to the decreasing production in the *Offshore oil* sub-sector. Overall, the share of marine *Non-living resources* sector in the EU blue economy in 2019 was 0.2 % of jobs and 2.5 % of GVA.

The *Other minerals* sub-sector, continues to be on the rise, with a GVA of about EUR 160 million of GVA (3 % of the GVA in the sector of *Non-living resources*) and employment of 1,426 in 2019. Within Europe, the sub-sector mainly refers to marine aggregates rather than on mining activities. More than 50 million m^3 of marine aggregates, primarily sand and gravel, are extracted from the European marine seabed, mostly for the construction industry, beach nourishment and sea defence construction (EU, 2022). The demand is expected to continue rising as construction sector expands and coastal communities try to adapt to new pressures posed by climate change.

Extraction of marine aggregate material, together with dredging, is recognised as highly damaging to seabed habitats. These activities result with substantive (and often permanent) alteration to hydrodynamic and ecosystem processes. The main pressures linked to extraction/ dredging include seabed disturbance and disruption of habitat, disruption to wildlife, pollution and water contamination, and use conflicts (UNEP Finance Initiative, 2022).

[37] Including, for example, operation of gravel and sand pits, mining of clays and kaolin, extraction of salt.

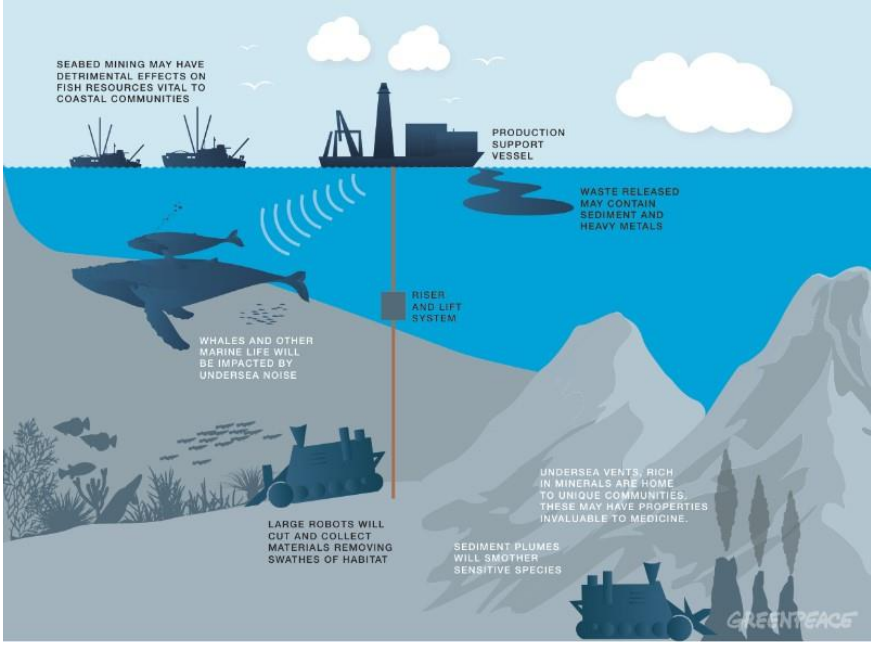


Figure 55. Deep Sea Mining...Out Of Our Depth – Mission Blue (mission-blue.org)

3.5.1.7. Water abstraction

The Mediterranean region has been estimated to hold about 1.2% of the world's renewable water resources and is recognised as one of the most water-challenged regions in the world (IAI, 2021). The pre-existing water scarcity is being aggravated by population growth, urbanization, growing food and energy demands, pollution, and climate change (UNEP/MAP and Plan Bleu, 2020).

The ten largest Mediterranean river basins are the Nile (Egypt), Rhone (France), Ebro (Spain), Po (Italia), Moulouya (Morocco), Meric/Evros (Greece, Turkey), Chelif (Algeria), Büyük Menderes (Turkey), Axios/Vardar (Greece) and Orontes/Asi (Turkey). In the last 50 years, a decline in water discharge from rivers has been observed, resulting from multiple stressors such as decreasing precipitation, an increasing number of reservoirs and increasing irrigated areas (UNEP/ MAP and Plan Bleu, 2020).

Total renewable freshwater resources of the countries belonging to the Mediterranean Basin were reported[38] at between 1,212 km^3 yr-1 and 1,452 km^3 yr-1, with Northern Mediterranean countries holding between 72 and 74% of the resources and the SEMCs sharing the remaining 26 to 28% (MedECC, 2020); MedECC further reported that 180 million people in the southern and eastern Mediterranean suffered from water scarcity (<1,000 m^3 capita-1 yr-1) and 80 million people from extreme water shortage (<500 m^3 capita-1 yr-1).
Analyses conducted towards preparation of the Fifth Assessment Report of the IPCC showed that by 2014, 44 out of 73 catchments[39] in the Mediterranean region were under high to severe water stress, with hotspots in southern Spain, Tunisia, Libya, Syria, Lebanon, Jordan, Israel and Palestine. Furthermore, it was assessed that except for France and the Balkans, all the catchments in the Mediterranean would be

[38] In the MedECC's First Mediterranean Assessment Report, based on the data of the FAO's Aquastat database and previous research
[39] Areas area where water is collected by the natural landscape.

under high to severe water stress by 2050, mainly due to climate change (reduced mean precipitation and groundwater availability, increased frequency and duration of droughts etc.), leaving 34 million people under high water stress and 202 million under severe water stress (IAI, 2021).

As pointed out in the SoED, the FAO water statistics also allow for a conclusion that water resources of the Mediterranean countries have deteriorated, with internal freshwater resources (IRWR) per capita decreasing by 29% between 1997 and 2014. The most affected countries were Lebanon (- 45%) and the State of Palestine (-37%), whereas the decrease for the EU Mediterranean countries was on average 4%. An opposite trend was recorded in the Balkans where the IRWR per capita increased on average by 5% between 1997 and 2014 (UNEP/ MAP and Plan Bleu, 2020).

Total renewable water resources per capita in the Mediterranean range from 103 in Libya to more than 25,500 m3 per inhabitant per year in Croatia (Table 14). With the exception of Turkey, all the SEMCs experience water stress or water scarcity; Malta and Cyprus also belong to the groups of water-scarce/ water-stressed countries (with 115 m3 and 651 m3 per inhabitant per year respectively). Water shortages are especially pronounced during summer season, coinciding with tourism peaks in coastal areas.

Table 13: Total renewable water resources per capita and the level of water stress in the Mediterranean, 2019

Country	Total renewable water resources pc (m^3)	SDG 6.4.2: Level of water stress (%)
LY	103	817.14
MT	115	81.19
PS	168	47.01
IL	209	100.42
DZ	271	137.92
TN	395	96.00
EG	573	141.17
CY	651	27.61
LB	657	58.79
MA	795	50.75
SY	984	124.36
ES	2,386	40.18
TR	2,536	45.71
IT	3,159	30.00
FR	3,240	23.51
GR	6,531	20.46
AL	10,483	6.80
BA	11,360	2.03
SI	15,332	6.38

HR	25,543	1.49

Note: Data for Monaco and Montenegro not available

Source: FAO, 2023. AQUASTAT Core Database. Food and Agriculture Organization of the United Nations. Database accessed on 21 February 2023

Note on the graphical presentation of the data from table 1:

Data could be mapped using the following colour codes (consistent with figure 148 of the SoED):

	≤ 500 m^3 per inhabitant a year (scarcity)
	500 – 1,000 (stress)
	1,000 – 1,700 (vulnerable)
	1,700 – 5,000 (security)
	≥ 5,000 (comfort)

The map could be supplemented with values of SDG 6.4.2 indicator by country.

With water resources in the range of app 2,390 – 3,240 m3 per inhabitant per year, Spain, Italy, France and Turkey can be classified as water-secure countries. Abundant water resources (of more than 5,000 m3 per inhabitant per year) are found in the northern rim countries across the Balkans – from Slovenia to Greece. The SDG indicator 6.4.2 – level of water stress[40] – is above 50% for Morocco, Lebanon, Malta and Tunisia, it exceeds 100% for Israel, Syria, Algeria and Egypt and reaches as much as 817% in case of Libya.

Water withdrawals

According to the data from the FAO's Aquastat database, total freshwater withdrawals in the Mediterranean countries were at the level of 290 billion m3 in 2019. The largest consumers were Turkey and Egypt with cca 61.5 and 77.5 billion m3 respectively; freshwater withdrawals of around 10 billion m3 or higher were recorded in Algeria, Greece, Morocco, Syria, France, Spain and Italy. Per capita withdrawals ranged from less than a hundred m3 in Palestine to close to 1,000 m3 in Greece and Syria (Table 15).

Even though the structure of water uses varies significantly across the region, irrigated agriculture remains the most demanding sector accounting for near 80% or more of total withdrawals in countries such as Egypt, Greece, Libya, Morocco, Syria, Tunisia and Turkey. Besides freshwater withdrawals, a total of 6.6 billion m3 of treated wastewater is used across the region, primarily in Egypt, Spain, Israel, France and Greece. Israel is the leader among the SEMCs when it comes to reuse of treated wastewater (with a rate of over 85% of collected wastewater). Among the EU Mediterranean countries, Cyprus and Malta are the most advanced with 90% and 60% of their treated of their treated wastewater reused (UNEP/ MAP and Plan Bleu, 2020, based on IPEMED, 2019).

According to the FAO Aquastat database, the largest producers of freshwater through desalination in 2019 were Israel (645 million m3), Algeria (631 million m3), Spain (405 million m3) and Egypt (200 million m3). In relative terms, Malta is the desalination leader, with more than half of its drinking water supply produced via desalination (UNEP/MAP and Plan Bleu, 2020). The available projections suggest that the production of desalinated water in the Middle East and North Africa (MENA) region will increase thirteen times by 2040 in comparison with 2014 (*Ibid.*)

[40] Freshwater withdrawals as a proportion of available freshwater resources.

Table 14: Freshwater withdrawals per capita and by sector, 2019

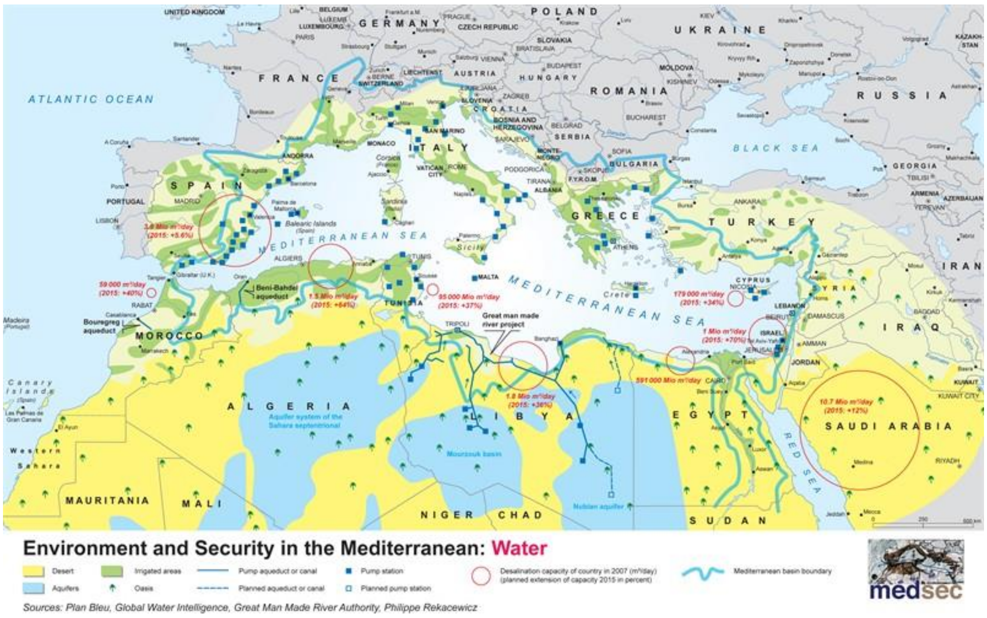
	Total freshwater withdrawal (10^9 m^3/ year)	Total withdrawal per capita (m^3 pc/ year)	Withdrawals by sector (%)		
			Agriculture	Municipal	Industrial
AL	1.13	392.58	61.2	21.0	17.8
DZ	9.802	243	63.8	34.4	1.8
BA	0.3055				
HR	0.67	176.74	11.0	62.6	26.4
CY	0.202	231.11	59.9	40.1	0.0
EG	77.5	772	79.2	13.9	7.0
FR	26.85	412.24	11.1	19.8	69.1
GR	10.115	965.77	80.2	16.7	3.2
IL	1.16	272.09	51.4	43.1	5.5
IT	34.05	564.62	49.7	27.8	22.5
LB	1.812	268.39	38.0	13.0	48.9
LY	5.72	860.21	83.2	12.0	4.8
MT	0.041	143.06	36.5	61.9	1.6
MC	0.005	128.32	0.0	100.0	0.0
ME	0.16	256.22	1.1	59.9	39.0
MA	10.573	286	87.8	10.2	2.0
PS	0.33	83.89	45.6	46.2	8.2
SI	0.944	454.11	0.3	18.0	81.7
ES	29.469	630.53	65.3	15.3	19.4
SY	13.964	981.86	87.5	8.8	3.7
TN	3.781	328.76	76.3	22.5	1.2
TR	61.534	742.18	87.7	10.6	1.7

Source: FAO, 2023. AQUASTAT Core Database. Food and Agriculture Organization of the United Nations. Database accessed on 21 February 2023

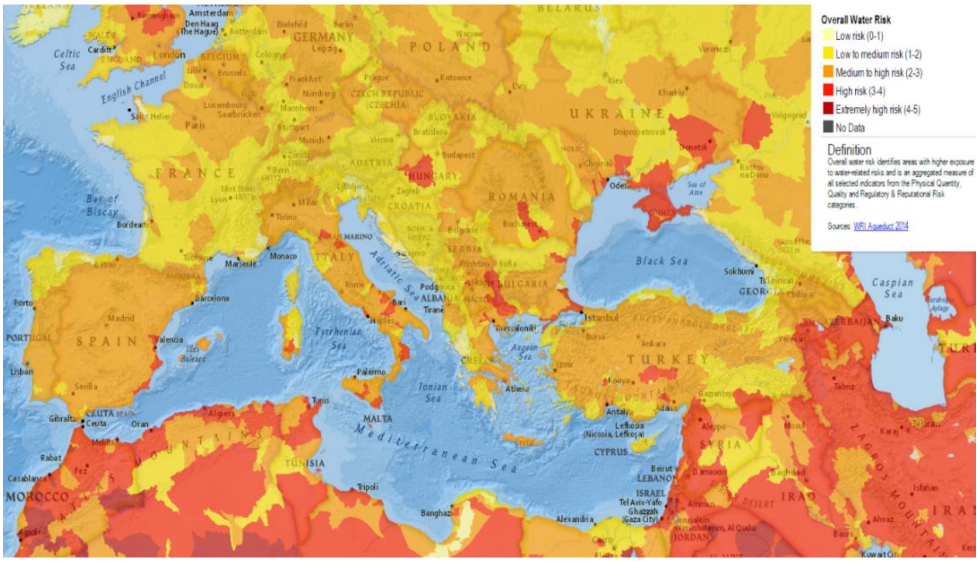
Note on the graphical presentation of the data from table 1: Data on per capita withdrawals could be represented on the map, using different sizes of pie charts (smallest for withdrawals of up to 100 m^3 per capita, medium for 100 – 500 m^3 per capita and large for 500 – 1,000 m^3 per capita) providing the structure of withdrawals (agriculture, municipal, industrial), consistent with figure 156 of the SoED.

According to De Roo et al., the Mediterranean is a water scarce region already under current climate and water use conditions, with high ratios of water abstraction and consumption compared to water availability, where regional groundwater depletion is already an issue. Under the scenario of global warming of 2^{0}C, projections indicate that the water availability in the Mediterranean could decrease by 10 – 30% locally. In cush a context, implementation of irrigation and urban water efficiency measures gains importance. Water re-use is seen as an important measure to reduce abstractions, but the costs of treatment for reuse (as per the new EU standards) may however exceed the current willingness to pay for water in agriculture. Desalination could become an increasingly applied option (De Roo et al., 2021).

Visual LME GEOMAP n°6 (Tables 14, 15, and Figure 56)



Map A. Overall Water Risk around the Mediterranean



Map B. Shows level of overall water risk (physical quantity, quality and access). Source: Aqueduct-Water Risk Atlas.

Figure 56. Water resources at risk in the Mediterranean region.

3.5.1.8. Use of marine waters for wastewaters and waste disposal

Waste generation in the Mediterranean

According to the latest available data (as presented in Table 16), more than 198 million of tonnes of municipal solid waste (MSW) is generated in the Mediterranean countries[41] annually; this equates to an average of around 400 kg per capita per year (or 1.1 kg a day). Per capita MSW generation is below the regional average of 1.1 kg in the SEMCs (with the exception of Turkey where 1.16 kg of MSW is produced per person per day and Israel with 2.07 kg/d) as well as in Albania and Bosnia and Herzegovina. In other NMCs, per capita MSW quantities range between 1.22 kg/d in Croatia and 1.9 kg/d in Malta; in Monaco, daily generation of MSW exceeds 3 kg per person.

Table 15: Municipal waste generation and recycling rates in the Mediterranean

Country	Year	MSW (t)	MSW pc (kg/y)	Share of MSW recycled	
				%	year
MA	2014	7,126,000	202	8	2014
SY	2009	4,500,000	216	2.5	--
TN	2014	2,686,000	219	4	2014
EG	2016	22,000,000	284	12	2013
DZ	2016	12,378,740	305	8	2016
PS	2016	1,629,000	340	3	2013
BA	2015	1,248,718	353	n.a.	--
LB	2014	2,149,000	358	8	2015
AL	2019	1,087,447	381	18.1	2020
LY	2011	2,420,000	385	n.a.	--
TR	2019	35,374,156	424	11.3*	2019
HR	2019	1,810,038	445	29.5	2020
ES	2019	22,408,548	476	36.4	2020
IT	2019	30,088,400	499	51.4	2020
SI	2019	1,052,325	504	59.3	2020
GR	2019	5,615,353	524	21	2020
ME	2018	329,780	530	4.6	2020
FR	2019	36,748,820	548	42.7	2020
CY	2019	769,485	642	16.6	2020
MT	2019	348,841	694	10.5	2020
IL	2015	6,531,000	757	24	2017
MC	2012	46,000	1,217	5.4	--
Med		198,347,650	400		

Note: * own calculation based on the data from EEA and UNEP/ MAP, 2021

Sources: World Bank What a Waste Global Database[42] available at https://datacatalog.worldbank.org/search/dataset/0039597 accessed January 2023

[41] Close to 97 million in the SEMCs and around 101 million in the NMCs. The regional/ sub-regional sums were derived from the data referring to 2019 for most North Mediterranean countries and Turkey, while as the last available data for the Southern and Eastern Mediterranean countries mainly refer to the period 2014 – 2016; data for Syria and Libya were only available for 2009 and 2011 (respectively).

[42] According to the World Bank, information presented in the database is the best available based on a study of current literature and limited conversations with waste agencies and authorities. While it is recognised variations in the definitions

EEA and UNEP/MAP, 2021; EEA, 2023 data available at https://www.eea.europa.eu/ims/waste-recycling-in-europe accessed February 2023

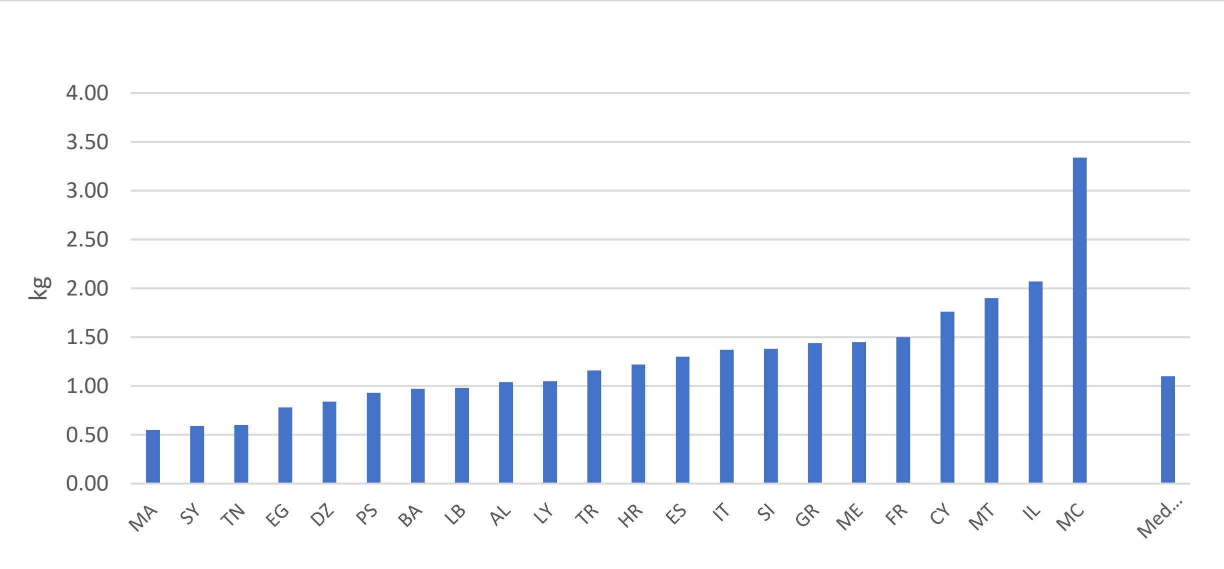
Notes on possible graphic presentation of the data from table 16:

- a map can be generated (consistent with Figure 124 of the SoED) with the following colour codes

Colour	Countries with annual MSW generation (kg/pc)
	200 – 300
	300 – 400
	400 – 500
	≥ 500

The map generated in this way could be supplemented with data on recycling and/ or data on waste composition (the latter available for most of the countries from the WB database, an excerpt from which is included in the related excel sheet).

- The following graph can be used (alternatively, per capita figures could be shown on the map for respective countries)



- Presentation of data on waste treatment options (consistent with Figure 125 of the SoED) is not recommended as the WB database contains discrepancies for two countries (with sums of the shares for different options exceeding 100%). In the EEA/ UNEP MAP report (2021), figures on the shares of different waste treatment options are only partially available (for the SEMCs).

Figure 57: Daily MSW generation per capita

Total quantities of e-wastes generated in the Mediterranean countries are at the level of 8.3 millions of tonnes, while generation of hazardous wastes exceeds 28.5 millions of tonnes annually (World Bank database, accessed January 2023).

Per capita MSW generation in the countries of the southern and eastern shores of the Mediterranean is approximately half that of generation in the EU Member States, primarily due to lower income levels and

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and quality of reporting for individual data points might exist, the general trends depicted by the database records are believed to be representative of the global reality.

different lifestyles. Among the SEMCs, Turkey and Egypt generate by far the largest quantities of MSW – around 35 and 22 million of tonnes respectively. While their contribution to the overall quantity in the Mediterranean is low, Cyprus and Malta are the countries with very high per capita MSW generation (in the range of cca 650 to 700 kg annually). As regards the MSW composition, organic materials represent the main fraction in most of the SEMCs, accounting for as much as 68% in Tunisia and 70% in Libya (World Bank database, accessed January 2023). Share of plastics ranges from few percents to more than a fifth of the total quantity and is generally higher in the NMCs (*Ibid*.)

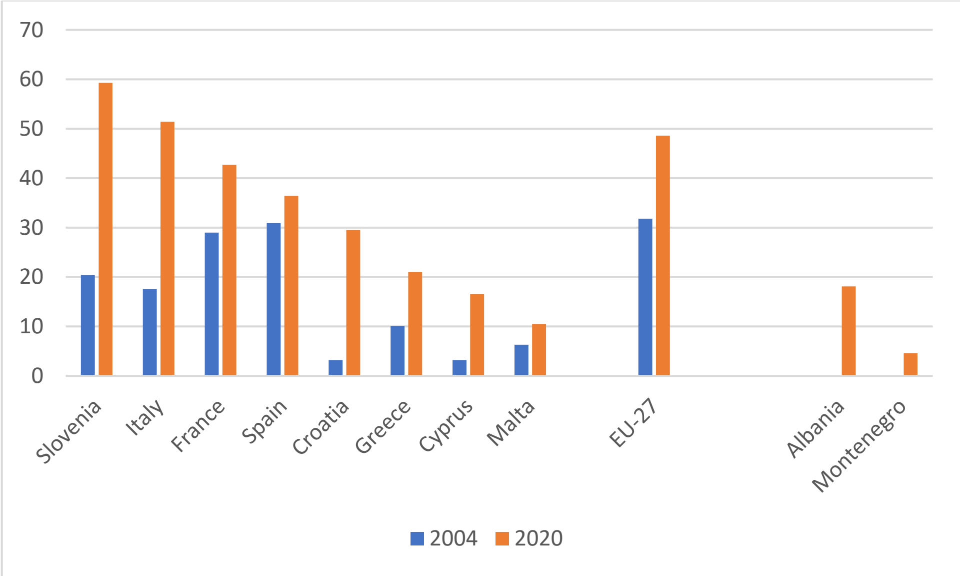
MSW generation has been increasing across the Mediterranean and a growing trend is expected to continue in the coming decades. Projections suggest total MSW quantities will increase by 29% in 2030 and by 50% in 2050 in the SEMCs, although with significant differences between rural and urban areas (EEA and UNEP/MAP, 2021). Other projections (for example the World Bank's report More growth, less garbage from 2021) suggest that overall waste generation in Middle East and North Africa region is expected to more than double by 2050 (from 140 in 2020 to 297 millions of tonnes) whereas projected increase in Europe and Central Asia region was more modest – around a quarter between 2020 and 2050 (Kaza et al., 2021).

While municipal waste generation in the NMCs is significantly higher compared to the SEMCs, waste management systems are more advanced. Despite notable improvements, collection of MSW is still a significant issue in most SEMCs where only a few countries are succeeding in reaching full waste collection coverage (EEA and UNEP/ MAP, 2021), whereas collection services are, as a rule, underdeveloped in rural areas, suburbs and slums.

According to EEA and UNEP/ MAP report (2021), more than a half (54%) of total MSW is, on average, disposed at open dumps in the SEMCs[43], while as the share goes to as high as 80% in some countries. Landfilling (different types of landfills) has been reported as the main disposal option in Algeria (accounting for 89% of total MSW), Israel (75%) and Tunisia (70%). On the other hand, the overall landfill rate – waste sent to landfill as a share of generated waste – decreased from 23% to 16% during 2010 and 2020 in the EU as a whole, in line with the objective of reducing reliance on landfilling; total quantity of waste sent to landfill in this period decreased by 27.5% – from 173 million tonnes to 125 million tonnes[44]. Reported recycling rates are mainly below 10% in the SEMCs, except for Egypt where the rate is somewhat higher (12%) due to a significant impact of informal recycling activities, and Israel (where nearly a quarter of MSW is recycled). Recycling rates are also low in Turkey (around 11%) as well as in the non-EU NMCs (Table 16); with a recycling rate of 18.1% in 2020, Albania made a significant step forward in recent years (Figure 58).

Over the past 15 years, the EU Mediterranean countries made significant progress with recycling, with Slovenia and Italy doubling the recycling rates and countries like Croatia and Cyprus increasing the rates by as much as eight and four times respectively (Figure 58). Nevertheless, recycling rates in most EU Mediterranean countries (the only exceptions being Slovenia and Italy) were well below the EU-27 average and are particularly low in Malta (10.5%) and Cyprus (16.6%).

[43] Including Jordan.
[44] https://www.eea.europa.eu/ims/diversion-of-waste-from-landfill accessed January 2023



Source: https://www.eea.europa.eu/ims/waste-recycling-in-europe accessed February 2023

Figure 58: Recycling rates in the Mediterranean EU Member States, Albania and Montenegro (2004 and 2020)

In the SEMCs, coverage and reliability of data on recycling are limited, partly due to the role of the informal sector in the collection of recyclables. Opportunities have been identified to improve waste management by exploiting the high share of organic waste (by putting in place composting treatment plants) that could have positive impacts on the environment and on the economy, creating jobs, and promoting a circular economy approach (EEA and UNEP/MAP, 2021). A long-term goal of the EU is to transition to a circular economy that avoids generating waste and uses unavoidable waste as a resource wherever possible[45].

Marine litter

While as the waste management systems are improving across the region, the progress is uneven. Mismanaged wastes, in particular plastics, are identified as the key source of marine litter (EEA and UNEP/MAP, 2021; the EEA web report, 2023) – a growing problem for oceans and seas around the globe, including the Mediterranean Sea. Inadequate wastewater treatment and poor stormwater management in some Mediterranean areas exacerbate the problem (UNEP/MAP and Plan Bleu, 2020). Due to its almost closed nature, the Mediterranean Sea retains most of its plastic debris; a growing body of evidence suggests that unlike the other major oceans/ seas, there are no specific regions in the Mediterranean in which plastic debris accumulates (Baudena et al. 2022).

Coastal population and tourism, associated with take-make-waste economic models, are the main drivers of plastic waste generation and marine litter in the Mediterranean. The evidence suggests that efforts to adequately prevent, collect and process such wastes are far from sufficient to reduce leakages into the sea (EEA and UNEP/MAP, 2021).

[45] https://www.eea.europa.eu/ims/diversion-of-waste-from-landfill accessed January 2023

According to UNEP (2021) *Drowning in plastics* report, global plastic production has risen exponentially during the last decades, amounting to 400 million tonnes per year. Available estimates suggest that only slightly over a fifth of the produced quantity is incinerated (12%) and recycled (9%) The rest is either landfilled or released into the environment, including the oceans. The UNEP (2021) reiterates that without meaningful action, flows of plastic waste into aquatic ecosystems are expected to nearly triple from around 11 million tonnes in 2016 to around 29 million tonnes in 2040.

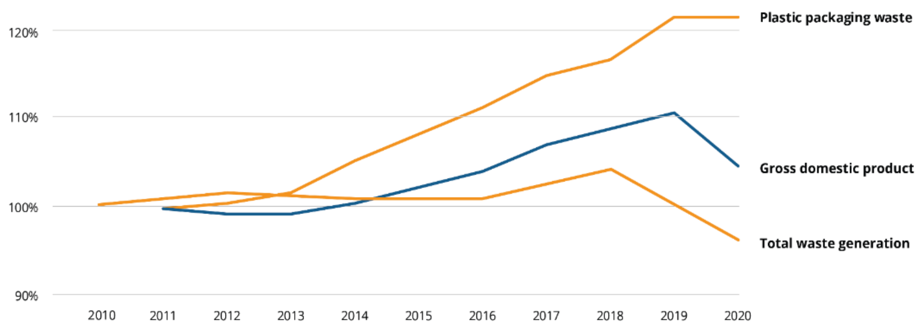
The key messages of the recent EEA web report (EEA, 2023a) are presented below:

- Marine litter is defined as all human-made solid items that end up in the coastal or marine environment. The major cause is poor waste management and littering on land, although seaborne activities contribute to the problem.
- Land-based sources account for 80% of marine litter and approximately 85% of it is plastic. This is a big problem because of plastic's impact on marine life and human health via the food chain. The persistent nature of plastic means that it can last up to 500 years in some cases.
- Plastic packaging and small plastic items comprise nearly 80% of plastic waste and are prevalent on European beaches. Although the amount of waste continues to increase, current waste management capacity is limited. Most plastic items that are used and thrown away are either recycled, incinerated or properly stored in waste facilities. However, a mismanaged part of that waste continues to pollute our seas.
- The waste that cannot be collected or properly managed eventually leaks into the environment and is carried to the seas by rivers. The outcome is that 75% of assessed marine areas are polluted.
- European plastic waste generation is growing at an even faster pace than economic growth. Continuous increasing waste generation is not in line with the EU's goal of significantly preventing waste and reducing plastic waste.
- The EU zero pollution action plan, circular economy action plan (including its plastics strategy), Marine Strategy Framework Directive and Single-Use Plastic Directive all aim to curb the problem. Yet to achieve Europe's green goals, we need a more holistic understanding of marine litter — from source to sea.

Source: EEA, 2023a, available at https://www.eea.europa.eu/publications/european-marine-litter-assessment/from-source-to-sea-the, accessed February 2023

While the total waste quantities are projected to rise, there is little or no evidence on decoupling between economic growth and waste generation, in particular when plastic packaging waste is taken into account. As shown in Figure 59, generation of plastic packaging waste grows much faster than GDP in the EU-27. Case studies presented in Kaza et al., 2021, including Slovenia's experience, show that decoupling of waste generation from economic growth is possible, with a right mix of policies targeting actors and behaviours along the entire value chain. The plastic packaging recycling rates in the Mediterranean EU Member States range from 23.5% in Malta to 62.3% in Cyprus (EEA and UNEP/ MAP, 2021).

Estimates from UNEP/ MAP, 2015, and EEA and UNEP/MAP, 2021 reports suggest the amount of plastic waste littered at sea from the Mediterranean countries ranged from approximately 0.5 kg per coastal inhabitant a year in Albania, Morocco and Palestine and cca 0.7 kg in Lebanon, to between 1 and 2 kg in most other riparian countries and slightly over 2 kg in Israel and Spain.



Source: https://www.eea.europa.eu/data-and-maps/figures/total-waste-and-plastic-packaging accessed February 2023

Figure 59: Total waste and plastic packaging waste generation versus GDP in EU-27

Estimates from the study prepared for IUCN, taking into account data for the Mediterranean watershed areas, offer different conclusions suggesting the highest leakage of macroplastics comes from the non-EU North Mediterranean countries (app 3 kg per watershed inhabitant in Albania and Bosnia and Herzegovina and as much as 8.7 kg in Montenegro), while contributions from the EU Member States and SEMCs were estimated at below 1 kg per inhabitant per year (Boucher and Bilard, 2020). The same study estimated total plastic leakage (from watershed areas) at between 150,000 (low estimate) and 610,000 tonnes per year. The mid-range estimate was assessed at 229,000 tonnes annually, made up of 94% macroplastics and 6% microplastics. Taking into account absolute amounts, Egypt, Italy and Turkey were identified as the top three countries contributing to plastic leakage (Boucher and Bilard, 2020).

Wastewater

According to the data available in the FAO Aquastat database (referring mainly to the period 2017 – 2019), total municipal wastewater generation in the 22 riparian countries of the Mediterranean Sea was at the level of 32,872 millions of m^3 (Mm^3) per year (Table 17). Around three quarters of produced wastewater (24,847 Mm^3) were treated (FAO, 2023), with uneven treatment shares across the region.

The analysis conducted for the EEA and UNEP/ MAP report (2021) showed that wastewater generation was on the rise across the region (resulting mainly from population growth and fluctuations from tourism), as was the case with wastewater collection and treatment. The largest volumes are generated by the Mediterranean EU countries, where almost all the produced municipal wastewaters (96% on average) are treated. While significant progress with wastewater treatment has been achieved in the non-EU NMCs and most of the SEMCs during the past decade, significant volumes (estimated at around 5 km^3/yr) of wastewater are still discharges untreated into the environment, streams, wadis or directly into the sea (EEA and UNEP/ MAP, 2021). The conflicts and instability in Lebanon, Libya and Syria have either resulted in the shutting down of wastewater treatment plants or the suspension of constructing new ones (*Ibid.*)

The SoED (UNEP/ MAP and Plan Bleu, 2020) identified inadequate level of treatment as one of the key challenges in the Mediterranean, with 21% of treated wastewater (25% in southern countries) undergoing only basic treatment, and less than 8% (1% in southern countries) undergoing tertiary treatment. This finding is corroborated in the EEA and UNEP/ MAP report (2021) which notes that despite significant improvements in the level of treatment (in particular in the EU Mediterranean countries), tertiary treatment is lagging behind in all the sub-regions.

Table 16: Generation and treatment of municipal wastewater

Country	Municipal WW (Mm3/year)		Treated WW share (%)
	produced	treated	
AL	54.0*	20.5	38.0
DZ	1,500.0	400.0	26.7
BA	82.3	57.0	69.2
HR	360.0	300.0	83.3
CY	30.0	30.0	100.0
EG	7,078.0	4,282.0	60.5
FR	4,000.0	3,770.0	94.3
GR	568.0*	568.0	100.0
IL	500.0	450.0	90.0
IT	3,926.0	3,902.0	99.4
LB	310.0	56.0	18.1
LY	504.0	40.0	7.9
MT	26.0	24.0	92.3
MC	8.0	6.0	75.0
ME	31.0	9.5	30.6
MA	700.0	166.0	23.7
PS	122.0 *	83.0	68.0
SI	241.0	158.0	65.6
ES	5,870.0	5,465.0	93.1
SY	1,370.0	550.0	40.1
TN	312.0	274.0	87.8
TR	5,280.0	4,236.0	80.2
Med	32,872.3	24,847.0	75.6

Notes:
For Albania, data on produced wastewater was used as reported in EEA and UNEP/ MAP, 2021 (data recorded in the database seems to be an outlier). For Greece and Palestine, data on produced municipal wastewater was not available in the database; data on collected wastewater is recorded instead

Source: FAO AQUASTAT Core Database https://www.fao.org/aquastat/en/databases/maindatabase accessed on 17 February 2023

Available data on overall pollution loads for Biological Oxygen Demand (BOD), Total Organic Carbon (TOC)[46], Total Nitrogen (TN) and Total Phosphorus (TP) from wastewater treatment and other industries are presented in Table 18, based on the National Baseline Budget of Pollutants (NBB)[47] 2018 reporting and the European Pollutant Release and Transfer Register (*E-PRTR*)[48] V17.

Table 17: Overview of pollution loads, 2017 and 2018

Country	BOD (t/yr)		TN (t/yr)		TP (t/yr)	
	WW treatment	Other industries	WW treatment	Other industries	WW treatment	Other industries
AL	1,503.5	19,882.0	902.0	1.8	120.9	390.0
DZ	4,862.0	407,000.0	2,917.0	6,960.0	972.0	2,320.0
BA*	14.8	2,040.0	24.4	11.6	2.7	68.0
EG						
IL	786.2	1,265.0	201.5	2,770.0	29.8	507.0
LB*	65,700.0	72,000.0	10,220.0		2,628.0	
LY						
ME	626.0	1,401.0	218.2	333.0	70.2	103.0
MA	16,658.0	8,367.0	2,159.0	1,509.4	518.0	120.4
PS*	35,418.0					
SY*	18,904.0	51,613.0	3,093.0	6,435.0	343.0	3,561.0
TN	15,041.0	4,876.0	967.6	4,562.0	1,183.6	2,886.0
TR	31,149.0	12,130.0	18,643.0	1,106.0	3,371.0	180.7
	TOC (t/yr)		TN (t/yr)		TP (t/yr)	
	WW treatment	Other industries	WW treatment	Other industries	WW treatment	Other industries
HR			1,178.0		99.2	
CY			56.7	500.0	9.5	85.8
FR	8,455.9	22.1	12,748.0	896.4	1,202.2	28.1
GR	5,583.0	7.2	3,422.0	475.7	789.2	86.3
IT	23,898.6	86.0	21,776.9	1,839.9	2,573.0	183.9
MT		694.4	525.0	1,037.0	139.0	136.2
MC						
SI						
ES	10,184.1	8.0	32,240.4	5,070.6	2,468.4	541.7

[46] Under E-PRTR reporting, TOC is reported instead of BOD
[47] Refers to coastal hydrological basins.
[48] Data for coastal river basin districts used; as E-PRTR data only covers urban wastewater treatment plants of over 100,000 pe, smaller discharges are not included, hence the actual loads are higher.

Note: In the case of Lebanon and Bosnia & Herzegovina, values refer to nutrient loads of the untreated wastewater. The same is assumed for Syria as WWTPs are currently not operating optimally. In Palestine, BOD loads refer to both treated and untreated wastewater.

Source: EEA and UNEP/ MAP, 2021

The EEA and UNEP/MAP (2021) report concludes that the achieved progress with waste and wastewater management is not sufficient to curb the pressures and that further reduction in key pressures, such as waste and marine litter, wastewater and industrial emissions, is required to achieve a clean Mediterranean and the Good Ecological Status of its sea.

C. Spiteri et al. / Marine Pollution Bulletin 102 (2016) 295–308

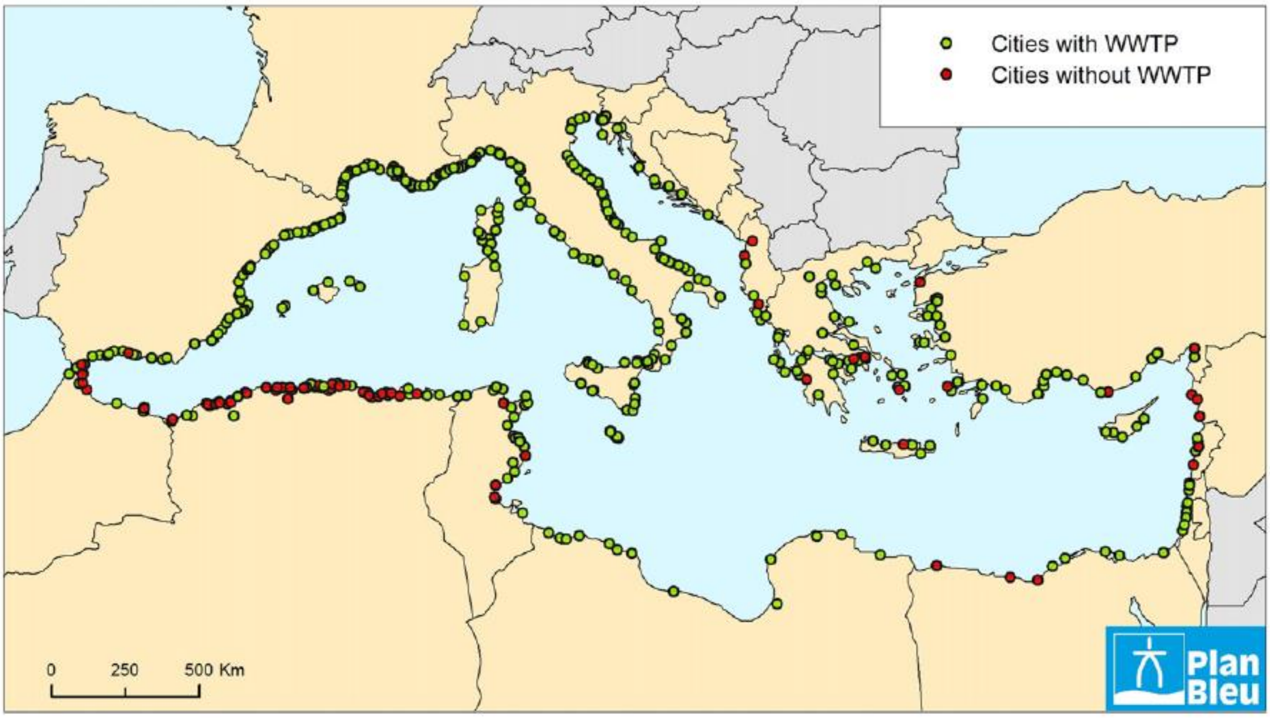


Fig. 7. Overview of the major coastal cities with/without WWTPs in 2010. Source: Based on UNEP/MAP/MED POL/WHO, 2011.

Figure 60. Overview of the major cities with/without WWTPs in 2010 (In Spiteri et a., 2016. Data from UNEP/MAP/MEDPOL/WHO, 2011)

3.5.1.9. Infrastructures (underwater cables and pipelines, ports and marinas)

Underwater cables

Over the past 15 years, the Mediterranean region has seen a rapid spread of information and communication technologies (ICTs), with, for example, total number of mobile cellular telephone subscriptions doubling between 2005 and 2021 to exceed 580 million. The share of population using internet has increased by several folds in a number countries, most notably in Albania and Algeria, but also in Lebanon, Tunisia, Syria, Egypt, Morocco and Turkey. As of 2021, the share of internet users in the national populations is above 70% in almost all the Mediterranean countries, and above 90% in Cyprus, Israel and Spain. The number of mobile-cellular subscriptions per 100 inhabitants is the lowest in Libya (around 43) and remains below 100 in Albania, Egypt, Lebanon, Palestine and Syria (Table 19).

Table 18: The key ICT indicators in the Mediterranean countries, 2005 and 2021

	Internet users (% of pop)			Mob-cell. Tel. subscriptions		Mob-cell. Subscr. Per 100 inhab.		
	2005	2021	Ch '21/05	2005	2021	2005	2021	Ch '21/05
AL	6.04	79.32	1212.40	1,530,244	2,635,466	50.46	92.32	82.96
DZ	5.84	70.77	1111.00	13,661,355	47,015,757	41.45	106.42	156.74
BA	21.33	75.68	254.84	1,594,367	3,728,775	38.94	114.00	192.74
HR	33.14	81.25	145.18	3,649,700	4,402,213	82.39	108.43	31.60
CY	32.81	90.76	176.62	782,503	1,320,794	105.18	148.74	41.42
EG	12.75	72.06	465.18	13,629,602	103,449,734	17.24	94.68	449.31
FR	42.87	86.10	100.83	48,088,000	72,751,000	79.47	112.74	41.86
GR	24.00	78.49	227.06	10,260,396	11,494,008	92.32	110.04	19.19
IL	25.19	90.30	258.42	7,757,000	12,500,000	115.53	140.45	21.57
IT	35.00	74.86	113.89	71,500,000	78,114,933	122.85	131.86	7.33
LB	10.14	86.59	753.94	993,557	4,288,221	21.40	76.68	258.32
LY	3.92			2,000,000	2,922,000	34.26	43.38	26.64
MT	41.24	87.47	112.10	323,980	649,919	78.98	123.38	56.22
MC	55.46	86.10	55.23	17,191	36,255	53.49	98.83	84.77
ME	27.10	82.22	203.39	543,220	1,120,074	85.83	178.40	107.84
MA	15.08	88.13	484.25	12,392,805	51,333,884	40.69	137.46	237.81
PS	16.01	*70.62	341.24	567,584	4,052,968	15.86	77.60	389.19
SI	46.81	89.00	90.14	1,759,232	2,607,268	87.75	123.02	40.19
ES	47.88	93.90	96.12	42,694,115	56,896,715	97.73	119.82	22.60
SY	5.65	*35.78	533.49	2,950,000	16,990,714	15.87	79.68	401.93
TN	9.66	78.99	718.11	5,680,726	15,644,663	54.68	127.58	133.30
TR	15.46	81.41	426.58	43,608,965	86,288,834	63.47	101.79	60.36

Notes: * last available data for 2019 and 2020

Source: International Telecommunication Union (ITU), 2023. https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx accessed February 2023

Note: Indicators could be shown on a map, possibly with different colour shadings for countries depending on the level of selected indicator/s; value of other indicators could be also shown on the map.

The SoED pointed out the imbalanced deployment of submarine cables, promoting connections of the most developed regions of the world while maintaining a digital divide in the SEMCs where despite remarkable progress, significant shares of population remained excluded from the use of ICTs (because of inability to access technologies or lack of skills to use them). The digital transition seemed to be slower and mainly focused on urban areas in Algeria, Egypt, Libya, Tunisia and Syria (UNEP/ MAP and Plan Bleu, 2020).

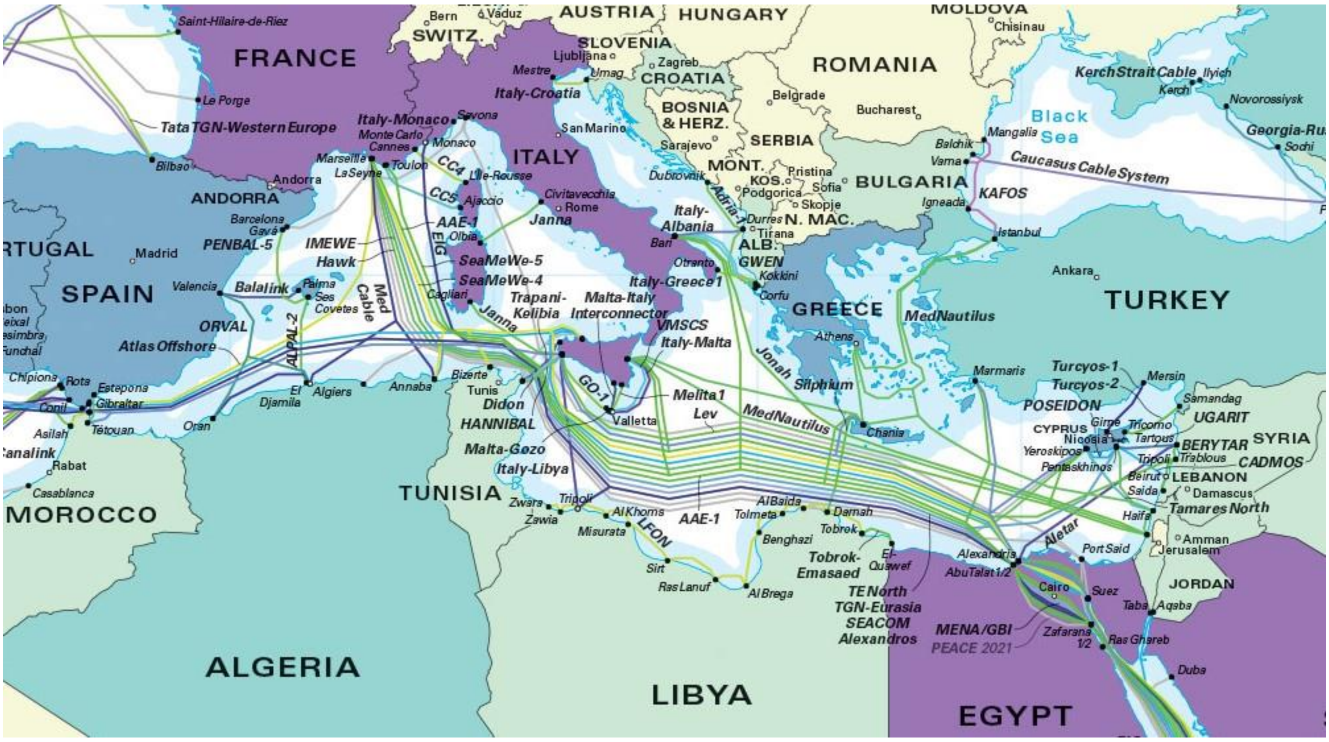


Figure 61. Underwater Mediterranean infrastructures.

The 2021 version of the map of submarine cables is available from https://submarine-cable-map-2021.telegeography.com/

A full overview of the existing and planned oil and gas pipelines (onshore and underwater) for the Mediterranean is not available. One of the older gas conveyors is the 2,475 km long Trans-Mediterranean Pipeline built in 1983 to transport natural gas from Algeria to Italy via Tunisia and Sicily, with capacity of more than 33.5 billion cubic metres a year (bcm/ yr)[49].

Several new gas pipelines, such as the Trans-Adriatic and EastMed Pipelines are planned to respond to the need for an increased gas supply to Europe and to diversify natural gas import routes by the EU, thus reducing/ avoiding dependency on Russia. The recent construction of the TANAP (Trans-Anatolian Pipeline) was supported by the European Commission and identified Turkey as the Southern European gas corridor. The TANAP is to be connected to the Trans-Adriatic Pipeline to reach Greece and Italy and provide the EU with access to 16 bcm/ yr of gas extracted by Azerbaijan from the Caspian Sea (UNEP/ MAP and Plan Bleu, 2020).

Development of 1,900 km long Eastern Mediterranean (EastMed) Pipeline is planned[50] to connect the gas reserves of the eastern Mediterranean to Greece. From there, through the Poseidon extension, the pipeline would reach Italy. The ultimate goal is to link the gas deposits of Israel and Cyprus – and eventually those of Egypt – with Italy. Planned capacity of the pipeline is 10 bcm/ yr, which is expected to double to a maximum of 20 bcm/ yr in the second phase. The energy ministers of Greece, Israel, and Cyprus signed the final agreement for the pipeline project in January 2020.

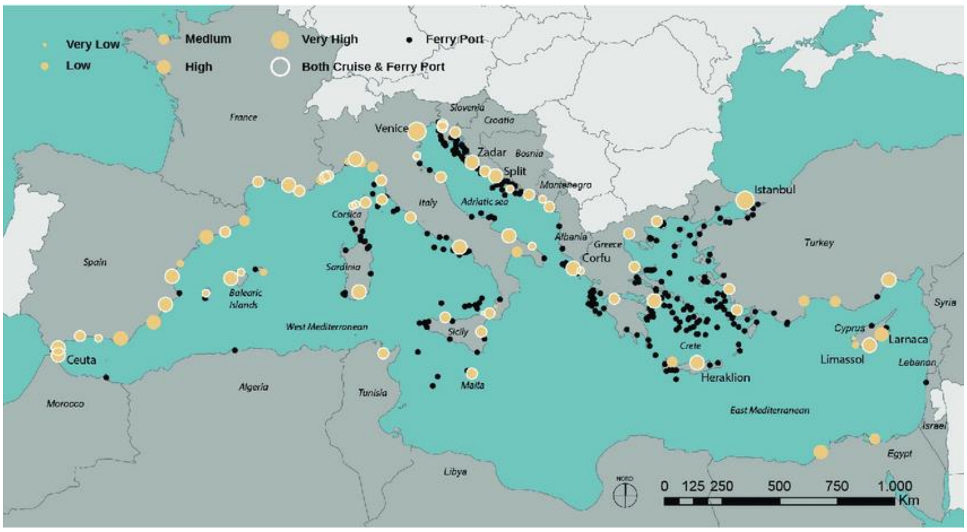
[49] https://www.hydrocarbons-technology.com/projects/trans-med-pipeline/
[50] https://www.nsenergybusiness.com/projects/eastern-mediterranean-pipeline-project/

Ports and marinas

The largest ports (in terms of tonnage) are mainly located in the North. Despite growth of ports, the SEMCs are home to just three (Arzew-Bethioua, Izmit and Alexandria) of the 12 largest ports (alongside Marseille, Algeciras, Valencia, Genoa, Trieste, Barcelona, Gioia Tauro, Taranto and Tarragona). The development of large ports in the SEMCs is a result of ambitious national policies and significant public/private investments; examples include Marmara, Izmir and Mersin in Turkey, Port Said, Alexandria, Damietta in Egypt, and Tanger-Med, Casablanca, Agadir in Morocco (UNEP/ MAP and Plan Bleu, 2020).

The Mediterranean region is the world's second-largest destination for cruises. Ports accommodating more than 120,000 cruise passengers each year are considered major ports. 36 ports in the Mediterranean fall under this category, 25 of which are located in the Western Mediterranean area, 7 ports in the Adriatic and 4 ports in the Eastern Mediterranean area. Moreover, 15 Western Mediterranean ports, 11 Eastern Mediterranean ports and 6 ports located in the Adriatic had fewer than 120,000 cruise passengers in 2017 include (UNEP/ MAP and Plan Bleu, 2020).

The Mediterranean passenger ports[51], as identified by Sakib et al., 2018, are presented in Figure 63.



Source: Sakib et al., 2018

Figure 62: Mediterranean cruise and ferry ports assessed for passenger transport and accessibility criteria

Land take due to port infrastructure and impacts from anchoring on seabed habitats are the main environmental issues linked to construction and operation of ports and marinas. Increasing attention is being paid to the environmental impacts of recreational boating/ yachting, in view of the sector's rapid growth. Yachts and associated infrastructure (ports, marinas, etc.) can threaten marine fauna and habitats and cause conflicts with other sectors from recreational users to professional fishers (UNEP/ MAP Plan Bleu, 2020). Figrue 64 shows distribution of marinas along northern Mediterranean shores in relation to potential fishing zones, based on the work conducted within PHAROS4MPAs project.

[51] In total, 79 cruise ports (majority of them serving also a ferry ports) and 362 ferry ports were analysed for passenger transport and accessibility (T&A) criteria considered to be the enablers of sustainable development.

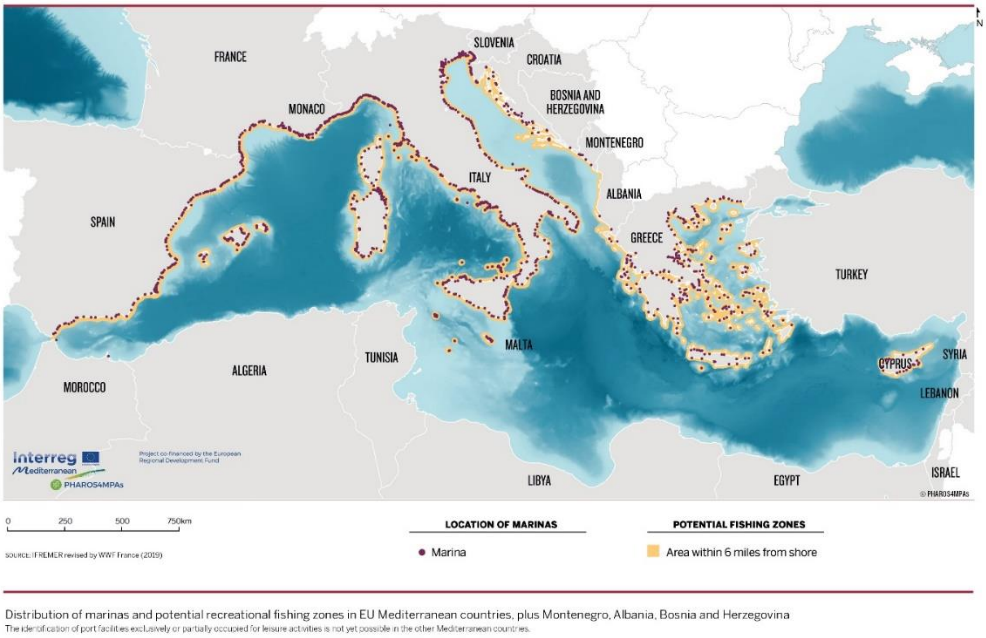


Figure 63: PHAROS4MPAs project: Distribution of marinas and potential recreational fishing zones. Source: PHAROS4MPAs

3.5.1.10. Coastal development

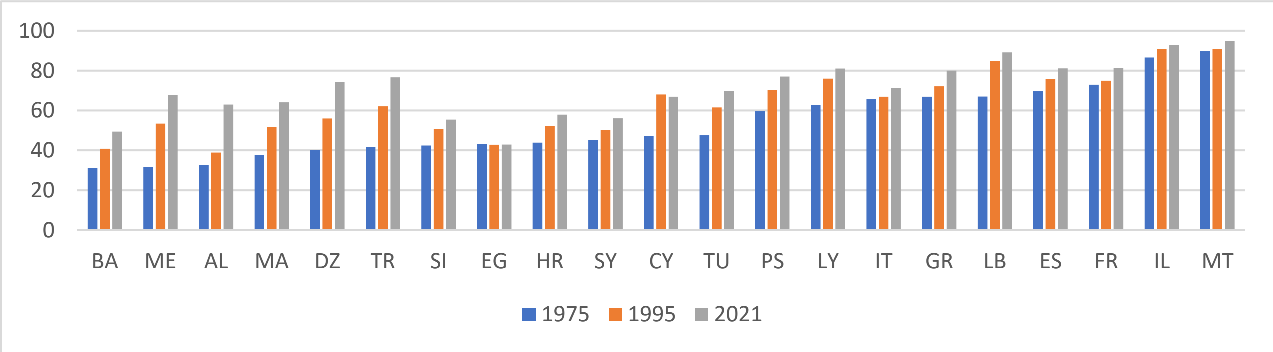
Coastal areas are considered one of the most attractive parts of the Mediterranean countries. Due to a range of amenities (including favourable climate, landscape, cultural, recreational and other benefits) and development and employment opportunities, they are among the most sought-after areas for living and frequently an end point for internal migration flows, including rural – urban population movements. Coastal areas are also highly valued as locations for secondary/ holiday homes.

Moreover, coastal and marine natural capital is a basis for development of a range of economic sectors and activities such as tourism, maritime transport, fisheries and others. In 2019, for example, international tourist arrivals (ITAs) in the Mediterranean countries accounted for close to 28% of the global ones and were to a large extent linked to coastal areas. In the EU, maritime economy (often referred to as the blue economy)52 is recognised as a powerful driver of socio-economic growth and is expected to double by 2030 (EEA, 2019). In the EU countries such as Croatia, Cyprus, Greece and Malta, for example, blue economy generated 5 to 8% of the national GVA and accounted for as much as 15% of all the jobs in 2019 (European Commission, 2022).

Population growth in the Mediterranean has been identified as one of the main drivers of coastal areas development and related environmental change (UNEP/MAP and Plan Bleu, 2020; MedECC, 2020). During the past two decades alone, population of the Mediterranean countries increased by nearly a quarter: from 427.8 million in 2001, to 531.7 million in 2021[53] (UN DESA, 2022). Shares of urban population increased steadily across the region, standing at or above 70% in over half the countries (Algeria, France, Greece, Israel, Italy, Lebanon, Libya, Spain, Malta, Palestine, Tunisia, Turkey) in 2021. Egypt is the only

[52] Including traditional/established sectors, such as fishing, shipping, tourism, aquaculture and the extraction of non-living resources (e.g. oil and gas, marine aggregates), as well as emerging sectors, such as offshore renewable energies, desalination, blue biotechnology and the extraction of mineral resources specifically in the deep sea.
[53] Cumulative change 2021/1990 is 41%.

Mediterranean country where rural population (around 57% in 2021) still prevails, while the shares of rural and urban population are about the same in Bosnia and Herzegovina (World Bank, 2022).



Source: World Development Indicators | DataBank (worldbank.org), accessed November 2022

Figure 64: Shares of urban population across the Mediterranean 1975 – 2021

The pace of urban population growth[54] in the region varied significantly over time. Countries like France, Greece, Israel, Italy, Malta, Spain and Palestine had already reached high levels of urbanisation by mid 1970s and the rates of growth of urban population remained relatively low and even over the past 50+ years. By 1975, urban population also prevailed in Lebanon and Libya, where strong growth of urban population continued until mid-1980s. Urbanisation peaked in Bosnia and Herzegovina, Croatia, Cyprus, Montenegro, Morocco and Slovenia in the period 1975 – 1980. In Algeria, Tunisia and Turkey, the highest urbanisation rates were recorded during 1980's and in Albania in the period 2000 – 2010. Negative urbanisation rates were recorded in Egypt, Cyprus (since 2000) and Syria (in the period 2010 – 2015).

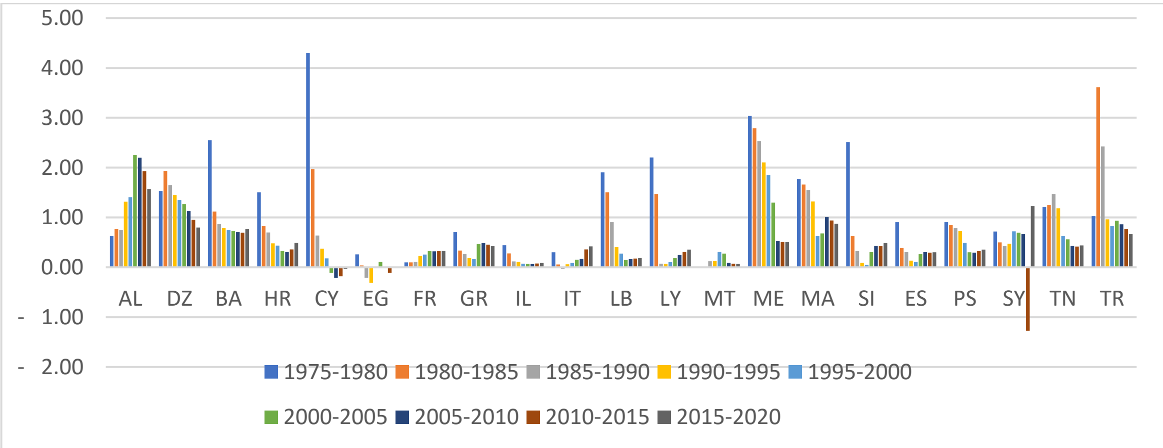


Figure 65: Quinquennial rates of urban population changes 1975 – 2020

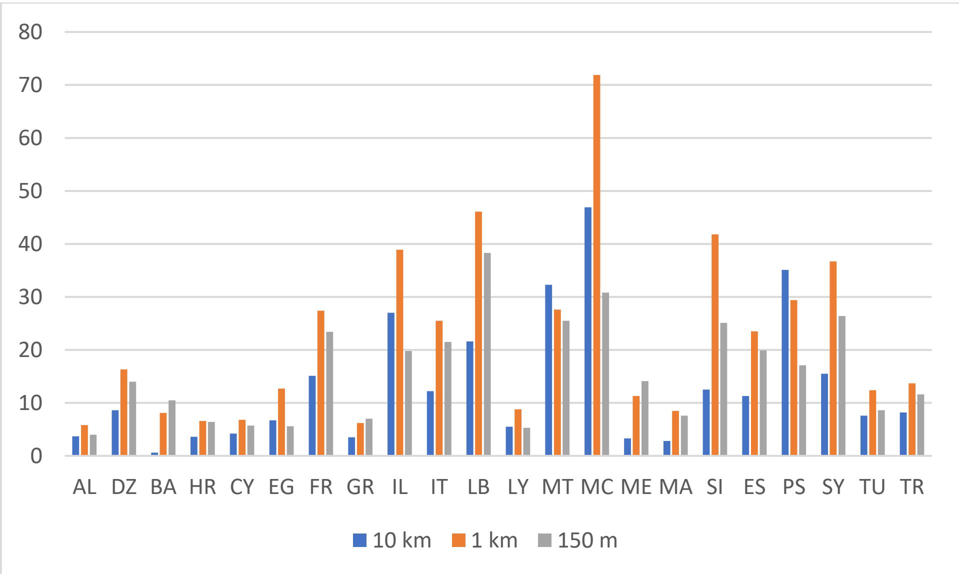
Source: United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision, Online Edition.

The existing analyses suggest that approximately one third of the total Mediterranean population (170 – 180 million in 2021) lives in coastal areas. Shares of coastal population range from 5% in Slovenia to 100% in island countries (Cyprus, Malta) and Monaco; highest population density (inhabitants per km2) in the Mediterranean coastal regions is found in Monaco, Palestine, Malta, Lebanon, Syria, Israel, and Algeria (UNEP/ MAP and Plan Bleu, 2020). In addition to population growth/ movements, coastal

[54] Measured by the average annual rate of change of the percentage of urban population.

urbanization is driven by economic activities concentrated in the coastal belts. According to SoED, urban pressures increased in 75% of Mediterranean countries over the period 1965-2015, whereas built areas within one kilometre from the sea doubled or increased by several folds. Population densities in coastal areas have continued to increase at unsustainable rates over the last decade. Rapid growth of urban and peri-urban areas is recorded all over the Mediterranean, especially along the coasts of North Africa and among eastern Mediterranean countries (IAI, 2022). The analysis UNEP-GRID[55] prepared for PAP/RAC in 2017 showed evolution of coastal urbanization around the Mediterranean between 1975 and 2015 (UNEP-GRID, 2017)[56]. Data on built-up areas was calculated for three coastal belt widths of 150 m, 1 km and of 10 km. In addition to built-up areas, the report assessed the land take, i.e. urbanization on previously undeveloped land.

Total length of the Mediterranean costs has been assessed at 57,422 km (UNEP-GRID 2017). Countries with the longest coast are Greece (16,491 km or 28,7% of the total), Italy (10,043 km or 17,5%), Turkey (6,961 km or 12.1%), Croatia (6,381 km or 11.1%) and Spain (3,188 km or 5.6%). Morocco, Albania, Cyprus, Algeria, Tunisia, Libya, France and Egypt have coasts of cca 500 – 2,500 km (accounting for 1 to 4.4% of the total. The shortest coasts (less than 100 km) are found in Monaco, Bosnia and Herzegovina, Palestine and Slovenia; length of coast in Israel, Malta, Syria, Lebanon and Montenegro is in the range of 200 – 300 km.



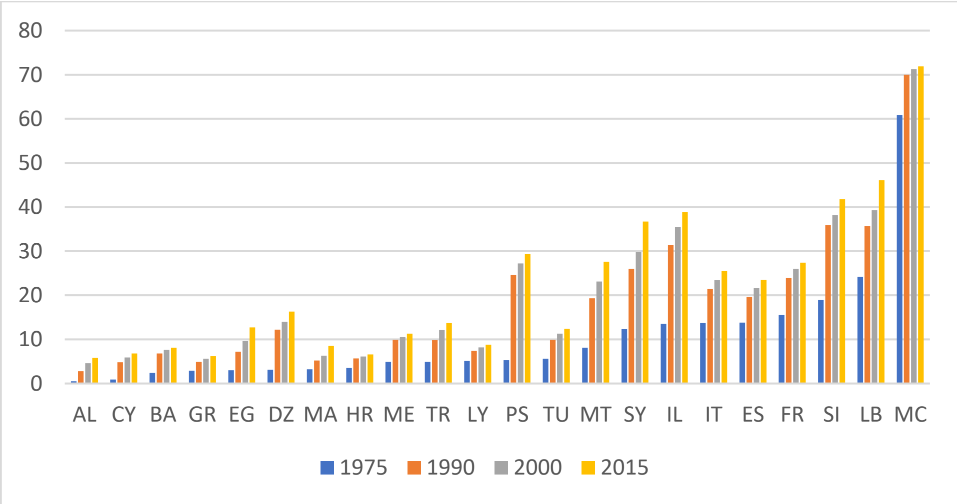
Source: UNEP-GRID, 2017. NOTE: length of coasts can be presented as a chart, possibly coupled with other graphic presentations

Figure 66: Shares of built-up areas within 10 km, 1 km and 150 m coastal belts, 2015

In majority of the Mediterranean countries, the highest concentration of built-up areas is found within the 1 km wide coastal belt. Exceptionally, coastal belts of 150 m are somewhat more densely developed in Bosnia and Herzegovina, Greece and Montenegro. In Malta and Palestine, the zone with the highest share of built-up areas is 10 km belt. The countries where built-up areas in at least two out of three analysed zones exceed 20% are mainly the ones with short (less than 500 km) or very short coast such as Israel, Lebanon, Malta, Monaco, Slovenia, Palestine and Syria, but also Italy, Spain and France.

[55] United Nations Environment Programme Global Resource Information Database
[56] Change in built-up areas was assessed based on the data from the Landsat collection (Global Human Settlement Layer – GHSL) provided by the European Commission's Joint Research Centre (JRC).

Analysis of the dynamics of urbanisation of 1 km coastal belt over the period 1975 – 2015 showed that land take increased by several folds in majority of the countries, most notably in Albania and Cyprus, but also in Palestine, Algeria, Egypt, Malta, Bosnia and Herzegovina and Syria, as well as in Israel, Turkey and Tunisia. Somewhat more moderate but still significant rates of change (with the shares of built-up areas increasing by a factor of 2 to 3 between 1975 and 2015) were seen in Montenegro, Tunisia, Slovenia and Greece. The lowest level of new urbanisation was recorded in some of the countries where coastal zones were already highly urbanised prior to 1975 (e.g. Monaco, Lebanon, France, Spain, Italy), but also in Croatia and Libya.



Source: UNEP-GRID, 2017

Figure 67: Changes in the percentage of built-up areas, 1975 – 2015

NOTE: Map from page 19 of the Summary SoED (or page 194 of the full report) could be included to illustrate density of built-up areas in 150 m coastal belt

Growing population and littoralisation of the development i.e. concentration of settlements and economic activities in the narrow coastal strips have intensified pressures on the coastal zones, reducing their environmental quality and capacities of the Mediterranean ecosystems to provide adequate services to economies and societies in the region. These impacts are amplified and accelerated by the effects of climate change, contributing to further degradation of the natural capital of Mediterranean coastal areas (Grimes et al., 2022).

The SoED highlights significance of the coastal zones for Mediterranean economies and societies as the areas with high population density and high concentration of infrastructure, tourism, commercial and industrial facilities, often situated near the shore. Intensification of coastal uses is at the origin of many impacts that alter the invaluable capital that is the Mediterranean, leading to increased fragmentation of landscapes and disrupting ecological continuity. It also makes coastal zones highly vulnerable to sea level rise, storm surges, flooding and erosion (UNEP/MAP and Plan Bleu, 2020).

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CHAPTER 4. LME transboundary changes and challenges (CCA)

4.1. Identification and prioritization

As indicated in Chapter 2, a first selection of nine transboundary themes was performed (Table 19), by observing the current region-wide science-policy concerns and reviewing those in the TDA report from 2005, and therefore, listed and refined after a knowledge pooling phase. The GEF 'transboundary' concept aims at addressing water-system related environmental issues that requires the participation of two or more countries. The integrative approach of this report analyzes environmental LME concerns (ca. changes) from a transboundary perspective and includes other subjects related or affected by pollution issues which also influence other transboundary concerns by themselves (e.g., coastal and marine pollution, rivers flow discharges, catchment areas, water systems connectivity, marine biodiversity, oceanography, climate variability, etc.). On the other hand, 'transboundary' is also interpreted as 'shared' environmental concerns, which not necessarily need to be transboundary connected (e.g., marine chemical pollution, scientifically speaking, is connected as it would be the same at national or transboundary level), but are important common issues at national level (ca. challenges), as well as fundamental to solve their transboundary direct or indirect effects, such as, research and technology gaps (e.g., existence or not of environmentally targeted databases, digital transition paths), environmental law developments (e.g., updated legislative frameworks, e.g., climate mitigation and adaptation policies, etc.). The rationale behind the use of transboundary and shared conceptualizations closely in this report is to broader the causes and effects relationships as higher environmental complexity problems are recognized since the TDA in 2005.

Table 19. TDA/SAP changes and challenges in the Mediterranean LME.

TDA/SAP changes and challenges in the Mediterranean LME	Mediterranean transboundary areas of importance
Changes: environmental transboundary issues	
Reversing Pollution	4.1. on Land and sea-based chemical, biological and physical pollution in transitional waters, coasts and offshore
Stopping Litter	4.2. on sources and fate of marine litter and waste pollution, including offshore seafloor
Enhancing Nature	4.3. on Nature value loss, focusing on marine habitats, biodiversity, and ecosystems
Fighting Climate	4.4. on Climate change adaptation, mitigation, and socio-ecological resilience
Challenges: welfare shared issues	
Sustaining Assets	4.5. on Coastal belts degradation, sustainability, and restoration
Switching Livelihoods	4.6. on Socio-economic drivers of transformation, green recovery and sustainable blue finance
Integrating knowledge	4.7. on Observing infrastructures, including joint IMAP national monitoring data flows, regional and global indicators
Boosting Digitalization	4.8. on Environmental digitalization, marine literacy and forecasting research
LME long-term functioning, protection, and conservation	
Preventing Crises	4.9. on Long-term global regulation affecting the Mediterranean LME

The identification and prioritization of the long-term issues involved in the regulation of the LME (4.9. on Long-term global regulation affecting the Mediterranean LME, Table 9) was developed by Plan Bleu in the report entitled - The Mediterranean Large Marine Ecosystem. Prioritization of the transboundary problems, analysis of impacts and causes, July 2022 - which initially served to frame the LME from an ecological scientific perspective (https://planbleu.org/en/publications) and is discussed and included in Chapter 8 (Scenarios). The following subsections present the elucidation of the prioritization of transboundary issues as a result of the CCA at regional level.

4.2. Transboundary environmental changes

4.2.1 Reversing pollution (environment)

The regional thematic assessment (***Pollution transboundary causality assessment report – contribution to the UNEP/MAP GEF TDA Report update by 2023***) highlighted the following three transboundary priority issues regarding to transboundary pollution themes (Reversing Pollution – 4.1. on Land and sea-based chemical, biological and physical pollution in transitional waters, coasts and offshore):

Priority issue 1: Eutrophication

Priority issue 2: Chemical pollution

Priority issue 3: Oil & HNS pollution

The Mediterranean LME is affected by pollution understood as many different alterations of the ecosystems' equilibrium, disregarding the natural or unnatural origin of the cause, conflicting with the anthropogenic uses (ca. ecosystem services), and mainly arising from unsustainable socioeconomic models since the industrial revolution (ca. late 19th century). Historically, some of the pollution sources and processes had no boundaries in the marine environment and were recognized as early as in the 20th century (e.g., pollution discharges - plumes diffusion) and rapidly increased in parallel to human population growth (e.g., chemical industry). The economic models, now and then, are not taking into account neither the limitations in raw materials nor the pollution generated directly or indirectly during the production and consumtion of goods and services. Thus, the classical socioeconomic and human development remains proportional to increased growing threats to the environment and continues in the 21st century, altough there exist for decades the global recognition of the problem through sicentific (and non-scientific) spheres and social awareness leading to international agreeements to address the global pollution issues. Pollution is included in the UN environmental triple crises and related directly to the transitions to alternative economic models (e.g., green economy, circular economy, sustainable blue economy, renwable energies, etc).

The eutrophication and chemical pollution sources relate primarily to the agricultural and industrial sectors discharges and inputs, respectively. The chemical industry, roughly speaking, both produce and consume chemical substances and fossil fuels, repectively, and are major contributors to the environmental chemical pollution on land and marine (water) systems, including the atmosphere, at a transboundary scale. On the contrary, acute oil pollution (by maritime transport) has decreased in the Mediterranean largely since last century and the focus is now on other substances transported by sea, namely, harmful and noxious substances (HNS), which could be gas, liqid or solid.

Large and continued efforts in the Mediterranean Sea under the coordination of the Barcelona Convention Secretariat (i.e., the Barcelona Convention and its Protocols, see Chapter 7) have been succesful limiting many of the legacy pollution flows into the marine ecosystems (e.g., a growing number of waste water treatment plants related to the Land-based Sources Protocol), altough the human modern life styles and continued development and expansion have introduced newer chemical pollutants in the environment, known as chemicals of emerging concern (CECs). Therefore, today, chemical pollutants are grouped in two main groups, the so-called legaly pollutants and CECs. The reduction of the first group has been achieved mainstreaming knowledge, action and policy through the Mediterranean countries supported with large efforts in pollution reporting, monitoring and assessment for continental waters, coastal and marine environments (such as the MEDPOL Programe from UNEP/MAP), aimed at covering the entire Mediterranean basin, thus it was well recognized that pollution (ca. legacy), is and was, one of the transboundary environmental changes occurred in the marine environment in the Mediterranean LME, as it was highlighted in the TDA 2005. In the last decades, and since the adoption of the Ecosystem Approach by the Contracting Parties of the Barcelona Convention, the holistic understanding of the environmental pressures and effects into the living and non-living natural resources have unlocked the ecosystems hidden complexity and shown that the countries increased cooperation at larger scales is still necessary (ca. transboundary cooperation) for the abatement of the legacy and contemporary pollution transboundary issues in the Mediterranean Sea.

Reversing pollution, refers not solely to chemical substances. There are new types of know pollution in the global agendas, namely, marine debris and, surely, physical (energy) and biological (toxins and microorganisms). It could be defined as “disruptions caused by the introduction of substances, matter and energy prokoving deleterious effects and reduction of ecosystem services”, in accordance with well know Clark’s definiton (Clark, 1986). As this, with the ecosystem approach, the study of marine pollution involves many scientific disciplines and the concept becomes larger and complex today. The human health and biological effects of marine pollution, eg., contaminated seafood, could be consequence of multiple causes, such as untreated watewater discharged substances, industrial chemicals, altogether with harmful algal blooms (HABs) and water quality in terms of microbiology (ca. bacteria). However, the large number and complexity of chemical substances detected in the environment and their effects, estimated on thousands of chemicals introduced in the envrionment since the mid 20th century is only monitored, assesed and understood poorly. Further, as an examples, new concerns such as viruses and noise effects on zooplancton species are new topics under initial scientific research.

Priority issue 1: EUTROPHICATION (&COASTAL WATER QUALITY)

Description of the problem and its transboundary importance

Eutrophication, either natural or unnatural, results from the nutrient enrichment of a water body. Although the Mediterranean Sea is generally oligotrophic, nutrient enrichment may occur in sheltered coastal waterbodies, such as harbors, semi-enclosed or coastal lagoons to mention few subject to nutrient inputs, for example, from urban effluents and industrial discharges. The main substances that indicate nutrient enrichment are total nitrogen (TN) and total phosphorus (TP). In the Mediterranean, natural eutrophication is not a basin-scale issue, disregarding the well studied HABs blooms in some parts (e.g., Adriatic Sea). Still, it is relevant to consider nutrient enrichment/eutrophication as a transboundary issue as once in the marine environment, these increased nutrient concentrations, could be carried into adjacent marine waters.

On the contrary, unnatural eutrophication and the well-known eutrophication consequences (ca., hypoxia and potential mass mortality) mainly occurs close to densely populated areas characterized by intensive agricultural and anthropogenic activities. Both land-based untreated wastewater and runoff dishcarges flows might introduce an excess of nutrients which play a significant role altering the marine geobiochemical cycles (ca. essential chemical compounds for living organisms). However, the uncertainties in the average discharges in the Mediterranean LME still large, particularly for the runoff contributions from rivers and coastal plains regarding agricultural activities and urban wastewater. Ayache et al. (2020) modelled (LPJmL-Med model), using datasets for fertilizer, manure and wastewater nutrient contents (1961-2005), for three main Mediterranean rivers, the Po, Rhone and Ebro rivers concluding that the fluxes of NO3 and PO4 exhibit opposite trends in the Mediterranean Sea. Whilst NO3 showed a steady increase from the beginning of the 1960s until the present in all three rivers the PO4 trends were more heterogeneous in those three main catchment areas. Over these period of time the ban of phosphates in detergents and the construction of WWTPs in different countries (ca. policy responses) is reflected in the PO4 decline trend since the second half of the 1980s. It is important to observe the order of magnitude of the concentrations both for NO3 and PO4 in the different datasets (ca. fertilizer, manure and wastewater). The agricultural practices still different in the Mediterranean countries and are characterized by differences in crop types, fertilization and irrigation methods, as well as livestock and manure quality (Ayache et al., 2020 and references therein). All together reveals the nitrogen and phospate agricultural cycles (Figure 69).

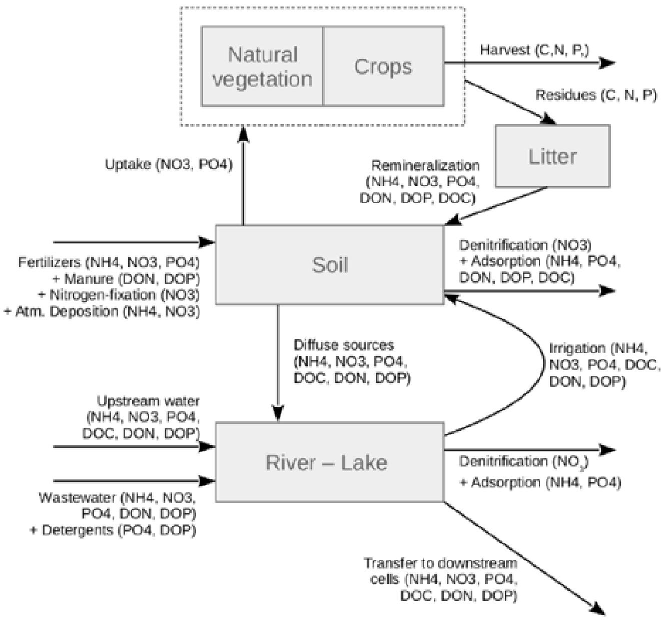


Figure 68. The NO3 and PO4 flows depicting the processes in land from agricultural practices. The outputs through the water flows might runoff to the coastal and marine waters (Arache et al., 2020).

Accordingly, this research reconfirms that wastewater strongly contributes to the river phospate fluxes, while both agriculture and wastewater control the nitrogen fluxes from rivers to the Mediterranean Sea (Figure 70).

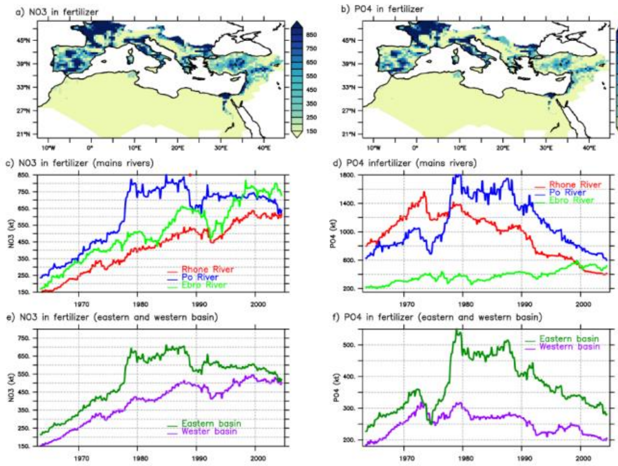
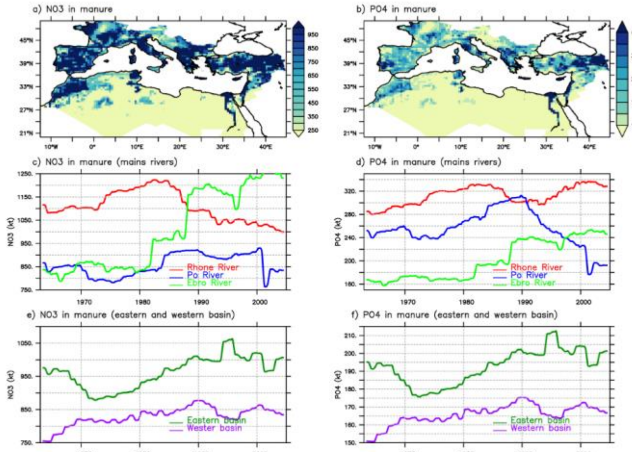


Figure 3. A compilation of nutrient inputs data set from fertilizer data (in kilotons/pixel of NO3 and PO4), (a and b) horizontal maps represent LPJmL-Med annual input of fertilizers averaged between 1960 and 2005. (c and d) time series for Rhone catchment in red, Po catchment in blue and Ebro catchment in green. (e and f) times series for eastern and western basins.



'igure 4. Same as Fig. 3 but for Manure data in kilotons of NO3 and PO4

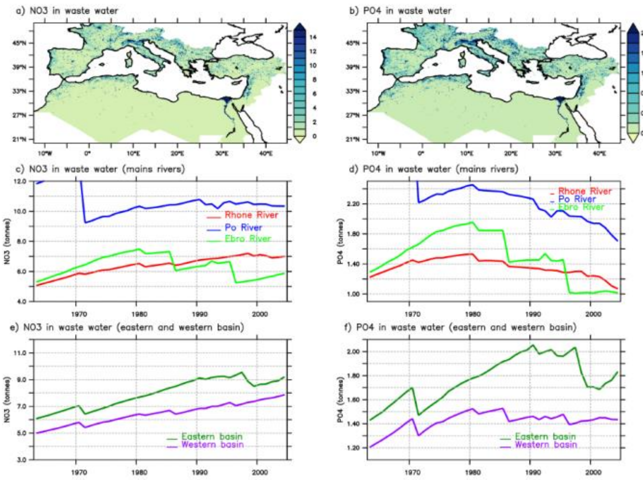


Figure 5. Same as Fig. 3 but for wastewater release (in tons/pixel of NO3 and PO4)

Figure 69. Estimated levels of NO3 and PO4 in the Mediterranean basin from different sources (ca. fertilizer, manure and wastewater) in three major rivers and comparison between western and eastern basins (Ayache et al., 2020).

Various anthropogenic activities, both as point and diffuse sources, lead to N and P emissions. The overall inputs of N and P to the Mediterranean are estimated at 1.5-4.5 and 0.1-0.4 Mt yr-1, respectively (MedECC, 2020). Although the area of the Mediterranean Sea five times larger than the Black Sea, the nutrient inputs are of the same order as those to the Black Sea (1.116 Mt yr-1; 0.055 Mt yr-1) that is surrounded by a large drainage. The Mediterranean basin exports 1.95 Mt-N yr-1 and 0.15 Mt-P yr-1 through the Gibraltar Strait and receives 1.25 Mt-N yr-1 and 0.034 Mt-P yr-1 from the atmosphere as a bulk deposition (Cozzi et al., 2018).

The Figure 70 below shows the mean annual river basin discharges of N and P for the period 2003-2007 in the coastal watersheds draining into the Mediterranean Sea. According to the model simulations, an average of 1.87 Mt TN yr-1, 1.22 Mt N-NO3 yr-1, 0.11 Mt TP yr-1 and 0.03 Mt P-PO4 yr-1 were discharged into the Mediterranean Sea during the period 2003–2007[57]. The Nile, Po, Rhone and Ebro were the main river basins that contributed to the nutrient discharge in the Mediterranean Sea. Ultimately, the socio-economic activities in a river basin, such as the development of wastewater infrastructure in relation to urbanization, fertilizer use in agriculture, implementation of environmental policies etc., can affect the amount and forms of nitrogen and phosphorus exported to the coastal waters, altering the N:P ratio and strongly influencing the eutrophication process (Malago et al., 2019).

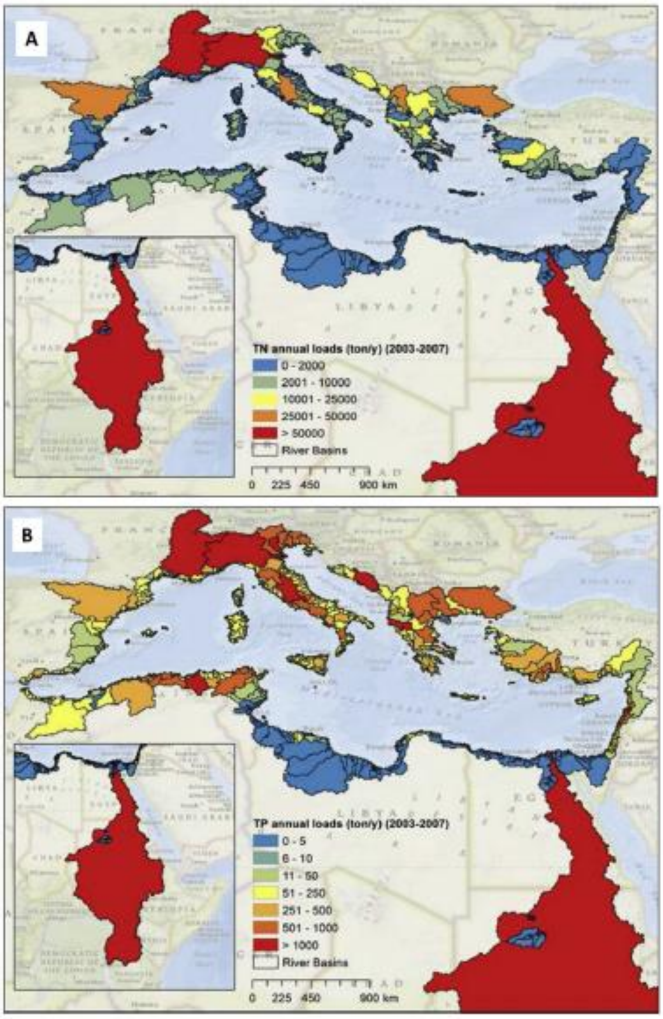


Figure 70. Mean annual river basins discharge of (A) TN and (B) TP for the period 2003-2007. Source: Malago et al. (2019)

[57] The original units in Malago et al. (2019) were in Tg yr^{-1}, equivalent to Mt yr^{-1}

Biogeochemical cycles are currently undergoing major changes due to the human activities such as intensive agriculture and fossil fuel burning. The former, has clear consequences, such as the increase supply of nutrients through water flows from land ecosystem towards the sea with the potential for mortality events (e.g. hypoxia) and habitat degradation. Human-induced eutrophication in coastal waters could have its orgin in nutrient loads through rivers, runoff, WWTP effluents, and groundwater discharges. However, the nutrients are not freely dissolved into the water systems and there are interactions and equilibrium with the composition of the water matrix.

On the other hand, natural eutrophication occurs in known locations across the basin despite the Mediterranean Sea is generally considered an oligotrophic basin, with primary productivity decreasing from west to east. The main coastal areas historically known to be influenced by natural and/or anthropogenic inputs of nutrients are the Alboran Sea, the Gulf of Lion, the Gulf of Gabès, the Adriatic Sea, Northern Aegean and the SE Mediterranean (Nile-Levantine) (Colella et al. 2016; UNEP/MAP, 2017; Macias et al. 2018 – Figure 71 and 71).

The geographical distribution of anthropogenic eutrophication (ca. nutrients excess) in the Mediterranean Sea occurs in densely populated areas characterized with intensive economic development (ca. agriculture), but large unnatural eutrophication phenomena is not commonly observed in the basin, with the exception of local and restricted problems in sheltered coastal waterbodies, such as harbors and semi-enclosed areas subject to land-based inputs of urban and industrial effluents, e.g. Venice Lagoon (Italy), Mar Menor Lagoon (Spain), Mar Chica (Morocco), or lagoons in the Nile Delta. The offshore waters of the Mediterranean are characterized by extremely low biological productivity (ca. primary production). This contrasts with other semi-enclosed seas, such as the Baltic Sea which receives comparable loads of nutrients per unit area, but is highly susceptible to nutrient enrichment, eutrophication, and therefore, its ecological impacts.

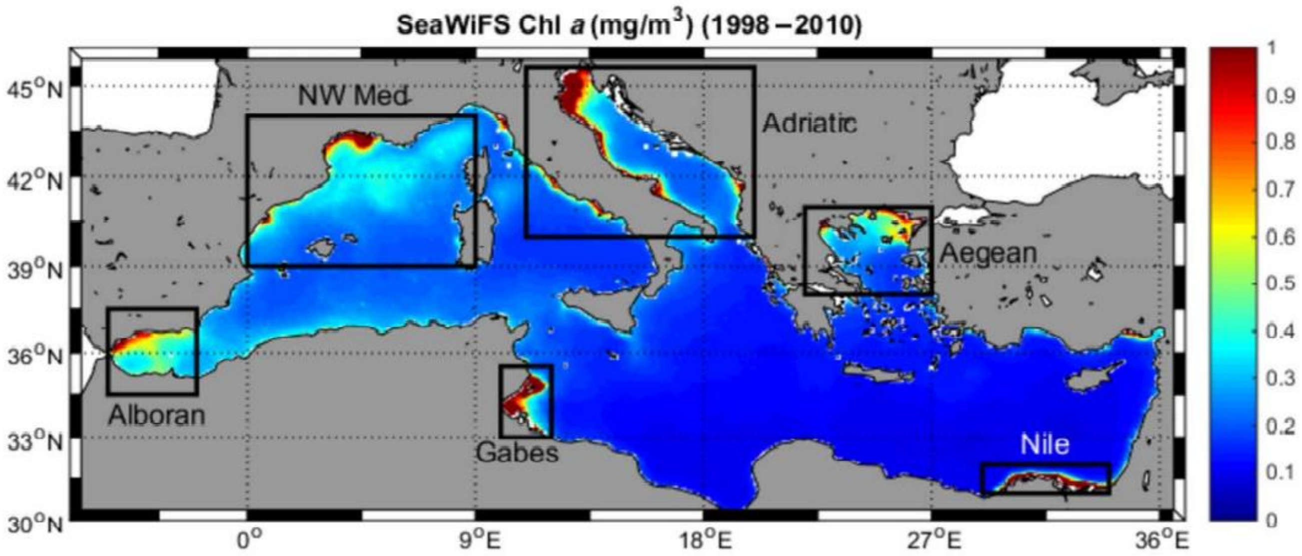


Figure 71. Climatological surface chlorophyll concentration (mg m^{-3}), used as a proxy of phytoplankton biomass to detect eutrophication, during 1998–2010 derived from the SeaWiFS sensor. Production "hotspots" are indicated with black boxes along with their corresponding names. Source: Macias et al. (2018)

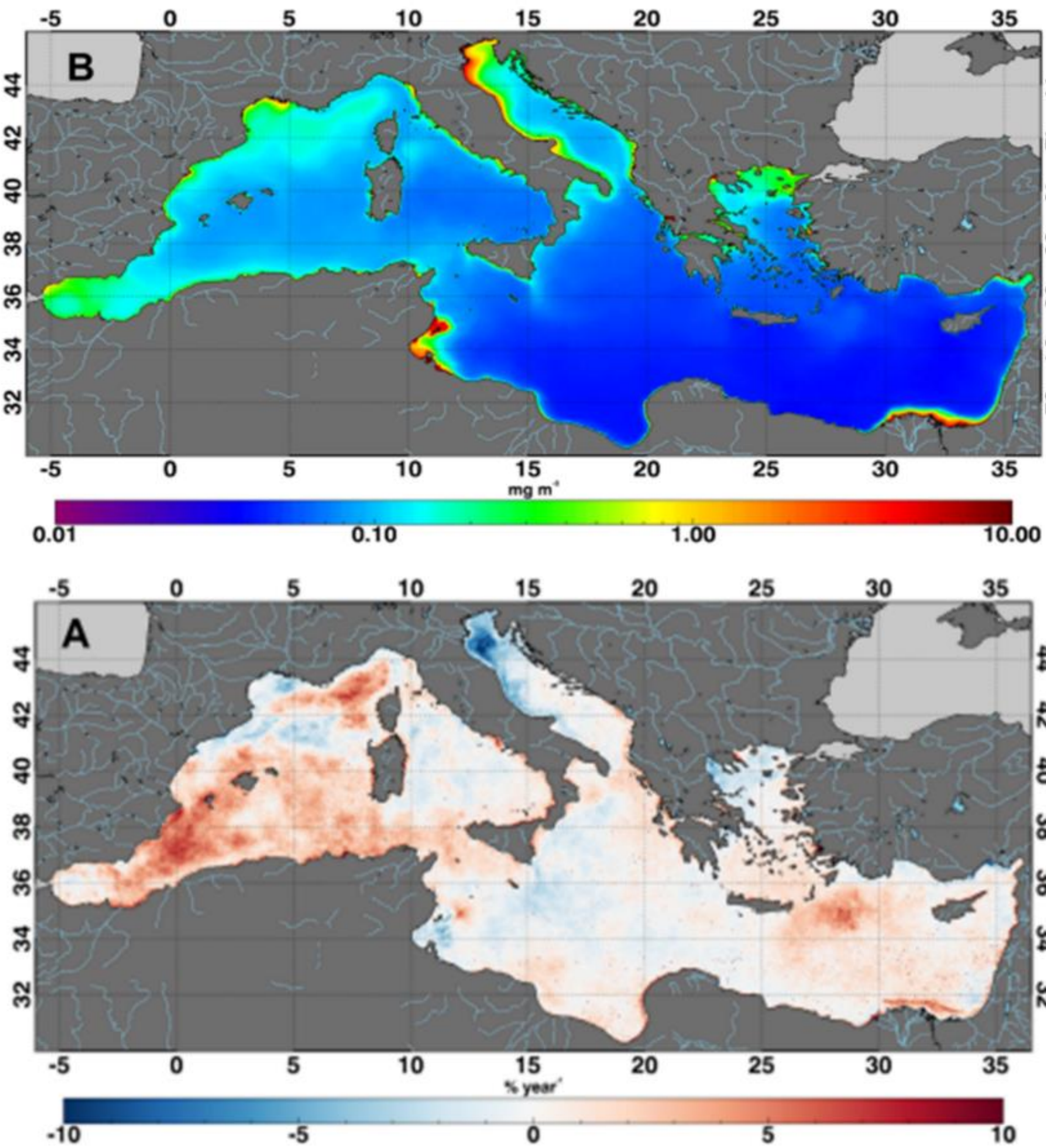


Figure 72. Chlorophyll concentration climatology over the Mediterranean Sea relative to 1998–2009 period. Highest chlorophyll concentrations are generally found in coastal water, in proximity of river nutrient discharges (top). Chlorophyll concentration trend over the Mediterranean Sea, relative to 1998–2009 period. Color bar scale represents the relative changes (%) corresponding to the dimensional trend [mg m^{-3} y^{-1}] with respect to the climatological Chlorophyll (bottom). Source: Colella et al. (2016)

The analyses of satellite images of the Mediterranean Sea over the last 20 years show that chlorophyll concentration has been increasing in the southeast Spain coast, the Ligurian–Provençal basin, and the Rhodes Gyre region (Colella et al., 2016). The evidence also indicates that eutrophication problems persist in the area of influence of the Nile Delta. These trends result from the expansion of urban areas and the intensification of fertilizers use in agriculture. Colella et al. (2016) also reported decreasing trends in the North Adriatic Sea, off the Rhone River mouth, and in the Aegean Sea (1998–2009), as a result of the implementation of policies to reduce agricultural nutrient pollution or wastewater discharges, such as in the Rhone and Po River basins, following the enforcement of the EU Nitrates Directive (91/676/EEC) and Urban Waste Water Directive (91/271/EEC). The work of Colella et al. (2016) is supported by Ayache et al. (2020) for the Po river (North Adriatic Sea) with a slight decline of the annual NO3 and declining trends of PO4 over the last 20 years).

Different multi-metric or univariate indices have been applied to the Mediterranean Sea to evaluate the trophic status based on direct and indirect indicators of eutrophication, namely nutrients, chlorophyll-a, dissolved oxygen saturation level in deep water, Secchi Disk Depth, phytoplankton composition, and macro-benthic diversity change indices. The tools commonly applied in the Mediterranean region are Trophic Index (TRIX) developed by Vollenweider et al. (1998), Eutrophication Index (EI) by Primpas et al. (2010), HELCOM Eutrophication Assessment Tool (HEAT) used by HELCOM (2009) and Andersen et al. (2011), HEAT+ (EEA, 2019), typically developed for highly productive seas. Turgul et al. (2019) applied different eutrophication classification tools (TRIX versions, EI and Chl-a scaling, and HEAT) to the Northeastern Mediterranean coastal, offshore areas and bays to test their sensitivities to waters with different trophic status. They concluded that the scaling results of classical TRIX, EI, and Chl-a indices in the Northeastern Mediterranean water masses are not sensitive enough to differentiate mesotrophic and eutrophic water bodies because these indices principally assume to have higher concentrations of eutrophication-related parameters in the least effected (reference) water bodies. The HEAT tool, which uses a site-specific reference value for each eutrophication-indicator, has allowed for the production of more reliable and sensitive scaling of the current trophic status of the Northeastern Mediterranean shelf, calling for revision requirements of the multi-metric classification tools.

Major environmental impacts and socio-economic consequences (including gender aspects)

The major environmental impacts and socio-economic consequences of eutrophication, including their interlinkages are shown in Figure 73. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of ecosystem goods and services The mechanism of eutrophication is complex and depends on additional factors other than high nutrient input. An excess of nutrients in the water alters the nutrient ratio, giving rise to a chain of reactions that disrupt aquatic ecosystems. The increased phytoplankton biomass results in an enrichment of suspended particulate organic matter reducing the water column transparency and hence the light permeability. Eutrophication leads to a sequence of ecological changes, such as alterations in biological interactions and trophic structure; changes in the species composition of the primary producers to shifts in the zooplankton community (i.e., increased BOD5 by higher consumption of dissolved oxygen and total organic carbon); loss of suitable benthic habitats and changes in benthic biodiversity; induced selection of tolerant and opportunistic species. One of the most severe impacts is the development of hypoxic conditions due to rapid consumption of oxygen in the bottom layers, with consequences for ecosystem functioning and services provision, including and mass mortality of fish in severe events.

Socio-economic consequences are related to the direct loss of ecosystem services due to harmful algal blooms (HABs), blooms of nuisance species (e.g., jellies such as Noctiluca), and algal scums. The red tides caused by several species of microscopic plant-like cells or phytoplankton that produce chemical toxins result in fish kills and contamination of shellfish (i.e., HABs). Other impacts include aquaculture losses and a decrease in the recreational value of coastal areas (e.g., smells that keep tourists away from the beaches). Eutrophication in key areas may have transboundary implications by serving as a “source” for nuisance species (jellyfish, toxic algae, and their cysts) that may spread in basin-wide into adjacent parts of the Mediterranean, beyond the locations where they originate. Hence, the transboundary aspects of eutrophication relate primarily to its ecological effects.

In the MED TDA 2005 (UNEP/MAP/MEDPOL, 2005), the northern and western coasts of the Adriatic Sea were featured as the most important cases of eutrophication. Starting in the 1970s, eutrophication phenomena, such as algal blooms and the production of mucilage gave rise to great concern, particularly

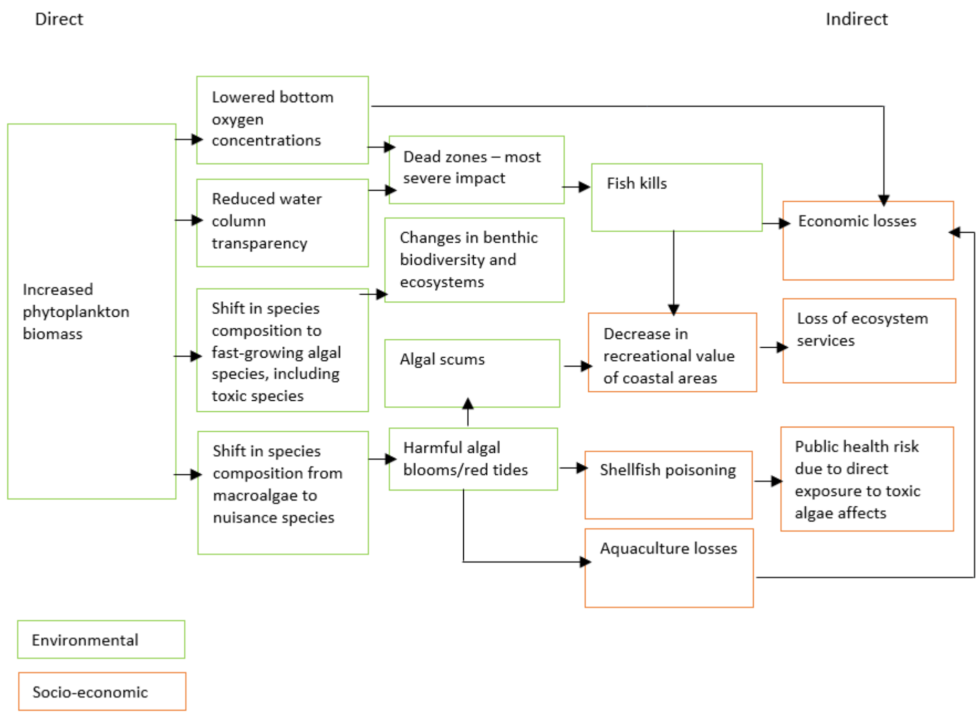


Figure 73. Eutrophication: Major environmental impacts and socio-economic consequences

in the northern Adriatic. Episodes of anoxia had devastating consequences for local fisheries due to fish kills and recurrent toxic poisoning of mussels (Mytilus galloprovincialis) by dinoflagellates leading to harvesting and sales bans. The serious deterioration was attributed to the anthropogenic inputs of nutrients from agriculture and large coastal cities, as well as from rivers such as the Po, in amounts that exceed the basin's natural assimilative capacity (ca. overload). Since the 2000s, a general trend reversal has been observed with lower chlorophyll-a concentrations; decreased loads of river nitrogen (except from the Po River, for which the load has increased), phosphorus and silica; with fewer hypoxic events than during the late 1980s and 1990s; but an increased N/P ratio (Giani et al., 2012). The reduction in phosphate concentration in the late 1980s due to new regulations preventing polyphosphate in detergents has changed the nutrient ratios. However, the seawater nitrogen concentrations showed a constant increase, indicating that inputs of nitrogen are still affecting the ecosystem, altering the phytoplankton community (Giani et al., 2012). Nevertheless, the assessment tools might offer controversial findings related to nitrogen compounds at different spatial and time scales (Ayache et al., 2020). Lately, it has been observed the so-called 'oligothopication' in the Central Adriatic (e.g. Bojana river), where the low concentration of nutrients discharged are predominant.

More recent eutrophication events have been reported in other areas, such as the Mar Menor in Spain, the largest salty coastal lagoons in the Mediterranean basin (Sandonnini et al., 2021). In 2016, the Mar Menor reached a stage of severe eutrophication that ended in an ''environmental collapse'', including the loss of 85 % of seagrass meadows (Posidonia oceanica). The increase in nutrients from agriculture led to changes in the structure and function of the lagoon ecosystem, namely the known steps of the eutrophication phenomena – the epibenthic and suspension feeder organisms have benefited from this imbalance (e.g. larger primary producers suspension after the nutrients input), proliferating and reaching a high population density lowering the dissolved oxygen concentrations. The absence of oxygen caused a massive mortality of benthic organisms (molluscs, polychaetes, etc.), endangered species with limited mobility, such as seahorses (Hippocampus guttulatus) and a dramatic fish mass mortality. Critically endangered species like the bivalve Pinna nobilis suffered a drastic reduction in their populations

(Giménez-Casalduero et al., 2020). According to the Guardian news article[58] "The lagoon stank. House prices plummeted, tourist numbers fell, and the economy suffered".

In contrast, 'red tide' populations well below the fish kill level pose a serious problem for public health through shellfish poisoning due to mainly paralytic shellfish toxin (PST) contamination. Paralytic shellfish poisoning is a human intoxication syndrome associated with the consumption of seafood that has been contaminated with PSTs, a group of natural neurotoxic alkaloids produced by marine dinoflagellates, including some Alexandrium species. The study by Bazzoni et al. (2020) on PSTs in mussels (Mytilus galloprovincialis) during 2018-2019 in several mollusc production areas of Sardinia, Italy suggested a spatio-temporal expansion of Alexandrium pacificum and Alexandrium minutum in recent years. The increasing number of PSTs present in molluscs and increasing occurrences of toxicity cases suggest a potential risk of poisoning by bivalve molluscs bred in Sardinia where shellfish production is a key industrial sector, despite routine public control programs.

Eutrophication has become one of the main causes of seagrass decline (e.g., Pazzaglia et al., 2020). Seagrasses appear to be particularly vulnerable to the direct effects of eutrophication, due to the lack of feedback inhibitory mechanisms for inorganic nitrogen uptake as suggested by several studies (e.g., Burkholder et al., 1992; Touchette and Burkholder, 2000). Under eutrophic conditions, long-living and slow-growing plants that are important for biodiversity may be outcompeted by fast-growing opportunistic species. Therefore, macrophytes such as Cystoseira spp., Dictyota spp., and Halymenia spp., are seen to decline in the Mediterranean and are replaced by short-lived nuisance algal species. Posidonia oceanica meadows have been degrading very rapidly throughout the last century, to a large extent, caused by multiple anthropogenic pressures such as nutrient pollution, combined with sea warming, extreme weather events, coastal development, trawling fishing, free anchoring and the presence of invasive species (Burgues-Palau, 2022).

Eutrophication processes can occur in the Mediterranean in transitional waters flowing through different habitats and ecosystems characteristics of the Mediterranean, such as the lower river parts and coastal lagoons of different sizes. Caballero et al. (2022) reviewed the work undertaken due to episodes of eutrophication in the Mar Menor Lagoon (Spain), with an average depth of 6.5 meters, by using the environmental variables coupled to satellite imagery. Similarly, Androulidakis et al. (2021) assessed eutrophication in the northern part of the Thermaikos Gulf (ca. inner, central and outer parts of the gulf) with a maximum depth of about 35 meters, Tugrul et al. (2019) studied the eutrophic/mesotrophic in the NE Mediterranean in the southern coast of Turkey (ca. Levantine Sea) impacted by discharges of urban wastewaters in addition to compare the Tropix Index (TRIX), Eutrophication Index (EI), Chl-a, and HELCOM Eutrophication Assessment Tool (HEAT), and finally, Kress et al. (2019) as well, in the Israel coast highlighting the local variability of nutrient concentrations over time in shallow waters (as observed in satellite images) by using in-situ data. There are many other known areas where the bathymetry and coastal circulation patterns affects to the potential for eutrophication and their ecological effects in the marine environments (ca. the well-known Gulf of Gabes, Tunisia; Gulf of Lions, France). However, most of the offshore waters of the Mediterranean Sea basins are oligotrophic with a marked interannual variability.

[58] https://www.theguardian.com/environment/2020/nov/18/can-spain-fix-its-worst-ecological-disaster-by-making-a-lagoon-a-legal-person

Priority issue 2: CHEMICAL POLLUTION (&EMERGING)

Description of the problem and its transboundary importance

The trends and levels of legacy pollutants (e.g., heavy metals, persistent organic pollutants, and pesticides) continues to be the targeted chemical groups, despite inputs have generally decreased significantly in the most impacted areas in the Mediterranean Sea as a result of the implementation of environmental measures (ca. 'legacy'). However, the contamination of coastal sediments by heavy metals remains an issue, even though levels of cadmium, mercury and lead in coastal waters show an acceptable environmental status (QSR, 2017). Harbors and coastal areas adjacent to industrial activities were the most contaminated by the PAHs and PCBs in almost all studied sites, followed by lagoons (Merhaby et al., 2019). The concentrations of dissolved PAHs measured during two sampling open sea cruises were higher in the Eastern Mediterranean than in the Western Mediterranean (Berrojalbiz et al., 2011), reflecting different pollutant loads, trophic conditions and cycling in the two sub-basins. In a separate review study (Castro-Jimenez et al., 2021), higher concentrations of PAHs and PCBs were reported in Northwestern countries, coinciding with the location of the majority of study sites. PCB in seawater showed a significant spatial variability in dissolved concentrations with lower levels in the open Western and Southeastern Mediterranean (Berrojalbiz et al., 2011). Although banned for years, the levels of organochlorine pesticides and PCBs were still elevated when compared to the common cetacean toxicological thresholds in Northwestern Mediterranean. PCBs bioaccumulate preferentially in the higher trophic levels (fish and cephalopods), whereas PCDD/Fs (and polybrominated diphenyl ethers (PBDEs)) tend to bioaccumulate in lower trophic levels (phytoplankton and zooplankton). The limited availability of recent quality assured data with sufficient spatial geographical coverage allows a biased determination of the current contamination status of the Mediterranean basin.

Recent scientific studies on emerging chemical contaminants, also known as contaminants of emerging concern (CEC) highlight the ubiquitous occurrence of a myriad of substances contained in pharmaceuticals, personal care products (antiseptics, sun lotions, cosmetics, etc.) and pesticides (Figure 74). CECs have been reported in the ng/L range; concentrations are highly variable depending on the geographical location and the time of year (Plan Bleu, 2021b).

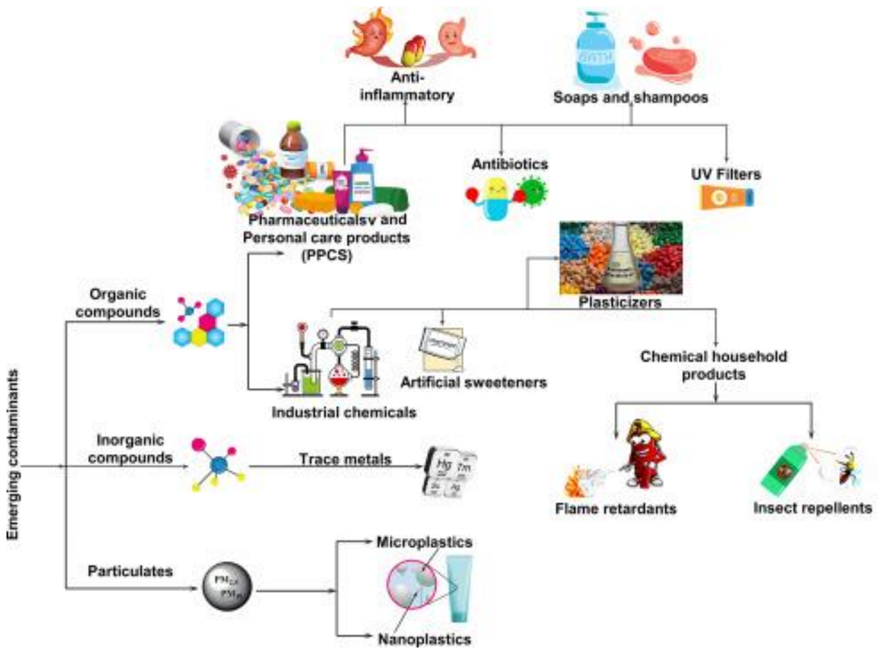


Figure 74. Simplified classification of emerging contaminants. Source: Antunes et al. (2021)

The table above identifies the potential chemical compounds of interest both legacy and emerging of interest in the Mediterranean basin (UNEP/MAP/MEDPOL, 2017)

Table 20. The Barcelona Convention Candidate Chemicals List (MEDPOL, 2017)

Categories	Substances (and primary target matrices)	Origins/Regulation
Organohalogenated compounds	Perfluorooctanesulfonate (PFOS) – b, s	USEPA; OSPAR, 2013; HELCOM, 2010
	Perfluorooctanoic acid (PFOA) – b, s	USEPA; OSPAR, 2013; HELCOM, 2010
	Perperfluorobutanoic acid (PFBA) – b, s	USA (Richarson and Kimura, 2016)
	Perfluorobutanesulfonate (PFBS) – b, s	USA (Richarson and Kimura, 2016)
	Tetrabromobisphenol (TBBP-A) – b, s	OSPAR, 2013
	Dicofol (pesticide) – b, s	OSPAR, 2013
	Hexabromocyclododecanes (HCDs) – b, s	HELCOM, 2010; Asia-Pacific (Tanabe et al., 2012); US (Dodder et al., 2014)
	Endosulfan (pesticide) – b, s	OSPAR, 2013; HELCOM, 2010
	Hexachlorocyclohexane isomers (HCHs) – b, s	OSPAR, 2013
	Methoxychlor (pesticide) – b, s	OSPAR, 2013
	Pentachlorophenol (PCP) (pesticide) – b, s	OSPAR, 2013
	Trifluralin (pesticide) – b, s	OSPAR, 2013
Organic nitrogen compounds	4-(dimethylbutylamino)dyphenilamin (6PPD) – b, s	OSPAR, 2013
Organic ester	Neodecanoic acid, ethenyl ester – w, b, s	OSPAR, 2013
Environmental phenols	Nonylphenol/Ethoxylates (NPs/NPEs) – w, s	USEPA; OSPAR, 2013; HELCOM, 2010
	Octylphenol/Ethoxylates (Ops/OPEs) – w, s	USEPA; OSPAR, 2013; HELCOM, 2010
	2, 4, 6-tri-tert-butylphenol – w, s	OSPAR, 2013
Pharmaceuticals	Clotrimazole – w	OSPAR, 2013
	Triclosan (phenol) and by-products – w, b	USA (California), 2015
	NSAIDs (e.g. Diclofenac) – w, b	EU-WFD Watch List, 2015
	Other antibiotics, bactericides, etc. – w, b, s	Sea-based sources (JRC, 2015)
Hormones	Estrone (E1) – w	EU-WFD Watch List, 2015
	17βEstradiol (E2) – w	EU-WFD Watch List, 2015
	17αEthylinestradiol (EE1) – w	EU-WFD Watch List, 2015
Phtalate esters	Dibutylphthalate (DBP) – s	OSPAR, 2013
	Diethylhexylphthalate (DEHP) – s	OSPAR, 2013
Synthetic musks	Musk xylene	OSPAR, 2013
	Tonalide (AHTN) – w, b, s	USA/Asia (Nakata et al., 2012)
	Galaxolide (HHCB) – w, b, s	US/Asia (Nakata et al., 2012)
Plastic additives (BVUSs)	Benzotriazoles (e.g. UV-P, UV-320, UV-326, UV-327, UV-328) – b, s	USA/Asia (Nakata et al., 2012; EU (Picot et al., 2014)
Metals/Elements	Arsenic – b, s	Sea-based sources (JRC, 2015)
	Barium – b, s	Sea-based sources (JRC, 2015)
	Iron – b, s	Sea-based sources (JRC, 2015)
	Manganese – b, s	Sea-based sources (JRC, 2015)
	Molybdenum – b, s	Sea-based sources (JRC, 2015)
	Nickel – w, b, s	Sea-based sources (JRC, 2015)
	Vanadium – w, b, s	Sea-based sources (JRC, 2015)
Organometallic compounds	Organic mercury (e.g. methylmercury) – b (fish)	WHO (World Health Organisation)

Note: w-seawater, b-biota and s-sediment

According to recent regional assessments (UNEP/MAP, 2017), the trends and levels of the legacy pollutants (e.g. heavy metals, persistent organic pollutants and pesticides) have decreased significantly in the most impacted areas in the Mediterranean Sea after the implementation of environmental measures (e.g. leaded-fuels ban, mercury regulations, anti-fouling paints ban), However, several point and diffuse pollution sources are still releasing both priority and emerging chemical contaminants (e.g. pharmaceuticals, personal care products, flame retardants) in the Mediterranean.

Heavy metals

o Cadmium, Lead and Mercury in sediment and biota (mussels, fish)

Sediments are considered as the main sink for heavy metals in aquatic environments, although they are also known to accumulate in marine organisms and biomagnify through the trophic web. Due to heavy metal toxicity, their persistence and tendency to accumulate into sediment and biota, these two matrices should be preferred for monitoring and assessment purposes with respect to water. Heavy metals are the major MEDPOL contaminant groups for which there is a significant number of quality assured datasets available from Mediterranean countries. A detailed assessment of status and trends of heavy metals in the Mediterranean Sea based on MEDPOL data was presented in UNEP/MAP Quality Status Report -QSR (2017).

The levels of cadmium, mercury and lead in bivalves and fish assessed against Environmental Assessment Criteria (EAC) show an acceptable environmental status. Nevertheless, according to the UNEP/MAP QSR (2017), 10 % of stations show lead levels above the set threshold levels in mussels. In general terms, for biota (bivalves and fish), the percentage of stations with acceptable environmental status falling below the EC threshold criteria range from 92 % to 100 % for Cd, Pb and HgT, with the exception of Pb in mussels above Pb EC for 8 % of the stations at a regional level (UNEP/MAP, 2017).

Contamination of coastal sediments with lead and mercury remains an issue (Cappelletto et al., 2021). The sediment assessment presented in UNEP/MAP (2017) showed that threshold levels for Cd, Pb and HgT were exceeded in 4 %, 15 % and 53 % of the monitored stations, respectively. UNEP/MAP (2017) called for the need to revise the sub-regional assessment criteria of total mercury, given that a mixture of natural and anthropogenic known sources might influence the assessment, especially in the Adriatic Sea, the Aegean Sea and Levantine Seas. The UNEP/MAP/MEDPOL recommended further investigation and assessment against the assessment criteria, taking into consideration subregional specificities.

Molina Jack et al. (2020) highlighted the challenges associated to the standardization, harmonization and compatibility of data monitoring, reporting and management approaches in transboundary areas, through a case study on heavy metals in the Adriatic-Ionian Sea, a region bordered by both EU and non-EU countries and hence subject to different environmental monitoring requirements. Stankovic and Jovic (2012) provided a review of heavy metal concentrations (Pb, Cd, Hg, and As) in the soft tissues of the Mediterranean mussel Mytilus galloprovincialis, often cultivated for human consumption. The measurement of their concentration in mussel soft tissue has become increasingly significant. The regional program called the Mediterranean Mussel Watch (MMW) was established in as early as in the 80s (offically, it was initiated 1993 with the internationalization of the Mussel Watch Programme) for the detection of radionuclides and trace contaminants in sentinel organisms using the mussel M. galloprovincialis as the bioindicator species in the coastal waters of the Mediterranean. Overall, the concentrations of pollutant metals were in the following order: As > Pb > Cd > Hg (Stankovic and Jovic, 2012), although the review was based on data from around 2010 and older.

Persistent Organic Pollutants (POPs)

Persistent Organic Pollutants (POPs) are a set of organic compounds that possess toxic characteristics. They are persistent, liable to bio-accumulate, mobile and prone to long-range atmospheric transport and deposition – hence have transboundary implications. POPs can result in adverse environmental and human effects at the locations near and far from their source (UNECE, 1998), with marine ecosystems representing major sinks.

The increased contamination of the ecosystems by POPs, along with analytical improvements allowing to quantify their presence, led to the establishment of lists of priority substances that should be banned or limited for their production and usage. The first one was the Stockholm Convention list signed in 2001 and regularly updated since then. The list now contains 29 POPs, grouped under Elimination, Restriction and Unintentional production[59]. Concurrently, the European Union adopted a first list of 33 priority substances (Decision 2455/2001), which also included hazardous inorganic substances. In 2008 the Environmental Quality Standards (EQSs) for those substances and eight other pollutants already regulated at EU level were set in the Directive 2008/105/EC (or EQS Directive), which was amended by the Directive 2013/39/EU. Along with the list of priority substances, a "watch list" of contaminants that could pose a potential threat and for which monitoring in aquatic environment was added (Directive 2013/39/EC[60] and complementary watch list C/2022/5098[61]).

Table 21. Legacy POPs controlled under Stockholm convention (UNEP, 2001), United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) POPs protocol (substances also specified in UNEP Governing Council Decision 19/13c for initial inclusion in the global POPs convention are shown in bold type) (UNEP, 2001). Source: Merhaby et al. (2019)

Chemicals	Period of emissions estimates	Cumulative global production or annual Emissions (Kt)	References (31)
Organochlorine Pesticides			
Aldrin [a]			
Chordane [a]			
Chlorodecone [a,d]			
DDT [a,b]	1940s-present	4500 kt	Li and Macdonald (2005)
Dieldrin [a]			
Endrin [a]			
Heptachlor [a]			
Hexachlorobenzene (HCB) [a,c]	~1995	~23 t/year	Bailey (2001)
Hexachlorocyclohexane (HCH) [a,b,d]			
Mirex [a]			
Toxaphene [a]	1950-1993	1330 kt	Voldner and Li (1993) see also Li and Macdonald (2005)
Industrial products			
Hexabromobophenyl [a,d]			
Polychlorinated biphenyls (PCBs) [a,b]	1930-1993	1326 kt	Breivik et al. (2007)
Unintentional by-products of combustion and industrial processes			
Polycyclic aromatic hydrocarbons (PAHs) [c,d,e]	1966-1969	5000 t/year	Suess (1976)
Polychlorinated dibenzo-p-dioxins (PCDDs) [c]	~1995	9.9 kg TEQ/year	UNEP (1999); Fiedler (2003a,b)
Polychlorinated dibenzofurans (PCDFs) [c]	~1995		

[a] Listed under Annex I of the protocol (substances scheduled for elimination).
[b] Listed under Annex II of the protocol (substances scheduled for restriction on use).
[c] Listed under Annex III of the protocol (substances scheduled for emission reductions by the use of BAT (best available technology).
[d] Only Regulated under the Aarhus Protocol on POPs (UNECE, 1998).
[e] Data emissions refers to B[a]P only (Suess, 1976).

[59] http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx
[60] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013L0039
[61] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022D1307&from=en

POPs include legacy chlorinated pesticides and industrial chemicals, such as the polychlorinated biphenyls (PCBs), many of which have already been prohibited at the global scale under the Stockholm Convention. Organochlorinated pesticides, such as DDT and its metabolites (DDs) and HCHs (HCH isomers), are contaminants of high concern due to their toxicity and persistence in the environment. PCBs is a large class of substances (209 congeners) that assume particular physical and chemical properties depending on the chlorine substitution on the biphenyl rings. Other compounds considered as POPs include polyaromatic hydrocarbons (PAHs), dibenzo-p-dioxins (PCDD), polychlorinated dibenzo-p-furans (PCDF) and tributyltin (TBT). According to Avellan et al. (2022), the large majority of substances and groups of substances that were listed by the Stockholm Convention could still be found in seawater or in sediments in these recent years, including the ones that were banned 20 years ago. In 2023, the Stockholm Convention agreed to eliminate another chemical, methoxychlor, an insecticide used as an alternative to the well-known pesticide DDT.

In Merhaby et al. (2019) a recent comprehensive review of sediment pollution by PCBs and PAHs in Mediterranean basin, more specifically in harbors and industrial coastal areas, coastal lagoons, river inputs and open sea is presented. The review considered 192 studied sites from the last 30 years by more than 121 authors. From the 21 riparian Mediterranean countries, only 12 countries have published research papers on POPs.

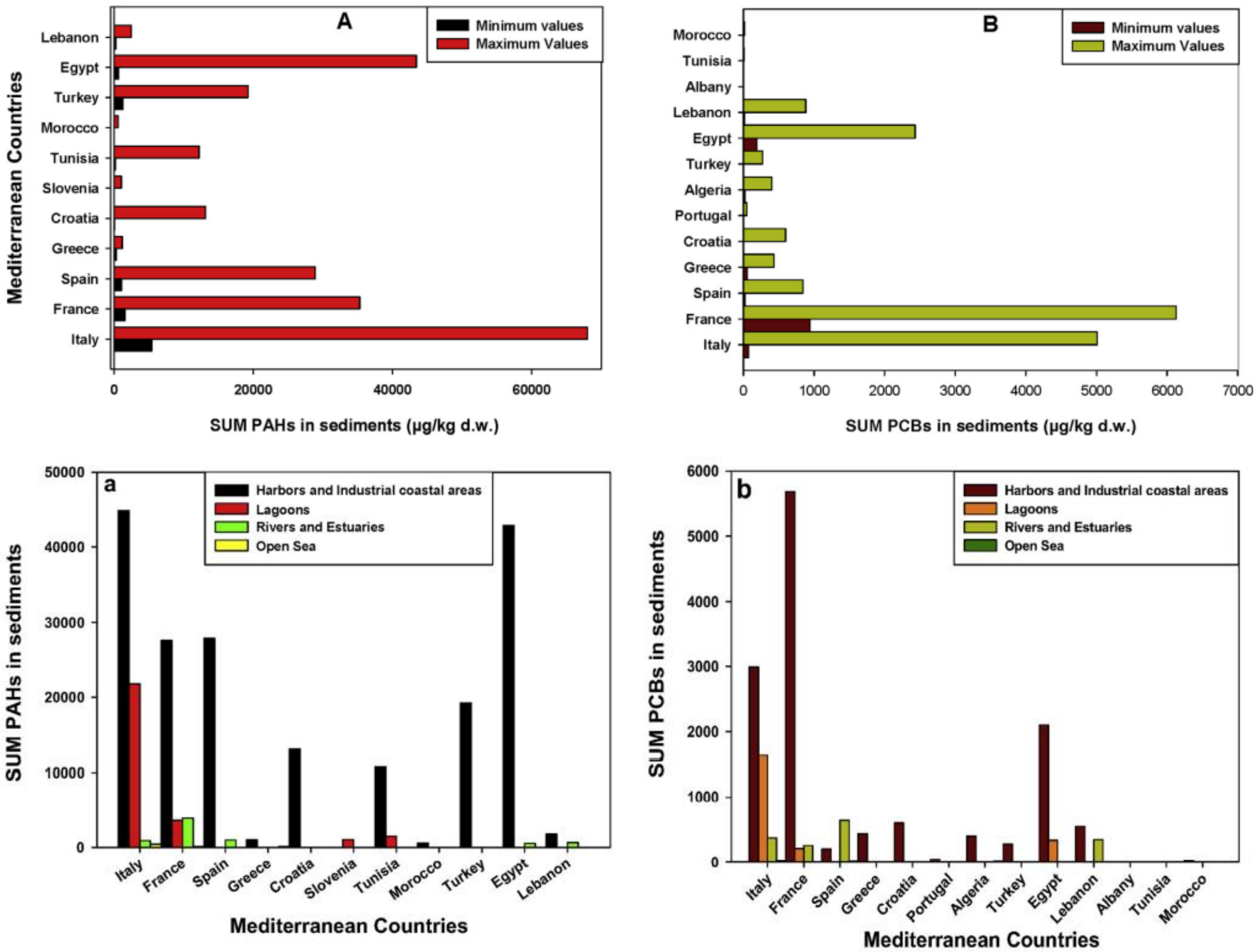


Figure 75. Top: The total means concentrations of PAHs (A) and PCBs (B) in sediments for each Mediterranean country. Bottom: Total mean concentrations of the $\sum_{10-26}$PAHs (A) and $\sum_{7-41}$PCBs (B) in sediments for each Mediterranean country for the four categories. Source: Merhaby et al. (2019)

Table 22. Review data on PAHs and PCBs (Mediterranean Sea). Source: Merhaby et al. (2019).

Note: Data also available in table format with possibility to produce maps (below)

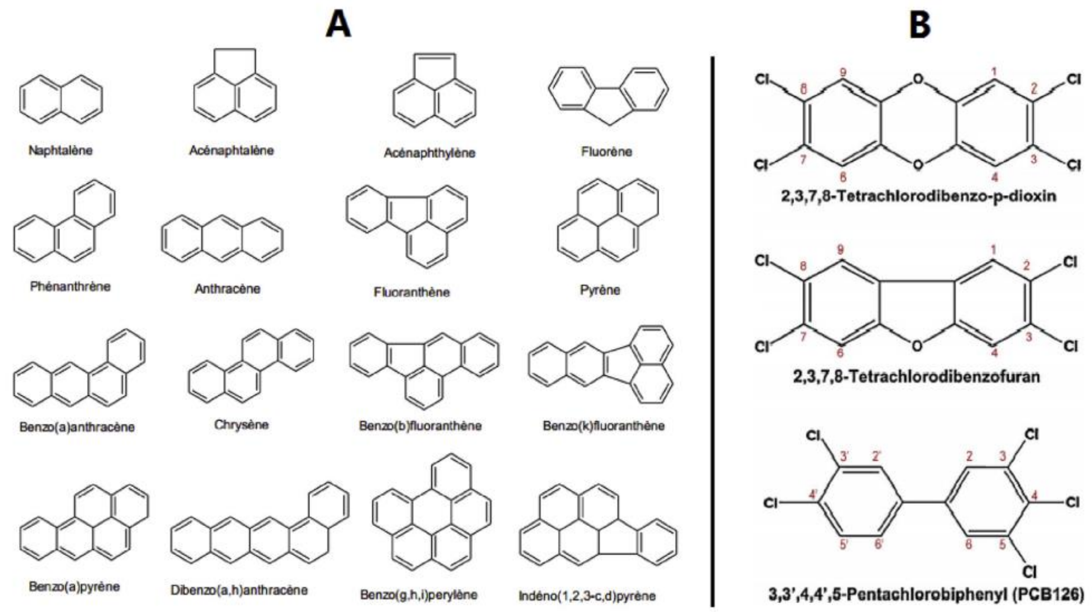


Fig. 1. A: Structure of 16 PAHs listed as priority compounds in the U.S. EPA and B: basic structures of polychlorinated biphenyls (PCBs), chlorinated dibenzofurans (furans) and Chlorinated dibenzo-p-dioxins.

Table 3
Highest total concentrations of ΣPAHs (μg.kg^{-1} d.w.) found in sediment samples collected from Mediterranean sites.

Studied sites	Min. Concentration	Max. Concentration	N° PAHs	References
Italy				
Naples harbour	9	31774	16	Sprovieri et al. (2007)
Venice Lagoon	65	48000		La Rocca et al. (1996)
Venice Lagoon	315	810		Frignani et al. (2003)
Venice Lagoon	15.1	388.9		Parolini et al. (2010)
Venice Lagoon	20	502		Secco et al. (2005)
Pialassa Baiona	1000	135000		Vassura et al. (2005)
Pialassa Baiona	3030	87150		Guerra, 2011)
Mar Piccolo, Taranto	380	12750	16	Cardellicchio et al. (2007)
Mar Piccolo, Taranto	100	180		Cardellicchio et al. (1989)
Gulf of Taranto	1484	262446	16	Annicchiarico et al. (2011)
Po River	100	1800		Viganò et al. (2003)
France				
Ajaccio harbour, Corse		20440	26	Baumard et al., (1998a)
Lazaret Bay	1440	48090	14	Benlahcen et al. (1997)
Lazaret navy harbour		13010	14	Baumard et al., (1998a)
Gulf of Lions	80.00	1500.00	11	Tolosa et al. (1996)
Gulf of Lions	161.00	2176.00	21	Bouloubassi et al. (2012)
Berre Lagoon	38	2323		Jacquot et al. (1999)
Berre lagoon	334	853	16	Kanzari et al. (2012)
Thau Lagoon	59	7679		Leaute., 2008
Rhone Delta	325	3182		Lipiatou and Saliot. (1991)
Rhone River	1070	6330	15	Bouloubassi and Saliot. (1993)
Gironde Estuary	18.5	4888	17	Budzinski et al. (1997)
Spain				
Barcelona harbour	1740	8420		Baumard et al., (1998b)
Barcelona harbour	300	10320	16	Martínez-Lladó et al. (2007)
Besós River		1299		Eljarrat et al. (2001)
Francolí River		3050		Eljarrat et al. (2001)
Llobregat River		3650		Eljarrat et al. (2001)
Greece				
Thermaikos Gulf	580	930		Kilikidis et al. (1994)
Morocco				
Moroccan Coast	15	551	16	Pavoni et al. (2003)
Turkey				
Izmit Bay	2500	25 000	14	Tolun et al. (2001)
Izmit Bay	30000	1670000		Telli-Karakoç et al. (2002)
Gemlik Bay, Turkey	50.8	13482	13	Ünlü and Alpar. (2006)
Egypt				
Alexandria Harbour	8	131150	43	Mostafa et al. (2003)
Alexandria Harbour	180	14100		Barakat et al. (2011)
Nile Rive	305	933		Badawy and Emababy. (2010)
Tunisia				
Sfax–Kerkennah coastal zone	113	10720	10	Zaghden et al. (2007)
Bizerte Lagoon	83.3	447.1		Trabelsi and Driss. (2005)
Bizerta Lagoon	1.5	2500		Louiz et al. (2008)
Slovania				
ŠKocjan		1026		Bajt, 2008
Croatia				
Rovinj area	32	13681	16	Bihari et al. (2006)
Rijeka Bay	53	12532		Alebic-Juretic, 2011
Lebanon				
Port of Beirut		3772.6	16	Merhaby et al., (2015b)
Abou Ali Estuary		667.8	16	Merhaby et al., (2015b)

Table 4
Total concentrations of ΣPCBs (μg.kg^{-1} d.w.) found in sediments collected from Mediterranean sites.

Sites	Min. Concentration	Max. Concentration	N°CB	References
Italy				
Naples harbour	1	899	38	Sprovieri et al. (2007)
Gulf of Taranto	85	1780		Annicchiarico et al. (2011)
Naples Bay	6	3200		Baldi et al. (1983)
Venice Lagoon	6	1590		Frignani et al., 2003
Mar Piccolo, Taranto	2	1684		Cardellicchio et al. (2007)
Tiber River	28	770		Puccetti and Leoni. (1980)
Provencal basin, open sea	2	3		Tolosa et al. (1995)
Tyrrhenian Sea	0.8	1.3		Geyer et al. (1984)
North Adriatic	3.2	58		Burns and Villeneuve. (1983); Burns et al. (1985)
France				
Cortiou, Marseille	5503	22900		Lecouffe, 1986
Rhone estuary	159	416		Tolosa et al. (1995)
Arc River	0.3	467	7	Kanzari et al. (2012)
Berre Lagoon	468.8	541.4	7	Kanzari et al. (2012)
Greece				
Keratsini harbour	4.78	351.8	11	Galanopoulou et al. (2005)
Spain				
Barcelona Coast	4	654		Fernandez (1991)
Catalan Coast (10 Rivers)	1.1	311		Eljarrat et al. (2001)
Ebro River	5.3	1,772		Fernández et al. (1999)
Ebro estuary	1	410		Grimalt et al., 1983
Catalan basin, open sea	4	11		Tolosa et al. (1995)
Egypt				
Alexendria Harbour	0.9	1211		Barakat et al. (2002)
Port-Said	53	1500		El-Dib and Badawy et al. (1985)
Manzala Lake	125	330		Yamashita et al. (2000)
Turkey				
Istanbul strait	0.179	539.746	18	Okay et al. (2009)
Tunisia				
Bizerte Lagoon	0.89	6.63	20	Derouiche et al. (2004)
Algeria				
Algerian Coast (Alger and Oran)	7	323		Cousteau, 1979
Algerian margin, open sea		9		Elder and Villeneuve., (1977b)
Croatia				
Rijeka Bay, coast	0.9	597		Picer et al. (1981) Picer et al., 1992)
Albany				
Adriatic coast	1	5		Koci, 1998
Lebanon				
Port of Beirut		1303	28	Merhaby et al., (2015b)
Port of Jiyeh		718.2	28	Merhaby et al., (2015b)
Abou Ali Estuary		339.4	28	Merhaby et al., (2015b)

According to the data collated by Merharby et al. (2019):

- Higher concentrations of PAHs and PCBs were reported in Northwestern countries, where most study sites are located.
- Harbors and industrial coastal areas were the most contaminated by the PAHs and PCBs in almost all studied sites.
- Significant PAHs and PCBs contamination was found in coastal lagoons in some Mediterranean countries, notably Italy and France
- Riverine inputs play an important role in the transition of PAHs and PCBs to the Mediterranean Sea, in particular in Spain, Italy, and France and Lebanon in the case of PCBs
- Most samples originated from coastal areas, with the exception of a few PAHs measurements from the open sea, more specifically the Adriatic Sea, Aegean Sea and Northwestern Mediterranean Sea
- As most studies are ~ 20 years old, the collated data does not give an accurate picture of the current state of contamination by POPs.

The concentrations of POPs measured in samples of seawater (dissolved and particulate phases) and plankton during two east - west sampling cruises in June 2006 and May 2007 were discussed in Berrojalbiz et al. (2011a) and Berrojalbiz et al. (2011b). Berrojalbiz et al. (2011a) analyzed 41 PCB congeners (Figure 77 and Figure 78), hexaclorochyclohexanes (HCHs) and hexachlorobenzene (HCB). The comparison of the measured HCB and HCHs concentrations with previously reported dissolved phase concentrations suggested a temporal decline in their concentrations since the 1990s. On the contrary, PCB seawater concentrations did not exhibit such a decline, but showed a significant spatial variability in dissolved concentrations with lower levels in the open Western and Southeastern Mediterranean. The PAH concentrations measured in samples of seawater (dissolved and particulate phases) and plankton were presented in Berrojalbiz et al. (2011b) and shown in Table 23.

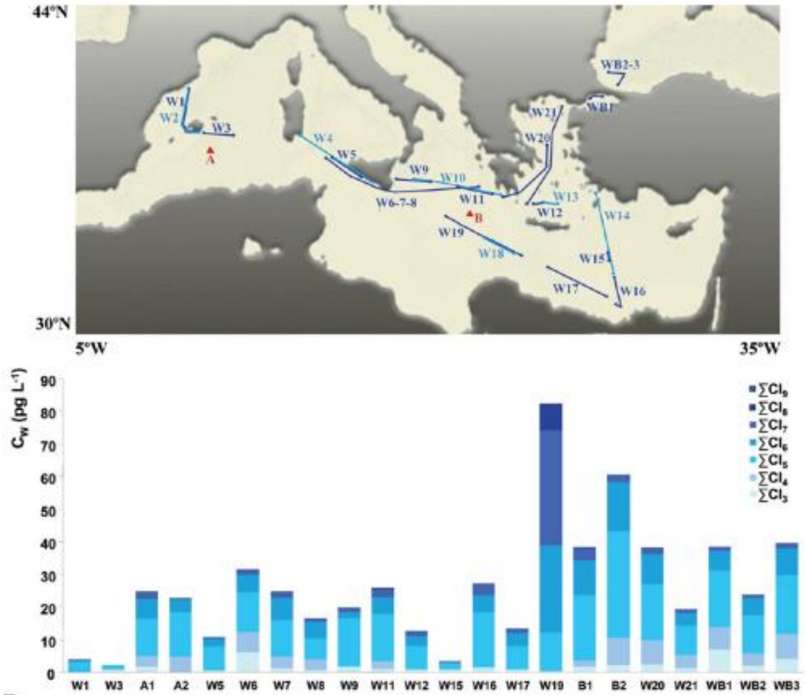


Figure 76. Map showing the sampling transects of dissolved and particulate phase samples and the corresponding spatial variation of the concentrations of PCBs in the water dissolved phase samples. Samples indicated in dark and light blue were processed using methodologies A and B, respectively, described in Berrojalbiz et al. (2011ª). Source: Berrojalbiz et al. (2011ª)

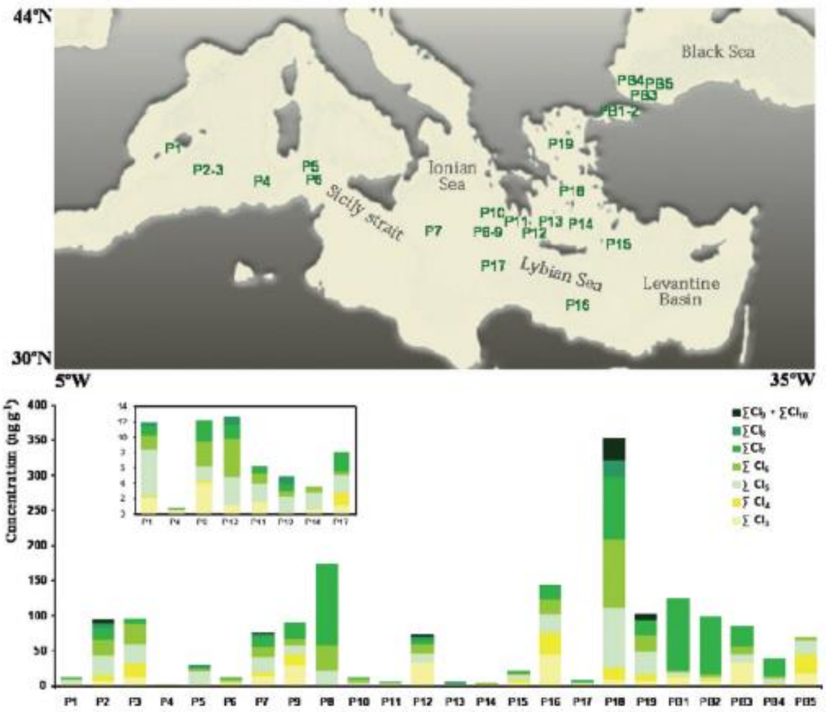


Figure 77. Map showing the sampling sites of plankton samples and spatial variation of the concentrations of PCBs in plankton. Source: Berrojalbiz et al. (2011a)

Table 23. PAH concentrations (mean and range) in the different matrices [dissolved, particulate, plankton]. Source: Berrojalbiz et al. (2011b)

	Dissolved Phase ($pg\ L^{-1}$) n=35 a		Particulate Phase ($pg\ L^{-1}$) n=20 a		Plankton Samples ($ng\ g^{-1}$ Dry Weight Basis) n=35	
Compound	Mean	Range	Mean	Range	Mean	Range
Fluorene	82.24	(9.80–584.27)	13.8	(2.68–45.99)	17.39	(0.00–49.65)
DBT	12.55	(0.00–57.33)	3.77	(0.08–28.85)	8.63	(0.00–38.91)
ΣMethylDBT	22.61	(0.00–230.86)	4.28	(0.00–18.23)	19.92	(0.00–97.39)
Anthracene	7.26	(0.00–36.70)	0.5	(0.00–2.29)	8.49	(0.00–42.25)
Phenanthrene	163.43	(38.19–1504.7)	16.22	(1.12–43.65)	77.33	(8.88–234.52)
ΣmethylPhe	82.83	(0.00–1287.16)	44.25	(3.54–157.90)	106.16	(6.25–447.73)
ΣdimethylPhe	64.16	(0.00–888.58)	6.73	(0.00–44.78)	87.24	(4.19–417.87)
Fluoranthrene	62.26	(13.00–198.94)	4.92	(0.77–16.55)	31.89	(4.46–224.20)
Pyrene	59.68	(7.78–387.43)	8.49	(0.64–32.74)	36.6	(1.91–251.42)
Benzo[a]anthracene	4.78	(0.00–43.04)	0.82	(0.00–6.98)	8.84	(1.39–29.57)
Crysene	16.85	(1.83–54.65)	3.79	(0.77–11.78)	27.79	(3.79–93.45)
Benzo[b]fluoranthene	5.92	(0.00–73.33)	3.8	(0.00–23.22)	23.23	(0.00–117.48)
Benzo[e]pyrene	5.32	(0.00–29.41)	2.7	(0.43–7.16)	7.65	(0.00–42.20)
Benzo[a]pyrene	3.13	(0.00–43.27)	2.52	(0.00–11.77)	7.94	(0.00–33.99)
Perylene	1.59	(0.00–11.70)	5.93	(0.23–12.52)	3.82	(0.00–12.41)
Dibenzo[a,h]anthracene	3.44	(0.00–28.78)	2.52	(0.00–6.22)	4.15	(0.00–27.03)
Benzo[ghi]perylene	3.14	(0.00–15.78)	0.07	(0.00–0.79)	0.2	(0.00–4.69)
Indeno[1,2,3-cd]pyrene	4.08	(0.00–28.53)	12.93	(0.00–50.54)	3.89	(0.00–16.03)
Σ PAHs	605.28	(158.3–3655.9)	129.11	(33.34–380.26)	605.28	(158.36–3655.96)

a – Values corresponding to the water (W27 and W27a) collected near the Nile River mouth are not included

The concentrations of dissolved PAHs were higher in the Eastern Mediterranean than in the Western Mediterranean, reflecting different pollutant loads, trophic conditions and cycling. This presented one of the most extensive data set available for the Mediterranean Sea, providing clear evidence of the important physical and biological controls on PAH occurrence and cycling in the marine environment (Berrojalbiz et al., 2011a).

In a separate study, Dron et al. (2022) measured the concentrations of organochlorine compounds (31 PCB congeners and 15 banned pesticides or metabolites) in 5 tissues of 68 striped dolphins stranded along the Northwestern Mediterranean coast in 2010–2016. The results were compared to historical data from 1988–2009. Although banned for years, the levels of organochlorine pesticides and PCBs in 2010–

2016 were still elevated compared to common cetacean toxicological thresholds, despite showing a slow decreasing trend. The analysis pointed towards changing patterns in concentrations, most likely reflecting the exposure of dolphins to the remobilization of pollutants from contaminated soils and sediments, with a prominent role of rivers. This implies that a further decrease of organochlorine contaminants in striped dolphins is expected to be much slower (Figure 79).

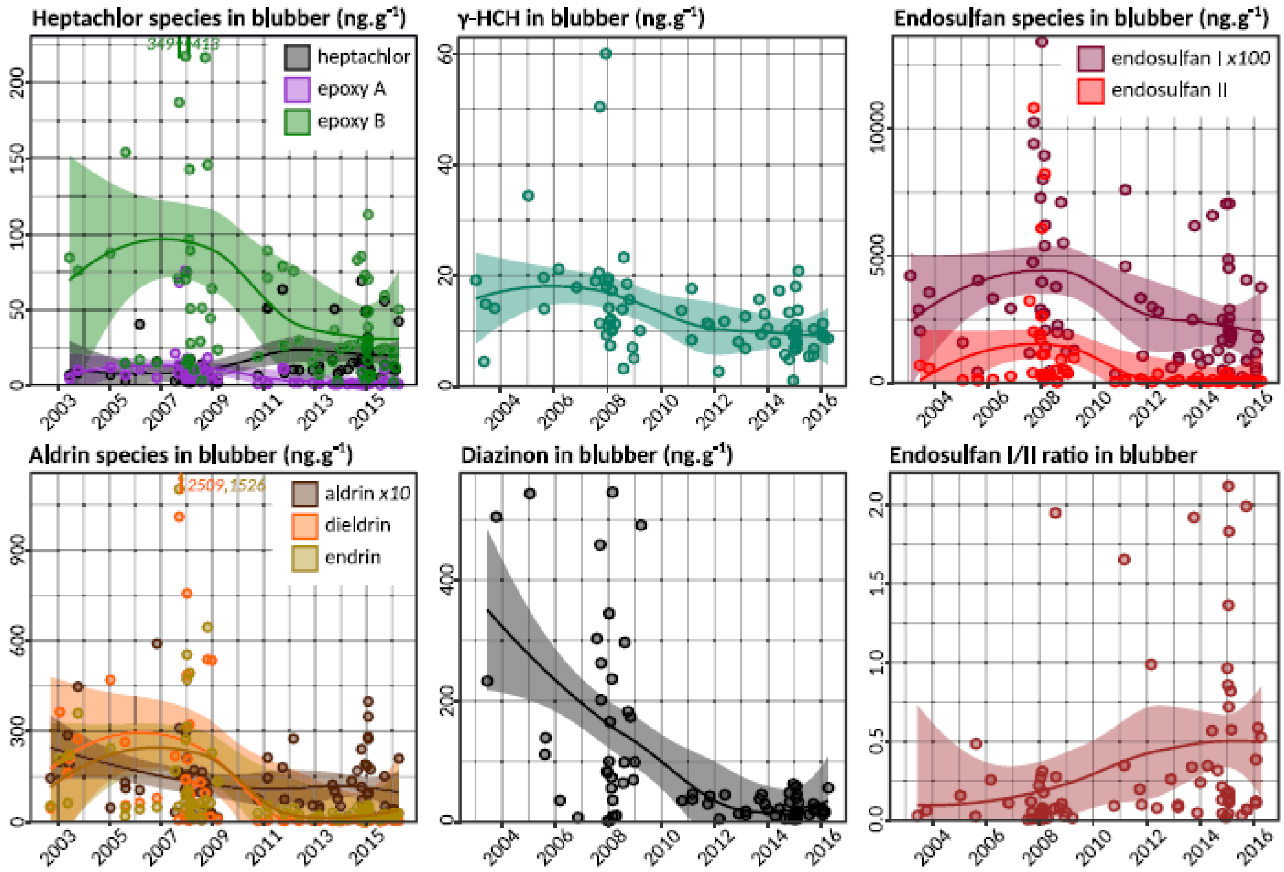


Figure 78. Evolution of organochlorine pesticides levels in blubber (ng·g^{-1} l.w.) samples of striped dolphins stranded in the Northwestern Mediterranean from 2003 to 2016. Source: Dron et al. (2022)

Note: Scarpato et al (2010) published the results Mytilos project related to the monitoring of PCBs and pesticides accumulation in Mytilus galloprovincialis in Western Mediterranean coastal waters by active mussel watching. The results refer to the monitoring period of 2004-2006.

A number of studies and reports (e.g. UNEP/MAP, 2017; Merhaby et al., 2019; Cappelletto et al., 2021) referred to the limited data availability to allow for a comprehensive regional assessment, and mostly non-detected concentrations. Despite the implementation of the MEDPOL monitoring for chlorinated compounds during almost two decades, the availability of new quality assured data with sufficient spatial geographical coverage impedes the further assessment of the contamination status of the Mediterranean Sea region, beyond known sources and hotspots in coastal areas (UNEP/MAP QSR, 2017).

Emerging chemical contaminants

Emerging pollutants or contaminants of emerging concern (CEC) refer to a heterogeneous set of thousands of compounds whose presence in the environment has been detected only recently (see Figure 74). This category includes personal care products (antiseptics, sun lotions, cosmetics, etc.), pharmaceuticals and antibiotics, flame retardants, additives, plasticizers such as phthalates, nanoparticles used in food, medicine, construction and textiles, plant-derived substances, perfluorocarbons, and non-halogenated substances to mention a few. These substances constitute also complex chemical mixtures which can be toxic for marine organisms and humans, if not removed from wastewater. The study of their interactions with the environment and human health is difficult. Their accurate analytical determination in the biotic compartment represents a very important first step to understand their potential risks. Although wastewater treatment is improving to eliminate certain substances, the Mediterranean region is far from phasing existing substances out. In addition, there is a lack of regulations on the emergence of new substances (Cappelletto et al., 2021). The State of the Environment and Development Report for the Mediterranean Sea (UNEP/MAP & Plan Bleu, 2020) identified the excessive use of chemical and pharmaceutical products as one of the eight major threats for the region. In a recent review, Desbiolles et al. (2018) provided an updated inventory of the contamination of aquatic environments by 43 drugs representing different classes of pharmaceuticals, such as antibiotics, anti-inflammatory drugs, anti-depressants, sex hormones, lipid regulators and beta-blockers routinely evidenced in an international context (Table 24). This database includes 6072 concentrations values, consisting of 904 values for wastewater treatment plants (WWTP) influents, 1451 for WWTP effluents, 2964 for rivers, and 753 for seawaters. The concentrations correspond to the dissolved phase (d) except for the Mediterranean Sea (dissolved and particulate, d + p).

Table 24. Therapeutic classes and targeted molecules

Therapeutic class	Molecules
Analgesic anti-inflammatory drugs	Diclofenac, ibuprofen, ketoprofen, naproxen, acetaminophen, salicylic acid, acetylsalicylic acid
Lipid regulators	Bezafibrate, gemfibrozil, atorvastatin fenofibrate, clofibric acid
Psychotropic drugs	Carbamazepine, fluoxetine, venlafaxine, amitriptyline
Beta-blockers	Propanolol, atenolol, sotalol, metoprolol
Antibiotics	Sulfamethoxazole, trimethoprim, ofloxacin, norfloxacin, clarithromycin, azithromycin, erythromycin, ciprofloxacin, metronidazole, amoxicillin
Contrast products	Iopromide
Cardiovascular products	Enalapril
Antihistamines	Ranitidine
Diuretics	Furosemide
Bronchodilators	Salbutamol
Anti-diabetics	Metformin
Hormones	17β-Estradiol, estriol, estrone, estrone-3-sulfate, 17α-ethinylestradiol, progesterone, testosterone

The data collected focused on contamination levels reported in wastewater, river and sea waters (Figure 80). Levels of pharmaceuticals ranged from 100 to 10,000 or even 100,000 $ng \cdot L^{-1}$ in sewage waters (not shown here), dropping to 1 to 10,000 $ng \cdot L^{-1}$ in rivers and to not detected to 3000 $ng \cdot L^{-1}$ in sea water (Figures 78, 79 and 80). Overall, 41 out of the 43 selected pharmaceuticals were detected in river waters of the Mediterranean Basin. As expected, the median concentrations, ranging from about 1 (atorvastatin, metronidazole, estrone-3-sulfate) to 43 $ng \cdot L^{-1}$ (salicylic acid), found in rivers were significantly lower than in WWTP effluents, due to the dilution effect. Although the frequencies of detection in rivers and seawater were often below 60 %, implying that compounds were below methods detection limits in many cases, the range of concentrations found in rivers was impressively wide, covering 6 log10 units. The surprisingly high concentration levels were related to river or marine case studies carried out next to WWTPs outfall or in seafront of major cities.

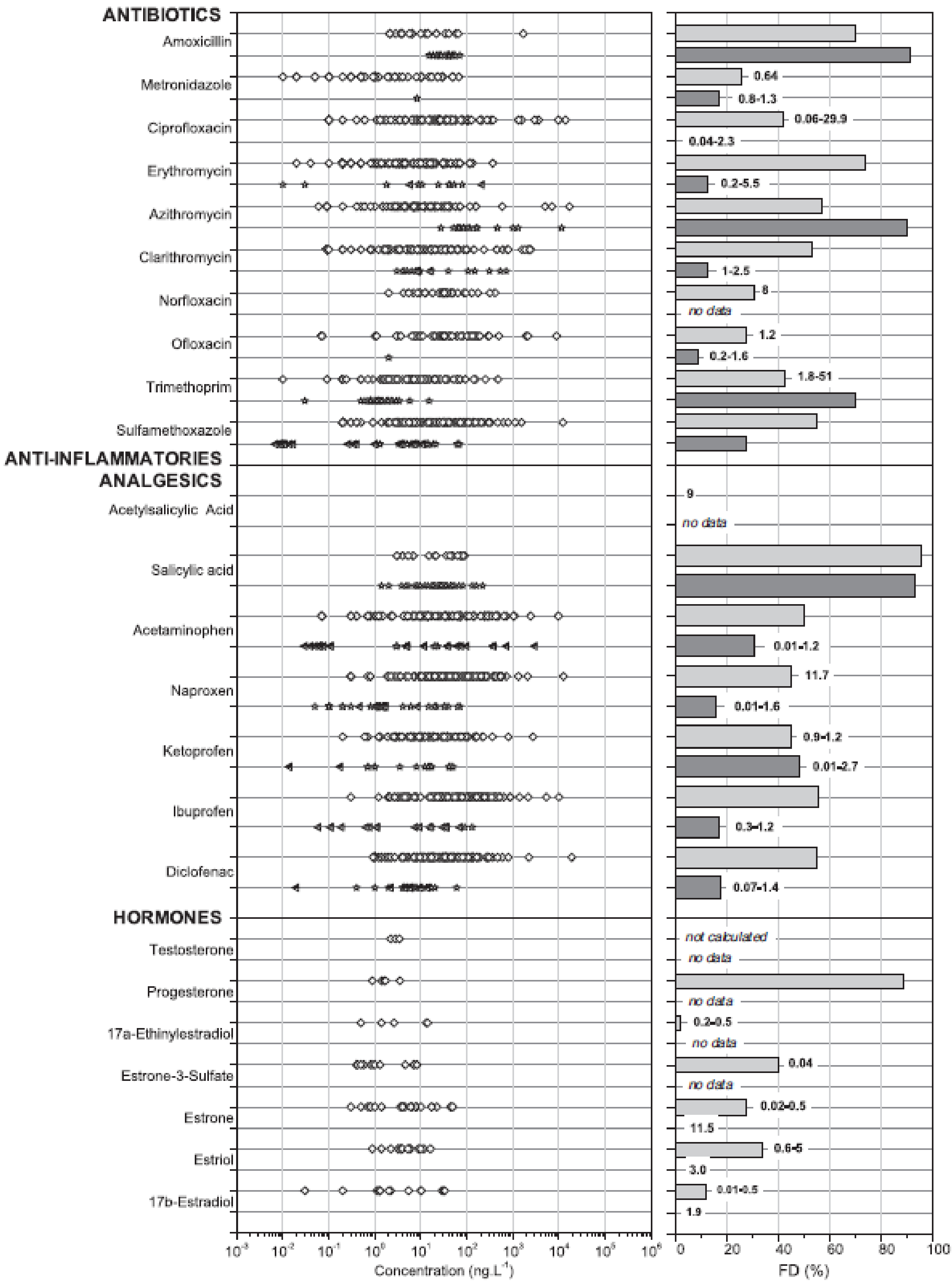


Figure 79. Concentrations in ng·L^{-1} of 3 classes of pharmaceuticals (i.e. antibiotics, anti-inflammatories/analgesics and hormones) in rivers ( ) and in Mediterranean seawater.

(✯) in the dissolved phase of filtered samples and in both dissolved and particulate phases ( ) of unfiltered samples from Mediterranean countries (Spain, France, Italy, Greece, Turkey, Israel, Lebanon, Tunisia, Algeria, Croatia, Palestine) and frequency of detection (FD) in rivers (light grey) and in Mediterranean seawater (dark grey) according to 67 scientific papers from2002 to 2018. Data tag on FD graphic, represent the method detection limit in ng·L−1 when a compound is detected below 50 %. Source: Desbiolles et al. (2018)

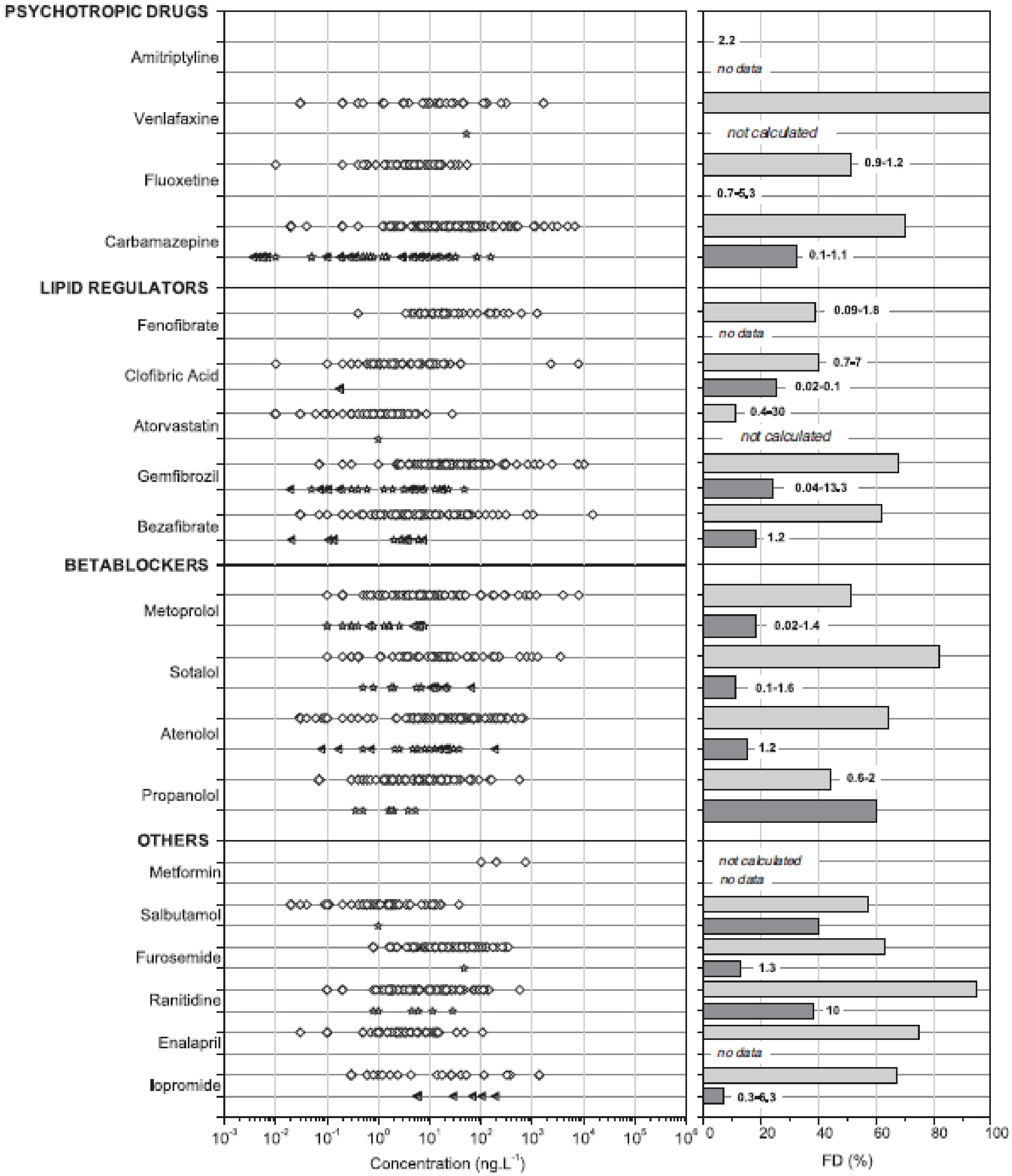


Figure 80. Concentrations in ng·L^{-1} of 4 classes of pharmaceuticals (i.e. lipid regulators, psychotropic drugs, beta-blockers and others) in rivers ( ) and in Mediterranean seawater.

(✭) in the dissolved phase of filtered samples and in both dissolved and particulate phases ( ) of unfiltered samples from Mediterranean countries (Spain, France, Italy, Greece, Turkey, Israel, Lebanon, Tunisia, Algeria, Croatia, Palestine) and frequency of detection in rivers (light grey) and in Mediterranean seawater (dark grey) according to 67 scientific papers from 2002 to 2018. Data tag on FD graphic, represent the method detection limit in ng·L−1 when a compound is detected below 50 %. Source: Desbiolles et al. (2018)

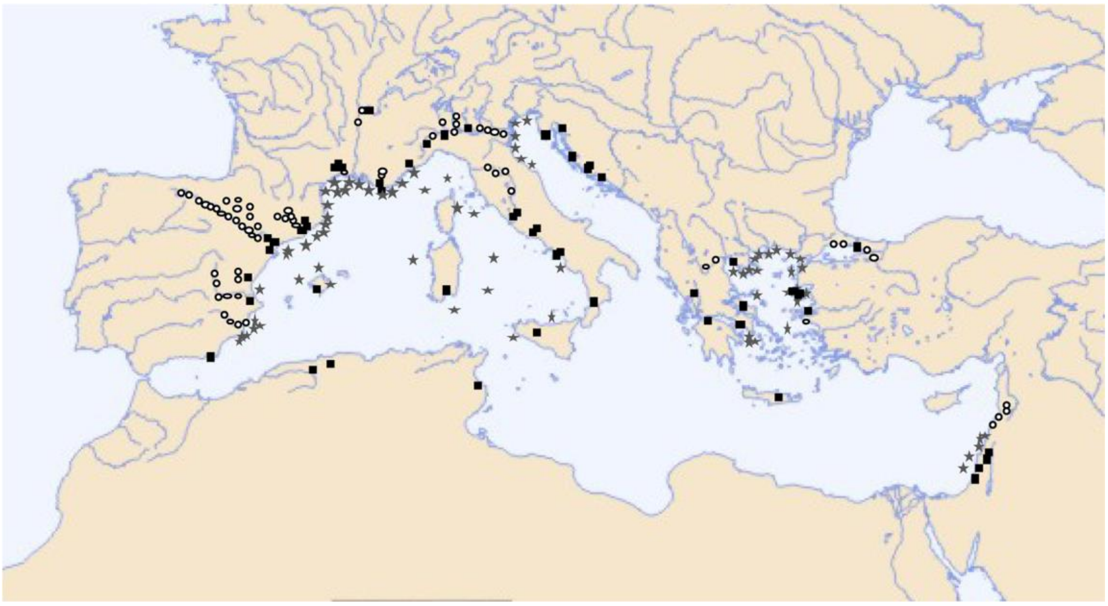


Figure 81. Locations of WWTPs (■), rivers (O) and sea (★) samples referenced in the 67 articles published from 2002 to 2018 and used in the database. Source: Desbiolles et al. (2018).

Desbiolles et al. (2018) highlighted the lack of data for seawater and for several countries along the Southern coast of the Mediterranean Sea. The need for further research and collaborative projects was underscored to complete the regional picture on the basis of programmes such as Horizon 2020, Mediterranean Action Plan (MEDPOL, Program for the Assessment and Control of Marine Pollution) and Mediterranean Strategy for Sustainable Development. More broadly, the findings also emphasized the importance of research dealing with the development and optimization of new tertiary treatment processes to remove pharmaceuticals in WWTP more efficiently (Meribout et al., 2016).

On transitional, coastal, and offshore distribution and occurrence of chemicals Avellan et al. (2020) provides a very comprehensive picture of the phase partitioning and sources at global level which fits with the Mediterranean evidences (Figue 81). Organic contaminants in marine sediments and seawater: A review for drawing environmental diagnostics and searching for informative predictors. http://dx.doi.org/10.1016/j.scitotenv.2021.152012

In a separate study (Figrue 82), Brumovksy et al. (2017) investigated the occurrence of 58 chemicals in the open surface water of the Western Mediterranean Sea for the first time. 70 samples in total were collected in 10 different sampling areas. Three current-use pesticides (CUPs), 11 pharmaceuticals and personal care products (PPCPs) and two artificial sweeteners were detected at sub-ng to ng L-1 levels. Among them, the herbicide terbuthylazine, the pharmaceuticals caffeine, carbamazepine, naproxen and paracetamol, the antibiotic sulfamethoxazole, the antibacterial triclocarban and the two artificial sweeteners acesulfame and saccharin were detected in all samples (Table 25). Saccharin was the most abundant artificial sweetener ranging from 0.49-5.23 ng L-1.

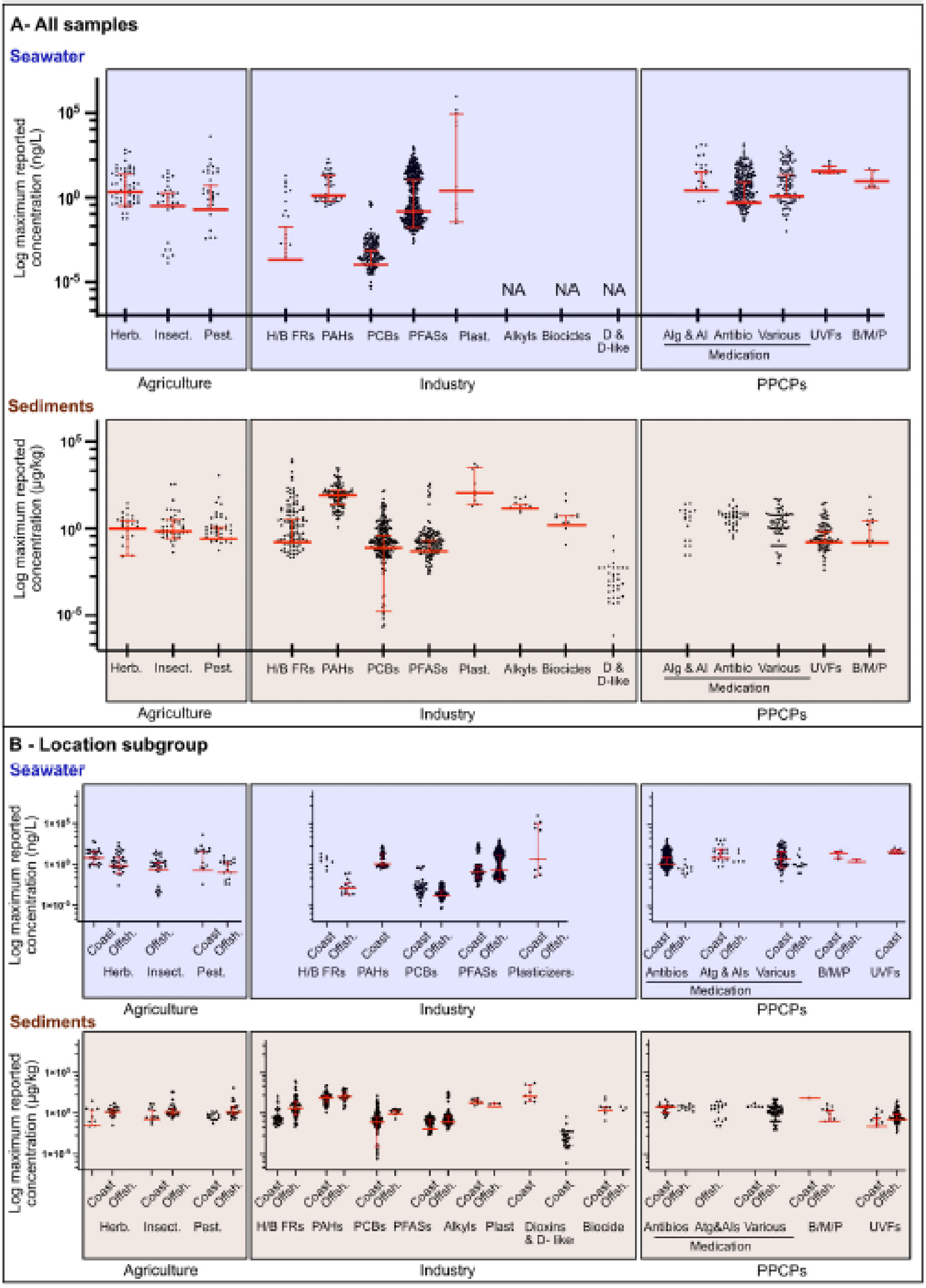


Fig. 4. Maximum reported concentrations in seawater (blue, ng/L) and sediment (brown, µg/kg) samples issues from agricultural, industrial activities, or pharmaceutical and personal care products (PPCPs). Results are displayed (A) without or (B) with location subgroups defined as coastal (<1 km from the coast) or offshore (>1 km from the coast). In red: Median with interquartile ranges. Note that the median or the lower quartile can be missing if lower than 10^{-2}, as the concentration scale is in log 10. Herb: Herbicides. Insect: Insecticides. Pest: Pesticides. D & D-like: Dioxin and Dioxin-like. Alg & AI: Analgesics and Anti-inflammatories. Antibio: Antibiotics. B/M/P: Biocides, Musks, Preservatives. UVFs: UV filters. PPCP: pharmaceutical and personal care products. H/B FRs: Halogenated or brominated flame-retardants. PCBs: Polychlorinated biphenyls. PAHs: Polycyclic aromatic hydrocarbons. PFASs: *Per-* and polyfluoroalkyl substances. Plast: Plasticizers.

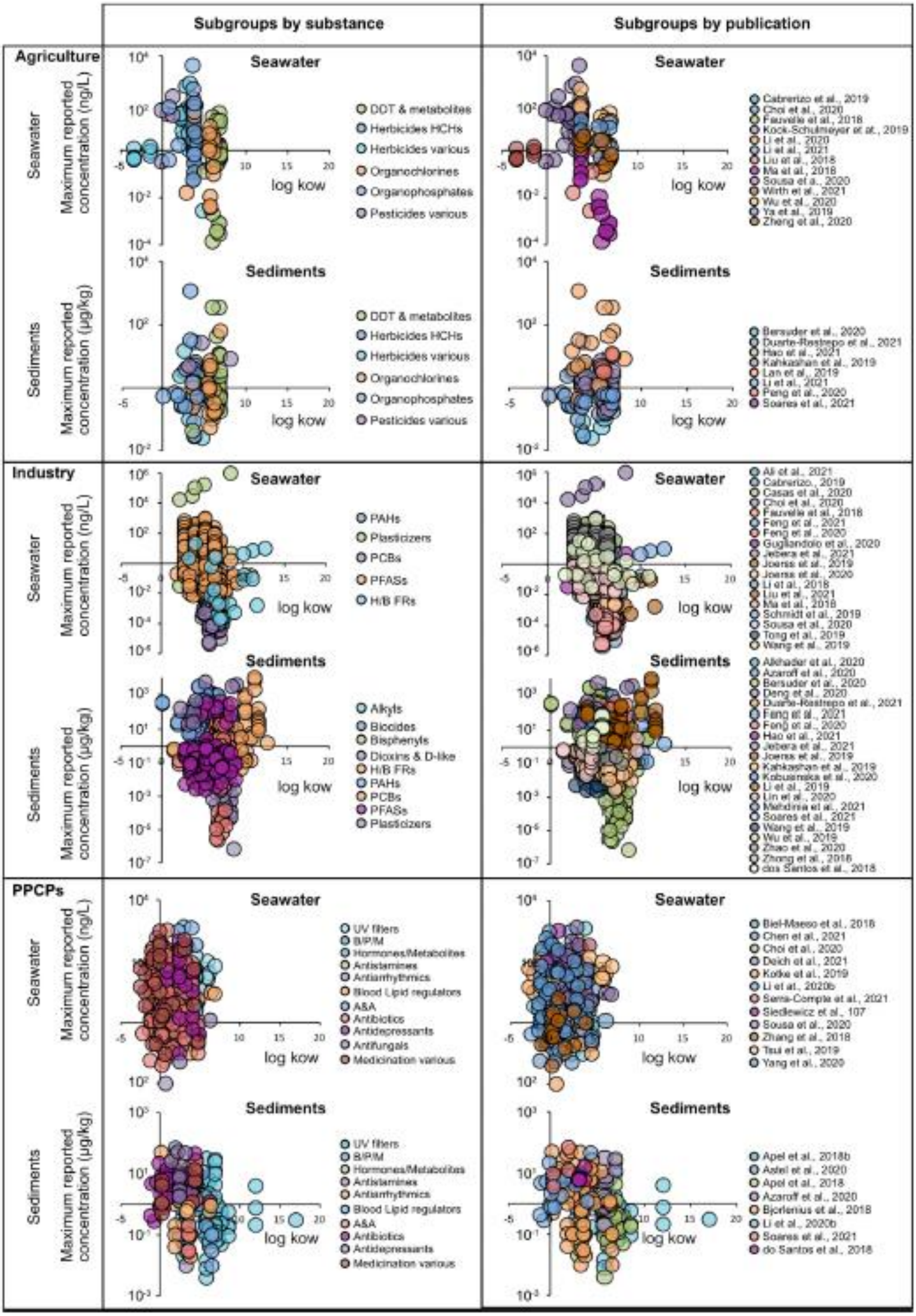


Figure 82. Phase distribution of legacy and CECs chemical substances. Avellan et al., 2020.

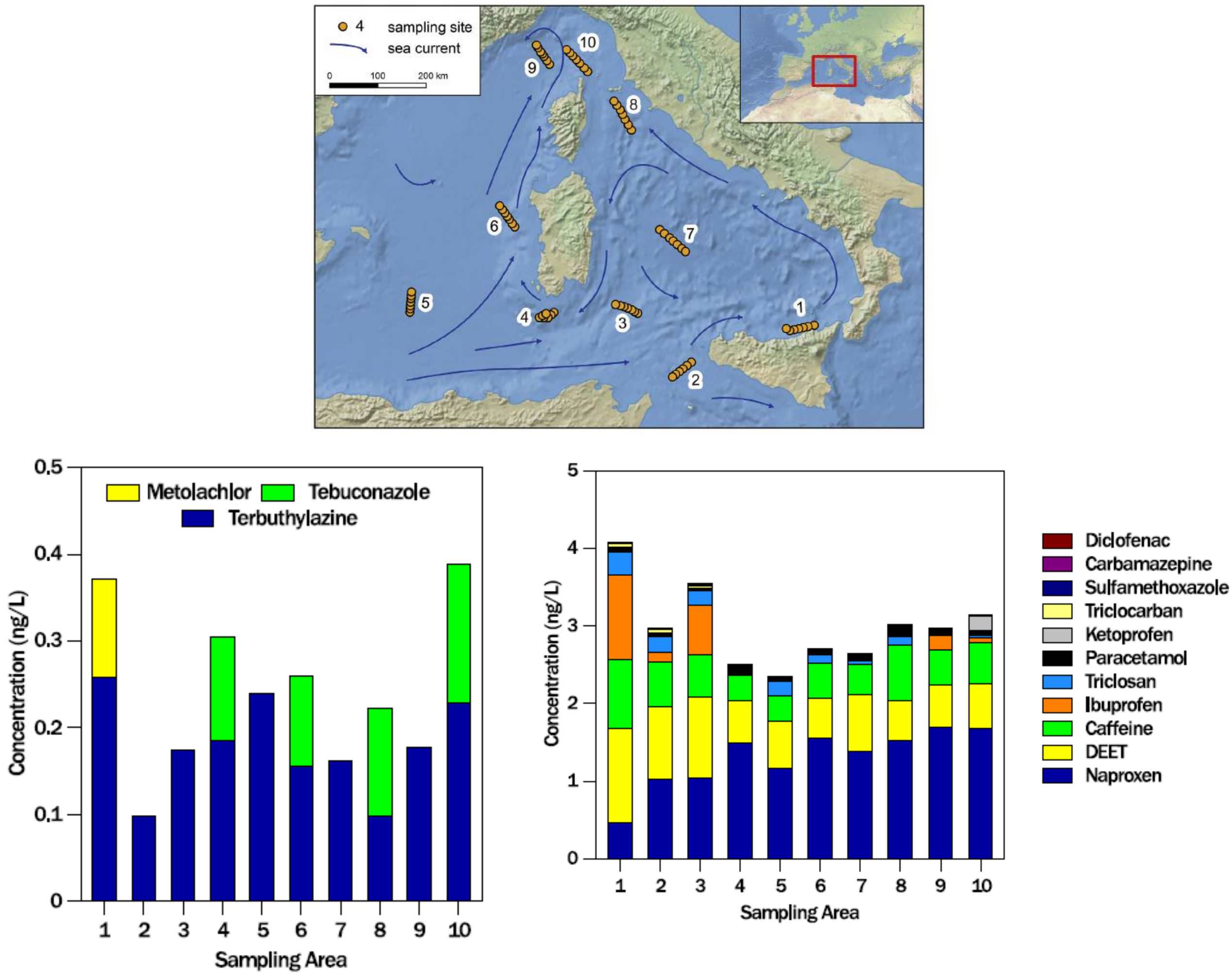


Figure 83. Map of sampling sites for R/V Urania cruises in autumn 2014 (EMSO-MedIT_02 þ ICHNUSSA2014). Arrows in the map display surface currents (top). Detected concentrations of current-use (bottom left) and pharmaceuticals and personal care products (bottom right) found in the Western Mediterranean Sea in ng^{-L} (November 2014). Only detected compounds are presented. Source: Brumovsky et al. (2017).

Table 25. Detection frequencies. Source: Brumovsky et al. (2017)

CUPs	% detection	PPCPs	% detection	Artificial sweeteners	% detection
		Caffeine	100		
		Carbamazepine	100		
Metolachlor	10	DEET	100	Acesulfame	100
Tebuconazole	40	Diclofenac	10	Saccharin	100
Terbuthylazine	100	Ibuprofen	50		
		Ketoprofen	20		
		Naproxen	100		
		Paracetamol	100		
		Sulfamethoxazole	100		
		Triclocarban	100		
		Triclosan	80		

Alygizakis et al. (2016) investigated the occurrence and spatial distribution of 158 pharmaceuticals and drugs of abuse in the seawater of the Eastern Mediterranean Sea (Saronikos Gulf and Elefsis Bay in central Aegean Sea), constituting the largest study in terms of number of analytes in this environmental compartment. Twenty-two samples were collected at three different depths in 9 sampling stations to assess the presence and the spatial distribution of the target compounds. Thirty-eight out of the 158 target compounds were detected, 15 of them with frequencies of detection equal to or higher than 50

%. The highest detected values corresponded to amoxicillin, caffeine, and salicylic acid, with concentrations in the range of <5.0–127.8 ng L−1; 5.2–78.2 ng L−1 and <0.4–53.3 ng L−1, respectively (Figure 83). The concentrations of some compounds varied significantly with depth suggesting that currents play an important role in the dilution of the target compounds.

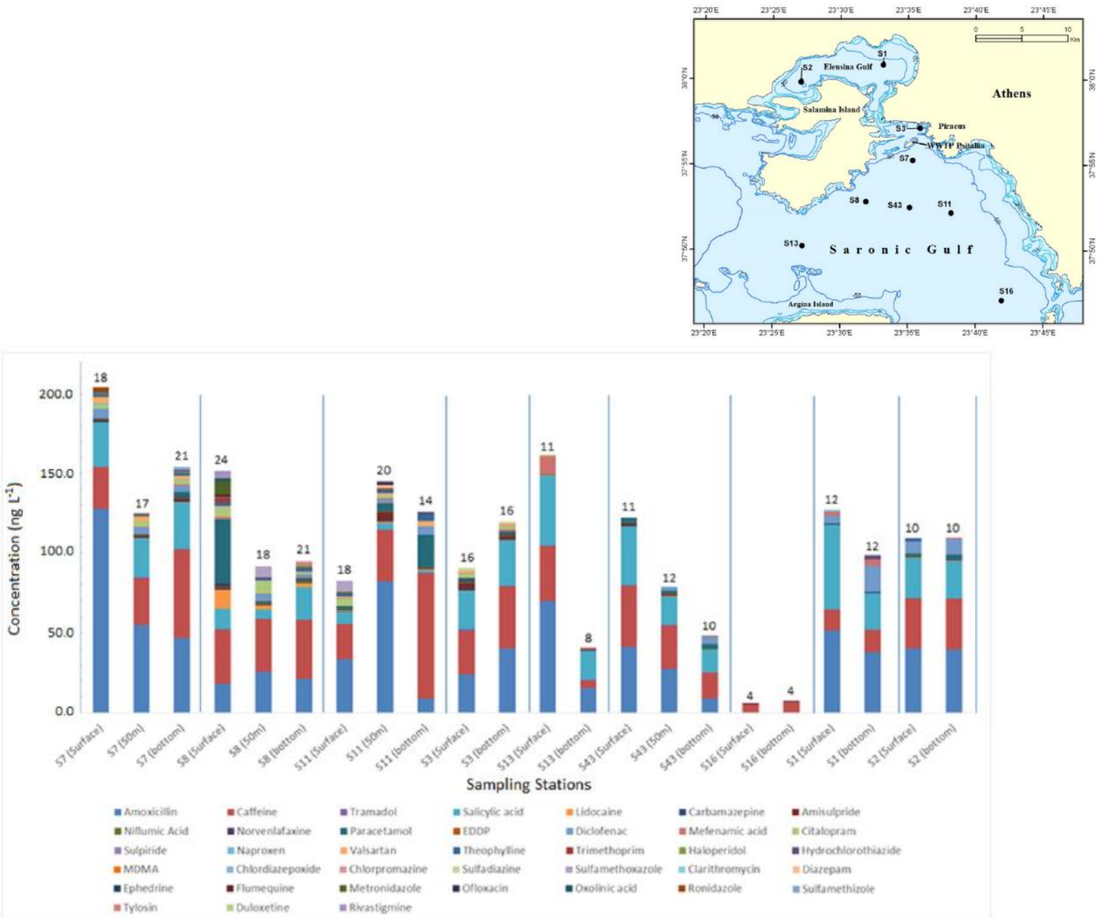


Figure 84. Map showing study area and sampling locations (top). Cumulative levels of the target compounds displayed as a stacked bar plot at the different sampling stations. Numbers above bars depict the number of analytes found in each station (bottom). Source: Alygizakis et al. (2016)

Land-based sources, such as WWTPs, are regarded as the primary source of pharmaceuticals and other CECs. However, sea-based sources can also be an important source of chemical contaminants. Tornero and Hanke (2016) provided a review of chemical substances entering the marine environmental from sea-based sources in the four European seas, including the Mediterranean Sea. Amongst the sea-based sources are shipping and offshore activities, mariculture and associated releases of a myriad of chemicals to enhance productivity and growth, including medicinal products and antibiotics to control disease, pesticides to control parasites and algae, food additives and antifouling biocides, seabed mining and dredging. The resulting list contains 276 substances: 22 antifouling biocides, 32 aquaculture medicinal products and 34 warfare agents, of which 19 are metals/metalloids, 10 organometallic compounds, 24 inorganic compounds, 204 organic compounds, and 19 radionuclides. The offshore oil and gas operations contribute to this list with the highest number of substances, followed by shipping and mariculture activities. The study also provided an overview of the consideration of these substances under relevant legislative/regulatory frameworks and Regional Seas Conventions, i.e. Barcelona Convention in the case of the Mediterranean Sea.

Studies on chemical pollution are performed either in targeted or screening approaches, however, there are no cases where only a single substance occurs in the environment, the so-called 'chemical cocktails', as the direct cause and effect chemical relationships do not apply. This research topic on mixtures of chemicals, including many more substances than just priority or parent chemical substances, are typically present simultaneously (EEA, 2018).

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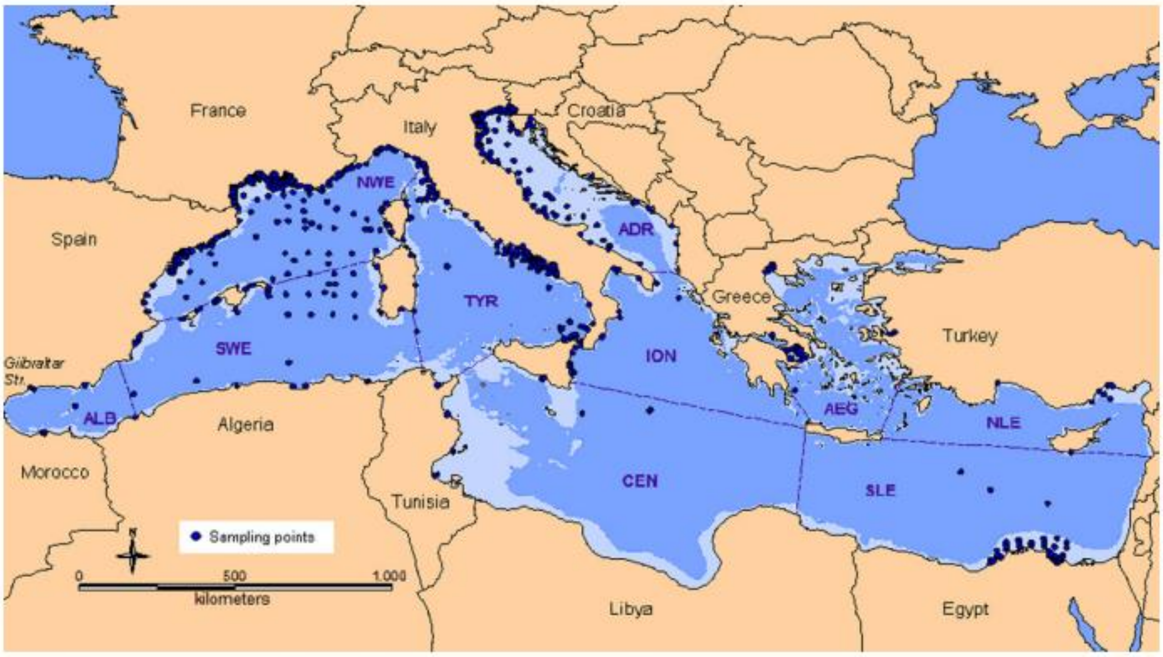


Fig. 1. Location of the samples gathered in this study. The Mediterranean sub-basins are indicated as follows: ADR, Adriatic Sea; CEN, Central Sea; AEG, Aegean Sea; ALB, Alboran Sea; ION, Ionian Sea; NLE, North Levantine Sea; NWE, Northwestern Mediterranean Sea; SLE, South-Levantine Sea; SWE, Southwestern Mediterranean Sea; TYR, Tyrrhenian Sea.

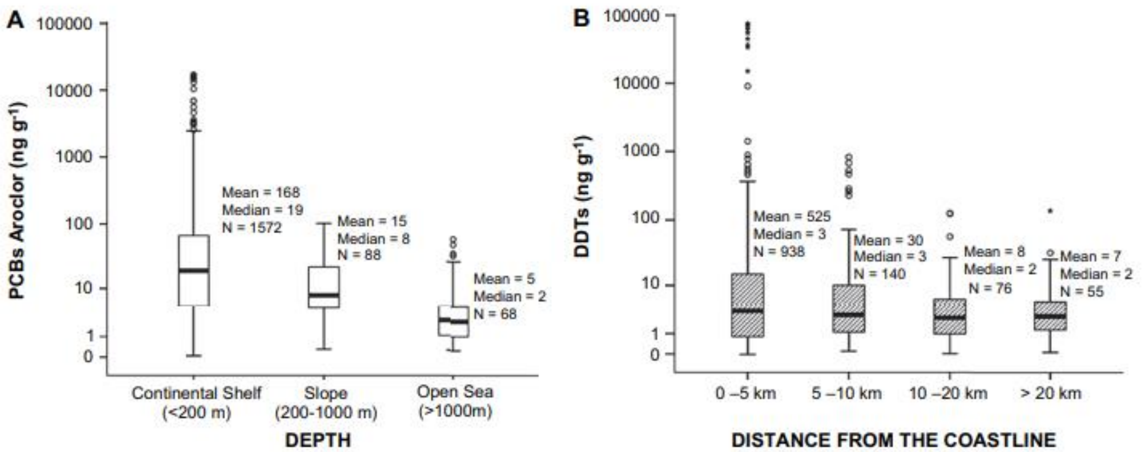


Fig. 3. Ranges, mean and median concentrations (box-and-whisker plots) of (A) PCBs (Aroclor eq.) according to the depth of sampling sites, and (B) DDTs according to the distance from the coastline.

Table 4
Ranges of PCBs, DDTs and HCB concentrations in sediments within an area of 10 km from the principal Mediterranean urban centres (>100,000 inhabitants)

Urban areas (<10 km)	Sub-basin	PCBs (Aroclor, ng g^{-1})	DDTs (ng g^{-1})	HCB (ng g^{-1})	References
Venice (Italy)	ADR	6–5600	1–43	2–2400	Cousteau, 1979; Donazzolo et al., 1983; Fossato, 1983; Pavoni et al., 1987, 1990, 1998; Raccanelli et al., 1989; Galassi et al., 1993; Fattore et al., 1997; Bonamin et al., 1999; Marcomini et al., 1999; Frignani et al., 2001, 2005; Moret et al., 1999, 2001
Naples (Italy)	TYR	2–3200	1 -312	0.2–1.3	Cousteau, 1979; Baldi et al., 1983, 1991; SIDIMAR, 2005
Marseille (France)	NWE	14–15815	2–225	0.2	Arnoux et al., 1981b; RNO, 1987, 1998; Wafo et al., 2006
Barcelona (Spain)	NWE	6–2224	1–195	3–40	Cousteau, 1979; Broto et al., 1985; Sánchez-Pardo and Rovira, 1985a,b; Bayona et al., 1991; Tolosa et al., 1995
Piraeus (Greece)	ION	1–775	0.3–1406	0.1–5.2	Dexter and Pavlou, 1973; Cousteau, 1979; Hatzianestis and Botsou, 2005
Thessalonica (Greece)	ION	1–299	0.3–33	0.1–1.3	Larsen and Fytianos, 1989; Hatzianestis et al., 2001; Catsiki et al., 2003
Alexandria (Egypt)	SLE	0.1–96	0.7–299	5–60	Cousteau, 1979; Abd-Allah, 1992; Abd-Allah et al., 1992; Abd-Allah and Abbas, 1994; Barakat et al., 2002
Oran (Algeria)	SWE	323	–	–	Cousteau, 1979
Alger (Algeria)	SWE	–	40	–	Cousteau, 1979

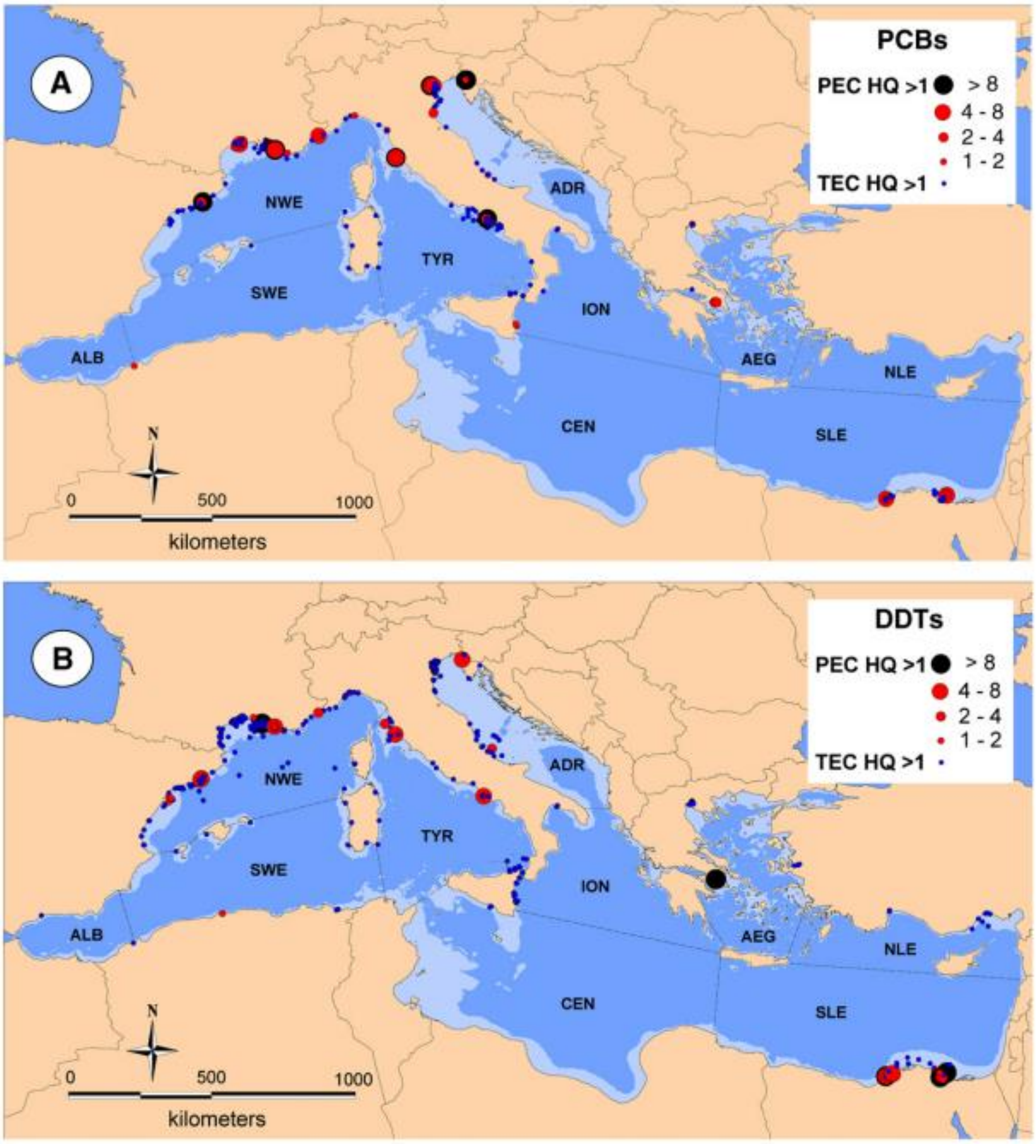


Fig. 5. Geographical distribution of the hazard quotients (PEC HQ and TEC HQ) for the concentrations of PCBs (A) and DDTs (B) in sediments from the different Mediterranean sub-basins. ADR, Adriatic Sea; CEN, Central Sea; AEG, Aegean Sea; ALB, Alboran Sea; ION, Ionian Sea; NLE, North Levantine Sea; NWE, Northwestern Mediterranean Sea; SLE, South-Levantine Sea; SWE, Southwestern Mediterranean Sea; TYR, Tyrrhenian Sea.

Figure 85. 2007 Screening ecological risk assessment of persistent organic pollutants in Mediterranean sea sediments doi:10.1016/j.envint.2007.04.002

2019 Spatial and temporal trends in the ecological risk posed by polycyclic aromatic hydrocarbons in Mediterranean Sea sediments using large-scale monitoring data

https://doi.org/10.1016/j.ecolind.2021.107923

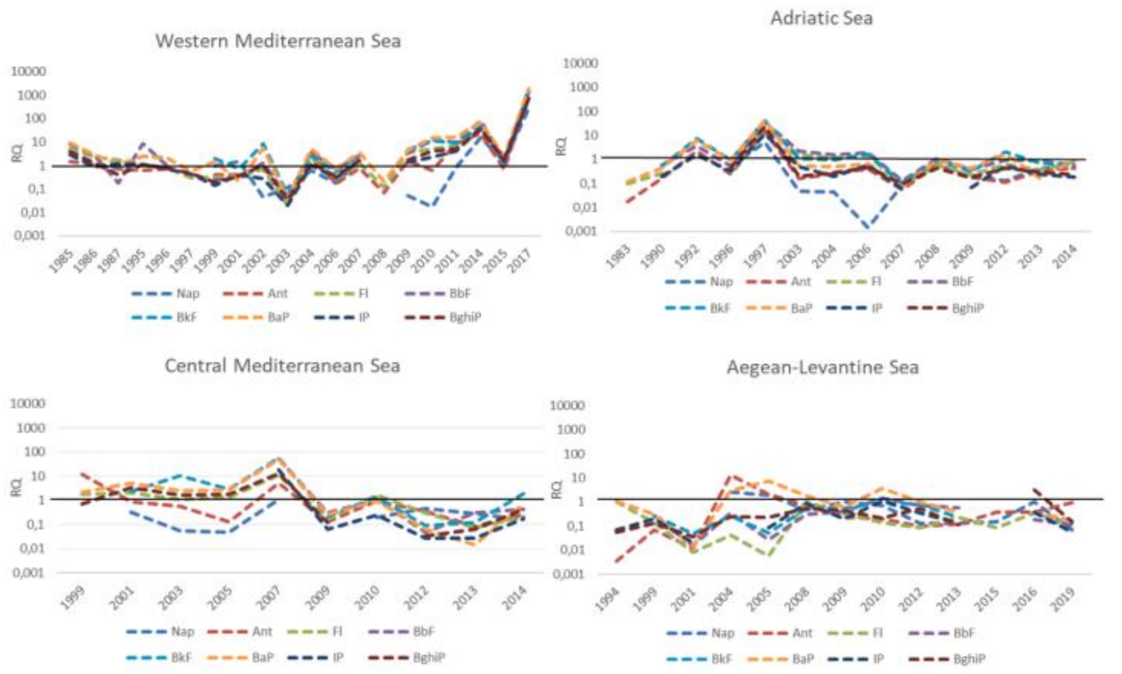


Fig. 5. Temporal trend of risk quotient for the eight PAHs regulated by Directive 2013/39/EU.

Figure 86. 2019 Spatial and temporal trends in the ecological risk posed by polycyclic aromatic hydrocarbons in the four Mediterranean Sea basin.

Major environmental impacts and socio-economic consequences (including gender aspects)

The scientific investigations evidenced multiple environmental concerns of chemical contamination in the marine environment and the major environmental impacts and socio-economic consequences, including their interlinkages are shown in Figure 87. Chemicals, such as POPs, bioaccumulate in the food web and pose a risk of adverse effects both to human health and the environment. Studies have pointed out the importance of the trophic status in the occurrence of POPs in aquatic environments. For example, Castro-Jimenez et al. (2021) assessed the storage capacity, trophic magnification and risk of 62 POPs in a well-characterized pelagic food web (including phytoplankton, zooplankton, six fish and two cephalopods' species) from an impacted area in Northwestern Mediterranean Sea. The planktonic compartment showed high capacities for the storage of PCDD/Fs (and PBDEs), while PCBs were preferentially bioaccumulated in the higher trophic levels (six fish species and two cephalopods) with median concentrations reaching 4270 and 3140 ng g^{-1} lw (ΣPCBs) in Atlantic bonito (*Sarda sarda*) and chub mackerel (*Scomber colias*), respectively. For these edible species, the estimated weekly intakes of dioxin-like POPs for humans based on national consumption standards exceeded the EU tolerable weekly intake.

Chemical pollution can also alter the development, reproduction, behavior, survival and mortality rates of individual species and populations, thereby negatively affecting species diversity and the ecosystems as a whole. For instance, pesticides, especially if subject to irrational use, can lead to the inability to reproduce normally in certain non-targeted animal species. Exposure to certain pesticides, directly or indirectly, can cause cancer, neurological effects, diabetes, respiratory diseases, fetal diseases and genetic disorders in humans (Andersson, Tago & Treich, 2014). Studies point towards contaminants being partly responsible for the observed increase in disease outbreaks in marine mammals by adversely affecting their immune systems, with a possible link to low survival and reproductive failures in marine mammals, birds and reptile groups due to early-life or prenatal exposures to contaminants (Mauffret et al., 2019).

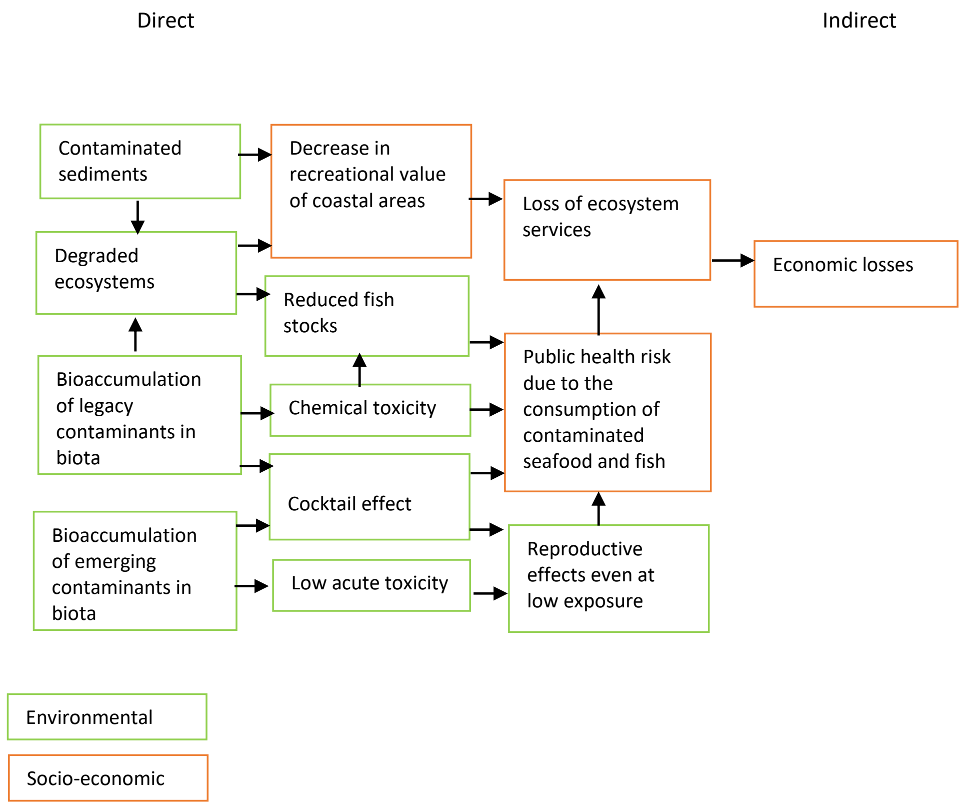


Figure 87. Chemical pollution: Major environmental impacts and socio-economic consequences

Chronic pollution generates long term changes in ecosystem services, which differ substantially from acute effects on marine ecosystems that may take place as a result of acute pollution events. The amount of chemicals released in any single discharge is usually not large enough to represent a great concern for its immediate impact on the ecosystem. However, chronic pollution from operational and illicit discharges poses a cumulative, long-term threat to the marine and coastal environment (see Priority issue 3: Oil & HNS pollution). The runoff and infiltration of chemicals into the sea affects the marine environment at a slower pace due to the bioaccumulation and biomagnification through the food chain. Therefore, the long-term chronic exposure to contaminants can impact marine biodiversity, affect their functional habitats resilience and functioning (Peterson et al., 2003) and degrade ecosystems. These processes might be transgenerational, with potential consequences for natural populations of long-lived marine species. The study of the impacts of contaminant levels on aquatic organisms and ecosystems is challenging due to the exposure to multiple sources and the complexity of ecosystems. It is common that single contaminants act concurrently, resulting in synergistic effects to denote the "mixture effect". Evidence of direct relationships between exposure to pollutants and their effects on organisms under field conditions is currently limited. The influence of various environmental factors on the biological responses to pollution, or the interactions between toxicants present in the marine matrices, limit the understanding of the observed biological effects (Mauffret et al., 2019). An overview of the impacts for each chemical category is shown in Table 26.

Table 26. Overview of impacts on the environment and human health emerging pollutants. Source: Plan Bleu (2021b)

Categories	Environmental Impacts	Human health Impacts
Polycyclic aromatic hydrocarbons (PAHs)	• Have moderate to high acute toxicity to aquatic life and birds • In high concentrations in soil, can have ad- verse effects on terrestrial invertebrates including on reproduction, development, and immunity, and may cause tumours	• Carcinogenic and potential neurotoxin
Pesticides	• Can contaminate soil, water, turf, and other vegetation • Can cause mortality in insects and weeds. • Toxic to other organisms including birds, fish, beneficial insects, and non-target plants	• Short-term impacts such as headaches and nausea • Chronic impacts such as cancer, reproductive harm, and endocrine disruption
Environmental oestrogens	• Impact fish physiology and can affect reproductive development in both domestic and wild animals • Can mitigate the effects of other environmental stresses on the plant	• Have been linked to breast cancer in women and prostate cancer in men • Oestrogen has a wide range of effects on the body and brain, including on emotional processing via neuropsychological factors
Phthalates	• Toxicity impacts in animals including damage to liver, kidney, lungs and reproductive systems	• Damage to the liver, kidneys, and lungs • Damage the reproductive system, and can cause infertility and reproductive problems in men
Pharmaceuticals	• Development of antibiotic-resistant strains of bacteria that can critically disturb natural bacterial ecosystems in the environment • Under certain conditions direct impact on fish reproduction	• Development of antibiotic-resistant strains of bacteria that can lead to a serious threat to human health
Personal Care Products	• Negative impact on aquatic ecosystems, especially related to endocrine disruption and reproductive disorders • Create a layer on the water surface that hinders gaseous exchanges between the air and the sea	
UV filters	• Endocrine-disrupting potential impacting animals • Create a layer on the water surface that hinders gaseous exchanges between the air and the sea	• Certain chemical filters are potential endocrine disruptors.
Flame retardants	• Toxic effects on marine fauna	• Have carcinogenic properties. • Brominated and chlorinated flame retardants can increase fire toxicity including fire growth rate and smoke toxicity.
Disinfection by-products	• There is evidence of carcinogenic and mutagenic properties of these by-products in small animals	

The extent of the impacts of pharmaceutical and other emerging contaminants on the Mediterranean aquatic ecosystem is still largely unknown. Some studies have analyzed the effects of prolonged exposure to these substances, which can be toxic for marine organisms and humans in minute doses. Yet, there is still limited understanding of the CECs lifecycle in the ecosystem, the ecotoxicological significance, cumulative and synergistic effects of the different chemicals and their impact on human health, in particular of the "cocktail effect". Antibiotics, antidepressants and non-steroidal anti-inflammatory drugs are known to induce cocktail effects. Although the combinations of compounds can act synergistically or antagonistically from an ecotoxicological point of view, the prevalent observation is that the mixtures increases the toxicity of molecules. For example, when five pharmaceuticals and personal care products were exposed to marine biofilms, mixture effects were observed even at their individual no-observed-effect concentrations. The study of the multitude of emerging contaminants, their interactions with the environment and human health and their treatment is extremely complex and costly. It has been insufficient for a number of substances and does not currently keep up with the pace at which new substances are being created (UNEP/MAP and Plan Bleu, 2020).

An analysis of how chemical pollution may lead to a loss of human welfare benefits by threatening the provision of marine ecosystem services was presented in Cinnirella et al. (2013). This analysis was based on a conceptual model that identified the links between chemical pollution and changes in state, ecosystem services and benefits (Figure 88).

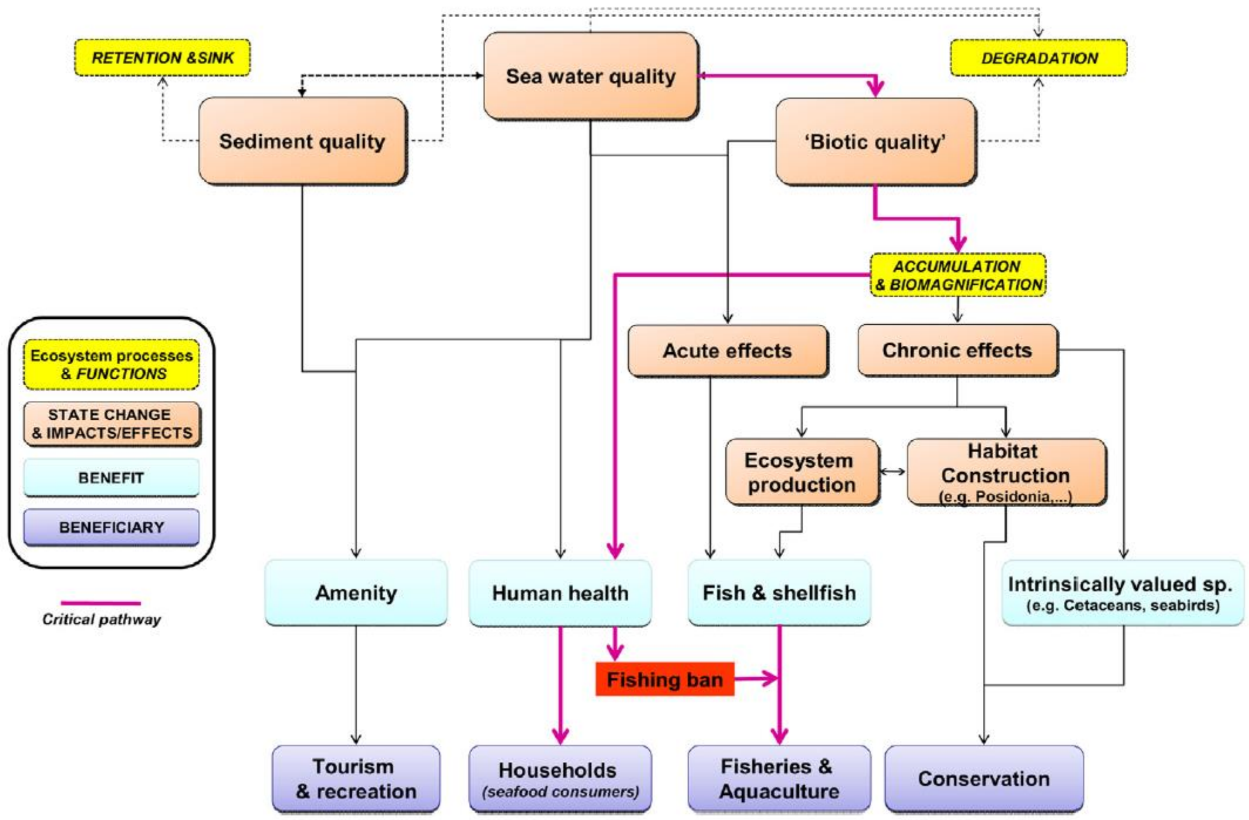


Figure 88. Conceptual model to link chemical pollution with changes in state, ecosystem services and benefits, and eventually changes in beneficiaries or human welfare. Source: Cinnirella et al. (2013)

In the case of the Mediterranean Sea, fisheries and mariculture, tourism, recreational activities by households and public, and environmental health are assumed to be the most substantially affected benefits in monetary terms (Cinnirella et al., 2013). Despite the complexities of the calculation techniques and the lack of standardized data, preliminary estimates of the value of the benefits under consideration provided by the Mediterranean Sea currently accounts for 25 800 million Euro per year (base year 2010) (Cooper et al., 2011). One of the identified socio-economic impacts of chemical pollution is the increased public health risk due to the consumption of contaminated seafood and fish. Sophisticated detection techniques have shown adverse effects at very low mercury exposure levels on electrical transmission in the brain (Murata et al., 2004), leading to a large impact over population. The costs of damages caused by mercury pollution has been calculated as external costs associated with measurable damages to human health and the environment ((Sundseth et al. (2010) and references therein). For instance, the intake of mercury-containing food during pregnancy is thought to be linked to the loss of intelligence quotient (IQ), and hence has direct and indirect effects on future earnings. According to Bellanger et al. (2013), the total annual benefits of exposure prevention within the EU would be 600,000 IQ points per year, corresponding to a total economic benefit between 8000 and 9000 million Euro per year. The highest benefit would be found in the Southern European Countries with a total of 7892 million Euro. The specific economic impact of other contaminants, e.g. PAHs on the provision of ecosystem services and welfare benefits still needs to be properly evaluated.

Priority issue 3: OIL AND HNS POLLUTION

Description of the problem and its transboundary importance

Oil and HNS pollution can be considered as a sub-category of the chemical pollution issue discussed above. Crude oil is composed of about 4,000 thousand chemical compounds and its chemical composition changes dynamically (e.g., biodegradation and photooxidation) after release into the marine environment. PAHs, often comprising up to 10 % of the organic compounds in crude oil, can be used as tracer for the general distribution of petroleum hydrocarbons in the environment associated with a spill, as well as for anthropogenic non-point sources. Oil spills are also an important source of other chemicals, including Volatile Organic Compounds (VOCs) such as hexane, heptane, octane, nonane, benzene-toluene-ethylbenzene-xylene isomers (BTEX), and other lighter substituted benzene compounds. Other components of interest include compounds containing nitrogen, sulfur, and oxygen acids, esters, ketones, phenols and metals such as iron, nickel, copper, chromium and vanadium.

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, to damage amenities or to interfere with other legitimate uses of the sea", in accordance with the OPRC-HNS Protocol (2000)[62]. 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.

One of the reasons why oil and HNS pollution was considered as a separate issue is that shipping, a major sector in the world's busiest waterway and the main cause for oil pollution in the Mediterranean

[62] Protocol on Preparedness, Response and Co-operation to pollution Incidents by Hazardous and Noxious Substances, 2000

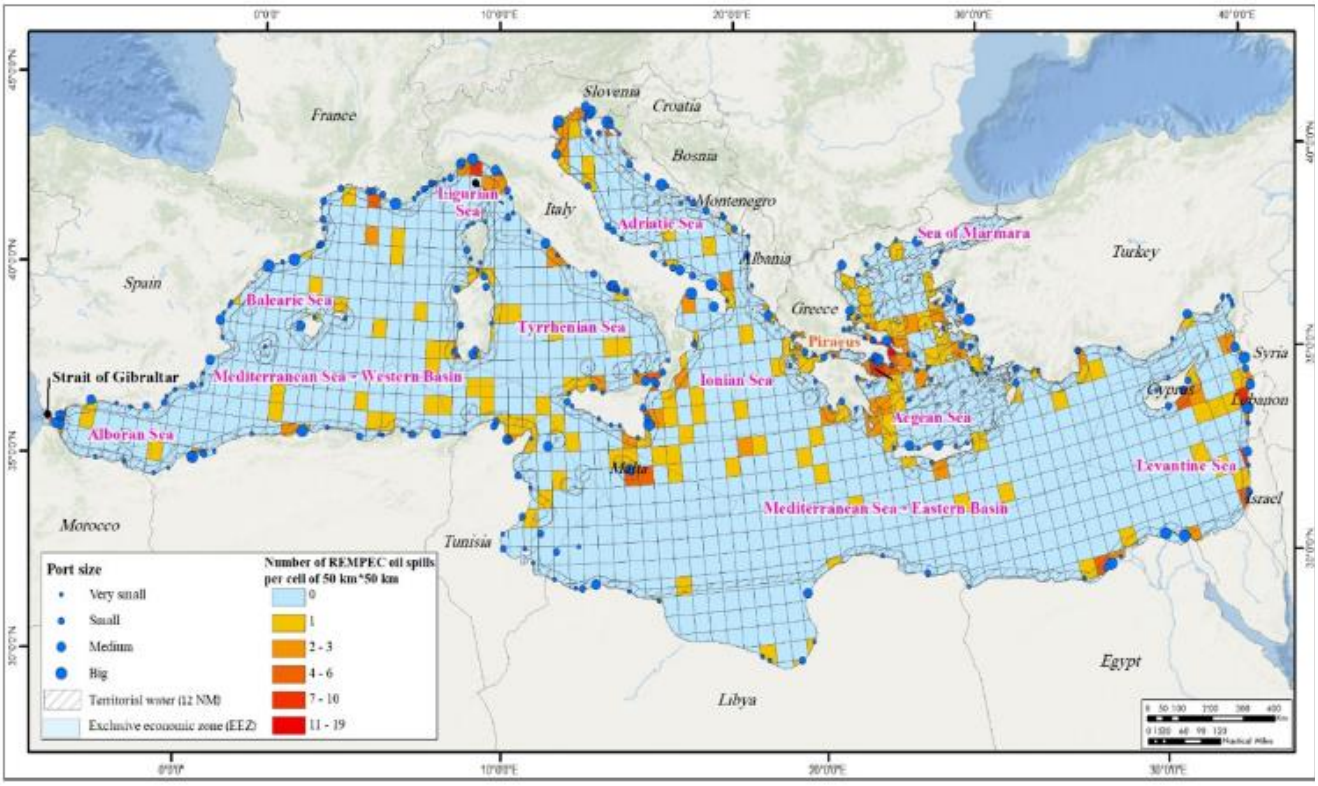
Sea, is both a mobile source and a major cause of transboundary pollution. Oily discharges from ships range from operational discharges of bilge water from machinery spaces, fuel oil sludge, to oily ballast water from fuel tanks. Commercial vessels, other than tankers, release operational discharges of oil from machinery spaces to the sea, unless treated. Cargo-related operational discharges from tankers include the discharge of tank-washing residues and oily ballast water.

Over the last fifty years, there has been a marked downward trend in oil spills from tankers at the global level. The average number of spills per year in 1970 was about 79 and now is reduced to 6 average (ITOPF, 2020) (from REMPEC, 2020). The Mediterranean oil pollution incidents trend is coherent with that observed at the global level. 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 ton. Approximately 32 000 tons of oil have been released into the Mediterranean Sea as a result of incidents between 1994 and 2013 (UNEP/MAP, 2019) (from REMPEC, 2020). The rates of incidents have decreased globally and regionally despite the increase in maritime traffic, thanks to the impact of the international regulatory framework adopted through IMO and cooperation activities at the regional level (UNEP/MAP, 2017) (from REMPEC, 2020).

The recent study by Polinov et al. (2021) provided a geostatistical analysis of oil spills using three databases for the Mediterranean Sea: REMPEC (1977–2000) with 385 spills (17/year), ITOPF (1970–2018) with 167 spills (3.5/year) and EMSA (2015–2017) with 2066 detections (688/year). The oil spill distribution maps (Figure 88) indicate high REMPEC and EMSA oil spill concentrations in specific areas in the Mediterranean Sea, pointing towards centralized and chronic pollution. According to the REMPEC database, the Aegean Sea had the highest concentration of oil spills at the regional level, whereas at the local level, the highest concentration of oil spills was found in the vicinity of the port of Piraeus (Greece), Israel, the Lebanese coastline, the Northern Adriatic Sea, the Ligurian Sea, and the coasts of Malta. The EMSA database confirmed that the highest concentrations of oil spills were in the Aegean Sea, near the eastern coast of Malta, as well as near the Straits of Gibraltar (the Alboran Sea), and in the Levantine basin.

It is important to highlight that the oil databases in the work form Polinov et al. (2021) have a different origin. The REMPEC database (1977-2000) has been built based on reported spill in the Mediterranean waters, whilst the EMSA database (2015-2017) uses new developed technologies, such satellites and telemetry (e.g, Synthetic Aperture Radar, SAR). Therefore, EMSA detection density is large in only two years than over 20 years in the REMPEC database (Figure 88). It can be observed, however, coincidences, in some areas close to important developed maritime hubs in the Mediterranean, such as Malta and Greece.

The oil density values based on the three databases for each EEZ were summed up to evaluate a country’s overall oil spill history (Error! Reference source not found.).



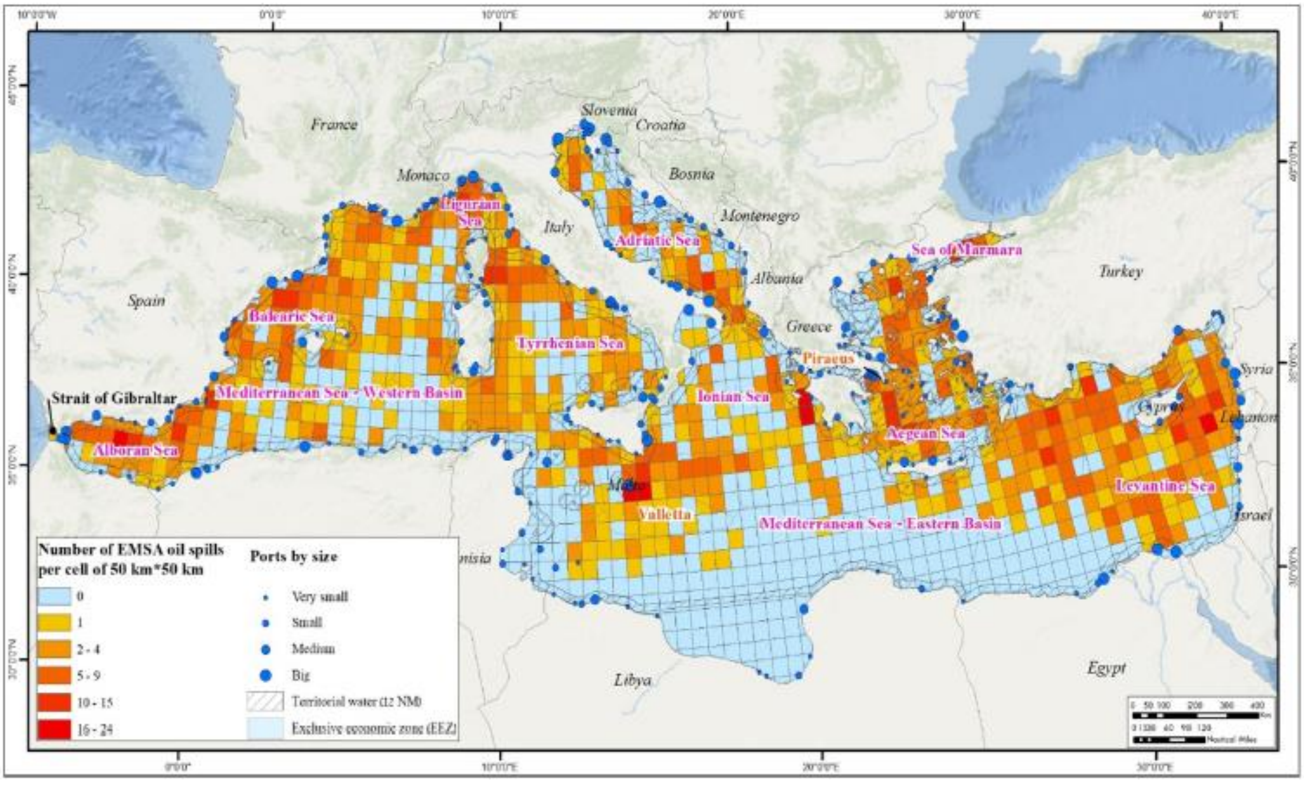


Figure 89. The distribution of 385 REMPEC spills in the Mediterranean Sea for the period 1977–2000 (top). The distribution of 2066 EMSA oil spill detections in the Mediterranean Sea for the period 2015–2017 (bottom). The distribution of the ITOPF spills is not shown since the exact location of spills is not available. Source: Polinov et al. (2021)

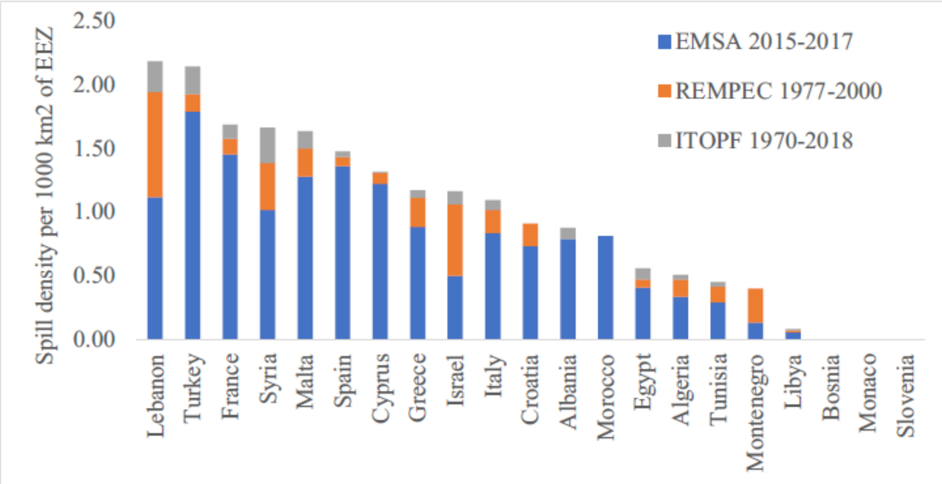


Figure 90. Cumulative and individual densities of oil spill density per 1000 km2 in the EEZs of the Mediterranean countries. Source: Polinov et al. (2021)

Following an oil spill, several means of cleanup are used to reduce the overall impacts on marine ecosystems. This includes oil spill dispersants which are composed of surfactants and solvents and are used to facilitate mixing, dilution, and subsequent natural biodegradation (EMSA, 2016) (in Tornero & Hanke 2016). Typical surfactants in today's formulations include fatty acid esters or sorbitan esters (e.g., sorbitan, mono-(9Z)-9-octadecenoate), ethoxylated fatty acid esters (polyethylene glycols, PEGs) or ethoxylated sorbitan esters, and sodium di-isooctyl sulphosuccinate (DOSS). Solvents help keep the chemicals mixed and help them dissolve into the oil. Typical solvents include light petroleum distillates and glycol ethers (e.g. propylene glycol, 2-butoxyethanol, di-propylene glycol monomethyl ether, and di-propylene glycol monobutyl ether) (EMSA, 2010) (in Tornero & Hanke 2016). Despite improvements in dispersant formulations, the toxicity of the dispersant/oil mixture is often a major environmental concern (ITOPF, 2005) and hence chemical dispersants can be considered as another pollutant.

Despite the clear decreasing trend in historical levels of petroleum hydrocarbons, exemplified by the significant reduction of accidental and acute pollution events in the Mediterranean Sea compared to previous decades, continuous chronic oil pollution associated to harbors, sea-based sources and atmospheric inputs, remains an issue. Such operational discharges, i.e. release of pollutants in the general operation of ships, include various types of emissions, such as bilge water from machinery spaces, ballast water of fuel oil tanks, tank residues, bunker oils etc. 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, sewage and garbage. 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, as 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 (REMPEC, 2020). The chronic pollution resulting from operational discharges is more difficult to assess than that caused by large catastrophic spills. Operational pollution has become a common practice in the Mediterranean basin, representing the main source of marine pollution from ships (Figure 91).

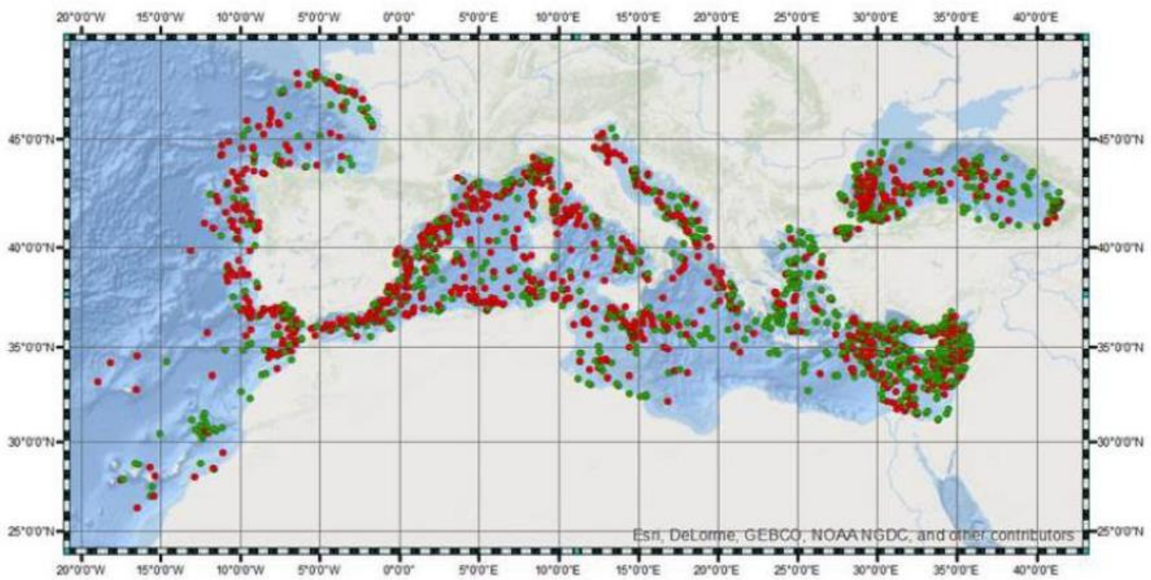


Figure 91. Spills detected in 2016 by satellite Class A (red dots on the map): the detected spill is most probably oil (mineral or vegetable/fish oil) or a chemical product. Class B (green dots on the map): the detected spill is possibly oil (mineral/vegetable/fish oil) or a chemical product. Source: UNEP/MAP (2017) & reused in REMPEC (2020)

Hazardous and Noxious Substances (HNS) can be defined as any substance other than oil likely to induce harm to living resources and human health or that has a harmful impact in the environment if introduced in the sea. HNS comprise of inorganic or organic chemical compounds, minerals, etc. for use within or derived from the manufacturing, petrochemical, textile, pharmaceutical, food and agrichemical industries. It is estimated that about 2000 different chemicals are regularly transported by sea, either in bulk or in packaged form. Due to the diversity and high number, putting together a comprehensive list of HNS is complex. According to REMPEC (2020), the quantities of HNS accidentally spilled have considerably decreased in the Mediterranean during the period 1994 – 2013, becoming insignificant since 2003 (Figure 91; UNEP/MAP, 2019).

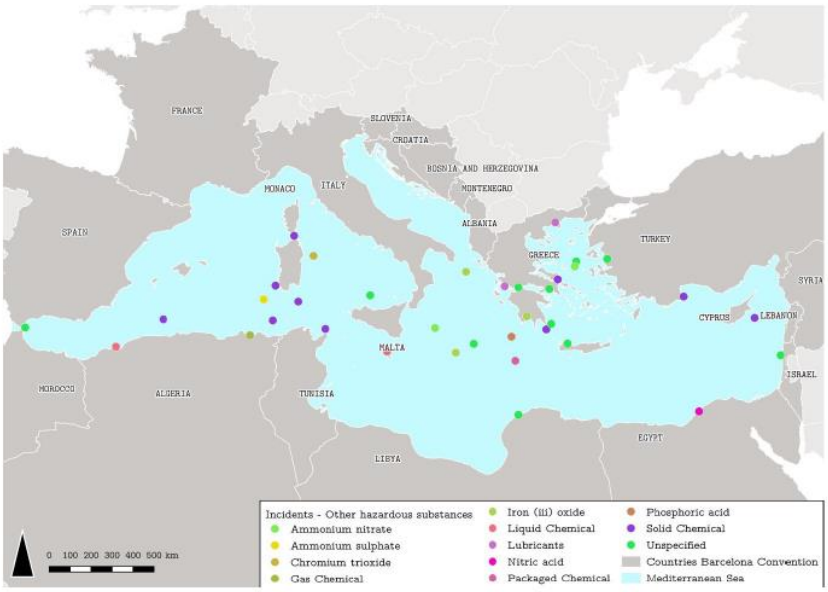


Figure 92. Map of accidents causing release of HNS to the Mediterranean in the period 1977-2018, categorized by type of pollutant. Data source: REMPEC MEDGIS-MAR, data retrieved on 30.06.2020. Source: REMPEC (2020)

Offshore operations, such as the oil exploitation present another source of chemical pollution to the marine environment. Accidental spills from offshore installations, such as 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, may release oil. This, however, can differ substantially from ship-sourced oil spills, principally due to the potentially larger quantity and prolonged release of fresh oil (Tornero and Hanke, 2016). Apart from PAHs from accidental spills, offshore oil and gas operations generate significant quantities of wastes in the form of drilling fluids (drilling muds) and produced water – a combination of formation water, condensation water and re-produced injection water. The drilling fluids circulated through the well hole contain toxic materials, including oil/grease, arsenic, chromium, cadmium, lead, mercury, and naturally occurring radioactive materials. Typical compounds found in produced waters include PAHs and other dissolved hydrocarbons (e.g. benzene, toluene, ethylbenzene, and xylene), alkylphenols, heavy metals (e.g. barium, chromium, lead, and nickel), organic acids (e.g. formic and acetic acid), and radioactive isotopes such as 226Ra and 228Ra, to addition to large numbers of additives, corrosion inhibitors, biocides, antifoams, and flocculants (Tornero and Hanke, 2016 – and references therein). Produced water represents the largest waste stream generated in the offshore platforms, in both volume and quantity of pollutants. Data and information on the quantity and composition of produced waters discharged in the Mediterranean Sea are not readily available.

Major environmental impacts and socio-economic consequences (including gender aspects)

The major environmental impacts and socio-economic consequences, including their interlinkages are shown in Figure 93. A wide range of impacts have been studied and documented in the scientific and technical literature over several decades. These include physical smothering with an impact on physiological functions; chemical toxicity giving raise to lethal or sublethal effect or causing impairment of cellular functions; as well as indirect effects, such as habitat degradation and the consequent elimination of ecologically important species. The severity of the damages of oil pollution in the marine environment depends on both the quantity spilled and the quality-type of oil (e.g. which determines the biological availability of the compounds; fate of the spill in terms of ambient conditions, including wind and weather conditions at the moment of the accident; and the sensitivity of the marine area impacted and of the affected organisms to the oil pollution). Although the concentration of a substance may be reduced below a lethal dose upon release to the marine waters due to sea dispersal and evaporation, lower doses can produce sublethal effects over a wider area. Such sublethal effects may produce detrimental impairments to individual organisms, species, populations, or marine communities over a longer term period (i.e., years to decades), depending upon the persistence of the released oil and HNS in the marine environment. In many respects, the environmental impacts of oil and HNS pollution are like those described for chemical pollution above. The amount of oil released in any single discharge is usually not large enough to represent a great concern for its immediate impact on the ecosystem. However, operational and illicit discharges pose a cumulative, long-term threat to the marine and coastal environment. Other impacts of oil and HNS pollution could include changes in the environment conditions (e.g., variation in salinity and pH, and deoxygenation (ca. hypoxia)) when oils are degraded or used biologically in the marine environment. These can also induce to lethal effects in marine ecosystems. When it comes to HNS discharges, these incidents happen regularly in European waters (EMSA, 2020). However, the ecological impacts caused by these spills are less recognized and understood than those involving oil pollution (Neuparth et al., 2011).

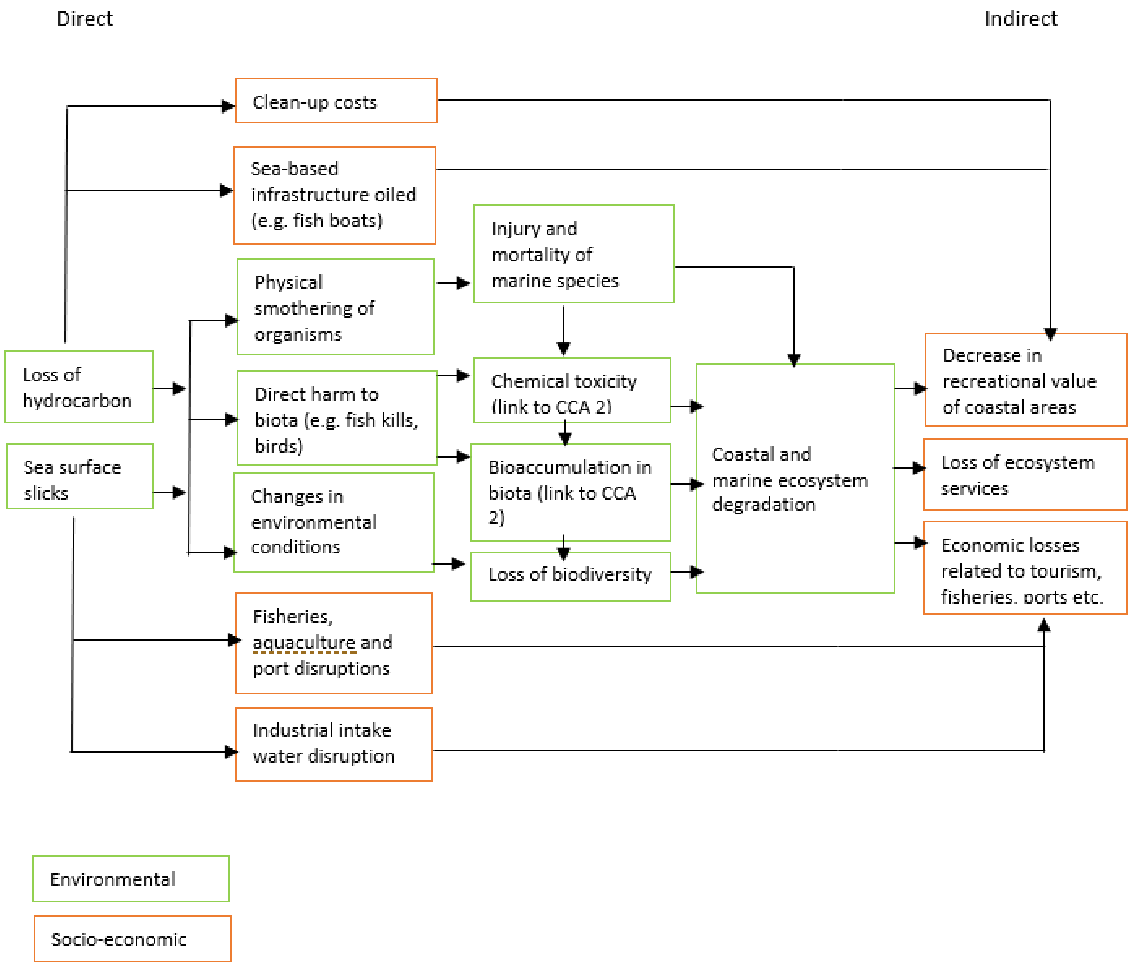


Figure 93 Oil & HNS Pollution: Major environmental impacts and socio-economic consequences

Depending on the oil type, the location of the eventual spill and the area in which the contamination occurs, spills from oil and gas activities pose a persistent threat to the marine environment, the seabed habitats, and species, both during the exploration and production phases. Although the expected impacts of oil spills from offshore oil installations are somewhat like those for oil spills from shipping activities, many of the impacts of offshore activities on marine environments are uncertain. This is primarily due to difficulties associated with conducting research in depth. Offshore drilling has moved further out into deep and ultra-deep waters due to technological innovations and decreasing productivity of the coastal oil and gas fields. The multiplication of drilling wells in increasingly deep waters undoubtedly brings greater consequences and threats for the environment and natural resources, including the fact that our knowledge of the species and processes in deep environments is more limited and difficult to obtain.

Oil and HNS pollution, caused by acute accidental spills, can impact human activities and economic sectors that rely in clean seawater and coastal areas causing financial losses and social impacts. Typically, tourism and commercial fisheries are the most significantly impacted sectors, although several other activities, such as power and desalination plants, may have far-reaching consequences due to precautionary shutdowns. In the assessment of costs, a distinction between private and collective/public costs is often made. Private costs concern a limited group of individuals and are associated to economic activities for which market values are available e.g. fisheries and seafood sector (extractive, transport, processing and marketing firms) and coastal tourism. Collective or public losses are usually associated with cleaning and restoration costs. Social damages, e.g. in terms of lost recreation opportunities for residents (use of beaches, landscape, etc.) and passive use losses (cultural, existence and heritage values) cannot be readily assigned a market price although non-market valuation methods are available to estimate collective non-marketed losses.

Oil spills can directly affect tourism-based economies and communities through the direct impact of oil on beaches and coastlines (eg., waterfront properties and the disruption of traditional coastal activities such as bathing, boating, angling, and diving. Tourism sector has a Gross Value Added (GVA) (~ 83 % of the total 169 billion euro blue economy GVA) and the highest employment rate (~ 79 % of the total 4.2 million jobs blue economy) (UfM, 2017), and is the Mediterranean's biggest blue economy sector and the world's leading tourist destination. Therefore, the economic losses of decreased tourism are reflected in many connected subsectors such as accommodation, transportation, professional guide companies, tourist entertainment and recreational fisheries. Although the physical disturbance to coastal areas and recreational activities from a single oil spill is usually relatively short-lived, the impacts from adverse public perception and media coverage lead to disproportionate and longer-lived damages (ITOPF, 2011a).

Damages to fisheries and mariculture resources occur through physical contamination due to oiling of boats, fouling of fishing gear and mariculture facilities, toxic effects on stocks and disruptions of business activities. Public health concerns and the detection of taint are likely to lead to produce being withdrawn from the market. Bivalve molluscs and other filter-feeding, sedentary animals are particularly vulnerable to tainting, since they filter substantial quantities of water and risk the ingestion of dispersed oil droplets and oiled particles suspended in the water column. The presence of PAHs in the oil presents the main concerns. 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. The use of dispersant, aggressive or inappropriate clean-up techniques, such as washing with high pressures may present an additional source of damage to seafood and the marine ecosystem in general.

After the recent offshore oil spill that caused 1200 tons of tar and contaminated materials to wash up along 160 km of the Israel's 195 km coastline, national authorities announced a precautionary ban of the sales fish and other seafood for consumption[63] and asked the local communities to avoid going to the beach, since encountering tar can irritate the skin and cause illness[64]. 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, with implications for the marketability of seafood due to the influence of media coverage potentially to an irrational extent. A loss of primary market confidence may lead to price reductions or outright rejection of seafood products by commercial buyers and consumers.

Although port, marinas and fishing harbors are usually enclosed by sea defenses 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. Oil spills can cause considerable disruption to normal port

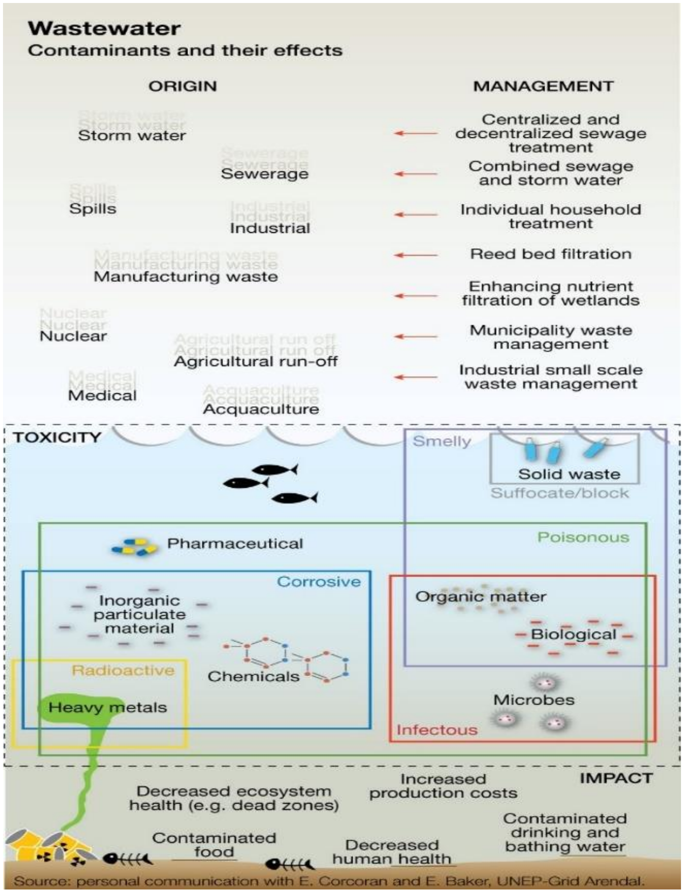
[63] https://www.timesofisrael.com/israel-bans-sale-of-all-seafood-from-mediterranean-after-massive-oil-spill/
[64] https://apnews.com/article/fish-oil-spills-coronavirus-pandemic-israel-3360f790b9938682f15307026e410c91

operations while vessels undergo cleaning. 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. In general, the sheltered nature of ports and harbors 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.

A compounding impact of oil spills, especially of liquified oil, is the impact oil pollution can have on desalination plants that rely on seawater as a feedstock and as a coolant and on other industries, such as thermal and nuclear power station and refineries that use seawater as a coolant (ITOPF, 2011b). Whereas multistage flash instillation desalination plants can tolerate a certain level of oil pollution without contamination of the freshwater product, reverse osmosis systems rely on semi-permeable membranes to remove salt from seawater. In the latter, oil contamination could foul the surface of these membranes. In 2017, 100 m^3 of oil caused the shutting down of three desalination plants for three days in Israel[65], which relies on ~ 75 % of its drinking and industrial water supplied by five desalination plants on the Mediterranean coast.

Linkages with other transboundary problems

Wastewater Treatment Plants (WWTPs) and solid waste management facilities are linked to all pollution types (nutrients, chemicals, including marine litter and microplastics) and these infrastructures are considered as sources (i.e, causes) in the causal chain analysis. The potential wastewater pollution sprectrum into the mairne environment is shown in the inforgraphics and picture below (Figure 94).



65 https://www.timesofisrael.com/2017-oil-spill-closed-three-desalination-plants-for-three-days-official-reveals/

Figure 94. Infographic (top) and image (bottom) of the Barcelona WWTP (Llobregat river) in 2023. Credits: C.Guitart

An extract of the current priorities at national level related to the multiple pollution issues and regarding WWTPs can be found for each Contracting Parties to the Barcelona Convention, as a result of the implementation of the Land-Based Sources (LBS) Protocol and elaboration of the SAP-MED, in their National Action Plans (NAPs) approved in 2004-2005 and updated in 2015. The NAPs 2016-2025 comprise legally binding programs of measures and timetables set out by the countries in line to achieve Good Environmental Status (GES). Information on priority land- and sea-based pollution issues identified in the NAPs 2016-2025 has been extracted and consolidated in the Table 27, which relates to the priorities at national level.

Table 27. Overview of land and sea-based sources of pollution identified in the NAPs 2016-2025.

Country	Location	Priority issue*	Description of issue
Albania	Drini basin	2. chemical polln and emerging contamn	The bad quality of surface water may put constraints on the use of water, especially: From rivers such as Kiri River (industrial wastes), Drini river (industrial and domestic sewage). The trend of COD content grows as a result of waste discharge into the river as the water flows through populated areas, industrial developments and agricultural areas.
Albania	Drini basin	4. marine litter & plastics	Increased of solid waste and marine litter deposited on the coastline and on the seafloor. Marine litter is a growing problem, where 100 % of marine litter comes from land-based sources. Different materials that contribute to marine litter are mainly plastic and metal. The other materials are: processed wood, cloth, rubber, paper and glass.
Algeria	All concerned hotspots 1: Tlemcen; 2: Oran; 3: Chlef; 4: Alger; 5: Béjaia; 6: Skikda; 7: Annaba	4. marine litter & plastics	
Bosnia and Herzegovina	Neum	5. wastewater and solid waste management facilities and plans	The sewerage cover not just the city of Neum but also several other small costal agglomeration in Croatia. The final WW outlet to the sea is equipped with only primary treatment and is located in Croatian territory. WWTP load is affected by large oscillations due to tourism in the region. (about 30.000 P.E.).
Bosnia and Herzegovina	Trebišnjica river basin	5. wastewater and solid waste management facilities and plans	Existing WWTP is in process of operation since 1980, this project comprises the rehabilitation and extension including also phosphorus and nitrogen removal.
Bosnia and Herzegovina	Trebišnjica river basin	5. wastewater and solid waste management facilities and plans	Construction of the sanitary landfill for sound and sustainable solid waste management, leading to pollution reduction in trans-boundary sensitive karstic area
Egypt	No identification of specific transboundary issues		
Lebanon	No identification of specific transboundary issues		
Libya	No NAP		

Montenegro	Bay of Boka - Port of Herceg Novi	5. wastewater and solid waste management facilities and plans	Most pollution hotspots and sensitive areas are located in the Bay of Boka. Port of Herceg Novi scored "4" (significant) for transboundary effect - classified as Sensitive Area (B).
Montenegro	Ada Bojana and Port Milena	5. wastewater and solid waste management facilities and plans	Ada Bojana and Port Milena scored "3" (moderately) for transboundary effect; classified as Hotspot (B) and Priority Hotspot (A)
Morocco	Saidia	5. wastewater and solid waste management facilities and plans	Saidia: Although this area was not taken into consideration as a Hot Spot in 2005, it has experienced increased tourist development since that date, which prompted the Government to set up an efficient WWTP and a controlled landfill for the protection of the site, legally protected (SIBE), at the mouth of the Moulouya
Tunisia	Jendouba Governorate	5. wastewater and solid waste management facilities and plans	The governorate has 8 WWTPs, 3 of which (Tabarka, Tabarka Airport and Jendouba) are quite old and require rehabilitation/extension. Wastewater treatment is of the secondary type. Some delegations not equipped with WWTPs, in particular Oued Meliz and Beni Mtir, discharge their wastewater directly into Oued Medjerda, which can affect the quality of the water in the Oued
Tunisia	Béja Governorate	5. wastewater and solid waste management facilities and plans	The governorate has 5 WWTPs, 2 of which (Béjà and Mjez El Bab) are quite old and require rehabilitation/extension. Wastewater treatment is of the secondary type. Some industries not equipped with pre-treatment stations (sugar, yeast, etc. in the city of Béja) discharge water discharges into wadis (Oued Bsim, Oueb Béjà leading to the Sidi Salem dam) which can affect the quality of drinking water

*The list of priority issues comprises: 1. Eutrophication; 2. chemical pollution and emerging contaminants; 3. oil pollution & acute pollution events; 4. marine litter & plastics; 5. wastewater and solid waste management facilities and plans; and 6. Other

BATHING WATER QUALITY (MICROBIOLOGY)

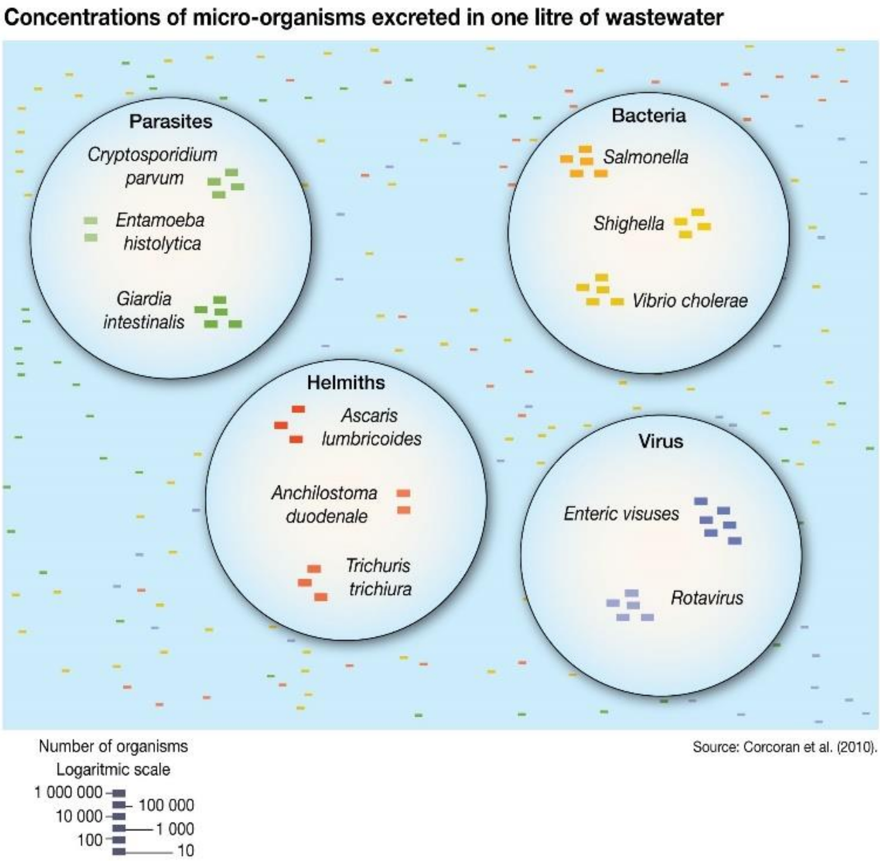
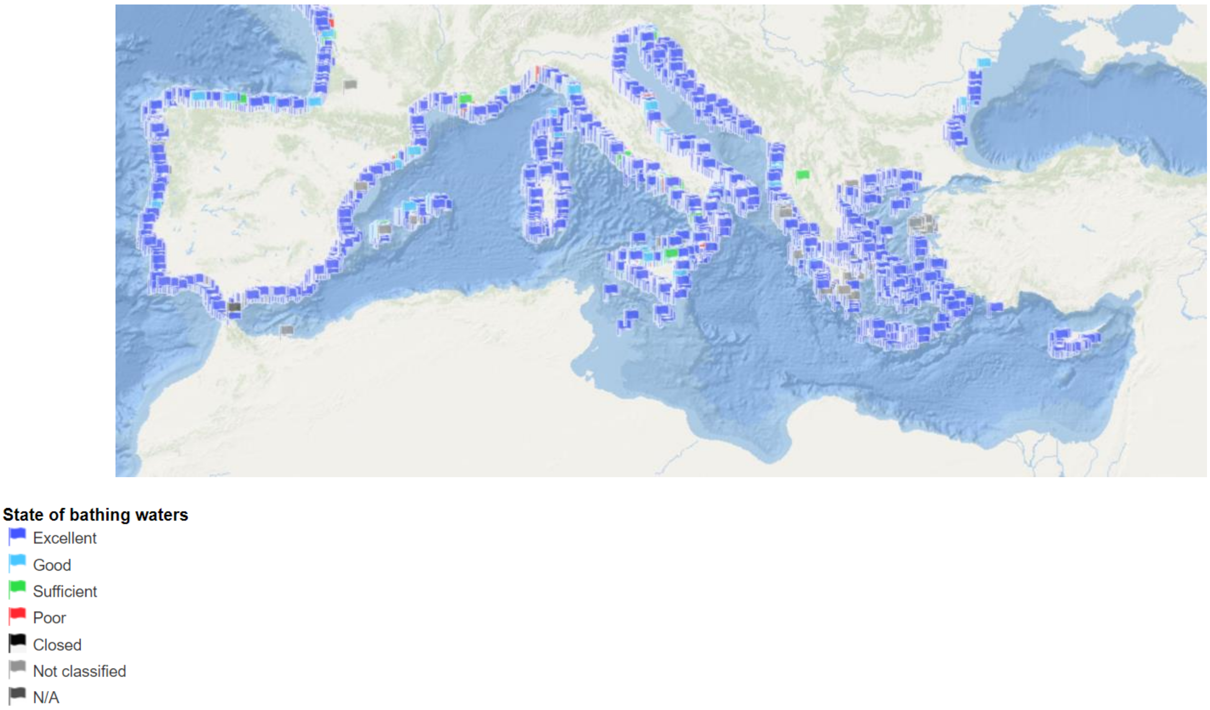


Figure 95. ***Evidence of viral dissemination and seasonality in a Mediterranean river catchment: Implications for water pollution management (2015); DOI: 10.1016/j.jenvman.2015.05.019***



This map gives an overview of the bathing water quality (e.g. excellent, good, sufficient and poor) along the European coasts. It presents a compilation of data from 1990 until 2016 reported by the Member States (EU28) and made available by the European Environment Agency. https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas

Figure 96. Bathing water quality (BWQ) in the Northern Mediterranean. Source: EU.

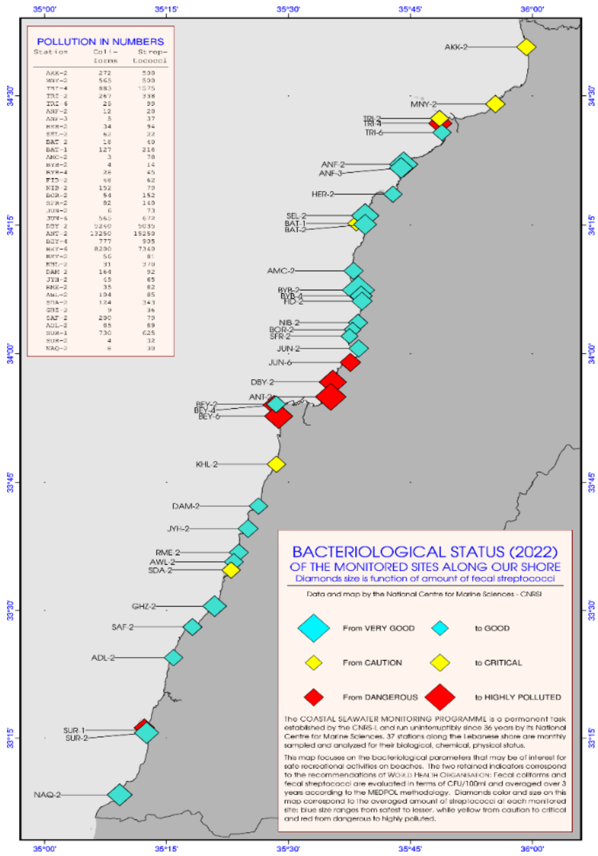
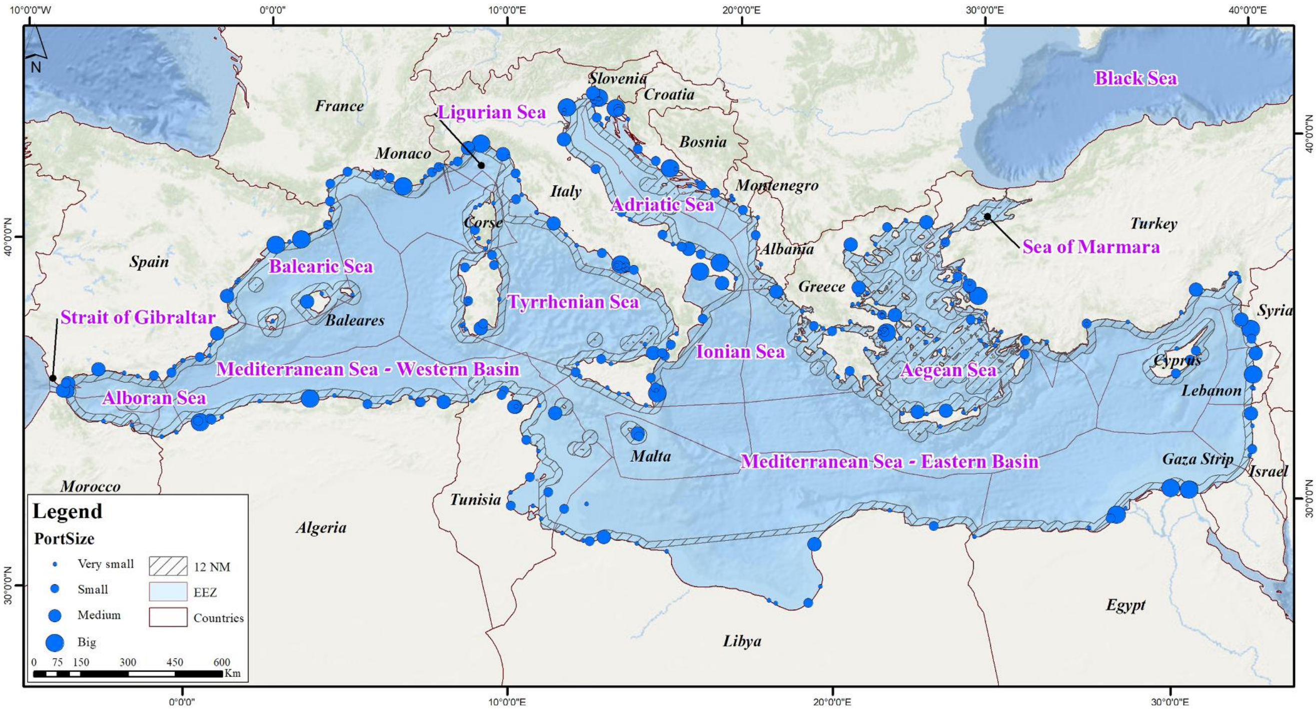


Figure 97. Bathing water quality (2022) based on fecal streptococci concentrations. Source NCMS, Lebanon.

Conventional wastewater treatment does not completely remove and/or inactive viruses; consequently, viruses excreted by the population can be detected in the environment. This study was undertaken to investigate the distribution and seasonality of human viruses and faecal indicator bacteria (FIB) in a river catchment located in a typical Mediterranean climate region and to discuss future trends in relation to climate change. Sample matrices included river water, untreated and treated wastewater from a wastewater treatment plant within the catchment area, and seawater from potentially impacted bathing water. Five viruses were analysed in the study. Human adenovirus (HadV) and JC polyomavirus (JCPyV) were analysed as indicators of human faecal contamination of human pathogens; both were reported in urban wastewater (mean values of 10(6) and 10(5) GC/L, respectively), river water (10(3) and 10(2) GC/L) and seawater (10(2) and 10(1) GC/L). Secondary biological treatment (i.e., activated sludge) and tertiary sewage disinfection including chlorination, flocculation and UV radiation removed between 2.22 and 4.52 log10 of the viral concentrations. Climate projections for the Mediterranean climate areas and the selected river catchment estimate general warming and changes in precipitation distribution. Persistent decreases in precipitation during summer can lead to a higher presence of human viruses because river and sea water present the highest viral concentrations during warmer months. In a global context, wastewater management will be the key to preventing environmental dispersion of human faecal pathogens in future climate change scenarios.

COASTAL POLLUTION HOTSPOTS/SOURCES

Harbours, ports and pollution hotspots.

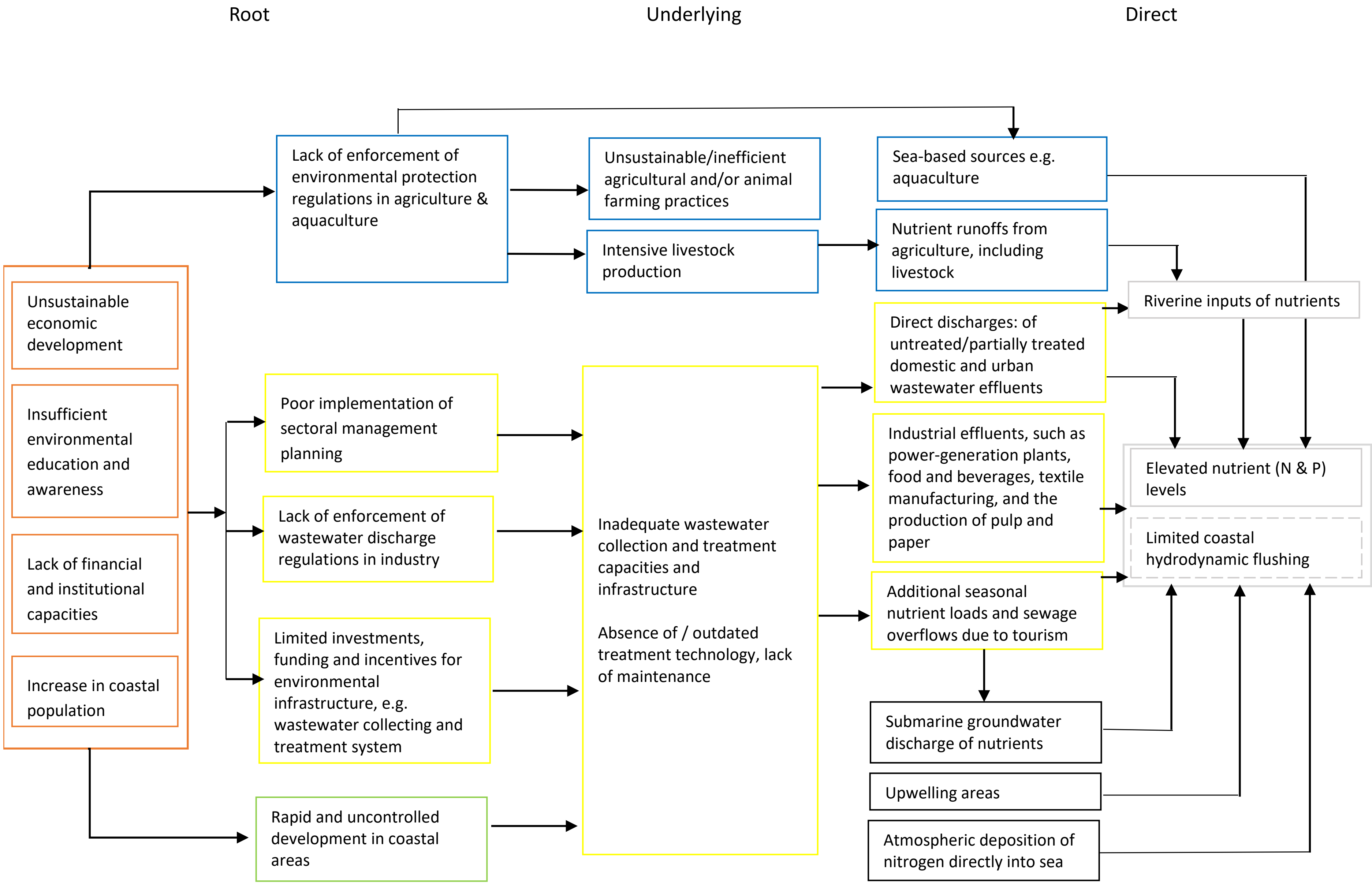


** Polinov et al. Marine Pollution Bulletin 167 (2021)

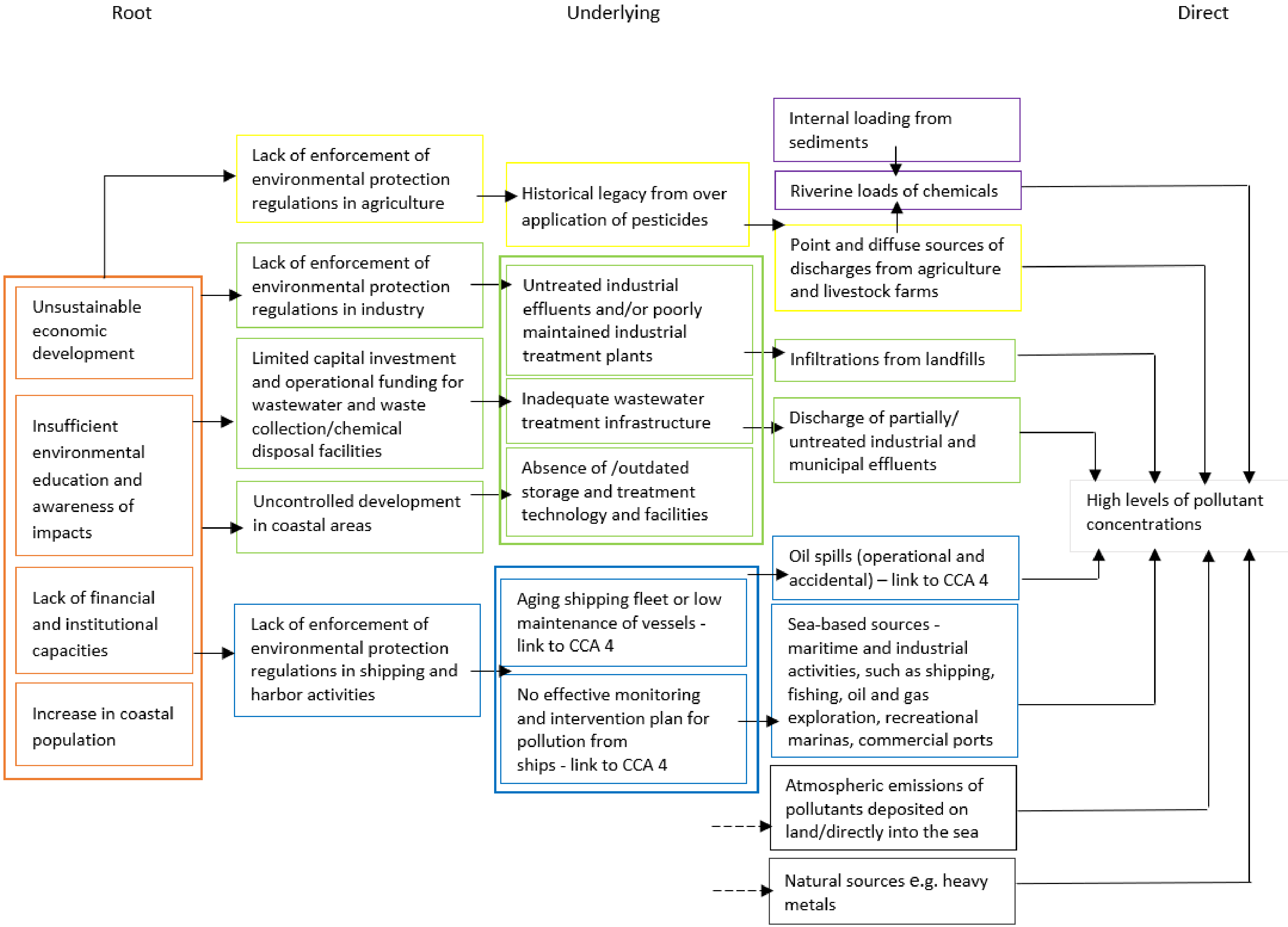
Figure 98. Major port and pollution hotspots in the Mediterranean Sea.

Immediate, underlying and root causes (diagrams)

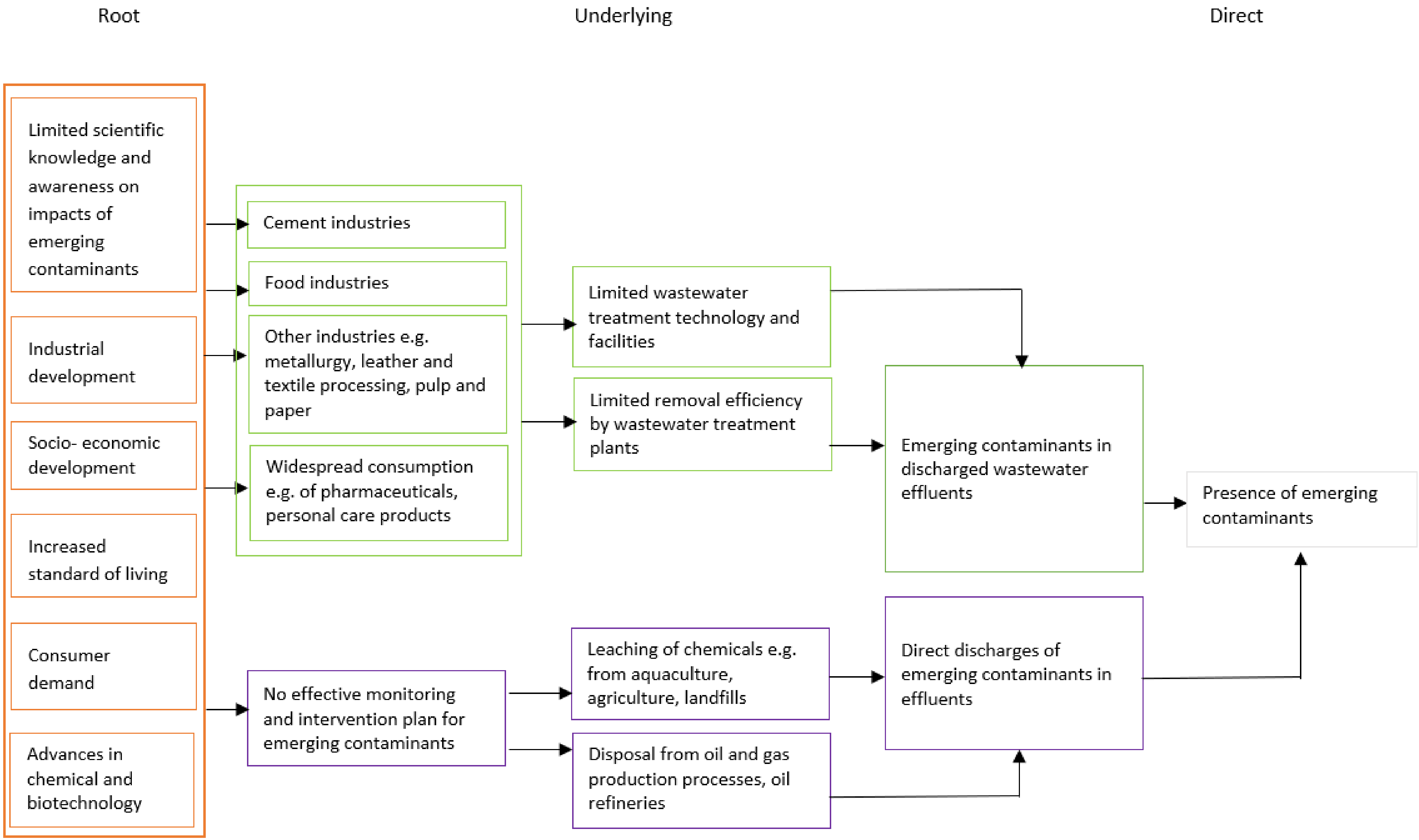
CCA Priority issue 1: Eutrophication



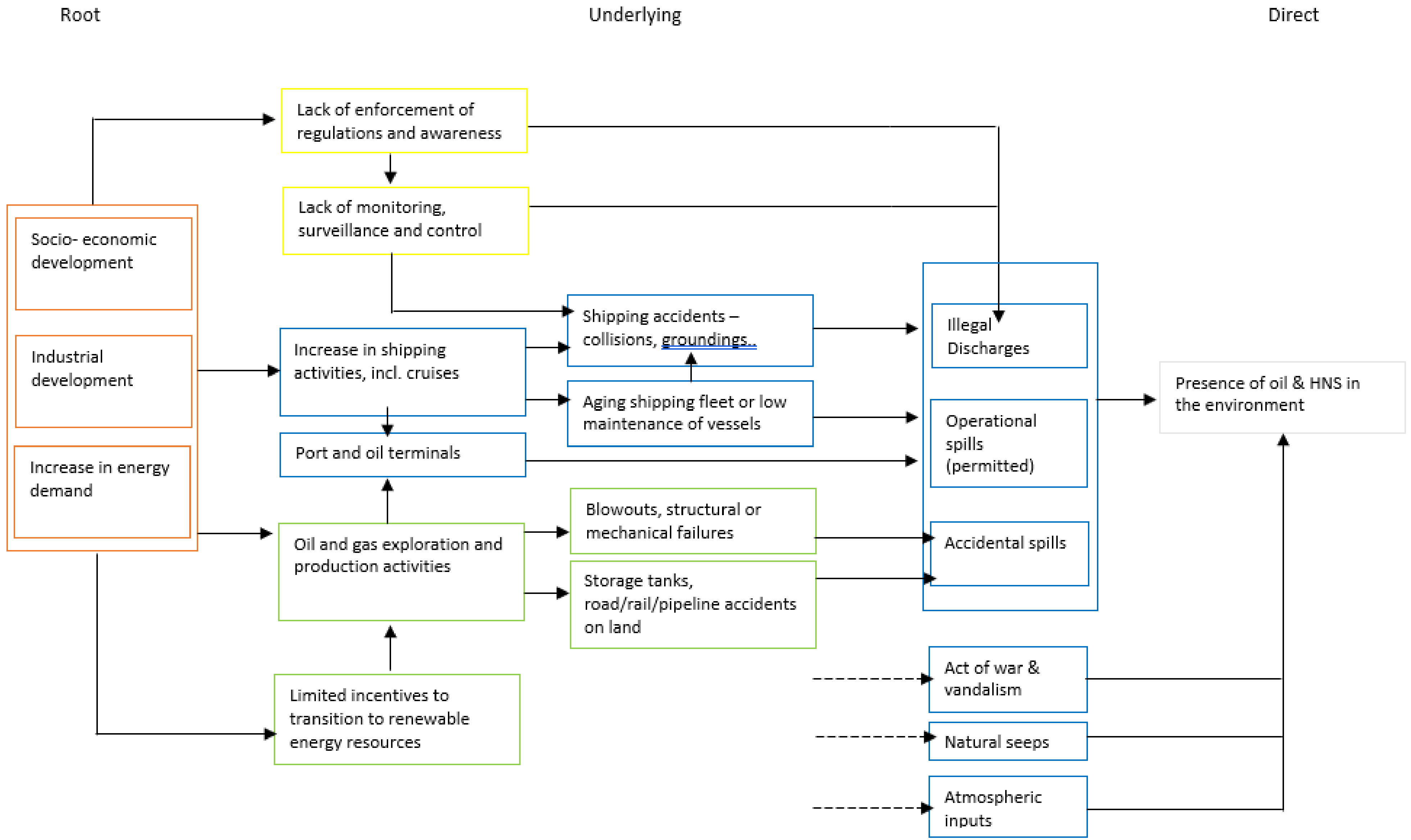
CCA Priority issue 2a: Chemical pollution (legacy chemicals)



CCA Priority issue 2b: Chemical pollution (emerging chemicals)



CCA Priority issue 3: Oil & HNS pollution



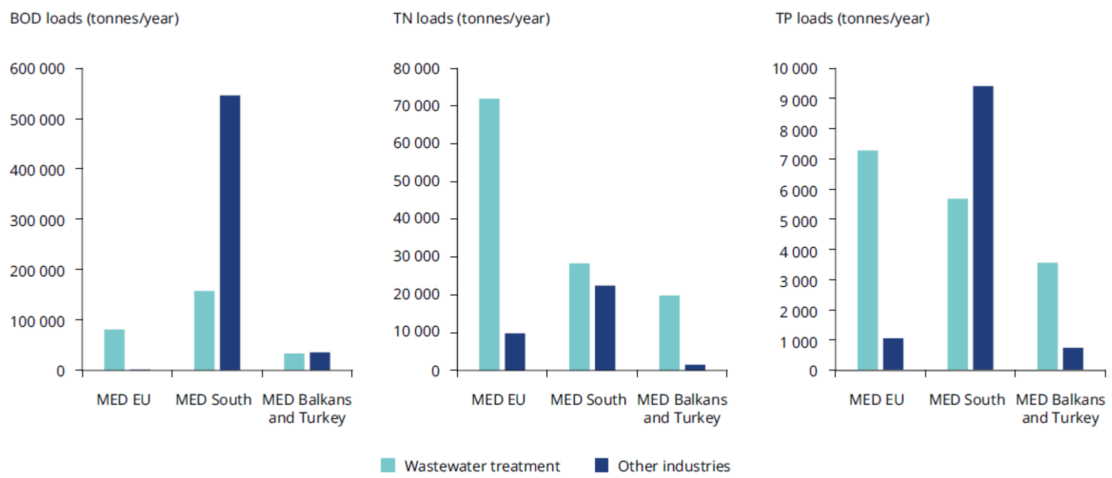
Conclusions and Knowledge gaps

In the Mediterranean, eutrophication is caused by both point sources, such as urban effluents, industrial discharges, and aquaculture activities, as well as non-point sources, namely, transboundary components including agricultural runoffs, riverine inputs, and atmospheric deposition. The direct causes of non-natural eutrophication (ie., commonly anthropogenic point-sources) are elevated nutrients (N and P) and limited hydrodynamics in semi-enclosed and enclosed coastal areas. The non-direct causes of transboundary euthropication are closely linked to biogeochemical processes (and therefore, primary productivity) both in coastal areas and offshore, despite the Mediterranean is characterized by oligotrophy. Multiple activities contribute elevated nutrient levels, grouped as land-based or sea-based sources and either point or diffuse sources. The diverse anthropogenic activities lead to N and P emissions. The key diffuse sources include inputs from agriculture, atmospheric deposition, and mobile sources like shipping, whilst point sources include emissions from municipal treatment plants or sewage outfalls and industrial activities. Although most point sources are land-based, others can be sea-based, such as aquaculture, considered as an emerging sector in the region with prospects for further growth. Some studies indicate that loads of nutrients from diffuse sources, including agriculture, atmospheric deposition, and mobile sources like shipping, commensurate with point sources (Malagó et al. 2019). The causal chain analysis (CCA Priority 1) provides a structured and analytical assessment of the sources and addressing the linkages between land, water, coast and marine. An overview of the main sources and their characterization is shown Table 28.

Table 28. Overview of nutrient sources and their characterization

Sources		Nitrogen	Phosphorus
Land-based	Point sources	Untreated/partially treated domestic and urban wastewater effluents or sewage outfalls	Untreated/partially treated domestic and urban wastewater effluents or sewage outfalls
		Industrial discharges	Industrial discharges
	Diffuse sources	Agricultural runoffs, including livestock	Agricultural runoffs, including livestock
		Riverine inputs (national and transboundary)	Riverine inputs (national and transboundary)
		Submarine groundwater discharge	
Sea-based sources		Aquaculture	
		Upwelling sources	Upwelling sources
	Mobile sources	Shipping	
Other	Diffuse sources	Atmospheric deposition	

Industrial activities, such as power-generation plants, food and beverages, textile manufacturing, and the production of pulp and paper are important sources of nutrients, depending on whether the releases are transferred to the collection system (EEA-UNEP/MAP, 2020). The situation varies between the Mediterranean EU countries, Mediterranean South countries, the Balkans and Turkey (Figure 99). In the Mediterranean EU countries, loads of total nitrogen and phosphorus from wastewater treatment plants (WWTPs) are generally higher than from other industries, amounting to 90 % of total loads (EEA-UNEP/MAP, 2020). In the Mediterranean South region, total phosphorus loads from other industries are higher, probably related to phosphate-mining activities in certain countries.



Note: Data for the MED South and MED Balkans and Turkey are from NBB 2018 reporting; data for the MED EU are from 2017 E-PRTR V17, following extraction of data for Mediterranean coastal river basin districts (RBDs). E-PRTR data only consider UWWTPs of over 100 000 p.e. which means smaller discharges are not included and hence actual loads are higher. Note that BOD loads in MED EU countries are estimated from TOC loads in E-PRTR using the conversion ratio BOD/TOC = 1.68 +/- 0.375, after Dubber and Gray (2010).

Figure 99. Loads of BOD, TN and TP from WWTPs and other industries in coastal areas of the Mediterranean (tonnes/year). Source: EEA and UNEP/MAP (2020)

The level of wastewater treatment varies markedly from country to country due to different water management policies across the Mediterranean region. Based on SDG 6.3.1[66], the safely treated (domestic) proportion (Figure 100) in South countries is below 50 %, except in Algeria (76 %), Israel (93 %) and Tunisia (60 %), and as low as 17 % in Libya. In these countries, most of the wastewater generated is discharged untreated into the Mediterranean. The current political crisis and instability in Lebanon, Libya and Syria have either resulted in the shutting down of wastewater treatment plants or the suspension of constructing new ones. The volume of wastewater discharged untreated into the environment, streams, wadis or directly into the sea was estimated to be around 5 km3 yr-1 (EEA-UNEP/MAP, 2020). In the Southern and Eastern Mediterranean, 44 % of cities with more than 10,000 inhabitants are not served by WWTPs (Plan Bleu, 2021a). This is an important source of nitrogen and phosphorus pollution. In the Mediterranean EU region, most countries safely treat more than 75 % of the collected domestic wastewater, except for Croatia, Cyprus and Slovenia, where 50-75 % is treated safely. In the Balkans and Turkey, the proportion safely treated varies between 50-75 % (Turkey) and 0-50 % (Albania, Bosnia and Herzegovina and Montenegro).

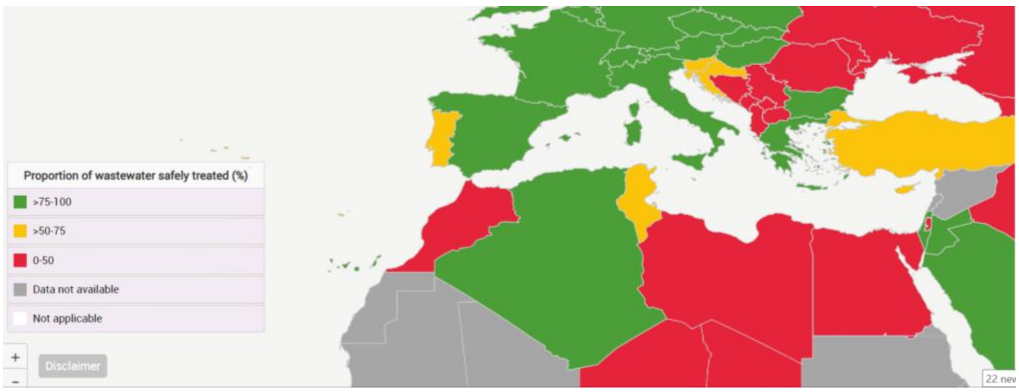


Figure 100. SDG 6.3.1 – Proportion of (domestic) wastewater flow (safely) treated in Mediterranean countries in 2020 (%). Source: https://sdg6data.org/en/indicator/6.3.1

[66] Sustainable Development Goal Indicator 6.3.1: Proportion of domestic and industrial wastewater flow safely treated (%)

There are several challenges that hamper progress on wastewater management around the Mediterranean. Amongst them are limited financial and institutional capacities required to operate and maintain infrastructure that can adequately serve the growing population, in particular in the Mediterranean South countries. These can be considered as major underlying causes to the nutrient enrichment leading to euthropication. Despite continuous efforts and investment in the region to improve wastewater management, the political, financial and institutional crisis faced by certain countries, notably Lebanon, Libya and Syria, has hit the wastewater sector hard. In these countries, several WWTPs are out of operation and the construction of new WWTPs has been discontinued. The European Mediterranean countries face other challenges, such as improving resource and energy efficiency and achieving full compliance with European legislation (EEA and UNEP/MAP, 2020).

In some areas, such as the Nile Delta, the main challenges related to the lack, malfunctioning and maintenance of treatment infrastructure are coupled with an overuse of fertilizers (Figure 101; Plan Bleu, 2021a) and the discharge of the collected runoff into lagoons without prior treatment. Despite key differences between agricultural practices in the North and South, in general the agricultural development model favours an increased consumption of fertilizers and other synthetic crop protection products, and the intensification of the use of land and water resources. The differences in the fertilizer consumption rates between Mediterranean countries are significant, ranging from 6.5 kg per hectare in Syria to 631.3 kg per hectare of arable land in Egypt in 2015 (Figure 101). Nevertheless, the consumption in most countries exceeds the global average of 141 kg per hectare of arable land (World Bank, 2020) pointing towards unsustainable and inefficient agricultural practices. These estimations account for nitrogen fertilizers, potash and phosphate (including natural lime phosphate fertilizers) (Figure 102) but do not include traditional nutrients, such as animal and plant manure. The far greater solubility of nitrogenous salts in fertilizers implies less adsorption onto soil/geological substrates and more leaching of the organic/inorganic nitrogen to groundwater, instead of being exported directly to surface waters.

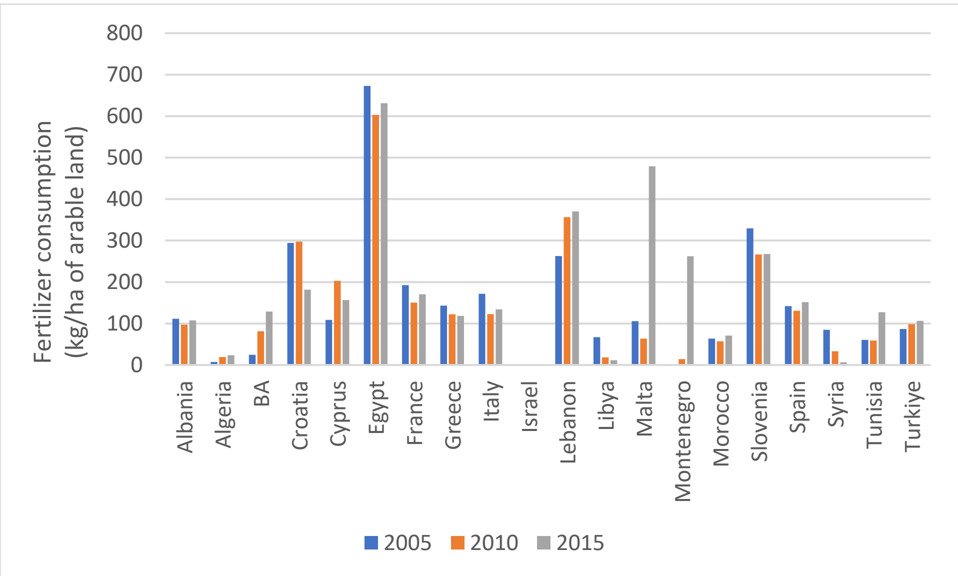


Figure 101. Fertilizer consumption in Mediterranean countries, in kg/hectare arable land, 2005, 2010 and 2015 (latest year available is 2016). Source: FAOSTAT (2022)

Riverine runoff and atmospheric deposition have been traditionally considered the main diffuse sources of nutrients to the Mediterranean Sea. The study by Rodellas et al. (2015) showed that submarine groundwater discharge (SGD) to the Mediterranean Sea should be considered as another major conveyor of dissolved compounds, including inorganic nutrients in particular nitrogen, but also heavy metals, e.g. Hg and rare earth elements. It was estimated that the median annual fluxes of nutrients through SDG were 190, 0.7, and 110·Gmol for nitrogen, phosphorous, and silica, respectively, comparable to riverine and atmospheric inputs (Figure 103: Nutrient fluxes via SGD were calculated by multiplying the estimated SGD flow range by the range of nutrient concentrations in SGD obtained from different studies conducted in the Mediterranean Sea. Dashed lines represent nutrient inputs derived exclusively from fresh SGD. Fluxes from rivers and atmosphere were obtained from the literature). The contribution of groundwater to river flows and to the direct submarine discharges into coastal waters implies that nitrogen from this original source could still make a large contribution to the nitrogen budget even decades after being applied to land.

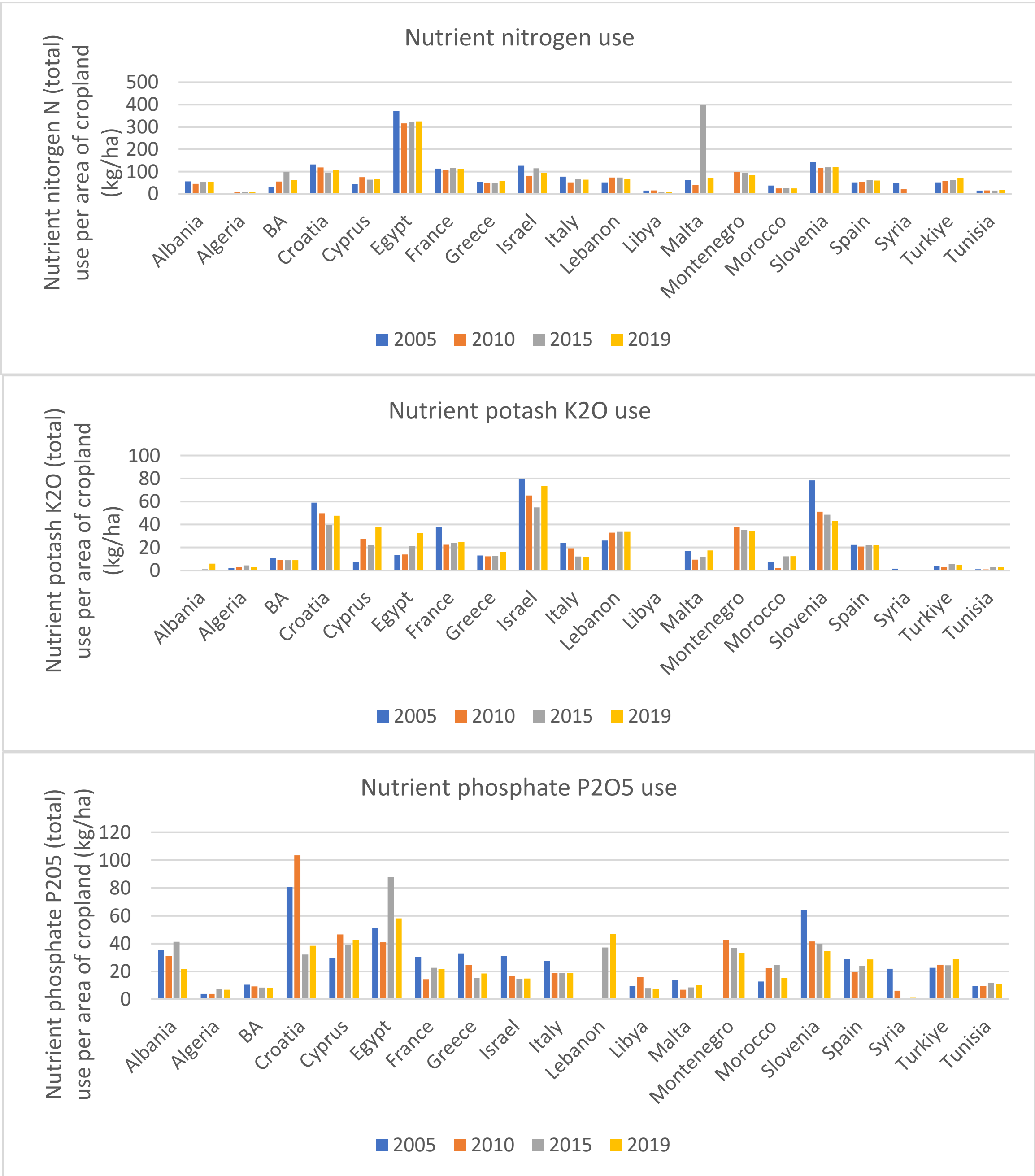


Figure 102. Nutrient nitrogen, potash and phosphate use in Mediterranean countries, in kg/hectare cropland, 2005, 2010, 2015 and 2019 (latest year available). Source: FAOSTAT (2022).

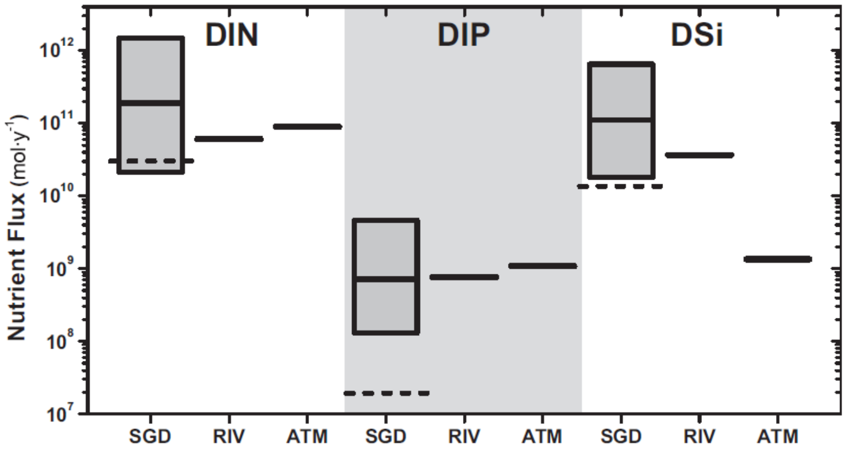


Figure 103. Comparison of nutrient inputs to the Mediterranean Sea derived from submarine groundwater discharges (SGD), rivers (RIV) and atmospheric deposition (ATM). Source: Rodellas et al. (2015).

At the root of the direct and underlying causes of the transboundary pollution issues are unsustainable economic development, insufficient environmental education and awareness, lack of financial and institutional capacities and the increase in coastal population. These root causes and systemic socio-economic drivers are common to the other CCAs and are analyzed in more detail in Chapter 3 addressing economic drivers and socio-economics aspects.

The sources of contaminants can be of natural origin (e.g., heavy metals) or synthetic man-made chemicals (e.g. pesticides). Chemical contaminants enter the marine ecosystem through different routes, such as inputs from land- and sea-based sources and atmospheric deposition (CCA Priority Issue 2a and 2b). The land-based sources of contaminants impacting the coastal environment represent a major input and enter both via treated and non-treated wastewater point-source discharges as mentioned. Small recreational marinas up to major commercial ports along the Mediterranean coast also constitute an important source of chemical pollution. In terms of diffuse pollution sources, river run-off and atmospheric deposition (wet/dry deposition and diffusive transport) are the two major contributors to the coastal areas. Sea-based sources include direct inputs from maritime and industrial activities, such as shipping, fishing, oil refining, oil and gas exploration and exploitation. Oil-related activities could be permanent chronic sources of pollution in the marine environment, as well as potential sources for acute pollution events (see Priority issue 4: Oil & HNS pollution).

Most Mediterranean countries have an important public industrial sector which is composed of large industries, such as energy production, oil refineries, petrochemicals, basic iron and steel metallurgy, basic aluminum metallurgy, fertilizer production, paper and paper pulp, and cement production. Distinctive chemical categories are produced from different sources and activities. An assessment of the sources and loads from industrial activities was carried out in EEA-UNEP/MAP (2020) by combining the reporting by Mediterranean EU countries under the European Pollutant Release and Transfer Register (E-PRTR) regulation and National Baseline Budget (NBB) reporting by Mediterranean non-EU countries (Mediterranean South; Balkans and Turkey). Although reporting coverage was incomplete, with a number of data gaps, it provided insightful information on the main sources of chemical pollution sources from industrial activities.

Heavy metal emissions from the energy sector dominate in the Mediterranean EU countries (Figure 104), whereas the manufacturing of refined petroleum products present the key sources in the Mediterranean South countries, the Balkans and Turkey. Generally speaking, loads of heavy metals are highest in the Mediterranean South countries (Figure 105).

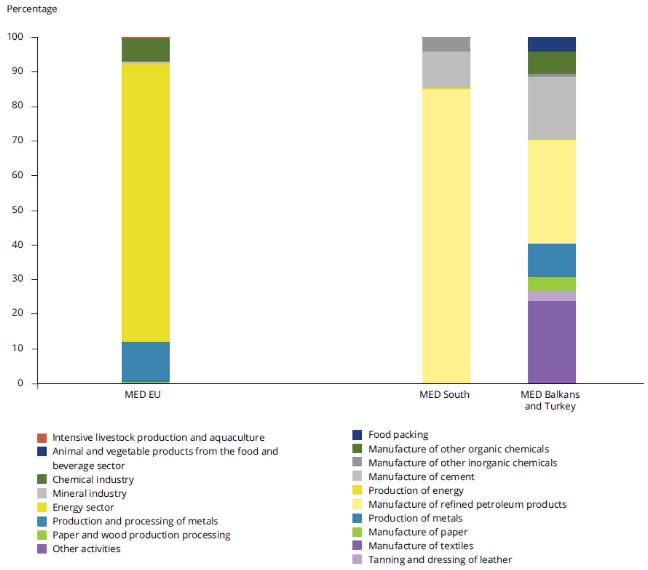
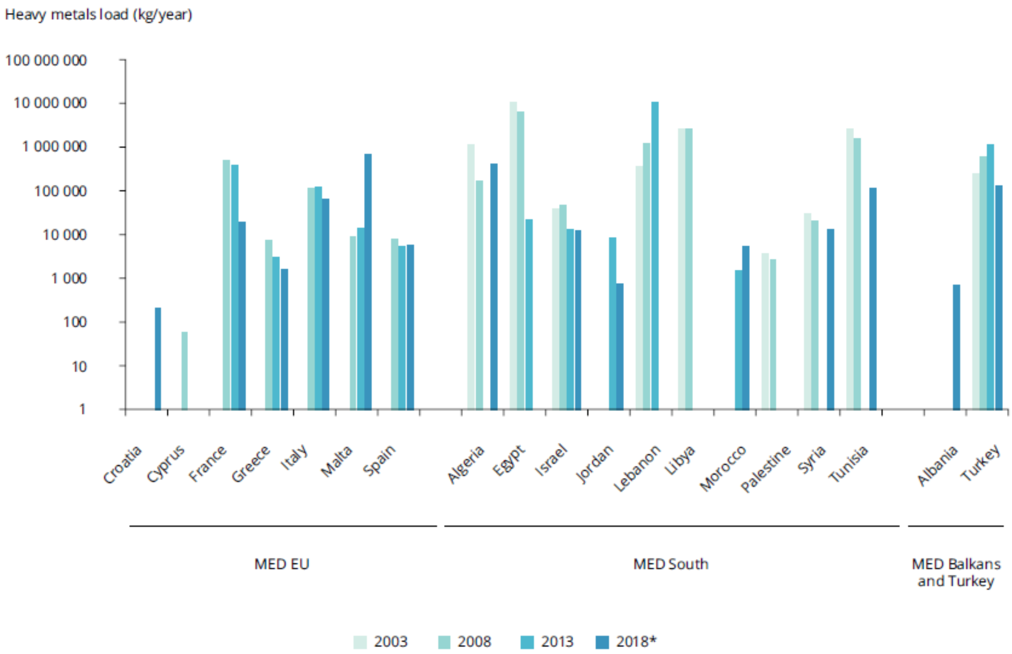


Figure 104. Percentage distribution of heavy metal loads by industrial sector discharged directly or indirectly into water. Note that the list of legends on the left refers to the E-PRTR sectors; to the right to the NBB sectors. Source: EEA-UNEP/MAP (2020).



Note: Datasets plotted in logarithmic scale. *For MED EU, year 2017.

Sources: NBB Reports — 1st to 4th Cycles: NBB, 2003, 2008, 2013, 2018, E-PRTR V17; EEA (2019f).

Figure 105. Cumulative loads of heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) for the industrial facilities in the Mediterranean countries from industrial sectors, discharged directly or indirectly into the environment. Source: EEA-UNEP/MAP (2020)

According to the analysis presented in EEA-UNEP/MAP (2020), Albania reported five industrial facilities discharging heavy metals which are manufacturers of cement (Albania NBB, 2019); Bosnia and Herzegovina reported a single energy production facility and around 10 cement manufacturing plants as the main contributors to releases of heavy metals (Bosnia and Herzogovina NBB, 2019); in Israel, two fuel-manufacturing facilities and nine thermal-power-generation plants release most heavy metals into water (Israel NBB, 2019); in Lebanon, heavy metals are released mainly by 21 thermal-power-generation plants and other combustion installations, as well as 8 mineral industries that produce cement clinker in rotary kilns (Lebanon NBB, 2019); and in Tunisia, five relatively large cement manufacturing plants are reported to produce heavy metals (Tunisia NBB, 2018).

PCBs, PCDD/Fs are widespread POPs with different environmental sources. PCBs are legacy industrial chemicals used in many applications (e.g. lubricants, fire resistant transformers, heat exchanger fluids, dielectric fluids, plasticizers, adhesives, chemical stabilizers in paints, insulating materials, flame retardant, aluminum, copper, iron and steel manufacturing processing, natural and synthetic rubber products). PCDD/Fs can occur as unintentional by-products in a number of industrial processes and domestic heating. The major primary sources for these two families of legacy POPs are considered under control in most parts of the world today, including the Mediterranean region. Yet, ongoing primary releases from diffuse sources, such as open fires and uncontrolled waste incineration, urban/industrial centres, as well as secondary sources, such as net re-emissions from environmental reservoirs, are still possible. Although their production ended in the late 1970s, the majority of the cumulative world production of PCBs are still in the environment. PCBs are often found both in the effluent and in the sludge of municipal wastewater (Merhaby et al., 2019). Data on PCDD/Fs discharges is limited with significant data gaps, making it difficult to determine the trends at the Mediterranean level (EEA-UNEP/MAP, 2020).

PAHs naturally contained in oil and petroleum products can be also formed during pyrogenic processes (e.g., fossil fuel combustion, forest and prairie fires) and as by-products of industrial processes. On average, PAH emissions to air in 2018 varied from 50 kg to 500 kg per year, with the exception of Algeria which reported over 60 000 kg per year. Similar to other contaminants, data on PAH discharges at the regional level is limited (EEA-UNEP/MAP, 2020).

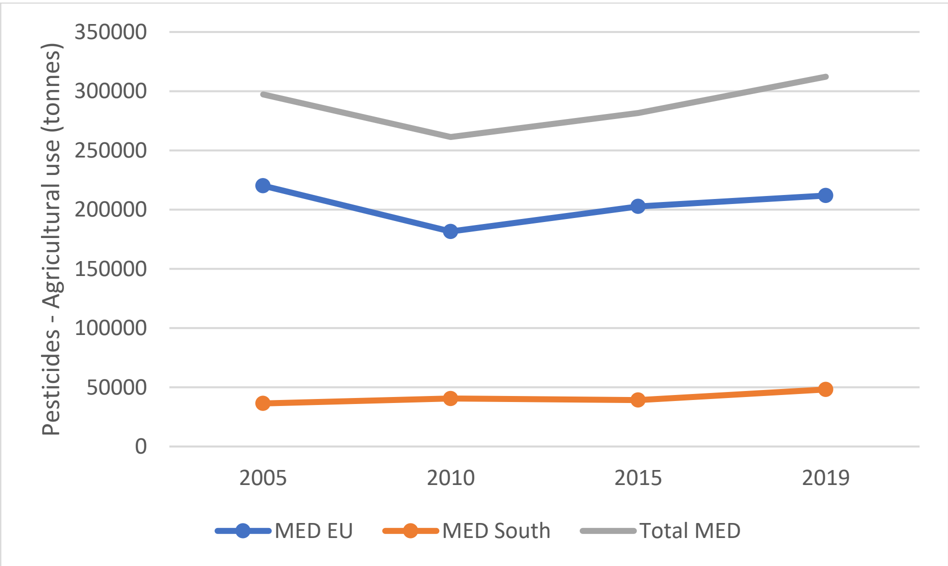


Figure 106. Pesticide use in Mediterranean EU countries (Croatia, Cyprus, France, Greece, Italy. Malta, Slovenia, Spain), Mediterranean South countries (Algeria, Egypt, Israel, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia) and Total MED (Mediterranean EU countries, Mediterranean South countries, Albania, Montenegro and Türkiye) in 2005, 2010, 2015 and 2019 (latest year available). Source: FAOSTAT (2022)

When it comes to pesticides, their use varies widely between Mediterranean countries, with marked differences between Mediterranean EU and South countries (Figure 106). In most Mediterranean countries, pesticide use per area of cropland exceeds the average global consumption of 1.81 kg/ha, by up to ten-fold in some cases, pointing towards industrial agricultural practices and a historical legacy from pesticide overapplication. Since 2005, a clear increase in pesticide use has been observed in some countries, such as Cyprus, Egypt, France and Spain, whereas others such as Israel, Italy, Malta and Slovenia have recorded a decreasing trend. The quantification of pesticide export from catchments is challenging since pesticides degrade through chemical, physical or biological processes and transform into other compounds, which may be more prone to leaching and bioaccumulation.

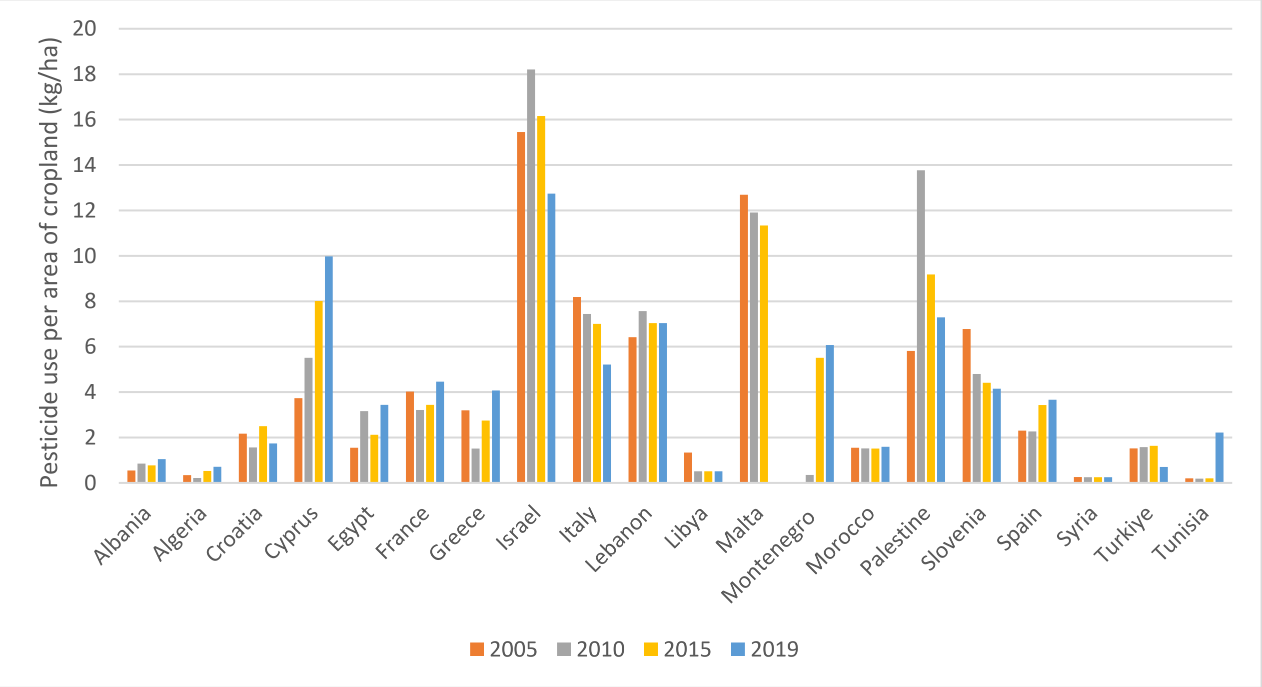


Figure 107. Pesticide use per area of cropland in Mediterranean countries, in kg/hectare, 2005, 2010, 2015 and 2019. Source: FAOSTAT (2022)

River discharges are another major source of chemicals in the marine environment. These could include loads of historical pollutants from river sediments (i.e., internal loading) and loads from diffuse sources seawards (e.g. from agriculture, direct industrial and municipal discharges to rivers). Data of chemical loads from rivers to the Mediterranean Sea are not readily available. Higher river flows are often associated with higher concentrations of chemical pollutants, so higher flows tend to deliver disproportionately higher levels of many chemical pollutants (BSC, 2017). This leads to considerable uncertainties associated with chemical load estimations of chemical pollutants, especially POPs. Values may differ wildly from year to year, subject to the exact sample locations and the hydrographic and weather characteristics of the catchment areas on a yearly basis. Internal loading through release/desorption from contaminated sediments is another source to both riverine chemical loads to coastal and marine areas. Sediment dredging, bioturbation and wind-induced mixing could lead to such internal fluxes, which may be important locally. No data are available to make such an assessment within the transboundary context.

A second CCA Priority Issue 2b, was elaborated for the chemical category of emerging contaminants. While the root and underlying causes of legacy chemical pollution are like the systemic factors identified for the first issues, the emerging contaminants may be driven by slightly different causes. Two key pathways are identified through which emerging contaminants enter into the environment. A number of emerging contaminants are incorporated into products used or ingested by humans, namely, pharmaceutical and personal care products (PPCPs) (e.g., cosmetic products, UV filters, non-steroidal anti-inflammatory drugs, antibiotics, beta-blockers, bactericidal and antifungal agents) and are discharged into the environment via the domestic wastewater. Further, industrial processes, such as energy production (drilling fluids, nanoparticles, mercury), food industries (food additives, plasticizers), metallurgy including organic metals (metals), chemicals and plastic production (plastic additives, nanoparticles, etc.), leather and textile processing (microplastics, metals, flame retardants), the cement industry (metals, fuel residue), the pulp and paper industries (metals) etc. may also produce molecules and metabolites that are not sufficiently treated at product end-of-life and end up in the environment. The removal efficiencies of WWTPs are highly variable because of the different physicochemical chemical properties (chemical structure, pKa, logKow, biodegradability, sorption) and the operating parameters of the treatment facilities (hydraulic/sludge retention time, temperature, pH). This represents a main pathway into the environment in developed countries. Conventional wastewater treatment plants are not designed to remove these contaminants and even where tertiary treatment is in place, removal is limited. The Table 31 list some sources for chemical categories of concern, including CECs.

Table 29. Overview of sources of emerging pollutants. Source: Plan Bleu (2021b)

Categories	Sources
Polycyclic aromatic hydrocarbons (PAHs)	Found in asphalt used in road construction, medicines, dyes, plastics, and pesticides. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar
Pesticides	Agricultural run-off and urban green spaces and parks (include herbicides and insecticides)
Environmental oestrogens	Synthetic chemicals found in food, animals and plant products and some household items
Phthalates	Industrial chemicals used to soften PVC plastic and as solvents in cosmetics and other consumer products
Pharmaceuticals	Introduced through sewage from households with patients using drugs
Personal Care Products	Health, beauty and cleaning products
UV filters	Found in sunscreen and other topical products
Flame retardants	Used as coatings
Disinfection by-products	From household and domestic, hospital and industry waste

A second pathway refers to the direct inputs from industrial activities, including shipping (sewage sludge, operational residue of antifouling agents and hydrocarbons), oil and gas production and oil refineries (petroleum and by-products of the production processes), aquaculture and agriculture (pesticides, fertilizers, pharmaceuticals) and landfill leachates regarding chemicals listed under the CECs categories.

Despite some of these groups were identified in earlier policy discussions at Mediterranean level (e.g., SAP-MED), these are of emerging concern and the complete lifecycle assessment in all the water-systems have only been successful for a few of them, whilst the majority remains as a data gap and should be assessed altogether with their occurrences through environmental monitoring, including the marine environment (i.g. IMAP).

Pharmaceuticals make up an important category of emerging contaminants. Due to their widespread consumption and limited removal efficiency by WWTPs, the presence and spread of pharmaceuticals in the environment have increased extensively, quantified at concentration levels of $ng \cdot L^{-1}$ to $\mu g \cdot L^{-1}$ in sewage waters and various receiving water bodies, such as freshwater, groundwater, drinking water resources and seawater (Desbiolles et al., 2018 and references therein). This is also because the Mediterranean basin is characterized by distinct differences in related factors, such as demographics, economic development and industrialization, wastewater treatment level, disposal and reuse, and pharmaceutical manufacture and prescription (Kookana et al., 2014). Some of the Mediterranean European countries, such as France and Italy rank in the top 5 pharmaceutical producers in Europe[67]. Others, such as Greece, France, Italy and Spain are amongst the major consumers of pharmaceuticals[68]. Compared to high income countries, lower income countries consume less by value of the world's medicines but have higher rates of over-the-counter self-medication and of occurrence of infectious diseases (Segura et al., 2015). The occurrence of pharmaceuticals, such as lipid regulators, antidiabetics and antihistamines, can be related to their prescription rates. For other classes of compounds, e.g. analgesics, prescription rates are not a reliable source, as mostly are sold over the counter or occurring naturally in wastewaters through human metabolism e.g. hormones (Desbiolles et al., 2018 and references therein).

On the other hand, chemical pollution related to sources of oil pollution in the Mediterranean Sea include shipping, oil and gas platforms, ports and oil terminals, land-based sources, military conflicts, natural oil seeps and atmospheric inputs. The actual volume of oil entering the Mediterranean Sea annually is unknown, particularly when land-based, atmospheric and natural seep sources are also taken into account. As shown in Kostianoy and Carpenter (2018), estimates of volumes of oil vary widely:

- According to the MED QSR 2017 report (UNEP/MAP, 2017), between 1994 and 2013, 32 000 tonnes of oil entered the Mediterranean Sea as a result of accidents. This included 13 000 tonnes from an incident at the Jiyeh power-plant in Lebanon in July 2006
- The estimate by UNESCO (2003) indicated as much as 400 000–1 000 000 tonnes a year; half coming from routine ship operations and the remaining half from land-based sources via surface runoff
- Other estimates suggest volumes around 15 000 tonnes/year (Cucco and Daniel, 2018) or 63 360 tonnes/year (Girin and Daniel, 2018)
- Different expert reports and estimates provide total volumes of oil pollution ranging from 1600 to 1 000 000 tonnes per year, if major oil spill accidents from ships are excluded.

These differences imply that actual volumes of oil pollution entering the Mediterranean Sea is still uncertain. Also, there is no information available on the contribution of the different vessel types, such

[67] https://pharmaboardroom.com/articles/top-5-pharma-producers-in-europe/
[68] https://www.statista.com/statistics/266141/pharmaceutical-spending-per-capita-in-selected-countries/

as tanker, cargo, container, fishing, leisure, cruise and defense fleets to the total input of oil in the Mediterranean. The same applies to offshore oil exploration and exploitation activities.

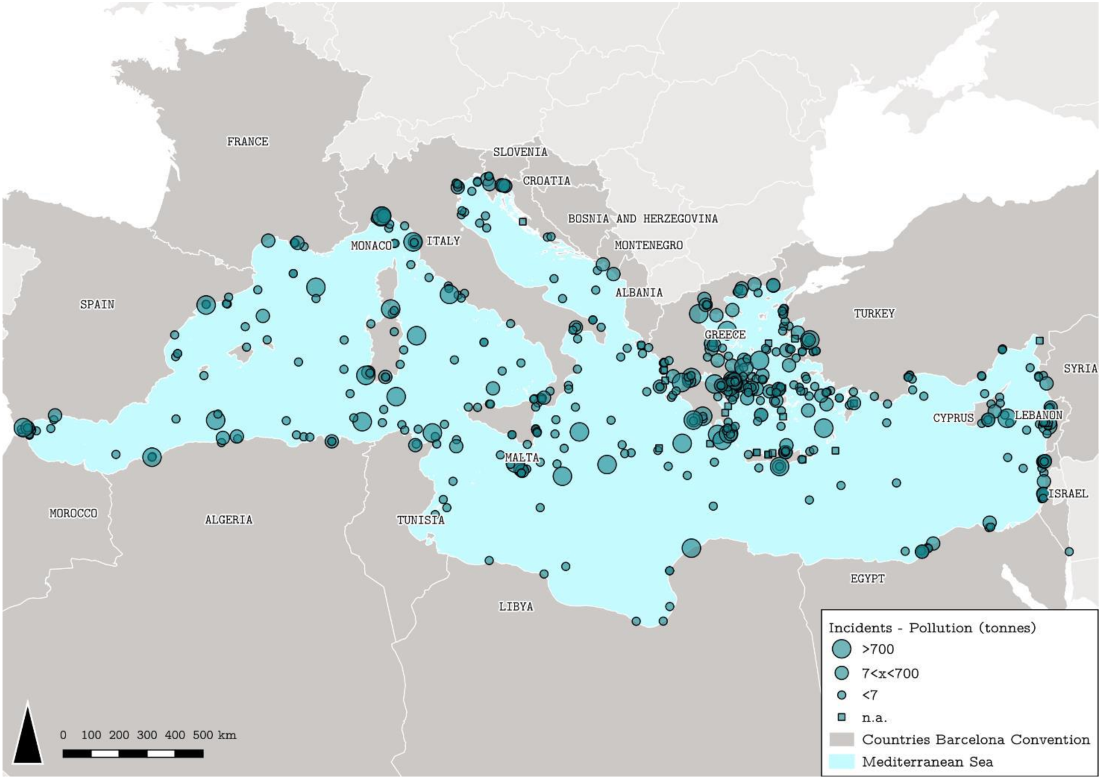


Figure 108 Map of accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by classes of pollutant volumes. Source: REMPEC (2020). Data source: REMPEC MEDGIS-MAR.

The CCA for oil and HNS pollution identifies three types of spills which represent the main direct sources of oil pollution: accidental, operational and illicit. In the Mediterranean Sea, the major source of oil pollution is from shipping while oil and gas production and exploration are relatively less important when compared to other areas in the world, like the Gulf of Mexico, Caspian Sea, North Sea and Arabian Sea. The detailed map of pollution incidents in the Mediterranean Sea (Figure 109) and a list of major oil spills due to ship accidents between 1966 and 2017 (Table 32).

The regional overview of incidents shows that causalities involving small volumes of oil and other pollutants are still numerous in the Mediterranean Sea and require continuous monitoring and reporting. Most of the incidents occur near the coast, in particular close to major ports and anchoring areas, whereas fewer incidents occur offshore. These include 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. The Aegean Sea, one of the busiest areas of the Mediterranean as the shipping route connecting to the Black Sea, is subject to a high concentration of incidents. During 1966-2017, the total amount of oil spilled from major incidents accounted for 537 600 tons. Although the majority of larger oil spills in the Mediterranean Sea occurred before 1981 (Kostianoy and Carpenter, 2018), the biggest ever event in the Mediterranean occurred in 1991 when the MV Haven split 144 000 tons oil spill in Genoa, Italy.

Table 30. List of major oil spills due to ship accidents occurred in the Mediterranean between 1966 and 2017. Source: REMPEC (2020) based on information from Kostianoy and Carpenter (2018)

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

Since 1970, statistics for the frequency of spills greater than 7 tonnes from tankers have shown a marked downward trend (Figure 109). The average number of spills per year in the 1970s was approximately 79, down by over 90 % to 6 in the 2010s and remained at a similar level for the current decade. 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 (UfM, 2017; UNEP/MAP and Plan Bleu, 2020), by virtue of the international regulatory framework adopted through International Maritime Organization and cooperation activities at the regional level (UNEP/MAP, 2017). The HNS accidentally spilled have also considerably decreased during the period 1994-2013 and have become insignificant since 2003 (UNEP/MAP and Plan Bleu, 2020).

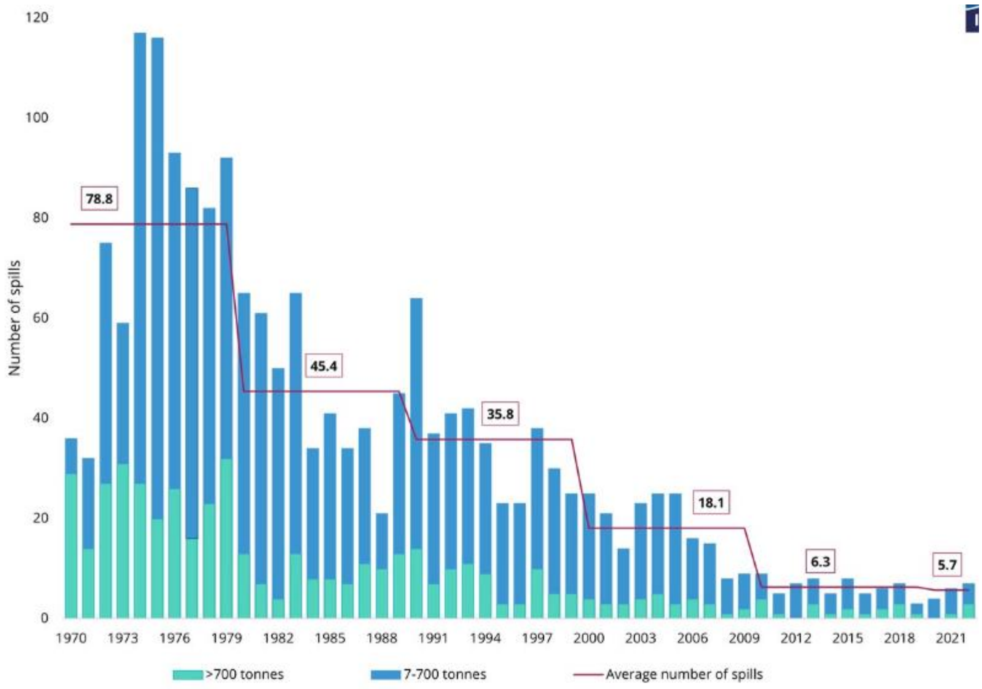


Figure 109 Number of medium (7-700 tonnes) and large (>700 tonnes) tanker spills, 1970-2022. Source: Oil Tanker Spill Statistics (https://www.itopf.org/knowledge-resources/data-statistics/statistics)

The causes oil spills (> 7 tonnes) are allisions/collisions (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 %) (Figure 110).

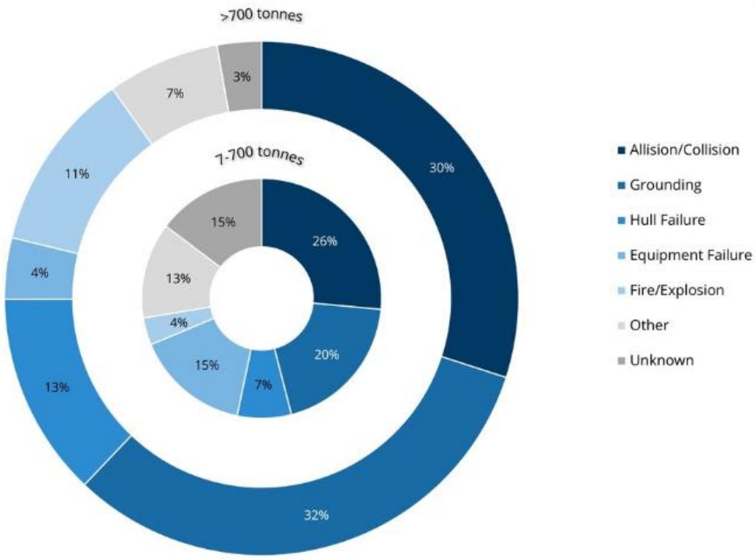


Figure 110 Causes of tanker spills, 1970-2022 (https://www.itopf.org/knowledge-resources/data-statistics/statistics)

Specifically in the Mediterranean Sea, a different accident typology is considered in MEDGIS-MAR database maintained by REMPEC (Figure 111) that also considers accidents other than shipping. The largest number of cases are classified as others (41 %) and include accidental discharges, illegal discharges (5 %), incidents during bunkering operation, leaking from land, generic mechanical damages, war operations and a high number of unknown causes. The most frequent causes of maritime incidents involving shipping relate to grounding (17 %), foundering (11 %) and collisions (9 %). Other accident types considered are oil and gas leaks (9 %), which can be due to accidental discharges, tank overflow, pipelines leakages and other typologies of undefined cases.

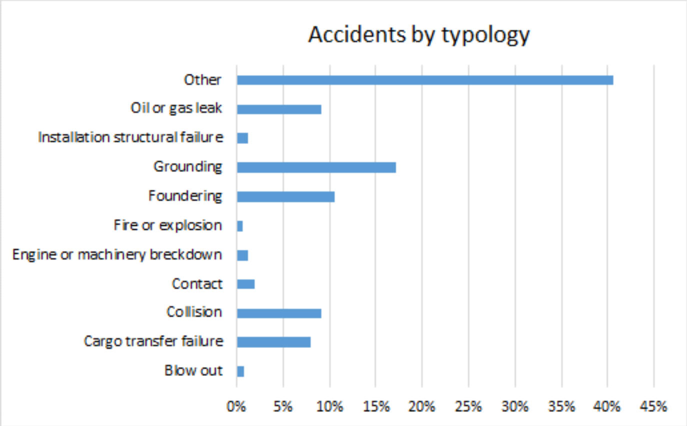


Figure 111 Accidents causing pollutant release to the Mediterranean in the period 1977-2018, categorized by typologies. Source: REMPEC (2020). Data source: REMPEC MEDGIS-MAR

With respect to offshore installations, accidental spills 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 and Hanke, 2016).

Despite the clear reduction of accidental and acute pollution events, continuous chronic oil pollution from operational discharges remains an issue. Operational discharges relate to ship-based pollution and represent a source of oil pollution and other contaminants. Vessel-related operational pollution includes releases of bilge water from machinery spaces and ballast water of fuel oil tanks. When made in compliance with MARPOL convention requirements, operational spills are considered legal. They are voluntary and individually small (less than 10 tons). Although environmental regulations for these operations are quite strict, operational discharges are still detected and have a common practice, representing the main source of marine pollution from ships and a major problem in the Mediterranean region.

The map of oil spills detection by satellite for 2016 (Figure 112) shows a clear correlation between detected oil spills and 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. Other characteristic routes include 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 (Greece) and Barcelona (Spain) ports. Kostianoy and Carpenter (2018) estimated that such discharges account up to an annual 1 500-2500 oil spill events in the basin, and to a total volume of 1 600 to 1 000 000 tons of oil per year. This very large range and uncertainty is not a peculiar characteristic of the Mediterranean basin but affects other regional seas as well.

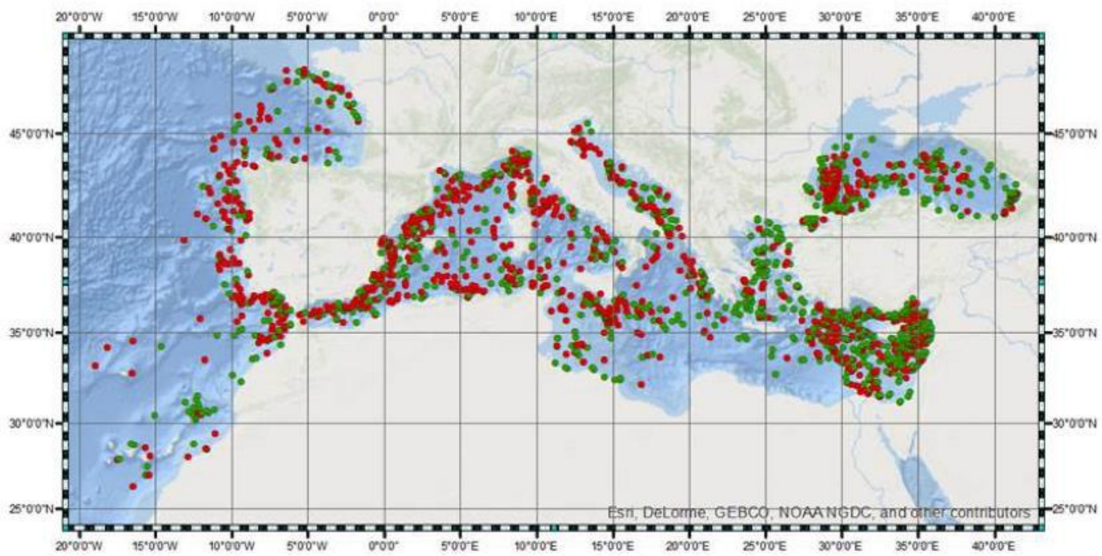


Figure 112 Spills detected in 2016 by satellite Class A (red dots on the map): the detected spill is most probably oil (mineral or vegetable/fish oil) or a chemical product. Class B (green dots on the map): the detected spill is possibly oil (mineral/vegetable/fish oil) or a chemical product. Source: UNEP/MAP (2017)

Offshore operations, such as the oil and gas exploitation present another source of chemical pollution to the marine environment from operational discharges in the drilling fluids and produced water. The quantity and composition of such discharges is largely unknown. 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. The drilling fluids circulated through the well hole contain toxic materials (including oil/grease, arsenic, chromium, cadmium, lead, mercury, and naturally occurring radioactive materials). The composition of drilling muds and produced waters varies widely depending on location and depth of well; and type of drilling fluid. Produced water, produced in oil and/or gas production operations, is a combination of formation water, condensation water and re-produced injection water; it also includes water used for desalting oil. Produced waters potentially impacting the surface or groundwater are typically disposed of in deep aquifers, but there is still the threat of accidental release from temporary storage. Produced waters represents the largest waste stream generated in the offshore production activities, in both volume and quantity of pollutants.

Apart from offshore installations, ports and oil terminals present a potential risk of oil pollution. More than 17 major oil ports and 15 refineries are found along the coasts of the Western Mediterranean, especially along the Italian and Spanish coasts. Algeria, one of the top three oil producers in Africa, has six coastal terminals for the export of petroleum products in Oran, Arzew, Algiers, Bejaia, Skikda and Annaba, and five oil refineries (three in coastal cities – Skikda, Arzew and Algiers) located along its coastline (Benmecheta et al., 2016). These represent a potential source of oil pollution on the southern shore of the Western Mediterranean Sea.

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.

When not in compliance with MARPOL convention requirements, operational spills are considered illegal/illicit. Such discharges from routine ship operations are among the main sources of oil pollution in the marine environment. Quantitative estimations of illicit discharges and related volumes show large differences and a high uncertainty (REMPEC, 2020). According to Kostianoy and Carpenter (2018), the estimated volume of oil illicitly discharged into the Mediterranean Sea every year ranges between 50 000-100 000 tons. Illicit discharges of oil, oily mixture and other HNS from ships occur at any time and from any location to the sea, making remote sensing and satellite imagery the only pragmatic monitoring tool for spill evaluation. The potential risk of large oil spills and consequential pollution therefore remains an important issue, with deliberate (operational and illicit) discharges posing a greater long-term threat to the marine environment than a single catastrophic incident. Yet, surveillance and monitoring of illicit discharges remain critical issues and major gaps, resulting in limited structured data to quantify the issue and reconstruct historical trends. Other shortcomings include discharges that are legally permitted due to the application of improper standards, either on a local or international scale. Collectively, these causes can be grouped under the root causes of lack of regulation, enforcement and environment awareness.

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4.2.2. Stopping litter (environment)

A special attention to marine litter due to the global environmental impacts and socioeconomic consequences was found necessary and were identified as transboundary issues and supported by the regional thematic assessment *(Pollution transboundary causality assessment report – contribution to the UNEP/MAP GEF TDA Report update by 2023)* and scientific research. The marine litter problem is colossal and highly complex, and yet becomes more difficult to manage as the impacts and solutions largely depend on litter sizes. As a consequence, the transboundary issues were approached as follow:

Priority issue 4: Marine litter and microplastics

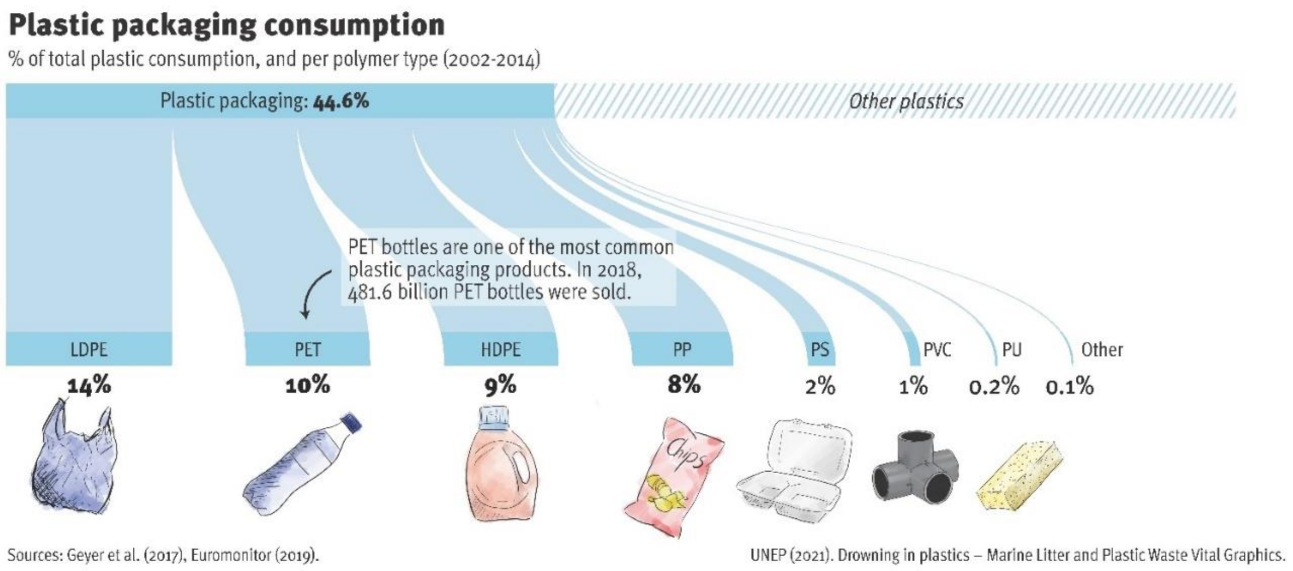
Priority issue 5: Nanolitter, chemicals leaching and toxicants

Priority issue 4: MARINE LITTER AND MICROPLASTICS (WASTES)

Description of the problem and its transboundary importance

Because of its distinguishing semi-enclosed morphology, densely populated coastline, and different surrounding plastic waste-generating activities, the Mediterranean Sea is highly vulnerable to marine litter and microplastic pollution. It is often suggested that the Mediterranean Sea is a marine environment with one of the highest levels of plastic pollution worldwide (e.g. Lebreton et al., 2012). The distribution of plastic debris in terms of abundance, mass and size at the surface of the Mediterranean Sea is uneven and marked by regional differences. Model simulations showed that despite regional and seasonal differences, the amount of transboundary litter in Mediterranean countries could be as high as 30 %. Areas of very high and low abundance reflect the high temporal and spatial variability of the currents. Yet, the Mediterranean Sea lacks permanent accumulation zones. Although various figures can be found in literature, recent estimates indicate that the Mediterranean Sea receives between 150 000 and 610 000 tonnes of plastics each year (average 229 000 tonnes), 94 % of which is microplastic debris and 6 % microplastics (Boucher and Bilard, 2020).

Microplastics are a ubiquitous and dominant constituent of beach litter. Higher microplastics presence is generally related to areas under high anthropogenic pressure and proximity to land-based sources. Hydrodynamic conditions and wind-driven processes influence the redistribution of microplastics, even far from their sources. An overall representation of microplastic pollution in the Mediterranean Sea is shown in Figure 113. Marine litter and microplastic pollution in the Mediterranean are a confirmed critical issue (UNEP MAP, 2015). Almost all the world's oceans and seas are contaminated with microplastics but the Mediterranean Sea has been recognized as a target hotspot of the world.



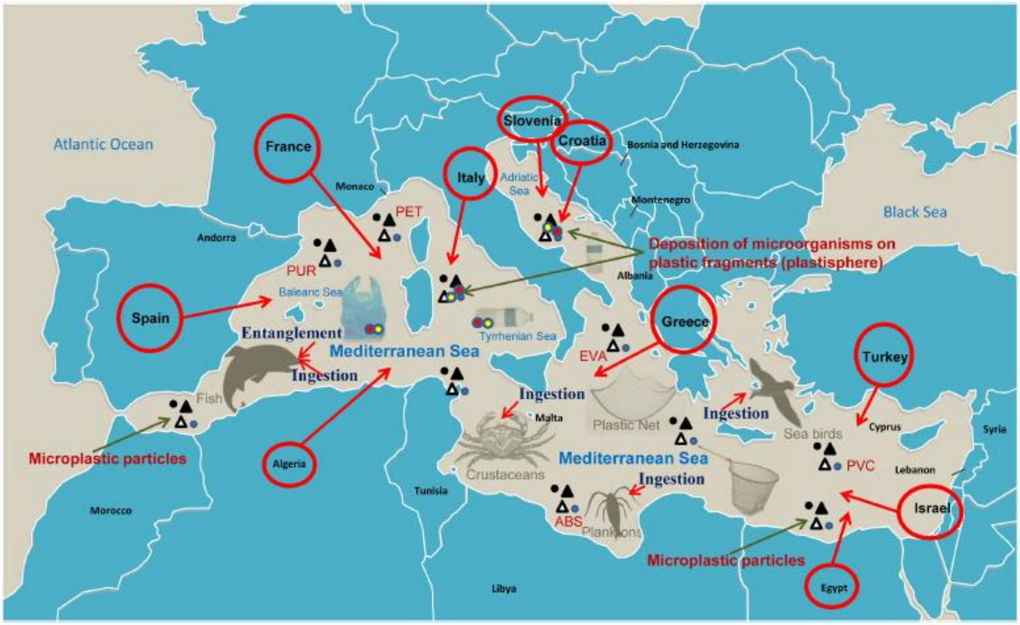


Figure 113. Primary origin of plastic pollution (top) and overall representation of plastic pollution in the Mediterranean Sea. The red circles indicate those countries that contribute to the major amount of plastic litter and microplastics. The plastisphere (microorganisms living on plastic fragments) and marine animals (inhabiting the Mediterranean Sea) affected due to entanglement and ingestion are also shown. Source: Sharma et al. (2021). Map source: https://yourfreetemplates.com

Marine litter can be transported across long distances and remain in the marine environment for an undetermined length of time often, making its geographic, sectorial and temporal origin difficult to assess. Marine litter can be found in different compartments, such as beach, floating, water column, seafloor, sediments. Assessments of the composition of beach litter in different regions of the Mediterranean Sea show that synthetic materials (bottles, bags, caps/lids, fishing nets, and small pieces of unidentifiable plastic and polystyrene) make up the largest proportion of overall litter pollution Table 31). Marine litter from smoking related activities may locally account for 40 % of collected items on beaches – a figure considerably higher than the global average. Buried litter is usually not sampled, though it may be a considerable proportion of beach litter (UNEP/MAP, 2015).

Table 31 Top ten items in the Mediterranean Sea. Total number is the number of items collected on 59.2 miles of beaches from 8 different countries. Source: International Coastal Clean-up (ICC, 2014) in UNEP/MAP (2015)

	cigarette butts	food wrappers	plastic bottles	caps	straws/ stirrers	Grocery bags (plast.)	glass bottles	other plastic bags	paper bags	cans
Total collected number	98117	6796	11295	16490	24724	6350	3443	4706	2436	6405
number /100m	175	12	20	29	44	11	6	8	4	11

In terms of beach litter quantities, SDG 14.1.1 data for the Mediterranean countries shows an overall decreasing trend for most countries, with the exception for Cyprus (Error! Reference source not found.). Despite efforts to harmonize methods for monitoring beach litter, the process of litter beaching might be complex and subject to the action of the waves, tidal movements and currents. In terms of marine litter floating in the sea, plastics account for more than 85 % and litter densities are generally comparable to those reported from many other coastal areas worldwide (UNEP/MAP, 2015). Despite being one of the most plastic polluted environments, quantitative assessments of the distribution and presence of floating plastic items in the Mediterranean Sea based on field data are traditionally scarce, although have been increasing in recent years (Lambert et al., 2020; Macias et al., 2021 and references therein). Most of the previous works dealing with basin-wide distribution of litter have relied on the use and application of numerical models, mainly applied to elucidate the distribution patterns of surface plastics in the basin and determine accumulation areas. However, so far field data have failed to confirm the presence of permanent retention areas. Moreover, due to the lack of a consistent and comprehensive dataset, the actual distribution of coastally located litter in Mediterranean shores is unknown, despite indications that this distribution is largely non-homogeneous.

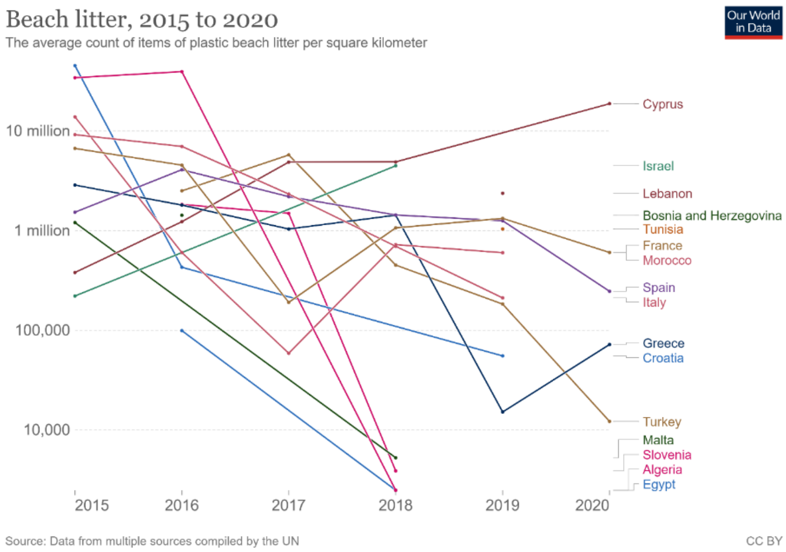


Figure 114. Average count of items of plastic beach litter per square kilometer (SDG 14.1.1) in Mediterranean countries. Source: https://sdg-tracker.org/oceans

Lambert et al. (2020) used data from the ACCOBAMS Survey Initiative (ASI) (Error! Reference source not found.) to provide the first abundance estimate of floating mega-debris (>30 cm) and map their distribution over the entire Mediterranean Sea. The survey was conducted from June to August 2018 and covered 77.3 % (1.92 million km^2) of the Mediterranean Sea.

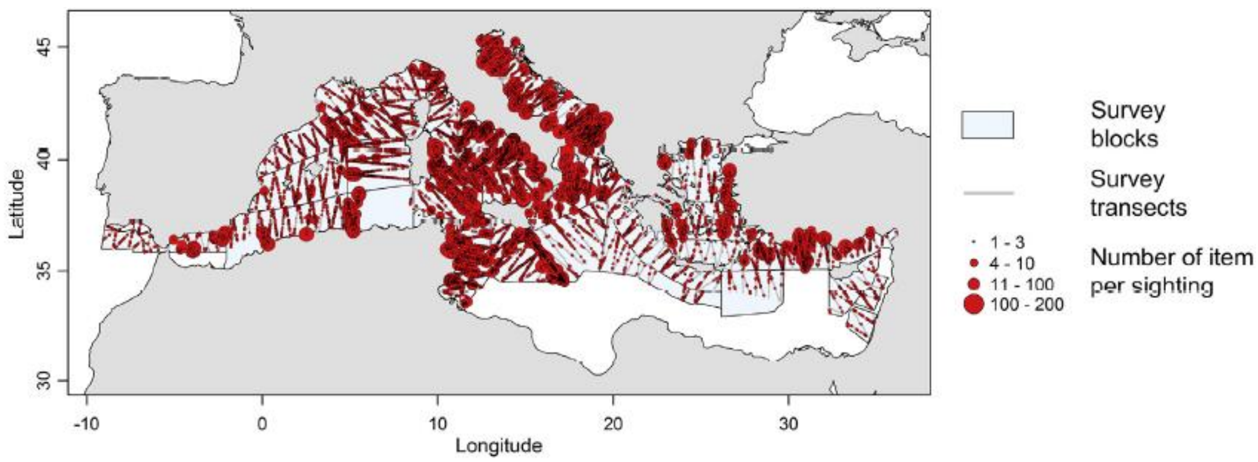


Figure 115. Map showing ACCOBAMS Survey Initiative (ASI) blocks, sampled transects and distribution of sighted floating mega-debris. Transects were sampled once by 14 different teams operating 8 planes simultaneously in different areas. There was no aerial survey effort off the coasts of Morocco, Libya, Egypt and east of Cyprus where the ASI survey was conducted by boat. Source: Lambert et al. (2020)

The total number of floating mega-debris was estimated at 2.9 million items (80 % confidence interval: 2:7 – 3:1 million; average density of 1.5±0.1 items per km^2), taking into account imperfect detection. Items larger than 30 cm represent only one fourth of the complete load of anthropogenic debris (>2 cm) in the Mediterranean, which scales up the estimate to 11.5 million floating debris. The estimated presence probability of floating mega-debris was highest in the central and western Mediterranean, in the Tyrrhenian, Northern Ionian, and Adriatic Seas and in the Gulf of Gabes (≥ 80 %; Error! Reference source not found. top panel). The lowest presence probabilities occurred in the Levantine basin, in the southern Ionian Sea and in the Gulf of Lion (≤ 50 %). High densities of debris were observed in the central Mediterranean (Tyrrhenian Sea, Adriatic Sea, Northern Ionian Sea, off Northeastern Algeria and the Gulf of Gabes (Error! Reference source not found. – bottom panel). Cells with the highest densities of up to 20 items per km^2 occurred along the Tyrrhenian coast of Italy and in the Adriatic Sea. The lowest densities were observed in the eastern Mediterranean Sea.

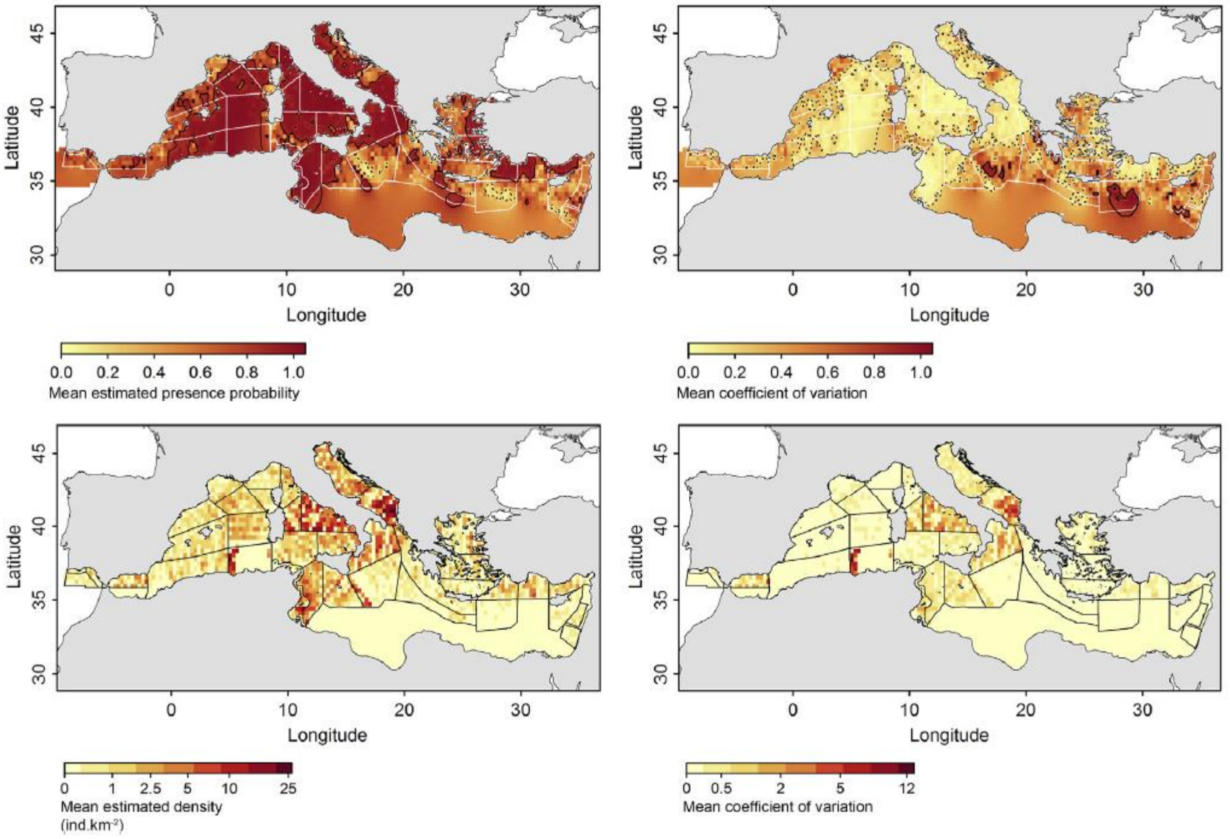


Figure 116. Estimated presence probability (posterior mean) of floating mega-debris (top left). Uncertainty in estimated presence probability (coefficient of variation) (top right). Isolines corresponding to contours of probabilities of 0.2 are shown in dotted black lines and 0.8 contours in solid black lines. Mean estimated densities of floating mega-debris (> 30 cm) in number of items per km^2 (bottom left). Mean coefficients of variation of estimated densities per cell (bottom right). ASI survey blocks are shown in solid black lines. Source: Lambert et al. (2020).

The recent study by Pedrotti et al. (2022) provided an integrative assessment of the plastic debris in the Mediterranean Sea based on an extensive sampling campaign in seven ecoregions from Gibraltar to Lebanon during the Tara Mediterranean expedition (June-November 2014). The main aim was to provide reliable estimates of regional differences in floating plastic loads and plastic characteristics. The abundance, size, surface, circularity and mass of 75,030 pieces were analyzed and classified in a standardized multi-parameter database. Plastic debris was present at all surface sampling sites in the Mediterranean Sea, confirming widespread contamination throughout the basin. The average abundance was 2.60 × 10^5 items km^{-2} (2.25 ×

10^3 to 8.50×10^6 km^{-2}) resulting in an estimate of about 650 billion plastic particles floating on the surface of the Mediterranean, weighing an average of 660 metric tons. The latter is at the lower end of literature estimates. A Lagrangian Plastic Pollution Index (LPPI) predicting the concentration of plastic debris was validated using the spatial resolution of the data. It allowed for linking the plastic concentration to the history of a water parcel and the magnitude of the land-based plastic sources it encountered in the previous days.

The distribution of plastic debris in terms of abundance, mass and size at the surface of the Mediterranean Sea is uneven and marked by regional differences with areas of very high and low abundance reflecting the high temporal and spatial variability of the currents. High concentrations of plastic were observed in the northwestern coastal regions, north of the Tyrrhenian Sea, but also off the western and central Mediterranean basins. The Levantine basin south of Cyprus had the lowest concentrations (**Error! Reference source not found.** 120 and Table 34).

The advanced state of plastic degradation detected in the analyses led to the conclusion that stranding/fragmentation/resuspension is the key process in the dynamics of floating plastic in Mediterranean surface waters. Weathering and fragmentation of larger debris lead to the formation of smaller particles, such as microplastics (see next section) and down to nanoplastics.

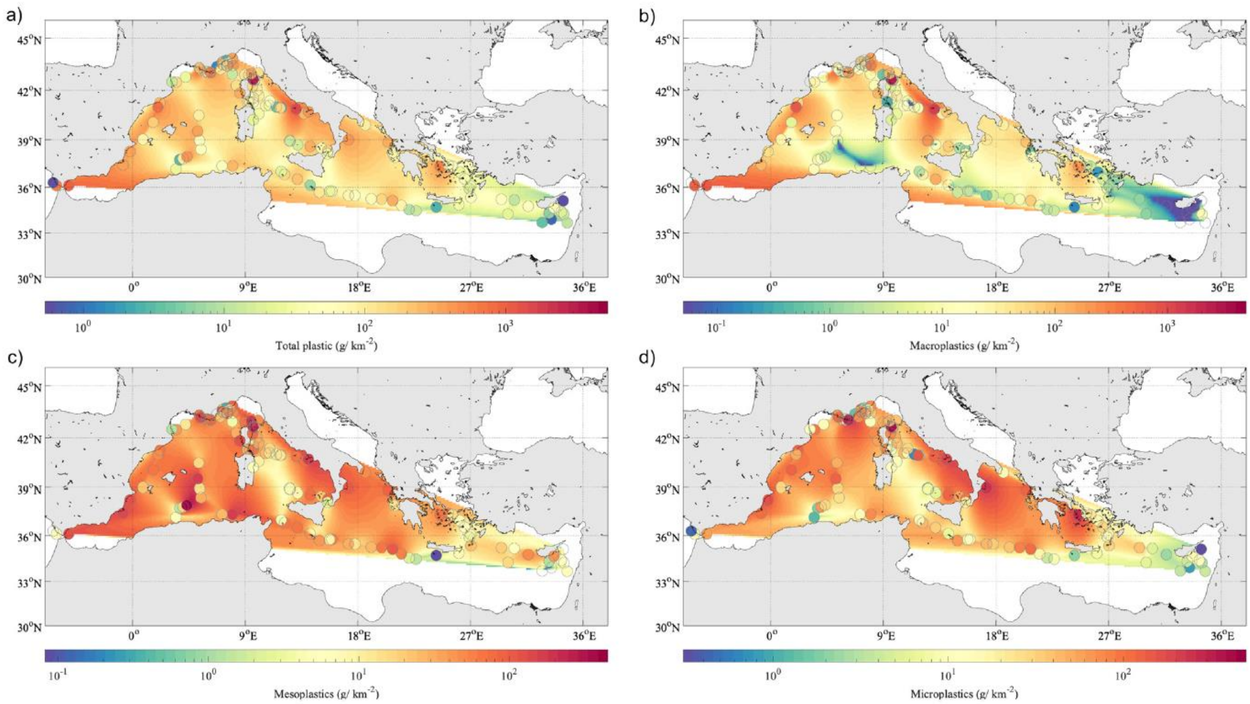


Figure 117. Concentration of plastic debris (g km−2) collected in surface waters during the Tara Mediterranean expedition. A) total mass concentration, b) macroplastics (size >20 mm), c) mesoplastics (5 < size <20 mm), d) microplastics (size <5 mm). Source: Pedrotti et al. (2022).

Table 32. Median and mean plastic concentrations (km^{-2}, m^{-3}, g), total surface area occupied by plastics (m^2 km^{-2}), size length (mm) and surface area of particles in the different sub-basin of the Mediterranean Sea. Significant differences between the sub-basins are indicated in red. Source: Pedrotti et al. (2022)

Bassin		Alboran	Tyrrhenian Sea	Ligurian-Provençal	WEST Med	Ionian Sea	Levantine Sea	Aegean Sea
Plastic abundance (items 10^5 km $^{-2}$)	median	*1.71*	*1.15*	0.93	1.68	1.69	*0.21*	*1.02*
	mean	1.85	4.69	1.63	1.67	2.08	0.29	2.49
	std	(± 1.61)	(± 1.36)	(± 1.81)	(± 1.21)	(± 2.10)	(± 0.26)	(± 4.10)
	n	*4*	*35*	*25*	*17*	*20*	*11*	*12*
Plastic abundance (Items m^{-3})	median	*1.07*	*0.72*	*0.56*	*1.15*	*1.06*	*0.13*	*0.64*
	mean	1.15	2.93	1.02	1.18	1.30	0.18	1.56
	std	(± 1.0)	(± 9.11)	(± 1.1)	(± 0.84)	(± 1.31)	(± 0.16)	(± 2.56)
	n	*4*	*33*	*22*	*17*	*20*	*11*	*12*
Plastic weight (g km^{-2})	median	524.81	88.1	175.18	149.05	83.75	11.9	42.15
	mean	514.68	380.18	395.87	231.18	127.15	19.66	97.20
	std	(± 425.00)	(± 850.52)	(± 1043.48)	(± 236.22)	(± 120.97)	(± 22.43)	(± 166.10)
	n	*4*	*33*	*25*	*17*	*20*	*11*	*12*
Total plastic surface area (m^2 Km^{-2})	median	*0.70*	0.53	0.73	0.58	0.54	*0.90*	0.30
	mean	0.73	2.60	0.890	0.67	0.94	0.11	0.74
	std	(± 2.59)	(± 0.88)	(± 1.04)	(± 1.26)	(± 1.16)	(± 1.56)	(± 1.50)
	n	*4*	*35*	*25*	*17*	*20*	*11*	*12*
Plastic median lenght (mm)	mean	1.11	1.14	1.17	1.12	1.25	1.18	1.17
	std	(± 0.16)	(± 0.05)	(± 0.06)	(± 0.08)	(± 0.07)	(± 0.10)	(± 0.09)
	n	*4*	*35*	*25*	*17*	*20*	*11*	*12*
Plastic surface area (mm^2)	mean	3.70	8.05	8.39	6.30	5.10	4.93	5.30
	std	(± 3.82)	(± 1.29)	(± 1.53)	(± 1.85)	(± 1.71)	(± 2.30)	(± 2.21)
	n	*4*	*35*	*25*	*17*	*20*	*11*	*12*

In a first assessment of transboundary litter pollution in the Mediterranean Sea, Macias et al. (2021) used a combination of hydrodynamic and particle-tracking Lagrangian models to simulate the movement of floating particles at sea and quantify how much of the floating items present on a given country coastal region has a transboundary origin. The results showed that transboundary litter (as defined therein) accounts for between 27 % (for the homogeneous initialization) and 13 % (in the non-homogeneous case) of all coastal litter with a high variability among countries (Table 33). Although the non-homogenous initialization presents the more realistic case of litter accumulating preferentially in certain areas, the homogenous initialization was also considered due to the difficulties and uncertainties associated with the definition of the actual distribution of litter.

Table 33. Mean and standard deviation of the percentage of transboundary litter for each Mediterranean coastal country. Source: Macias et al. (2021)

Country	Homogeneous initial % of transboundary litter – mean (SD)		Non-homogeneous initial % of transboundary litter – mean (SD)	
Spain	28.0	(9)	30.3	(14.4)
France	34.4	(11.7)	18.4	(9.9)
Italy	35.6	(9.4)	12.6	(4.5)
Croatia	21.1	(21.8)	30.2	(20.4)
Greece	17.3	(6)	20.1	(7.7)
Montenegro	37.0	(30.8)	16.3	(24.5)
Albania	21.3	(14.7)	14.6	(23.4)
Turkey	14.7	(9.9)	3.8	(7.2)
Syria	57.6	(25.3)	34.8	(27)

Lebanon	65.0	(17.5)	17.8	(25.4)
Israel	39.6	(32.5)	17.6	(21.4)
Egypt	23.1	(19.1)	11	(10.6)
Libya	24.5	(21.8)	5.2	(4.3)
Tunisia	28.5	(13.2)	14.6	(16.9)
Algeria	27.7	(25.3)	12.7	(19.1)
Morocco	55.4	(15.1)	41.8	(23.2)
TOTAL	27.8	(7.3)	13	(7.3)

The model simulations allowed for an analysis of the direction of movement of litter. The floating particles follow the general cyclonic circulation of the Mediterranean surface currents, implying that for the Northern countries, the transboundary pollution tends to come from their eastward neighbors. For the Southern countries the situation is the opposite, with pollution arriving from their west.

Contrary to more research studies to date that focus on the detection of plastic accumulation zones, Baudena et al. (2022) applied the "crossroad regions" approach. This approach relies on the application of an advanced numerical plastic-tracking model to identify areas through which large amounts of plastic debris flow. The model was validated by using observations (in situ measurements from Tara Expedition) and simulated plastic concentrations in the different Mediterranean sub-basins (the western Mediterranean, the Tyrrhenian and Aegean Seas, the central and the eastern Mediterranean) (Error! Reference source not found.). Model results showed that ~ 20 % of the Mediterranean plastic debris released every year passed through about 1 % of the basin surface. The most important crossroads intercepted plastic debris from multiple sources, which had often traveled long distances.

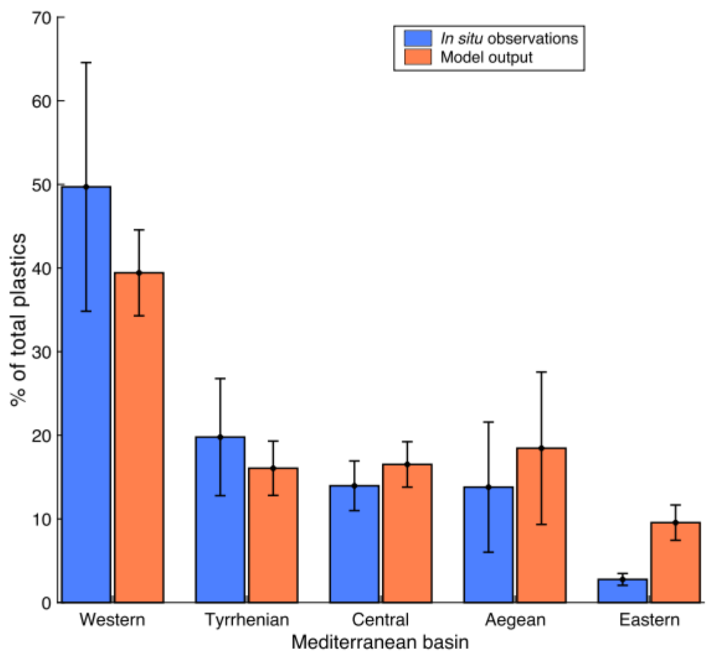


Figure 118. Normalized plastic concentrations across the Mediterranean sub-basins from the Tara Expedition in situ measurements (blue columns) and the model predictions (orange columns), with relative uncertainties (standard deviation: black error bars). The Adriatic Sea was not included in the validation, as no in situ observations were carried out in this basin.

Plastics with a higher density than seawater (1.02 g cm^{-3}) tend to sink and build up in the sediment, whereas low-density polymers are bound to float onto the surface or can be maintained in the water column as suspension (Chubarenko et al., 2018 in Sharma et al 2021). Plastics constitute the predominant litter on the seafloor in ranging from 45 % to 95 %. Fishing-related litter, including ghost nets, prevail in commercial fishing zones (UNEP/MAP, 2015). In a recent study, Kaandorp et al. (2020) estimated the floating plastic budget of the Mediterranean Sea: their results showed that 37–51 % of the plastic input to the basin tend to settle on the seafloor and that 49–63 % of these inputs end up beaching. Despite numerous literature studies on plastics in the Mediterranean, the discrepancy between plastic input and plastic floating on the ocean surface still remains unsolved. The total annual load of plastic is estimated at 17,600 metric tons, whereas approximately 3760 metric tons of plastic is assumed to be floating on the Mediterranean Sea. The so-called "missing" plastic problem reflects the lack of knowledge about the key processes that bring and selectively remove plastic debris from the surface (Pedrotti et al., 2022).

Priority issue 5: NANOLITTER AND CHEMICALS LEACHING (&TOXICITY)

Description of the problem and its transboundary importance

Although there is still some debate on the minimum size particle to be classified as microplastics (MPs), there is a general consensus that MPs are pieces of plastic with a diameter smaller than 5mm. MPs constitute even smaller particles known as nanoplastics. MPs are further classified as primary MPs, including e.g. plastic resin pellets, raw materials for plastic manufacture and small particles manufactured for use in cleansing or beauty products (microbeads), in textile (microfibres); and secondary MPs that result from the breakdown of larger pieces of plastics by physical and chemical degradation, or biological decomposition. MPs have now been observed in the water column, marine sediments, on beaches and in biota in the region and are considered emerging pollutants. The MP concentration in the Mediterranean Sea is approximately four times greater than the North Pacific Ocean (Sharma et al. 2021). Numerous research efforts in the Mediterranean Sea have been dedicated to defining the MP distribution and concentration levels. Most of the observations have focused on the investigation of MPs in the Western Mediterranean, whereas the Eastern Mediterranean remains less studied (Simon-Sanchez et al., 2022). The geographical distribution of surface water stations indicates a gap of knowledge on the MP concentration levels in the southern coast of the basin and in offshore waters, specifically in the Central Mediterranean and the Levantine basin (Error! Reference source not found.). The country-by country review of the Mediterranean Sea by Fytianos et al. (2021) showed that MP levels are diverse, and further studies are needed to assess the distribution dynamics of MPs in coastal areas. Higher MP presence is generally related to areas under high anthropogenic pressure and proximity to (micro)plastics land-based sources nearer to the shore, although hydrodynamic conditions and wind-driven processes influence their redistribution, even far from their sources (Simon-Sanchez et al., 2022 and reference therein). Hence just like marine litter, MP and lower sizes have important transboundary implications and environmental impacts.

The reported MP concentrations are comparable to those found in the convergence zone of ocean gyres, pointing to this basin as one of the world’s greatest plastic accumulation areas (Simon-Sanchez et al. (2022) and references therein).

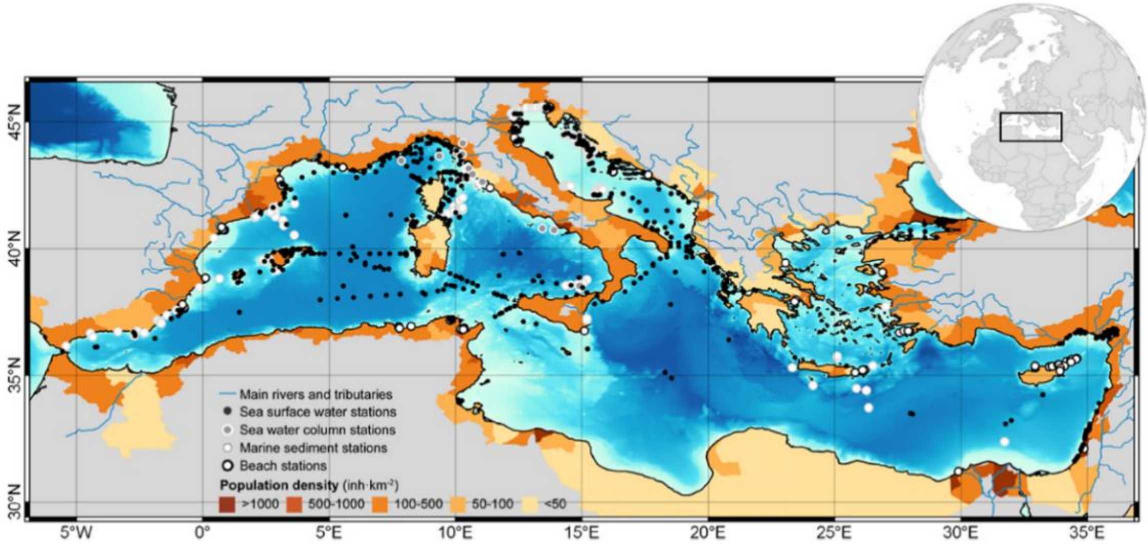


Figure 119. Map of the Mediterranean Sea showing the location of microplastics sampling stations: black dots for sea surface water stations, grey dots for water column stations, thin white circles for marine sediment stations, and thick black and white circles for beach stations. Source: Simon-Sanchez et al. (2022).

Table 34. Occurrence of MPs in sea sediments from the Mediterranean Sea. Source: Llorca et al. (2020)

	Average items/ Kg sediment DW ± SD		Ref.
Spanish Mediterranean Coast (Mediterranean W)	Algeciras	111.3 ± 15.9	[85]
	Málaga	280.3 ± 164.9	
	Castell de Ferro	81.4 ± 41.3	
	Almería	81.8 ± 20.2	
	Cartagena	133.4 ± 104.1	
	Benidorm	138.9 ± 54.7	
	Benicarló	94.8 ± 80.2	
	Vallcarca	74.5 ± 29.1	
	Barcelona	132.7 ± 67.8	
	Palma de Mallorca	45.9 ± 23.9	
Balearic Islands (Mediterranean W)	From 100.0 ± 60 to 900 ± 100		[66]
Aeolian Archipelago's islands, Tyrrhenian sea (NW Mediterranean)	From 151.0 ± 34.0 to 678.7 ± 345.8		[86]
Natural Park of Telaščica bay (Adriatic Sea)	From 32.3 ± 20.2 to 377.8 ± 88.8		[87]
Grand Harbour of Malta (Central Mediterranean)	From 4 to 12		[88]
Venice (North Adriatic Sea)	From 672 ± 124 to 2175 ± 466		[89]
Central Adriatic Sea	From 2.5 ± 5 /m^2 to 75 ± 15 /m^2		[90]
Northern Tunisian coast	From 141.20 ± 25.98 to 461.25 ± 29.74		[67]
Maremma Regional Park (Tyrrhenian Sea, Italy)	From 45 to 1069		[91]
Ebro Delta (NW Mediterranean)	422 ± 119		[64]
NW Mediterranean deep sea sediments	10 – 35 / 50 ml sediments		[92]

Table 35. Microplastics found in sea sediments and beaches around the Mediterranean Sea. Source: Sharma et al. (2021)

Places from where samples were collected	Average items/Kg sediment (dry weight ± SD)	References
Microplastics found in Sediments		
Balearic Islands (W Mediterranean)	From 100.0 ± 60 to 900 ± 100	Gundogdu and Çevik, 2019
Central Adriatic Sea	From 2.5 ± 5 to 75 ± 15	Mistri et al., 2017
Northern Tunisian coast	From 141.20 ± 25.98 to 461.25 ± 29.74	Abidli et al., 2018
Aeolian Archipelago's islands, Tyrrhenian sea (NW Mediterranean)	From 151.0 ± 34.0 to 678.7 ± 345.8	Fastelli et al., 2016
Natural Park of Telascica bay (Adriatic Sea)	From 32.3 ± 20.2 to 377.8 ± 88.8	Blaskovic et al., 2017
Venice (North Adriatic Sea)	From 672 ± 124 to 2175 ± 466	Vianello et al., 2013
Grand Harbour of Malta (Central Mediterranean)	From 4 to 12	Romeo et al., 2015
Maremma Regional Park (Tyrrhenian Sea, Italy)	From 45 to 1069	Guerranti et al., 2017
Ebro Delta (NW Mediterranean)	422 ± 119	Simon-Sanchez et al., 2019
Countries from where samples were collected	**Average litter density (items/m^2)**	**References**
Microplastics found in Beaches		
Italy	1.06	Giovacchini et al., 2018
Spain	0.116	Asensio-Montesinos et al., 2019
Morocco	0.054	Nachite et al., 2019
Greece	0.24	Vlachogianni et al., 2018
Croatia	2.9	Vlachogianni et al., 2018
Slovenia	1.5	Laglbauer et al., 2014
Montenegro	0.37	Vlachogianni et al., 2018
Albania	0.22	Vlachogianni et al., 2018

Yet, the high spatiotemporal variability of the Mediterranean Sea circulation prevents permanent accumulation areas of floating MP debris. MPs are a particularly challenging fraction of marine litter in terms of determining their origins and pathways, as they can originate from a number of sources and enter the ecosystem via different pathways. Llorca et al. (2020) and Sharma et al. (2021) provided an overview of microplastic concentrations in sea sediments around the Mediterranean Sea reported in other studies (
Table **34** and
Table **35**). An overview of MPs in beaches was also provided by Sharma et al. (2021).

Sediments are one of the most obvious sinks for microplastics deposition and have an immense potential for their accumulation. Although most of the studies were from the Western and Central Mediterranean, the concentrations varied according to the location.
Table **34** also shows that MPs are ubiquitous and dominant constituents of beach litter and were detected on the beaches of Israel (~ 90%) (Pasternak et al., 2017), eastern Italy (~ 81.1%) (Munari et al., 2016), Slovenia (~ 64%) (Laglbauer et al., 2014), and Greece (~ 51%) (Kordella et al., 2013) (referenced in Sharma et al. 2021). Despite these figures, the distribution of MPs on beaches varies temporally and is dependent on various external forces such as wind currents, precipitation rate, outflow layer, and finally on the proximity of the river mouth (Constant et al., 2019).

Concentrations of microplastics at the surface of the Mediterranean Sea are largely above 100,000 items km^{-2} (UNEP/MAP, 2015) and reach maximum value of more than 64 million floating particles km^{-2} (Van Der Hal, Ariel & Angel, 2017). Adamopoulou et al. (2021) provided an overview of sea surface MPs concentrations reported in various case studies in the Mediterranean Sea (Table 36).

Table 36. Sea surface MPs concentrations (items m-2) reported for the Mediterranean Sea, using surface manta nets. Source: Adamopoulou et al. (2021)

Area	Net mesh (μm)	MPs (items m^{-2})	Sources
Mediterranean Sea	200	0.24	Cózar et al., 2015
Mediterranean Sea	330	0.14 ± 0.025	Ruiz-Orejón et al., 2016
W. Mediterranean Sea	333	0.12 ± 0.13	Pedrotti et al., 2016
W. Mediterranean Sea	330	0.10 ± 0.09	de Haan et al., 2019
W. Mediterranean Sea	780/330	0.11	Schmidt et al., 2017
W. Mediterranean Sea	330	0.082 ± 0.079	Fossi et al., 2017
W. Mediterranean and Adriatic Seas	200	0.4 ± 0.7	Suaria et al., 2016
Adriatic Sea	330	0.3 ± 0.5	Zeri et al., 2018
E. Mediterranean Sea	333	0.14 ± 0.12	Güven et al., 2017
E. Mediterranean Sea	333	0.38	Gündoğdu and Çevik, 2017
E. Mediterranean Sea	333	1.5	van der Hal et al., 2017
E. Mediterranean Sea	330	0.26 ± 0.36 (0.012–1.62)	Present study

The study by Adamopoulou et al. (2021) focused on the distribution patterns of surface floating MPs in the Ionian, Aegean, and Levantine Seas and their morphological and chemical properties. Adamopoulou et al. (2021) observed that the presence of sea surface slicks, as recorded visually during samplings, played a key role on the distribution pattern of MPs, since highest concentrations were recorded in samples affected by these formations. Most MPs in open waters had sizes ≤2 mm peaking between 0.6- and 1.4-mm. Spectroscopic analysis of MPs revealed the presence of 11 polymer types in both open sea and gulfs; the most abundant type was polyethylene (PE), followed by polypropylene (PP), and polystyrene (PS). The relative abundance of polymer types was more diverse in Saronikos Gulf, compared to the open sea due to the proximity to major urban and industrial sources.

Further analysis of the chemical composition of MPs collected in the surface waters of the Mediterranean Sea as a function of particle size, mass and concentrations were conducted by Kedzierski et al. (2022). The chemical composition showed a certain homogeneity at the Mediterranean Sea scale. The main polymers identified by Fourier Transform Infra-Red (FTIR) spectroscopy were PE (67.3 ± 2.4 %), PP (20.8 ± 2.1 %) and PS (3.0 ± 0.9 %). Nevertheless, discrepancies, confirmed by the literature, were observed at a mesoscale level: in the North Tyrrhenian Sea, the proportion of PE was significantly lower than the average value of the Mediterranean Sea (57.9 ± 10.5 %), pointing towards anthropogenic sources and polymer ageing to be responsible for the variations observed. MPs can facilitate the delivery of POPs, which are added during manufacturing or adsorbed and concentrated from the surrounding seawater. As a result, MPs laden with high levels of POPs can be transferred via the food chain.

Other than density, the chemical composition and shape of the particles also play a significant role in determining their mobility in the aquatic environment. The dominant MPs shape type identified by Adamopoulou et al. (2021) were fragments (50–60 %), whilst filaments (1–23 %), films (3–26 %), and foams (0–34 %) varied among the studied areas (Error! Reference source not found.). It is known that relatively large particles tend to stay at the surface and accumulate, while very small and elongated ones are more effectively transported below the surface.

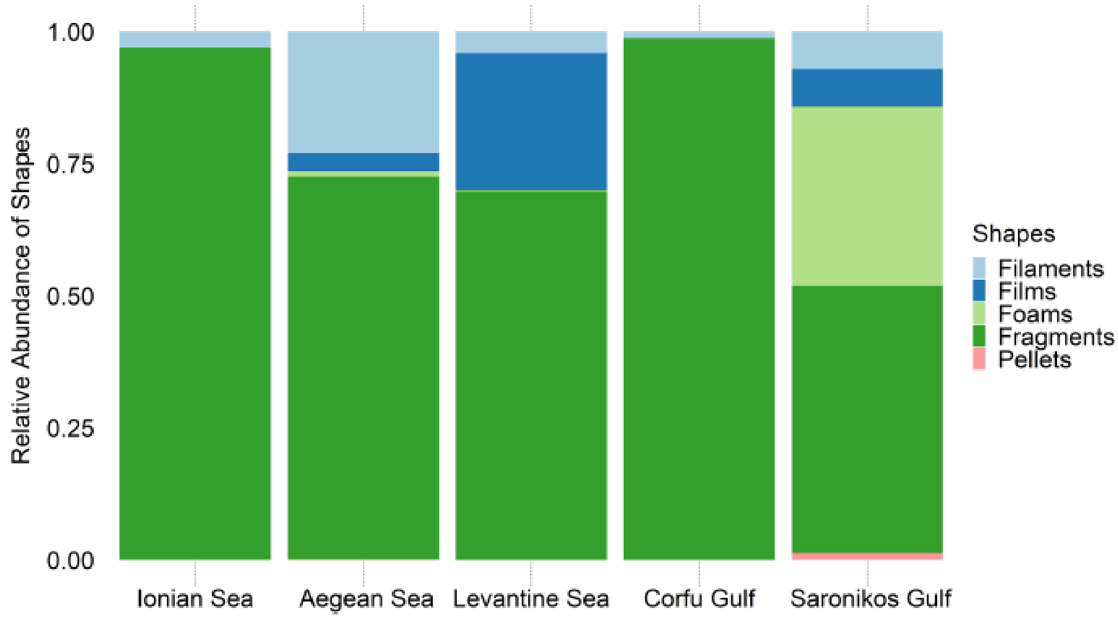


Figure 120. Relative abundance of MPs shape types at the studied areas. Source: Adamopoulou et al. (2021)

MPs ingestion by biota is an emerging threat to marine ecosystems. According to the review presented by Llorca et al. (2020), filter-feeding organisms are able to translocate MPs to the gut, making them a target of concern in the case of small size MPs and nanoplastics. Evidence also suggest that they are more likely to consume smaller MPs instead of larger microfibers. MPs were confirmed in four highly commercial marine species from Greek waters in the Northern Ionian Sea: in mussels (*Mytilus galloprovincialis*) and all three fish species (*Sardina pilchardus, Pagellus erythrinus,* and *Mullus barbatus*) (Dikga et al. 2018 – in Llorca et al 2020). The frequency of occurrence of ingested MPs was 46.25 % in mussels, while among fish species, *S. pilchardus* showed the highest frequency of ingestion (47.2 %). FTIR indicated PE as the most common polymer type in mussels and the studied fish species. Higher rates of contamination by MPs were found in the stomach contents from *Sardinia pilchardus* and *Engraulis encrasicolus* in the Adriatic Sea (Renzi et al. 2019 in in Llorca et al 2020) – both species being of great ecological and commercial importance in the Adriatic Sea. Over 90 % of samples from the two species contained marine litter, but sardines evidenced a higher number of MPs than anchovies.

One of the main limitations in the investigation of MPs in aquatic environments, sediments and biota is the lack of quantitative analytical methods. The available analytical techniques that combine quantification and characterization of MPs are limited (Llorca et al., 2020). Simon-Sanchez et al. (2022) analyzed the definitions and methods used in MP research in the Mediterranean basin. The discrepancies in the methodologies and lack of standardization have hindered the overall interpretation and intercomparison of published data and, hence also our current understanding of MP pollution in the region. Simon-Sanchez et al. (2022) reaffirm the pressing need to develop a common reporting terminology, and call for international collaboration between Mediterranean countries, especially with North African countries, to provide a complete picture of the MP pollution status in this basin.

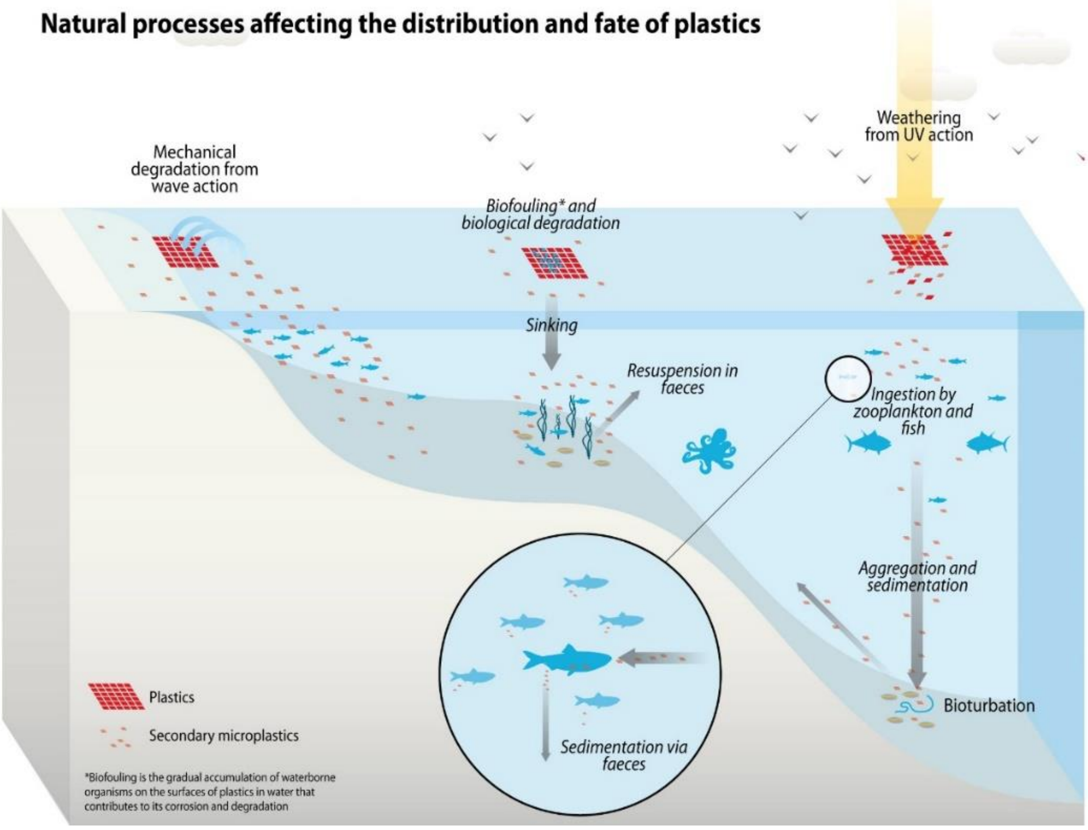
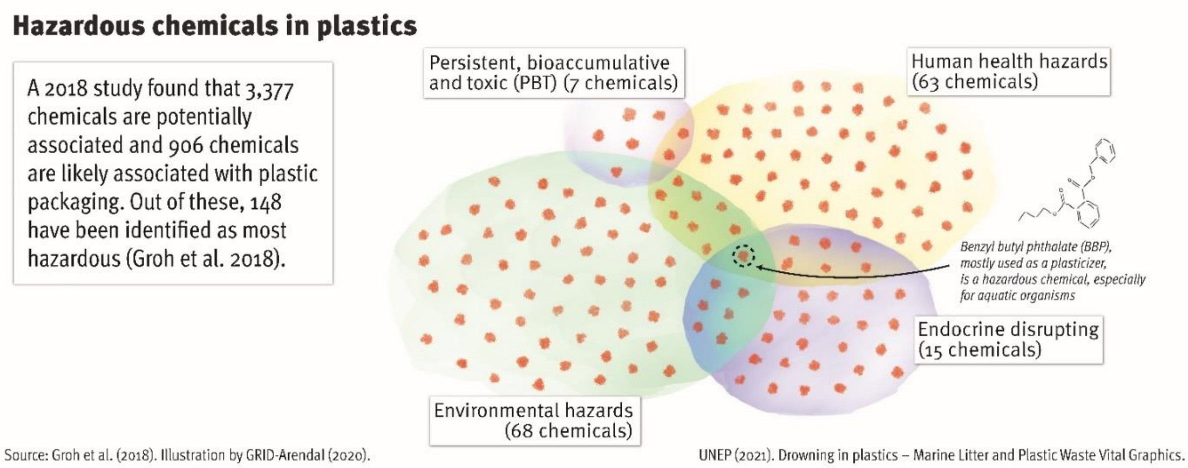


Figure 121. Natural processes affecting the distribution and fate of plastics. GRIDA.

The issue of marine litter and microplastics links to chemical pollution through the leaching of chemicals from plastic litter, posing an additional chemical hazard. This is particularly the case for plastics containing known or suspected endocrine disrupting chemicals as additives or contaminants (Figure 122). Although plastics will not be the only route by which marine species are exposed to chemical pollution, existing scientific evidence points towards plastics being a significant contributor to the exposures to complex mixtures of chemical contaminants (Gallo et al., 2018). The leaching of chemical compounds from micro- and nanolitter plastic items is reduced to a chemical substances pollution problem (Priority issue 2a and 2b).



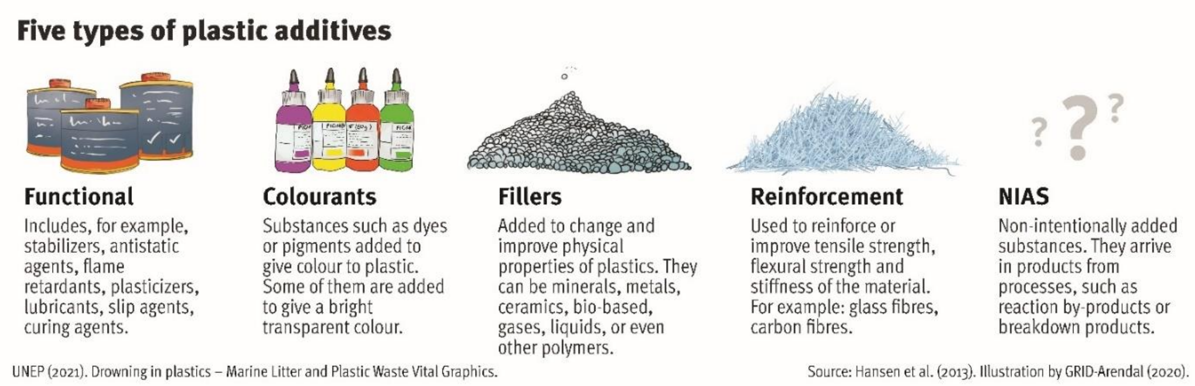


Figure 122. Hazardous chemicals in plastics. GRIDA.

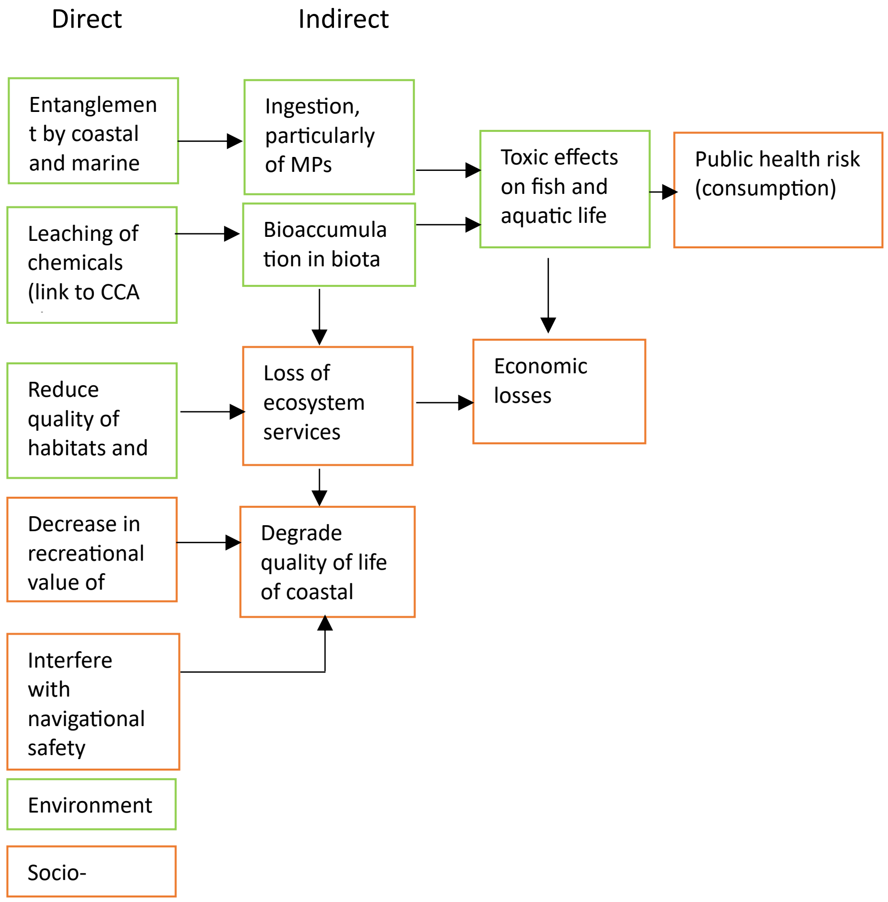
Major environmental impacts and socio-economic consequences (including gender aspects)

The impacts of marine litter in the Mediterranean Sea have been described in detail in UNEP/MAP (2015). These include impacts on wildlife through entanglement, primarily by derelict fishing gears, and ingestion of debris. Birds represented nearly 35 % of entangled wildlife followed by fish (27 %), invertebrates (20 %), mammals (almost 13 %), and reptiles (almost 5 %) (UNEP/MAP, 2015 and references therein). The sub-lethal effects of ingestion greatly affect population in the long term. The most serious effects of ingestion are the blockage of the digestive tract (occlusion) and internal injuries by sharp objects, which may be a cause of mortality. In the case of microplastics, ingested microplastic particles act as vectors for other harmful pollutants adsorbed onto their surfaces, e.g. phthalates, PCBs that may act as endocrine disruptors. Other direct or indirect effects may occur when the smallest particles travel through the food chain.

All in all, the effects of marine litter and microplastics on marine populations are difficult to quantify. An unknown number of marine animals die at sea and may quickly sink or be consumed by predators before they are potentially detected. The extent and mechanisms of the impacts of microplastics on the environment are still being established (Papadimitriu and Allison, 2022).

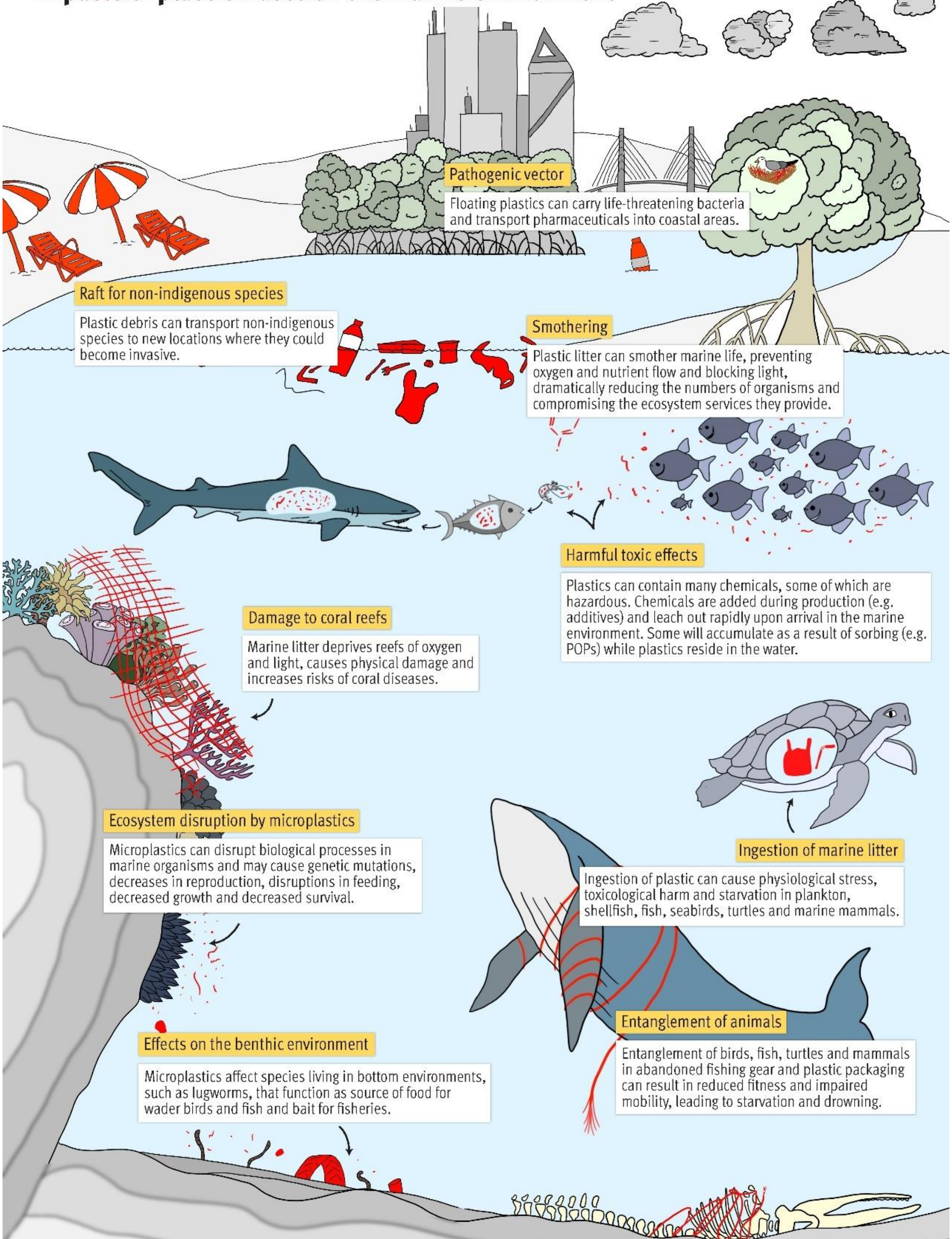
On top of the environmental and human health risks, marine litter and microplastic pollution cause serious impacts on the economic sectors in the Mediterranean basin, in particular in the tourism and fisheries sectors (Sharma et al., 2021). The loss due to marine litter is estimated at 61.7 million euro every year, because of the reduction in seafood demand as result of the concern on the quality of fish and other seafood items. Littered beaches discourage tourism and hamper the livelihood of people of the Mediterranean region. This loss includes the costs of beach cleaning, as is the case of the city of Nice in France which spends approximately 2 million euro each year to remove litter from its beaches.

The major environmental impacts and socio-economic consequences, including their interlinkages are shown in the infographics and diagrams below.



Direct
Indirect
Entanglement by coastal and marine
Ingestion, particularly of MPs
Toxic effects on fish and aquatic life
Public health risk (consumption)
Leaching of chemicals (link to CCA
Bioaccumulation in biota
Reduce quality of habitats and
Loss of ecosystem services
Economic losses
Decrease in recreational value of
Degrade quality of life of coastal
Interfere with navigational safety
Environment
Socio-

Impacts of plastic waste on the marine environment



Source: GRID-Arendal (2021).
UNEP (2021). Drowning in plastics – Marine Litter and Plastic Waste Vital Graphics.

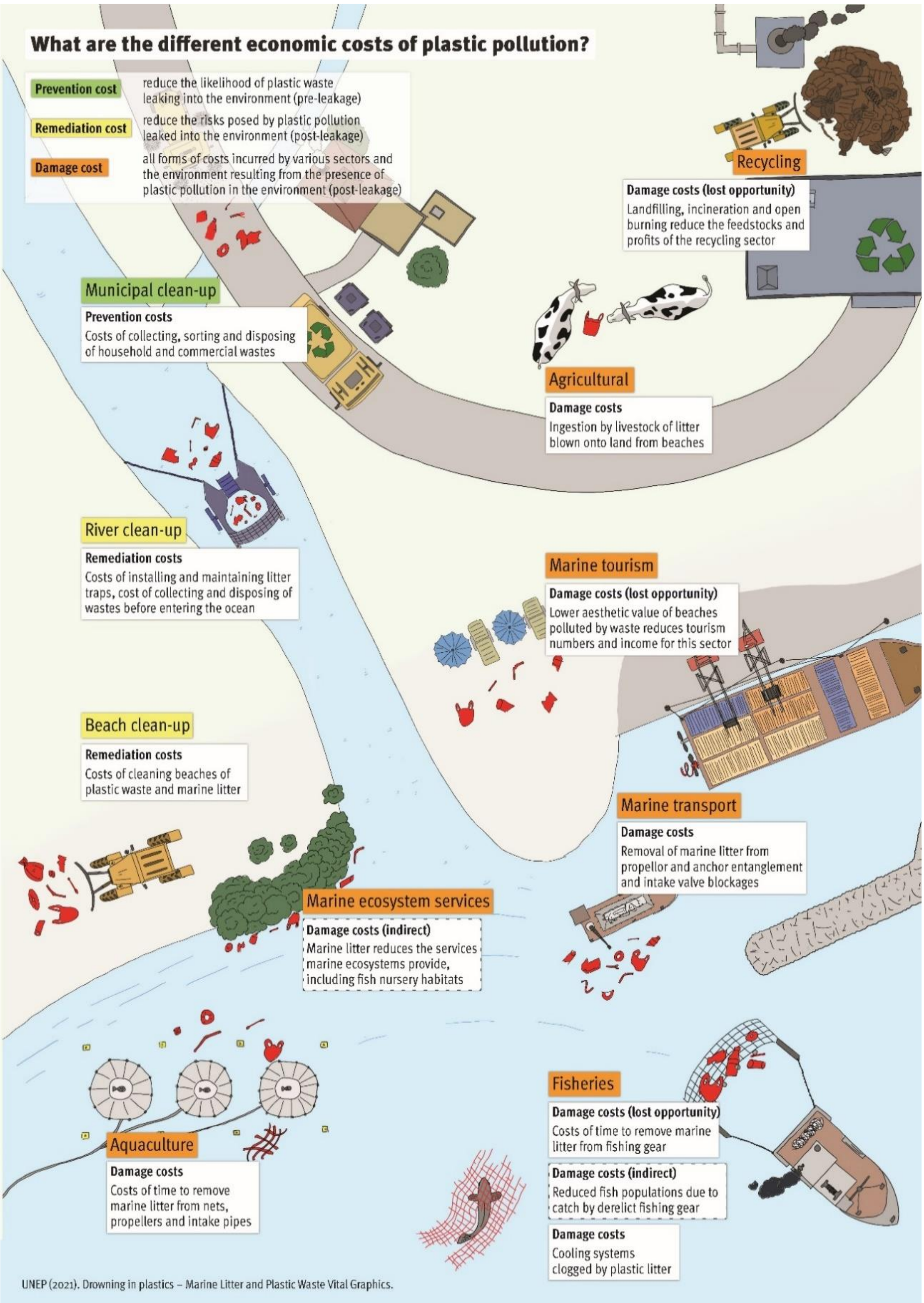
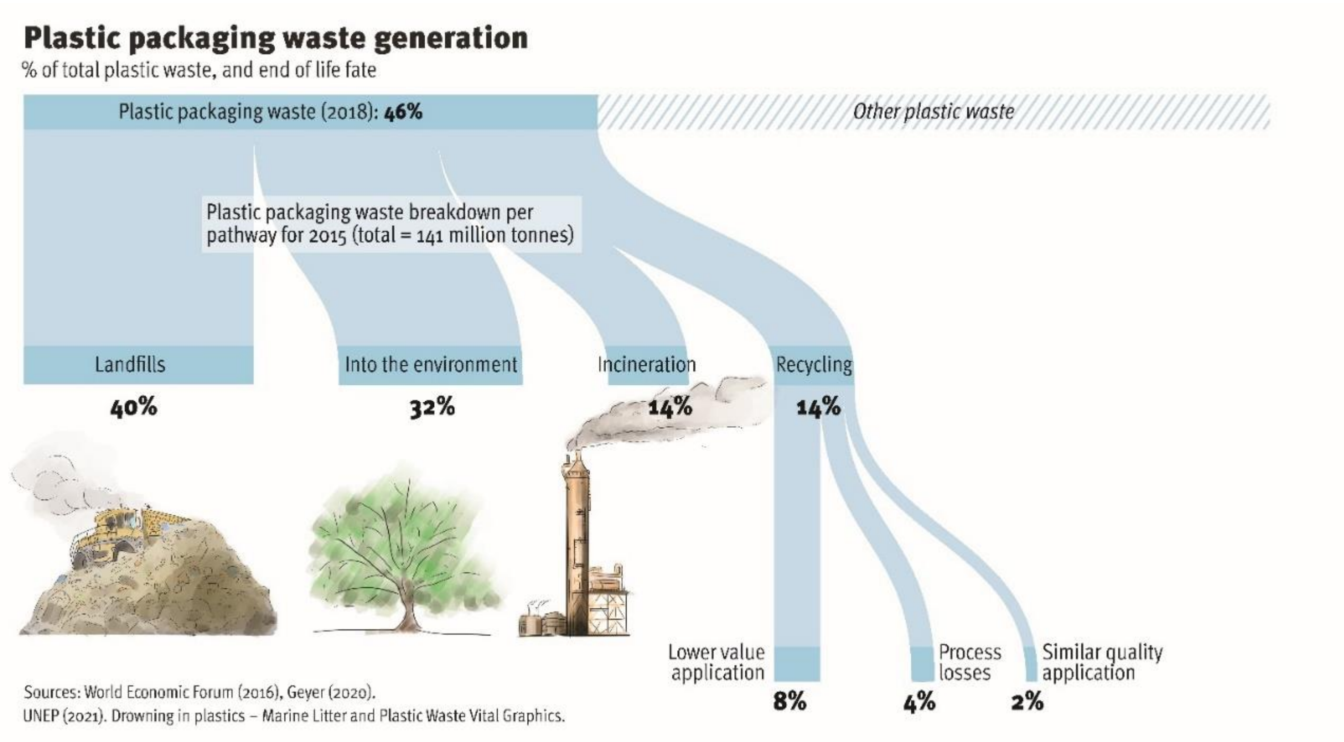


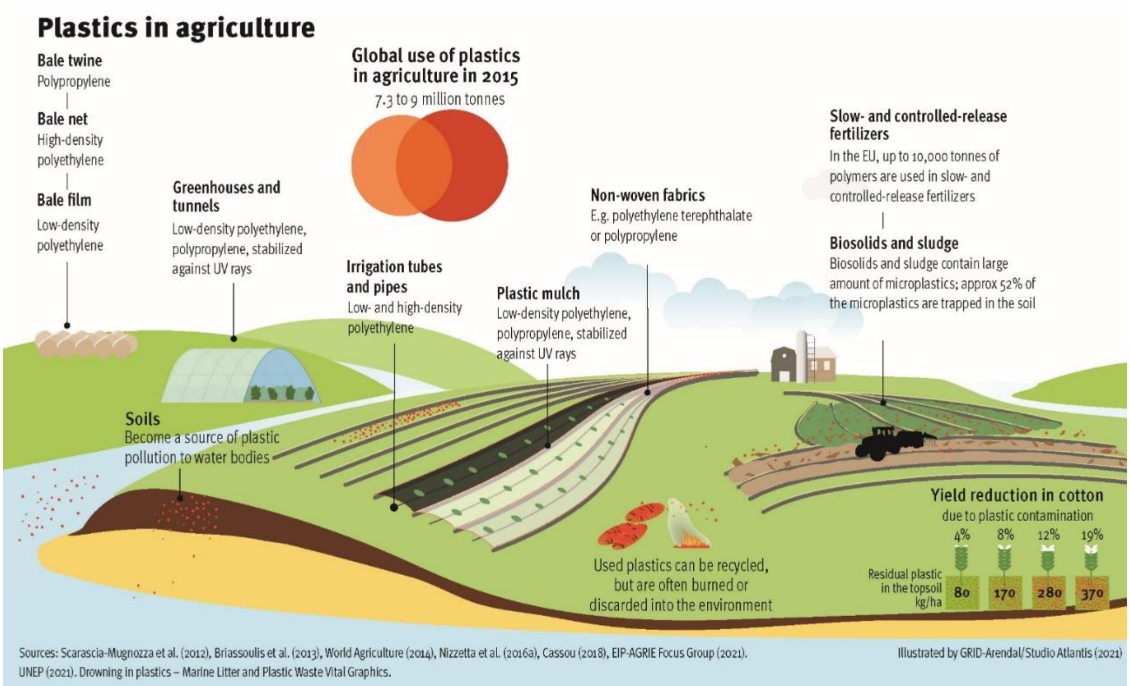
Figure 123. Direct and indirect impacts (top), major impacts of plastic and litter (middle) and socioeconomic consequences (bottom). GRIDA.

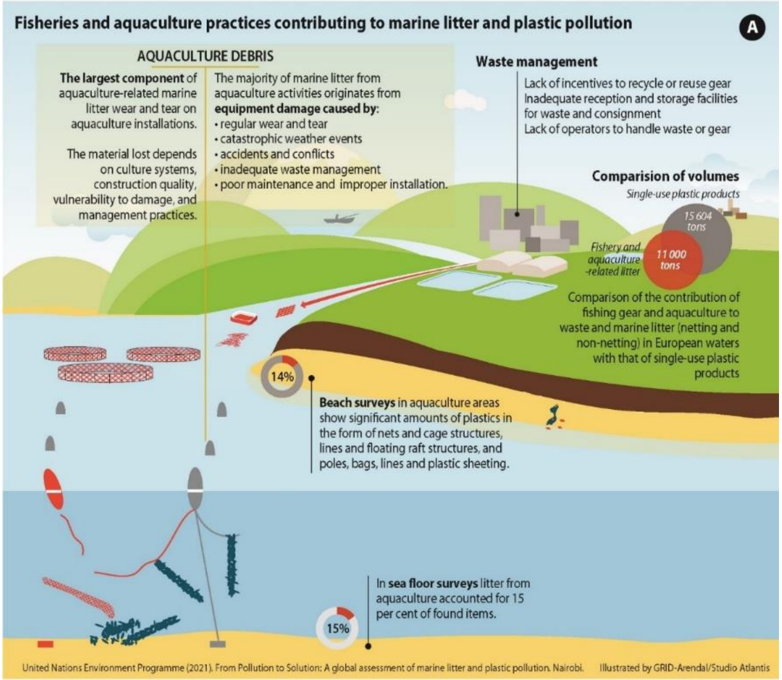
Linkages with other transboundary problems

SUSTAINABLE PRODUCTION AND CONSUMPTION. SOLID WASTE MANAGEMENT FACILITIES AND PLANS.



AGRICULTURE, FISHERIES AND AQUACULTURE SOURCES





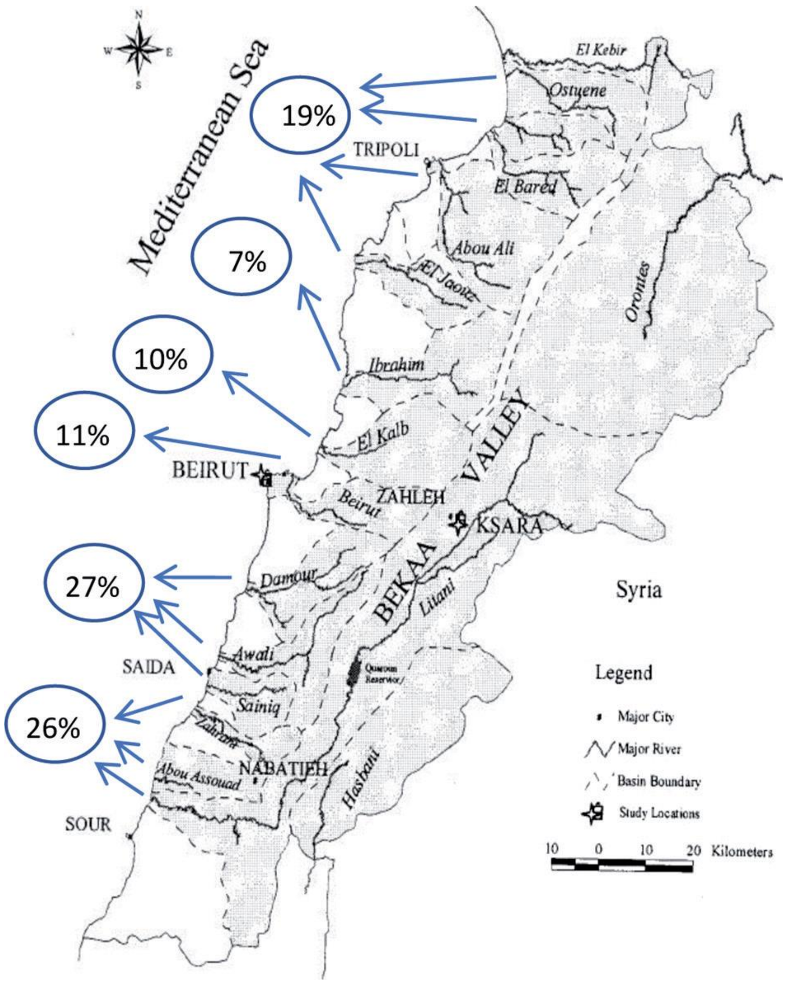
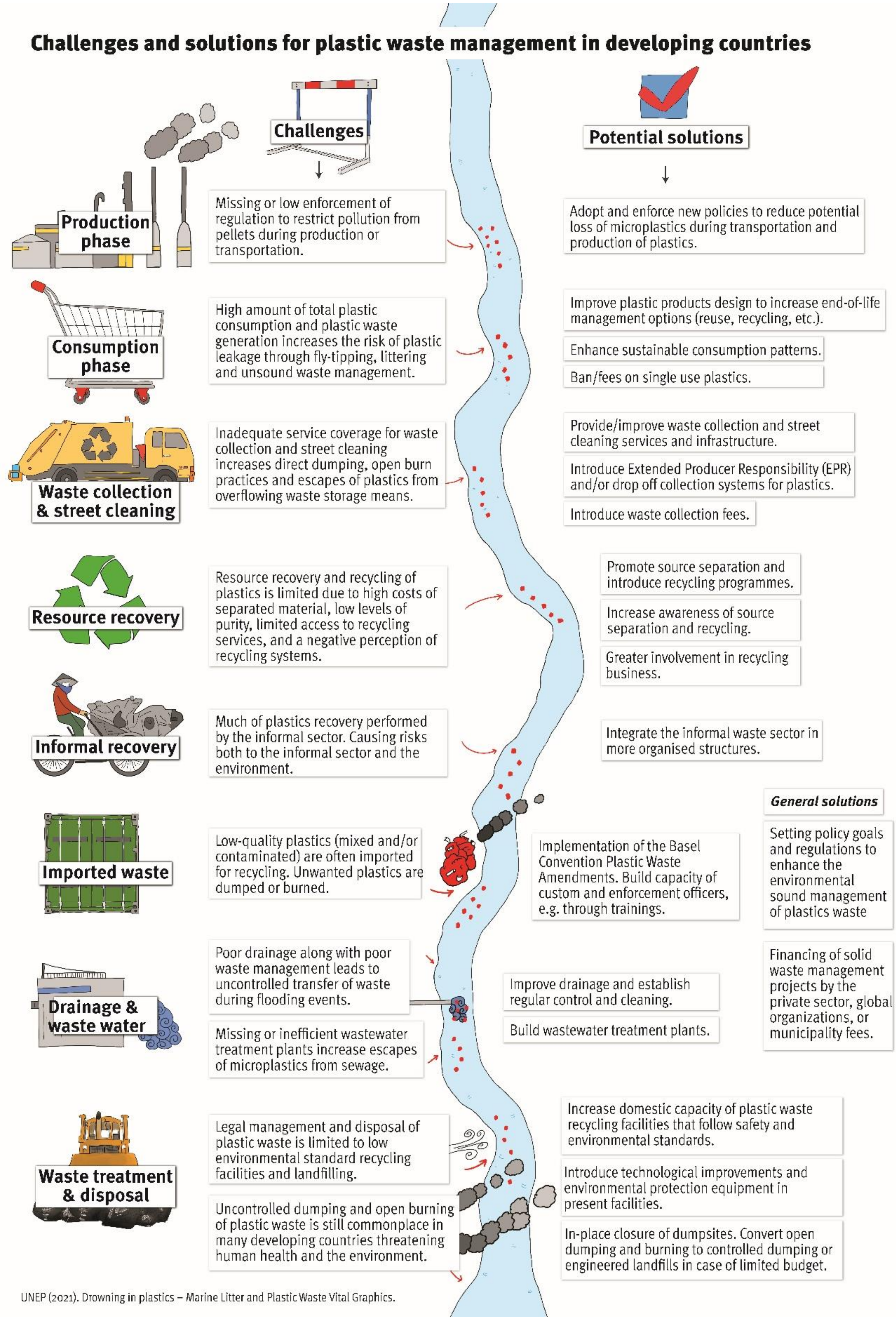
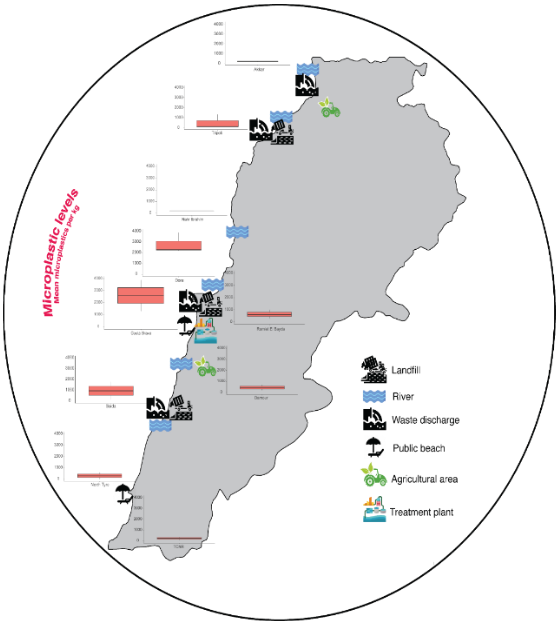


Figure 124. Percentage estimates of solid waste distribution along the Lebanese coast (Chalhoub, 2016).

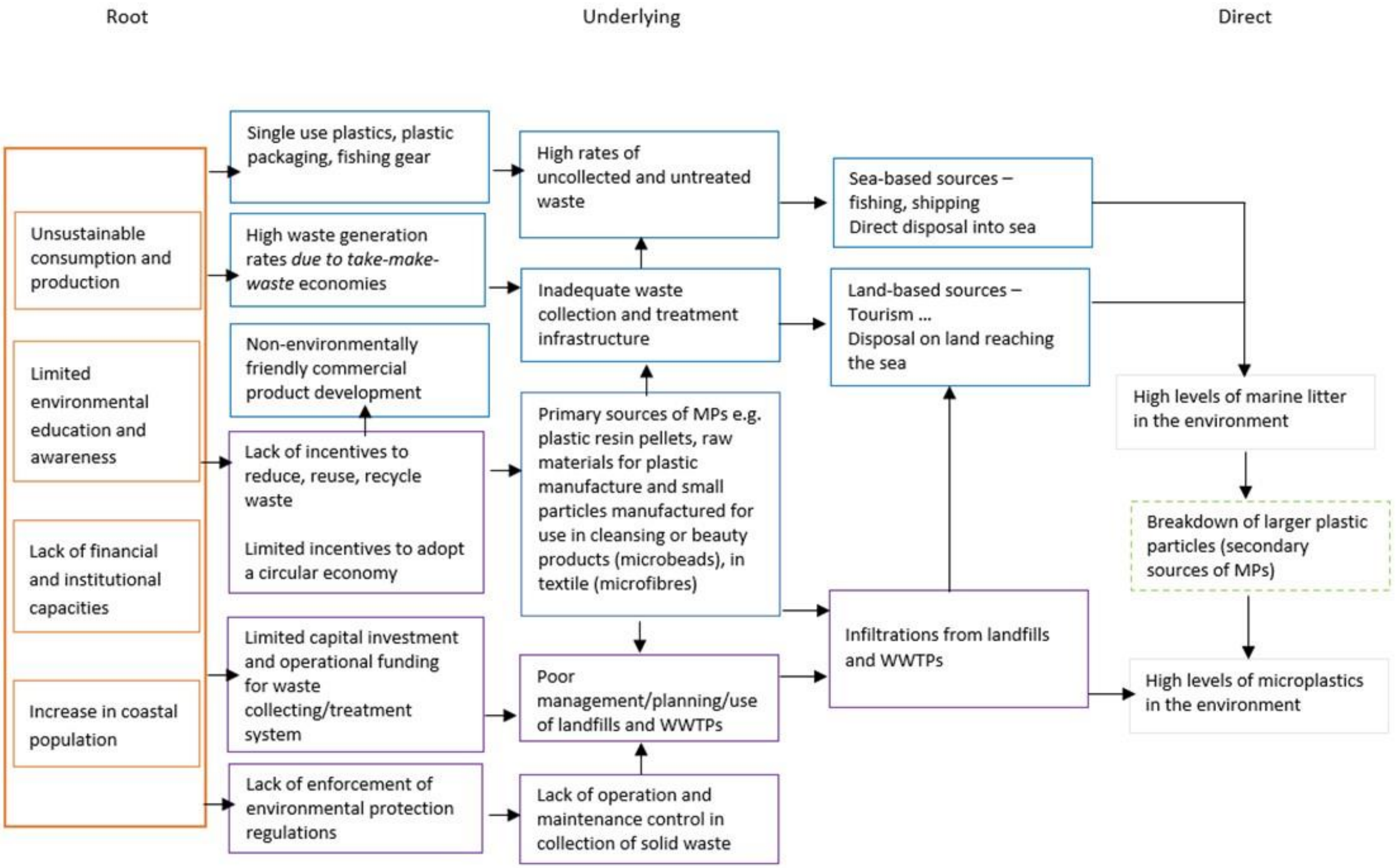

Challenges and solutions for plastic waste management in developing countries
Challenges
Potential solutions
Production phase
Missing or low enforcement of regulation to restrict pollution from pellets during production or transportation.
Adopt and enforce new policies to reduce potential loss of microplastics during transportation and production of plastics.
Consumption phase
High amount of total plastic consumption and plastic waste generation increases the risk of plastic leakage through fly-tipping, littering and unsound waste management.
Improve plastic products design to increase end-of-life management options (reuse, recycling, etc.).
Enhance sustainable consumption patterns.
Ban/fees on single use plastics.
Waste collection & street cleaning
Inadequate service coverage for waste collection and street cleaning increases direct dumping, open burn practices and escapes of plastics from overflowing waste storage means.
Provide/improve waste collection and street cleaning services and infrastructure.
Introduce Extended Producer Responsibility (EPR) and/or drop off collection systems for plastics.
Introduce waste collection fees.
Resource recovery
Resource recovery and recycling of plastics is limited due to high costs of separated material, low levels of purity, limited access to recycling services, and a negative perception of recycling systems.
Promote source separation and introduce recycling programmes.
Increase awareness of source separation and recycling.
Greater involvement in recycling business.
Informal recovery
Much of plastics recovery performed by the informal sector. Causing risks both to the informal sector and the environment.
Integrate the informal waste sector in more organised structures.
Imported waste
Low-quality plastics (mixed and/or contaminated) are often imported for recycling. Unwanted plastics are dumped or burned.
Implementation of the Basel Convention Plastic Waste Amendments. Build capacity of custom and enforcement officers, e.g. through trainings.
General solutions
Setting policy goals and regulations to enhance the environmental sound management of plastics waste
Financing of solid waste management projects by the private sector, global organizations, or municipality fees.
Drainage & waste water
Poor drainage along with poor waste management leads to uncontrolled transfer of waste during flooding events.
Missing or inefficient wastewater treatment plants increase escapes of microplastics from sewage.
Improve drainage and establish regular control and cleaning.
Build wastewater treatment plants.
Waste treatment & disposal
Legal management and disposal of plastic waste is limited to low environmental standard recycling facilities and landfilling.
Uncontrolled dumping and open burning of plastic waste is still commonplace in many developing countries threatening human health and the environment.
Increase domestic capacity of plastic waste recycling facilities that follow safety and environmental standards.
Introduce technological improvements and environmental protection equipment in present facilities.
In-place closure of dumpsites. Convert open dumping and burning to controlled dumping or engineered landfills in case of limited budget.
UNEP (2021). Drowning in plastics – Marine Litter and Plastic Waste Vital Graphics.



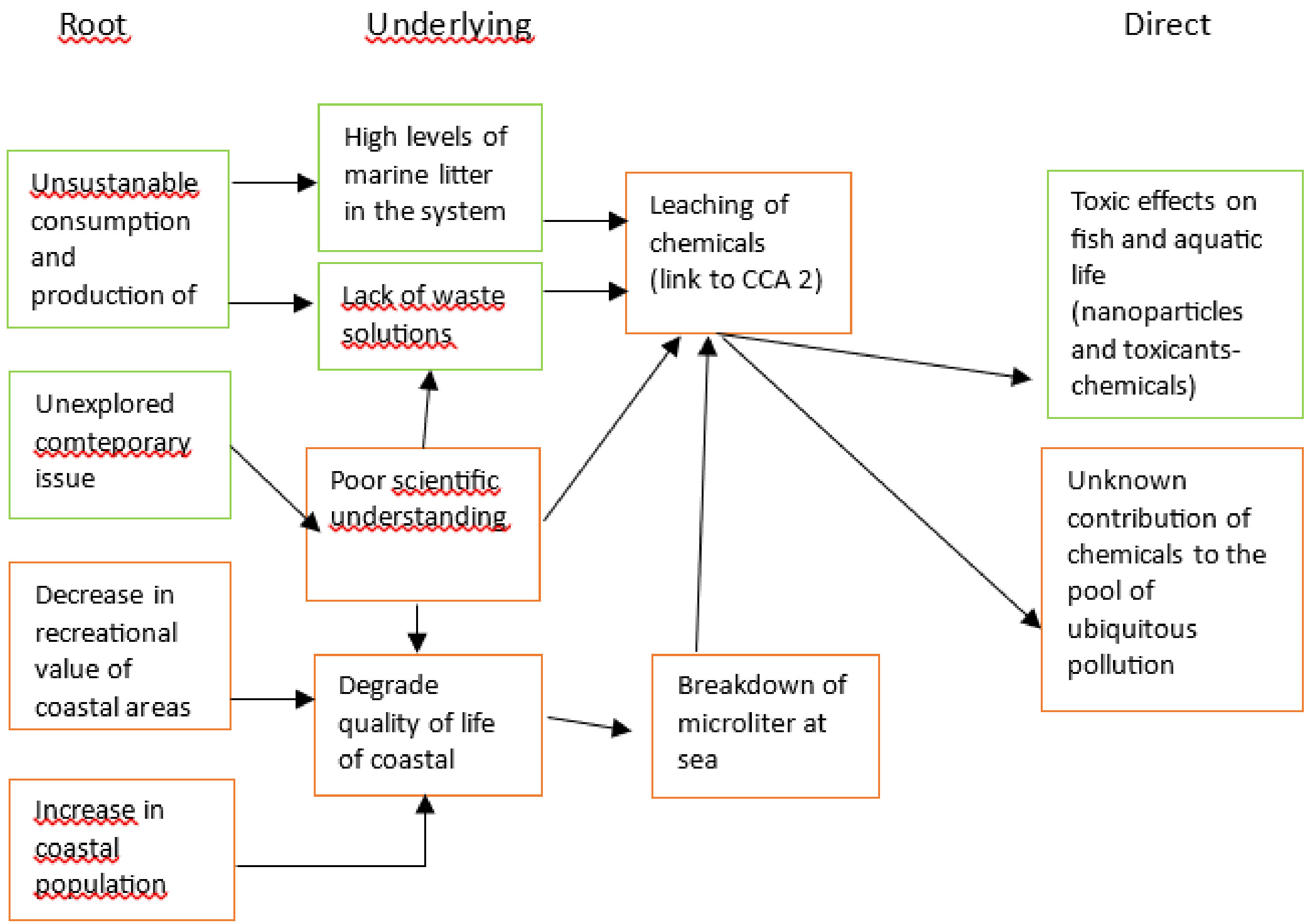
Map showing coastal landfills, waste discharge, WWTP, in addition to agricultural areas all representing sources of introduction of microplastics into the coastal area in Lebanon (Mahfouz et al.,2023).

Immediate, underlying and root causes (diagram)

Priority issue 4: Marine litter and microplastics



Priority issue 5: Nanolitter, chemicals leaching and toxicants



Conclusions and Knowledge gaps

Depending on the pathway through which litter enters the marine ecosystem, the sources of marine litter are traditionally classified as either land-based or sea-based. The vast majority of marine litter in the Mediterranean originates from land-based sources, which primarily include tourism, coastal recreational activities, general public litter, fly tipping, local businesses, industry, harbors, and infiltrations from unprotected landfills. 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. Marine litter on beaches is composed mainly of plastics (bottles, bags, caps/lids, etc.), metal (aluminum cans, pull tabs) and glass (bottles) (Figure 125) and originates from tourism and recreational activities. Marine litter from smoking-related activities may locally account for 40 % (collected items on beaches) and 53.5 % of the top 10 items counted in 2013. The latter figure is considerably higher than the global average (UNEP/MAP, 2017), making smoking-related litter a particularly serious problem in the Mediterranean.

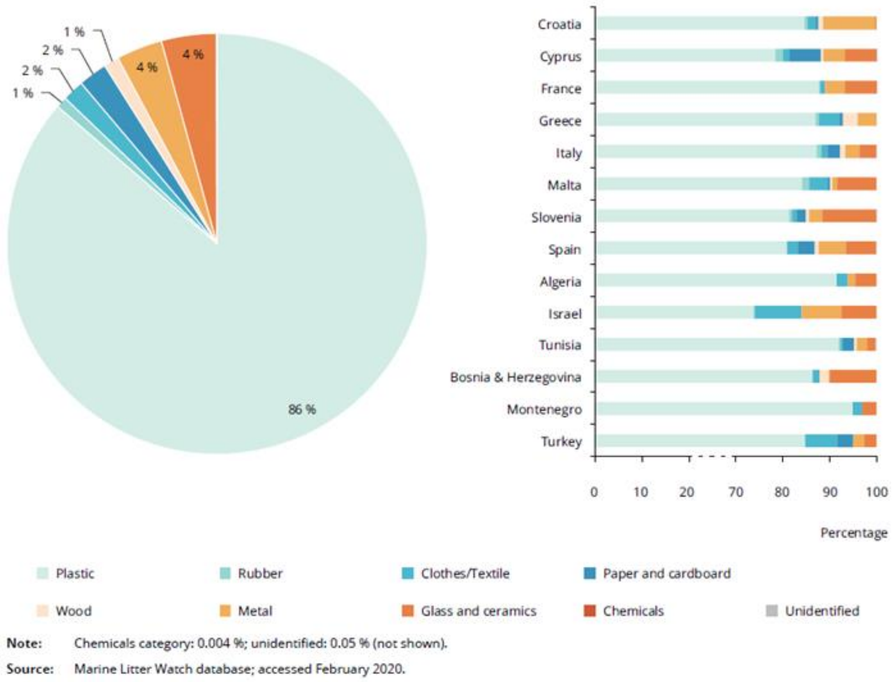


Figure 125. Composition of beach marine litter in Mediterranean countries (%). Source: EEA-UNEP/MAP (2020)

Items found on Mediterranean beaches indicate a predominance of land-based litter, recreational/tourism activities are the major sources (UNEP/MAP, 2015 and references therein). Other wastes, such as household-related waste, including sanitary waste, are also of great relevance (40 % in ARCADIS, 2014). Seasonal changes in the amount of litter originating from recreational/tourism activities are observed, with higher amounts of litter during and after the touristic season.

Egypt, Italy, and Turkey are considered to be the top three emitters of plastic, reflecting their high coastal populations (**Error! Reference source not found.**). The main hotspots are generally associated with coastal urban agglomerations and major rivers ().

Table 37.Coastal Population and Waste/plastic generation in 2010 in the Mediterranean countries (After Jambeck et al. (2015) and http://jambeck.engr.uga.edu/landplasticinput). (1) Coastal populations were estimated from global population around a 50 km buffer from the coastline, (2) World bank estimates, (3) modelled, (4) extrapolated/calculated. Source: UNEP/MAP (2015)

Country	Coastal population[1]	Waste generation rate [kg/person/day] [2]	% Plastic in waste stream[2]	% Inadequately managed waste[3]	Waste generation [kg/day]	Plastic waste generation [kg/day]	Inadequately managed plastic waste [kg/day][4]	Plastic waste littered [kg/day][4]
Albania	2 530 533	0,77	9	45	1 948 510	174 392	77 897	3 488
Algeria	16 556 580	1,2	12	58	19 867 896	2 374 214	1 378 693	47 484
Bosnia/Herzegovina	585 582	1,2	12	40	702 698	83 972	33 813	1 679
Croatia	1 602 782	2,1	12	9	3 365 842	402 218	37 053	8 044
Cyprus	840 556	2,07	12	0	1 739 951	207 924	831	4 158
Egypt	21 750 943	1,37	13	67	29 798 792	3 858 944	2 572 170	77 179
France	17 287 280	1,92	10	0	33 191 578	3 302 562	0	66 051
Greece	9 794 702	2	10	0	19 589 404	1 949 146	0	38 983
Israel	6 677 810	2,12	14	1	14 156 957	1 974 896	12 577	39 498
Italy	33 822 532	2,23	6	0	75 424 246	4 487 743	0	89 755
Lebanon	3 890 871	1,18	8	34	4 591 228	365 003	123 700	7 300
Libya	4 050 128	1,2	12	23	4 860 154	580 788	132 985	11 616
Malta	404 707	1,78	12	6	720 378	86 085	5 456	1 722
Monaco	34 050	2,1	12	0	71 505	8 545	0	171
Montenegro	260 336	1,2	12	30	312 403	37 332	11 353	747
Morocco	17 303 431	1,46	5	66	25 263 009	1 250 519	824 650	25 010
Gaza	3 045 258	0,79	8	6	2 405 754	191 257	11 515	3 825
Slovenia	336 594	1,21	12	1	407 279	48 670	550	973
Spain	22 771 488	2,13	13	0	48 503 269	6 281 173	0	125 623
Syria	3 621 997	1,37	13	65	4 962 136	642 597	419 763	12 852
Tunisia	7 274 973	1,2	12	60	8 729 968	1 043 231	621 077	20 865
Turkey	34 042 862	1,77	12	16	60 255 866	7 200 576	1 187 323	144 012
Total/mean	208 519 478	2	11	23	360 939 138	36 560 188	7 451 413	731 036

Table 38. Major sources of marine litter, including pollution intensity. Source: Sharma et al. (2021)

Major sources of marine litter in the mediterranean sea			Pollution intensity (Tons/year)
Cities/Country	Barcelona	Spain	1787
	Izmir	Turkey	1562
	Algiers	Algeria	1.22
	Alexandria	Egypt	2209
	Tel Aviv	Israel	3278
Rivers and water-way system/Country	The Po Delta	Italy	1350
	Ceyhan	Turkey	5109
	Seyhan	Turkey	3465
	Nile	Egypt	6772
	Rhone	France	1454
	Buyuk Menderes River	Turkey	2406
Shipping lanes	International		20,000

The table was constructed after extracting data from Liubartseva et al. (2018).

Although vast majority of marine litter in the Mediterranean Sea originates from land-based sources, in some regions, sea-based sources (shipping, fisheries) are very important. Sea-based sources of marine litter include shipping (merchant shipping, ferries and cruise liners), recreational boating, fishing activities (commercial and recreational fishing vessels), and offshore installations (oil and gas platforms, drilling rigs) and aquaculture sites offshore oil and gas platforms. Litter enters the sea through both accidental and deliberate discharges ranging from galley waste to cargo containers. Recent estimates for the Mediterranean indicate that sea-based sources account for 5 % of marine litter (EEA-UNEP/MAP, 2020). This may be attributed to the role played by port-reception facilities and to the result of the obligation for vessels above 400 tonnes or carrying more than 15 people to implement garbage management plans in accordance with international maritime law.

The amount of litter originating from ships in the Mediterranean was estimated at around one million tons (UNEP/MAP, 2015). This figure was based on the evaluation of global inputs from ships at 6 million tons, taking into account that 30 % of the maritime traffic worldwide passes through the Mediterranean Sea. The contribution of fishery-related litter could be estimated at between about 3 % and 15 % of marine litter (Addamo et al., 2017).

Identifying the sources of litter items is a complex task, as marine litter enters the sea from point and diffuse sources both land-based and sea-based and can travel long distances before being deposited onto shorelines or settling on the bottom of the ocean, sea, or bays. Yet, the identification of the origins and pathways a crucial step in monitoring and effectively addressing the issue of marine litter.

When it comes to microplastics, these enter the aquatic environment either as a readily manufactured ingredient through the treated wastewater effluent, or as product of the breakdown and photodegradation of marine litter, known as secondary sources. Examples of already manufactured microplastics are some raw materials in cosmetic products, or fibers from synthetic clothes that escape from WWTPs into the aquatic environment. In fact, WWTPs cannot remove plastics around the size of a cotton swab stick or below.

The root, underlying and direct causes elucidated in the CCA for marine litter and plastic pollution, including microliter, nanolitter and toxicants, highlight the so-called source-to-sea paradigm that links the waste management infrastructure and circular economy models on land to the marine litter issue downstream (Figure 126). One of the key underlying causes is the inadequate waste collection and treatment infrastructure, which fails to keep up with the increasing waste generation rates, in particular in the Mediterranean South countries (Figure 127). The current prevalent lifestyles of people living in the Mediterranean countries are based on unsustainable linear (non-circular) resource consumption, with a high demand for consumer goods and other processed products. The quantity of MSW generated in a country is closely related to its economic development, rate of urbanization, its types and patterns of product consumption, household revenue, and lifestyles. In particular in the Mediterranean South countries, population increase, improvements in the standard of living, represent the key drivers of waste generation, especially in coastal urban areas. In fact, consumption growth is generating changes in the production and composition of waste, including ‘new’ waste streams such as electronic and packaging waste. Approximately 50 % of marine beach litter items are single-use plastics (SUPs), including bottles, bags, caps/lids, strings and cords, cigarette butts, crisp packets and sweet wrappers, reflecting the changes in consumption and lifestyles (EEA-UNEP/MAP, 2020).

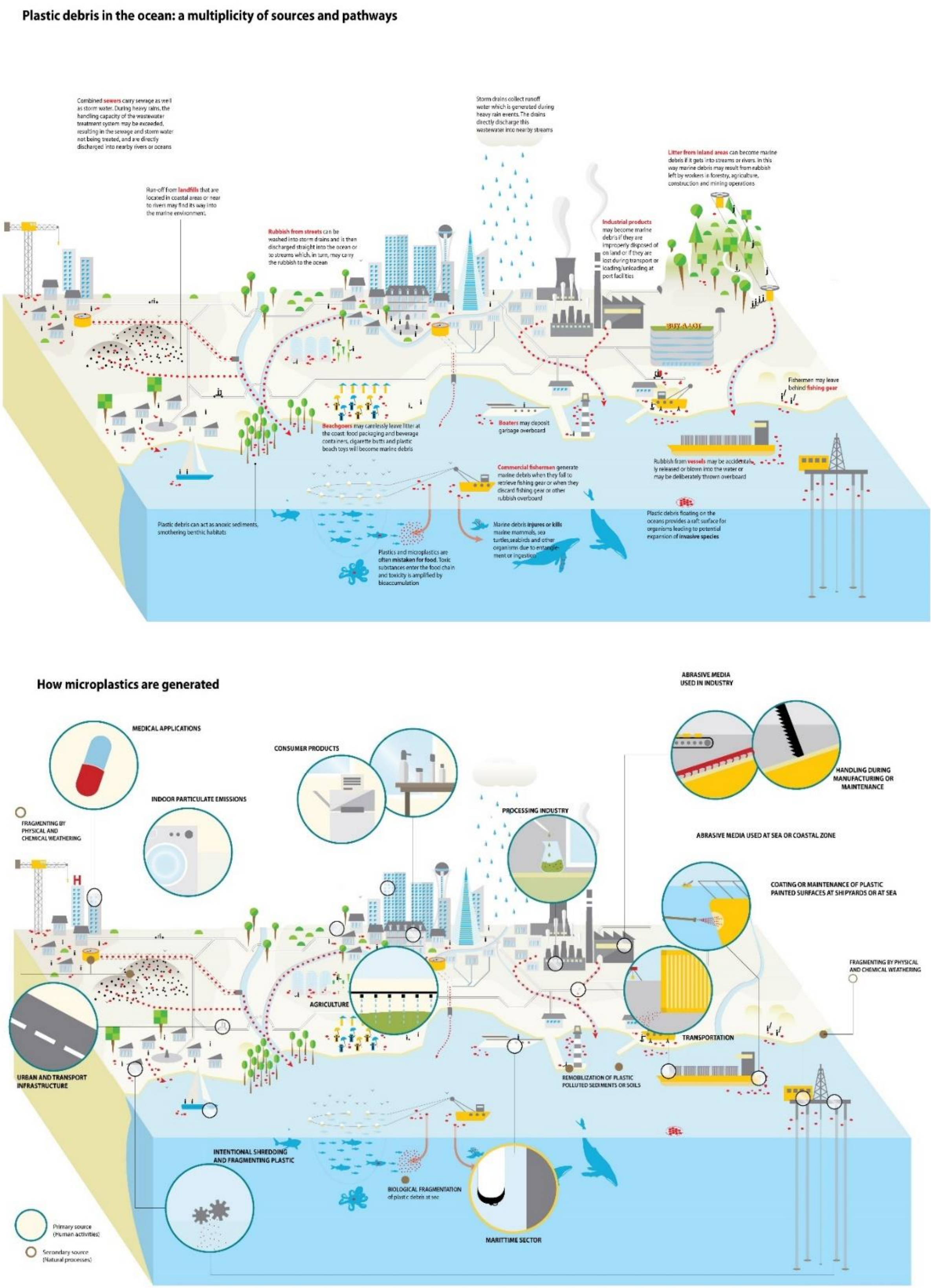
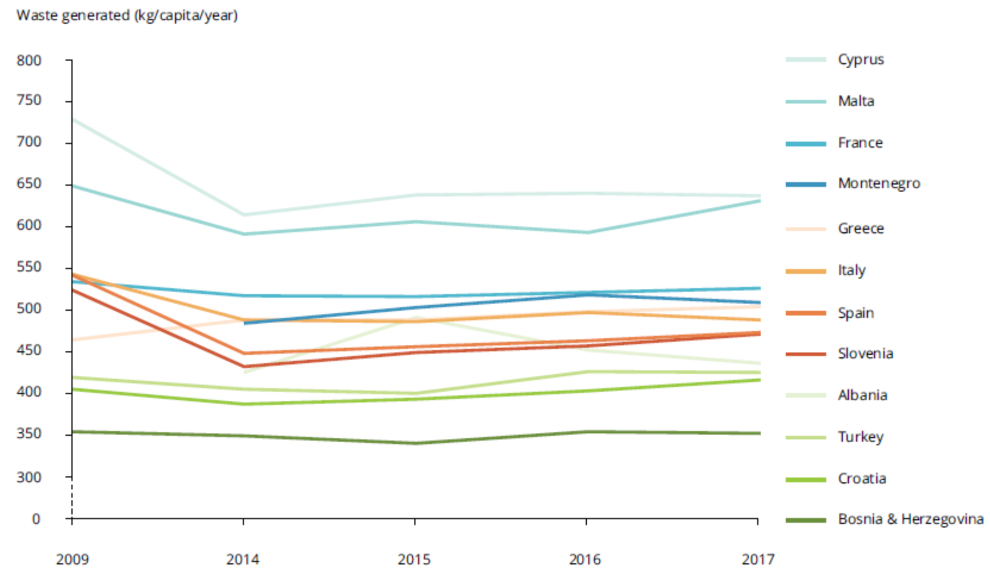
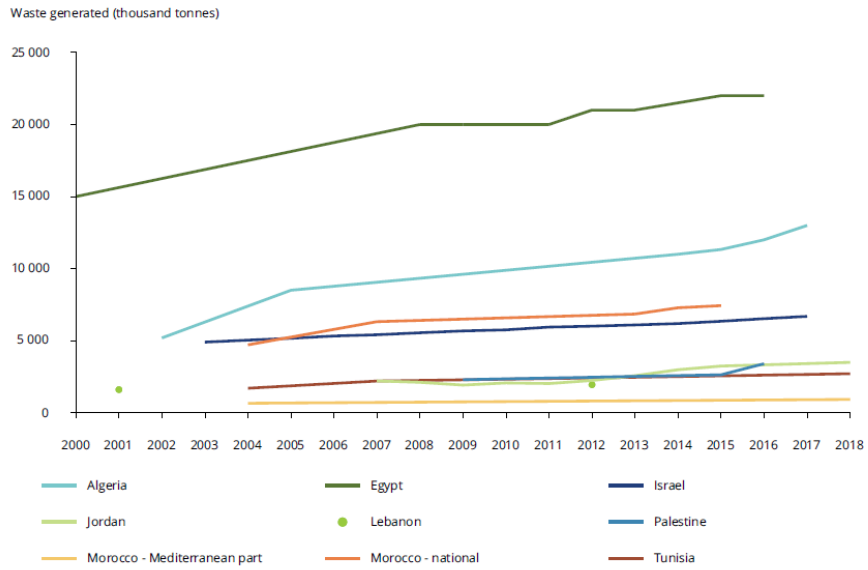


Figure 126. Multiplicity of plastics debris sources (top) and the generation of microplastics (bottom). Source: GRIDA.



Note: Albania, Montenegro: incomplete data series.

Source: Eurostat (2020).



Note: Data for Jordan, Morocco and Tunisia has been retrieved from a combination of sources.

Source: UNSD except Egypt: H2020 National Report for Egypt (2020); Israel: H2020 National Report for Israel (2020); Morocco (2007): H2020 National Report for Morocco (2020); Jordan (2014-2018) H2020 National Report for Jordan (2020); Palestine: H2020 National Report for Palestine (2020); Tunisia (2018): H2020 National Report for Tunisia (2020).

Figure 127. Top: Municipal solid waste generation per capita in Mediterranean EU countries, the Balkans and Turkey (kg per capita per year). Bottom: Waste generation in Mediterranean South countries. Source: EEA-UNEP/MAP (2020)

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4.2.3. Enhancing nature (environment)

Following on the priority transboundary problems the following environmental changes were identified as a high transboundary concern supported by the Biodiversity Loss transboundary causality assessment report – contribution to the UNEP/MAP GEF TDA Report update by 2023:

Priority issue 6: FISHERIES HARM (Overfishing)
Priority issue 7: BIODIVERSITY DECLINE (Key species & NIS)
Priority issue 8: COASTAL HABITATS (Degradation & Loss)

Priority issue 6: FISHERIES HARM (OVERFISHING AND TRAWLING)

Description of the problem and its transboundary importance

The impact of fisheries on key vulnerable taxa, including also vulnerable habitats, has been largely reviewed. The latest FAO´s SOFIA report (The State of World Fisheries and Aquaculture 2022) provides an updated and succinct summary of the status of fisheries in the Mediterranean basin. After reaching a historical maximum of about 2 million tonnes in the mid-1980s, total landings in the Mediterranean and Black Sea declined to a low of 1.1 million tonnes in 2014; since 2015, they have recovered slightly, with a catch of 1.4 million tonnes in 2019. Most of the commercially important stocks regularly assessed continue to be fished outside biologically sustainable limits, including the stocks of hake (Merluccius merluccius), turbot (Scophthalmus maximus) and European pilchard or sardine (Sardina pilchardus). A decreasing trend in the level of overfishing of some of these stocks has been observed in past years but according to the General Fisheries Commission for the Mediterranean (GFCM), the overall fishing mortality for all resources combined is estimated at nearly 2.5 times higher than sustainable reference points. In 2019, only 36.7 percent of the assessed stocks in the Mediterranean and Black Sea were fished within biologically sustainable levels (FAO 2022). The main value is that the report gives specific details on the catch of main stocks, catch trends by fleet segments, fisheries management, as well as socioeconomic information, however, the information on the stock status (biomass) of the situation of the main commercial species is quite scant.

Small pelagics (anchovy, sardine, sprat)

In the whole GFCM area of application, European anchovy (Engraulis encrasicolus) and sardine (Sardina pilchardus) continue to be the main species captured (333,340 tonnes and 185,700 tonnes on average, respectively), followed by European sprat (Sprattus sprattus) (57,400 tonnes). Sardine and European anchovy continue to be the most relevant species in the Mediterranean Sea, together accounting for 37% of total landings. The anchovy shows stability across the region, with a steady average since 2016 and a decrease (by 24%) in the maximum exploitation ratio in 2018. The average exploitation ratio of sardine, on the contrary, has been steadily increasing since 2010.

Demersal species

European hake, whiting (Merlangius merlangus), Norway lobster (Nephrops norvegicus) and turbot (Scophthalmus maximus) show continuous declines in catch since the 1980s–1990s, while sole (Solea solea) has remained at low levels since the late 1990s. Both mullet species, i.e., red mullet and surmullet (Mullus surmuletus), as well as priority mollusc and most of the crustacean species, i.e. common cuttlefish (Sepia officinalis), spottail mantis shrimp (Squilla mantis), deep water rose shrimp (Aristeus antennatus) and giant red shrimp (Aristaeomorpha foliacea), show a generally increasing trend, with fluctuations in some cases over recent years.

Other commercial species

Other than the main species, there are a number of species that despite having commercial importance are caught in much smaller volumes. For most of these, there is very little information available on the stock status and/or the fishing pressure. In these cases, the only information available is often the declared landed catch. The GFCM acknowledges the situation thus: Biomass reference points are not commonly available for assessed stocks; therefore, the percentage of stocks fished outside biologically sustainable limits is mainly estimated from the level of fishing mortality in relation to the fishing mortality reference point (FAO 2020).

Bottom trawling

This fishing method stands out as a main driver of biodiversity loss due to its highly impacting effects on a wide array of vulnerable benthic habitats, most of which are poorly studied, and which often are composed by long-lived, fragile species, unable to withstand this impact. Many of these species are also biogenic, so when the species disappear due to impact of trawling, the habitats they create are also lost. The ecological footprint of the bottom trawling fleet is widespread across the Mediterranean Sea. The level of compliance with the measures put in place to limit the impact of the bottom trawling fleet is low. Trawling activities have been detected even within the boundaries of marine protected areas.

Major environmental impacts and socio-economic consequences (including gender aspects)

Marine food webs alterations in the Mediterranean

Given that most of these species have a crucial role in the marine trophic webs, the situation is far from favourable. When fishing surpasses the sustainable level, it exerts an additional pressure on the marine trophic web that goes beyond the impact on targeted species. If unchecked, continued overfishing can result in cascade effects throughout the marine trophic chain and can trigger phase shifts similar as those described by Montefalcone et al (2015) for seagrasses. This is in line with the results from Piroddi et al. (2017). These authors found that, across the Mediterranean basin, over recent years there has been a reduction in abundance of important fish species (~34%, including commercial and non-commercial) and top predators (~41%), and increases of the organisms at the bottom of the food web (~23%). In more detail, Piroddi et al. (2017) found that, considering sub-regional seas, there was a clear decline of small pelagics (-41%), demersal fish (-49%) and elasmobranch (-60%) biomasses in the Western and Adriatic Seas, a fluctuation of these groups in the Ionian Sea while in the Eastern Mediterranean they respectively decreased, increased, and fluctuated. Invertebrate biomass slightly decreased in the Adriatic Sea (-13%); fluctuated in the Western and Ionian Seas; and increased in the Eastern Mediterranean (+53%). Total catch increased in all the areas (+189%) until the beginning of 1990s, but in the Western and Ionian Seas started to fluctuate afterwards, while in the Eastern and Adriatic Sea it gradually declined. As for the different trophic level indicators assessed, the mean trophic level (TL) of the community slightly increased in the Western Mediterranean (+10%) and decreased in the other sub-regions (-5%), while the mean TL ≥3.25 and mean TL catches decreased.

Overall, the findings from Piroddi et al. (2017) show that in general, both biomass trends and ecological indicators revealed that the combined effect of excessive fishing pressure and changes in the primary productivity have altered the Mediterranean marine ecosystem over time, especially reducing the proportions of top predators and larger fish (e.g., pinnipeds, elasmobranchs, large pelagic fish) and increasing the abundance of groups at lower trophic levels (e.g., invertebrates). They also show that small pelagic species decreased, at a different time scale, in the majority of the studied Mediterranean sub-areas; the only exception was the Ionian Sea where no clear trends were observed. These small pelagics fish (mainly European pilchard and anchovy) constitute the bulk of fish catches in the Mediterranean Sea, accounting for almost 40% of total landings, and they are of high commercial interest. Therefore, an increase of fishing mortality, together with changes in productivity, have affected these stocks throughout the Mediterranean Sea.

A clear sign of change in the structure of the Mediterranean Sea ecosystem is visible from results of the mean trophic level of the community, which shows a decline since 1950s reflecting the decline of large predators/fish stocks and increase of lower trophic level organisms (Piroddi et al., 2017). These results are consistent with previous ecosystem assessments. Moreover, the trophic level of the catches for the whole Mediterranean Sea and as well for the majority of the sub-areas (Western, Adriatic and Ionian Seas) presented a clear 'fishing down' effect that occurs when top predators and large sized fish are removed from the ecosystem and gradually replaced by lower trophic level organisms. Similar trends had been observed in the Mediterranean Sea, both at regional, sub-regional and more local scale. The only exception was found in the Eastern Mediterranean Sea where, contrary to the rest of areas, a situation of 'fishing up' was found. This might be a 'false fishing up effect' occurring when small pelagic fishes and invertebrates, with a low trophic level, and larger-size predators fish are both intensely fished and/or depleted.

There are indications of a basin-wide ecological shift driven by the loss of top predators (through direct overfishing, or bycatch), towards a poorer ecosystem dominated by lower trophic level species. It seems imperative to bring the GFCM to its full functionality, so that it can harness and reverse this trend.

Priority issue 7: BIODIVERSITY DECLINE (BY-CATCH, KEY SPECIES&NIS)

Description of the problem and its transboundary importance

The lack of implementation of measures to avoid or mitigate the accidental catch, or bycatch, of vulnerable species causes that each year, seabirds, marine turtles, elasmobranchs and other vulnerable species are killed in such amounts that jeopardise the sustainability of their populations and/or hampers the populations recovery. While other drivers (i.e. habitat loss, pollution including plastic litter) are also likely impacting vulnerable species, the main common factor for population declines amongst vulnerable marine taxa is direct or indirect mortality caused by fisheries bycatch.

This section will review the diversity and impacts threating the viability of several groups of vulnerable marine species. "Vulnerability" is used in the biological sense that the species assessed present biological and ecological traits (e.g. low fecundity, long lifespan, sessile) that render them intrinsically vulnerable to non-natural mortality of anthropic origin. The taxa studied fall within two main categories: marine vertebrates (seabirds, elasmobranchs, sea turtles and marine mammals), and benthic invertebrates. The latter category encompasses cold water corals and other vulnerable benthic communities. The single main threat common to all these vulnerable taxa is fisheries mortality, generally through accidental bycatch but also due to habitat loss.

Carpentieri et al. (Eds.) (2021) constitutes the key source of information for this review. It presents a large amount of excellent quality information about relevant taxa. Its results are presented below.

Seabirds

-The effects of fisheries on seabirds can be manifold: (1) overexploitation by fisheries can decrease the availability of some prey for seabirds; (2) abundant fishery discards provide a very predictable food resource for scavenging seabirds that would otherwise be unattainable; and (3) seabirds can get caught or entangled in some types of fishing gear or they can collide with warp cables during shooting and hauling (trawls).

-About 50% of the available literature and records in the Mediterranean on seabird bycatch refer to longline fisheries, followed by set nets (gillnets and trammel nets, 16.7%) and bottom trawls (14%). This dynamic is consistent with data available from other regions of the world.

-Available data on seabird bycatch in Mediterranean and Black Sea fisheries is scarce and unequally distributed, with data mainly gathered in the western Mediterranean (68% of records).

-The most impacting gear is drifting (pelagic) longline, also set nets and demersal longline. Impacts by pelagic longline seem concentrated in the Western Mediterranean, where most breeding colonies of seabirds are found (e.g., Balearic Islands).

-Of the 15 seabird species present in the Mediterranean, three have high susceptibility to bycatch: the Balearic shearwater (Puffinus mauretanicus) and the Yelkouan shearwater (Puffinus yelkouan) in set nets, and Scopoli's shearwater in pelagic and demersal longline.

-While bycatch is the main driver of decline, populations are also affected by other factors (decrease and degradation of available coastal habitat, introduced predators and pollution).

Sea turtles

-Globally there are seven species of sea turtles. Only two (Loggerheard turtle Caretta caretta and green turtle Chelonia mydas) are found to reproduce within the Mediterranean basin.

-Sea turtles are impacted by an array of gears. Set nets, bottom trawling and pelagic longline are the main ones (Figure 128). Each year set nets kill at least about 16,000 turtles. Bottom trawling (BT) causes about 9,000 deaths per year.

-The coasts of Turkey, Egypt and Lybia are also important feeding grounds and register a high rate of turtle bycatch by BT. In Turkey, the bycatch of scarcer green turtles (Chelonia mydas) is greater than that of loggerhead turtles (Caretta caretta).

-Two main hotspots of turtle bycatch by BT are Tunisia and southern Sicily (Gulf of Gabès), which represent 40% of total turtle bycatch by BT, and the Adriatic Sea, where 14,000 turtles are caught - annually by the fleet of more than 1,000 bottom trawlers.

-All BT mortality estimates refer to turtles that are already dead or dying at the time of the hauling. They do not include post-release mortality by injuries, stress, and decompression sickness. Hence the true impact of BT is likely higher than estimated.

Figure 128. Sea turtle incidentally caught by a bottom trawler ©Massimo Virgili

-Pelagic longlines are another main source of incidental catch of marine turtles. Between 27,000 and 56,000 sea turtles are caught annually by pelagic longlines in the Mediterranean, with a direct mortality rate of around

20%. The introduction of the mesopelagic longline in the early 2010s seems to have strongly reduced sea turtle bycatch by longline fleets in Spanish and Italian waters.

-Small-scale fisheries (SSF) in the Mediterranean use gillnets and/or trammel nets (set nets). Set nets represent a huge impact for sea turtles in coastal areas, where these types of nets are used. In the Adriatic Sea, Italy, Croatia and Slovenia combined catch 9,000 sea turtles per year in set nets. The eastern basin is another set nets turtle bycatch hotspot.

-The use of gillnets with small meshes should be encouraged to avoid sea turtle bycatch. Trammel nets should be replaced by alternative methods, such as fish pots.

-In total, for all gears, the estimated range is 121,000-150,000 turtles caught and 33,000-39,000 deaths per year.

-Anthropic land-based threats to sea turtle populations are mainly associated with modifications made to the beaches hosting nesting sites. The construction of new buildings, coastal erosion and sediment changes (due, for example, to breakwater barriers, beach nourishment and beach cleaning) reduce the habitat available for nesting. Artificial lights from land can scare away females approaching the beaches and disorient hatchlings. Stray animals may feed on eggs and hatchlings.

Elasmobranchs

-Elasmobranchs or chondrichthyans (sharks, skates, rays, chimaeras and guitarfishes) are globally threated by overfishing, finning and habitat loss. The Mediterranean and Black Sea contribute about 7% of global elasmobranch diversity, with at least 48 species of sharks, 38 species of batoids (rays and skates, Fig. 129) and two species of chimaeras.

-Between 53 and 71% of Mediterranean elasmobranch species are at risk, with many showing a worse regional conservation status, compared to their global status.

-Only 28% of Mediterranean and Black Sea elasmobranch species (the 24 species included in Annex II of the SPA/BD Protocol) have legal protection. The remaining species can be fished and marketed. There is a mismatch between conservation risk and legal protection.

-But even legally protected, IUCN Red List-classified species are commercially fished: Targeted fishing of protected guitarfishes (Rhinobatos spp.) and sandbar sharks (Carcharhinus plumbeus) occurs in the Gulf of Gabès (Tunisia), a key nursery area for several shark species.

-In the Levantine basin there is a target fishery for the endangered and protected Spinetail devil ray (Mobula mobular).


Figure 129. Spintail devil ray (Mobula mobular). ©Alessia Scuderi/Tethys

-Bycatch in fisheries probably presents the main threat to elasmobranch populations in the Mediterranean Sea, with all species potentially affected. All species may be caught in trawlers, almost all (94%) in various types of nets, and two thirds (67%) are vulnerable to bycatch by longliners.

-Fishing impacts vary regionally. 80% of captures in the central Mediterranean are due to longline, while in the Adriatic most captures are due to pelagic trawl. Overall, most elasmobranch bycatch comes from longliners (55%), followed by small-scale fisheries (18%), bottom trawlers (13%), pelagic trawlers (11 %), and purse and tuna seiners (almost 3%).

-Bycatch in pelagic longline is dominated by two species: blue shark (P. glauca) and shortfin mako (I. oxyrinchus). Bycatch in demersal longline is varied and consists mainly of batoids and demersal elasmobranch species, including guitarfish.

-Sharks and rays are not commonly distinguished at the species level in fisheries. Records usually report (only) the landed species as mixed sharks or skates.

-The highest diversity of elasmobranch priority species is in the eastern Mediterranean, followed by the central Mediterranean.

-Existing management and conservation approaches are insufficient. Applying the precautionary principle, legal protection should be extended to all additional species which are intrinsically vulnerable to fishing impacts and yet are still unprotected. Vulnerable elasmobranchs ought to receive the same legal protection, and equivalent level of effort in bycatch mitigation measures, than the other groups of vulnerable marine vertebrates (generally more favoured by the public).

-Potentially useful conservation measures for elasmobranchs are already known and include fishing bans in nurseries and breeding areas, as well as the release of all live specimens at sea.

Marine mammals

-Marine mammals in the Mediterranean and Black Sea fall into two main taxa, Pinnpedia and Cetacea. There is only one pinniped species, the Mediterranean monk seal (Monachus monachus). In contrast, between 18 and 21 different cetacean species have been recorded in the Mediterranean, of which 12 occur regularly. It is worth to mention there are 3 subspecies endemic to the Black Sea: the Black Sea common dolphin (Delphinus delphis ponticus), the Black Sea bottlenose dolphin (Tursiops ponticus) and the Black Sea harbour porpoise (Phocoena phocoena relicta).

-To a greater or lesser extent, all cetacean species may interact with different fishing gears and fishing activities. Some cetacean species, mainly those inhabiting coastal areas, are attracted to fisheries, which offer them concentrations of "easy food". Interactions between cetaceans and different types of fishing gear (e.g. trammel nets, gillnets and demersal longlines) are a concern.

-The common bottlenose dolphin (Tursiops truncatus) is the most common species in coastal and neritic areas and is considered the species that interacts the most with small-scale fishing activities.

-The common dolphin (Delphinus delphis) has shown a steep decline in its abundance and distribution in the Mediterranean basin over the last hundred years due to the impacts of human activities (fisheries, but also pollution and habitat loss). Currently, the most abundant populations occur in the Greek Ionian Sea, the Alboran Sea and off the northern coast of Africa.

-Population estimates for all other cetacean species present in the Mediterranean are much more difficult to calculate and results are less reliable.

-The use of large-scale driftnets targeting tuna, swordfish and other big pelagics during the 1980s and 1990s lead to 10,000 cetaceans caught per year. Since the implementation of the international moratorium on the use of driftnets, cetacean bycatch in the Mediterranean has decreased drastically (except for the Black Sea, where cetacean bycatch is still a huge concern).

-Large-scale driftnets are now banned, but some anecdotal evidence (e.g., stranded cetaceans showing typical signs of entanglement in large driftnets, images and videos on social networks, or online news sources) indicate that this activity may still be illegally practiced in some areas. Also, cetacean mortality due to interactions with small-scale fishing gear may be underestimated.

-As for the Mediterranean monk seal (MMS, Monachus monachus), the only pinniped species inhabiting the Mediterranean region, interactions between monk seals and fisheries often lead to accidental deaths of MMS if they get entangled in the nets. The majority of interactions between monk seals and fisheries occur in coastal areas and involve small-scale fisheries that overlap with seal habitat. A study about MMS mortality in Greece identified net entanglement as the cause of death in 65% of the recorded cases.

Macrobenthic invertebrates

-Macrobenthic invertebrates such as soft and hard corals, sponges, echinoderms, molluscs and other benthic organisms contribute to forming structured habitats that may constitute vulnerable marine ecosystems (VMEs).

-The General Fisheries Commission for the Mediterranean (GFCM) defined Mediterranean VMEs indicator taxa, habitats and features. VMEs are groups of species, communities, or habitats that may be vulnerable to impacts from fishing activities. A benthic ecosystem is classified as vulnerable based on its uniqueness or rarity, its functional significance, its fragility (both physical and functional), its structural complexity and the life-history traits of the species that make its recovery difficult.

-Cold water coral reefs and aggregations are the most well-known type of VME. Other types or VMEs might be less known but are equally relevant for biodiversity (Figure 130). Some VMEs found in the Mediterranean are: mesophotic stony corals, hard-bottom coral gardens, soft-bottom coral gardens (such as bamboo coral Isidella elongata), sea pen (Pennatulaceans) fields, deep-sea sponge aggregations, tube-dwelling anemone patches, crinoid fields, oyster reefs and other giant bivalves, seep and vent communities, and other dense emergent fauna (e.g. the mud sea anemone Actinauge richardi, the brachiopod Gryphus vitreus and bryozoan beds).

Figure 130. Examples of vulnerable marine ecosystem habitats. ©Oceana. Source: (Carpentieri et al. 2021)

-Many VMEs host a rich associated fauna, including endangered and protected species as well as fish and crustacean species of high commercial value. As a result, these habitats are often targeted and impacted by commercial fisheries.

-Cold-water coral reefs are marine bioconstructions structuring important habitats of the deep Mediterranean Sea, identified as biodiversity hotspots of considerable ecological and economic value. They are mainly composed of the so-called white corals, namely the colonial species Madrepora and Lophelia pertusa (currently renamed as Desmophyllum pertusum), as well as the solitary coral Desmophyllum dianthus.

-The Mediterranean near-endemic Bamboo coral Isidella elongata is classified as "Critically Endangered" in the IUCN Red List of Threatened Species, which is the maximum risk category before extinction. Soft-bottom coral gardens and sea pen fields are heavily impacted by trawl fishing, as these habitats support higher abundance and biomass of commercial crustaceans. Thus, Isidella elongata which was once a common species, is now restricted to a few and scattered patches that harbour the last living gardens of the species. Similarly, sea pen fields remain only in areas where trawling fishing pressure is generally low or absent, whereas they have disappeared from areas where they were formerly found.

-The impact of trawling in the degradation of VMEs is both direct (by scraping the seabed, resuspending the sediments and destroying habitat-formers), and indirect, by inducing long-term changes in the benthic community, reducing habitat complexity and affecting ecosystem functioning.

-The use of a VME encounter protocol for deep-sea fisheries using bottom-contact gear, as well as fishery monitoring protocols based on onboard observers, could provide new information on the distribution of VME indicators in many Mediterranean areas not covered by scientific surveys.

-The rare giant bivalve Atrina fragilis was reported as a dominant component of commercial "rapido" trawl bycatch in the northern Adriatic Sea, with most individuals highly damaged by this fishing practice.

-Although less impacting than bottom trawling, bottom-set (demersal) longlines and small-scale demersal fishing gear can also affect VMEs, directly, and as ghost fishing (lost longlines and gear from SSF represent the majority of the marine litter recorded in the proximity of rocky sea bottoms).

-Effective fishing closures represent useful spatial management measures to prevent the bycatch of VME indicator taxa by commercial bottom fishing and thus mitigate adverse impacts on marine ecosystems.

As conclusion, for all groups of vulnerable species impacted by different fishing methods, achieving an efficient monitoring and reporting of incidental catches is crucial. New technologies are available, but the role of scientifically trained observers is crucial. Much better fisheries observer coverage is needed. In fleet segments where observers cannot be deployed (due to the small size of the vessels), alternatives for adequate monitoring are needed. This is urgent for small-scale fisheries, which are extremely data-deficient.

Strict area closures will often be the best approach to ensure protection for the most endangered taxa (e.g., elasmobranchs). Best practices for mitigation of bycatch should be implemented across all main gears in the Mediterranean Sea.

Invasive Non-indigenous species (NIS)

Öztürk (2021) reviewed the impacts caused by Non-indigenous species (NIS) in the GFCM Convention area, i.e. the Mediterranean Sea, the Black Sea (including the Azov Sea) and the Marmara Sea. Although only a fraction of this work addresses the Mediterranean proper, still it yields several relevant results, listed below:

- Numerous Lessepsian species (NIS introduced through the Suez Canal built by Ferdinand de Lesseps) have invaded the eastern Mediterranean Sea entering through the Suez Canal, while others have expanded through the central and western sectors of the basin. A number of fish and invertebrate species originating in the Atlantic have also reached the eastern part of the Mediterranean Sea. In total, over 900 non-indigenous species have been reported in the Mediterranean Sea.
- Non-indigenous species (NIS) can enter from the Atlantic Ocean through the Strait of Gibraltar, from the Red Sea through the Suez Canal or from the Black Sea through the Strait of Çanakkale (Dardanelles), by intentional or unintentional human introduction. Some Lessepsian fish species have passed through the Strait of Sicily, which is regarded as a biogeographical boundary between the eastern and western Mediterranean Sea. On the other hand, some species of Atlantic origin have penetrated into the Mediterranean Sea farther east, reaching the coast of Sicily from their established areas near the Strait of Gibraltar.
- The main vectors of arrival for Mediterranean non-indigenous species are the Suez Canal, shipping and aquaculture. A general trend shows that the number of non-indigenous species has increased in recent years and climate change seems to be encouraging biological invasion.
- Non-indigenous species have a variety of consequences on fisheries, biodiversity, human health and the economy in the Mediterranean Sea. Some non-indigenous fish species have become economically important as target fisheries, after the establishment of sustainable populations, as in the case of lizardfish (Synodontidae), goatfish (Mullidae), mackerels (Scombridae) and round herrings (Clupeidae), mostly in the eastern Mediterranean region. Similarly, a number of non-indigenous crustacean species are also commercially valuable, including the kuruma prawn (Penaeus japonicus), green tiger prawn (Penaeus semisulcatus), mantis shrimps (Squillidae) and swimming crab (Portunus pelagicus). Meanwhile, some of the introduced mollusc species, such as the Pacific cupped oyster (Magallana gigas) and the Japanese carpet shell (Ruditapes philippinarum), already boast a market value.
- On the other hand, some non-indigenous species in the eastern Mediterranean present threats to human health, particularly poisonous pufferfishes (Lagocephalus spp.), devil firefish or lioinfish (Pterois miles), and the jellyfish Rhopilema nomadica.
- The introduction of the non-indigenous green algae, Caulerpa taxifolia and Caulerpa cylindracea, has also negatively impacted fisheries and ecosystems in the Mediterranean Sea.

Several results from Öztürk (2021) coincide partially or totally with those found by other authors. For instance, Wang et al. (2022) examined the pathways of NIS introduction via ballast water by shipping, focusing on the role of main ports as nodes for maritime transport, and the potential policy options for ballast water management to reduce NIS spread risk in the region. According to these authors, a major vector to introduce NIS to the Mediterranean is global shipping. Shipping activities cause biological invasions through ballast water discharge, biofouling, and secondary spread. The authors designed a set of policy scenarios to examine the role of regulating hub ports, and see whether regulation targeting these key ports may generate a disproportionate risk reduction compared to regulating all Mediterranean ports. The regulative framework is the 2004 Ballast Water Management (BWM)

Convention at the International Maritime Organization (IMO), which was established to reduce harmful aquatic organisms and pathogens (HAOP) introduced by ballast water discharge.

The main hub ports identified by Wang et al. (2022) were Gibraltar, Suez, and Istanbul; Gibraltar is the highest-risk port in the Mediterranean for the total study period and has a determinant role in determining the species spread risks of other Mediterranean ports. However, after its 2015 expansion, Suez became the port connecting the most different clusters, replacing Gibraltar.

Interestingly, these authors found that total shipping traffic and ballast water discharge are not immediately correlated: For the study period (2012-18), ballast water discharge in Suez increased, while the total traffic remained stable. One reason is that while the traffic of bulk vessels and tankers increased by 30%, the traffic of container ships decreased by 27%, effectively cancelling each other in terms of total number of ships passing through Suez. Thus, bulk vessels and tankers tend to discharge more ballast water than container ships. Also, another reason is that larger ships can now cross the Suez Canal. The average gross tonnage of container ships, general cargo vessel, and tankers increased by 50%, 23%, and 30%, respectively. Therefore, although the total traffic was the same, more ballast water was discharged.

As for the results on the policy scenarios, Wang et al. (2022) found that invasion risks to the hub ports decreased substantially when both international IMO Convention and regional stricter regulations in the Mediterranean are in place. But targeting only the hub ports cannot effectively reduce invasion risks; to reduce the risks of the Mediterranean as a whole, the most effective regulatory scenario is to set more stringent regulation towards all Mediterranean ports besides the IMO regulation.

In an earlier work, Katsanevakis et al. (2013) investigated the extent of NIS invasions in the Mediterranean and other European seas, and their main pathways. According to them, marine alien species may become invasive and displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food-webs and ecosystem processes, impede the provision of ecosystem services, impact human health, and cause substantial economic losses. Hence, assessing pathways of introduction of marine alien species is essential to identify management options to regulate and prevent new introductions.

Katsanevakis et al. (2013) found five pathways associated to NIS introduction: species intentionally released or escaped (aquaculture, aquarium and live food/bait trade), contaminants of commodities (aquaculture), stowaways on transport (shipping), and transport infrastructures (canals). They performed an extensive literature review, which identified 1,369 alien marine species in European seas, of which 1,257 were linked to the most probable pathway(s)/vector(s) of introduction. Invasion patterns were described for each pathway.

These authors found that the trend of new NIS introductions in Europe is increasing, with more than half (52%) of the species being introduced by shipping. Artificial waterways (primarily the Suez Canal) were the second most common pathway of introduction, followed by aquaculture and aquarium trade. Some remarkable specific results were:

- Considering all European seas, the rate of ship-mediated alien introductions is one new species approximately every 25 days.
- The rate of overall ship-mediated NIS introductions has kept increasing, with 147 new introductions between 2001-2010 (59% of total NIS by all pathways).
- At least 486 species have arrived through the Suez Canal. The rate of Lessepsian introductions has been increasing, reaching 80 species per decade between 2001-2010.
- Many more species are expected to invade the Mediterranean Sea through the Suez Canal, as it has been continuously enlarged and the ecological barriers to the invasion of Red Sea species (e.g. changes in the water salinity level) have been reduced.
- Efforts should be put on improving anti-fouling practices and on finding ways to restore, or raise new ecological barriers within the Suez Canal.
- The implementation of appropriate management measures on shipping and aquarium trade, e.g. the implementation of the Ballast Water Management Convention is required to reverse the increasing trend in NIS arrivals.
- Aquaculture was the only pathway with a decrease in new introductions during 2001-10, presumably due to compulsory measures at a national/EU level that were implemented by the industry and enforced by the authorities. Introductions via all the other pathways increased (in the aquarium trade especially).
- An integrated approach to the management of marine NIS invasions is needed. The EU Strategy on Alien Invasions should provide a fundamental mechanism for it.

Kleitou et al. (2021) bring novel perspectives to the work by Katsanevakis et al. (2013). Kleitou et al. 2021 propose a pragmatic analysis of the management of NIS in the Mediterranean. According to these authors, NIS are reshaping Mediterranean marine ecosystems, but on the other hand, stopping the spread of NIS is virtually impossible, and so the societal challenge is how to limit the socioeconomic, health, and ecological risks, and sustainably exploit the benefits provided by these organisms. Specially, fisheries need to adapt to the presence of NIS, to limit socioeconomic and ecological losses.

The authors propose a move away from the notion that NIS have only negative effects and suggest a turn towards an Ecosystem-Based Fishery Management approach for NIS (EBFM-NIS) in the Mediterranean Sea, the world's most invaded marine region. A species-specific exploitation strategy based on an economic and ecological cost-benefit analysis should be developed for each NIS. Hence, depending on the impact of a given NIS, policies could enable their commercial exploitation at a sustainable level, or conversely, at an unsustainable level (to curb their populations as consistently as possible). This in turn would need policy reforms to support each sustainable or unsustainable exploitation strategy.

Among other measures, the authors suggest fishery reforms such as multiannual plans, annual catch limits, technical measures for sustainable exploitation, and legitimization of unlimited fishing of selected NIS and introduction of a radical new license for NIS fishing for unsustainable exploitation. Specific strategies might include market promotion and valorisation of NIS products, development of novel NIS products, and innovative/alternative NIS fishing such as fishery-related tourism.

Part of what Kleoitou et al. (2021) suggest is already taking place. For instance, there are cases where small-scale fisheries have taken advantage of the presence of any NIS with commercial value. Such is the case of the two invasive species of “blue crab”, as stated by the GFCM (FAO 2020): the American blue crab (Callinectes sapidus) and the blue swimming crab (Portunus segnis) have been present in the Mediterranean since at least the first half of the twentieth century. The two species have followed different pathways of introduction: P. segnis most likely entered through the Suez Canal, while the appearance of C. sapidus has been attributed to a variety of possible vectors, including ballast waters. The appearance and establishment of both species around the Mediterranean has triggered a similar sequence of reactions. Initially, concerns were raised over both conservation (e.g. related to the quick expansion of these species and potential impacts on local ecosystems) and their negative interactions with existing fisheries (e.g. depredation and impacts on existing artisanal fishing gear). The development of dedicated strategies to control the populations and commercialize the catch (e.g. designing tailor-made fishing gear and analysing potential internal or external markets) followed. With this in mind, GFCM Recommendation 42/2018/734 sets the objectives of a research programme aimed at obtaining all the information necessary to properly evaluate the status of blue crab populations and to design strategies to develop targeted fisheries. In this way, fisheries could act as a tool to keep blue crab populations under control while providing opportunities for the fishing sector (FAO 2020). What the GFCM forecasts is already happening in several countries, where artisanal fishers are already fishing either or both species of blue crab: for instance, in the lagoons of the Nile Delta (Razek et al. 2016), in Morocco (Chaouti et al. 2020), and in Albania (Aliko et al. 2022). Aliko et al. (2022) brings another aspect of interacting environmental stressors: the development of fisheries for NIS species should be deemed a positive step; however, it can potentially turn into a hazard to human consumers if those NIS species appear to be polluted with microplastics.

Major environmental impacts and socio-economic consequences (including gender aspects

By-catch, vulnerable species and NIS

Due to the enormous variety of fisheries and fishing fleets operating in the Mediterranean, it is difficult to find a one-fits-all solution. However, several key lines of action ought to be taken. For some specific fishing methods, such as pelagic (drifting) longline, there exist bycatch mitigating measures that are easy to apply, are effective in reducing bycatch, and are economically acceptable by fishers. A good example is the reduction of seabird bycatch by pelagic longliners in the Western Mediterranean basin. In other cases, management measures such as spatial and/or seasonal closures may apply. For some highly impacting methods, gear replacement should be encouraged.

Regarding VMEs and emblematic species in the Mediterranean Sea, two examples can illustrate the exposure of the Mediterranean biodiversity, the fan shell (Pinna nobilis) and seahorses (Hippocampus spp.) in coastal areas presented in the following box 1 and 2.

Box 1. Pinna nobilis, a flagship bivalve species in critical risk of extinction

(Source: Kersting et al., 2019)

This long-lived bivalve is endemic to the Mediterranean Sea, where it has a range from Spain to Turkey along the northern and southern coasts and coasts of the Mediterranean islands. This species occurs in coastal areas between c. 0.5 and c. 60 m depth. Posidonia oceanica meadows are described as the main habitat of P. nobilis, although it is also found to inhabit Zostera marina and Cymodocea nodosa meadows. Additionally, the species is also known to form extensive populations on bare sand, rhodolith and detritic beds and other substrates, but not on muddy sediments.

Since 2016, a devastating and geographically widespread mass mortality event (MME) has impacted P. nobilis populations throughout the Mediterranean Sea. Previous to the MME, the species was widespread and locally abundant in some locations. The mortality is caused by a pathogen (Haplosporidium pinnae) and the associated die-offs have rapidly spread from the western (starting in Spain) to the eastern Mediterranean Sea in less than three years, causing mortality rates of 80-100% of the individuals in most locations, including those with long-term P. nobilis monitoring programmes. There are a few populations (less than ten subpopulations) that are known to remain pathogen-free and these are geographically isolated and located in sites characterized by very specific environmental conditions (lagoons with little access to the sea and differing salinities).

The presence of the pathogen throughout the environment hinders potential population recoveries through recruitment, which opens a highly worrying scenario. Fan mussels strongly rely on the survival of adults for the maintenance of populations and the slow population dynamics and low recruitment could seriously hinder recoveries following catastrophic events. In the past, major threats were and came from illegal fishing, habitat loss, boat anchoring, invasive species and most recently climate change. However none of these threats had led to the extremely widespread and rapid population declines in the species. The percentage of population size reduction over the last ten years is ≥80%, and the pathogen that has caused the MME is still present in the environment, with continuing declines expected. Therefore, this species is listed as Critically Endangered, mainly supported by criteria A2be and A4be.

Continuous monitoring of the species populations is mandatory, as well in those sites where the species has recently disappeared in order to detect potential recruitment in the future.

* Note of the author: at the time of writing this report (Sept-Oct 2022), Pinna nobilis can be deemed extinct from at least one Mediterranean country: Bosnia and Herzegovina, attending to the results of Čelebičić et al. 2018 and Čelebičić et al. 2021.

Box 2. Hippocampus spp., another dweller of Posidonia meadows

(Source: Correia et al. 2020)

Seahorses (Hippocampus spp.) are charismatic and iconic marine fishes, often used as flagship species for conservation issues, that live in some of the most vulnerable marine habitats in shallow areas around the world. They are characterized by sparse distribution, low mobility, small home ranges, low fecundity, lengthy parental care and mate fidelity. Seahorse life history and behaviour renders them vulnerable to population decline, which lead to the inclusion of many seahorse species in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES Convention) and in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

The short-snouted seahorse Hippocampus hippocampus Linnaeus, 1758 and the long-snouted seahorse Hippocampus guttulatus Cuvier, 1829 are two species present in the Mediterranean Sea. Although both species have been assessed as 'Data Deficient' at a global level, they have recently been re-assessed as 'Near Threatened' in the Mediterranean Sea. They are both typically present in coastal environment, and associated with habitats of different complexity. Despite the extended geographical distribution of both species there are only a few inshore locations where seahorse abundance, distribution and habitat use have been studied within the Mediterranean Sea.

Priority issue 8: HABITAT CHANGES (CONTAMINATION, DAMAGE&LOSS)

Description of the problem and its transboundary importance

Coastal development is a primary cause of habitat degradation and loss. The unharnessed development of the coasts of the Mediterranean basin is driven by population growth, expansion of agriculture, tourism (ca. massification), development of industrial and transport infrastructures, and real estate economic sectors. All these factors threaten coastal, infralittoral and circalittoral habitats through direct harm and even elimination (e.g., coastal wetlands artificialization) or indirect impacts (e.g, pollution by wastewater, silting or alterations in the patterns of sediment deposition and resuspension, water systems diversions, etc.).

Habitats

From the coast to the deep sea, the following categories or types of habitats have been found in the research as targeted habitats under pressure from the surface to the depth, namely, coastal wetlands, seagrass meadows, vermetid and sabellaria reefs, marine caves, maërl and coralligenous (rhodolith) formations, as well as down to mesophotic habitats, and deep sea habitats.

-Coastal Wetlands

Wetlands are critically important to both biodiversity and human wellbeing. In contrast to their limited area, they contain a disproportionally large share of global biodiversity and provide a wide array of ecosystem services (Taylor et al. 2021). Wetland conservation is crucial to fulfil several United Nations Sustainable Development Goals (Ramsar Convention on Wetlands 2018 In Taylor et al. 2021) and to ensure protection against floods and other extreme weather events, as in the Sendai Framework for Disaster Risk Reduction (Sebesvari et al. 2019 In Taylor et al. 2021).

Mediterranean wetlands are particularly diverse. They encompass many different sub-habitats such as coastal lagoons, natural salt marshes, man-made salinas, freshwater lakes, temporary ponds, rice paddies, peatlands, and river estuaries and deltas, including the delta of one of the longest rivers in the world, the Nile (Taylor et al. 2021). Many of these sub-habitats are often interspersed, forming habitat mosaics encompassed within a wider area. For instance rice paddies, coastal lagoons and salinas can all be found within the deltas of the Nile, Rhône, Po and Ebro rivers.

Although wetlands cover less than 3% of the land area of the Mediterranean basin, they harbour more than 30% of the region's vertebrate species (MWO 2018 In Taylor et al. 2021). Mediterranean wetlands are also crucial for the conservation of the biodiversity of several groups of plants and invertebrates, such as water starworts, freshwater molluscs, odonates and ostracodes among many other taxa, and include many endemisms. Worringly, it is estimated that about 36% of the species that inhabit these ecosystems today are threatened with extinction (Perennou et al. 2018). An exhaustive and taxonomically thorough list of Mediterranean wetlands endemisms of prioritary conservation is beyond the scope of this exercise, but it would include species such as the group of Unionidae freshwater bivalves (Unio spp., Anodonta spp.), currently undergoing a phylogenetic revision but known to include several endangered species (Lopes-Lima et al. 2021); the Cyprinid fishes Valencia hispanica and Aphanius iberus; the Iberian pond turtle Mauremys leprosa; and the Adriatic sturgeon Acipenser naccarii, the Greek red damselfly Pyrrhosoma elisabethae and the beautiful water starwort Callitriche pulchra (Taylor et al. 2021).

-Seagrass Meadows

According to Pergent et al. (2012), all the strictly marine species of vascular plants found to form seagrass meadows in the Mediterranean Sea belong to the Subdivsion Magnoliophyta. There are five species in total, of which one is endemic (Posidonia oceanica), three are native but also found in the Atlantic ocean (Cymodocea nodosa, Zostera marina and Zostera noltii), and one (Halophila stipulacea) is a non-native invasive species, originary from the Red Sea. A further group of invasive meadow-forming species is Caulerpa spp, but they are green algae, not vascular plants.

Among the five mentioned plant species, Posidonia oceanica stands out for forming vast meadows between the sea-surface and a depth of 35 to 40 m (i.e. the infralittoral), present in the entire Mediterranean basin with the exception of the extreme south-east. The species plays an important ecological role; it is also a powerful integrator of the quality of the water and plays a major role in carbon fixation and storage, as a "carbon sink" (Pergent et al. 2012).

Giakoumi et al. (2013) developed a map of the distribution of P. oceanica, shown in Figure 132.

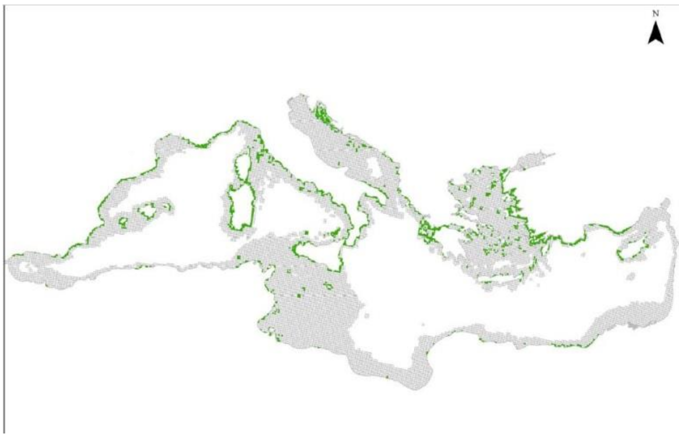


Figure 131. Distribution of Posidonia oceanica meadows in the Mediterranean Sea (Source: Giakoumi et al. 2013)

Following Giakoumi et al. (2013), P. oceanica meadows are a priority habitat for conservation by the EU Habitats Directive and the Barcelona Convention. Posidonia meadows are key nursery grounds for a many fish and invertebrate species, hence contributing to the maintenance of marine biodiversity. Over 400 plant species and several thousands of animal species inhabit this habitat. At the same time, Posidonia beds are one of the most productive ecosystems on the planet; their primary production is comparable to or greater than that of tropical forests and coral reefs. Seagrass meadows provide a number of ecosystem services, including food provision, coastal protection, carbon sequestration, water purification, ocean nourishment, and life cycle maintenance. Despite their importance, they are among the most threatened coastal ecosystems on earth with a global decline rate estimated at 110 km2 yr-1 since 1980 (Giakoumi et al. 2013). From the genetic diversity perspective, Mari et al. (2021) found that that the region centered in the Gulf of Gabès plays an especially important role in the large-scale metapopulation dynamics of the species, and thus this area ought to be at the center of any effort focused on preservation of Posiodonia oceanica.

Giakoumi et al. (2013) identify coastal development, pollution, trawling, fish farming, mooring, dredging, dumping of dredge spoil, and introduced species as the major factors responsible for the loss of P. oceanica meadows. Climate change further exacerbates the effects of local threats. Due to its very slow growth (2 cm yr-1), P. oceanica recovery and recolonization may take centuries depending on the severity of impacts. Regression of seagrass meadows results in decline of the services they provide, emission of vast quantities of stored carbon, decline in the distribution range of associated species, and disruption of critical linkages with other habitats (Giakoumi et al. 2013).

Another source of information concerning threats to Posidonia meadows is Pergent-Martini et al. (2016). According to this source, the lower limit of this habitat is threatened by mechanical damage from trawling, boat anchoring and turbidity. Coastal development including shoreline artificialization, urban and harbour infrastructure, and sand mining affect also the upper limit distribution of Posidonia meadows. Eutrophication (originated from the discharges of agriculture nutrients, organic matter, aquaculture and urban waste) and pollution, especially in coastal regions that are heavily populated, are a problem in many coastal areas. Invasive macroalgae such as Caulerpa taxifolia can grow on Posidonia rhizomes and sand and it is believed that their proliferation could accelerate the decline of the meadow. The proliferation of other epiphytic invasive species, such as Lophocladia lamellandii in the western Mediterranean can also threaten the survival and affect the density and complexity of the assemblages in the meadow. Climate change would be an additional threat through the water warming, sea level rise and extreme weather events.

Following with the classification of Mediterranean seagrass meadow types, Pergent et al. (2012) state that Cymodocea nodosa is found all over the Mediterranean basin, in the Sea of Marmara and in the Atlantic. It ranks second, after Posidonia oceanica, in terms of occupied surface areas in the Mediterranean; it is particularly evident in the eastern part of the Oriental Basin. In fact, according to these authors, in several sectors of the Mediterranean, Cymodocea nodosa has taken advantage of the regression of Posidonia oceanica to further its own development.

The third seagrass species that forms meadows in the Mediterranean is Zostera marina. Again, according to Pergent et al. (2012), Z. marina is the most widely distributed species, from the Atlantic Ocean to the Pacific Ocean, and from temperate regions to the Arctic Circle. It forms very large meadows in sublittoral zones between the sea surface and a depth of about 10 metres. In the Mediterranean, this species is above all present in a number of coastal lagoons and at the innermost part of very sheltered bays, and similarly to P. oceanica, it is declining. The main causes of its regression are of an anthropogenic nature (eutrophication, sedimentation, mechanical degradations and pollution). But also, Zostera marina is one of the cold affinity species likely to regress, or even disappear from the Mediterranean if global warming intensifies. Today, this species seems to have disappeared from numerous sites where it was present several decades ago and, in localities where this species is still present, significant regressions have already been recorded (Pergent et al. 2012, Otero and Pergent-Martini 2016).

The fourth species is Zostera noltii, which often develops in the loose substrates of the intertidal zone where it can form very vast meadows, subject to wide variations of light intensity and temperature. In the Mediterranean, it is confined to coastal lagoons, the innermost part of some sheltered bays and small harbours where it forms permanently submerged meadows. This species is often associated with Zostera marina or Cymodocea nodosa, with which it may form mixed meadows. In terms of dynamics, this species demonstrates high resilience, and similarly to Cymodocea nodosa, Z. noltii may benefit from the regression of other species of marine Magnoliophyta (Pergent et al. 2012). At Mediterranean level, Zostera noltei, Z. marina and Cymodocea nodosa are included in the Annex II (List of endangered or threatened species) of the Barcelona Convention (Otero and Pergent-Martini 2016).

The fifth species is Halophila stipulacea, which in the Mediterranean can form meadows extending to depths of 35 to 40 m, though it is most often found in shallower habitats (-2 to -10 m), in zones of low hydrodynamism and within or near harbours. The natural range of Halophila stipulacea is the western part of the Indian Ocean, the Persian Gulf and Red Sea. The opening of the Suez Canal enabled it to enter the Mediterranean, having been first reported in 1894. Since then, it has continued to advance, usually following prevailing currents, and thus colonizing a large part of the eastern basin. This trend seems to have accelerated (Pergent et al. 2012).

As for common threats to seagrass meadows in the Mediterranean, Otero and Pergent-Martini (2016) coincide largely with Giakoumi et al. (2013), pointing out to mechanical damage from trawling and anchoring from boats, as well as coastal development, eutrophication, competition from alien macroalgae species like Caulerpa taxifolia and Caulerpa cylindracea, urban and industrial waste dumping, modification of lagoon environments and coastal development. Thus, the four natural marine angiosperms that form seagrass meadows in the Mediterranean are subjected to natural and anthropogenic pressures likely to lead to significant regressions (Pergent et al. 2012).

However, not all the species are equally impacted. Posidonia oceanica represents an extreme of the impact scale, being the most threatened species/habitat. In fact, according to Telesca et al. (2015), the estimated regression of P. oceanica meadows was 34% in the last 50 years, which, based on the IUCN's Red List criteria for ecosystems, makes P. oceanica meadows an "endangered" ecosystem. Zostera marina seems also to be in regression. The picture on Cymodocea nodosa and Zostera noltii is less clear, as they might be undergoing localized regression but simultaneously also potentially expanding in others parts of their ranges. On the other extreme of the scale, the invasive Halophila stipulacea is expanding, and the warming climate scenarios favour its progression northwards and westwards.

Pergent et al. (2012) point out that depending on the characteristics specific to the various species of Magnoliophyta found in the Mediterranean (physiological, biological and ecological), their resilience, adjustment stability and capacity to adapt may differ. Hence, while Posidonia oceanica constitutes the "climax" species for a large part of Mediterranean shorelines, Cymodocea nodosa and, to a lesser extent, Zostera noltii, can constitute pioneer species in the succession, allowing for the settlement of Posidonia oceanica meadows. When environmental conditions become unfavorable for one species, it may be replaced by another. However, while Posidonia oceanica can be replaced by native species, it can also be replaced by opportunistic invasive species. Furthermore, these substitutions by species with weaker structuring capacities may trigger profound changes within the communities.

Indeed, replacement of a seagrass species with another with less structural complexity can trigger a loss of biodiversity. This is so because there are three levels of structural complexity that can be distinguished among the seagrass meadows. The lowest complexity is found in Halophila stipulacea meadows; Cymodocea nodosa and Zostera spp. Meadows give slightly higher structural complexity, while Posidonia oceanica meadows show the highest structural complexity and a wide diversity of habitats (Pergent et al. 2012). These differences are shown in Figure 132.

Figure 132. Rising structural complexity of Magnoliophyta meadows in the Mediterranean, from a Halophila stipulacea meadow (A), to a Cymodocea nodosa meadow (B) and lastly a Posidonia oceanica meadow (C). (Source: Pergent et al. 2012)

Still according to Pergent et al. (2012), a rise in water temperature is likely to lead to the replacement of "cold" affinity seagrass species of average structural complexity, such as Z. marina, by 'warm' affinity seagrass species of lower complexity, such as C. nodosa and H. stipulacea. This diminishment of structural complexity will be more marked in areas where P. oceanica is in regression. In short, the rise in surface water temperature causes two types of modification in seagrass communities: a) modification of the relative abundance of closely related species, benefitting those with the most "meridional" affinities; and b) modification through introduction of alien species. The threat of stressor-mediated substitution of seagrass species was explored by Montefalcone et al. (2015). They concluded that the structural degradation of the Posidonia habitat, consequent to increasing coastal degradation and climate change, may result in the progressive replacement of this species by opportunistic competitors, either native or alien.

Habitat complexity is the cornerstone of high biodiversity upon which many other functions and services depend (Montefalcone et al. 2015). The replacement of the highly structured and productive P. oceanica habitat with C. nodosa or invasive species will alter sediment biochemistry, nutrient cycling, water-column oxygen profiles, water filtration capacity, primary and secondary production, carbon storage, support of higher trophic levels and the ecosystems response to disturbance. This threat of ecological replacement becomes even more relevant because once certain thresholds of various global stressors or of external elements are passed, seagrass beds could completely change their conservation status (Houngnandan et al. 2020).

-Vermetid and Sabellaria reefs

Vermetid reefs

Vermetid reefs are mentioned by Coll et al. 2010 as one of the marine habitats of particular interest and according to Templado et al. (2016), Vermetids are a peculiar group of sessile, uncoiled, suspension-feeding, marine gastropods that include more than 160 living species, mainly found in shallow waters in warm temperate to tropical environments. Members of this family attach their shells on hard substrata and may be solitary or live in aggregates sometimes exhibiting a colonial behaviour. Taxonomy and systematics of Vermetidae is currently in a state of disarray and many species remain undescribed because of the difficulty in finding diagnostic phenotypic characters. Approximately ten vermetid species are present in the Mediterranean Sea. However, Templado et al. (2016) show that several of these species are clusters of cryptic species. The authors focus on the Dendropoma petraeum species complex, which is included in Annex II (Endangered or Threatened Species) of the Protocol for Specially Protected Areas and Biodiversity in the Mediterranean (Barcelona Convention), and its reefs have been listed as threatened biostructures in the Mediterranean Red Data Book. The authors highlight that whereas the cryptic Dendropoma species complex had a broad geographical range along all Mediterranean Sea coasts, true biological species in this complex have more limited distributions in different sub-basins within this sea, making each more prone to extinction. Indeed, some populations along the Israeli coast might be already extinct. Therefore, all the species comprising the so-called Dendropoma petraeum species complex should be included in Annex II of Endangered or Threatened Species of the Barcelona Convention and in the national red lists of the countries where they inhabit.

Sabellaria reefs

According to Gravina et al. (2018), some polychaetes of the Sabellariidae family (honeycomb worms) build large and durable aggregate structures that may cover several km2 on sand flats (Figure 133). They build tubes from sand and shell fragments held together with cement and form dense aggregations on sandy and mixed substrata and on bedrock; these aggregations can spread over large areas. In the Mediterranean, Sabellaria spinulosa was deemed to be the most widespread species (Gravina et al. 2018). The ecological roles of the S. spinulosa reefs encompass providing a diversity of microhabitats hosting hard and sandy bottom species, sheltering rare species, and producing biogenic structures able to provide coastal protection (Gravina et al. 2018). The authors defend that although Mediterranean S. spinulosa reefs do not shelter a distinctive associated fauna, their richness in species composition underscores the importance of Sabellaria reefs as a marine biodiversity hotspot.

Figure 133. (*Sabellaria alveolata* (Linnaeus, 1767) observed in France ©Frédéric Andre (licensed under http://creativecommons.org/licenses/by-nc/4.0/) *No changes were made*.

In another recent study, Sanfilippo et al. 2020 found that S. alveolata, originally described from British waters and initially deemed to be infrequent in the Mediterranean, is actually found throughout the western Mediterranean. Indeed these authors report that S. alveolata forms aggregates that are larger and more persistent than those produced by its two congeneric species (S. spinulosa and S. alcocki) (Sanfilippo et al. 2020).

Lastly, Bonifazi et al. (2019) focus on the conservation interest of Sabellaria reefs. These authors concluded that Sabellaria reefs plays a key role in biodiversity enhancement, supporting a rich associated fauna and acting it as nursery for various coastal species. Therefore, Sabellaria reefs (of any species) should receive full protection as prioritary habitats within the Mediterranean basin, based on their importance as ecosystem engineers whose bioconstructions host a rich associated fauna and act as a coastal biodiversity hotspot.

-Mesophotic communities: sea caves, coralligenous formations and maërl

This section addresses the habitats present at the circalittoral section of the shelf, roughly from 30-40 to 200 m depth (Fig 134). Giakoumi et al. (2013) show that while some of the habitats listed by both the Habitats Directive and the Barcelona Convention can be easily mapped (essentially, supra-and infralittoral habitats) and they are protected by some of the existing instruments (e.g., Natura 2000 sites), most submerged habitat types have not yet been comprehensively mapped in the Mediterranean, and their protection is thus inherently incomplete. These authors highlight two submerged habitats: coralligenous formations (often assessed together with maërl), and sea caves.

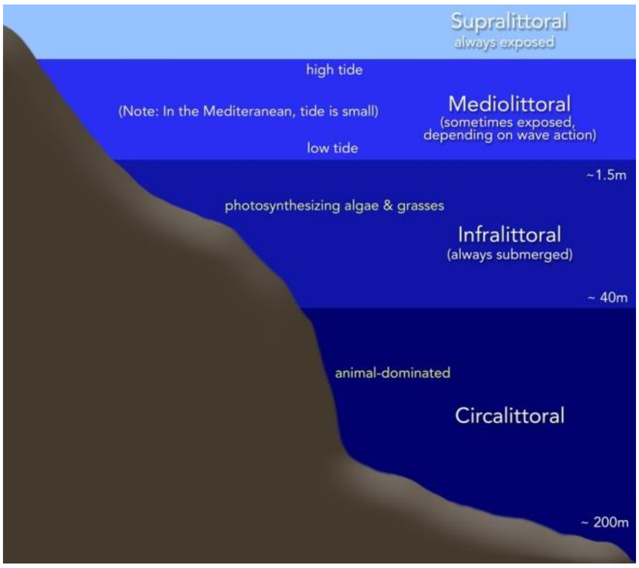


Figure 134. Schematic representation of marine vertical zoning (Source: dwejra.net)

Sea caves

Sea caves, or ''submerged or partially submerged sea caves'' are protected by the EU Habitats Directive as a distinct habitat type. Marine caves host a variety of communities characterized by a unique topographical complexity and associated abiotic gradients. These range from coralligenous algal-dominated assemblages to semi- and entirely-dark assemblages which in some cases resemble those of the deep sea. Mediterranean marine caves harbour a high number of rare, endemic, protected, and commercially important species such as the red coral Corallium rubrum. Sea caves have been considered as refuge habitats, ecological islands supporting isolated populations, bathyal mesocosms within the littoral zone, and biodiversity reservoirs (Giakoumi et al. (2013). But sea caves are also vulnerable habitats, with low resilience to mechanical disturbance, impacts of increasing water temperature, red coral harvesting, coastal infrastructure and development, and marine pollution. Although they are to some extent represented in some MPAs, they are not adequately protected. This is particularly the case in the southern part of the Mediterranean Sea, since 96% of MPAs are situated in the northern Mediterranean basin (Giakoumi et al. 2013).

Indeed, the adequate representation of marine caves either in existing or planned Mediterranean MPAs has been hindered by their patchy ‘‘known’’ distribution. Such heterogeneity encompasses two underlying sources of variability: (1) the uneven natural distribution of the habitat, and (2) the highly variable mapping and monitoring efforts across the Mediterranean basin. This is reflected in that there are almost 3,000 marine caves recorded in 14 Mediterranean countries (Albania, Croatia, Cyprus, France, Greece, Israel, Italy, Lebanon, Malta, Montenegro, Morocco, Spain, Tunisia, and Turkey), but the vast majority (97%) was located in the northern Mediterranean basin. The Aegean Sea presented the highest abundance of marine caves (Giakoumi et al. 2013). the Adriatic Is also rich in sea caves, as shown by Petović & Mačić (2021). These authors highlight the ecological value and rarity of sea caves, acknowledging that different habitats might fall under the general category of “sea caves”. They list the different types of marine caves as: submerged karst, sea caves, cold sea caves, pits with bathyal elements, vruljas (submarine springs), karst estuaries, submerged river canyons, submerged tufa barriers, marine lakes and bare karst in the sea. According to Giakoumi et al. (2013) the northern basin encompasses 92% of the Mediterranean rocky coastline, while south and extreme southeastern areas are dominated by sandy coasts. Hence, the concentration of marine cave systems in the Adriatic, Aegean, and Tyrrhenian Seas is highly related to the presence of extensive rocky coasts in these areas, with Italy, Greece, and Croatia covering 74% of the Mediterranean’s rocky coasts. (However, note the almost total absence of records from the coasts of Morocco, Algeria and Tunisia; Figure 135).

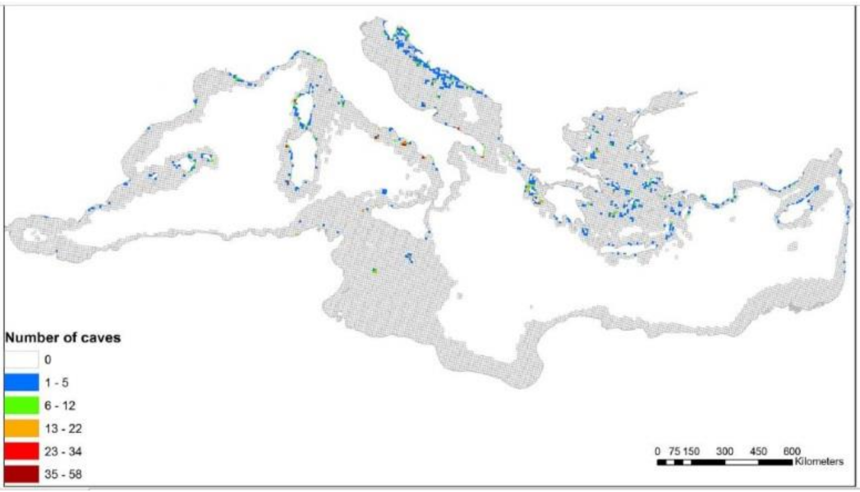


Figure 135. Distribution of marine caves in the Mediterranean Sea. Warmer colours illustrate planning units with higher number of caves. (Source: Giakoumi et al. 2013)

Coralligenous algae and rhodolith beds/maërl (biogenic calcareous formations)

According to Rindi et al. 2019, coralline (also termed "calcareous") algae have existed in the Mediterranean for ~140 My and are ubiquitous on modern Mediterranean rocky shores. They are key components in some of the most common Mediterranean benthic communities, such as coralligenous concretions and maërl/rhodolith beds. In these communities coralline species often play a key role as ecosystem engineers: the accumulation of their calcareous thalli produces bioconstructions that modify the tridimensional structure of the substratum and profoundly influence ecosystem functioning Mediterranean bioconstructions built by corallines are known as major repositories of biodiversity. Furthermore, although coralligenous bioconstructions exist in every sea, in the Mediterranean they reach a particularly high spatial and bathymetric extent (Mediterranean coralligenous concretions are estimated to exceed 2,700 km2 in surface).

Giakoumi et al. 2013 remark that coralligenous formations are the second most diverse benthic habitat of the Mediterranean Sea after P. oceanica meadows. They are included in the EU Habitats Directive under the generic habitat type ''Reefs''. An Action Plan has been adopted by contracting parties of the Barcelona Convention specifically aiming at their conservation. Coralligenous formations comprise various benthic assemblages, which form typical underwater seascapes in the sublittoral zone. Conservative estimates list more than 1,700 species inhabiting the coralligenous assemblages (15–20% of Mediterranean species). Their extensive distribution, structural complexity, species diversity, role in energy flux and carbon cycle, and economic value render coralligenous structures as one of the most important coastal habitats in the Mediterranean. Currently, they are among the most threatened habitats in the region; as key engineering species they are long-lived with slow growth rates, while the dynamic equilibrium between the bioconstruction and bio-erosion processes is particularly susceptible to environmental changes. Direct or indirect human-induced disturbances include mechanical damage by destructive fishing practices, pollution, sedimentation, diver frequentation, biological invasions, mass mortality outbreaks related to temperature anomalies, and the synergistic effects of these stressors. Similarly, as in sea caves, Giakoumi et al. (2013) found that coralligenous habitats have been recorded in 16 Mediterranean countries, but available information was substantially greater for the northern than the southern part of the Mediterranean. The Adriatic and Aegean Seas presented the highest abundance, followed by the Tyrrhenian Sea and the Algero-Provencal Basin (Figure 136).

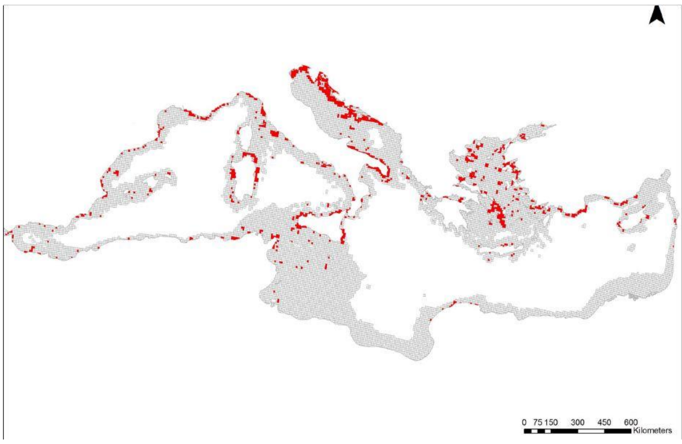


Figure 136. Distribution of coralligenous formations in the Mediterranean Sea (Source: Giakoumi et al. 2013)

Rindi et al. (2019) stressed that the specific composition of the coralligenous formations themselves is still in need of research. There are some 60 species of coralline algae currently reported from the Mediterranean, but this figure is likely to increase, since recent studies incorporating molecular data suggest that the correct estimate is probably much higher. Of these species, at least seven are Mediterranean endemics: Amphiroa rubra, Lithophyllum trochanter, L. woelkerlingii, Lithothamnion minervae, L. valens, Mesophyllum macedonis, and Pneophyllum cetinaensis. Besides the inherent species richness in the coralligenous algae, there is another aspect highly significant from the biodiversity perspective: marine macroalgae host a wide range of microbial organisms, among which bacteria are the dominant group. Bacterial communities associated with algae establish strict biochemical interactions with their algal hosts and differ significantly from those found in the surrounding seawater (Rindi et al. 2019). Therefore, bacterial species associated to coralligenous formations might harbour an important biodiversity that has been barely investigated until now.

As for rhodolith beds, also called maërl beds, in their composition they are very similar to coralligenous formations, since they also are formed by calcareous algae (Phymatolithon calcareum, Lithothamnion coraloides), combined with algae of the genus Peyssonnelia. The substrate thus formed provides an anchor for other types of algae of the red Gigartinales and Ceramiales orders and certain green species, such as Codium bursa. Other organisms that adhere to these bottoms are sponges (Clionia viridis), sea squirts (Phallusia mamillata), bryozoans (Myriapora 255rea255onm) and various kinds of cnidarians and tubicolous polychaetes (Mas et al. 2017). However, rhodolith beds are structurally different from coralligenous formations, as they form calcareous nodules -the rhodoliths- which provide a regular three-dimensional structure, and hence are regarded as distinctive habitats by some authors. It is worth noting that the distinction between coralligenous grounds and rhodolith beds/maërl is complex and includes a certain level of subjectivity. Still, the key concepts are: 1) that these habitats are closely related, all being formed by coralline algae ("biogenic calcareous formations") with a similar bathymetric range; 2) they harbour a very high biodiversity; and 3) they are threatened by common stressors.

Basso et al. (2017) reviewed 125 locations of rhodolith beds in the Mediterranean Sea, equally distributed in the eastern and western sub-basins. The rhodolith beds occur from 9 to 150 m of water depth, although they are most frequent within the depth range 30–75 m. The deepest and the largest (300 km2) Mediterranean rhodolith beds are in the Balearic Sea, with significant areas also found in the Ligurian, Thyrrenian and Egean seas (Figure 11).

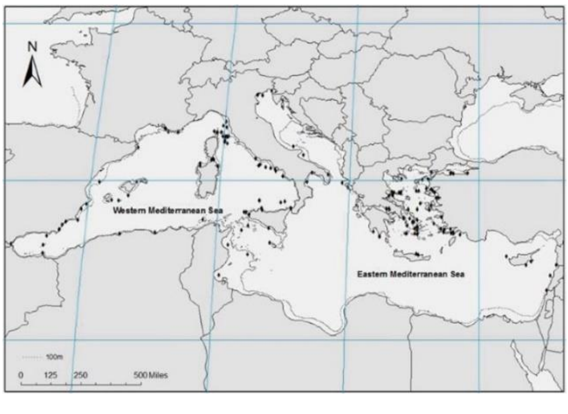


Figure 11

Figure 137. The rhodolith beds of the Mediterranean Sea. (Source: Basso et al. 2017)

Rindi et al. (2019) remark that there is evidence that coralligenous formations are undergoing substantial degradation, with the coralline algae suffering a loss of vitality. Observations of bleaching and necroses in Mediterranean corallines have become increasingly common in recent years, and the combined effects of ocean warming, and acidification can also make corallines more sensitive to other environmental stressors.

As for maërl/rhodolith beds, they are vulnerable to physical disturbance by fishing gears and smothering, and to water pollution by organic enrichment and sewage (Basso et al. 2017). Rhodolith assemblages are a matter of conservation concern because they represent a non-renewable resource due to the slow rate of growth and carbonate deposition (about 1 mm $year^{-1}$); and because they undergo various anthropogenic threats, ranging from the physical damage induced by fishing (i.e. impacts of towed fishing gear) to the degradation of the habitat and water quality (Basso et al. 2017). The vulnerability of these habitats has been recognized through the adoption of a range of protection instruments. Within the European legislation two main tools have been put in place: the Habitat and Species Directive 92/43/EEC and the EC Council Regulation 1967/2006 EC. Particularly, the Habitat Directive in the Annex V includes Phymatolithon calcareum and Lithothamnion corallioides among those species subject to exploitation and for which Member States have to ensure appropriate management measures (Basso et al. 2017).

-Mesophotic zone

As put by Castellan et al. (2022) the mesophotic zone extends from 30 m to where photosynthesis compensation point occurs. This lower boundary is variable due to differences in light penetration and environmental and ecological drivers that can vary over short distances. Mesophotic ecosystems are represented by a mosaic of assemblages composed of algae, cnidarians, sponges, bryozoans, crinoids, brachiopods, and ascidians, both on hard and soft substrates. However, information on Mediterranean mesophotic ecosystems is limited to few taxonomic groups, while other assemblages have been seldom explored (e.g., brachiopod-dominated communities and deep-sea oyster reefs).

These authors also highlight that the lack of a clear definition of the borders of the mesophotic zone at temperate latitudes may not pose much of a problem as long as the term "mesophotic" intends to refer to intermediate-depth biological communities. But, from the Mediterranean biodiversity viewpoint, problems arise when scientific information must be transferred to policies that require a coherent spatial definition to plan proper management and conservation. Thus, although the 30-150 m bathymetric range is commonly adopted in the literature to constrain the mesophotic zone, such depth interval varies depending on sunlight penetration, which is primarily a function of solar radiation incidence and water clarity. In the Mediterranean Sea, with its peculiar biophysical properties, this can imply a significant variability. On the other hand, bathymetry characteristics imply a different surface spatial area in different parts of the Mediterranean, such as in the large extension of shallow waters in the Gulf of Gabes and North Adriatic (Figure 131).

Castellan et al. (2022) undertook a mapping of the mesophotic zone in the Mediterranean, which yielded some previously overlooked results: most remarkably, the existence of an ample mesophotic zone in Tunisian waters (the second largest, after the Adriatic Sea) (Figure 131). This ample mesophitic habitat extension in Tunisian waters is continued into the infralittoral zone with seagrass meadows of high importance as feeding grounds for vulnerable species including marine turtles and several elasmobranchs (CCA Priority issue 7). Moreover, Mari et al. (2021) pointed out the Gulf of Gabes to play a crucial role in the metapopulational dynamics of Posidonia oceanica. Hence, a highlighted result from this literature review exercise is the emerging acknowledgement of the key importance of protecting this area of the southern-central Mediterranean basin.

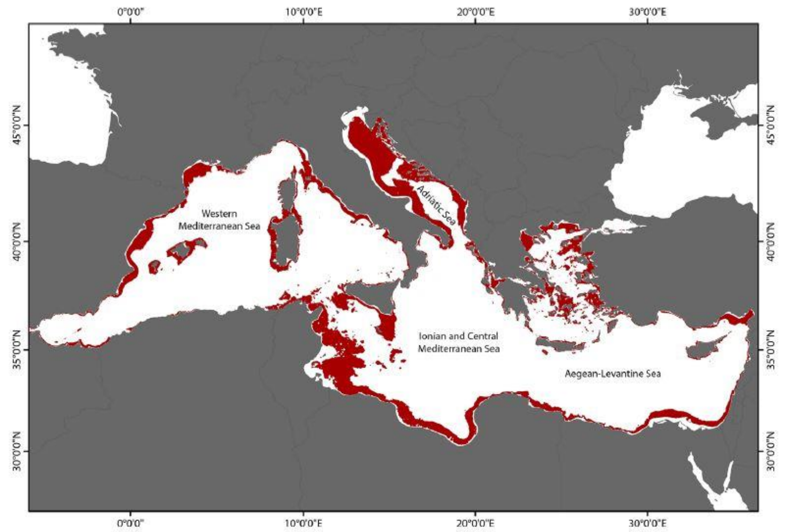


Figure 138. Estimated spatial extent of the mesophotic zone in the Mediterranean Sea. Portions of seabed characterized by mesophotic conditions (red shaded area). The upper and lower limits were set at 30 m depth and at 0.0001 mol photons m– 2 day– 1 of irradiance, respectively. (Source: Castellan et al. 2022)

As highlighted also by Castellan et al. (2022), in the Mediterranean Sea, mesophotic communities are already threatened by natural and anthropogenic pressures, including seawater temperature increase, heat waves, bottom trawling and marine litter, which trigger a gradual but irreversible process of habitat degradation. A better understanding of the bathymetric and spatial extension of mesophotic zone in the Mediterranean Sea is urgent to orient conservation actions. In this context, their mapping effort becomes highly relevant.

-Deep sea habitats

Danovaro et al. (2010) carried out an extensive study of Mediterranean deep-sea ecosystems. The thoroughness of their work means that despite over a decade has passed, it is still one of the best sources of information on these essentially unknown habitats, which represent a significant share of the Mediterranean´s marine biodiversity. Their main findings are presented below.

- Available information about benthic biodiversity (prokaryotes, foraminifera, meiofauna, macrofauna, and megafauna) in different deep-sea ecosystems of the Mediterranean Sea (from 200 to >4,000 m depth) was collected, including open slopes, deep basins, canyons, cold seeps, seamounts, deep-water corals and deep-hypersaline anoxic basins. The authors also assessed longitudinal and bathymetric patterns of biodiversity.

- Within the bathymetric range of 200–1,000 m, some 650 sp belonging to the Eukarya domain have been identified. This is an underestimate, not only due to the large number of still undiscovered species, but also because the diversity of many phyla (e.g., Nemertea, Gnathostomulida, Kinorhyncha, Loricifera, Rotifera, Gastrotricha) could not be studied.

- In contrast to what was expected from the sharp decrease in organic carbon fluxes, the deep-sea biodiversity of the eastern and the western basins of the Mediterranean Sea is similarly high.

- The main features of the deep Mediterranean Sea are (a) high homeothermy and bottom temperatures (13°C to 15.5°C) much higher than in deep-sea Atlantic areas (in the Atlantic Ocean the temperature decreases with depth); (b) high salinity; (c) limited freshwater inputs; (d) a high oxygen concentrations, and oligotrophic conditions, with strong energetic gradients and low nutrient concentrations in the eastern basin.

- The abyssal basins of the Mediterranean are extremely unusual deep-sea systems. With water temperatures at 4,000 m in excess of 14°C (rather than 4°C or colder for the deep oceanic basins), the entire benthic environment is as hot as the water around a hydrothermal vent system, but lacks the vents' rich chemical energy supply (in fact, most hydrothermal vents in the Mediterranean are different from the oceanic deep-sea vents because they occur in shallow depths of less than 100 m and present photosynthetic primary production; hence, they are very specific sea bottom habitats rather than deep-sea habitats).

- Submarine canyons represent hotspots of species diversity and endemism and are important habitats for commercially fished species. The biodiversity in marine canyons can be markedly different from that on the adjacent open slopes ("canyon effect"). Their biomass and abundance can be 2 to 15-fold higher than that in the surrounding areas at similar depths.

- Cold seeps and mud volcanoes have been found in the Mediterranean at 1,700–2,000 m depth. They are rich in megafauna (e.g., gastropods, crustaceans, sponges).

- Deep hypersaline anoxic basins (DHABs) have been discovered in the Eastern Mediterranean Sea at depths ranging from 3,200 m to 3,600 m. Their isolation may have resulted in the evolution of specific microbial communities in each DHAB.

- Among the major threats to deep-sea biodiversity in the Mediterranean Sea are the deposition of litter upon the sediment, chemical contamination of the sediments, disruption of vertical circulation and deep-water formation processes due to increasing temperature, and bottom trawling in vulnerable and still poorly known deep water ecosystems.

And, as particularly interesting findings from the biodiversity perspective, Danovaro et al. (2010) reported that:

- Deep-sea Mediterranean ecosystems show very particular characteristics that make them unique at a global level.

- Little is known about the biodiversity of benthic prokaryotes in the deep sea. Deep-sea benthic Archaea, in particular, are very poorly known.

- Mediterranean deep-sea bacteria assemblages are 85% different to those of the deep-sea habitats in the Atlantic at similar depths; the drivers of prokaryotic diversity in the Med deep-sea sediments have yet to be identified.
- The overall deep-sea Mediterranean biodiversity (excluding prokaryotes) reaches approximately 2,800 species of which about 66% is still undiscovered.
- Nematodes are the dominant meiofaunal taxon (on average more than 80% of entire Meiofauna); this group displays a high variability at all depths.
- The biodiversity of Mediterranean seamounts remains largely unexplored.
- Mediterranean deep-water coral systems are as diverse as the Atlantic ones. They can act as spawning or nursery areas for a high number of benthopelagic species.
- The temperatures in the deep Mediterranean are close to the upper limit for many cold-water corals living at bathyal depths, which makes them extremely vulnerable to any further temperature rise.
- The isolation of the Mediterranean cold seeps from the Atlantic Ocean after the Messinian crisis led to the development of unique communities.
- The combination of high salt concentration and corresponding high density and high hydrostatic pressure, absence of light, anoxia, and a sharp chemocline makes the deep hypersaline anoxic basins (DHABs) some of the most extreme habitats on Earth. Many prokaryotic taxa, including new groups, and even three metazoan species (Loricifera) have been found in the Mediterranean DHABs.

Major environmental impacts and socio-economic consequences (including gender aspects)

Coastal wetlands

Urbanization and agriculture appear as the two main threats/stressor root cause in wetland environmental impacts. They in turn encompass several specific sub-threats and stressors, such as water abstraction, pollution and eutrophication (all of which are also highlighted in other sections of the TDA). A swift synthesis of the measures advocated in the scientific literature might bring the focus down to two potential and complementary pathways: 1) ensuring that protection is extended to all wetlands of relevant conservation interest, and that this protection is real, being adequately monitored and enforced (i.e. avoid “paper parks”); 2) apply catchment basin- and aquifer-based management. This might translate into the application of moratoria for conversion of additional land from rain-fed to irrigated crops, and to the increase of tourism-driven urbane expansion.

Marine habitats

Several priority habitats, but not all, are legally protected. Thus, a first step would be to extend legal protection to all marine habitats of conservation interest. A second step would be to ensure that all Mediterranean countries put the necessary efforts into the protection of their priority habitats found within their territories. Some key stressors and threats have been clearly identified; for instance, damaging fishing gear and polluted water (Figure 139) are among the main drivers of regression for Posidonia oceanica meadows. Fisheries spatial closures and a stringent policy of full water treatment should apply to the areas where meadows are still found. Moratoria on the expansion of activities that irreversibly impact the benthos (e.g. bottom trawling, oil and gas extraction) would be needed to protect deep sea ecosystems.

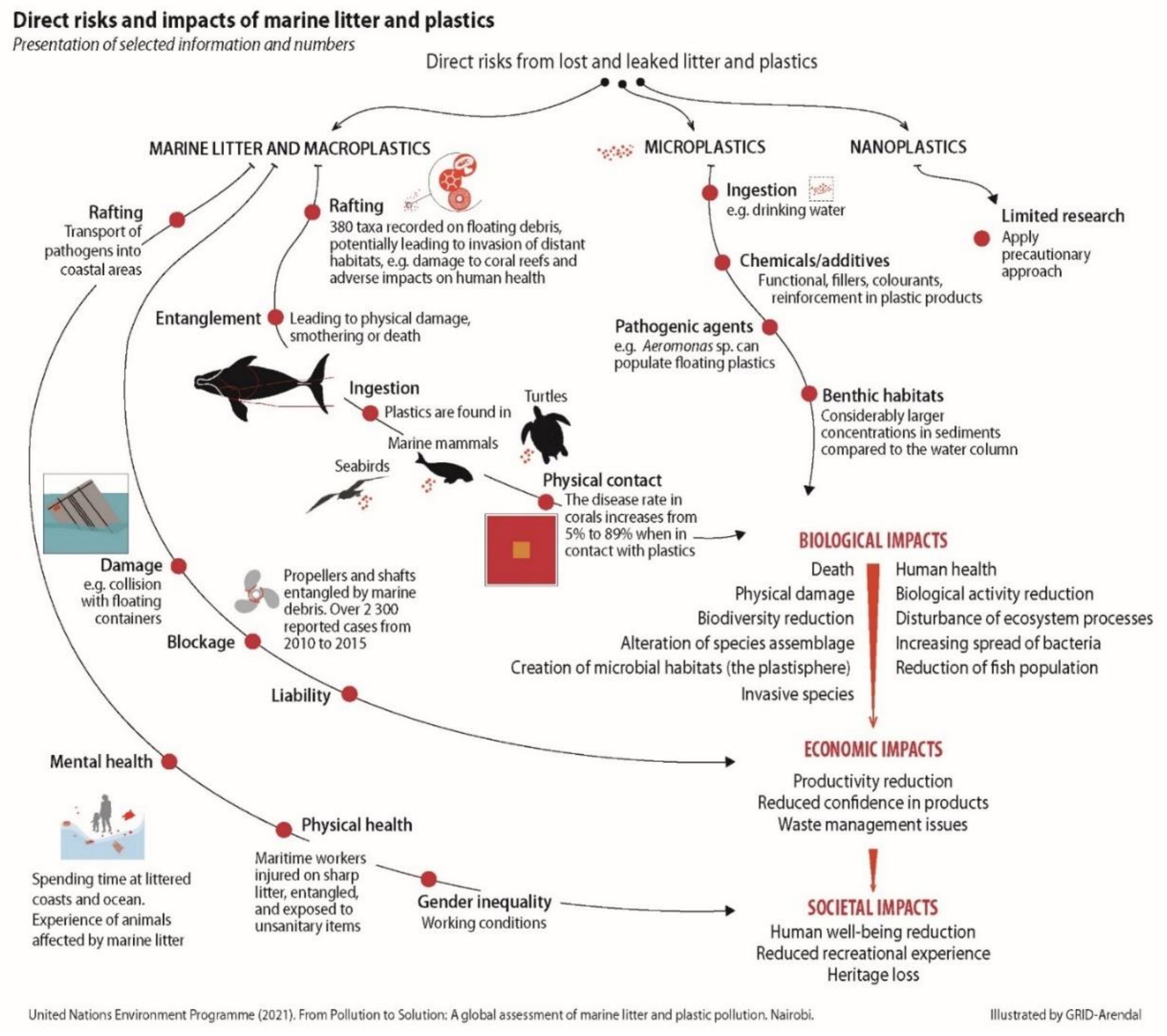


Figure 139. Direct risks and impacts of marine litter and plastics.

Linkages with other transboundary problems

Microplastics in marine food webs (habitats)

The transboundary issue of plastic and microplastics pollution in the Mediterranean Sea was examined in sections 4.2.2. and here specifically focus on its impact on marine food webs (i.e., within a given the habitat), and therefore, the relationships with habitat damage and loss; through examples.

Firstly, in a review of the overall ecological status of the Kune-Vaini lagoon complex (Albania), Aliko et al. (2022) found that two invasive, but edible crab species were abundant, targeted by the local artisanal fishery, and consumed within the region. But they were found to contain significant levels of microplastics. Microplastics represent a threat per se and also because they can these species absorb organic pollutants, heavy metals, and other hazard substances. Another example is according to the study form Avio et al. (2020), the Mediterranean Sea is highly polluted with plastic and these authors sampled Adriatic fish and invertebrates to assess presence of microplastic particles (MPs) and textile microfibers in their tissues. Their test hypothesis was that area, habitat and feeding strategy of each species might influence the occurrence of MPs.

The issue of prevalence of textile microfibers was also noted by Compa et al. (2022), who studied the transmission of artificial particles (microplastics and textile microfibers) across marine food webs, from zooplankton to their fish predators (of which several were commercial species), sampling several sites in the Catalan Sea. These authors highlighted the ample trophic availability and potential aggregation of Aps within the zooplankton aggregation layer, with predominance of fibres (96%). Compa et al. (2022) concluded that artificial particles are an increasing threat, with ingestion occurrence across the marine trophic web recorded from coastal to deep sea areas affecting meiofauna, nektonic, pelagic, semi-pelagic, benthic and demersal organisms. These were found ingested in all species of fish at each sampling site, with an overall ingestion occurrence of 21%. These authors remarked that in addition to policy measures that reduce the loss of plastic items in the marine environment, special attention ought to be given to wastewater management, in order to minimize the loss of fibres.

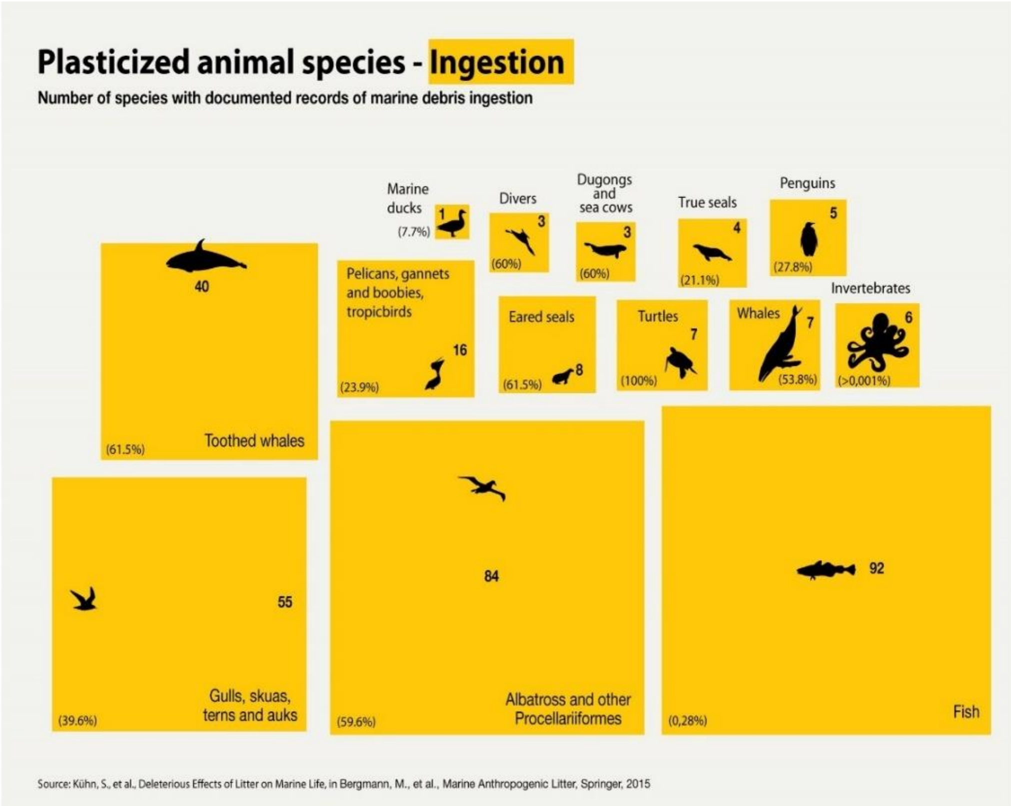
As for effects on marine biodiversity, Deudero and Alomar (2015) also remarked how the Mediterranean Sea is one of the most polluted seas worldwide, including plastic pollution; there are an estimated 62 million macrolitter items floating on the surface of the Mediterranean basin. These authors performed a review of scientific literature on the interaction of plastic with marine biota, which resulted in the identification of 134 species affected. Data from 17,334 individuals showed different levels of ingestion and effects on threatened and vulnerable species, in addition to several pelagic fish and elasmobranchs. Marine biota interacts with plastics in several manners, resulting in digestion, entanglement, toxicity, carcinogenesis, endocrine disruption and physical harm, including internal abrasion and blockage. Specifically in marine mammals, Deudero and Alomar (2015) found that interactions differed widely between misticetes and odontocetes and within families. Large effects were observed for sperm whale Physeter macrocephalus (average mean ingestion value of 91%) followed by fin whale Balaenoptera physalus (50%) and the porpoise Phocoena phocoena (12%). Besides cetaceans, the literature review also highlighted a high mortality (by entanglement or ingestion) in sea turtles and in some large pelagic elasmobranchs (Figure 140). Data on invertebrates were scarcer, but plastic ingestion was also found in several taxa (e.g. Holothurians).

In the same year, Cózar et al. (2015) also published a study with a similar focus, e.g. the effects of plastic pollution on the marine biota, especially on megafauna. The found that the average density of plastic and its frequency of occurrence (100% of sampled sites), are akin to the accumulation zones described for the five subtropical ocean gyres. 83% of plastic items were microplastics (<5 mm in length). According to these authors, the abundance of plastic litter and microplastics within the Mediterranean is due to high local inputs but also to the sink effect for Atlantic floating plastic pollution, given that the net water flow through the Strait of Gibraltar in the upper surface layer (10 m depth) is estimated to be 10^5 m3 s-1 toward the Mediterranean. Cózar et al. (2015) highlight the potential ecotoxicological effects of plastic ingestion by marine fauna, since plastic absorbs contaminants, including bioaccumulative compounds, about one hundred times more efficiently than naturally occurring suspended organic matter. Hence, chronic exposure of planktivorous animals (and their predators) to microplastic pollution could have toxicological impacts on organisms living in the plastic accumulation regions.

Moving down in the marine food web, Collignon et al. (2012) found the following results, quite aligned with those of Cózar et al. (2015):

- Microplastics are accumulating at the sea surface, especially within the neustonic habitat. This habitat harbors a diverse and specifically adapted zooplankton fauna.
- Microplastic particles can be uptaken (mistaken with food) by plankton filter feeders (the base of the food webs) in the neuston.
- The physiological effects related to plastic ingestion are poorly understood, as are the implications of plastic ingestion for food chains.
- Microplastics can be a significant carrier of lipophilic chemicals (POPs) and a source of pollutants such as polyethylene, polypropylene, and polyphenols that can potentially affect organisms.

Lastly, Fagiano et al. (2022) studied the prevalence of microplastics and its effects on zooplankton communities within the waters of an MPA, the Cabrera National Park in the Balearic Islands. MP particles were found at a density that is higher than in other sub-basins within the Mediterranean, results which agree with previous studies that identified high MP pollution in Balearic coastal waters. In fact, MP levels in the waters of Cabrera are amongst the highest registered for the Mediterranean. Their results also showed a significant correlation between MP abundance (items/m3) and zooplankton community composition.



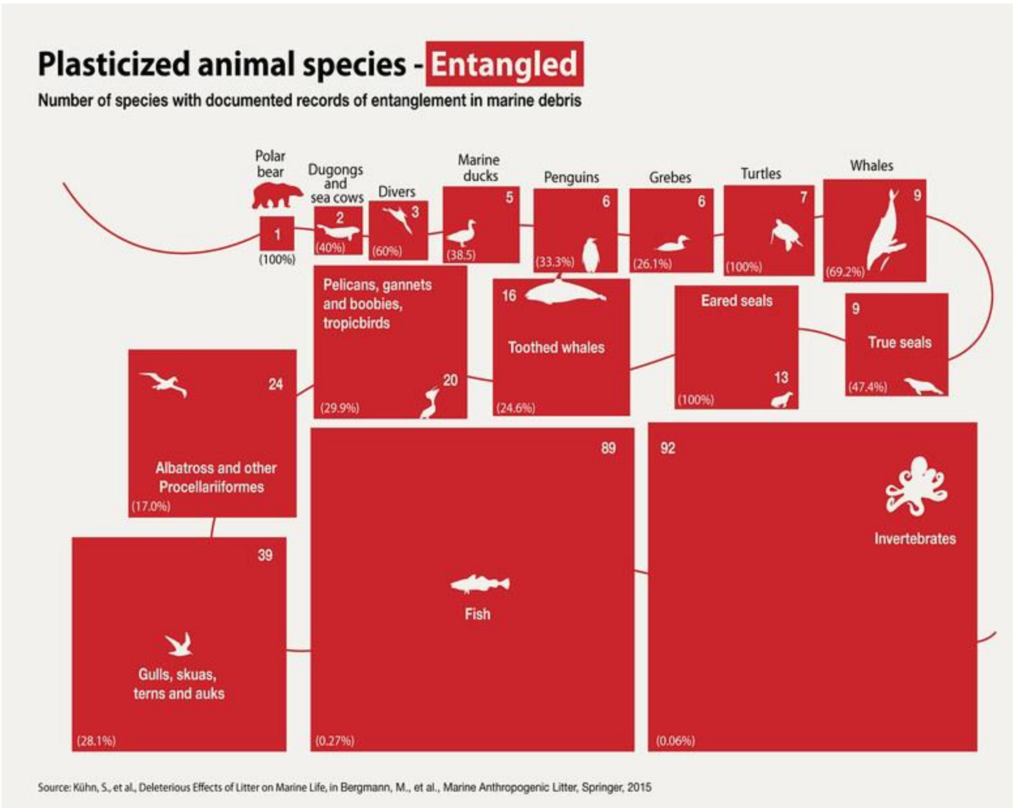
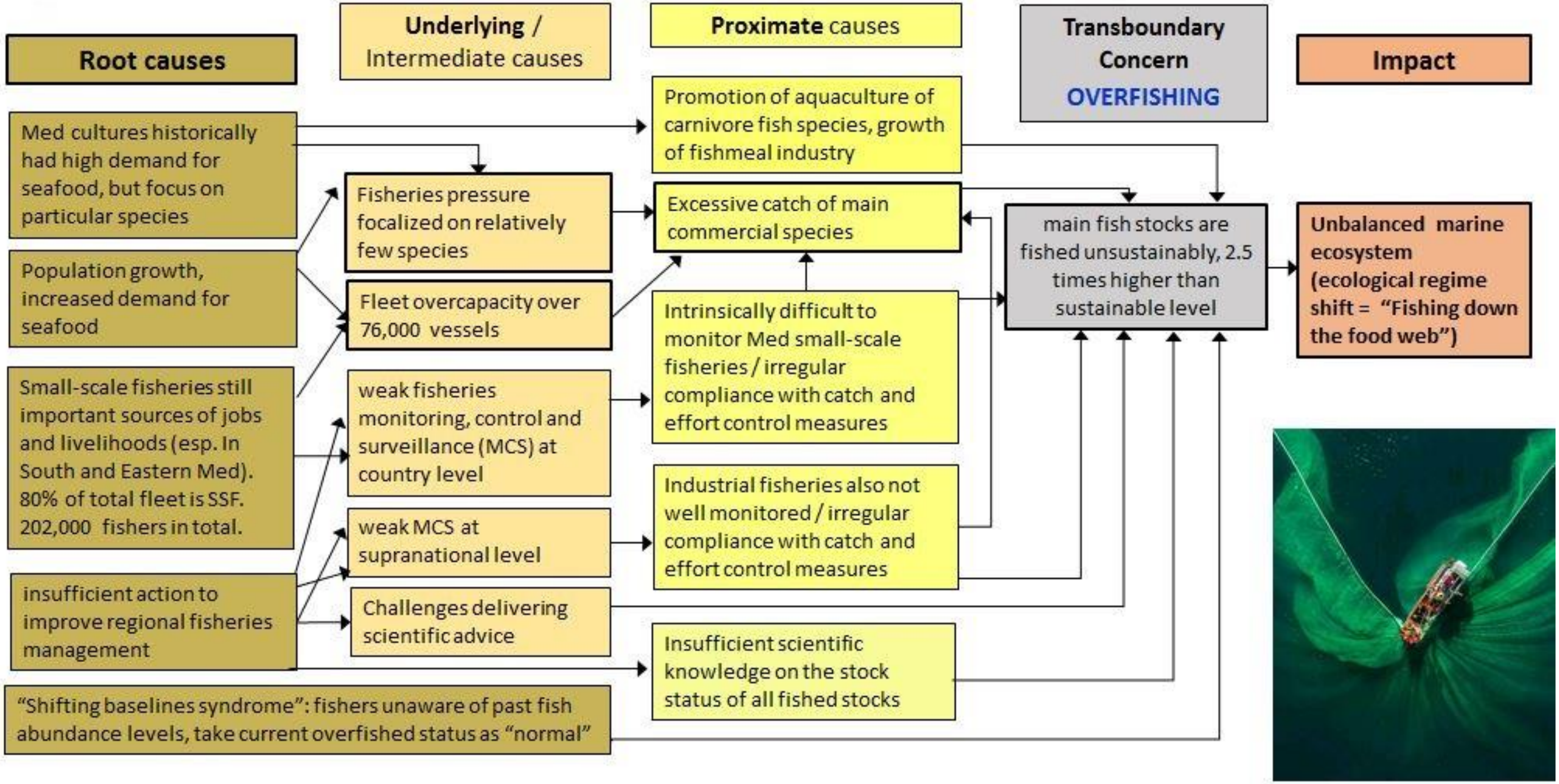


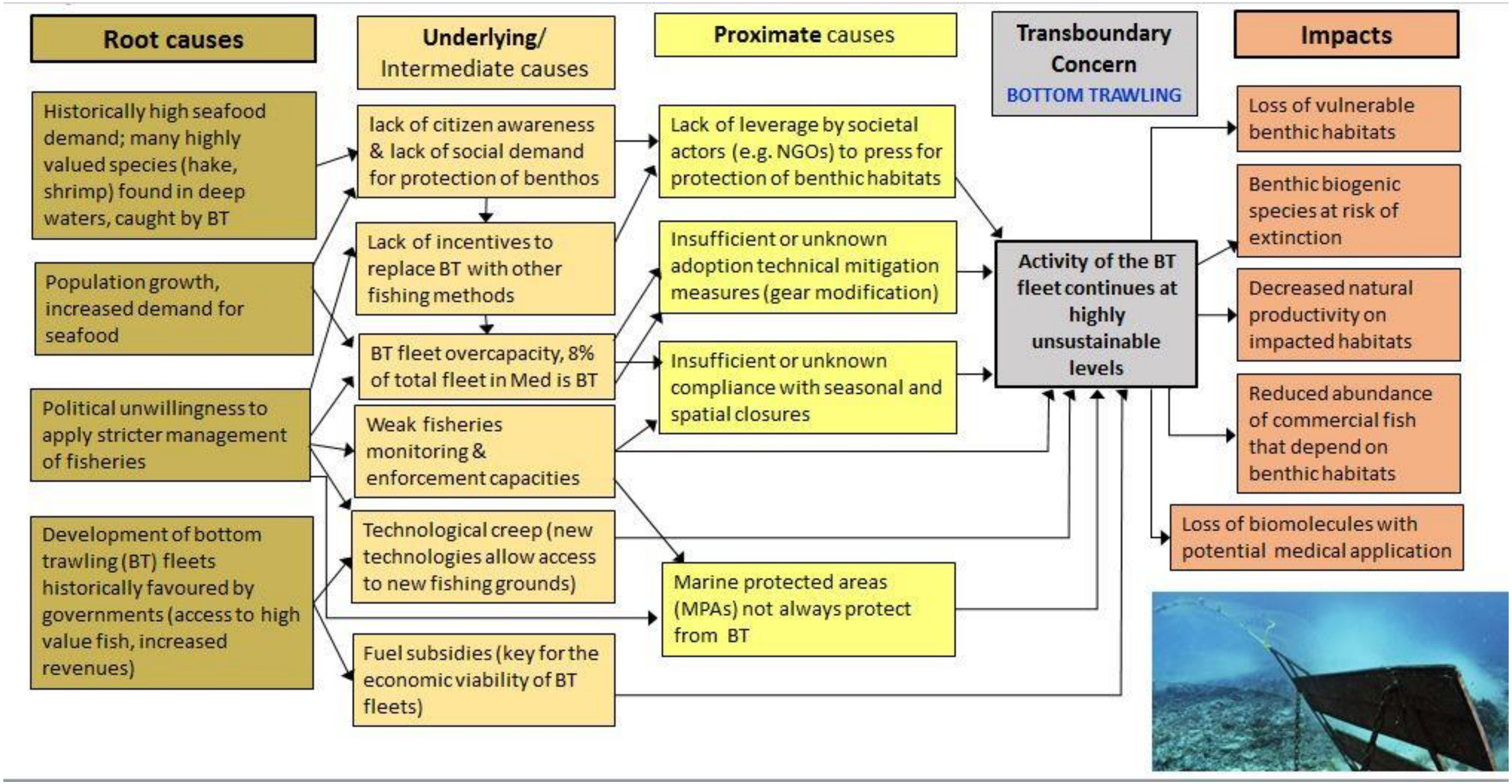
Figure 140. Plasticized animal species by ingestion and entanglement. (GRIDA and source references)

Immediate, underlying and root causes (with diagram)

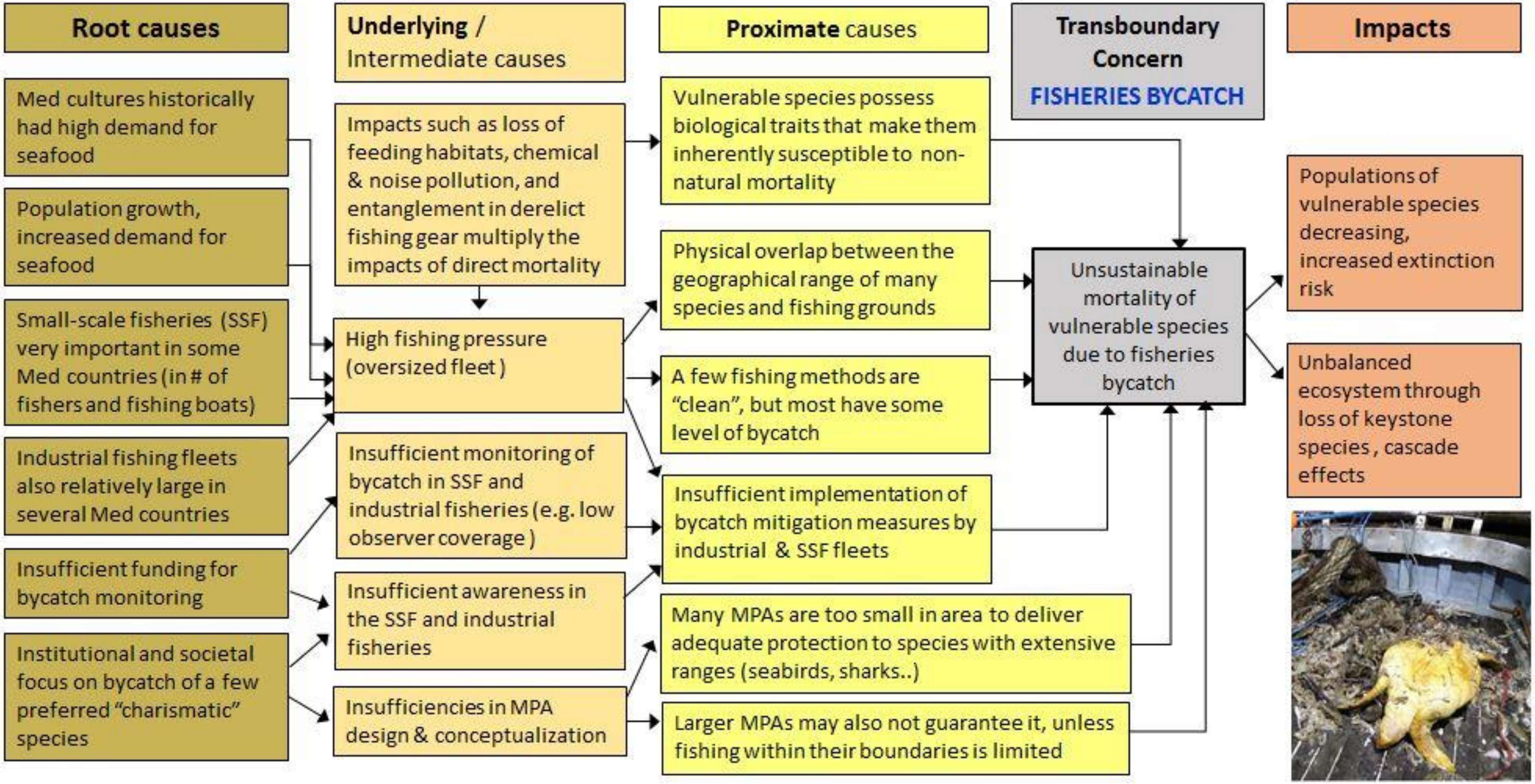
CCA Priority issue 6a: Fisheries harm (overfishing)



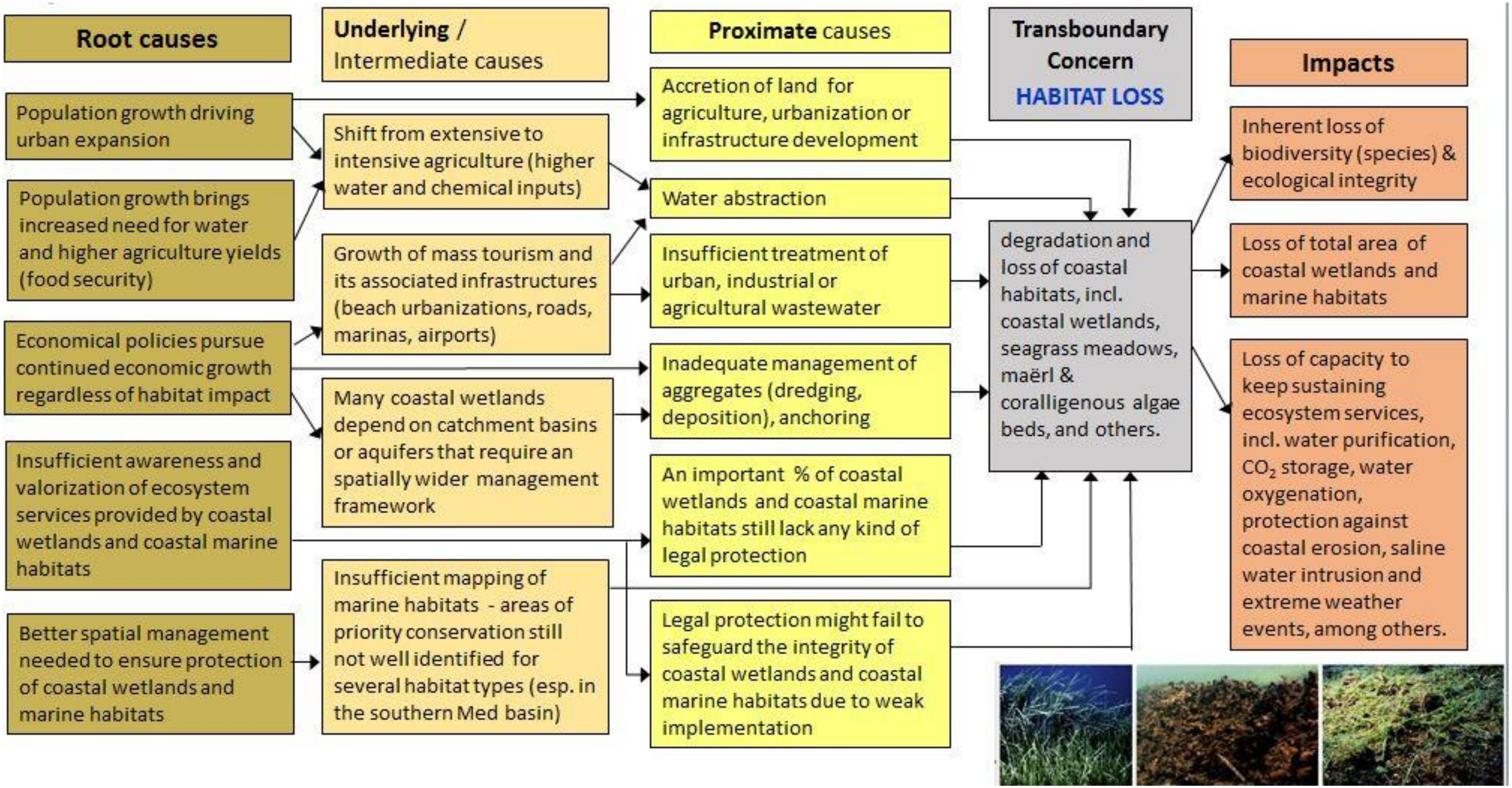
CCA Priority issue 6b: Fisheries harm (trawling)



CCA Priority issue 7: Biodiversity decline (by-catch)



CCA Priority issue 8: Habitat changes (Degradation&Loss)



Conclusions and Knowledge gaps

The overall status of fisheries in the Mediterranean is very poor: the 2022 report by FAO on the *State of World Fisheries and Aquaculture* (SOFIA) states that the overall fishing mortality for all fish stocks combined is nearly 2.5 times higher than sustainable reference points (FAO 2022). Most of the commercially important stocks that are regularly assessed are fished outside biologically sustainable limits, including hake (*Merluccius merluccius*), turbot (*Scophthalmus maximus*) and European pilchard or sardine (*Sardina pilchardus*). In short, Mediterranean fisheries are profoundly unsustainable, which jeopardises both the integrity of the Mediterranean marine ecosystem and the socioeconomic perspectives of the fisheries sector.

Historically, there has been a high demand for seafood within the Mediterranean countries (Altiok *et al*., 2021). Seafood consumption is deeply entrenched in the traditional gastronomies of many Mediterranean countries, with several of them showing relatively high per capita consumption rates of fish and seafood. In several Mediterranean countries, especially along the south and eastern basins, the small-scale or artisanal fisheries sector is a source of livelihoods and revenues, not only directly (for the artisanal fishers), but also indirectly (fishmongers, fish processors, cannery workers, landing site workers, etc.). There are substantial differences between countries and sub-basins, but in general most of this demand is focused on a subset of species that are specifically sought, either because they are very appreciated despite their usually high price (e.g. hake, tuna, turbot, pink shrimp, octopus), or because they are an affordable source of animal protein which can be consumed either fresh, when in season, or throughout the year, salted, pickled or canned (e.g. anchovy, sardines and other small pelagics, mussels and clams). Over time, this traditional demand has increased, both as a direct linear consequence of population growth across the Mediterranean region (especially in the south basin), and also due to additional factors such as the increasing popularity of fish as healthy food and the increase in demand associated to the massive expansion in the tourism sector over the past decades.

Another root cause of overfishing in the Mediterranean Sea is the insufficient application of the fishing effort regulations aimed at decreasing the fishing pressure. According to the 2017 Mediterranean Quality Status Report, the indicators of Good Environmental Status of Commercially Exploited fish are quantitative proxies to describe the status of a specific fish stock, as well as the anthropogenic pressure imposed on it through fishing activities. Those indicators are regularly used in fisheries management to assess the sustainability of fisheries, as well as the performance of management measures by monitoring how far the indicator is from previously agreed targets (i.e. reference points). Generally, stock status is determined by estimating both current levels of fishing mortality and spawning-stock biomass, and comparing these with reference points, which are typically associated with maximum sustainable yield, MSY (UNEP/MedPlan 2017). As seen above, both the spawning-stock biomass and the fishing mortality for the main commercial stocks in the Mediterranean are far from the sustainable levels. This is in direct contravention of the IMAP Ecological Objective 3 (EO3): "*Populations of commercially exploited fish and shellfish are within biologically safe limits*". Of the 60 fish stocks evaluated by the GFCM, in 2019, only 37% were fished within biologically sustainable levels.

Yet another root cause has cultural origins: although the fishers are usually well aware of the declining trends in their catches, especially when there is a sharp contrast between current and recent catches, fish stocks decline due to persistent overfishing extended over long periods (i.e. decades) may result more difficult to detect, not just by fishers, but also by other societal actors.

This is a sociocultural phenomenon which, while not exclusive of fisheries, was first coined in 1995 by the fisheries biologist Daniel Pauly: the shifting baseline syndrome. Applied to fisheries, it describes a situation where human perception fails to register the significance of differences between indirect stock status indicators in the current fish catch and in the past. For instance, these differences could be: decreased total fish abundance; disappearance of the most vulnerable species in favour of more generalist ones; the need for a higher fishing effort in order to reach the same catch volume; a smaller average size distribution of the catch; and decreased abundance of larger and more fertile adult fish ("megaspawners"), among others. It is especially relevant because it works at several socioeconomic levels, i.e. it can affect the fishers as well as the fisheries managers. In words of Pauly, who used the term for fisheries managers, "*this syndrome has arisen because each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers and uses this to evaluate changes. When the next generation starts its career, the stocks have further declined, but it is the stocks at that time that serve as a new baseline. The result obviously is a gradual shift of the baseline, a gradual accommodation of the creeping disappearance of resource species, and inappropriate reference points for evaluating economic losses resulting from overfishing, or for identifying targets for rehabilitation measures*" (Pauly 1995).

Shifting baseline effects on reference points and contemporary perceptions of historical stock status have been suggested as crucial factors contributing to the collapse of the Newfoundland cod stock in the 1990s (Schjins *et al*. 2021). The concept of "generational amnesia" is closely related to that of the shifting baseline syndrome and has been suggested in fisheries where the oldest fishers that remain active are the ones perceiving the greatest decline in fish catch, while younger fisheries are scarcely or not aware at all of such decline (Sáenz-Arroyo *et al*. 2005). The progressive impoverishment of the marine ecosystem over centuries of fishing activity and the sequential depletion of commercial stocks of large-bodied species such as skates, halibut, turbot and cod in the Dogger Bank (North Sea) has been identified as an example of the shifting baselines syndrome being still active in a current fisheries management framework (Plumeridge and Roberts 2017).

As mentioned earlier seafood demand within the Mediterranean is high, and the number of exploited fish and shellfish stocks is relatively large compared with other regions; however, most demand is focused on a relatively small subset of species, mainly: Atlantic bluefin tuna (*Thunnus thynnus*), hake (*Merluccius merluccius*), European pilchard (*Sardina pilchardus*), gilthead seabream (*Sparus aurata*), swordfish (*Xiphias gladius*), European anchovy (*Engraulis encrasicolus*), red mullet (*Mullus barbatus*), common octopus (*Octopus vulgaris*), deep water red shrimp (*Aristeus antennatus*), Giant red shrimp (*Aristeomorpha foliacea*) and deep water pink shrimp (*Parapenaeus longirostris*) (Altiok *et al*. 2021). Besides, many seafood consumers in the Mediterranean highlight the importance of freshness, quality and being locally sourced, i.e. given similar price ranges, they will favour fresh, local seafood from the Mediterranean over seafood imports from elsewhere (Claret *et al*., 2012; Nicolosi *et al*., 2018; Saidi *et al*. 2022).

Thus, the 2022 FAO's SOFIA report (*The State of World Fisheries and Aquaculture*) provided an updated summary of the status of fisheries in the Mediterranean basin. Most of the commercially important stocks regularly assessed continue to be fished outside biologically sustainable limits, including the stocks of hake (*Merluccius merluccius*), turbot (*Scophthalmus maximus*) and European pilchard or sardine (*Sardina pilchardus*). According to the General Fisheries Commission for the Mediterranean (GFCM), the overall fishing mortality for all resources combined is estimated at nearly 2.5 times higher than sustainable reference points. In 2019, only 37% of the assessed stocks in the Mediterranean and Black Sea were fished within biologically sustainable levels.

The unsustainably high level of fishing pressure, combined with seafood consumers preference by carnivore fish species (e.g. tuna, hake, turbot, swordfish), and the weak monitoring and enforcement have all combined to a situation of overfishing, which affects especially the species with higher trophic level. In turn, the overfishing of predator fish species may result in cascade effects throughout the marine trophic web and can trigger ecosystem phase shifts towards ecosystems dominated by species with lower trophic level. This process, termed "*Fishing down the food web*" (Pauly, 1998) was demonstrated to be happening in the Mediterranean by Piroddi *et al.* (2017). These authors found that across the Mediterranean basin there has been a reduction in abundance of important fish species (~34%, including commercial and non-commercial) and top predators (~41%), and an increase of the organisms at the bottom of the food web (~23%). In detail, Piroddi *et al.* (2017) found that there was a clear decline of small pelagics (-41%), demersal fish (-49%) and elasmobranch (-60%) biomasses in the Western and Adriatic Seas. Also, the mean trophic level (TL) of the community and mean TL of the landed catch decreased. These two indicators showed a decline since the 1950s, reflecting the decline of large predators/fish stocks and increase of lower trophic level organisms.

Piroddi *et al.* (2017) conclude stating that, with anthropogenic pressures rapidly expanding in the Mediterranean Sea, there is a serious risk that these may push the system beyond the "point of no-return", with consequences for marine biodiversity and the economies that depend on it, seriously constraining the ecosystem service options available to future generations. Ecosystem modelling tools can support the analysis and identification of the potential suitable options for ensuring the coexistence of sustainable human activities and the protection of healthy marine ecosystems. Since climate variability and climate change in combination with fishing pressure is expected to intensify in the region, modelling approaches are necessary in predicting the effect of changes of the above-mentioned pressures on the marine food web.

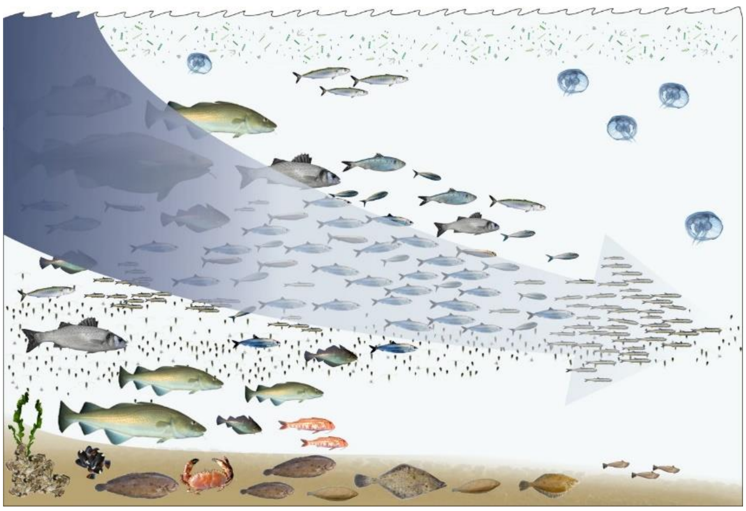


Figure 141. Fishing down the food web. Attribution: © Hans Hillewaert Source: Wikipedia (https://bit.ly/3H0muLP).

Vulnerable species and by-catch are directed towards biodiversity loss, because it can be a major contributor of sustained population declines leading to the extinction (local or absolute) of the impacted species. Confirming extinction for marine species is much more difficult than for terrestrial ones. But already, in the Mediterranean there are cases of localized extinctions of marine species in part of their range. For instance: the Smoothback angelshark (*Squatina*) is considered probably extinct from the Adriatic Sea, due to excessive fishing mortality through bycatch (Fondation Ensemble, 2023). Likewise, the sandy skate *Leucoraja circularis* and the Maltese skate *Leucoraja melitensis* (a Mediterranean endemic) were once abundant across the Mediterranean, but are now probably extinct in parts of their former range. For instance, the sandy skate is no longer found in the Gulf of Lyons nor in the Adriatic, and the Maltese skate is also absent in the Gulf of Lyons and in waters off Tunisia, being very rare in the western central Mediterranean. Both species are assessed as Critically Endangered under IUCN's Red List. It is remarkable that in all the areas where both skate species are extremely rare or possibly absent also exhibit very active bottom trawling fleets.

Another example is the Mediterranean monk seal (MMS, *Monachus monachus*), the only pinniped species inhabiting the Mediterranean region, whose current distribution range is a mere fraction of its original one original range: it once encompassed the entire Mediterranean Sea, the Black Sea and the Atlantic coasts of NW Africa. Nowadays the species is deemed extinct throughout most of its former range; the world population is reduced to about 700 animals with breeding colonies confined to the eastern Mediterranean (Greece, Turkey), Mauritania and the Madeira archipelago in Portugal (Panou *et al*. 2017).

Fisheries by-catch shares a number of root causes with the previous driver (overfishing):

- The *increase in coastal population* in combination with a traditionally *high demand for seafood* within the Mediterranean countries, and the pursuit of *unsustainable economic development* has spurred the expansion of the fishing fleets, at both the industrial and small-scale sectors.

- This expansion of the fishing fleets occurs while there is still *limited environmental literacy and awareness* among the wider public, including fishers, seafood consumers, and fisheries management institutions. As a result, addressing the issue of bycatch rarely is a priority in the agenda of the fisheries management authorities, taking a secondary role after what the institutions deem as more pressing issues such as stock depletion, negotiation and allocation of fishing quotas, or socioeconomic issues, among others. Generally, there is scant funding allotted to bycatch mitigation programmes.

- The concept of what constitutes a vulnerable species is still partially skewed towards certain taxa. Even when there is some level of concern towards the bycatch problem, this is usually framed as affecting a specific set of species that are preferred by the public, i.e. the so-called "charismatic" and "emblematic" taxa: usually, sea turtles, cetaceans, monk seals and perhaps seabirds. Keystone species such as elasmobranchs or sessile benthic biogenic invertebrates are rarely addressed, even though in terms of vulnerability they are no less vulnerable than the above-mentioned groups.

- The *lack of financial and institutional capacities* causes weak fisheries governance, with low levels of monitoring, control and surveillance not just of the target species but also of the bycatch. This is specially the case for the small-scale fleets, but also affects the industrial fleets.

- Specifically, there is a *lack of enforcement of environmental protection regulations.* In the case of fisheries bycatch, this is reflected in the insufficient compliance with measures aimed to offer protection of vulnerable species (e.g. limits on the use of specific fishing gears, controls of fishing effort, spatial or seasonal closures).

Immediate causes of by-catch:

- As seen before, some marine taxa possess biological and/or ecological traits that render them very vulnerable to non-natural sources of mortality. These species correspond to what in classical ecology was termed "K strategists": i.e. species that, in general, have relatively long lifespans, late maturity, have low fecundity, reach larger body sizes, and have a reduced number of progeny. In these species, any additional stressor that increases their total mortality over the natural mortality rate might trigger a population decline. This decline is self-reinforcing: the fewer animals reach maturity, the smaller the total offspring will be, and thus in each generation that suffers extra mortality the population will decrease. If this declining spiral is not curbed, it can drive population towards extinction.

- Also it has to be taken into account that in the Mediterranean there are already multiple other stressor acting in combination with bycatch mortality: for instance, habitat degradation and loss reduces the extent and quality of available nursery and feeding grounds; the chemical cocktail present in the marine water might have long-term ecotoxicological effects affecting the species lifespan and/or their fecundity; ingestion of marine litter can cause injuries or starvation.

- There are a few fishing methods that are highly selective: they have very little or no bycatch at all of vulnerable species. For instance: handline, trolling and pole and line. However, the majority of fishing gears are less selective, and hence have some bycatch level that affects vulnerable species. Bycatch rates might vary across gears, fleets, season, and geographical regions, among other factors. Despite these variability in bycatch rates, the main gears responsible for most bycatch of vulnerable species are clearly identified:

  -Within the industrial fisheries sector, bycatch is concentrated in some main gears responsible for most of the commercial catch: longline (pelagic and demersal), bottom trawl, dredges and purse seine with fish aggregating devices (FADs).
  -Within the small-scale fisheries (SSF) sector, bycatch can also be very high in several gears, especially the set net type (gillnets and trammel nets).

- Achieving adequate levels of fisheries monitoring is crucial to understand the problem of bycatch, but bycatch monitoring is very poor in the Mediterranean fleets: In the industrial fishing fleets the level of observer coverage is low to very low, while in the SSF it is virtually non-existent (Carpentieri *et al*. 2021). It is important to highlight that for the bycatch data to be adequate, observer coverage levels must reach certain thresholds, which vary across taxa and fishing gears.

For instance, to establish reasonably precise estimates of seabird bycatch, observer coverage of >20% is required; coverage of 5% is inadequate to quantify seabird bycatch (MRAG 2021). It is true that in the case of SSF, often the vessels are very small, carrying only one or very few fishers. There are alternative approaches when the physical deployment of observers is not viable; for instance, remote electronic monitoring (REM) with on-board cameras can be contemplated, although they do not fully replace the role of well-trained scientific human observers (Gilman *et al*. 2018, Van Helmond *et al*., 2020). However, there seem to be few initiatives within the Med following this approach.

- Regulations conveying the use of satellite-based vessel monitoring systems (VMS) and/or Automatic Identification System (AIS) are in place for larger vessels, but compliance is irregular as a result of weak enforcement capacities.

These high mortality levels are unsustainable and cause population declines in most of the species mentioned. It is not possible to assess the specific populational trends of all the vulnerable species in the Mediterranean; however, the IUCN Centre for Mediterranean Cooperation has compiled a list with the species included the Mediterranean Red List.

Regarding habitats, from the results of the literature review it can be inferred that several of the most important found marine habitats in the Mediterranean are experiencing a reduction in their distributional range, due to both direct destruction and accumulative stressor impacts. The area covered by coastal wetlands and seagrass meadows, especially of Posidonia oceanica is receding, while other infralittoral like vermetid or polychaete reefs are too poorly studied that allow drawing conditions (however, some massive mortalities events have been recorded). Circalittoral, mesophotic and deep-water habitats are more difficult to monitor; however, the available information points out to significant reduction of habitats such coralligenous formations, maërl/rhodolith beds, mesophotic stony corals, hard-bottom coral gardens, soft-bottom coral gardens, sea pen fields, and sponge aggregations. Besides the net loss in total geographical extent of these habitats, the information available points out to a decrease in habitat quality i.e. a poorer overall condition of the habitats for which there is relevant information (e.g. seagrass meadows, polychaete reefs, coralligenous formations).

To this regard, marine protected areas (MPAs) are very necessary and a key tool to safeguard marine biodiversity. However, several issues and shortcomings have been pointed out in the Mediterranean network of MPAs: 1) They are irregularly distributed across the Mediterranean basin, with the majority concentrated in the countries of the northern shore (Giakoumi *et al*. 2013), 2) Many are too small in area (average size 5 km^2, according to Lubchenco *et al*., 2016) to deliver adequate protection to highly mobile species with extensive ranges, and 3) Fully protected “no take” MPAs (i.e. MPAs that exclude fishing; the equivalent to land-based national parks) represent a minimal share of the total area. Claudet *et al*. (2020) studied 1,062 Mediterranean MPAs and found that while 6% of the Mediterranean is covered by an MPA, 85% of these MPAs do not impose regulations stronger inside than outside. Full and high levels of protection, the most effective for biodiversity conservation, represent only 0.23% of the basin. On the other hand, a large number of MCPA could deviate the focus to address the root causes of biodiversity decline and habitats loss, and enter in the ‘shifting baseline syndrome’.

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4.2.4. Fighting climate change (environment)

A special attention due to the global environmental impacts and socioeconomic consequences arising from climate change, the following issues were also identified as a high transboundary concern and supported by the Climate Change transboundary causality assessment report – contribution to the UNEP/MAP GEF TDA Report update by 2023:

Priority issue 9: Atmospheric emissions

Priority issue 10: Marine anomalies (SST-heat waves)

Priority issue 11: Coastal water systems (&flooding)

Priority issue 12: Coastal planning (assets&drought)

Rising temperatures and sea levels, intense and frequent heat waves, reduced precipitation, drought and other extreme weather events have transformed the Mediterranean into a climate hotspot of change, which means that climate is becoming more and more important in re-defining and shaping the current and future trajectories of countries and populations (Andrea Dessì and Flavia Fusco 2022). The Mediterranean region is exposed to several planetary risks, like earthquakes, volcano eruptions, floods, droughts and sea-level rise.

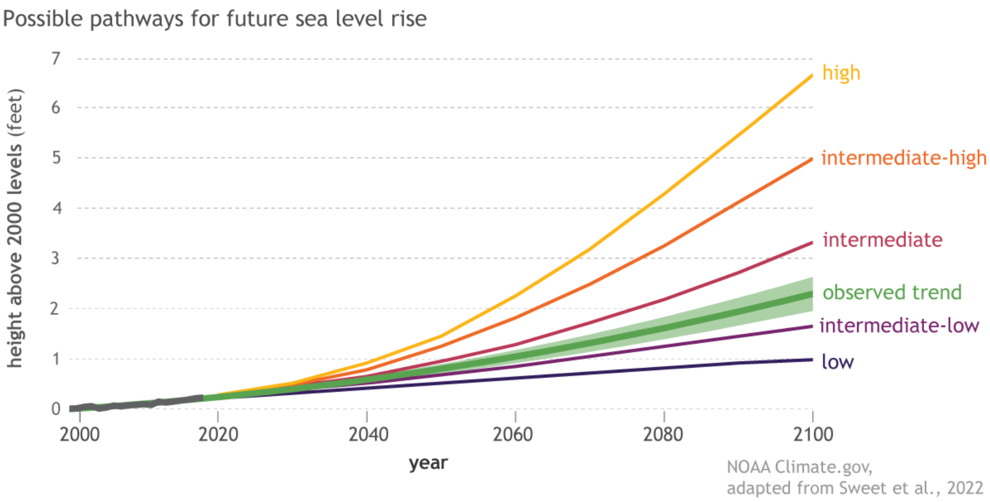


Figure 142. Possible future sea-level Rise; Source NOAA 2022

The estimated global mean sea level (GMSL) observed trend will have risen by 0.43 m in 2100 (Figure 142). The corresponding end-century rates of GMSL rise are between 4–9 mm/year and 10–20 mm/year (RCP2.6 and RCP8.5 likely ranges (Magnan et al., 2022); RCP, Climate scenario Representative Concentration Pathway). In the Mediterranean region, average annual temperatures are now 1.4 °C higher than during the period 1880-1899 (Figure 143), which is above current global warming trends, especially during summer. As estimated by IPCC in 2013, a rise in temperature from 2 to 6 ° C by 2100 is expected in the Mediterranean (for summer temperatures) and heat waves are likely to become more frequent and/or more extreme.

Climate-related impacts such as warming caused by greenhouse gas emissions have reached globally. Enormous scientific research and studies over the decades clearly point to the correlation between human activities and the indicators of the global climate changes (e.g., CO_2). It is widely recognized that climate change has already severely affected every living environment on the globe and the change will also have ripple effects on the entire spectrum of human livelihoods. Therefore, it is crucial to update and consolidate the scientific knowledge about climate and environmental change in the Mediterranean basin and to render it accessible to policymakers, key stakeholders and citizens (MedCC Report 2018).

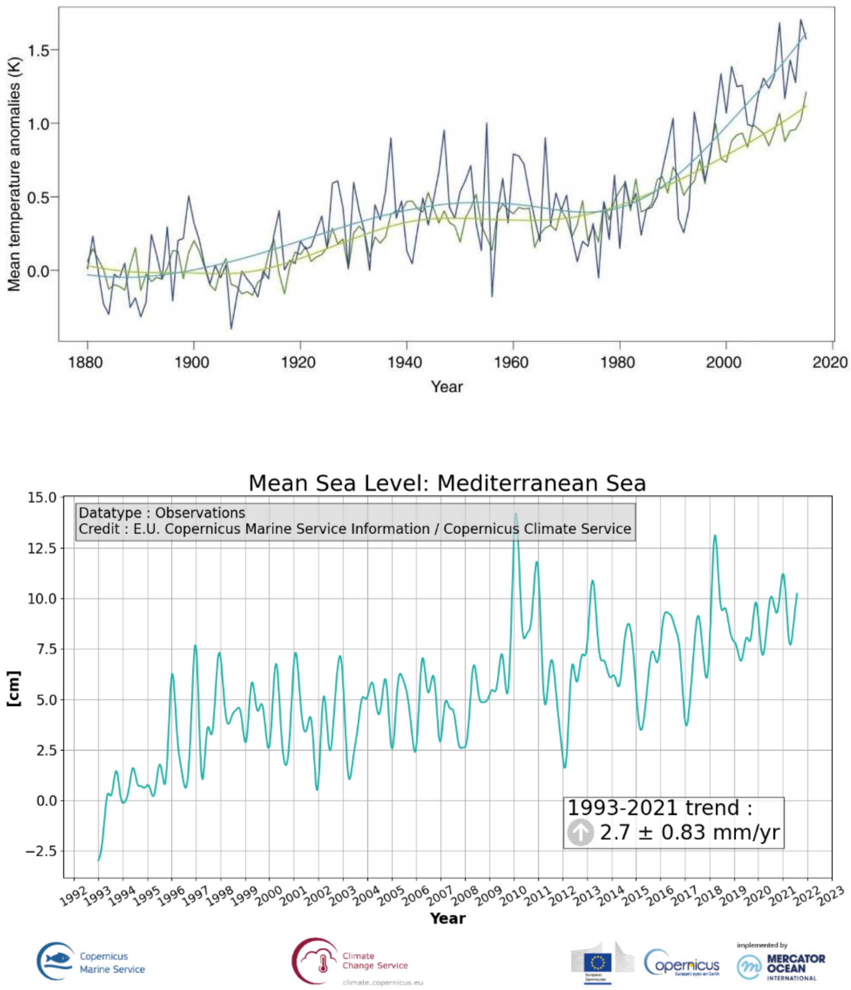


Figure 143. Average annual temperatures in the Mediterranean, above current global warming trends; SOURCE; MEDCC Report 2019 (top) and Copernicus 1993-2021 (bottom).

The Mediterranean basin is a unique rich marine ecosystem long affected by human influence, whose resilience is now questioned by climate change. The main environmental problems identified in the Mediterranean basin are directly or indirectly related to the climate and hydrology of the basin itself. Despite decades of national and regional science-policy efforts to address coastal hazards, mitigation, and adaptation programs and strategies, the scarcity of water resources, erosion and coastal degradation processes, flooding along low-lying coastal areas, and many more continues. Human pressure on the Mediterranean ecosystem, altogether with climate change effects might pose costly consequences for the Mediterranean biodiversity in the medium and long term, such as in fisheries (e.g., commercial species), as climate change is expected to modify migration patterns, as well as for the population dynamics of many species including ourselves.

Priority issue 9: ATMOSPHERIC EMISSIONS (&POLLUTANTS)

Description of the problem and its transboundary importance

-GREEN HOUSE GASES, POLLUTANTS AND PARTICLES

Transboundary atmospheric pollution and particles

Transboundary flows are explained as contributions from climate change and natural hazards. Meteorological variability also plays an important role in the transboundary fluxes of air pollution in terms of increasing concentrations and long-range distribution of greenhouse gas emissions (ca. pollution). Much higher transboundary contributions are observed through emitted SO_4, the emitted SO_2 has traveled some distance before it is fully oxidized to SO_4. This example explains why in the smaller countries around 90% of the emission of sulphur is SO_4 originates from outside the country (Figure 144), implying only a 10% indigenous contribution. For the larger countries, the transboundary and indigenous contributions are about 75% and 25%, respectively. Therefore, there are concerns that regional air pollution control strategies may be ineffective in a situation where background air pollutant concentrations are increasing due to rising emissions in other parts of the world.

Green House Gases Emission (GHG)

Greenhouse gases produced by human activities have caused an overall warming influence on the Earth's climate since 1750. The largest contributor to warming has been carbon dioxide, followed by methane and black carbon. Although aerosol pollution and certain other activities have caused cooling, the net result is that human activities on the whole have warmed the Earth (NOAA, 2020). Global carbon dioxide emissions are increasing faster in some parts of the world; for example, in East Asia and the Pacific, than in others (Figure 145). The majority of emissions come from three regions: East Asia and Pacific, Europe and Central Asia, and the United States, which together accounted for 74 percent of total global emissions in 2018.

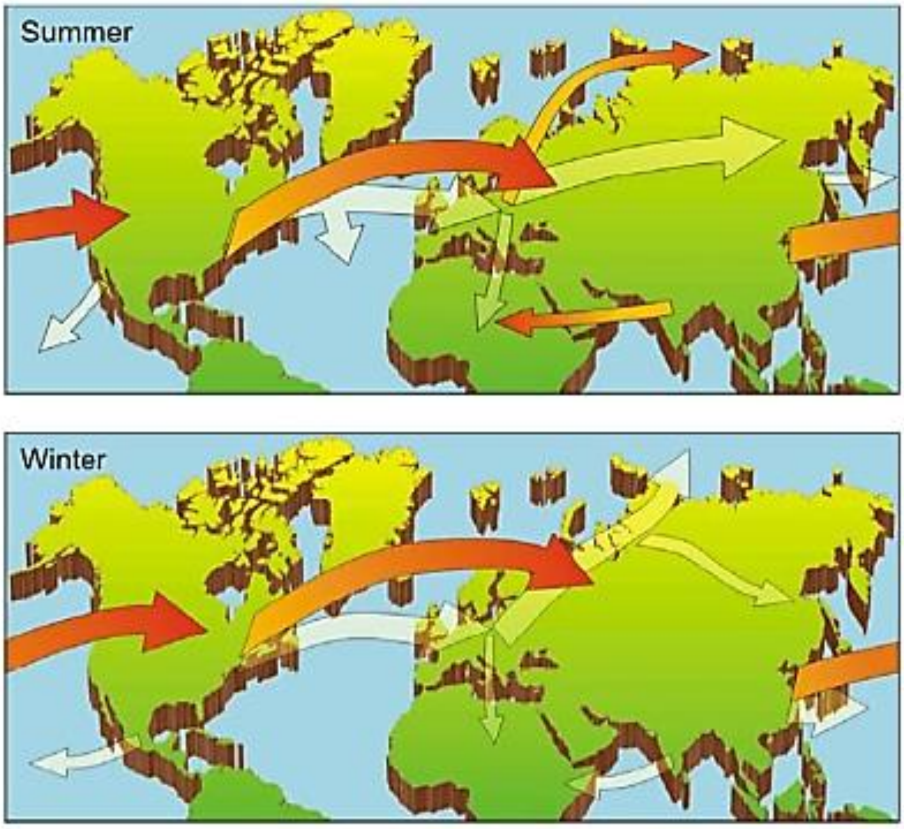


Figure 144. Schematic illustration of the pathways of the average transport of pollutants from the three Northern Hemisphere continents. The orange arrows illustrate transport in the middle and upper troposphere, whereas the light shaded arrows illustrate lower-level transport. The arrows' widths qualitatively indicate how much pollution is transported along the respective pathways (EMEP REPORT, 2005)

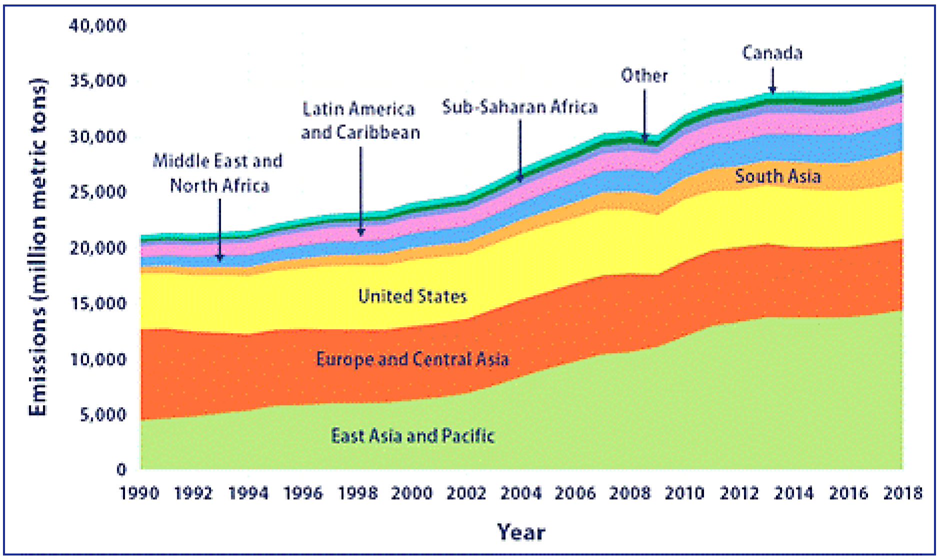


Figure 145. Global Carbon Dioxide Emissions by Region, 1990–2018 (source: NOAA, December 2020)

According to data compiled from UNFCCC (2022), the most recent inventory of net GHG emissions indicates that North Mediterranean Countries (NMCs) emitted a total of 1.2 million kt CO_2 equivalent, representing 8% of the total countries in 2019 (see Figure 146).

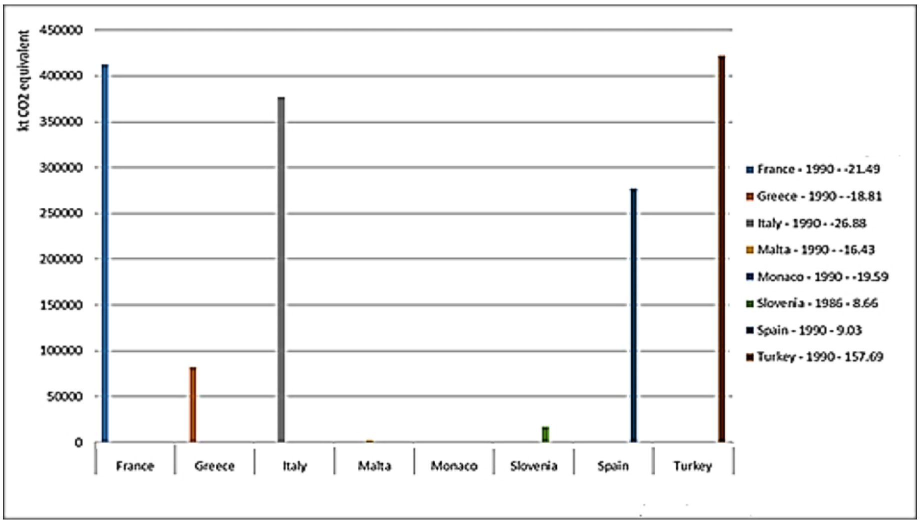


Figure 146. GHG emissions generated by annex 1 countries in the Mediterranean (source UNFCC, April, 2022)

Helman &Bonil, 2022 assessed the impact temperature and CO_2 on wheat yield using statistical analysis of data collected along the six-decade wheat yields for the top 12 global wheat-producing countries. They presented the first evidence that warming and drought in the world's leading wheat-producing countries offset the benefits of increasing [CO_2] to wheat yield in the last six decades. They underscored that, warming of 1.2 °C from 1961 to 2019 reduced the annual yield by nearly 2.8% , and an increased water deficit of 28.8 mm H_2O m^{-2} for the same period reduced the yield by almost 1%. They suggested shifting efforts towards more experimental studies set in currently warm and dry areas and combining these results with statistical and numerical modeling to improve our understanding of future impacts of a warmer and drier world with higher [CO_2].

These results, came by Castaldi et al., (2022), who analyzed the climate sustainability of the Mediterranean diet (MD) and the greenhouse gas emissions (EGHG) associated with current dietary patterns in Mediterranean and non-Mediterranean EU countries, focusing on the major deviations from the MD health and environmental targets in Mediterranean countries. Their findings showed that the EGHG associated with the ideal MD pattern, 2.3 kg CO_2 equivalents (CO_2eq) $capita^{-1}$ d^{-1}, are in line with planetary GHG climate targets, though GHG emissions associated with food consumption in Mediterranean countries strongly diverged from the ideal MD. The results of this study support the positive role that the MD could have on EU climate mitigation targets if it were fully adopted by Mediterranean citizens. The analysis also displayed the nutritional transition experienced by Mediterranean countries, in particular over the last 30 years, which has undermined this potential. A significant dietary shift to the dietary patterns of the Mediterranean tradition would bring significant environmental gains as well as increased health benefits related to non-communicable diseases, including a lower incidence of cancer, cognitive disease and cardiovascular diseases as well as for metabolic syndrome, obesity and type 2 diabetes (Castaldi et al., 2022).

Luca Franza (2021), discussed the CO2 intensity metrics in Mediterranean countries and greening the Mediterranean, as pathways for Sustainable Energy and Climate Cooperation. In terms of response to climate risk mitigation, she underscored that, the energy projects can have positive political, economic and security. Clean gas would in fact contribute to be future-proof, by being compatible with net-zero-by-mid-century objectives. As such, it would be wise to promote solar in high- yield regions such as most of North Africa, electrification in the sectors where it can be achieved more cost-efficiently and hydrogen use in hard- to-abate sectors and for international low-carbon energy withdrawal. Coherent visions underpinned by solid and broad political consensus are key in this respect. Finally, hydrogen would be an enabler of large-scale in hard-to-abate sectors and win-win outcomes between prospective exporting and importing countries.

Major environmental impacts and socio-economic consequences (including gender aspects)

Warming

The average Mediterranean SST for study period (2015, 2016, and 2018) was higher than in 2003, and the average warming rate in the Mediterranean Sea from 1982 to 2019 was 0.38°C per decade, more than three times higher than the global average of 0.11°C per decade. In the Aegean and Levantine Sea ecoregions the average temperatures over the study period (2015 to 2019) were 1.4 ± 0.25°C and 1.3 ± 0.23°C warmer than the first 5 years of the satellite record (Figure 143 and Garrabou et al., (2022).

According to preliminary assessment of climate and environmental changes in Mediterranean by MEDCC 2020, the warming of the Mediterranean is expected to increase at rates above the global average, depending on the level of future mitigation of greenhouse gas emissions. Mediterranean Sea surface temperature maximum increases of 0.16°C per year were found in June in the Tyrrhenian, Ligurian and Adriatic Seas and close to the African coast. The Balearic Islands, the northwest Ionian, the Aegean and Levantine Seas have been identified as the regions with maximum increase of sea surface temperature. However, warming of 2°C or more above the preindustrial level is expected to generate conditions for many Mediterranean land ecosystems that are unprecedented in the last 10,000 years.

Acidification

Acidification refers to a reduction in the seawater pH over a long period of time, mainly due to the uptake of carbon dioxide (CO2) from the atmosphere. When CO2 is absorbed by seawater, the carbonate equilibrium is displaced resulting in an increase of hydrogen ions concentration causing the seawater prone to acidification by estequiometry, and thus, and less abundant carbonate ions.

Acidification would affect the entire world's oceans in the long run, including coastal estuaries and lacks (NOAA report February, 2021). Ocean acidification in recent decades is occurring a hundred times faster than during past natural events over the last 55 million years. It already reaches into the deep ocean, particularly in the high latitudes. Average surface-water pH is projected to decline further to 7.7 or 7.8 by the year 2100, depending on future CO2 emissions. This decline represents a 100 to 150 % increase in acidity. OA may affect many marine organisms within the next 20 years and could alter marine ecosystems and fisheries (EEA; Ocean acidification report July 2022).

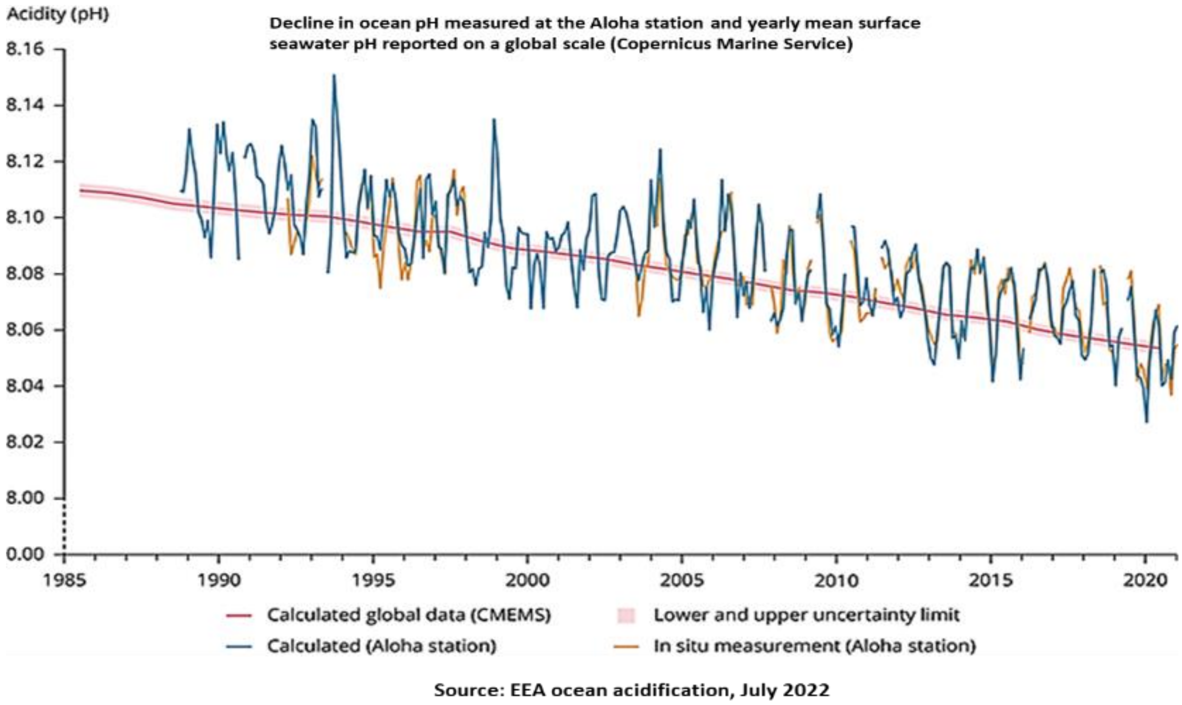


Figure 147.

Calculated decline in ocean pH at the Aloha station EEA, July 2022).

As recounted by MEDCC report 2020, ocean pH has decreased by 0.1 pH units since the preindustrial period, which is unprecedented during at least the last 65 million years. Globally, CO_2 uptake by the oceans is expected to lead by 2100 to acidification of 0.15-0.41 pH units. Similar rates are expected for the Mediterranean, which is currently estimated to decrease by 0.018 to 0.028 pH units per decade.

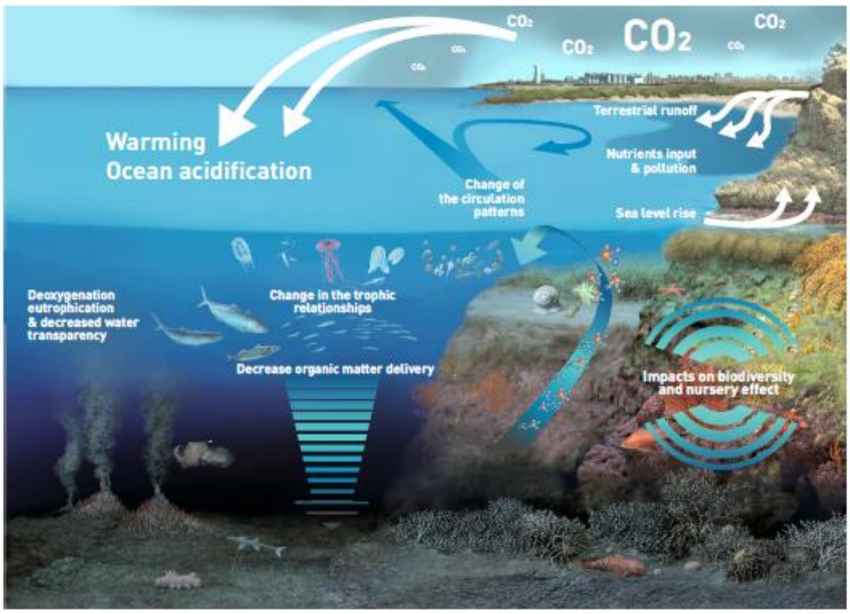


Figure SPM.6 | Climate change drivers potentially affecting marine pelagos and benthos in the Mediterranean Sea.

Marine fauna and acidification

The systematic review of the acidification trends and impact on marine organisms, by OA-Med Hub (Hassoun et al, 2022), gives a clear picture of various aspects and future projections. Due to the features of the Mediterranean Sea, the anthropogenic CO2 is efficiently transferred to deep layers and is observed in all water masses the in various basins of Mediterranean Sea. The review shows the carbonate system is still poorly quantified in coastal zones, and long-term time-series are still sparse across the Mediterranean Sea, which is a challenge for studying its variability and assessing coastal OA trends. The most studied groups of organisms are autotrophs (algae, phanerogams, phytoplankton), mollusks, and corals, while microbes, small mollusks (mainly pteropods), and sponges are among the least studied. As a final recommendation by the authors to tackle acidification in the Mediterranean Sea; there is a strong need to adopt and implement firm statements in parallel with systematic and clear actions, particularly by the most industrialized countries.

Dorey et al., (2022) evaluated the direct and indirect effects of pH (pH 8.0, 7.6 and 7.2) on the development and transition from a planktonic larva to a benthic juvenile in the green Sea urchin S. droebachiensis. The formation of the primordial juvenile was delayed by two days at pH 7.2. Further, the larvae raised at pH 8.0, and transferred to 7.2 after competency exhibit mortality rates five to six times lower than those kept at 8.0, indicating that pH also has a direct effect on older, competent larvae. Similarly, Barbara et al. (2020) investigated the combination effects of elevated CO2, warming and acidification on oligotrophic Eastern Mediterranean Coccolithophore community, plankton communities through applying Mesocosm experiments. The results showed that; Coccolithophore cell abundance drastically decreased under ocean warming (OW), and combined OA and OW (greenhouse, GH) conditions. Emiliania huxleyi calcite mass decreased consistently only in the GH treatment; moreover, anomalous calcifications (i.e., coccolith malformations) were particularly common in the perturbed treatments, especially under acidification. Overall, these data concluded that the projected increase in sea surface temperatures, including marine heatwaves will cause rapid changes in Eastern Mediterranean coccolithophore communities, and these effects will be exacerbated by acidification.

It should be stated here, as mentioned earlier, that such variations in pH values as used in laboratory experiments are not expected even beyond the year 2100 and do not consider the buffering effects (ca. ‘matrix effects’) of seawater, despite confirming that species are sensible to pH variations. Warming as a direct effect of changing climate conditions (ca. heat waves) poses the highest risk in the short-term.

Priority issue 10: MARINE ANOMALIES (SST-HEAT WAVES)

Description of the problem and its transboundary importance

SEA SURFACE TEMPERATURE ANOMALIES (MARINE HEAT WAVES)

Climate change led to increase in the frequency and intensity of marine heat- waves (MHWs) which affected more than 90% of the surface water of the Mediterranean Sea. The mortality events (MMEs) of marine organisms are one of their main ecological impacts. According to the recent scientific research by Garrabou et al., (2022), the Mediterranean Sea over 2015–2019 period has experienced exceptional thermal conditions resulting in the onset of five consecutive years of widespread MMEs across the basin. These MMEs affected thousands of kilometers of coastline, from the surface to 45 meters depth. The mortality was observed with exceptional marine heat waves affecting more than 90% of the Mediterranean surface and reaching temperatures of more than 26ºC. The most affected species are Posidonia Oceanica and coral assemblages, which are both the most symbolic habitats in Mediterranean. The authors also underscored that, the number of taxa and phyla exhibiting mass mortality per year during the 2015–2019 period was on average 23 taxa and 7 phyla (including corals, sponges and macroalgae, among others). These values are much higher than reports for most previous years from 1978 to 2014.

Major environmental impacts and socio-economic consequences (including gender aspects)

Being a contemporary phenomenon occurring in the last's years in the summer seasons in the Mediterranean and linked to other land environmental issues (ca. fire forests) still difficult to accurately assess its impacts and socio-economic consequences. For example, even if the warming of seawater could be or not be liked by the tourism sector, the analysis of the consequences goes beyond pure economic considerations. In fact, the impacts at environmental levels are unknown, and a few mass mortality events were recorded, however, difficult to fully elucidate its causality. In turn, MHW are linked to heat waves as well, thus, are related to public health factors that pose an unprecedented threat to the health and functioning of both terrestrial and marine ecosystems.

Priority issue 11: COASTAL WATER SYSTEMS (POLLUTION&FLOODING)

Description of the problem and its transboundary importance

Floods and weather-related hazards and their patterns are likely to be significantly affected by climate change. Floods are already the most frequent and among the most costly and deadly natural disasters worldwide (NatCat Service 2015). This was also confirmed in the Mediterranean region. In 2018, the EM-DAT International Disasters Database (http://www.emdat.be/) lists for example €200 billion in damages related to various disasters since 1900 in the countries surrounding the Mediterranean, of which 85 billion are associated with river flooding. I am confident that damage costs have increased with the acceleration of climate change under the current scenario.

Full comprehension of the dynamics of hazardous sea levels is indispensable for assessing and managing coastal flood risk, especially under a changing climate. Coastal flood events are among the most disastrous natural phenomena of major risk along the Mediterranean coastline, and their risk has increased in the last decades, mainly due to mean sea-level rise. Coastal flooding is determined by anomalously high sea levels which are the sum of several tidal and non-tidal processes acting at different temporal and spatial scales (Figure 148). The devastating flood in the historic city of Venice (Italy), located in the northern end of the Adriatic Sea, a semi-enclosed regional basin with one of the largest tidal ranges (the height difference between high tide and low tide) and extreme sea levels (ESLs) in the Mediterranean

Sea (Ferrarin et al., 2022). Flood risk in Venice increased during the last century and will certainly worsen in the future due to RSLR and the number and the duration of flooding events in Venice will increase in the future (Figure 149). Furlan, E., et al., (2022) evaluated potential risks of loss or degradation of ecosystem services due to projected extreme sea level scenarios in the Italian coast. The analysis results are summarized in an explicit spatial risk index, useful in classifying coastal areas most vulnerable to environmental and social losses or degradation due to coastal inundation at the national level.

In general, the Northern Adriatic coast is scored at high risk of Ecosystem Services loss or degradation in the future scenario. Other small coastal strips with medium risk scores are the Eastern Puglia coast, Western Sardinia, and Tuscany's coast. Three coastal regions are not threatened by the risk of Ess loss and/ or degradation by inundations; Sicily, Calabria, and Liguria, whereas five regions are slightly threatened; Abruzzo, Marche, Molise, Sardinia, and Basilicata. Moreover, most of the regions with risk hot spots (e.g., Tuscany, Apulia, Lazio, and Campania) show that only a small percentage of the regional coastal territory (≈10%) are threatened by inundation. These results could support policy makers and local and/or regional stakeholders in selecting green-based solutions, ensuring sustainable management of coastal communities, assets, and ES, facing climate change and potential future emergencies in the context of ICZM.

A considerable number of coastal World Heritage Sites (WHS) located in coastal areas are gradually exposed to risk from coastal hazards particular flooding due to sea-level rise. Threatening the outstanding Universal Value (OUV) of affected sites leading to economic revenue losses. Reimann et al., (2018) assessed Mediterranean cultural World Heritage sites (WHS) at risk from coastal flooding and erosion under four sea-level rise scenarios until 2100. This study offered an index-based approach that allows for ranking WHS at risk from coastal hazards, and a first-order assessment of where adaptation is most urgently needed and can support policymakers in steering local-scale research to devise suitable adaptation strategies for each WHS.

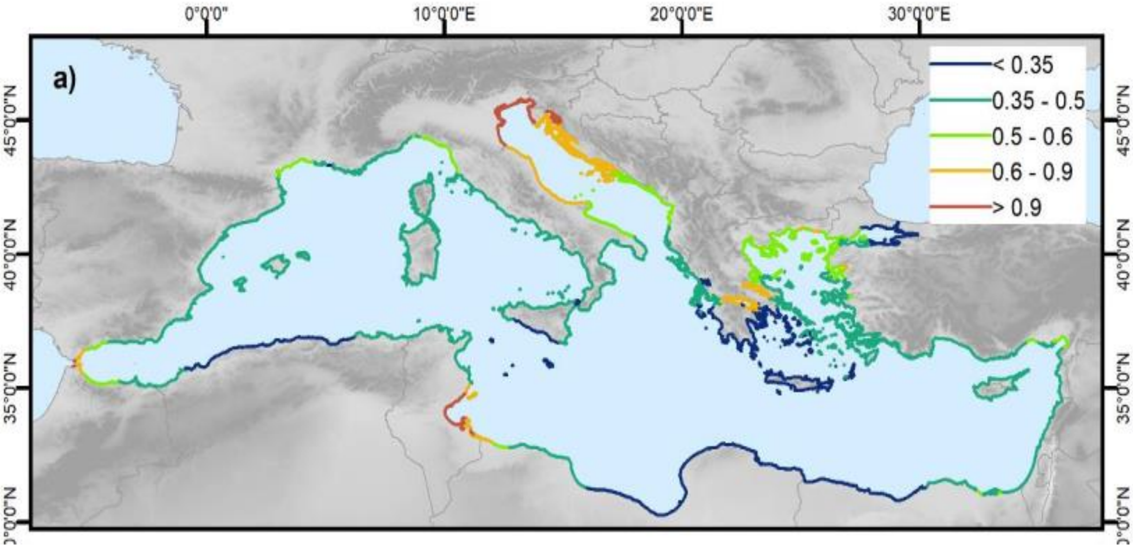


Figure 148. ***100-year storm surge (in m) taken from the Mediterranean Coastal Database of Spatial patterns of the extreme sea level components (storm surge and sea-level rise) Kopp et al., (2017)***

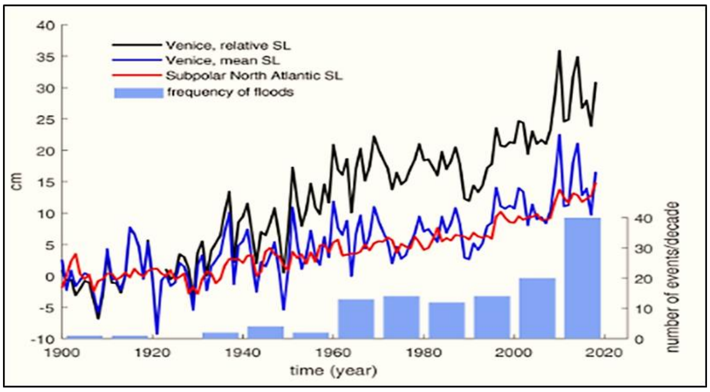


Figure 149. *Venice Relative Sea-level rise and frequency of flooding (source; EEA, 2022)*

Priority issue 12: COASTAL PLANNING (ASSETS&DROUGHT)

Description of the problem and its transboundary importance

DROUGHT EFFECTS AND COASTAL WATER-SYSTEMS

Drought vulnerability

Droughts are a phenomenon in the earth system resulting from a number of meteorological, hydrological and biophysical processes with social and economic impacts and generally arises as a meteorological phenomenon, where periods of low rainfall may lead to water scarcity in different parts or all over the world. The hydrological cycle, in turn, affects different crops and ecosystems (Wilhite and Pulwarty, 2017; Vicente-Serrano et al., 2020).

Climate change and its impact on droughts will pose a systemic challenge to society. Indeed, the Mediterranean region, which now concentrates over 531.7 million habitants (UN DESA 2021) in countries with various levels of development, is considered one of the regions of the globe with the highest socioeconomic exposure to droughts that is likely be exacerbated in the future. Drought can also pose a threat human health, mainly as an indirect indicator of the impacts of other extreme climatic events, such as atmospheric pollution and/or heatwaves (Salvador et al., 2020).

The groundwater component is also crucial for appropriately provide mitigation of droughts due to the importance of aquifer status to satisfy water demands during droughts (Carmona et al., 2017). There is a crucial need to deepen the understanding between anthropogenic effects and the effects of climate change in monitoring land surfaces (vegetation, humidity). This aspect is essential in the Mediterranean context for a better characterization of drought and its evolution.

Climate change and Water resources

The world is facing serious challenges from rising temperatures and limited water supplies, which are insufficient to meet the increasing demand for water in the coming years in light of the successive increase in the population. As an acknowledged fact, climate change has affected surface waters and deteriorated in both quality and quantity. As a result, the aquaculture and fisheries sectors suffer, and aquifers in semi-arid parts of the region will eventually be depleted. Freshwater resources in the Mediterranean, particularly the southern part and North Africa regions, the world's most water-scarce regions, are expected to decline by 50 percent by 2050 (Hadi Jaafar , 2021) .

Global warming has also affected the northern Mediterranean. Until now, there is still limited evidence that precipitation patterns are changing, with the exception of Italy and Greece where a declining trend can be detected over the past 30 years if compared to the century average. On the other hand, climate projections indicate that Spain will see an average decrease of 10 mm/month in all months by 2100, while France will see a decrease of 15-20 mm in precipitation in the summer month. Most countries in the Mediterranean region have responded with adaptation strategies in several categories such as sustainable resources and water management as well as technological development, perhaps more in the north than in the south (Harmanny and Malek, 2019).
The distribution of water resources in the Mediterranean is also very heterogeneous, causing numerous supranational and international conflicts mostly in transboundary basins and regions with water transfers between basins that may aggravate due to droughts or changes in ecosystem service supply (Cramer et al., 2018). Mediterranean societies will face the double challenge of meeting higher water demands from all sectors with less available freshwater water resources.

As a consequence of enhanced evapotranspiration and reduced rainfall by climate change variability, fresh water availability is likely to decrease substantially (by 2–15% for 2 °C of warming), among the largest decreases in the world. River flow will generally be reduced, particularly in the south and the east where water is in critically short supply. For example, the largest Mediterranean river ("Climate Change and Sustainability: Mediterranean Perspectives (2021)".

To recap this subject; as highlighted by the authors of "Climate Change and Sustainability: Mediterranean Perspectives (2021)", Currently 44 out of 73 catchments in the Mediterranean region are under high to severe water pressure, with hot spots in southern Spain, Tunisia, Libya, Syria, Lebanon, Jordan, Israel and Palestine. It is estimated that climate change, along with poor management policies, will leave all Mediterranean watersheds under high to severe water pressure by 2050, with the exception of France and the Balkans. The result would be 34 million people suffering from high water stress and 202 million people suffering from acute water stress. Climatic factors are expected to reduce average rainfall and groundwater availability, with increased frequency and duration of droughts, as well as increased air temperatures. This is likely to exacerbate the scarcity of fresh water, especially in arid and semi-arid watersheds .

River basin and climate change variability

Climate change is a major threat to freshwater resources and an obstacle to continued poverty reduction across many dimensions. People will feel the impact of climate change most strongly through changes in the distribution of water around the world and its seasonal and annual variability. As noted in the previous paragraphs, freshwater ecosystems in various regions have been endangered and have become unsustainable. Climate change has affected the river basins in the Mediterranean, as well as buildings, infrastructure and practices on the Rivers; For example, the Nile River is the primary source of water for Egypt, providing more than 97% of the country's water supply, and recently faced new challenges after the construction of the Grand Ethiopian Renaissance Dam.

Global warming in the last 50 years and climate change are already affecting the Nile Basin in far-reaching ways. Certain types of extreme weather events associated with climate change are becoming more frequent and/or intense, including long periods of heat, rare rainy periods, and, in some areas, floods and droughts. In addition, warming is causing sea levels to rise and the oceans which affect river mouths and aquifers, These and other aspects of climate change are disrupting people's lives and harming some sectors of our economy (The Handbook of Environmental Chemistry; Nile River, 2018)

Analysis of rainfall and river-flow records during the twentieth century (Khir-Eldien and Ahmed Zahran (2017) demonstrates high levels of inter-annual and inter decadal variability. This is experienced locally and regionally in the headwater regions of the Nile and internationally through its effects on downstream Nile flows in Sudan and Egypt. Examples of climate variability are presented from areas in the basin where it exerts a strong influence on society; Flooding may intensify in many Nile basin regions, even in areas where total precipitation is projected to decline.

Short-term (seasonal or shorter) droughts are expected to intensify in most of Nile basin regions. However Longer-term droughts are expected to intensify in large areas of the eastern Nile. Changes in precipitation and runoff, combined with changes in consumption and withdrawal, have reduced surface and groundwater supplies in many areas. These trends are expected to continue, increasing the likelihood of water shortages for many uses. Increasing flooding risk affects human safety and health, property, infrastructure, economies, and ecology in many regions across the Nile basin.

Climate change is expected to affect water demand, groundwater withdrawals, and aquifer recharge, reducing groundwater availability in some areas especially at Egypt Nile valley and delta. Sea level rise, storms and storm surges, and changes in surface and groundwater use patterns are expected to compromise the sustainability of coastal freshwater aquifers and wetlands.

The impact of climate change on the Llobregat River Basin, Spain have been studied by Vesrsini et al, (2016). This basin has been much affected by severe drought in the recent past. The authors developed a methodology to assess the effects of global change on the quantity and quality of water resources and offered adaptation strategies based on results from various scenarios and cost-benefit analysis.

The authors showed significant variability in their results (annual water availability ranges from 147 ha m3/year to 274 m3/year), making accurate projections difficult. The outcomes of this study enabled the definition and testing of different sets of adaptation measures for the basin, which can be further evaluated through cost benefit analysis. The integration of the results contributes to efficient decision making on how to adapt to Global Change impacts.

Living marine resources (LMRs) and the marine ecosystems within which they exist are critical to human health and coastal economies, providing services worth US$21 trillion each year (Costanza et al., 1997). LMRs are strongly influenced by climate variability (Cushing and Dickson, 1976; Sharp, 1987; Lehodey et al., 2006; Brander, 2007, 2010; Drinkwater et al., 2010; Ottersen et al., 2010), creating a challenge for marine resource managers and fishers. Temperature fluctuations, serving as proxies of important climate-driven ocean or ecosystem processes, are often associated with variation in the productivity and spatial distribution of LMRs (e.g., Ellertsen et al., 1989; Dorn, 1992; Peterman et al., 1998; Mueter et al., 2002, 2011; Beaugrand et al., 2003; Perry et al., 2005; Sullivan et al., 2005; Nye et al., 2009; Hunt et al., 2011; Kristiansen et al., 2011; Lindegren and Checkley, 2013; Pinsky et al., 2013; Pershing et al., 2015).

Century-scale temperature projections have been used to show the impact of climate change on LMRs (Stock et al., 2011). More recently, seasonal SST forecasts have started to improve management and industry decisions at shorter time-scales (Hobday et al., 2016; Tommasi et al., 2017a). Many decisions, however, would benefit from climate forecasts over multi-annual scales, in which both climate change and internal climate variability can act to provide predictability (Tommasi et al., 2017b). For instance, catch advice is dependent on a forecast of fish abundance 1–3 years into the future (Brander, 2003). To set rebuilding targets for overfished stocks, such forecasts need to be extended 10 years into the future (NRC, 2014). Currently, these stock status projections are developed using historical observations that often span 30–50 years (RAM Legacy Stock Assessment Database, www.ramlegacy.org). Fisheries managers are therefore interested in assessing if temperature over the next years to decade will be high or low relative to the past 30–50 years used to develop their management frameworks. Such forecasts can inform managers on the need to develop reference points more reflective of future conditions and climate-informed stock status projections (Tommasi et al., 2017b). Multi-annual climate predictions can also benefit long-term spatial planning decisions regarding changes to closed areas, the setting of future closures, preparation for emerging fisheries, adjustment of quotas for internationally shared fish stock, and industry capital investment decisions (Tommasi et al., 2017b). However, while the skill of seasonal SST forecasts has been assessed at an LMRs-relevant spatial scale (i.e. the coastal shelf) (Stock et al., 2015), multi-annual SST predictability in coastal ecosystems has not been quantified, limiting their use in LMRs management decisions.

How SST will evolve across inter-annual to decadal time scales is a function of both internal climate variability (e.g., El-Niño Southern Oscillation, ENSO; the Pacific Decadal Oscillation, PDO; Atlantic Multidecadal Variability, AMV) and forced climatic changes from greenhouse gases and aerosol emissions, as well as natural forcings like volcanoes and solar variations (Meehl et al., 2009, 2014; Doblas-Reyes et al., 2013). Thus, multi-annual predictive skill is dependent on initializing a climate model in the correct state of internal climate variations (i.e., an initial-value problem), imposing accurate external forcing (i.e., a boundary-value problem), and correctly simulating the evolution of the predictable climate system components arising from the initial state and external forcing. Each of these is challenging on its own. Several studies, however, have now shown that in the North Atlantic Ocean, the Southern Ocean, and, more weakly, the western North Pacific Ocean, initialization of the present climate state can significantly contribute to forecast skill over many years (van Oldenborgh et al., 2012; Doblas-Reyes et al., 2013; Yang et al., 2013; Meehl et al., 2014; Msadek et al., 2014; Corti et al., 2015). Further studies suggest that, over most of the globe, the main source of 2–10 year SST prediction skill is the externally forced signal due to greenhouse gases and aerosols (van Oldenborgh et al., 2012; Corti et al., 2015). That is, greenhouse gases, ozone and aerosol conditions today and their future evolution allow one to make meaningful predictions about the next decade relative to the range of conditions over the past half-century.

By exploiting both sources of predictability, skillful multi-annual SST predictions are possible (Smith et al., 2007; Keenlyside et al., 2008; van Oldenborgh et al., 2012; Doblas-Reyes et al., 2013; Yang et al., 2013; Corti et al., 2015), with the North Atlantic, Indian Ocean, and western Pacific being regions of significant skill even at the longer lead times of 6–10 years (Meehl et al., 2014). Interpretation of these results must be tempered by the limited effective sample size for assessing decadal predictions (Meehl et al., 2014) but they provide reason for cautious optimism concerning the use of multi-annual to decadal predictions for marine resource applications. It remains to be assessed if the observed multi-annual prediction skill over large ocean regions results in useful multi-annual prediction skill at the coastal scales relevant to most marine resource decisions. Furthermore, it is unclear whether the forced signal, which becomes prominent across century scales, is also sufficient to produce significant skill relative to the 30–50 year reference data sets common in fisheries management. That is, will the next 1–10 years be warmer or cooler than the past 30–50 years upon which decisions are being made?

In this paper, multi-annual SST forecasts are evaluated through this fisheries lens. More specifically, we assess the ability of the forecast system to predict if conditions over the next year, 1–3 or 1–10 years will be warmer or colder than the last 50. This is also the first time that these multi-annual SST predictions are evaluated over Large Marine Ecosystems (LMEs) (Figure 1), a coastal scale relevant to managed fisheries stock. LMEs are coastal areas of 200,000 km2 or greater, whose extent is determined by similarities in ecologically relevant variables including bathymetry, hydrography, productivity, and trophic relationships (Sherman, 2014). These coastal ecosystems serve as a particularly relevant scale for LMRs decisions as, while only making up ~1/10th of the world's oceans, they provide 95% of the world's total fish catch (Stock et al., 2017). We focus on assessing the probabilistic skill of the upper and lower terciles of SST, as these events are of greatest concern to LMRs managers and industry stakeholders (e.g., Spillman et al., 2015). While forecast users are largely concerned with the overall forecast skill, to improve multi-annual prediction systems it is also important to identify sources of prediction skill. Thus, to determine the sources of multi-annual SST predictability in LMEs we verify forecasts with both initialization and external forcing via greenhouse gases and aerosols ("initialized") and those that include just the external forcing ("uninitialized").

One of the most comprehensive research of coastal risks and socio-economic impacts of climate change in Mediterranean coastal areas was carried out by Satta et al.,(2018). They harnessed the Coastal Hazards Index and 13 variables from the Mediterranean Sea, using the CRI-MED method. The authors categorized the relative and potential risks for each coastal area (coastal erosion and coastal flooding) generated and/or exacerbated by climatic and non-climatic influences. CRI-MED provided relative hazard, exposure, vulnerability and risk maps of the Mediterranean region that allow researchers and policymakers to identify the most coastal areas at risk from coastal erosion and coastal flooding, the so-called "hot-spots". In terms of results, the application of CRI-MED in 21 Mediterranean countries documented the coastal hotspots that mostly located in the southeastern Mediterranean region. The definition of coastal hot-spots aims to support the prioritization of policies and resources for adaptation and Integrated Coastal Zone Management (ICZM). In particular, the resulting risk maps enable identification of suitable and less suitable areas for urban settlements, infrastructures and economic activities.

Countries with the highest percentage of extremely high risk values are Syria (30.5%), Lebanon (22.1%), Egypt (20.7%), and Palestine (13.7%). The CRI-MED method is intended as a scientific tool which produces easily understandable outcomes, to support international organizations and national governments to enhance and mainstream decision-making based on information that is accessible and useful.

The demonstration of coupled socio-environmental factors has often been ignored in vulnerability assessment that handling by many authors. Wolff et al.,(2018) developed a new coastal database for coastal impact and adaptation assessment to sea-level rise and associated hazards on a Mediterranean basin. An integrated socio-environmental Coastal Vulnerability Index (CVI) combines information from five vulnerability groups: biophysical, hydroclimate, socio-economic, ecological, and shoreline; beside Multi-Criteria Decision Making approach (MCDM) was applied. By comparison of the modelled and observed extreme sea level with a 10-year return period for the GTSR dataset the authors figured this out that; Extreme sea levels are generally in 0.15 m and 1.24 m.; Off the coast of Tunis, the Strait of Gibraltar, and near Venice, extreme sea levels are relatively high. This is corresponding with the relatively high tidal range in these areas.

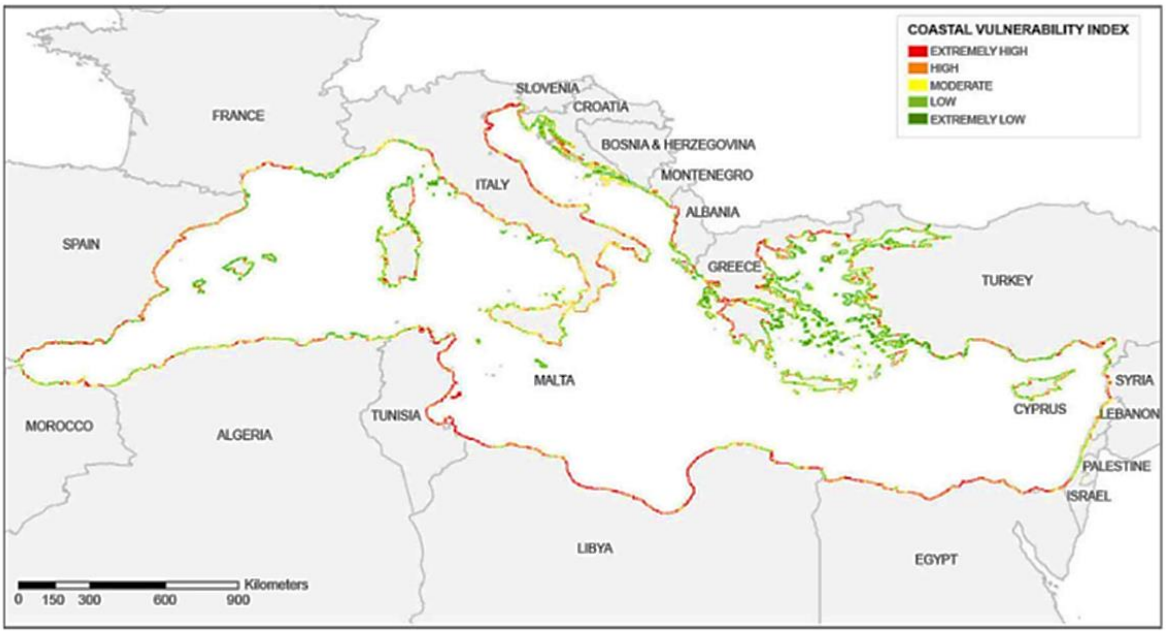


Figure 150. Coastal Risk Index map of the Mediterranean, spatially depicting five levels of risk (Satta et al., 2017)

In terms of results, a new coastal database for the Mediterranean Basin (MCD) has been created. The MCD includes two extreme sea level datasets, the first one is GTSR-MCD derived from the Global Tide and Surge Reanalysis, and the second dataset included in the MCD is the DINAS-COAST Extreme Sea Levels (DCESL). This dataset is the first global extreme water level dataset and it was developed using a simple empirical model. The authors anticipated that the Mediterranean Coastal Database (MCD) would be a valuable source of information for a wide range of coastal applications.

The main lesson from the regional risk assessment is that areas of extremely high risk are also areas of high vulnerability. At the same time, however, not all areas presenting extremely high vulnerability present extremely high risk, as the values of hazards and exposure for these cells could range from extremely low to moderate.

Major environmental impacts and socio-economic consequences (including gender aspects)

Drought and agriculture as future food demand

Droughts have substantial environmental and socio-economic impacts in the Mediterranean region, particularly for countries that depend on rainfed agricultural production and in areas where natural vegetation has been modified or exposed to water stress. Recent studies have made significant progress in understanding drought and its impact on the Mediterranean region. For example, Tramblay et al., (2020), provided an analysis of the complexity of drought in the Mediterranean region and emphasized different perspectives on drought in current and future climate change scenarios. There is consensus on the increase in droughts over the past decades and future climate scenarios for most parts of the Mediterranean basin. However, due to the phenomenon's complexity, with different types of droughts and complex interrelated effects, there are still great uncertainties in the future. This will require a better estimate of vegetation evapotranspiration, likely to evolve under ongoing climate change and direct human influences. Thus, more research is needed to deal with the still-existing uncertainty in regional climate responses, which can be addressed through recent advanced methodology and climate modeling.

Exacerbation of droughts with climate change can pose a serious threat to rangeland productivity. J. Martínez-Valderrama et al. (2021) presented an assessment of using a multidirectional ANOVA based on 5400 simulations of a multidisciplinary integrated model. The study aimed to assess the sensitivity of valuable species of Spanish commercial grasslands to increases in the frequency and severity of droughts caused by climate change. The authors concluded that, integrated multidisciplinary models are valuable educational tools for gaining insight into the relationships between climatic, environmental, and socioeconomic factors.

Backing irrigated agriculture in semi-arid regions is vital to meet future food-demand and as an adaptation response to climate and socio-economic change. Mediterranean region is a dynamic region, highly dependent on irrigated agriculture. In this context, Harmanny, K and Malek, Z, (2019), provided insight into adaptation strategies implemented based on applying a systematic analysis of 124 different Mediterranean farms. The main driver in these area is water scarcity and adaptations often affected water use and resources in addition to farm practices. They concluded that farmers are more likely to adapt in less rural areas with lower poverty values and better market access, and in areas with higher temperatures and less rainfall. This demonstrates that both biophysical and socio-economic factors determine the context in which adaptations to climate changes.

Draught and Socio-economic and food-security

Recently as stressed by many authors, the unprecedented socioeconomic impacts of extreme drought weather-driven are expected to increase, in both frequency and intensity, under future global warming conditions. Early identification and predictability of such events are paramount as they mostly affect several human activities. Despite the effort in monitoring and evaluating such extreme events, a quantitative assessment of their interaction is still a challenge and called for more effort. In this context, Russo et al., (2019), measured to what extent the occurrence of extremely hot months in the Mediterranean region is preceded by drought events in spring and early summer. This analysis allowed to identify the Iberian Peninsula, northern Italy, northern Africa and the Balkans as the main hotspots of predictability of extreme hot temperatures in the summer preceded by drought events in the spring or early summer. Their findings suggested some predictive capacity of drought indicators and data through the identification of hotspots to anticipate a higher probability of occurrence of extreme events in the summer heat.

It is generally accepted that climate change is having a negative impact on food security. However, most of the literature variously focuses on the links with food production or productivity rather than food security, and future rather than current effects. Dasgupta and J. Z. Robinson (2022) presented a novel and rigorous approach to determining the impact of climate change on food security, and to estimate whether the relationship between food insecurity and temperature anomaly is changing over time. Their results highlighted a severe food insecurity was 0.88 percentage-points higher between 2014 and 2019, and for every 1 C of temperature anomaly, severe global food insecurity has increased by 1.4% (95% CI 1.3–1.47) in 2014 but by 1.64% (95% CI 1.6–1.65) in 2019. In some cases, the climate change has been responsible for reversing some of the improvements in food security with the highest impact in Africa.

In terms of results; based on a GIS application, CRI-MED provided relative hazard, exposure, vulnerability and risk maps of the Mediterranean region that allow researchers and policymakers to identify coastal areas most at risk from coastal erosion and coastal flooding, the so-called "hot-spots". Through the application of CRI-MED in 21 Mediterranean countries, coastal hotspots are found to be predominantly located in the south-eastern Mediterranean region. Countries with the highest percentage of extremely high risk values are Syria (30.5%), Lebanon (22.1%), Egypt (20.7%), and Palestine (13.7%). The CRI-MED method is intended as a scientific tool which produces easily understandable outcomes, to support international organizations and national governments to enhance and mainstream decision-making based on information that is accessible and useful. The definition of coastal hot-spots aims to support the prioritization of policies and resources for adaptation and Integrated Coastal Zone Management (ICZM). In particular, the resulting risk maps enable identification of suitable and less suitable areas for urban settlements, infrastructures and economic activities.

The main lesson from the regional risk assessment is that areas of extremely high risk are also areas of high vulnerability. At the same time, however, not all areas presenting extremely high vulnerability present extremely high risk, as the values of hazards and exposure for these cells could range from extremely low to moderate.

A: Decisions made by fishers and fisheries managers are informed by climate and fisheries observations that now often span more than 50 years. Multi-annual climate forecasts could further inform such decisions if they were skillful in predicting future conditions relative to the 50-year scope of past variability. We demonstrate that an existing multi-annual prediction system skillfully forecasts the probability of next year, the next 1–3 years, and the next 1–10 years being warmer or cooler than the 50-year average at the surface in coastal ecosystems. Probabilistic forecasts of upper and lower seas surface temperature (SST) terciles over the next 3 or 10 years from the GFDL CM 2.1 10-member ensemble global prediction system showed significant improvements in skill over the use of a 50-year climatology for most Large Marine Ecosystems (LMEs) in the North Atlantic, the western Pacific, and Indian oceans. Through a comparison of the forecast skill of initialized and uninitialized hindcasts, we demonstrate that this skill is largely due to the predictable signature of radiative forcing changes over the 50-year timescale rather than prediction of evolving modes of climate variability. North Atlantic LMEs stood out as the only coastal regions where initialization significantly contributed to SST prediction skill at the 1 to 10 year scale.

Mediterranean catchments are particularly sensitive to temperature oscillations, rainfall intensity and human activities. Especially intensive precipitation events, changing land-use and thin soil layer trigger surface runoff generation and hence, soil erosion, sediment transport, flooding and related damages. In this study, we propose a methodology using remotely sensed data, terrain analysis and stochastic modeling to characterize the soil hydrological and physical components of the Teiro catchment. Particularly, we focus on the triggering land-cover and soil information that can be derived with multispectral remote sensing techniques. To study the hydrological dynamics of the Teiro catchment we applied the Soil Conservation Service Curve Number method implemented in a GIS system for different precipitation events related to various return periods. The input data was calculated based on multispectral indices describing the heterogeneity of soils and vegetation. The discharges obtained show reasonable values that have been validated with mapped flooded areas of the 4 th October 2011 flood event. This event corresponds roughly to a 10 years return period. However, it is striking that a 50 years return period event was calculated to yield the double amount of discharge and thus, implies a major hazard for the local population.

Linkages with other transboundary problems

Biodiversity Pattern changes

It is now clear that climate change also impacts biodiversity at all levels from genera to species level on land and at sea. Climate change affecting genes, populations, species, ecosystems, and human livelihood. A warming of 2°C or higher, would lead to deep changes in Mediterranean land ecosystems, and projections with the highest emission scenarios along with increased human pressures point to an important modification of Mediterranean biodiversity, including numerous species extinction (Balzan et al., 2020).

The increased frequency, intensity and extent of Marine Heat Waves are causing massive mortality events in all coastal ecosystems of the Mediterranean. Hence it is essential to know the relationship between different biological responses of marine biodiversity and different levels of heat exposure. Forty-eight scientists from 11 countries (Garrabou et al., 2022), have undertaken an integrated study of the ecological impact of the intensity of marine heat waves (MHWs) on the mass mortality of marine organisms, using field survey and data analysis (2015-2019) from different sources. The scientist’s team underscored that, the Mediterranean Sea is experiencing an acceleration of ecological impacts associated with climate change, posing an unprecedented threat to the health and functioning of its ecosystems. The populations of some 50 species (including corals, sponges and macroalgae, among others) were affected by these events along thousands of kilometers. The most affected species are Posidinia oceanica meadows and coral assemblages.

Mass mortality events in the Mediterranean are equivalent to the bleaching events also observed consecutively in the Great Barrier, suggesting that these episodes are already the norm rather than exception (Alfono Ramos). Direct and indirect effects of pH (pHT 8.0, 7.6 and 7.2) on the development and transition from a planktonic larva to a benthic juvenile in the green sea urchin S. droebachiensis, were investigated by Dorey etal., (2022). They concluded that Continuous exposure to low pH negatively affected larval mortality in coastal and marine ecosystem.

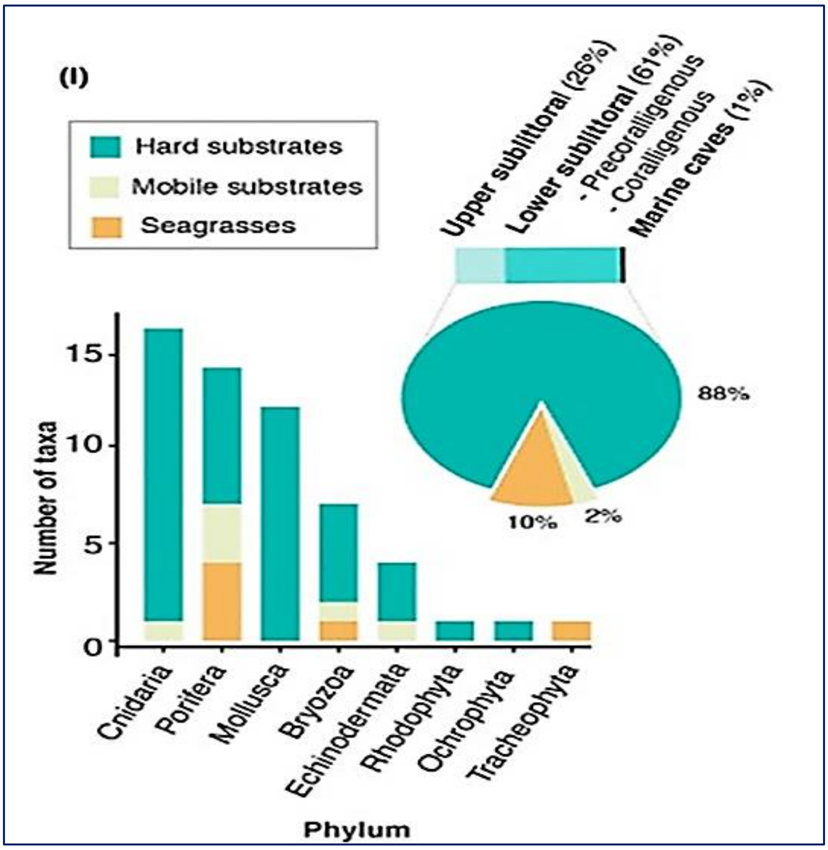
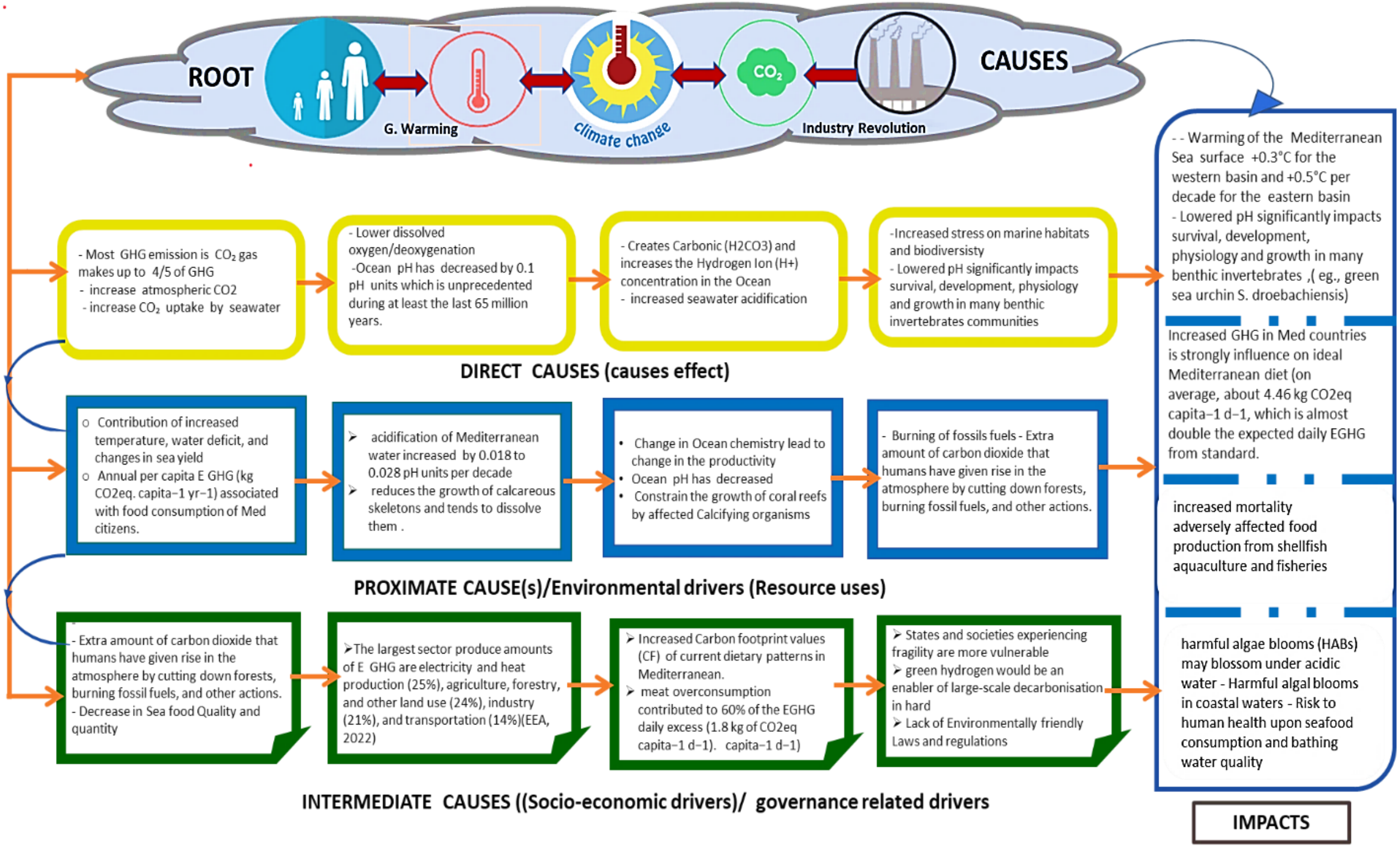


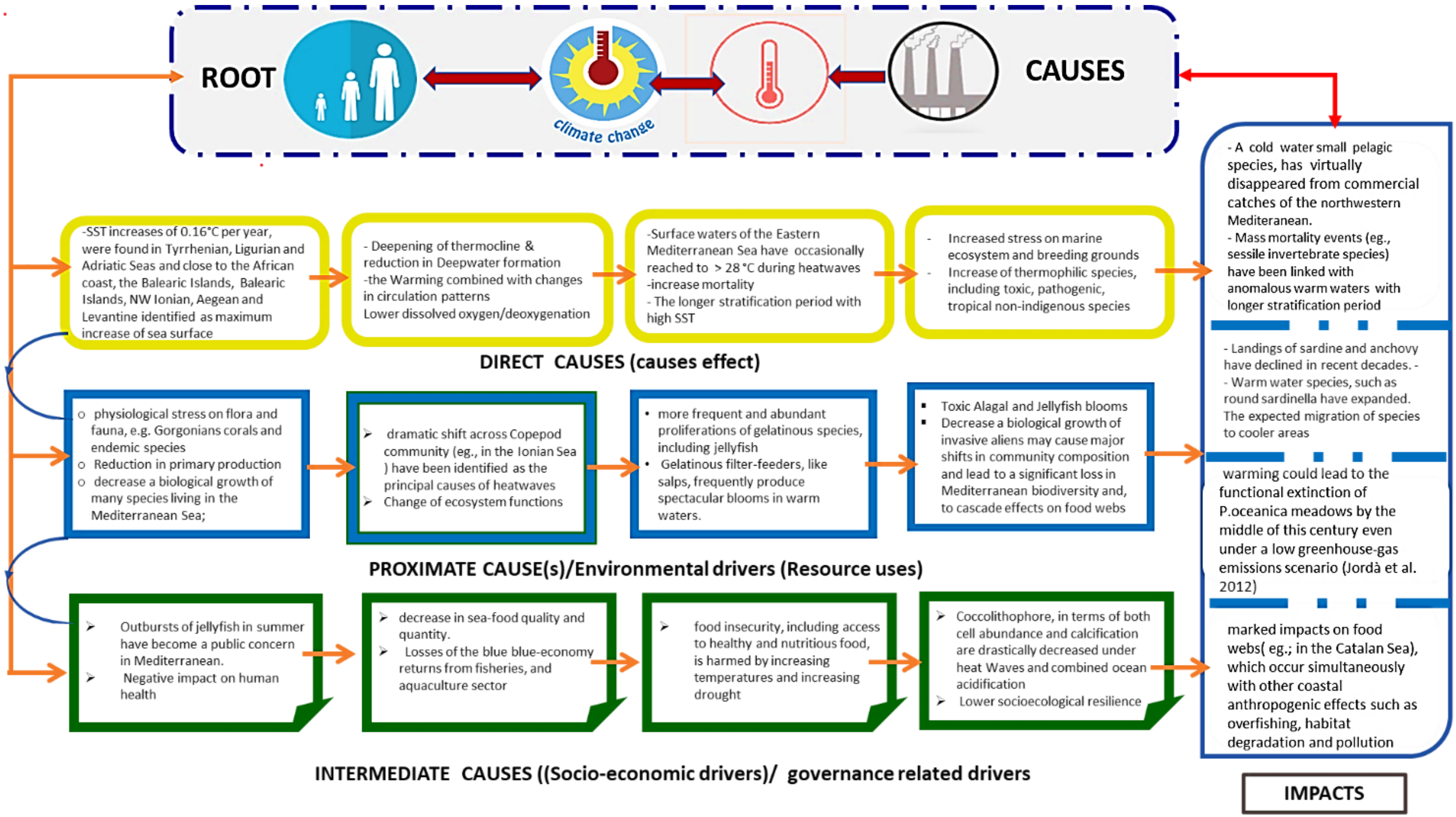
Figure 151. The most affected genera by MHWs (Source; Garrabou et al., 2022)

Immediate, underlying and root causes (diagrams)

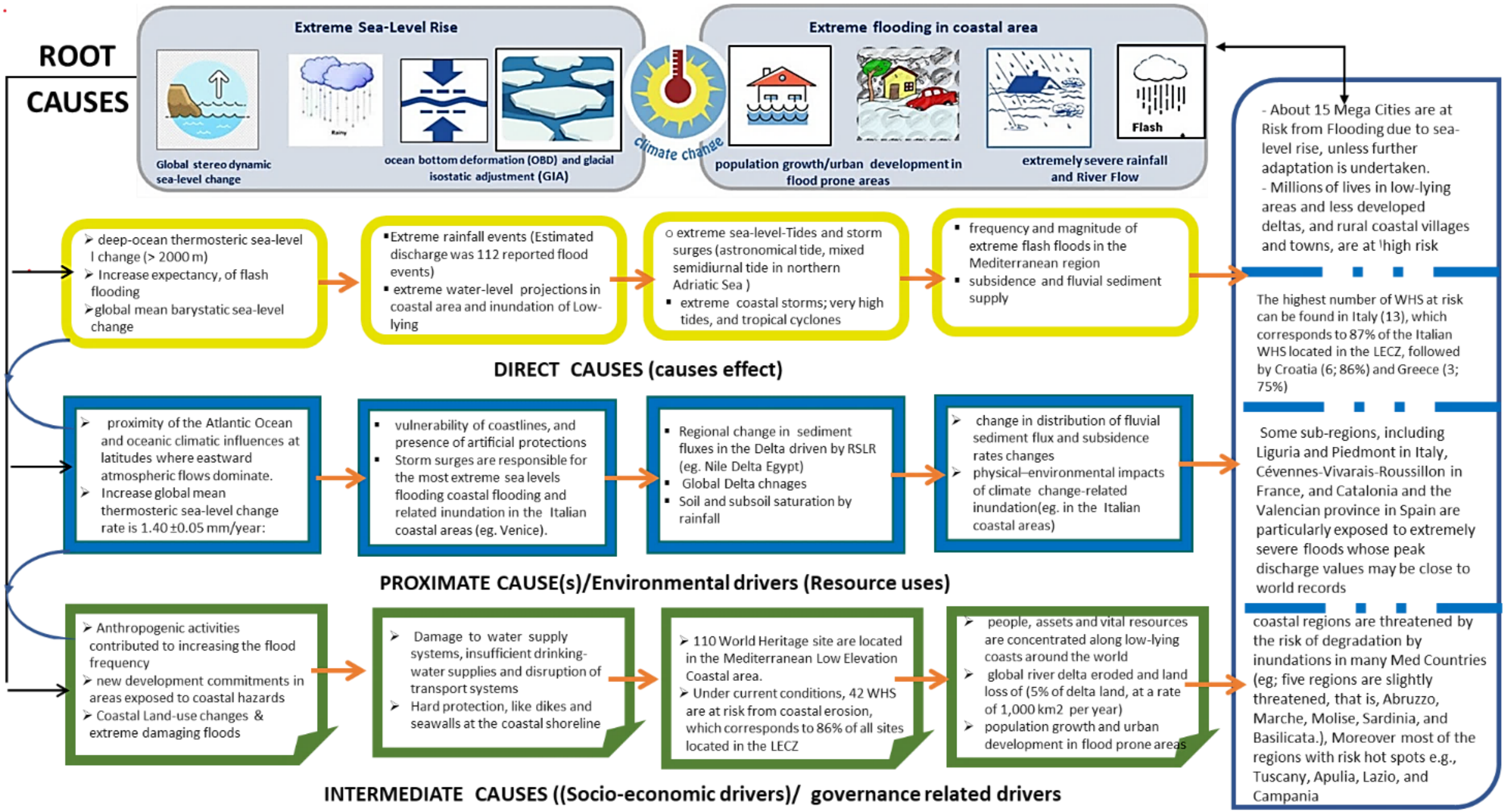
CCA Priority issue 9: Atmospheric emissions



CCA Priority issue 10: Marine anomalies (SST-Heat waves)

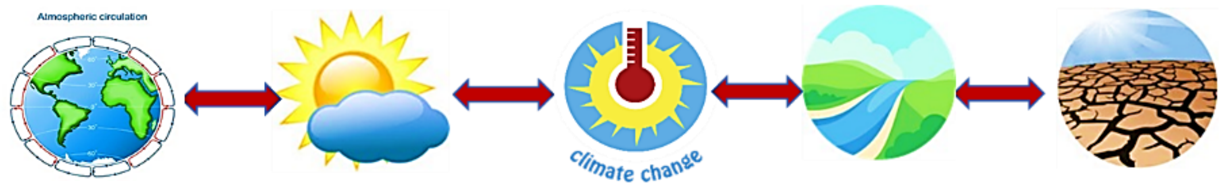


CCA Priority issue 11: Coastal water systems (&flodding)



CCA Priority issue 12: Coastal planning (assests&drought)

ROOT CAUSES



- Changes in global atmospheric circulation lead to change in rain in some areas
- Decrease Rainfall than the normal severe shortage of water in a particular location and variation in seasonal rain

- water levels in the natural deposits of a region, such as lakes , rivers , aquifers and dams, fall below the expected average for a certain period,
- Change in River basin hydrology(eg. Nile River basin)

Changes in precipitation and runoff, combined with changes in consumption and withdrawal,
- Intensive exploitation and impacts of the shallow groundwater potentials, in the Med coast (eg. Egypt)

-Decrease in fresh water availability in the Mediterranean region by 2 to 15% for 2°C warming, among the largest decreases in the world.
- severe shortage of water in a particular location and variation in seasonal rain

DIRECT CAUSES (causes effect)

- Less rainfall and worst temperature rise and intense drought conditions in the wheat-growing areas
- Recent occurrences of recurrent episodes of drought coincide with dramatic reductions in annual flow volumes of the river's flow

- desertification and turning fertile regions into deserts
- Increased the soil depth because the severity of droughts reduced the total amount of rain fallen
- critical drops of groundwater levels in many areas

- Agricultural drought, associated with agricultural-type industrial activities,
- Inadvisable Med. irrigated agriculture system
- intensity of cropland activities, particularly irrigated cropland

- Installing greenhouses combined with more efficient irrigation system.
- the evaporation losses from major swamp areas which cause up to 30% of the basin's rainfall to be lost before being used for any purpose

PROXIMATE CAUSE(s)/Environmental drivers (Resource uses)

- Deforestation leads to less water being stored in the soil
- Removing trees and vegetation reduces the amount of moisture in the atmosphere making the area drier.

- Constructing dams and reservoirs reduces the flow of water downstream that lead to drought in other areas
- improving the irrigation systems by switching to more efficient irrigation methods

- changing crop types (permanent instead of annual crops) or adding a different crop variety
- adjustments in crop rotation and agriculture activities
- The consumption of water by humanity

- the links between preceding drought conditions and temperature anomalies can be further investigated in coupled seasonal forecast systems.

INTERMEDIATE CAUSES ((Socio-economic drivers)/ governance related drivers

- Both warming and drought-induced water deficits are negatively affecting yields in Med countries
- the adverse impacts of warming and drought in countries like Germany and France, with a net yield loss of 3.1%
- The occurrence of drought induced extreme temperatures, in particular heatwaves, can have costly impacts on economy

Coastal wetlands, such as the Camargue (France), the Nile Delta (Egypt) and other similar regions, are particularly affected by coastal erosion, Construction in coastal regions, sand erosion and instabilities in beaches have destructive effects on fauna and flora and, in particular, on endemic species (e.g. monk seal and loggerhead sea turtle)

Deserts would expand in Med countries (eg. southern Spain and Portugal, northern parts of Morocco, Algeria, Tunisia, Sicily, southern Turkey and parts of Syria)

Loss or degradation of wetlands and lakes; Spread of exotic and invasive water weeds; Waterborne diseases such as malaria, diarrhea, and bilharzia (schistosomiasis) are among the leading impact of drought in the Nile Basin

IMPACTS

Conclusions and Knowledge gaps

The CCA analysis presented here focuses on the four transboundary climate issues affecting the Mediterranean. In this context, the four main issues related to transboundary climate change have been deliberated within the discussion of other issues in the previous section through a detailed qualitative and quantitative analysis of scientific literatures and reports (see the previous sections). This leads to the identification of their direct, proximate, intermediate, root causes and accordingly their impacts. In formal causal chain analysis, each direct cause must be directly related to one or more problems or impacts and down to the root cause. But, to give the reader a concrete overview, we have developed an integrated outline for each stand-alone issue, then we presented a summary of the impact on the surrounding environment, economy, and society, in a separate figure so as to help to distinguish between complicated interventions in terms of causality of four issues.

A causal chain analysis was conducted on each of the prioritized transboundary climate change concerns in the Mediterranean region, resulting in the identification of main drivers, priority issues and their immediate and underlying causes.

The global annual mean atmospheric CO2 concentration exceeded 400 ppm in 2016, which is more than 40 % above the pre-industrial level. Ocean acidification will affect many marine organisms and could alter marine ecosystems and fisheries. These rapid chemical changes are an added pressure on the ecosystems of Mediterranean and economy as well.

There are many causes of global warming that affect the life and health of the Earth in many aspects. The main *root cause of our climate crisis* is the population growth and human use and exploitation of Earth's resources plus economic development. The impact of these causes are going to get worse very quickly. Climate change is recognized here as a root cause of four transboundary climate change concerns.

The fundamental direct (immediate) cause of GHG and sea acidification; is Continuous rising atmospheric anthropogenic carbon dioxide (CO2), which run across all other causes and bring most of critical regional concerns which eg., (i) Warming of the Mediterranean Sea surface +0.3°C for the western basin and +0.5°C per decade for the eastern basin;(ii) acidification of Mediterranean sea lead to increase mortality and loss of biodiversity. The cascade of causes (see CCA diagram) leads to increase mortality that lead to losses of economy returns from fisheries and aquaculture and food insecurity.

The warming of the Mediterranean is expected to increase at rates above the global average, depending on the level of future mitigation of greenhouse gas emissions. GHG emissions must be halved by 2030 if global warming is to be limited to 1.5°C compared to pre-industrial levels by the end of the century (UN Report 2021). Our analysis of scientific and policy reports confirms that phasing out fossil fuel consumption, using renewable energy, and trading in low-carbon technology will have profound implications for reducing carbon emissions that may have meaningful effects on human wellbeing.

According to quantitative assessment of climate and environmental changes in Mediterranean scientific resources, the average Mediterranean SST for study period (2015, 2016, and 2018) was higher than in 2003, and the average warming rate in the Mediterranean Sea from 1982 to 2019 was 0.38°C per decade, more than three times higher than the global average of 0.11°C per decade. However, warming of 2°C or more above the preindustrial level is expected to generate conditions for many Mediterranean land ecosystems that are unprecedented in the last 10,000 years (MedCC 2021).

Climate change led to increase in the frequency and intensity of marine heat- waves (MHWs) which affected more than 90% of the surface water of the Mediterranean Sea. Along with climate change as a key root cause, the industrial revolution and unsustainable human activities driven by population increase that leads to increased warming, which is turn the main driver of increasing SST and growing Marine Heat Waves.

The key *proximate causes* of expansion the SST and MHWs patterns in Mediterranean Sea are; (i) reduction in primary production attributed to increase marine mortality which leading to food insecurity including access to healthy and nutritious food; presence invasive aliens that may cause major shifts in community composition and lead to a significant loss in Mediterranean biodiversity and, possibly, even collapse of several marine populations.

The proximate causes (as changes in ecosystem functioning and add physiological stress on flora and fauna) run across all other causes and bring three critical social and environmental effect, (intermediate causes) such as; affect Posidonia Oceanica and coral assemblages losses of the blue blue-economy returns from fisheries, and aquaculture sectors and negative impact on human health as a consequence of toxic Algal and Jellyfish blooms

The direct, proximate and intermediate identified are not discrete from each other, as the same effect or the same cause producing several different impacts. Immediate (Direct) causes can often be very close to underlying (Proximate) causes, So here It is considered as component parts of a continuum,

The direct, proximate and intermediate identified are not discrete from each other, as the same effect or the same cause producing several different impacts. Immediate (Direct) causes can often be very close to underlying (Proximate) causes, So here It is considered as component parts of a continuum. For example; the increase in the SST (direct cause) in the Catalan Sea, Spain has been linked with the expansion of round Sardinella (Proximate cause), with the decline of sardine (*Sardina pilchardus*).

The associated marine heat waves are causing massive mortality events in all coastal ecosystems of this basin as a result of their increased frequency, intensity and extent

The impacts of massive mortality events (MMEs) of marine organisms are one of the main associated impacts of MHWs affecting more than 90% of the Mediterranean surface, when reaching temperatures of more than 26ºC", (proximate cause) and accelerate in the environmental impacts of public health factors that pose an unprecedented threat to the health and functioning of ecosystems in general (intermediate causes).

The mortality events (MMEs) of marine organisms are one of their main ecological impacts. The Mediterranean Sea over the period 2015–2019 has experienced exceptional thermal conditions resulting in the onset of five consecutive years of widespread MMEs across the basin. These MMEs affected thousands of kilometers of coastline, from the surface to 45 meters' depth (Garrabou et al., (2022).

Global sea levels are rising as a result of human-caused global warming, with recent rates unprecedented over the past 2,500 years. Sea level rise is mainly caused by two sets of root causes. The first is climate change and population growth in the coastal areas; additional water added to the ocean from the net melting of glaciers and small ice caps, and from the disintegration of the large Greenland and Antarctic ice sheets; -The second is Stereoscopic global dynamic sea level change, ocean floor deformation (OBD) and glacial equilibrium adaptation (GIA), and extremely severe rainfall and rivers Flow.

The relative sea level rise, due to any root cause, has a number of effects that run through a causal chain extending from direct causes to intermediate causes and ending with a real-world effect. As shown in CCA chart ( ), an increased expectation of flash floods (proximate cause) leads to vulnerability of coastlines, increased erosion, and their potential for flooding (intermediate causes), causing damage to water supply systems, inadequate drinking, and alteration of land-use (impact), in turn, these have direct and indirect social and economic effects depending on degree of exposure to these causes.

Coastal flooding is determined by anomalously high sea levels which are the sum of several tidal and non-tidal processes acting at different temporal and spatial scales. The root cause of floods and weather-related hazards and their patterns are likely to be significantly affected by climate change. Floods are already the most frequent and among the most costly and deadly natural disasters worldwide.

It is important to note there are two types of floods that are most common and occur all over the world;

- Flash floods that resulted from heavy rains in low-lying areas. This type of flood is a destructive and dangerous force due to its astonishing speed which prevents people from taking proper precautionary measures. As overhead mentioned, there are simultaneous root causes of flooding, the most significant one is a heavy rainfall in the low-lying areas, particularly the coastal ones. Heavy rainfall in the course of the river contributes to the occurrence of floods when the water overflows on the banks of the rivers to the surrounding area. One of the immediate causes of flash floods is the lack of soil and vegetation acting as a barrier.

- The second type is weather floods (dry climate). The root cause of a flood weather event is extreme sea level tides and storm surges (astronomical tides, mixed semi-periodic tides). This happens during tropical storms, cyclones, and hurricanes, as the sea water flows into the land, especially in the coastal area. The vulnerability of coastlines, and presence of artificial protections;- regional change in sediment fluxes in the Delta driven by RSLR (eg. Nile Delta Egypt); - physical–environmental impacts of climate change-related inundation (eg. In the Italian coastal areas) and Increase global mean thermosteric sea-level change rate is 1.40 ±0.05 mm/year are most significant the proximate causes.

- The scientific sources that were analyzed (section 2) elucidated the Mediterranean coastal areas are threatened by the risk of degradation by inundations in many countries (eg; five regions are slightly threatened, that is, Abruzzo, Marche, Molise, Sardinia, and Basilicata.), Moreover most of the regions with risk hot spots e.g., Tuscany, Apulia, Lazio, and Campania. Some sub-regions, including Liguria and Piedmont in Italy, Cévennes-Vivarais-Roussillon in France, and Catalonia and the Valencian province in Spain are particularly exposed to extremely severe floods whose peak discharge values may be close to world records.

- The tidal flood-sea-level rise hit the Nile Delta and Venice city are a warning light for us to recall of the impact of floods on society, the economy, and the cultural world heritage. The highest number of WHS at risk can be found in Italy (13), which corresponds to 87% of the Italian WHS located in the LECZ, followed by Croatia (6; 86%) and Greece (3; 75%).

- Floods and Droughts are the two faces of the same coin (Ivan Ray Tannehill as early as 1947)

As definite in numerous geological and meteorological literatures, drought is an extended period of unusually dry weather and an acute lack of precipitation. Drought generally originates as a meteorological phenomenon, in which periods of low precipitation may produce water scarcity in various parts or the whole of the hydrological cycle which in turn affects crops and various environmental systems. It creates a variety of problems for local communities, including damage to crops and a lack of drinking water. These effects can lead to devastating economic and social disasters, such as famine, forced migration away from drought-stricken areas, and conflict over remaining resources (see section 3 for more detail).

A drier climate with higher temperatures and lower potential for evapotranspiration are central root causes. Most droughts occur when normal weather patterns are disrupted, causing a disruption of the water cycle. Changes in atmospheric circulation patterns can cause storm tracks for months or years. This disturbance can greatly affect the amounts of precipitation that the area normally receives. Changes in wind patterns can also disrupt how moisture is absorbed in different regions.

Meteorology as root causes begins with changes in global atmospheric circulation affecting rain in some regions (direct cause), then leads to lower precipitation and worse rise in temperature (direct causes) leading to severe drought in wheat-growing regions (intermediate causes). In terms of Impacts (see CAA chart), Drought affected several sectors of the Mediterranean, such as agriculture and fresh water availability. It impeded nature’s ability to provide a wide range of crops and caused human insecurity. Drought can also pose a threat to human health and food demand, mainly as an indirect indicator of the impacts of other extreme weather events.

Drought is expected to affect water demand, groundwater withdrawals, and aquifer recharge, reducing groundwater availability in some areas especially in Nile valley and delta Sea level rise, storms and storm surges, and changes in surface and groundwater use patterns are expected to compromise the sustainability of coastal freshwater aquifers and wetlands.

As has already been unanimously confirmed in climate change reports, drought is a major threat to freshwater resources and a rapid way to perpetuate poverty across many dimensions. People will fast feel the impact of drought through changes in the distribution of water around the world and its seasonal and annual fluctuations. Our analysis highlights scientists’ arguments that the availability of fresh water is likely to decline dramatically (by 2-15% for a 2°C warming). One of the most important effects of drainage is the decrease in the flow of rivers, especially in the Nile River Basin.

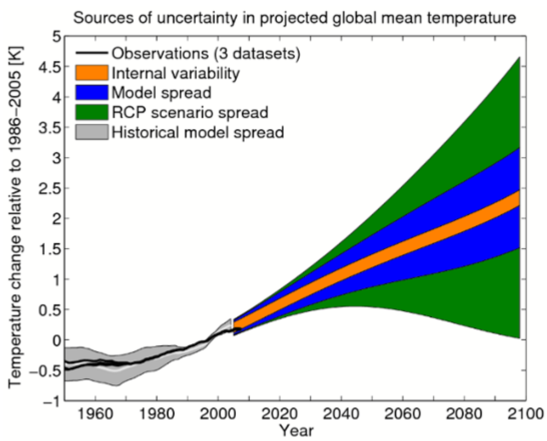
Droughts have substantial environmental and socio-economic impacts in the Mediterranean region, particularly countries that depend on rain-fed agricultural production and in areas where natural vegetation has been modified or exposed to water stress. Because the full effects of droughts can develop slowly over time, however, droughts can have severe and long-term effects on social, environmental, and economic fronts. As such, governments downplay their mitigation and adaptation strategies.

The main hurdle for society is knowing what climate impacts will occur, where and on what scale. This knowledge is necessary to subsequently determine the most appropriate approach and plan to help communities adapt and reduce the impact of climate change or take precautions before them starting, as in the case of floods.

As the effects of climate change hazards on the environment, economy, and society become visible and gain global momentum, now is the time to bridge the gaps of knowledge and data. The availability of consistent information and data on chemical, physical, ecological, social, economic, and other characteristics is a prerequisite for policymakers to address climate change pressures and support effective future adaptation policies and appropriate future mitigation/adaptation plans.

Scientific understanding of climate action has accelerated in recent decades; unfortunately, there remains a general lack of understanding at the scientific and public level regarding the best policy choices, which can be attributed to the complex management of direct and indirect impacts. These barriers lead to insufficient access to and sharing of data and information and impede much-needed progress toward effective decision-making at the regional level (Kramer et al., 2018).

Uncertainty is substantial to climate change, as the climate is changing, that is a fact, but we do not precisely know how fast, how much, or in what ways. We must thoroughly understand these changes' social and economic consequences or the options available to limit climate change. Moreover, the uncertainty on these issues is not easily quantified in probabilistic terms: we are faced with deep uncertainty rather than known risks. We review sources of uncertainty about all aspects of climate change, separate these into scientific and socioeconomic components, and examine their relative importance. We then review which decision-making frameworks may be more appropriate in the absence of unique possibilities including non-probability approaches and those based on multiple premises, and discuss their application in the context of the economics of climate change (Hill & Antoney 2018)



Climate and weather in turn, present a large variability both in space and in time which results in different uncertainty types. Any change in weather and or climate conditions in the coming decades due to climate change may increase this uncertainty. Three factors affecting Uncertainty: Natural variability; Lack of sufficient data; inappropriate scenario (Kutiel H., 2018). Kutiel demonstrated and quantify these uncertainties in various parts of the Mediterranean and discussed their impacts on different activities mainly tourism and agriculture. He pointed out, the Mediterranean basin is characterized by sizeable climatic variability either in space or in time. Accurate quantification of this variability requires dense measurements which in many cases are not enough. Lack of enough measurements (e.g., rain gauge density), use of inappropriate approaches in handling or analysing data (e.g., assuming continuity for discrete variables), erroneous interpretation of results (e.g., interpretation of averaged dynamical pressure maps), may increase our uncertainty regarding the behavior of the parameter in question.

A combination of the significant large uncertainty, anticipated increasing variability and a rapid population growth, will result in additional demands for water allocation for domestic use and for other activities such as tourism and agriculture. This will increase challenges for a rational planning of a large spectrum of activities in the Mediterranean Basin.

A significant case- study of climate uncertainty addressed by Kamali et al, (2022) in southern Spain Maize fields. They investigated the main drivers of uncertainty in simulating the irrigated maize yield at southern Spain under historical conditions as well as scenarios of temperature increase and change in irrigation water availability using the three crop models.

Historical climate-based analysis showed that irrigation strategies were the main driver of uncertainty in simulated yields (66%). However, under temperature-increasing scenarios, the contribution of crop model and cultivar selection to uncertainty in simulated yields was as crucial as the irrigation strategy. This was partly due to the different modular structures in the processes related to temperature responses. The mismatch between the simulated and observed irrigated crops value is mainly related to missing information about irrigation strategies conducted by farmers to reduce Uncertainty in simulated yields. As a lesson learned from the case study, uncertainty increases due to the lack of real data, different analyzes or approaches by different users, and an essential lack of detail in the spatial dimension.

Based on the key concepts and facts covered in the references and compiled scientific reports (see references section), the Mediterranean basin is a unique rich marine ecosystem long affected by human influence, whose resilience is now questioned by climate change. The main environmental problems have identified in the Mediterranean basin are directly or indirectly related to the climate and hydrology of the basin of the basin itself.

In the Mediterranean region, average annual temperatures are now 1.4 °C higher than during the period 1880-1899, which is above current global warming trends, especially during summer. As predicted by IPCC 2013 (RCP, Climate scenario Representative Concentration Pathway), a rise in temperature from 2 to 6 ° C by 2100 is expected in the Mediterranean (for summer temperatures) and heat waves are likely to become more frequent and/or more extreme.

The frequency of flooding because of the Sea-level (SLR) along low-lying coasts areas, despite decades of national, regional and global coastal hazards, mitigation, and adaptation programs and strategies; the scarcity of water resources, erosion and coastal degradation processes; Human pressure on the ecosystem of the Mediterranean, which has been more intense in recent decades that led to dramatic consequences for the Mediterranean biodiversity in the medium and long term. Several species, in particular those of commercial interest, climate change is expected to modify migration patterns and consequences population dynamics of many species particularly fish. Some adaption strategies ignored the fact that the Mediterranean Sea is a unique water basin that has multiple environmental factors interact. Thus any alteration and impacts on ecosystem functioning would be far from being able to assess. The observed and potential consequences of climate change at different scales, from the economic level to the ecosystem level and from the community level to the individual level are more than our expectations. Climate change is expected to affect the physiology of individuals with consequences for community assemblies and population dynamics.

The Mediterranean basin is a unique rich marine ecosystem long by human influence, whose resilience is now questioned by climate change. The main environmental problems we have identified in the Mediterranean basin are directly or indirectly related to the climate and hydrology of the basin itself. The frequency of flooding because of the Sea-level (SLR) along low-lying coasts areas, despite decades of national, regional and global coastal hazards, mitigation, and adaptation programs and strategies; the scarcity of water resources, erosion and coastal degradation processes; Human pressure on the Mediterranean, which has been more intense in recent decades that led to dramatic consequences for the Mediterranean biodiversity in the medium and long term. For several species, in particular those of commercial interest, climate change is expected to modify migration patterns and consequences population dynamics of many species particularly fish.

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The observed and potential consequences of climate change at different scales, from the economic level to the ecosystem level and from the community level to the individual level are more than our expectations. Climate change is expected to affect the physiology of individuals with consequences for community assemblies and population dynamics. Despite 25 years of experience in coastal hazards, mitigation, and adaptation, the knowledge and the competitive scope about the effectiveness and feasibility of societal transformation to those risks still needs to be improved.

The data and information offered in this report are taken or adapted (based on my expertise) from peer-review scientific more than 80 scientific resources and global reports released by international organizations and networks working in the field of climate change (see literatures section)

Short conclusion of the Climate change concerns in Mediterranean

- The Mediterranean basin is a unique rich marine ecosystem long affected by human influence, whose resilience is now questioned by climate change. The main environmental problems we have identified in the Mediterranean basin directly or indirectly are related to the climate and hydrology affected the basin itself.

- Despite decades of adaptation and mitigation programs and strategies, the frequency of flooding (because of the Sea-level (SLR) along low-lying coasts areas), causing the scarcity of water resources, increase of erosion and coastal degradation processes. The human pressure on the Mediterranean, which has been more intense in recent decades led to dramatic consequences of the Mediterranean biodiversity in the medium and long term. For several species, in particular, those of commercial interest, climate change is expected to modify migration patterns and consequences population dynamics of many species particularly fish.

- Some adaption strategies ignored the fact that the Mediterranean Sea is a unique water basin that has multiple environmental factors interact. Thus any alteration and impacts on ecosystem functioning would be far from being able to assess.

- The transboundary fluxes of climate change in terms of warming, reduced precipitation, and extreme greenhouse gas emissions, broadly reflect the energy consumption of daily human activities. Much higher transboundary contributions are observed by emitted CO2 and SO3. The emitted of both gases has come a long way from large industrialized countries (such as the USA and China). For such, 90% of GHG in smaller countries comes from outside the country As a consequence, in the smaller countries around 90% of the Emission of GHG originates from outside the country As such, there are true concerns that regional climate mitigation/adaptation control strategies are still ineffective in a situation where background air pollutant concentrations are increasing due to rising emissions in other parts of the world.

The observed and potential consequences of climate change at different scales, from the economic level to the ecosystem level and from the community level to the individual level are more than our expectations. Climate change is expected to affect the physiology of individuals with consequences for community assemblies and population dynamics.

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4.3. Shared-transboundary challenges

4.3.1. Sustaining assets (environment&economy)

Ecological assets, ecosystem services and sustainable growth

Ecological assets and livelihoods are interrelated. Ecology, economy, and human well-being (ca. standards of living) are fundamental, all necessary and need to be well balanced and in equilibrium. The figures below (Figure 152 and 153) represent a current approach to the multilevel dimensions of these interrelations were both ecological assets and livelihoods pair conceptually to ecosystem services values and their use for human well-being, respectively.

The transboundary environmental change evidence in the Mediterranean Sea LME, are highlighted and included in Figure 152 with mid- and long-term ecosystem implications at different scales and would affect, therefore, the related ecological assets. The Figure 153 below shows the complex relations between the multiple dimensions of different ecosystem, economic and welfare elements, in particular, to elucidate the benefits of the MPA strategies. The MPA strategies are transboundary positive and provides a certain degree of connectivity between the basins of the Mediterranean Sea under pressure, despite the area represented by MPA cannot be included entirely in the coastal zone in all the cases (ca. coastal belts).

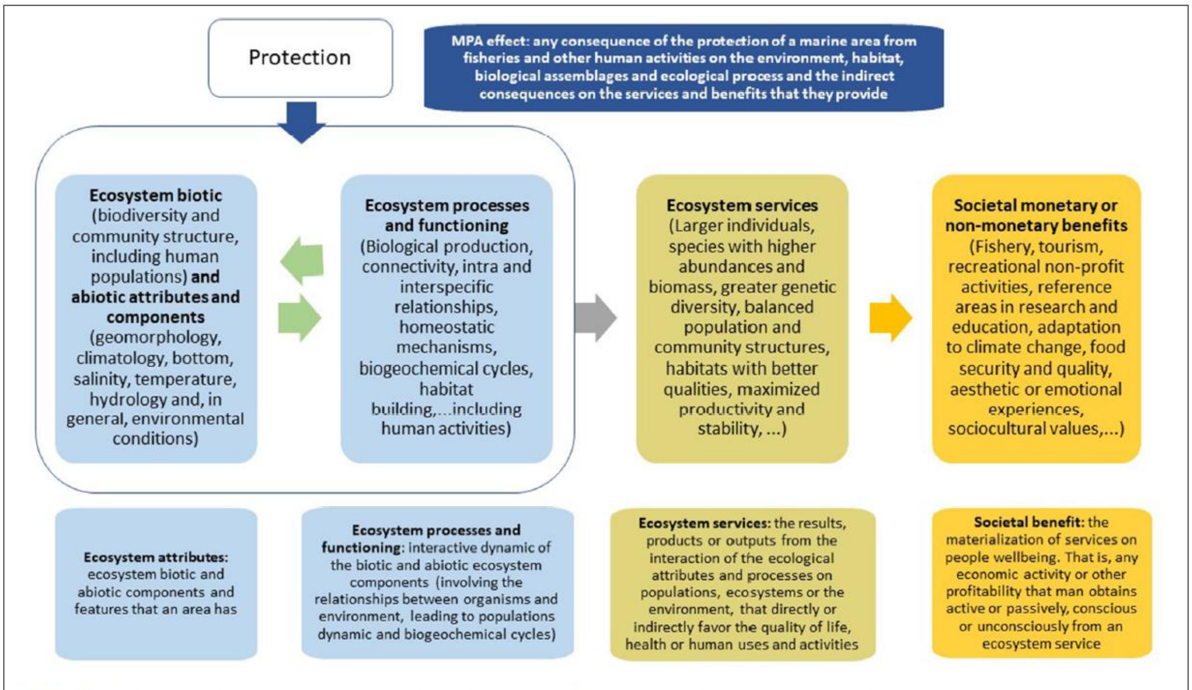


FIGURE 1 | Basic scheme that shows the sequence of relationships between the components of an ecosystem that condition its functioning, the services they provide and the benefits that humans can obtain in the case of an MPA. The definitions of MPA effect, ecosystem attribute, process and functioning, ecosystem service, and societal benefit are included. A clear difference is established between the services that an ecosystem offers and the benefits, economic or non-economic, material or not, that man obtains.

Figure 152. Ecosystem services and socioeconomic relationships. In: Reviewing the ecosystem services, societal goods, and benefits of marine protected areas (2021). (Source: doi: 10.3389/fmars.2021.613819)

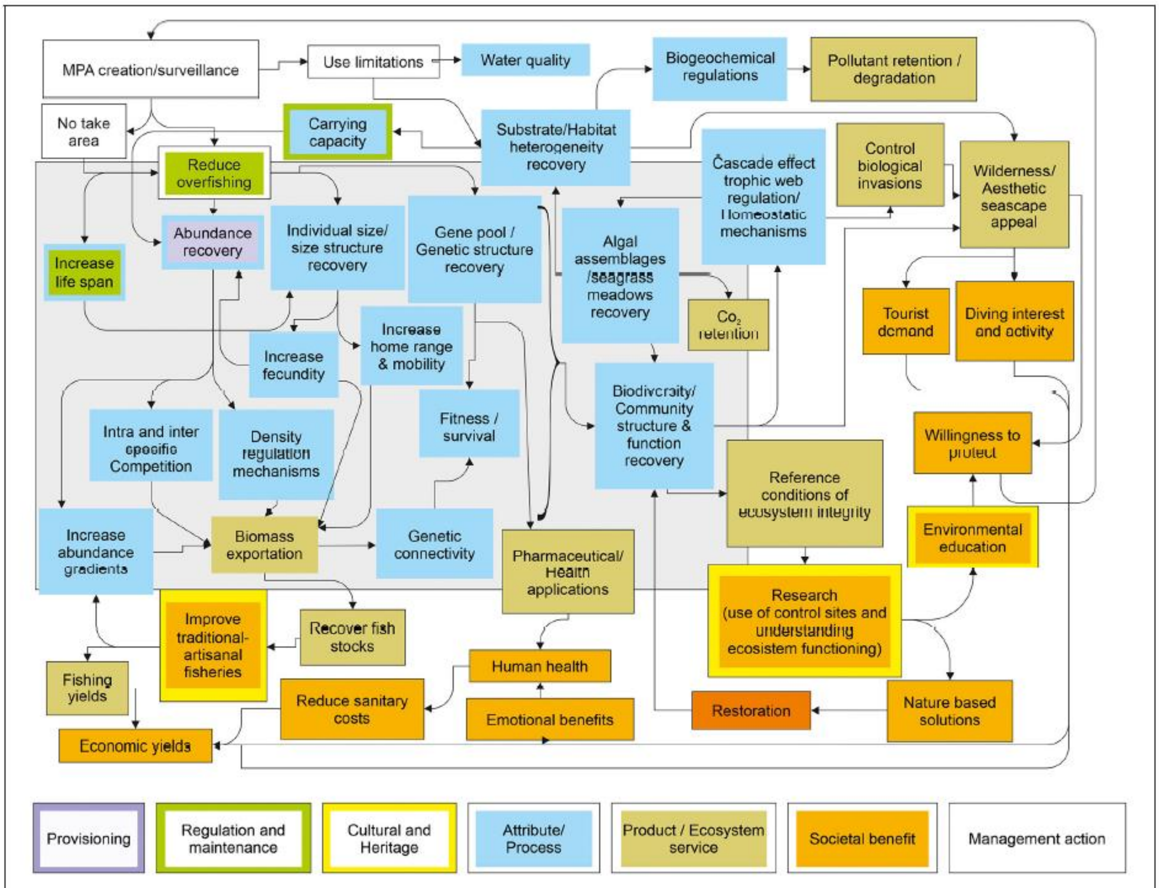


FIGURE 8 | Cause effect relationships diagram considering human actions, MPA attributes and the effects of protection on biological and ecological processes and the ecosystems services and societal benefits provided.

Figure 153. Elucidation of the complex interrelationships between the MPAs benefits in terms of ecological assets and livelihoods sustainability. (Source: doi: 10.3389/fmars.2021.613819)

The Mediterranena Sea coastal areas from an ecological asset prespective, as well as an unit of economical value, is the focus of the Priority Actions Programme Regional Activity Center (PAP/RAC) of the UNEP/MAP System. The coastal area, and the Barcelona Convention ICZM Protocol, aims to guide the path for coastal sustainability as the majority of the ecosystem services we rely on are located in the coastal belts and is the zone were the Mediterranean population inhabits. The ICZM aims to balance the highly ecologically diverse resources at the interface between the land and sea exhibiting a number of valued ecosystems and habitat services. The Table 39 summarizes the length of the coastline by country in the Mediterranean with aproximately 46,000 Km of coastline. It is important both to observe the national allocation of coastlines and their geographical location in the Mediterranean region from a transboudary perspective in order to perform an analysis of the causes and effects of the transboundary environmental concerns.

Table 39. Length of the coastline by country. Source: PAP/RAC (2017): Evolution of built-up area in coastal zones of Mediterranean countries between 1975 to 2015.

Iso3	Country name	Coastline length (km) - this work	*Notes (this work)*	Coastline length (km) - CIA	Coastline length (km) - WRI
ALB	Albania	**715**		362	649
DZA	Algeria	**1'669**		998	1'557
BIH	Bosnia and Herzegovina	**21**		20	23
HRV	Croatia	**6'381**		7'368	5'664
CYP	Cyprus	**809**		648	671
EGY	Egypt	**2'519**	*1*	2'450	5'898
FRA	France	**2'436**	*1*	4'853	7'330
PSE	State of Palestine	**42**		40	
GIB	Gibraltar	**14**		12	
GRC	Greece	**16'491**		13'676	15'547
ISR	Israel	**214**		273	205
ITA	Italy	**10'043**		7'600	9'226
LBN	Lebanon	**319**		225	294
LBY	Libya	**2'174**		1'770	2'025
MLT	Malta	**214**		252	198
MCO	Monaco	**7**		4	
MNE	Montenegro	**325**		293	
MAR	Morocco	**573**	*1*	1'835	2'009
SVN	Slovenia	**45**		47	41
ESP	Spain	**3'188**	*1*	4'964	7'628
SYR	Syrian Arab Republic	**239**		193	212
TUN	Tunisia	**2'037**		1'148	1'927
TUR	Turkey	**6'961**	*1*	7'200	8'140

In the urban coastal areas, the existing ecological assets within the watersheds are threatened by human induced multiple pressures, which have a cumulative nature. Therefore, at the land-sea interface the most fragile ecological assets and livelihood are to be protected, and therefore their need for study and analysis. The Figure 153 shows in terms of pollution the number of ecological assets by pollution, however, the pressures in the Mediterranean Sea are much more diverse due to human impacts related to present and past socio-economic models which might differ to some extent among the riparian countries (ca. multiple drivers and pressures) as presented in Chapter 1.

There are several studies that attempted to assess the pressures through multiple stressors occurring in the Mediterranean Sea rather than to look for sectoral impacts of different origin which are well known but most of the time assessed individually and addressed by countries without establishing their links and being most of them of transboundary concern. The Figure 154 (Micheli et al., 2013) represents the zonation of the cumulative impact effects in the Mediterranean (and Black Sea) assessed through the study of 22 drivers and 17 marine ecosystems selected by the authors (within the division of 7 ecoregions, Spalding et al., 2007).

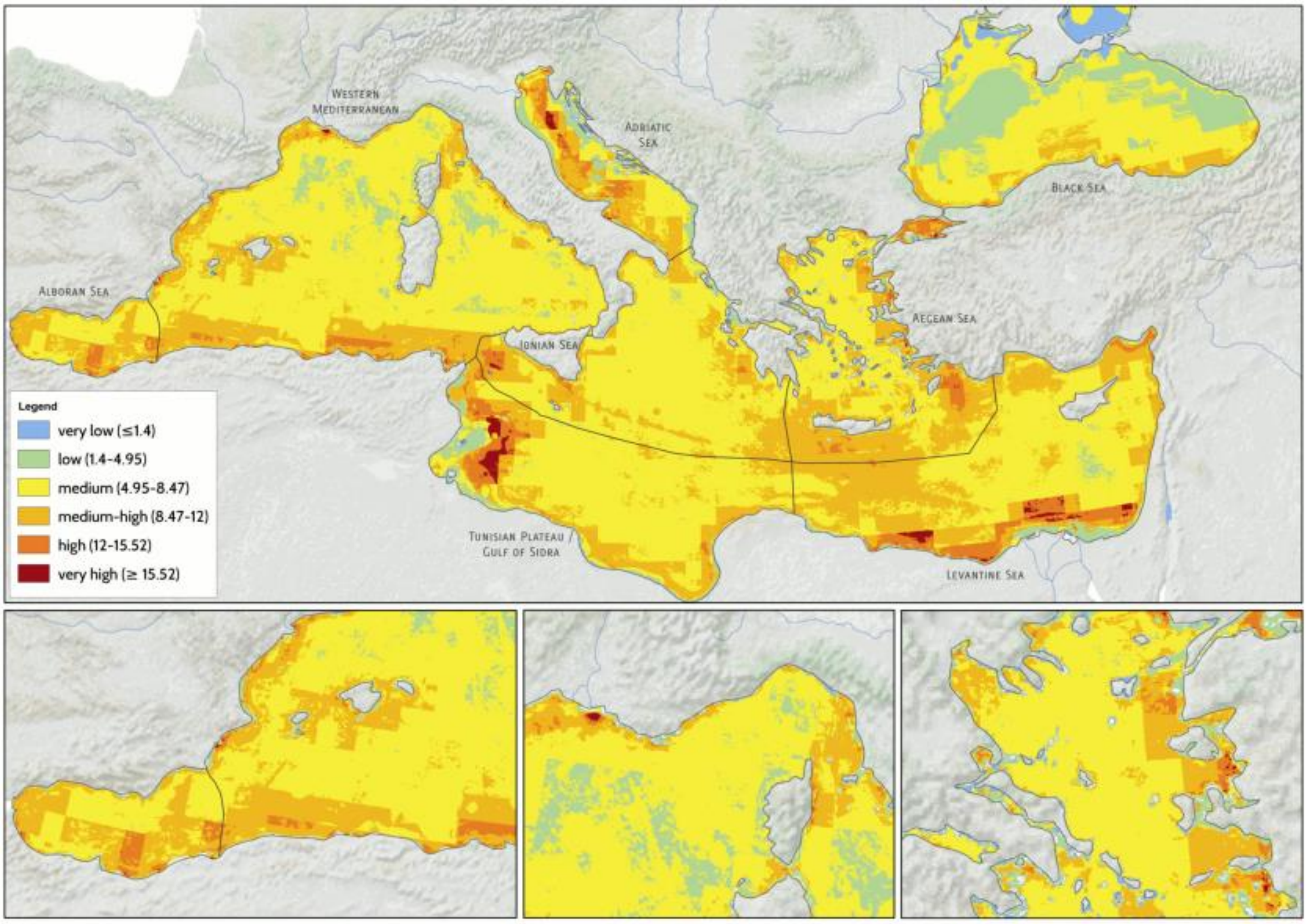


Figure 154. Cumulative pressures in the Mediterranean and Black Seas (Micheli et al., 2013)

However, the majority of studies does not take into account at the land-sea interface, namely the coastal zone and the demographic pressures which is a critical dimension threatening, directly or indirectly, the transboundary ecological assets and livelihoods of the people inhabiting the Mediterranean region. The following plots are extracted from an analysis by PAP/RAC (*PAP/RAC (2017): Evolution of built-up area in coastal zones of Mediterranean countries between 1975 to 2015*). In the Figure 155 below, and as described, it can be observed the average magnitude of the percentage of built-up areas in the coastal zone (ca. coastal belt at 10km, 1,km, and 150 m) in the Mediterranean Sea which to some extent causes the main current environmental and transboundary concerns.

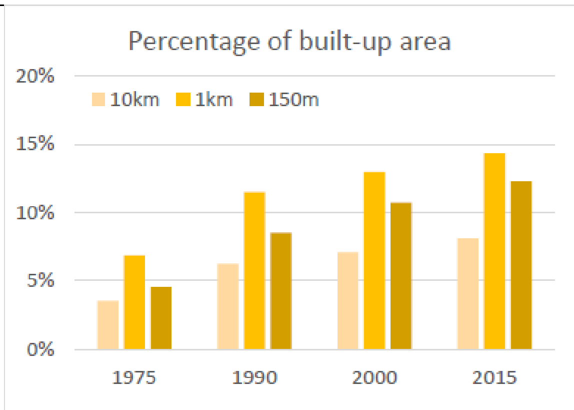
To the above regard, a number of satellite application products, such as the Coastal Zones LC/LU Change (CZC) 2012-2018 of the Copernicus program[69] could support in the near future a more accurate and enormous information regarding coastal areas devlopment in the Mediterranean Sea.

[69] Coastal Zones Change 2012-2018 (vector), Feb. 2021 | Copernicus

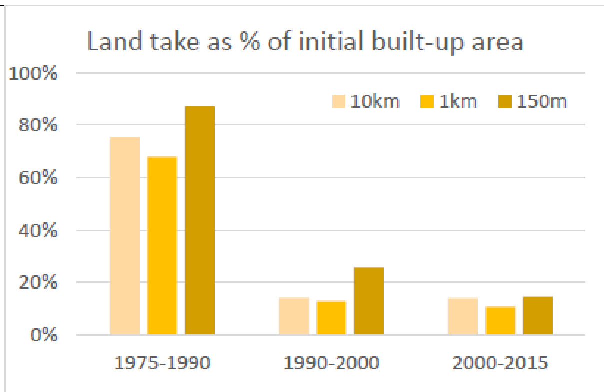
Charts

The charts have been realized for each analytical belt (150 m, 1 km and 10 km width), and for the periods 1975, 1990, 2000, and 2015.

Whole Mediterranean area



The whole Mediterranean area shows a constant and regular increase of the built-up area during the entire period of observation. The graph also shows that the development appears relatively homogeneous within the three different coastal belt areas.

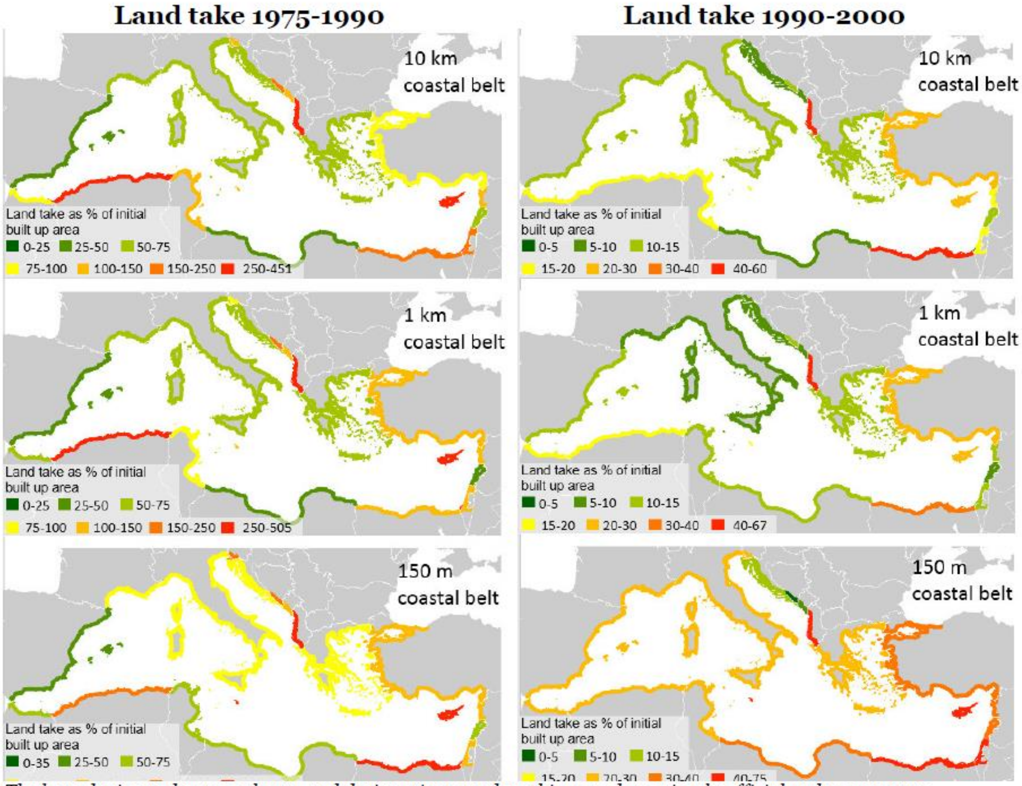


This graph shows quite clearly how the greatest coastal development occurred between 1975 and 1990, with a land take between 65 and 80%, depending on the coastal belts. In the following two periods the urbanization on previous undeveloped land remains clearly more limited.

Figure 155. Built-up area and land take as % of initial built-up area for three periods in the zonations of the coastal belt. PAP/RAC (2017): Evolution of built-up area in coastal zones of Mediterranean countries between 1975 to 2015

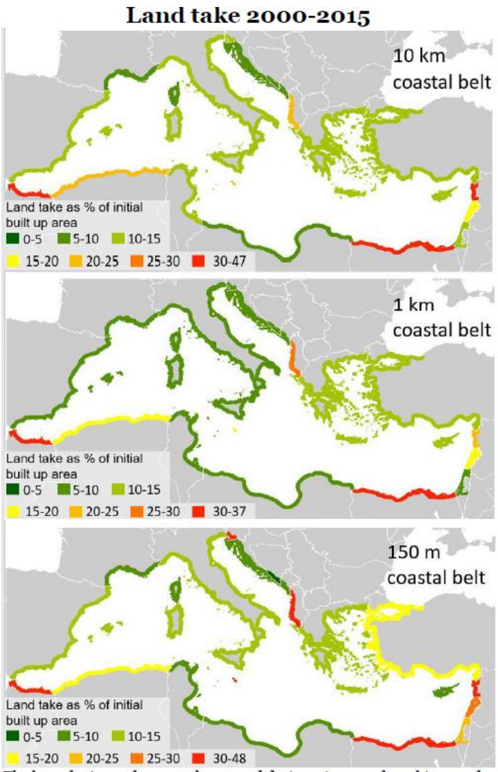
Similarly, Figure 156 shows an estimated country coastline built-up area and land take as % of initial built-up area for the three periods in the 1km and 150-meter zonation of the coastal belt in regional scale maps since 1975.

It can be observed in Figure 156, that apparently the Western Mediterranean countries (northwestern) exhibit only about a 25% of the coastal belt occupied, however, the expansion in terms of land built-up area happened before 1975 earlier than any other countries in the Mediterranean and is not shown. This later statement, despite due to a data gap, could be inferred from Figure 157, where it can be observed the high density of marinas in the northwestern Mediterranean reflecting the full developed tourism locations largely before 1975 (ca. particularly the Côte d'Azur in the south of France).



The boundaries and names shown and designations used on this map do not imply official endorsement or acceptance by the United Nations.

Sources: JRC-GHSL, UN cartographic section



The boundaries and names shown and designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 156. Regional scale maps for the time periods and coastal belt zonation PAP/RAC study. PAP/RAC (2017): Evolution of built-up area in coastal zones of Mediterranean countries between 1975 to 2015

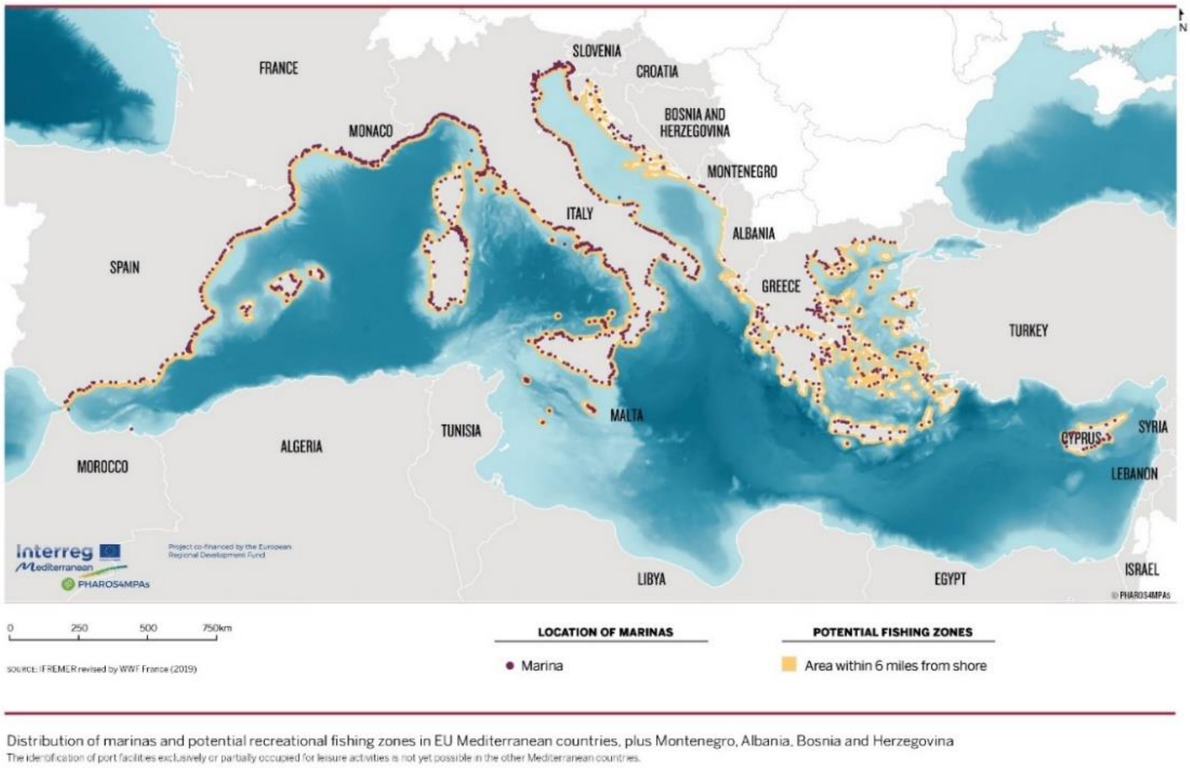


Figure 157. PHAROS4MPAs project: Distribution of marinas and potential recreational fishing zones. Source: PHAROS4MPAs

Related to the above the Figure 157, the Figure 158 shows one of the impacts of the built and recreational coastal areas in terms of erosion concerns.

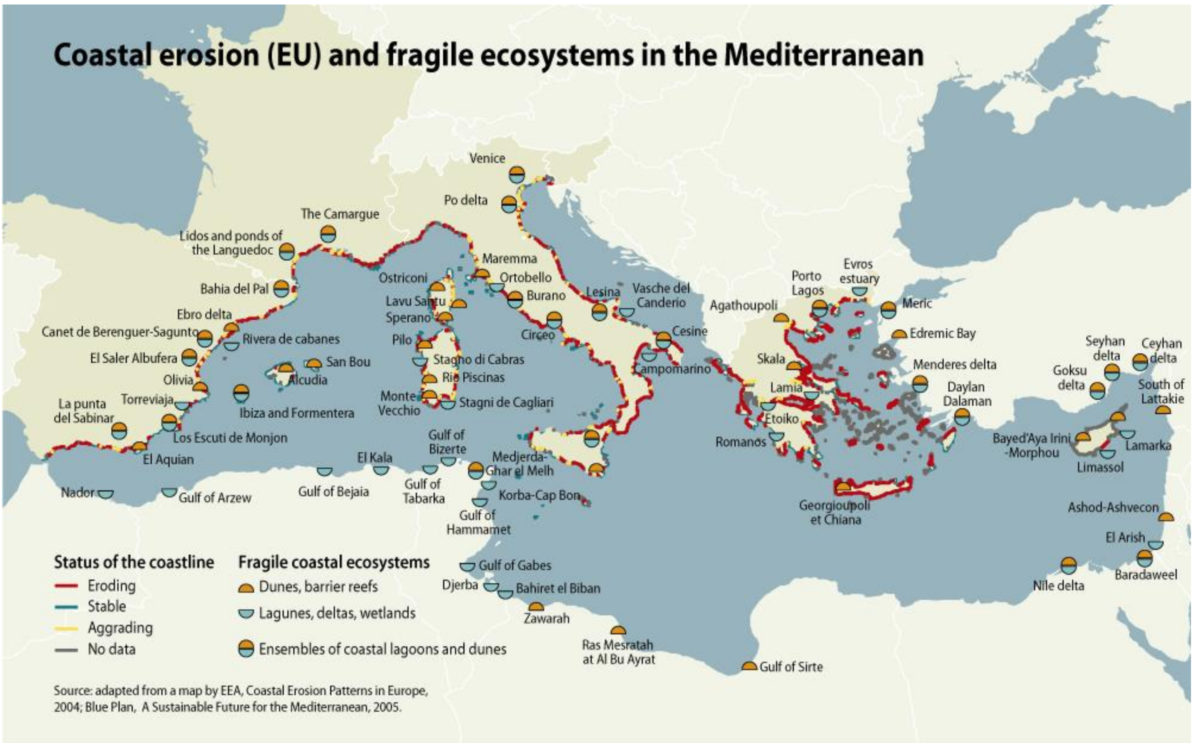


Figure 158. Erosion in the coastal areas of the Mediterranean Sea.

4.3.2. Switching livelihoods (economy&society)

As mentioned, the diverse pressures and living models in the coastal zone directly affects the marine environment at a transboundary scale and the natural capital (Figure 159). Therefore, within the Mediterranean coastal zonation there is a coexistence of the marine ecological assets (ca. natural capital and ecosystem services), such as the ones within the ecosystem services categories presented in Table 40. However, the natural monetary value accounting into national and macroeconomic models is a very recent concept that would need to be accelerated globally to halt the deterioration of the environment.

Table 40. Ecosystem services and their typology for the marine environment. (Source: Bönkhe-Henrichs et al., 2013)

Table 1
Typology of marine ecosystem services.

	Ecosystem service	Description	Example
Provisioning Services	1 Sea Food	All available marine fauna and flora extracted from coastal/marine environments for the specific purpose of human consumption as food (i.e. excluding for consumption as supplements)[a]	Fish, shell fish, seaweed
	2 Sea Water	Marine water in oceans, seas and inland seas that is extracted for use in human industry and economic activity	Seawater used in shipping, industrial cooling, desalinization
	3 Raw Materials	The extraction of any material from coastal/marine environments, excluding which is covered by service 6	Algae (non-food), sand, salt
	4 Genetic Resources	The provision/extraction of genetic material from marine flora and fauna for use in non-marine, non-medicinal contexts, excluding the research value on Genetic Resources which is covered by service 20.	The use of marine flora/fauna-derived genetic material to improve crop resistance to saline conditions
	5 Medicinal Resources	Any material that is extracted from the coastal/marine environment for its ability to provide medicinal benefits, excluding the research value on Medicinal Resources which is covered by service 20.	Marine-derived pharmaceuticals; marine/coastal-derived salt-water used for health purposes
	6 Ornamental Resources	Any material extracted for use in decoration, fashion, handicrafts, souvenirs, etc.	Shells, aquarium fish, pearls, coral
Regulating Services	7 Air Purification	Air Purification provided by a coastal/marine ecosystem	The removal from the air of pollutants like fine dust and particular matter, sulphur dioxide, carbon dioxide, etc.
	8 Climate Regulation	The contribution of the biotic elements of a coastal/marine ecosystem to the maintenance of a favourable climate via their impact on the hydrological cycle and their contribution to the climate-influencing substances in the atmosphere	The production, consumption and use by marine organisms of gases such as carbon dioxide, water vapour, nitrous oxides, methane, and dimethyl sulphide;
	9 Disturbance Prevention or Moderation	The contribution of marine ecosystem structures to the dampening of the intensity of environmental disturbances such as storm floods, tsunamis, and hurricanes	The reduction in the intensity of and/or damage caused by environmental disturbances resulting directly from marine ecosystem structures like salt marshes, sea grass beds, and mangroves
	10 Regulation of Water Flows	The contribution of marine and coastal ecosystems to the maintenance of localized coastal current structures	The effect of macro algae on localized current intensity; The maintenance of deep channels by coastal currents which are for shipping
	11 Waste Treatment	The removal by coastal/marine ecosystems of pollutants added to coastal/marine environments by humans through processes such as storage, burial, and biochemical recycling	The breakdown of chemical pollutants by marine microorganisms; The filtering of coastal water by shell fish
	12 Coastal Erosion Prevention	The contribution of coastal/marine ecosystems to Coastal Erosion Prevention, excluding what is covered by service 10 (i.e. transportation or deposition of sediments by coastal currents)	The maintenance of coastal dunes by coastal vegetation; The reduction in scouring potential that results from near-shore macro-algae forests
	13 Biological Control	The contribution of marine/coastal ecosystems to the maintenance of natural healthy population dynamics to support ecosystem resilience through maintaining food web structure and flows.	The support of reef ecosystems by herbivorous fish that keep algae populations in check; the role that top predators play in limiting the population sizes of opportunistic species like jelly fish and squid

Habitat Services	14 Lifecycle Maintenance	The contribution of a particular habitat to migratory species' populations through the provision of essential habitat for reproduction and juvenile maturation	The reproduction habitat of commercially valuable species that are harvested elsewhere
	15 Gene Pool Protection	The contribution of marine habitats to the maintenance of viable gene pools through natural selection/evolutionary processes	Inter- and Intra-specific genetic diversity that is supported by marine ecosystems which enhances adaptability of species to environmental changes
Cultural & Amenity Services	16 Recreation and Leisure	The provision of opportunities for Recreation and Leisure that depend on a particular state of marine/coastal ecosystems	bird/whale/…-watching, beachcombing, sailing, recreational fishing, SCUBA diving, etc.
	17 Aesthetic Information	The contribution that a coastal/marine ecosystem makes to the existence of a surface or subsurface landscape that generates a noticeable emotional response within the individual observer. This includes informal Spiritual Experiences but excludes that which is covered by services 16, 18, 19, and 21.	The particular visual facets of a 'sea-scape' (like open 'blue' water), a 'reef-scape' (with abundant and colourful marine life), a 'beach-scape' (with open sand), etc. that emotionally resonate with individual observers
	18 Inspiration for Culture, Art and Design	The contribution that a coastal/marine ecosystem makes to the existence of environmental features that inspire elements of culture, art, and/or design. This excludes that which is covered by services 6, 16, 17, and 21.	The use of a marine landscape as a motif in paintings; The use of marine environmental features (like waves) in jewellery; The construction of buildings according to a marine-inspired theme; the use of marine organisms or marine ecosystems in films (including Jaws and Finding Nemo)
	19 Spiritual Experience	The contribution that a coastal/marine ecosystem makes to formal religious experiences. This excludes that which is covered by services 17 and 21)	Several Greek and Roman gods were connected to the sea; A prominent Christian symbol is the fish; Marine organisms (such as whales and salmon) sometimes play important roles in various indigenous communities' religion
	20 Information for Cognitive Development	The contribution that a coastal/marine ecosystem makes to education, research, etc. This includes the contribution that a coastal/marine ecosystem makes to bionic design and biomimetics and to research on applications of marine Genetic Resources and pharmaceuticals.	The environmental education of children and adults; The development of surfaces to reduce marine biofouling based on similar surfaces found in marine environments; the application of hydrodynamic flow analysis to marine animals for ship design; Utilization of marine animal swimming mechanisms in engineering design[b]
	21 Cultural Heritage and Identity	The contribution that a coastal/marine ecosystem makes to Cultural Heritage and Identity (excluding aesthetic and formal religious experiences). This includes the importance of marine/coastal environments in cultural traditions and folklore. This covers the appreciation of a coastal community for local coastal/marine environments and ecosystems (e.g. for a particular coast line or cliff formation) as well as the global importance that may be associated with a particular marine landscape.	The Wadden Sea is listed as UNESCO World Heritage site

[a] The marine fauna referred to here may come from both capture fisheries and aquaculture operations.

[b] For example see the AirPenguin, AirJelly, and Air_ray created by Festo Robotics (Deutschland). Available at: http://www.festo.com/cms/de_corp/9780.htm, http://www.festo.com/cms/de_corp/9647.htm, and http://www.festo.com/cms/de_corp/9789.htm.

Source: Adapted from De Groot, Wilson and Boumans (2002), Beaumont et al. (2006), (De Groot et al., 2010).

Ecosystem valuation, sustainable blue economy and sustainable consumption and production

Figure 2 | SEEA Conceptual Framework

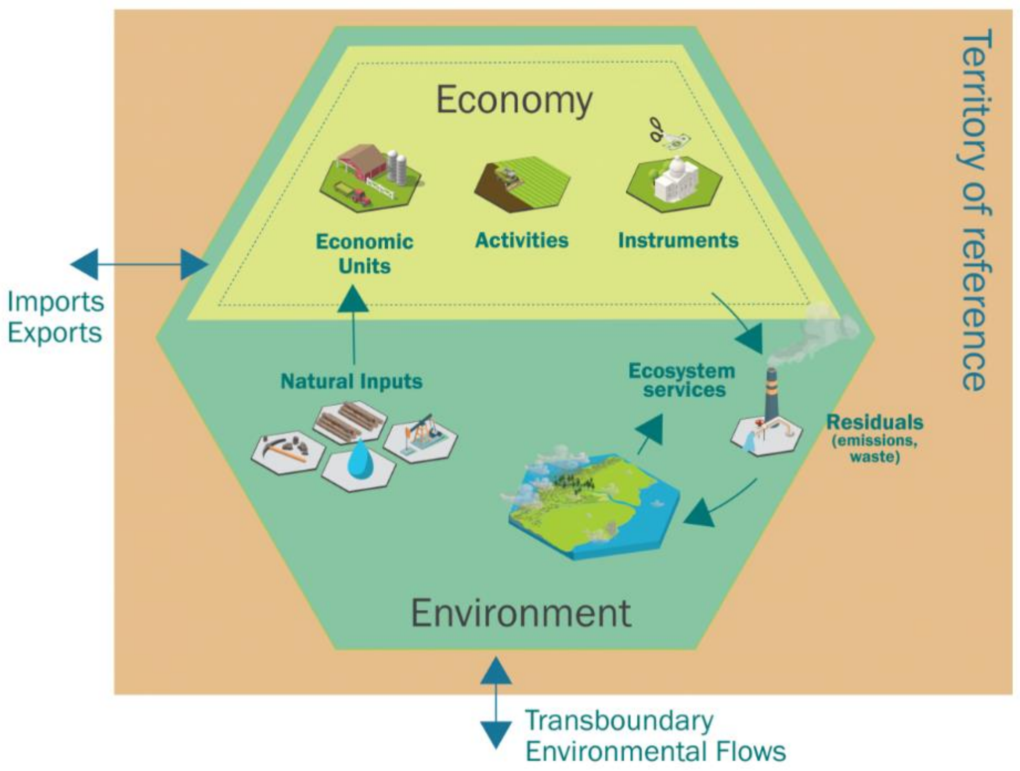
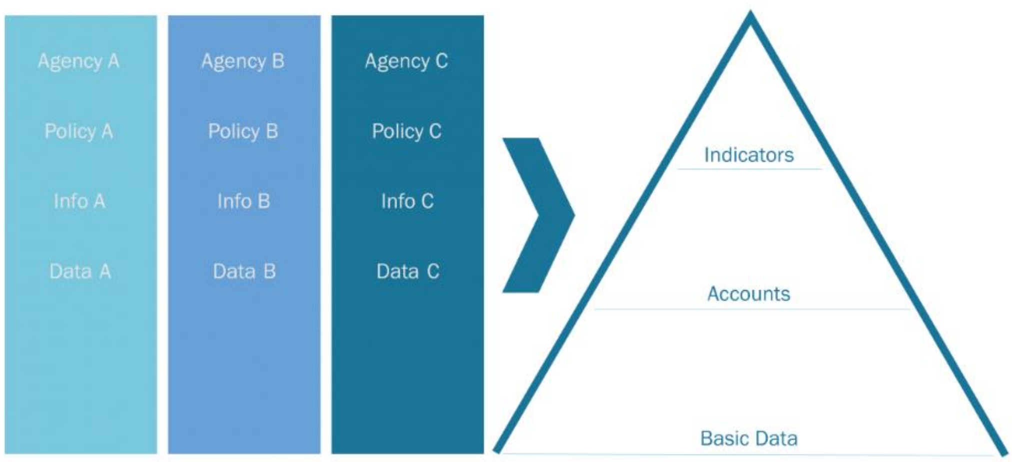


Figure 1 | From Silo Approach to Integration



The SEEA Central Framework (SEEA CF) was adopted by the UN Statistical Commission as the first international standard for environmental economic accounting in 2012. It takes the viewpoint of the economy and examines how natural resources like fish, timber and water are used in production and consumption, along with resulting pollution in the form of waste, water and air emissions. The figure below shows its general structure.

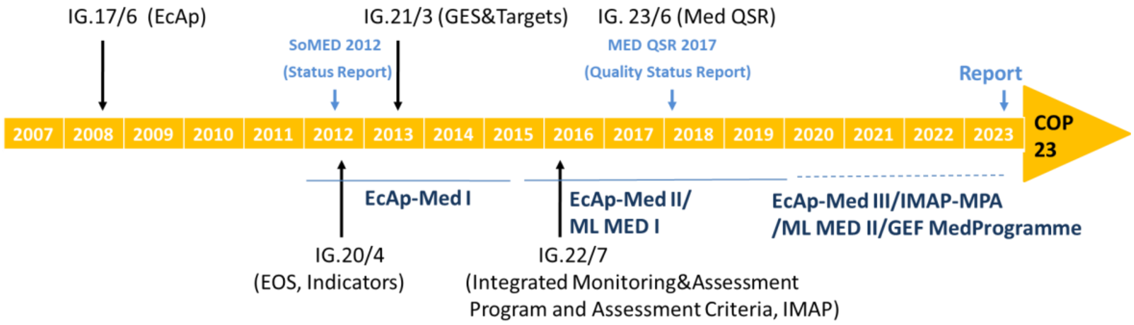
Figure 159. Schemes depicting the 'natural capital' transboundary concept within the macroeconomic model and the basic accounts model for SEEA. Source: UN.

4.3.3. Integrating knowledge (monitoring&policy)

Shared issue: National academia and scientific research (Data access)
Shared issue: Agencies and observatories (Data access)
Shared issue: Gender observatories (Data access)

In terms of scientific environmental data, information, and knowledge, the ecosystem approach implementation in the Mediterranean integrated a few disciplines and tools which were progressing independently and were not jointly applied (or not commonly) in marine matters towards integrative and holistic assessments. For example, the study of noise pollution (ca. energy in the marine environment and interactions with biodiversity) is not a new field but for the first time was included under the ecosystem approach management of the marine environment under IMAP (the UNEP/MAP Integrated Monitoring and Assessment Program of the Mediterranean Sea and Coasts). Similarly, advances in satellite-based data programs generating products for the marine environment are more and more frequently considered, as well as geographical information systems to include de facto the spatial scale analysis and geographical assessments allowing to communicate and to scale up the scientific knowledge to other stakeholders.

To this regard, the Barcelona Convention UNEP/MAP system ITC structure initiated the steps to be update for the purpose of handling the above explained amount of new information from different disciplines, as well as to align with international schemes, in particular the European Union data management protocols (e.g., EMODnet). The INFO/RAC (Rome, Italy) hosts the ITC structure of the UNEP/MAP Barcelona Convention system, named InfoMAP System (ca. InfoMAP platform) as agreed by the Contracting Parties of the Barcelona Convention (Figure 160), for which a Decision on Data Policy has been very recently agreed during COP22 in 2021. As this, the number of multidimensional information sources (as well as raw data) supporting national datasets and scientific evidence of environmental change in the Mediterranean is coordinated in a manner that fulfill the next challenges ahead. In Annex B, the links to the Mediterranean information through EU platforms are provided, which includes some data from the Contracting Parties of the Barcelona Convention in the Mediterranean Sea. It should be mentioned that several countries have their own databases regarding the environment matters, including hosting the marine environmental information and other related information tools (ca. geographical information); however, other countries are in the early stages of the development of marine databases and environmental information.



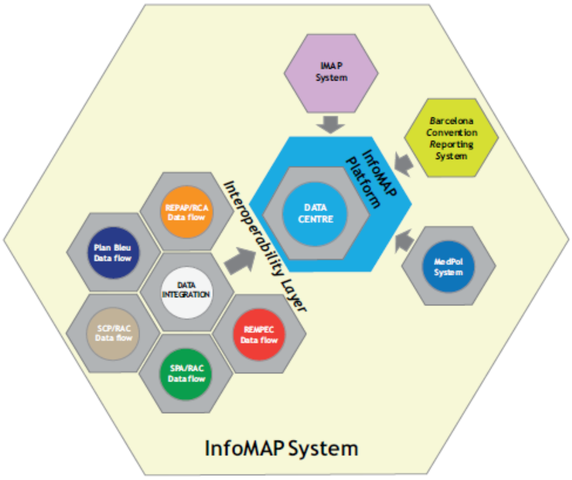


Figure 160. The EcAp implementation roadmap (top) and the InfoMAP System architecture (in development) for the UNEP/MAP and the Barcelona Convention. Source: Joint EEA-UNEP/MAP Report, Technical assessment of progress towards a cleaner Mediterranean. Monitoring and reporting results for Horizon 2020 regional initiative, EEA Report No 08/2020.

The InfoMAP System is expected to fulfill the gaps in environmental data supporting countries through generating databases, as well as supporting UNEP/MAP IMAP implementation. To compare with the EU regional existing frameworks and strategies, the Figure 161 shows the flow diagram presenting the relationship of EMODnet and the process of data collection. To this regard the InfoMAP System would be equivalent to the European Data collection frameworks (Figures 160 and red circle in Figure 161).

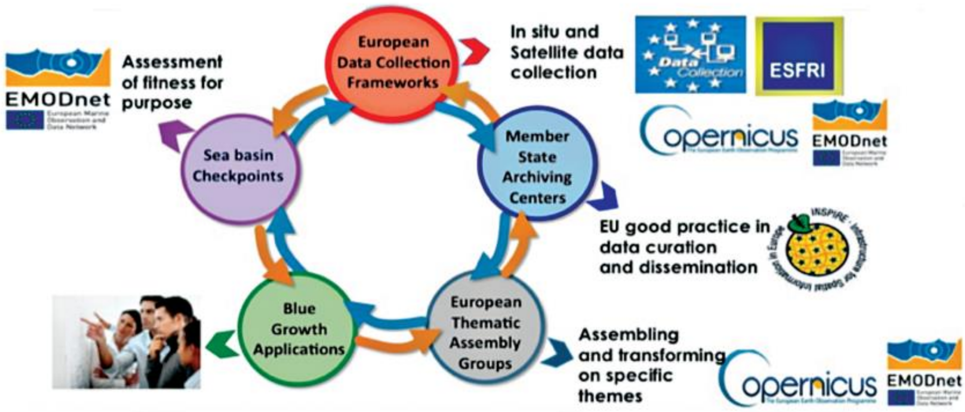
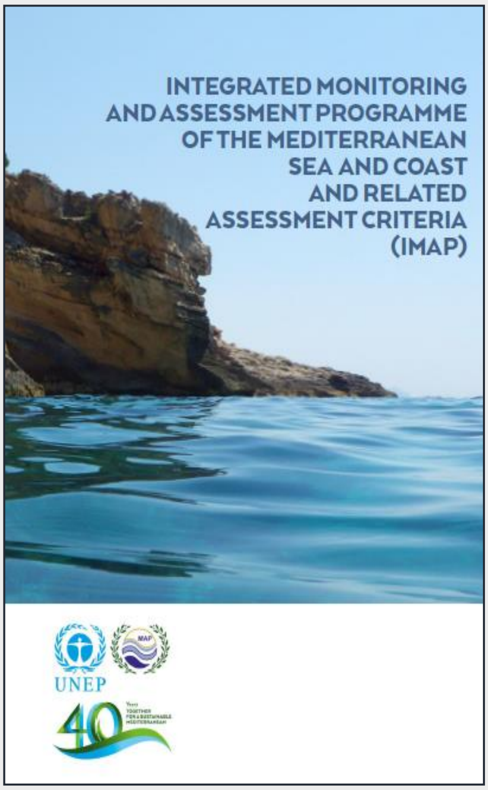


Figure 161. Flow diagram presenting the relationship of EMODnet and the process of data collection and contribution to the applications. In: MONGOOS SCIENCE AND STRATEGY PLAN (2018). Sofianos, Sarantis, Álvarez Fanjul, Enrique Coppini, Giovanni. Puertos del Estado, Spain. ISBN: 978-84-88740-08-3

To achieve the goal of an holistic ecosystem-based management, one of the most important strategic points within the ecosystem approach roadmap was the establishment of an enlarged marine monitoring program for the Mediterranean Sea: the IMAP (Integrated Monitoring and Assessment Program of the Mediterranean Sea and Coast and related Assessment Criteria.



BIODIVERSITY AND NIS

EO1 Biodiversity
EO2 Non-indigenous species
EO3 Fisheries
EO4 Food webs (to be further developed)

POLLUTION

EO5 Eutrophication
EO9 Contaminants
EO10 Marine Litter
EO11 Marine Noise

COASTAL ECOSYSTEMS AND HYDROGRAPHY

EO6 Sea-floor integrity
EO7 Hydrography
EO8 Coastal ecosystems and landscapes

Figure 162. The main three pillars of the IMAP with their respective Eocological Indicators. UNEP/MAP Brochure, 2016.

The three pillars of IMAP are Pollution, Biodiversity and Hydrography (Figure 162). The structure followed almost closely the EU Marine Strategy Framework Directive (implemented in the northern part of the Mediterranean by the Mediterranean EU-countries), except for the ecosystem indicator related to Coasts (Ecological Objective 8) included in IMAP. The reason for this, obviously is that the marine environment is exposed to the human activities mostly happening at the land-sea interface. There are both direct and indirect relationships between the coastal development and the degradation of the surrounding marine environment. There are many examples, such as increased tourism pressures during summer seasons leading to acute impacts into the coastal and marine environment in the short- and mid-term (e.g., pollution) with other impacts, such as coastlines and land use transformations in the long-term (see previous Sections).

The Figure 162 shows as well as the different Ecological Objectives (EOs) (ca. descriptors) of the marine ecosystem for which the Good Environmental Status (GES) of the marine environment will be assessed. As mentioned, IMAP has a strong focus on the Coastal Ecosystems and Hydrography which are closely related to human pressures and large-scale phenomena anomalies (ca. climate adaptation, long-term ecosystem regulation, etc.), along with the two other fundamental pillars within the marine ecosystem, to monitor healthy (as opposed to polluted) and biodiverse ecosystems providing short- and mid-term marine ecosystem services altogether in the Mediterranean societies and economies. Additionally, in terms of pollution IMAP includes the Bathing Water Quality within the monitoring and not separately (e.g. EU Marine Strategy Framework Directive, MSFD and EU Bathing Waters Directive) to provide integrated monitoring of a fundamental ecosystem service in the Mediterranean Sea (Figure 163).

Although the scientific debate is open regarding the formulas to interlink the different Ecological Indicators, still some of the EOs and their Common Indicators (Cis) still in early stages of development (e.g., EO4 and EO6, Table 41). The success of the implementation of IMAP in the Mediterranean Sea should provide a larger integrated database and information at national level, and therefore, scalable region-wide to address transboundary concerns as well.

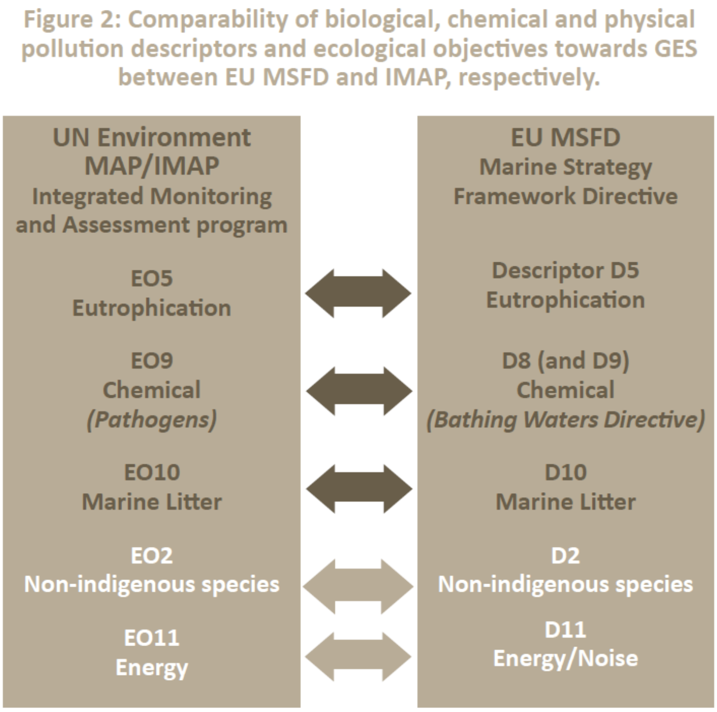


Figure 163. Partial comparison between the UNEP/MAP IMAP and EU MSFD (see text).

However, the implementation of the IMAP is being proven challenging from all points of view, namely both for science and policy, as the number of the marine subjects has largely increased, and the coordination of efforts require strong work and exeprt knowledge. The Table 41 below show the complete list of Common Indicators and Ecological Objectives within IMAP and its comparison with the EU MSFD Descriptors (D1MSFD, D2MSFD, etc.) and Table 42 shows the proposed Climate Change indicators, lacking currently in IMAP, as a result of the Workshop on Climate Change indicators undertaken during the elaboration of this TDA report.

Table 41. Full list of Cis and EOs of the Integrated Monitoring and Assessment Programme. Note: the first column indicates the equivalent ecological indicator regarding the EU MSFD.

D1MSFD	EO1	BIODIVERSITY (EO1): CI1-CI5
	CI1	CI1. Habitat distributional range (EO1) to also consider habitat extent as a relevant attribute
	CI2	CI2. Condition of the habitat’s typical species and communities
	CI3	CI3. Species distributional range (EO1 related to marine mammals, seabirds, marine reptiles);
	CI4	CI4. Population abundance of selected species (EO1, related to marine) mammals, seabirds, marine reptiles

	CI5	CI5. Population demographic characteristics (EO1, e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates related to marine mammals, seabirds, marine reptiles)
D2MSFD	**EO2**	**NON-INDIGENOUS SPECIES (EO2): CI6**
	CI6	CI6. 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)
D3MSFD	**EO3**	**FISHERIES (EO3): CI7-CI12**
	CI7	CI7. Spawning stock Biomass
	CI8	CI8. Total landings
	CI9	CI9. Fishing Mortality
	CI10	CI10. Fishing effort
	CI11	CI11. Catch per unit of effort (CPUE) or Landing per unit of effort (LPUE) as a proxy
	CI12	CI12. Bycatch of vulnerable and non-target species (EO1 and EO3)
D4MSFD	**EO4**	**MARINE FOOD WEBS (EO4)**
D5MSFD	**EO5**	**EUTHROPICATION (EO5)**
	CI13	CI13. Concentration of key nutrients in water column
	CI14	CI14. Chlorophyll-a concentration in water column
D6MSFD	**EO6**	**SEA FLOOR INTEGRITY (EO6)**
D7MSFD	**EO7**	**HYDROGRAPHY (EO7)**
	CI15	CI15. Location and extent of the habitats impacted directly by hydrographic alterations (EO7) to also feed the assessment of EO1 on habitat extent
do not exist	**EO8**	**COAST (EO8)**
	CI16	CI16. Length of coastline subject to physical disturbance due to the influence of man-made structures (EO8) to also feed the assessment of EO1 on habitat extent
	cCI25	candidateCI25. Candidate Indicator: Land use change
D8MSFD	**EO9**	**CONTAMINATION (EO9)**
	CI17	CI17. Concentration of key harmful contaminants measured in the relevant matrix (EO9, related to biota, sediment, seawater)
	CI18	CI18. Level of pollution effects of key contaminants where a cause and effect relationship has been established
	CI19	CI19. Occurrence, origin (where possible), and extent of acute pollution events (e.g. slicks from oil, oil products and hazardous substances) and their impact on biota affected by this pollution
D9MSFD	**CI20**	**CI20. Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood**
EU Bathing Directive	**CI21**	**CI21. Percentage of intestinal enterococci concentration measurements within established standards**
D10MSFD	**EO10**	**MARINE LITTER (EO10)**
	CI22	CI22. Trends in the amount of litter washed ashore and/or deposited on coastlines (including analysis of its composition, spatial distribution and, where possible, source)
	CI23	CI23. Trends in the amount of litter in the water column including microplastics and on the seafloor
	cCI24	candidateCI24. Candidate Indicator: Trends in the amount of litter ingested by or entangling marine organisms focusing on selected mammals, marine birds and marine turtles
D11MSFD	**EO11**	**ENERGY (EO11)**
	cCI26	candidateCI26. Candidate indicator: 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
	cCI27	candidate27. Candidate Indicator: Levels of continuous low frequency sounds with the use of models as appropriate

Table 42. Proposed set of climate change transboundary indicators (Plan Bleu Climate Change Indicators Workshop Report, January 2023).

Essential Ocean Variables	Climate change transboundary indicators	Parameters (and links with EcAp EO)	Transboundary issues	Links with IMAP Common Indicator
Atmosphere	Air quality	GHG levels	Global warming	/
Surface and subsurface	Sea pH	Sea pH anomalies	Acidification	CI18
	Sea surface temperature (SST)	Sea surface temperature (SST)	Sea warming	/
		Sea surface temperature anomaly (SST)		/
		Marine Heat Waves (MHWs)		/
	Ocean color	Chlorophyll-a concentration (CHL) - EO5	Biological productivity	CI14
		Chlorophyll-a concentration anomaly[70] (CHLA) - EO5		CI14
	Ocean currents	Geostrophic velocity (GV)	Sea Currents	/
		Total kinetic energy (TKE)	Ocean Circulation Variability	/
	Ocean surface stress	Wind	Wind speed and direction	/
	Temperature	Ocean heat contents (OHC) - EO7	Hydrographic Property and Water Mass Variability	/
	Salinity	Ocean salt contents (OSC) - EO7		/
	Water temperature and salinity	Mixed layer depth (MLD) - EO7	/	/
		Mixed layer temperature (MLT) - EO8	Sea warming	/
		Mixed layer salinity (MLS)		/
Sea level	Sea level Rise	High Tide- Storm Surge	Sea-level Rise Flash flooding	/
Biodiversity	Plankton/non-plankton Diversity and species	Density of thermophilic species - EO1	Structure and functioning of key marine habitats	CI1, CI2, CI3
		Density of Non-indigenous species - EO2		CI1, CI2, CI3, CI6
		Mass mortalities of species - EO1		CI1, CI2, CI3, CI4
Coastal ecosystem	Coasts	Hydrographic changes - EO7 & EO8	Coastal land-use integrity	CI16 CI25
		Exposed coastline and flooding zones[71] - EO8 Coastal wetlands migration	Decreased rain-fall Coastal Drought Low-lying coastal area Salt-water intrusion	CI16

[70] Chlorophyll-a concentration anomaly

[71] Developed as a low elevation coastal zone (under 5m asl) within GEF MEDProgamme CP 2.1.

Water	Drought effects	IW resources/reservoirs	/	/
		underground water River	Pollution, Increase salinity of coastal aquifer	CI17 CI18
		Water discharge Fresh water scarcity	/	/
		Water reuse	/	/

On another level, many initiatives during the last's decades have strived to integrate knowledge, particularly for complex environmental problems such as in coastal areas. It is important to mention here that, beyond purely policy matters, the scientific concerns about the changes introduced in the land-sea interface have been the target of multiple interest groups by a variety of stakeholders leading key global programs, such as the Land–ocean Interactions in the Coastal Zone (LOICZ) project established in 1993 as a core project of the International Geosphere–Biosphere Programme (IGBP) to provide the science knowledge to address those complex coastal concerns. In its first phase of operation (1993–2003) LOICZ began a fundamental investigation focused on biophysical dimensions, including influential assessments of coastal seas as net sources or sinks of atmospheric CO2, river discharge to the oceans, and biogeochemical modelling. In the second generation of LOICZ (2004–2014), the focus was on the human dimensions of the coast, involving the inclusion of cross-cutting themes such as coastal governance, social-ecological systems, ecological economics and activities around capacity building and the promotion of early career scientists. The global LOICZ programme was closed in 2015 and continued under Future Earth (Figure 164). The new global framework and vision (ca. 'LOICZ third generation') is to support transformation to a sustainable and resilient future for society and nature on the coast, by facilitating innovative, integrated and solutions-oriented science. The LOICZ as Future Earth Coasts will continue to address 'hotspots' of coastal vulnerability, focusing on themes of dynamic coasts, human development and the coast, and pathways to global coastal sustainability and constraints thereof.

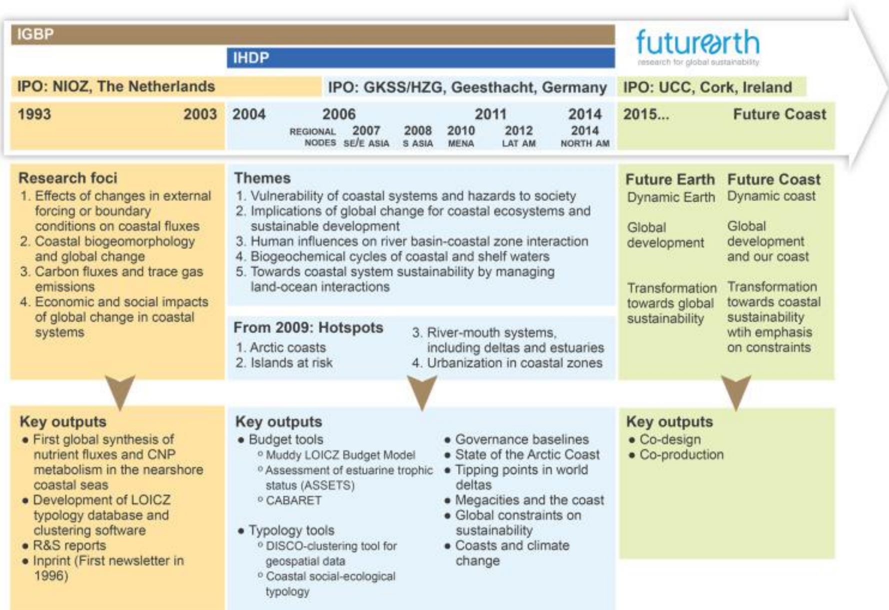


Figure 164. Future and past timeline of the leading science-based coastal interactions program to support understanding and policy development. https://doi.org/10.1016/j.ancene.2016.01.005

Therefore, the integrative and digitalization tools landscape that dominates the present have been applied to the marine environmental matters to support the environmental crisis management and the Mediterranean Sea region is not an exception. The holistic approach to the marine ecosystem management must aim to include all the dimension beyond scientific to assess, analyze, and evaluate potential solutions for the urgent strategic actions across the Mediterranean region in constant development.

It is worth to mention here, that the IMAP is well aligned with the DPSIR model assessment for environmental management in terms of understanding the causes and effects of pressures and impacts, respectively, in the ecosystems within a 6-year cycle and reporting assessment (ca. the Mediterranean Quality Status Report, Med QSR). However, the long-term and strategic management requires higher degree of integration and tools, disregarding the spatial scale (ca. local, national, regional, transboundary). For example, the Integrated Coastal Zone Management (ICZM) framework effective implementation the full IMAP monitoring program requires as well newer digital tools and management strategies from different stakeholders to intervene along the national governments which lead the process. In this sense, the integration and digitalization go beyond the scientific matters. Different authors have been discussing the multiple levels for a successful ICZM implementation and the Figure 166 shows a summary of the findings.

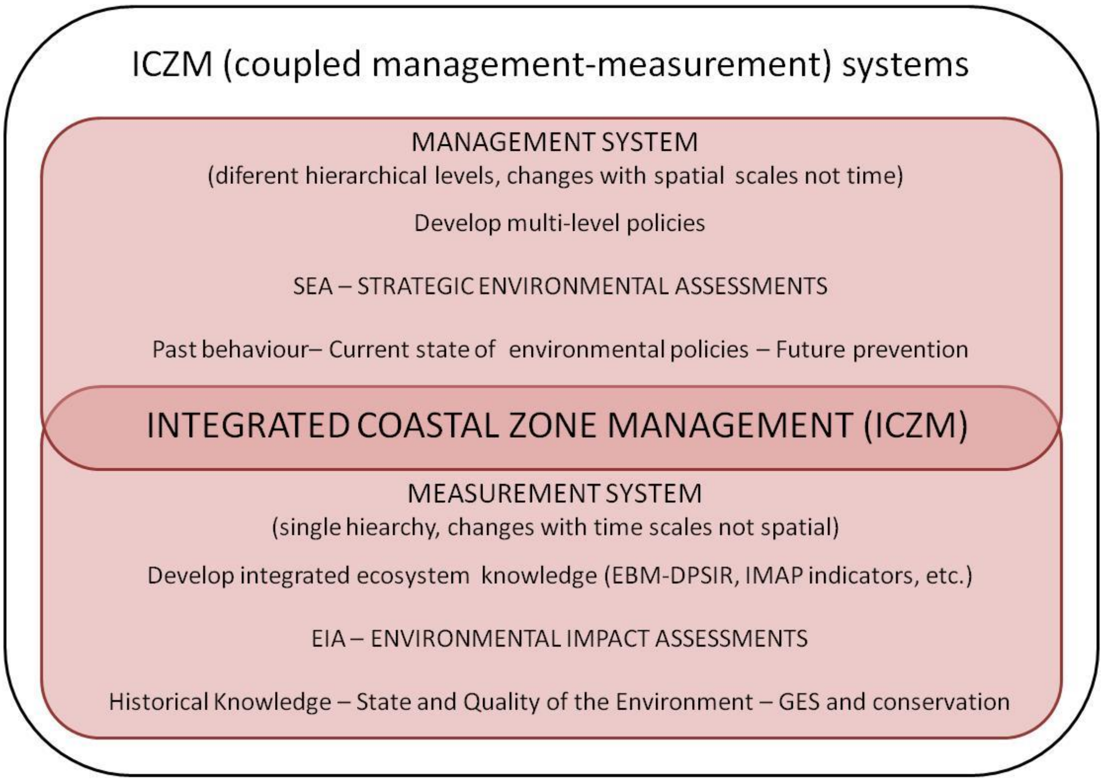


Figure 165. Different levels for a successful implementation of the ICZM at national scale having an impact at transboundary level. It can be observed that IMAP is part of the Measurement System along other mechanisms and does not belong to the Management System with a primary strategic role in governance and multi-level policies.

In Figure 165, the Measurement System implies both the long-term environment marine monitoring, such as IMAP, but also the EIAs integration from the different socioeconomic activities taking place at the marine environment which might pose a risk to maintaining and conserving the sustainability of the marine ecosystem disregarding the spatial or temporal scales. Further, to establish a coherent measurement framework to inform policy and governance, the drivers and pressures (ca. causes) causing the environmental changes need to be at the forefront of the ICZM framework with the aim to correct or to adjust the development of the socioeconomic activities causing pressure and modifying the state of the marine and coastal ecosystems.

4.3.4. Boosting digitalization (science&technology)

Shared issue: Regional observing systems and cooperation

The integration of data and information from different existing initiatives, primarily scientific (e.g., IMAP) but including the support of non-scientific (e.g., civil science), should test the validity of a new number of digitalization tools which could contribute to develop more targeted network for the different transboundary environmental concerns in the Mediterranean, such as for marine litter pollution (Figure 166).

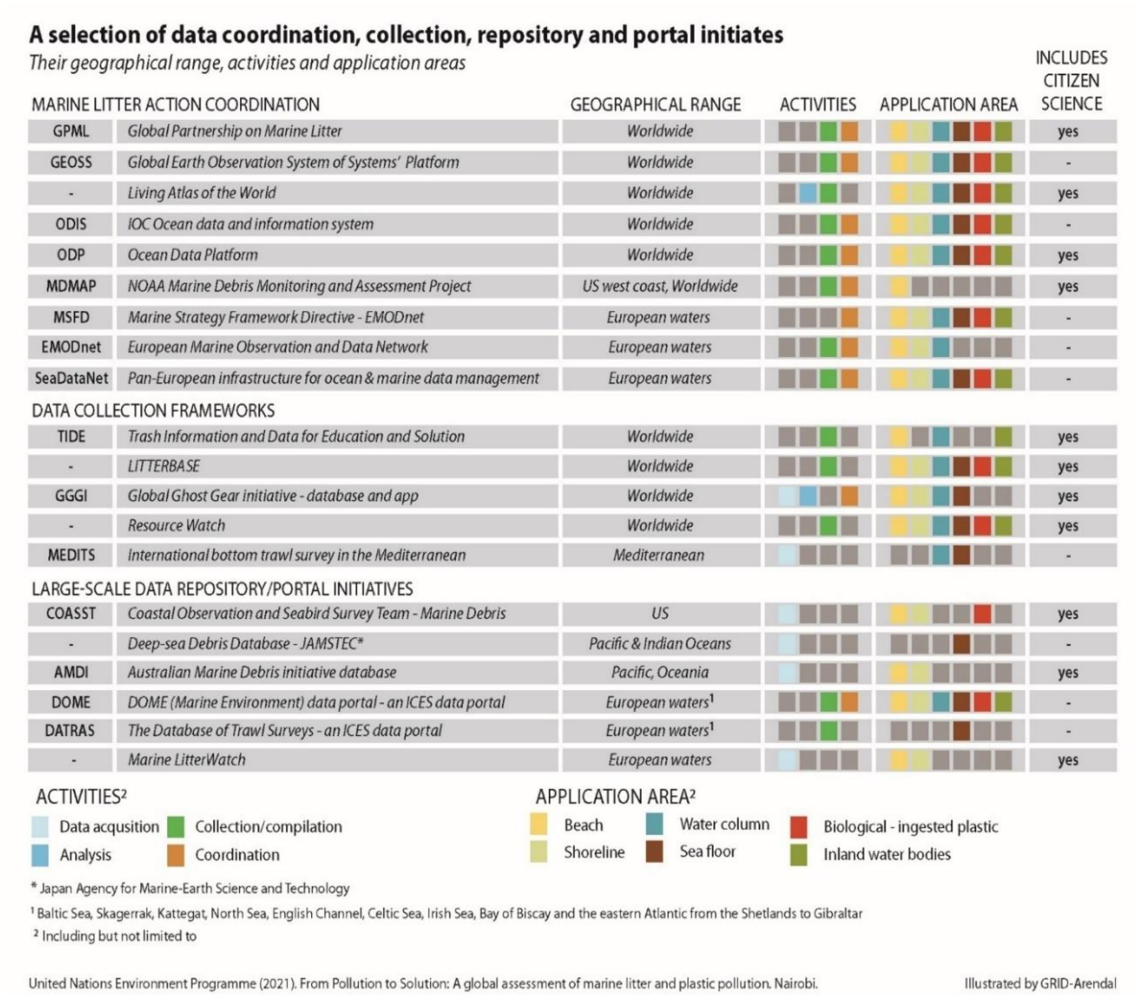
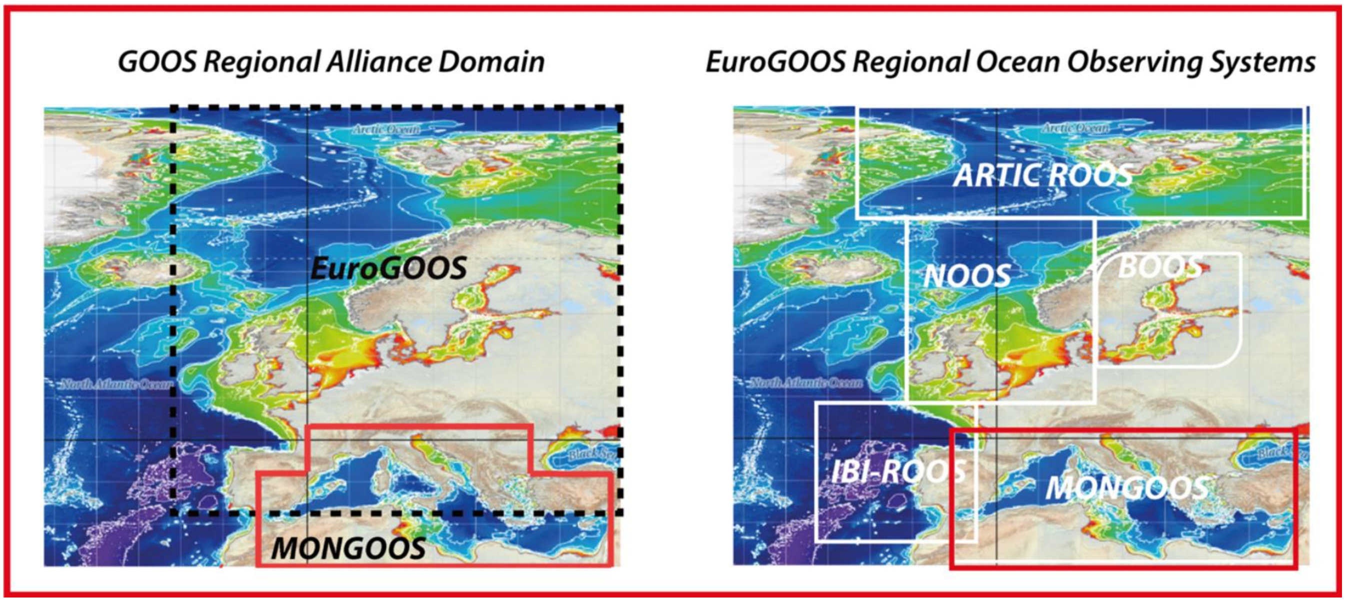


Figure 166. Summary of existing digitalized tools allowing scientific information coordination and integration for marine litter pollution, including civil science (Source: UNEP, 2021)

Helping to bridge the gap between the northern (Europe) and southern (Africa) shores of the Mediterranean Sea (MONGOOS and EuroGOOS).

The Mediterranean Oceanography Network, together with EuroGOOS, is one of the 15 Global Regional Alliances of the Global Ocean Observing System (GOOS), which aims to develop both sustainable ocean monitoring and tailored services to meet regional and national priorities, balancing the global goals of GOOS with the implementation of fit-for-purpose applications to meet local needs. At the European level, MONGOOS plays a key role as one of the five Regional Operational Oceanographic Systems (ROOS) of EuroGOOS, helping to bridge the gap between the northern (Europe) and southern (Africa) shores of the Mediterranean Sea. This alliance focusses on the cooperation on improved national and regional services and products. Further, the European Marine Observation and Data Network (EMODnet) and the Copernicus Program funded by the European Union contribute to the satellite-based observing systems and information digitalization (Figure 167)

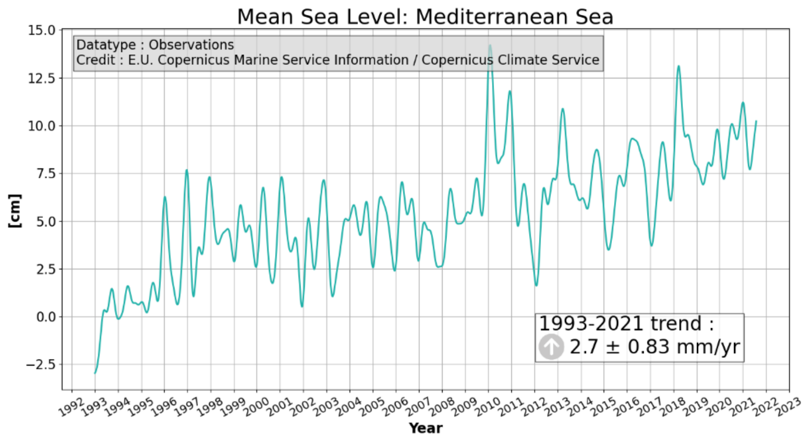


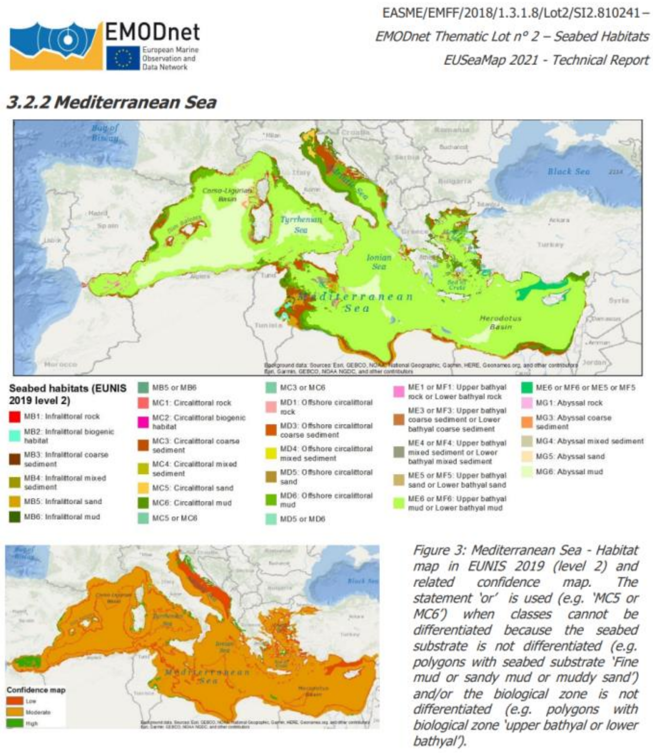
MonGOOS The Mediterranean Operational Network for the Global Ocean Observing System

Mongoos | Data Center (eurogoos.eu)

The major Mediterranean Sea environmental and societal problems and challenges that are of concern for MONGOOS are: 1. changes in the basin hydrological cycle (also due to man-induced changes in the river basins and their runoff), in underground waters, and in precipitation events; 2. climate change impacts and the definition of mitigation and adaptation strategies including the definition of nature-based solutions for the coastal and marine areas 3. fate and dispersion of pollutants in the marine environment (including oil spill and litter) and other contaminants in coastal waters and in the open sea; 4. fate and dispersion of land-derived nutrients and contaminants; 5. habitat loss, coastal erosion, and storm surge; 6. sustainable development of coastal and maritime industry (e.g fishery, aquaculture tourism, transport, extraction of oil and gas, and collection of raw material); 7. marine renewable energies; 8. maritime safety and issues related to border surveillance; 9. algal blooms and adverse effects in coastal areas (anoxia, turbidity, etc.); 10.

ecosystem changes, invasive species, and long term adverse marine trends. 11. increasing threats to coastal and underwater cultural heritage All these problems require a scientific basis of understanding, monitoring, and modelling of the marine environment that is far from being established. The MONGOOS Science and Strategy Plan tries to envisage the research and technology developments necessary to cope with these problems building on a scientific and research-based information system. This system has been developed for operational oceanography and needs to be consolidated now for the rest of the marine environmental variables and for the development of applications pertaining to environmental and societal challenges.




EASME/EMFF/2018/1.3.1.8/Lot2/SI2.810241 –
EMODnet Thematic Lot n° 2 – Seabed Habitats
EUSeaMap 2021 - Technical Report

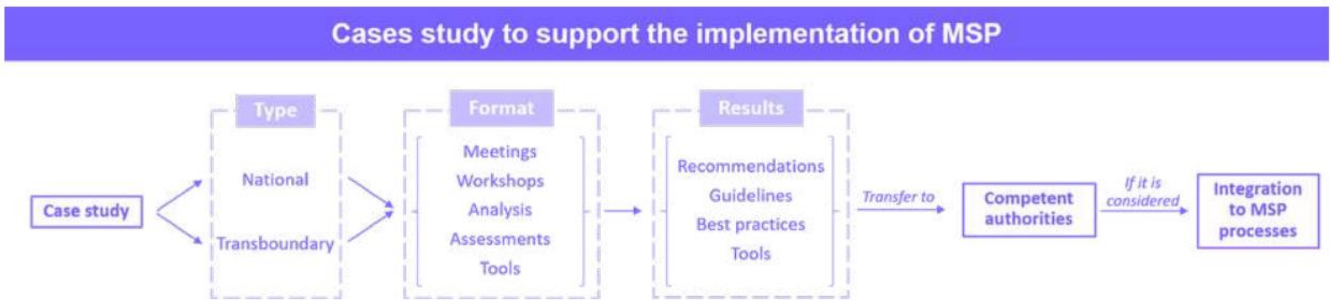
3.2.2 Mediterranean Sea

Seabed habitats (EUNIS 2019 level 2)
MB1: Infralittoral rock
MB2: Infralittoral biogenic habitat
MB3: Infralittoral coarse sediment
MB4: Infralittoral mixed sediment
MB5: Infralittoral sand
MB6: Infralittoral mud
MB5 or MB6
MC1: Circalittoral rock
MC2: Circalittoral biogenic habitat
MC3: Circalittoral coarse sediment
MC4: Circalittoral mixed sediment
MC5: Circalittoral sand
MC6: Circalittoral mud
MC5 or MC6
MC3 or MC6
MD1: Offshore circalittoral rock
MD3: Offshore circalittoral coarse sediment
MD4: Offshore circalittoral mixed sediment
MD5: Offshore circalittoral sand
MD6: Offshore circalittoral mud
MD5 or MD6
ME1 or MF1: Upper bathyal rock or Lower bathyal rock
ME3 or MF3: Upper bathyal coarse sediment or Lower bathyal coarse sediment
ME4 or MF4: Upper bathyal mixed sediment or Lower bathyal mixed sediment
ME5 or MF5: Upper bathyal sand or Lower bathyal sand
ME6 or MF6: Upper bathyal mud or Lower bathyal mud
ME6 or MF6 or ME5 or MF5
MG1: Abyssal rock
MG3: Abyssal coarse sediment
MG4: Abyssal mixed sediment
MG5: Abyssal sand
MG6: Abyssal mud

Confidence map
Low
Moderate
High

Figure 3: Mediterranean Sea - Habitat map in EUNIS 2019 (level 2) and related confidence map. The statement 'or' is used (e.g. 'MC5 or MC6') when classes cannot be differentiated because the seabed substrate is not differentiated (e.g. polygons with seabed substrate 'Fine mud or sandy mud or muddy sand') and/or the biological zone is not differentiated (e.g. polygons with biological zone 'upper bathyal or lower bathyal').

Figure 167. Mediterranean Sea Mean Sea Level time series and trend from Observations Reprocessing from EU Copernicus (top) and EU EMODnet database (bottom).



Towards the operational implementation of MSP in our common Mediterranean Sea

In the project design, the support to Mediterranean MSP was conceived, also by strengthening the data frameworks. The involved countries needed to consider the cross-border dimension of data, by building a common knowledge base then sharing relevant information at basin scale. Downscaling to the national level, the analysis and development of geoportals and the organization of data meant a very practical step in the national planning activities.

European MSP Platform

European Sea Basins | The European Maritime Spatial Planning Platform (europa.eu)

As all EU Member states, the nations are developing MSP to fulfil their requirements under the EU Directive for MSP to deliver maritime spatial planning by March 2021. The following MSP activities are underway. Croatia adopted the Physical Planning Act, which came into force in July 2017 and fully transposed the MSP Directive into the Croatian legislation. The Ministry of Construction and Physical Planning and the Croatian Institute for Spatial Development – which is the expert institution that develops or coordinates the development of these plans – are both the competent authorities for MSP implementation in Croatia. Croatia is developing a new generation of spatial plans to improve the integrity of marine spatial planning, consideration of interactions, effective monitoring and reporting on the state of the maritime area. The country has also been involved in several European project, as described below.

Cyprus has transposed the MSP Directive through its MSP Law, approved by the House of Representatives in October 2017. The competent authority for MSP implementation is the Ministry of Transport, Communication and Works (Department of Merchant Shipping). The Law also established an MSP Committee which oversees the draft MSP. There is, therefore, no MSP Plan developed in Cyprus yet, but the country has been involved in several European projects on MSP.

As mentioned above, a higher degree of integration and effective environmental management also require modern tools to support the management of the complex issues and geographically relevant such as the marine environment. To this regard chart digitalization, and in particular the geographical information systems applied to the marine environment are growing in importance and interest by all the stakeholders and governments (ca. marine and maritime spatial planning. The recent GEF Adriatic project has addressed the issue in the Adriatic area. Figures 168-169 shown the spatial digitalization of the information for the coastal area and proposed IMAP monitoring areas in Albania from different sources, whilst Figure 170 show another application at regional level.

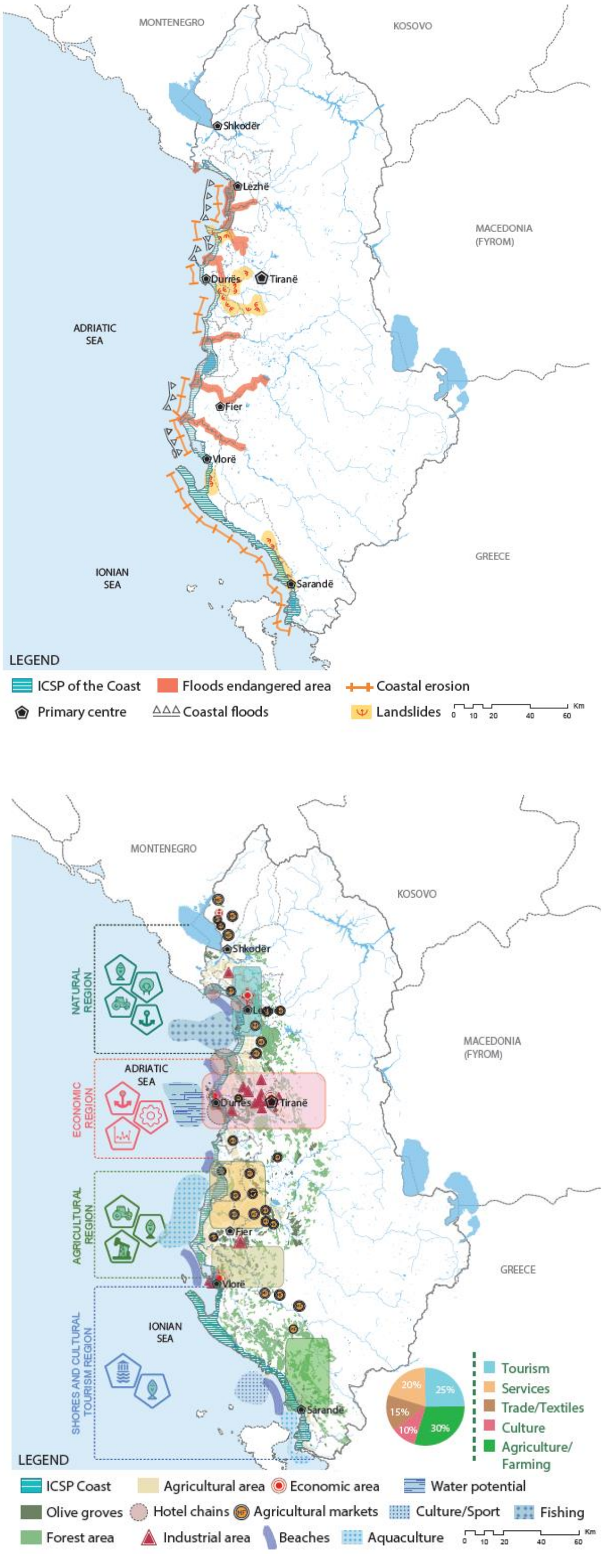


Figure 168. Examples of spatial information digitalization and communication to support stakeholders and civil society on framework and actions (Souce: Coastal Belt, 2030. Albania, 2018)

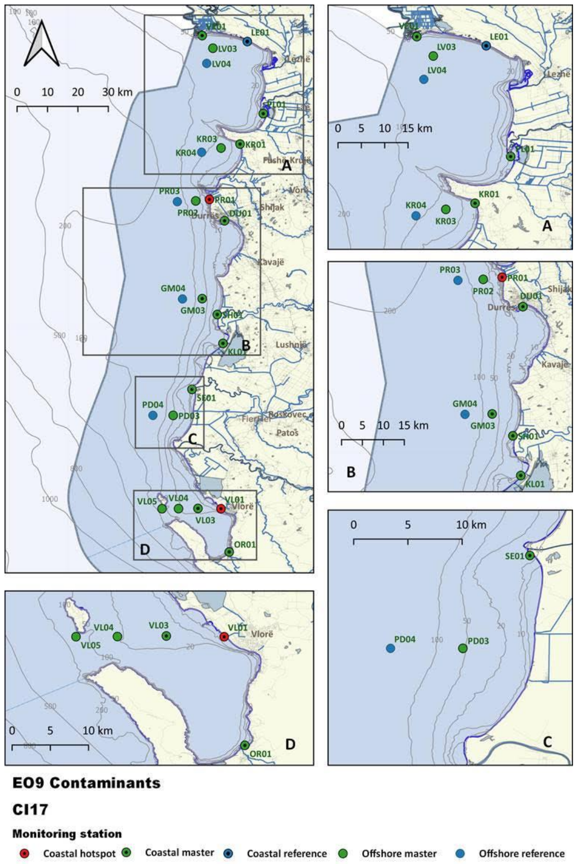


Figure 169. Proposed monitoring areas for the long-term management of the Albanese marine environment to support governance processes for the sustainability of the marine environment and its ecosystem services. (Souce: GEF Adriatic publications, 2021)

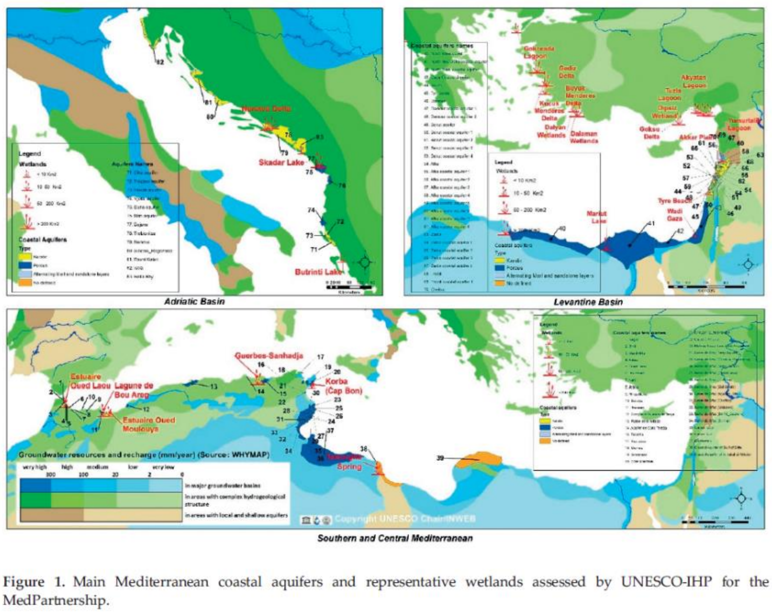


Figure 170. Example of both spatial and scientific information communication by means of geographical information system and information digitalization on Mediterranean coastal aquifers and groundwater resources (Souce: UNESCO/IHP, 2015)

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4.4. Transboundary and shared issues combined diagnostic analysis

INFOGRAPHICS (to be completed) – Tentative example below.

CHAPTER 5. Gender assessment

Overview

All Mediterranean states are committed to the promotion of gender equality and is key for sustainable environment development, including the major transboundary concerns. All countries have signed and ratified the UN Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW)[72] The 2020 State of the Environment and Development in the Mediterranean (SoED) report, recognized women as a key pillar for inclusive development, addressing inequalities and involving civil society in decision and action. It also noted that the socially constructed gender roles and gender-based perceptions result in different outcomes for women and men in relation to the environment. Regrettably, the lack of sex-disaggregated data constitutes a key knowledge gap to be addressed in the Mediterranean region.

Important progress has been made in the region, as legal frameworks have been revised to alleviate gender discrimination in legislation. Legal reform in Egypt made credit more accessible for women by removing gender-based discrimination in financial services, as part of the government's support for women's access to credit and enhancement of financial literacy[73] . This is key as, both women and men have financial stakes in the protection of the environment or whose economic activities affect the Mediterranean environment: fishers, farmers, tourism professionals and others.

However, gender discrimination in legislation persists. Unequal inheritance practices are enshrined in law in south Mediterranean countries (Algeria, Egypt, Morocco, Tunisia)[74]. For example, in Algeria sons and daughters do not have equal rights to inherit assets from their parents, while female and male surviving spouses have no equal rights to inherit assets, thus severely curtailing women's access to land and their ability to use land as collateral to seek finance for establishing a business. This limits women's potential to influence environmental decision-making, and environmental policymaking is often deprived of women's insights. This, in spite of women constituting the main producers of the region's staple crops, contributors to both the fishing and tourism sectors, as well as the majority of urban and rural poor in in densely populated coastal and low- lying areas[75]

North Mediterranean countries in the Balkan peninsula (Albania, Bosnia and Herzegovina, Montenegro) are ranked much higher in gender-specific global indices as compared to south Mediterranean countries (Algeria, Egypt, Lebanon, Libya, Morocco, Tunisia) according to UNDP's Gender Inequality Index (GII), which measures gender inequality using three dimensions: reproductive health, empowerment and the labor market (Figure 171), indicates Montenegro (32), Bosnia and Herzegovina (38) and Albania (39) among high-ranking countries; while Algeria (140), Morocco (136) and Egypt (129) among the lowest ranking countries[76]

[72] https://tbinternet.ohchr.org/_layouts/15/TreatyBodyExternal/Treaty.aspx?Treaty=CEDAW&Lang=en
[73] https://wbl.worldbank.org/en/wbl
[74] https://wbl.worldbank.org/en/wbl
[75] https://www2.ohchr.org/english/bodies/cedaw/docs/gender_and_climate_change.pdf
[76] https://hdr.undp.org/data-center/documentation-and-downloads

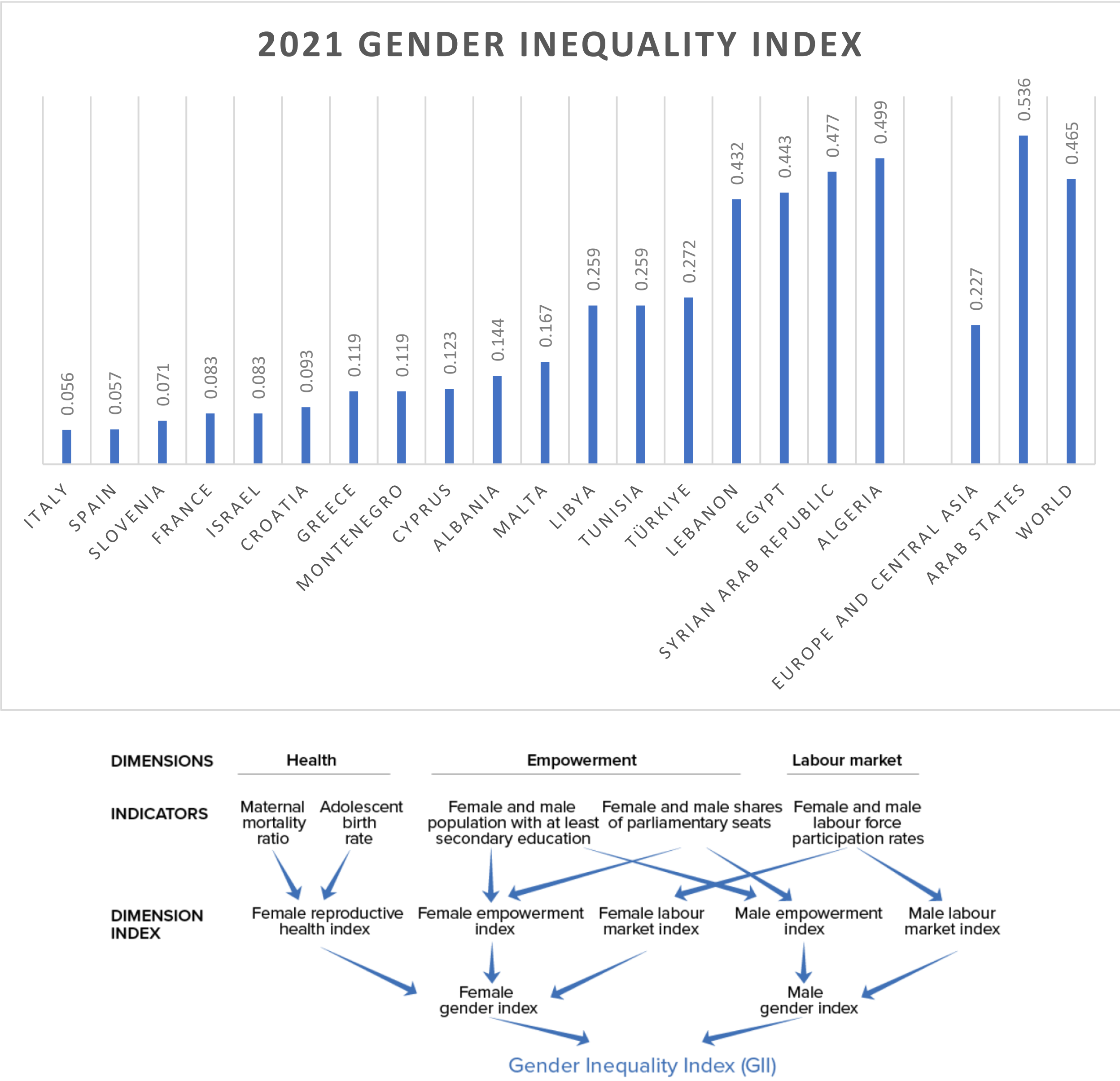


Figure 171. Gender inequality index using three dimensions: reproductive health, empowerment and the labour market. A low GII value indicates low inequality between women and men.

Some countries have also integrated gender considerations and targets in strategic environmental processes. For example, both Albania[77] and Bosnia and Herzegovina[78] have submitted National Adaptation Plans (NAPs) to UNFCCC, integrating gender considerations to varying degrees. Moreover, to Albania's Nationally Determined Contributions (NDCs)[79] ,planned adaptation measures across settlements, populations and tourism activities in the Albanian coast aim include the promotion of gender equality in decision-making, the undertaking of gender analysis at sectoral level to inform climate policies and actions, while discussing gender distribution, gaps and structural barriers regarding climate

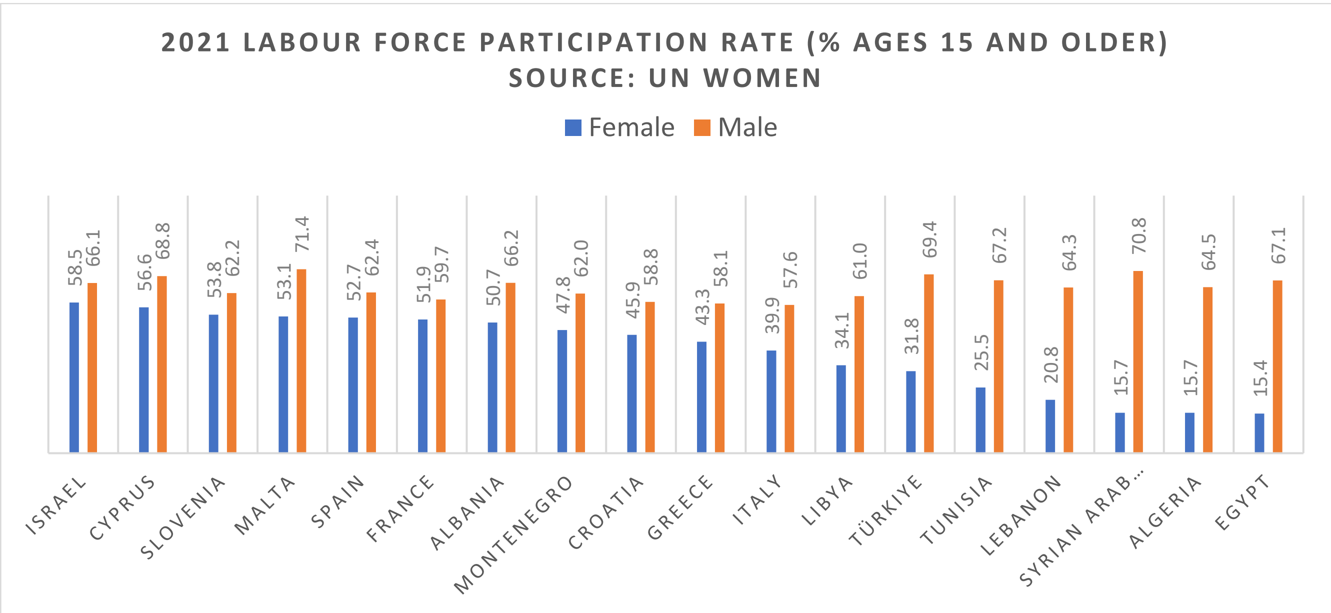
[76] https://www3.weforum.org/docs/WEF_GGGR_2022.pdf
[77] https://unfccc.int/sites/default/files/resource/National_Adaptation_Plan_Albania.pdf
[78] https://unfccc.int/sites/default/files/resource/NAP-Bosnia-and-Herzegovina%20.pdf
[79] https://unfccc.int/sites/default/files/2022-08/Albania%20Revised%20NDC.pdf

risks, impacts and vulnerability, and categorizes and prioritizes adaptive measures. Lebanon also prioritized a gender-responsive just transition in its NDC[80].

Women's Participation in the Economy

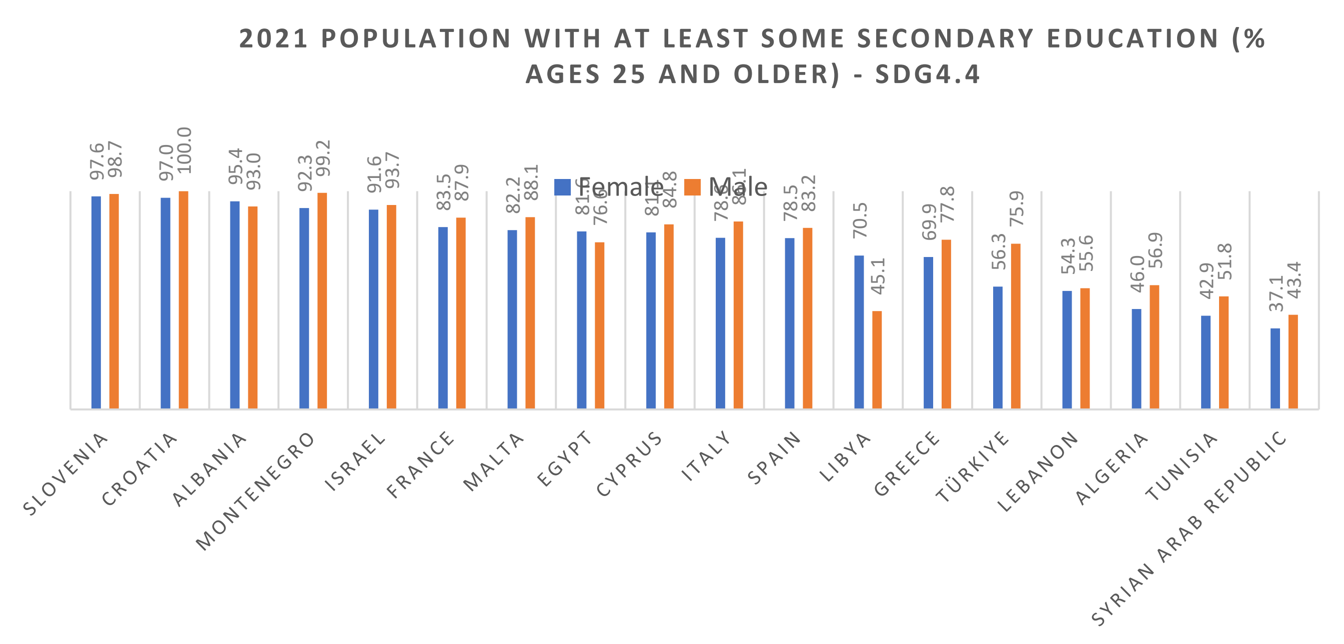
Female labor force participation is lower than male labor force participation in all TDA countries. Nevertheless, significant differences are observed between south and north Mediterranean countries. Egypt has the lowest rate of female labor force participation (18,5%), followed by Algeria (19,2%), Morocco (25,7%) and Tunisia (28,5%). On the contrary, Montenegro has the highest rate of female labor force participation, followed by Albania (42,9%) and Bosnia and Herzegovina (32,2%).

In all TDA countries, women are more likely to be unemployed as compared to men. Libya has the highest rate of female unemployment (26,8%), followed by Tunisia (24,7%) and Egypt (24,3%) as compared to male unemployment rates, which are about 10 percentage points lower in the three countries. Contrastingly, Morocco has the lowest female unemployment rate (11,5%) which is similar to male unemployment rate (10,8%). In North Mediterranean countries by comparison, gender gaps in unemployment rates are smaller and no major differences are observed between women and men: in Bosnia and Herzegovina, the unemployment rate stands at 17,7% for women as compared to 13,6% for men; and in Montenegro unemployment rate stands at 19,3% for women as compared to 17,8% for men. Women are often concentrated in lower-paid, lower-skilled jobs in certain sectors, earning significantly less than men. Women's self-selection into lower-paying sectors is due to their primary responsibility for family care and household duties, which means that women's careers are often regarded as secondary to their role as primary household managers. Gender gaps in employment and discriminatory practices may end up excluding women from green and blue economy growth, particularly in ecotourism, sustainable agriculture, aquaculture, and fisheries. For instance, women are over-represented in the agriculture sector in Morocco (52%, as compared to men (27%), and Bosnia and Herzegovina (20% as compared to men, at 16%).



[80] https://unfccc.int/sites/default/files/NDC/2022-06/Lebanon%27s%202020%20Nationally%20Determined%20Contribution%20Update.pdf

Relevant sectors for green jobs creation that are critical for women's employment include: fisheries, aquaculture, transport, trade, manufacturing, tourism, agriculture (organic farming), eco-tourism, circular economy (incl. recycling, waste-picking, plastic waste processing), blue economy and green innovation. For example, marine and coastal economic activities are characterized by a gendered division of labor: women in the region may rarely work in the marine areas (fishing, diving, working with watersport businesses) yet may often play a key role in fish processing and selling. Gender-based occupational segregation in the small-scale fishing sector and waste management indicates gender differences on the impacts of marine litter, often because of women's informal employment and lack of access to economic and natural resources[81].



Limited access to entrepreneurship is also a reality for women along the Mediterranean coasts. There is very low participation of women in firm ownership, in Lebanon (9,9%) and Algeria (15%), while higher participation of women in firms is noted in Montenegro (24%), Bosnia and Herzegovina (24,5%) and Tunisia (40%). Low levels of female participation in business represents a missed opportunity for job creation and economy growth, given women-owned firms tend to hire more women and have a ripple effect on women's economic opportunities[82]

There are many examples of women across the Mediterranean who have become environmental leaders, promoting sustainable environment development. For example, women in the Kneiss Islands in Tunisia have led marine protection activities promoting marine biodiversity and sustainable resource use in their communities (see Box 1). Other examples from Albania (see Box 2), Lebanon and Turkey, portray women as leaders in the management of MPAs, engaging with local communities to promote the benefits of conservation among fishers whose livelihoods depend on the MPA resources, "building a successful management model where women have a leading and managerial role in nature protection and monitoring".

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81 https://wedocs.unep.org/bitstream/handle/20.500.11822/25348/Gender_Environment_Kit.pdf?sequence=1&isAllowed=y

82 https://ufmsecretariat.org/women-entrepreneurs-from-the-mediterranean-region-meet-to-foster-business-and-investment-opportunities/

BOX 1. The gender approach in Tunisia in the AMCP of the Kneiss Islands, Tunisia

The clam collection business in Kneiss is female-dominated (about 97%) and about 80% of participants in knowledge exchanges are women. An effort is made to promote gender equality in all aspects of MPA creation and management in Kneiss, valuing the skills and knowledge of fisherwomen and involving them in other types of fishing, such as blue crab fishing and providing training on marketing and involvement in various stages of the value chain. Working with women's fishing development groups (Khawela, Zaboussa) and the Association of Women Clam Collectors in Kneiss is also key.

BOX 2. The gender approach in Karaburun-Sazan National Marine Park, Albania[83] [84]

The National Marine Park of Karaburun-Sazan in Albania is led by a woman, Director of the Regional Administration of Protected Areas in Vlora region (RAPA Vlora). According to the Management Plan, there is strong engagement with local communities to promote the benefits of conservation among fishers whose livelihoods depend on the MPA resources, including women. Gender gaps exist and need to be addressed, which is why there is a focus on gender equality in the management of MPAs (NAPA/Ministry of Tourism and Environment). Remedial actions include the promotion of women in decision-making positions, while emphasis is placed on promoting awareness-raising among youth, with a focus on women.

Women's Access to Assets

The southern Mediterranean countries exhibit the lowest rates of female land ownership. Limited land ownership prevents women from using land titles as collateral to access finance, decide on the use of land for irrigation, invest in agricultural (also climate-resilient) technologies, as well as climate-related inputs. Equitable land tenure security is so critical for closing gender gaps that is included in three SDG targets; it is more than formal land titles and encompasses group rights for access to natural resources (wetlands, mangrove forests, flora, fauna). Across Mediterranean countries for which data exists, the highest percentage of women agricultural holders is in Montenegro (12,9%) and much lower in Algeria (4,1%), Morocco (4,4%) and Egypt (5,25)[85]. Inequality in access to land can be attributed to social norms, whereby inheritance practices indicate a preference for sons instead of daughters.

Women are less likely than men to have a bank account at a formal financial institution, which constitutes an impediment to income-generating activities. The biggest gender gaps in bank account ownership between women and men are observed in Algeria (32,1% v. 56,8%), Morocco (32,7% v. 56%) and Tunisia (28% of women v. 45,1% of men). This may be attributed to social norms about women's role as mothers and household managers, indicating that women setting up and running businesses may be considered "inappropriate". Lack of access to credit finance, information on sustainable use and conservation, as well as new technologies may restrict women's potential to contribute towards sustainable solutions through nature-based solutions and climate resilience initiatives.

83 https://drive.google.com/file/d/1UW3YLiyVGpk5f2RKG_QL07wbzcdlKWpm/view
84 https://medmpaforum.org/en/DS30_en
85 https://www.fao.org/gender-landrights-database/data-map/statistics/en/?sta_id=982

Gender differences in environmental health

Gender interacts with the social, economic and biological determinants and consequences of marine pollution, posing health risks that affect women and men differently. Pollutants reach women and men through the consumption of contaminated and polluted water, seafood products, contact with contaminated water or seafood and polluted air intake. Marine products workers, swimmers, divers, consumers are all exposed to those risks; yet women's biological characteristics can render them and their infants disproportionately vulnerable to environmental health risks, particularly during menstruation, pregnancy, and breast-feeding[86].

Mercury, for instance, is a PCB and a critical environmental risk, as it can be transferred through the air, water and solid waste streams[87]. Women's exposure to mercury results in a higher incidence of hormonal disorders, reduced fertility and negative impact on the infant's development, posing risks of children's reduced IQ due to high levels of mercury. Studies show that the unborn fetus and small children are affected by the contamination of seafood by mercury that circulates globally, far from its original source of emissions[88]

Studies show also that women's exposure to various plastics such as heavy metals, microplastics and other highly toxic POPs has significant impacts on their health and as potential child bearers, as well as through exposure via cosmetics and other feminine products[89] For example, higher levels of phthalates, which are often used as a plasticizer and increase the risk of recurrent pregnancy loss, are found in women, since they are common in cosmetic products[90]. Moreover, microplastics were recently detected in human placentas[91] Finally, women's role as primary household managers, including the sorting, removal, and disposal of household waste, also poses significant health risks.

Women in decision-making

Women tend to occupy fewer decision-making positions when it comes to sustainable environment management in the Mediterranean, even though their role is critical in environmental governance. While women's participation in politics has gradually increased, women remain underrepresented in national parliaments. The highest share of women's participation in parliament is observed in Egypt (27,6%), Montenegro (27,2%) and Tunisia (26,3%), while the lowest share is observed in Lebanon (6,3%) and Algeria (8,1%)[92] in 2022.

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[86] Lynn H, Rech S and Samwel-Mantingh M, 'Plastic, Gender and the Environment. Findings of a Literature Study on the Lifecycle of Plastics and Its Impacts on Women and Men, from Production to Litter.' http://rgdoi.net/10.13140/RG.2.2.33644.26242, accessed 18 November 2020.

[87] https://ipen.org/sites/default/files/documents/ipen-gender-chemicals-report-v1_6dw-en.pdf

[88] *https://www.mercuryconvention.org/sites/default/files/documents/2021-08/Gender_Equality_Mercury_May_2021.pdf*

[89] https://wedocs.unep.org/bitstream/handle/20.500.11822/35417/EJIPP.pdf

[90] Gao C-J and others, 'Feminine Hygiene Products—A Neglected Source of Phthalate Exposure in Women' (2020) 54 Environmental Science & Technology 930

[91] Ragusa A and others, 'Plasticenta: First Evidence of Microplastics in Human Placenta' (2021) 146 Environment International 106274

[92] https://data.ipu.org/women-ranking?month=11&year=2022

Women remain underrepresented in ministerial positions, too, even if they enter parliament. In 2015, only 13% of fisheries-related ministries were headed by women in 2015, while women constituted 30% of top ministerial positions in environment-related sectors globally in 2017[93], testament to women's limited influence in environmental decision-making and policy-making that is less reflective of women's needs and priorities as a result of unequal representation in political life. Figure 172 shows the percentage of share of seats in parliament held by women in 2021.

Likewise, women's representation in local/community decision-making bodies is low, as a result of social norms. In some Mediterranean countries, women may not pariticpate in decision-making regarding water allocation and distribution, even though they are the primary managers for water collection and consumption. A study from Egypt showed a lack of women's representation in Water User Associations (WUAs) due to social norms[94]

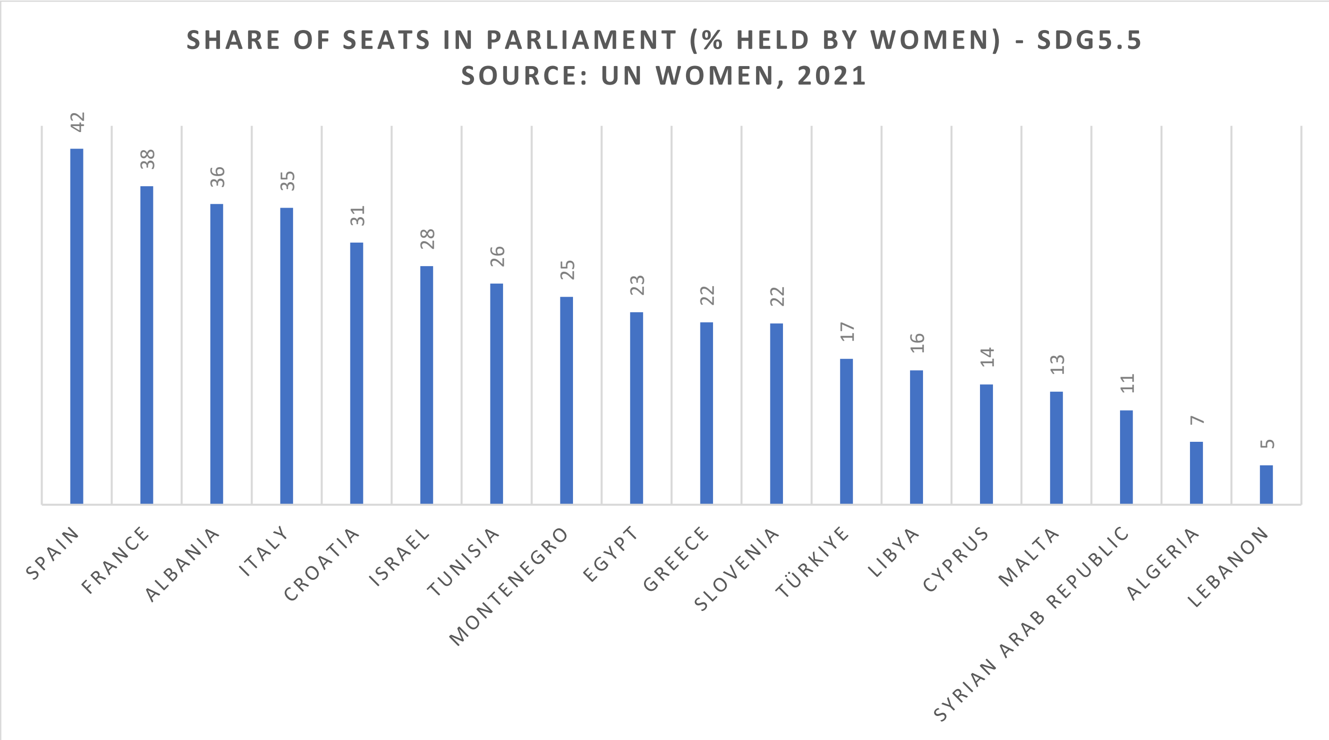

Figure 172. Share of seats in parliament (% held by women) - SDG5.5. Source: UN women, 2021

To address women's underrepresentation in leadership positions, organizations such as the General Fisheries Commission for the Mediterranean actively promote women's participation in decision-making processes. Recognizing that women constitute a significant share of member countries' aquaculture workforce (reaching 26% in some countries), their representation in leadership positions is rather limited. The GFCM is helping to ensure women's voices are heard by providing them with a strong basis for advancing in the field and empowering them in decision-making processes[95].

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93 https://www.iucn.org/news/gender/202103/new-data-reveals-slow-progress-achieving-gender-equality-environmental-decision-making
94 https://wocatpedia.net/wiki/File:GIZ_(2010)_Women_and_Water_Management_in_Egypt.pdf
95 https://fiskerforum.com/empowering-women-for-roles-in-aquaculture/

Table 43. Key Gender Indicators in CP1.1. GEF MedProgramme countries.

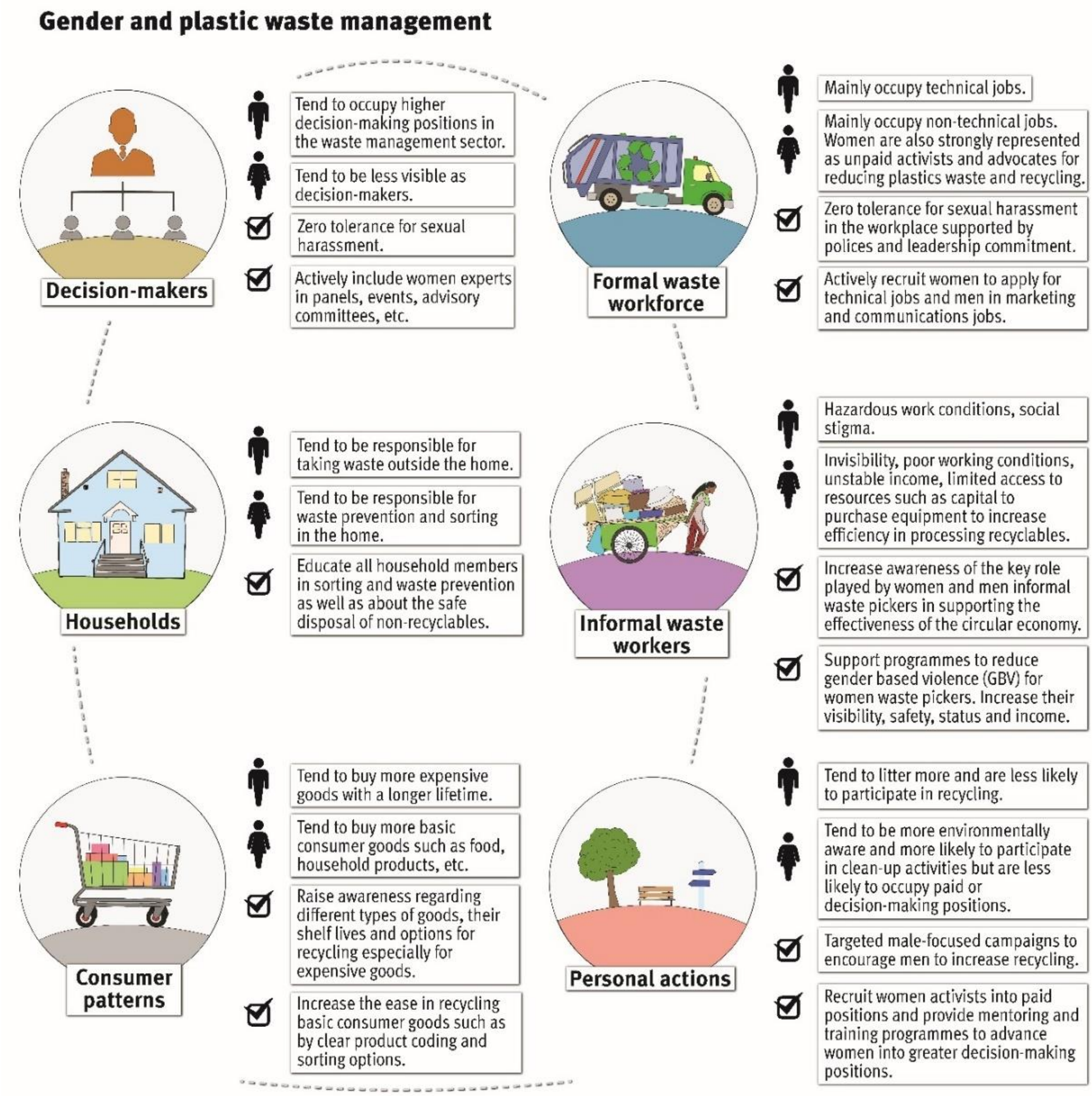
	Albania	Algeria	Bosnia & Herzegovina	Egypt	Lebanon	Libya	Montenegro	Morocco	Tunisia
Women's Participation in the Economy									
Labor Force, female (% of total labor force)[96] (2021)	42,9	19,2	39,2	18,5	24,5	35,6	45,4	25,7	28,5
Employment in agriculture, female (% of female employment) (2019)		3	20	21	9	16	7	52	9
Employment in agriculture, male (% of male employment) (2019)		11	16	48	12	17	8	27	15
Unemployment, female (% of female labor force) (2021)		22,1	17,7	24,3	18,6	26,8	19,3	11,5	24,7
Unemployment, male (% of male labor force) (2021)		10,4	13,6	15	13,1	15,5	17,8	10,8	13,7
Vulnerable employment, female (% of female labor force) (2019)		23	22	28	14	34	9	56	11
Vulnerable employment, male (% of male labor force) (2019)		28	17	15	36	36	17	43	21
Proportion of time spent on unpaid domestic and care work, female (% of 24 hour day)	22 (2011)	22 (2012)	-	22 (2015)	-	-	-	21 (2012)	22 (2006)
Proportion of time spent on unpaid domestic and care work, male (% of 24 hour day)	3 (2011)	4 (2012)	-	2 (2015)	-	-	-	3 (2012)	3 (2006)
Women's Access to Assets									
Distribution of Agricultural Holders by sex (%) (female)[97]	-	4,1 (2001)	-	5,2 (1999)	7,1 (1998)	-	12,9 (2010)	4,4 (1996)	6,4 (2004-5)

[96] https://data.worldbank.org/indicator/SL.TLF.TOTL.FE.ZS
[97] https://www.fao.org/gender-landrights-database/data-map/statistics/en/?sta_id=982

Account at a financial institution (%) (female)[98]	45,7 (2021)	31,2 (2021)	70,4 (2021)	24,2 (2021)	16,6 (2021)	59,6 (2017)	67,6 (2017)	32.7 (2021)	28,8 (2021)
Account at a financial institution (%) (male)[99]	42,6 (2021)	56,8 (2021)	88,7 (2021)	30,6 (2021)	24,7 (2021)	70,7 (2017)	69,2 (2017)	56 (2021)	45,1 (2021)
Women in Decision-Making/Leadership Roles									
Firms with female participation in ownership (% of firms)[100]	20,7 (2019)	15 (2007)	24,9 (2019)	17,8 (2020)	9,9 (2019)	-	24 (2019)	16,1 (2019)	40,1 (2020)
Firms with female top manager (% of firms)[101]	18,1 (2019)	-	17 (2019)	6 (2020)	6 (2019)	-	15 (2019)	5 (2019)	10 (2020)
Women in Parliament (lower/upper chamber) (%)[102] (2023)	35,7	8,1/4,3	16,7/20	27,6/13,3	6,3	16,5	27,2	24,1/12,5	26,3

	Albania	Algeria	Bosnia & Herzegovina	Egypt	Lebanon	Libya	Montenegro	Morocco	Tunisia
Human Development Index[103] (2021-2)	67	91	74	97	112	104	49	123	97
Gender Inequality Index[104] (2022)	39	126	38	109	108	61	32	104	61
Global Gender Gap[105] (2022)	18	140	73	129	119	-	54	136	120

[98] https://databank.worldbank.org/source/global-financial-inclusion
[99] https://databank.worldbank.org/source/global-financial-inclusion
[100] https://data.worldbank.org/indicator/IC.FRM.FEMO.ZS
[101] https://data.worldbank.org/indicator/IC.FRM.FEMM.ZS
[102] https://data.ipu.org/women-ranking?month=11&year=2022 (last accessed February 2023).
[103] https://hdr.undp.org/data-center/documentation-and-downloads
[104] Gender Inequality Index (GII) measures gender inequality using three dimensions: reproductive health, empowerment and the labour market. https://hdr.undp.org/data-center/documentation-and-downloads
[105] https://www3.weforum.org/docs/WEF_GGGR_2022.pdf



UNEP (2021). Drowning in plastics – Marine Litter and Plastic Waste Vital Graphics.

References

CHAPTER 6. Stakeholder analysis

From UNEP MAP Website (to be completed)

The Mediterranean Sea region and the MAP-Barcelona Convention system rests upon a solid foundation of partnership and cooperation with regional and global institutions since 1975. Over the years, MAP has sought to foster existing partnerships and to enter in new ones in line with the priorities set by the Contracting Parties[106] to the Barcelona Convention and its Protocols[107].

MAP Partnerships provide a mechanism through which other institutions contribute with their expertise and resources for joint endeavors relevant to the MAP mandate and vision, and with the Barcelona Convention and its Protocols as an overarching framework.

The UNEP/MAP—Barcelona Convention system cooperates with various UN entities, Multilateral Environmental Agreements (MEAs), and other Inter-Governmental organizations active in the field of Mediterranean or global environmental protection. It also recognizes the expertise of Mediterranean Non-Governmental Organizations (NGOs), supports their initiatives, and encourages their participation in MAP activities. Such partnerships support, inter alia, capacity building and technical assistance for the development of measures and the implementation of the Barcelona Convention and its Protocols.

Partnerships with Inter-Governmental Organizations (IGOs)

International governmental organizations active in fields relevant to the Barcelona Convention may be admitted as observers at the meetings and conferences of the Contracting Parties.

MAP works closely with several global and regional actors building on comparative advantages, complementarities and maximized synergies.

List of IGOs and other Partners

- Arab Forum for Environment and Development (AFED)
- Benguela Current Convention
- C.I.E.S.M. The Mediterranean Science Commission
- CEDARE Centre for Environment and Development for the Arab Region and Europe
- Centre International de Hautes Études Agronomiques Méditerranéennes (CIHEAM)
- European Environment Agency (EEA)
- European Landscape Convention
- Mediterranean Wetlands Initiative (MEDWET)
- RAMOGE Agreement
- RAMSAR Convention on Wetlands of International Importance especially as Waterflow Habitat
- Secretariat of the Bern Convention

The MAP Coordinating Unit signed Memoranda of Understanding or other collaboration agreements with:

[106] Contracting Parties | UNEPMAP
[107] Barcelona Convention and Protocols | UNEPMAP

- Agreement on the Conservation of Cetaceans of the Black Sea and contiguous Atlantic Area (ACCOBAMS)
- Basel, Rotterdam, and Stockholm (BRS) Conventions
- Food and Agriculture Organization of the United Nations (FAO)
- General Fisheries Commission for the Mediterranean (GFCM)
- Global Environment Facility (GEF)
- International Atomic Energy Agency (IAEA)
- International Maritime Organization (IMO)
- International Union for Conservation of Nature (IUCN)
- London Convention and Protocol
- Permanent Secretariat of the Commission on the Protection of the Black Sea Against Pollution (BSC PS)
- Union for the Mediterranean (UfM)
- United Nations Educational Scientific and Cultural Organization (UNESCO)
- World Bank

Partnerships with non-governmental Organizations (NGOs)

The Contracting Parties grant MAP Partner status to Non-Governmental Organizations, thus encouraging their participation in MAP meetings, activities, and overall goals set under the Barcelona Convention and its Protocols.

The Contracting Parties have adopted Decision IG.19/6 "MAP/Civil society cooperation and partnership", which includes the Code of Conduct for MAP Partners and the criteria and a procedure for admission as MAP Partners of the international, civil society Organizations/NGOs NGOs as well as national and local non-governmental organizations. MAP Partners are international and regional NGOs, as well as national and local NGOs from Mediterranean riparian States. They represent important sectors of public opinion and contribute to raising awareness and public participation on issues related to environmental protection and sustainable development in the Mediterranean.

MAP Partners participate as Observers in the meetings of the Contracting Parties and in activities as part of the implementation of the Programme of Work. They also provide expertise and technical support to pursue objectives and promote policies, strategies and programmes derived from the Barcelona Convention and its Protocols.

MAP Partners are also eligible for membership in the Mediterranean Commission on Sustainable Development (MCSD), an advisory body to the Contracting Parties to the Barcelona Convention.

List of MAP Partners

- All For Blue
- Arab Network for Environment and Development (RAED)
- Arab Office for Youth & Environment (AOYE)
- Asociación ONDINE
- Association de Recherche Environnement et Bio Innovation” (AREBI)
- Association for Nature, Environment and Sustainable Development (SUNCE)
- Association of Continuity of Generations (ACG)

- Association Sawa for Development
- BirdLife Malta (BLM)
- Blue World Institute of Marine Research and Conservation (BWI)
- Center for Energy, Environment and Resources (CENER21)
- Centre of Documentation, Research and Experimentation on accidental water pollution (CEDRE)
- Cercle Mallorquí de Negocis (CMN)
- Cittadini per l'aria onlus
- EcoPeace Middle East
- Eco-Union
- Egyptian Sustainable Development Forum (ESDF)
- Environmental Center for Administration and Technology (ECAT Tirana)
- European Topic Centre – University of Malaga (ETC-UMA)
- Fondation Mohamed VI pour la Protection de l'Environnement
- Fondazione IMC-Centro Marino Internazionale ONLUS
- Forum of Adriatic and Ionian Cities (FAIC)
- French Water Academy
- Global Balance Association
- Global Footprint Network (GFN)
- Greenpeace International
- Hellenic Marine Environment Protection Association (HELMEPA)
- Hellenic Ornithological Society (BirdLife Greece)
- Human Environmental Association for Development (HEAD)
- Innovation&Development Association (INNODEV)
- International Association for Mediterranean Forests (AIFM)
- International Association of Geophysical Contractors (IAGC)
- International Centre of Comparative Environmental Law (CIDCE)
- International Federation for Sustainable Development and Fight to Poverty in the Mediterranean-Black Sea (FISPMED)
- Marevivo
- Mediterranean Association to Save the Sea Turtles (MEDASSET)
- Mediterranean Coastal Foundation (MEDCOAST)
- Mediterranean Conservation Society
- Mediterranean Information Office for Environment, Culture and Sustainable Development (MIO-ECSDE)
- Mediterranean Programme for International Environmental Law and Negotiation (MEPIELAN)
- Mediterranean Protected Areas Network (MedPAN)
- Mediterranean SOS Network (MedSOS)
- Oceana
- OceanCare
- Palestine Wildlife Society
- Plastics Europe AISBL
- Secretariat MedWet (MedWet)
- Slovenian Marine Mammal Society (MORIGENOS)
- SUBMON
- Surfrider España
- Sustainable Development Solutions Network (SDSN) through the Università di Siena (UNISI)

- Syrian Environment Protection Agency (SEPS)
- The Agency for Sustainable Mediterranean Cities and Territories (AVITEM)
- The ARAVA Institute for Environmental Studies (AIES)
- The International Association of Oil & Gas Producers (IOGP)
- The Mediterranean network of cities (Med Cities)
- Tour du Valat Foundation
- Turkish Marine Environment Protection Association (TURMEPA)
- Turkish Marine Research Foundation (TUDAV)
- UniVerde Foundation
- World Ocean Council (WOC)
- WWF Mediterranean (WWF Med)
- Youth Love Egypt

The MAP Regional Activity Centres also enter into bilateral agreements with partners to further the implementation of the MAP-Barcelona Convention objectives in accordance with their mandate as approved by the Contracting Parties to the BC and its Protocols. Further information is provided on the RACs websites.

These open lists of regional stakeholders above supporting the UNEP/MAP system converges with the global stakeholders aligned through the UN system tackling the priority environmental emergencies some of which are found in the Mediterranean. In the Figure 173, an example of convergence among different UN system bodies (ca. stakeholders) for plastic pollution is shown and where the UNEP Mediterranean Action Plan (and Barcelona Convention Secretariat) appears under the Regional Seas Action Plans along a list of global stakeholders.

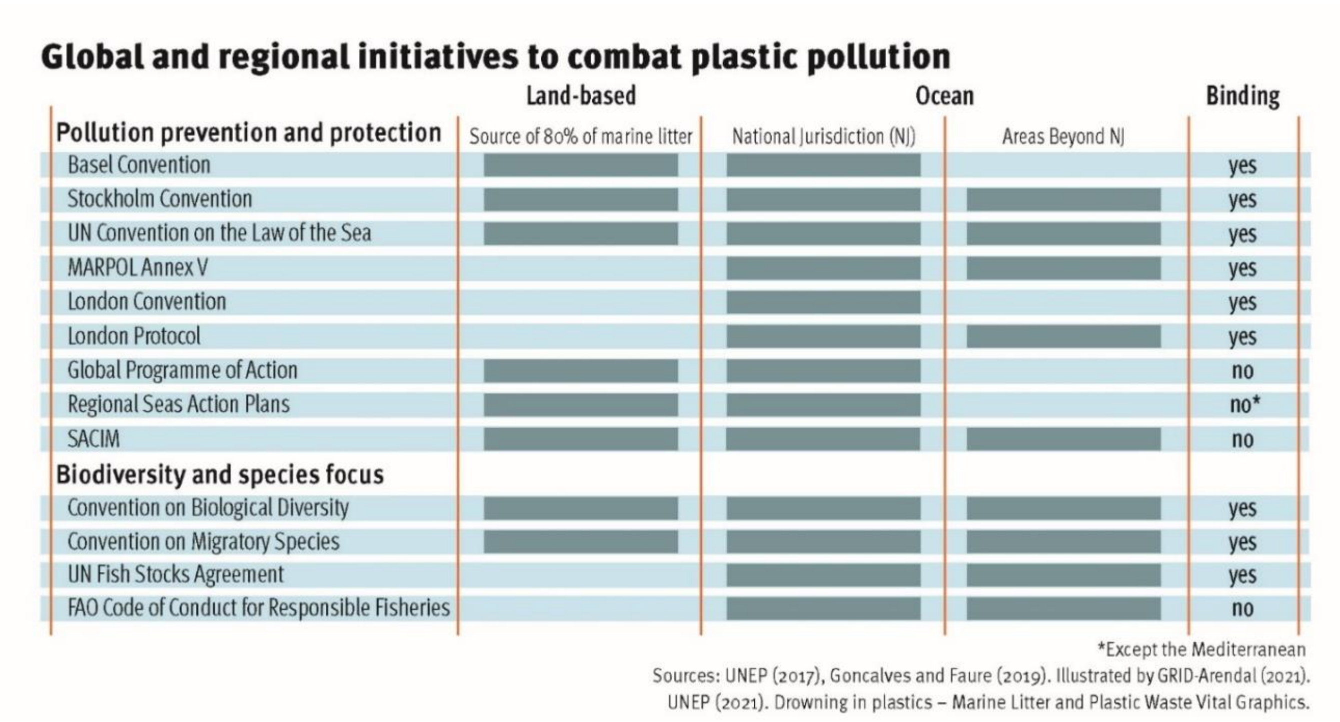
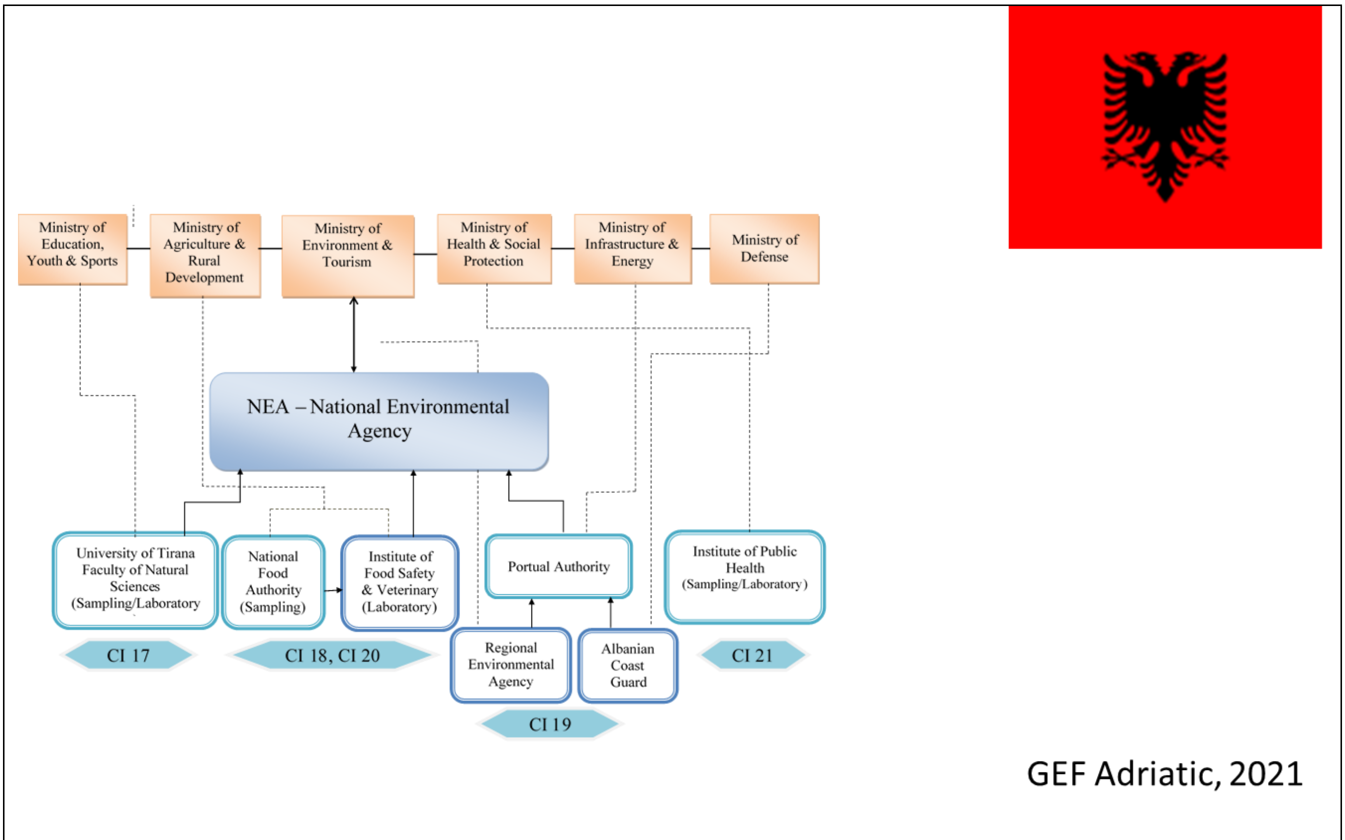


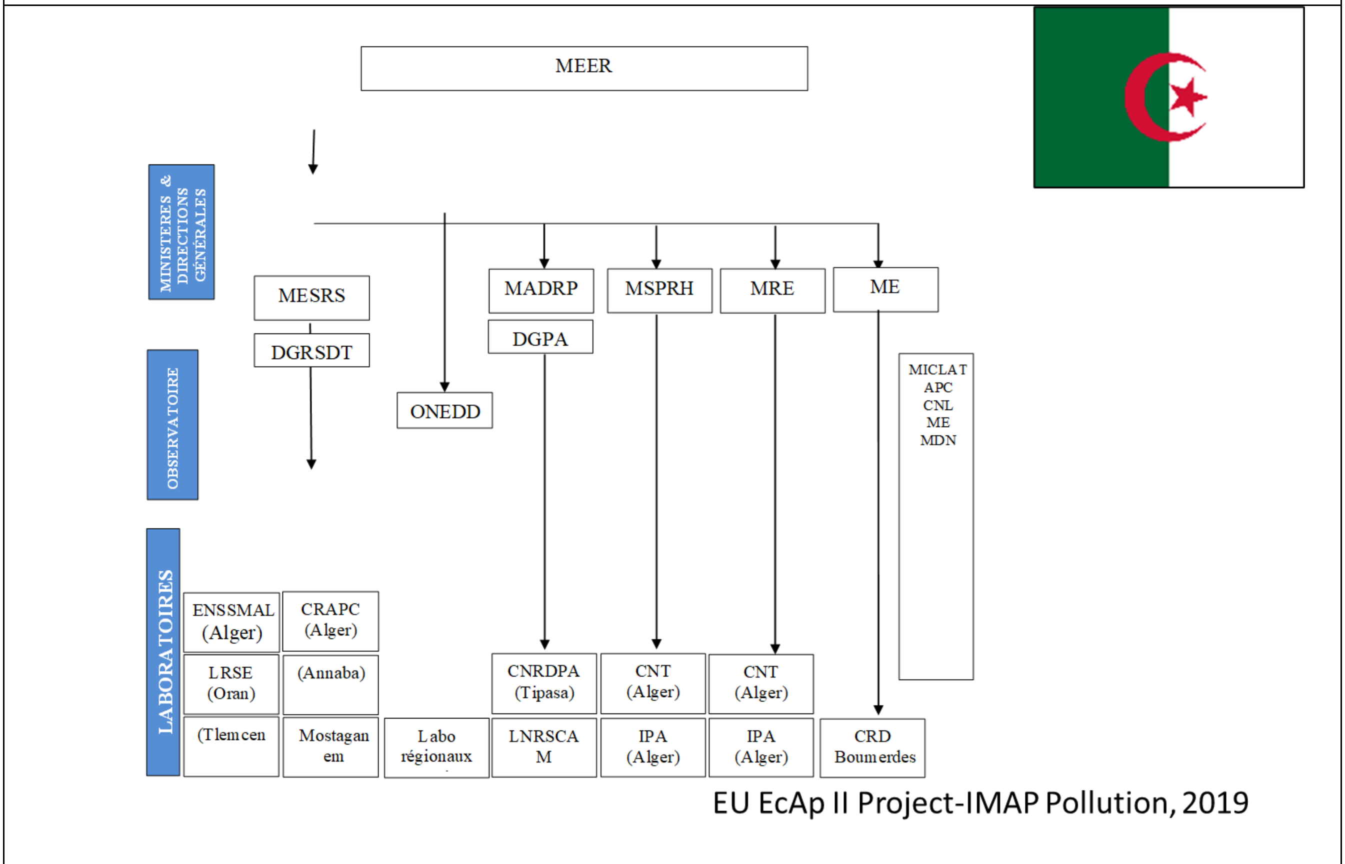
Figure 173. Global and regional initiatives to combat plastic pollution.

Finally, the Figure 174 below shows the organizational structure between 2019-2021 of the national governments within Contracting Parties directly involved through the GEF MedProgramme CP1.1. in the development of the national and regional strategies and plans related mostly to pollution, namely Albania, Algeria, Bosnia and Herzegovina, Lebanon, Egypt, Libya, Montenegro, Morocco and Tunisia. It is important to highlight that governmental structures are not yet enough similar among the countries to allow a harmonized and effective approach for the regional environmental management cooperation.

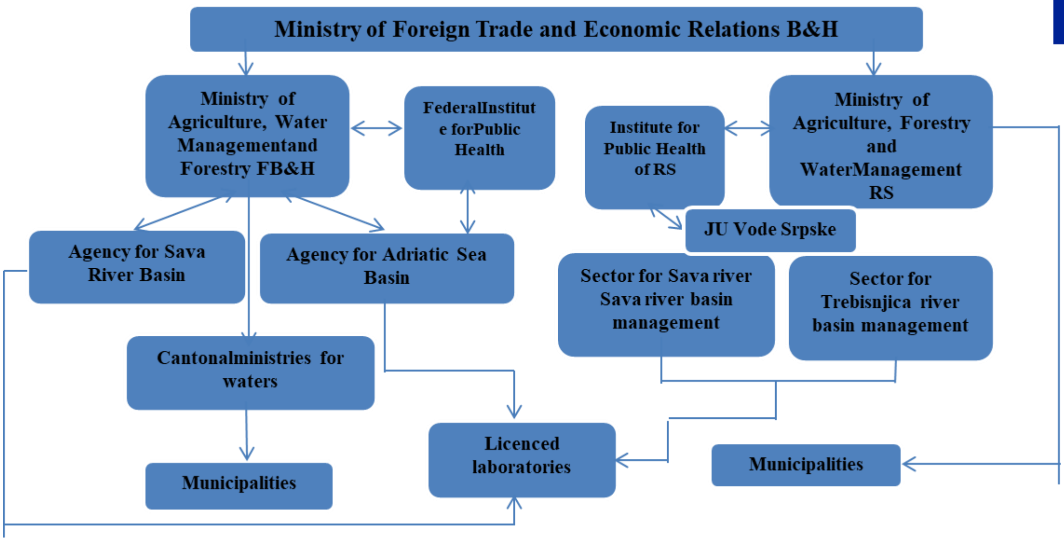
Figure 174. National organizational structures of the CP1.1. partner countries (stakeholders). Sources: EU EcAp MED II (2016-2019) and GEF Adriatic (2018-2020).



A) ALBANIA

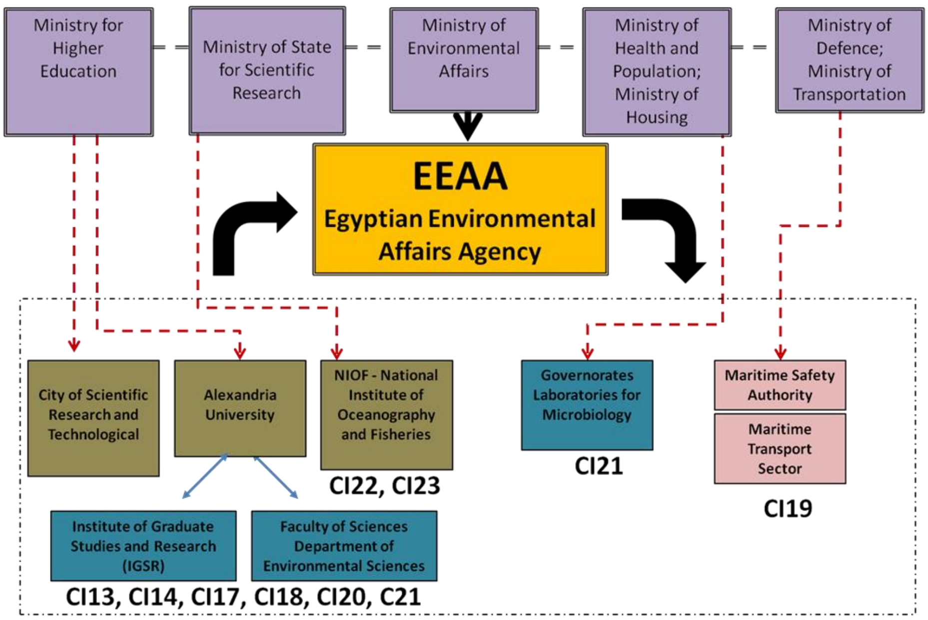


B) ALGERIA



EU EcAp II Project-IMAP Pollution, 2019

C) BOSNIA AND HERCEGOVINA



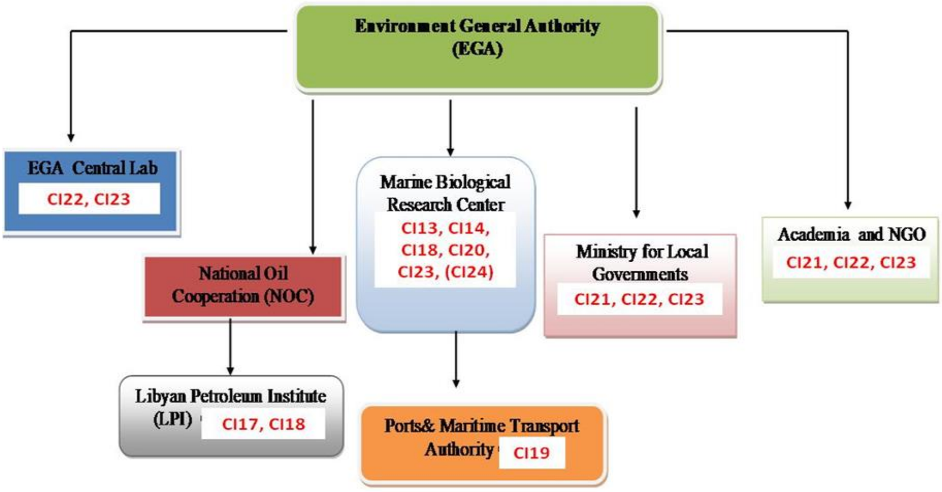
EU EcAp II Project-IMAP Pollution, 2019

D) EGYPT

- The Ministry of Environment (MoE)
- The Ministry of Public Works and Transport (MoPWT)
- The Ministry of Energy and Water (MoEW)
- The Ministry of Public Health (MoPH)
- The Ministry of Agriculture (MoA)
- The Ministry of Interior (MoI) and Municipalities
- The National Center for Marine Sciences (NCMS) affiliated to the National Council forScientific Research Lebanon (CNRSL)
- The National Center for Remote Sensing (NCRS) affiliated to the National Council for Scientific Research Lebanon (CNRSL)
- The National Center for Geophysics (NCG) affiliated to the National Council for Scientific Research Lebanon (CNRSL)
- The Lebanese Atomic Energy Commission (LAEC) affiliated to the National Council for Scientific Research Lebanon (CNRSL)
- Observatories for the environment and sustainable development
- Non-Governmental Organizations (NGOs)
- Monitoring programme(s), networks and other environmental monitoring initiatives

EU EcAp II Project-IMAP Pollution, 2019

E) EGYPT



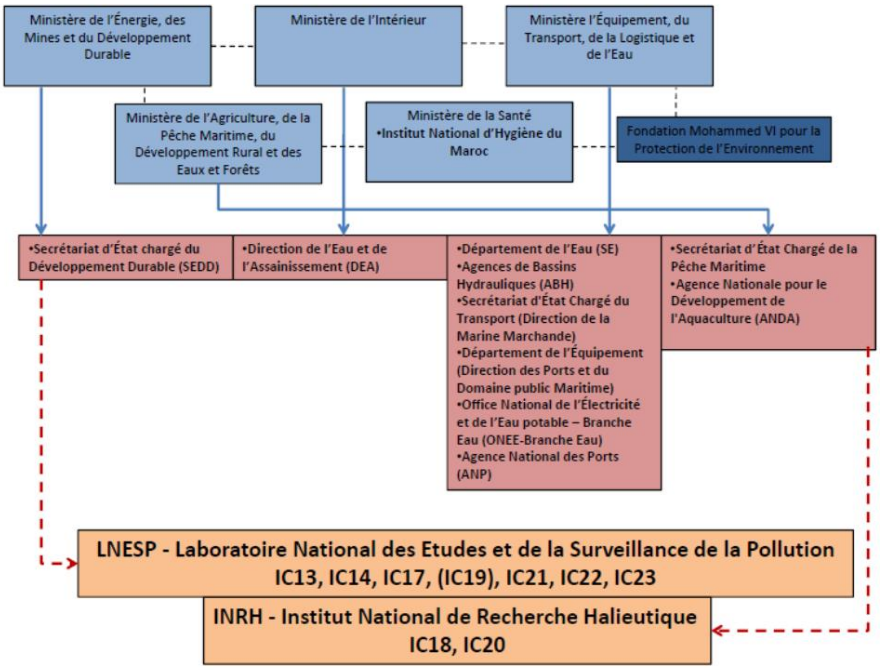
EU EcAp II Project-IMAP Pollution, 2019

F) LIBYA

- Ministry of Ecology Spatial Planning and Urbanism
- Environmental Protection Agency

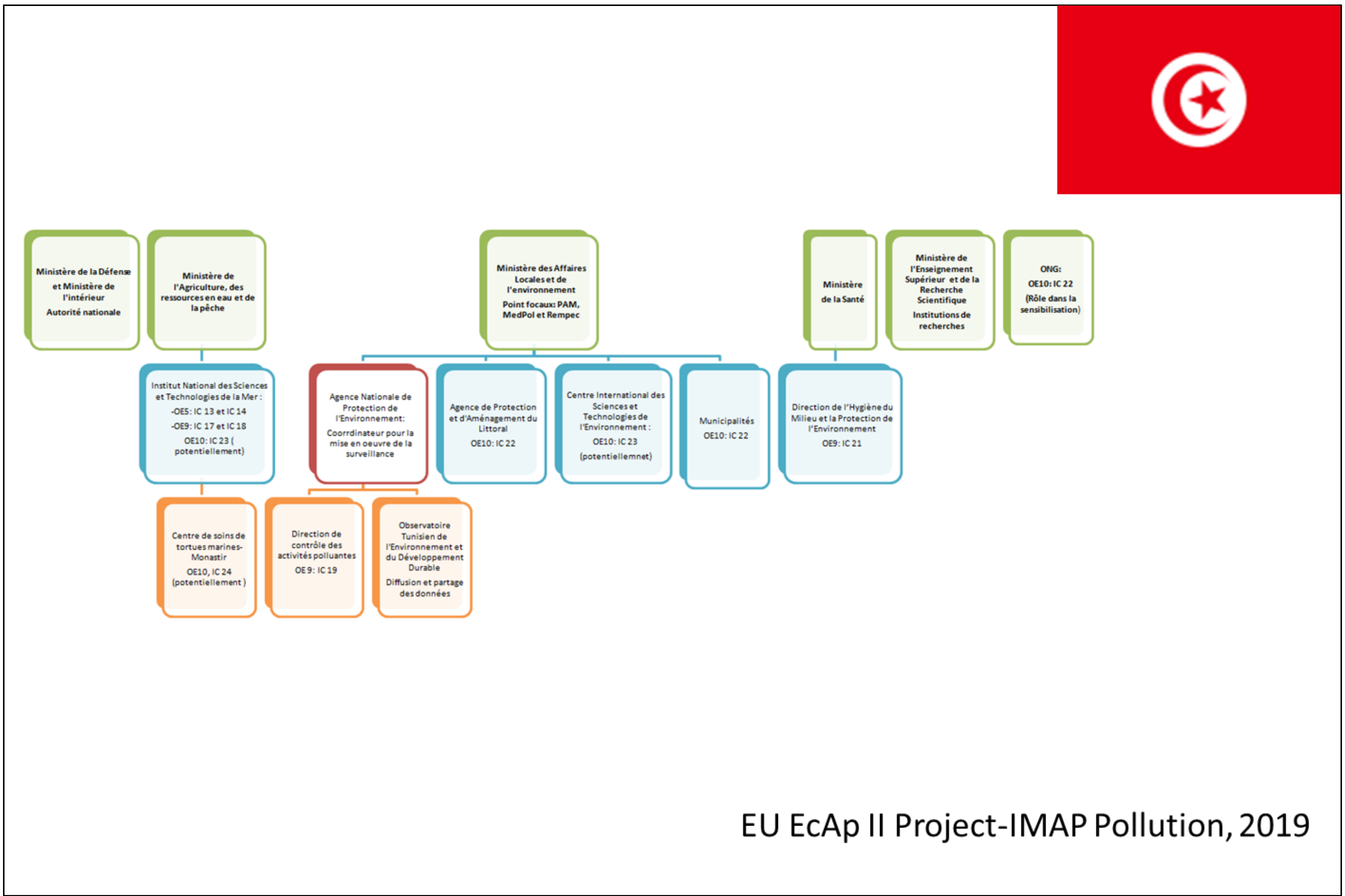
EU EcAp II Project-IMAP Pollution, 2019

G) MONTENEGRO



EU EcAp II Project-IMAP Pollution, 2019

H) MOROCCO



I) TUNISIA

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[Mediterranean | UNEP – UN Environment Programme](#)

CHAPTER 7. Governance analysis

The environmental governance of the Mediterranean Sea cannot be understood without understanding the motivations and experience built by the Mediterranean Action Plan and the declaration of the Barcelona Convention and its Protocols led by the riparian countries in the Mediterranean region back in the 70s. This chapter updates previous information provided both in published reports and at the UNEP/MAP website.

Historical note on the UNEP/MAP system: the United Nations Environment Programme / Coordinating Unit for the Mediterranean Action Plan (MAP) and Barcelona Convention Secretariat

The MAP system has primarily three dimensions from an executive perspective:

J) Institutional: Contracting Parties, UN Environment/MAP Secretariat composed of the UN Environment Coordinating Unit and seven components[108], and Mediterranean Commission on Sustainable Development as advisory body;
K) Regulatory: seven Protocols and an extensive body of strategies, action plans and decisions;
L) and Implementation-related: partnerships, programmes, projects and activities for the delivery of the mandate), the MAP system has a unique and prominent role in the Mediterranean region for the protection of the marine environment and its coastal region as a contribution to sustainable development.

The MAP was the first UNEP initiative to be developed under the Regional Seas Programme. MAP's initial objectives were to assist the Mediterranean Governments to assess and control pollution, as well as to formulate their national marine environmental policies. The Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention) and two Protocols addressing the prevention of pollution by dumping from ships and aircraft and cooperation in combating pollution in cases of emergency were also approved in 1975. In 1995, in the aftermath of the Rio Summit, the Contracting Parties decided to revise the MAP and the Convention. The Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (MAP Phase II) was adopted in 1995 with the following objectives:

- to ensure the sustainable management of natural marine and land resources and to integrate the environment in social and economic development, and land-use policies;
- to protect the marine environment and coastal zones, through prevention of pollution, and by reduction and as far as possible, elimination of pollutant inputs whether chronic or accidental;
- to protect nature, and protect and enhance sites and landscapes of ecological or cultural value;

[108] The Mediterranean Pollution Assessment and Control Programme (MED POL) based at the Coordinating Unit in Athens, Greece.
The Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) based in Valletta, Malta.
The Plan Bleu Regional Activity Centre (PB/RAC) based in Marseille, France
The Priority Actions Programme Regional Activity Centre (PAP/RAC) based in Split, Croatia.
The Specially Protected Areas Regional Activity Centre (SPA/RAC) based in Tunis, Tunisia
The Regional Activity Centre for Sustainable Consumption and Production (MedWaves) based in Barcelona, Spain
The Regional Activity Centre for Information and Communication (INFO/RAC) based in Rome, Italy

- to strengthen solidarity amongst Mediterranean coastal states, in managing their common heritage and resources for the benefit of the present and future generations; and
- to contribute to the improvement of the quality of life.

In 1995, the Contracting Parties adopted substantial amendments to the Barcelona Convention of 1976 and renamed it as Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, which entered into force in 2004. The amended Convention embodies international partnership to protect the sea, its coasts, and the uses and livelihoods that it supports. It provides a critical framework for setting environmental standards and targets agreed by all the Contracting Parties, as well as for sharing important information for management.

Seven Protocols[109], addressing specific aspects of Mediterranean environmental conservation, and a number of regional plans complete the MAP legal framework:

1. The Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft (Dumping Protocol)
2. The Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea (Prevention and Emergency Protocol)
3. The Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (LBS Protocol), including Regional plans under Article 15 of LBS Protocol
4. The Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA-BD Protocol)
5. The Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal (Hazardous Wastes Protocol)
6. The Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil (Offshore Protocol)
7. The Protocol on Integrated Coastal Zone Management in the Mediterranean (ICZM Protocol).

In addition, a number of key strategies have been developed and adopted:

- Mediterranean Strategy for Sustainable Development (MSSD)
- Strategic Action Program to address pollution from land-based activities (SAP-MED) and Action plans on pollution reduction deriving from specific provisions of the LBS Protocol
- Strategic Action Plan for the conservation of marine and coastal biodiversity in the Mediterranean (SAP-BIO) and Action plans on species deriving from specific provisions of the SPA-BD Protocol
- Regional Action Plan on Sustainable Consumption and Production (SCP) in the Mediterranean
- Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021)
- Ballast Water Management Strategy.
- Finally, given the increasing impact of climate change on the marine and coastal environment of the Mediterranean, the Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas was adopted in 2016.

[109] Barcelona Convention and Protocols | UNEPMAP ; Regional regulatory measures | UNEPMAP

In 2008, the Contracting Parties committed to apply the Ecosystem Approach with its vision for "A healthy Mediterranean with marine and coastal ecosystems that are productive and biologically diverse for the benefit of present and future generations". The following three strategic goals were identified for marine and coastal areas, based on the relevant priority field of action of the MSSD and the experience gained by other international and regional bodies:

1. To protect, allow recovery and, where practicable, restore the structure and function of marine and coastal ecosystems thus also protecting biodiversity, in order to achieve and maintain good ecological status and allow for their sustainable use.

2. To reduce pollution in the marine and coastal environment so as to minimize impacts on and risks to human and/or ecosystem health and/or uses of the sea and the coasts.

3. To prevent, reduce and manage the vulnerability of the sea and the coasts to risks induced by human activities and natural events.

In 2012, the Contracting Parties adopted 11 Mediterranean Ecological Objectives (EO) to achieve GES, as presented in table 1 below. Supported by thematic Correspondence Groups on Monitoring (CORMON) on pollution and marine litter, biodiversity and fisheries, and coast and hydrography, and based on the above-mentioned 11 Ecological Objectives, common indicators, Good Environmental Status (GES) definition and targets were developed and adopted by the Contracting Parties to the Barcelona Convention in 2012 and 2013.

In 2015 the first six-year MAP Medium-Term Strategy (MTS 2016-2021) and the Mediterranean Strategy for Sustainable Development (MSSD) 2016-2025, which provides a strategic policy framework for securing a sustainable future for the Mediterranean region consistent with the Sustainable Development Goals, are adopted by COP 19 Barcelona Convention. In 2016, the implementation of the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coasts and Related Assessment Criteira (i.e., UNEP/MAP IMAP) started and the first Mediterranean Quality Status Report (Med QSR) was published and presented at the COP20 in 2017.

In 2019, the COP 21 Barcelona Convention adopts the Naples Ministerial Declaration, which describes 2020 as a "critical turning point for the conservation and sustainable management of the Mediterranean Sea and coast" and underscores the "need for a systemic change supported by forward-looking and innovative strategies, policies, and behaviors".

The 22nd Meeting of the Contracting Parties to the Barcelona Convention and its Protocols (COP 22) took place on 7-10 December 2021 in Antalya, Türkiye. Branded the "COP for the Mediterranean, COP 22 marked 45 years of seamless environmental multilateralism and regional solidarity under the UNEP/MAP-Barcelona Convention system. COP 22 offered an inclusive platform for renewed commitment in the Mediterranean and sent a clear signal that UNEP/MAP is ready to act effectively and in a timely manner to support the region in building back greener with strong environmental objectives.

In 2021, at the COP 22 the Contracting Parties gave the green light to the Medium-Term Strategy (MTS - 2022-2027) of the United Nations Environment Programme's Mediterranean Action Plan (UNEP/MAP). The MTS will aim to achieve transformational change and contribute to bend current trajectories. The effective implementation of the MTS will situate the region on a path of sustainability, thus pushing for a green recovery in the Mediterranean.

The latest action-oriented decisions were adopted at the COP22 in December 2021:

Towards an Emission Control Area for Sulphur Oxides

COP 22 adopted a ground-breaking decision on the Designation of the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides (MED SOx ECA) pursuant to MARPOL Annex VI. The measure is expected to generate significant benefits for human health and for the integrity of ecosystems, which both suffer from harmful SOx emissions from the maritime transport sector, one of the pillars of the blue economy in the Mediterranean.

Biodiversity protection and conservation

On biodiversity, COP 22 adopted the Post-2020 Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region (Post-2020 SAPBIO), which is aligned with the building blocks of the Global Biodiversity Framework finalized in 2022 by UNCBD. This achievement was complemented with agreement on a Post-2020 Regional Strategy for protecting and conserving the Mediterranean through well connected and effective systems of marine and coastal protected areas and other effective area-based conservation measures, and with Action Plans for the conservation of species and habitats under the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean.

Land- and sea-based pollution

- Amendments to the Regional Plan on Marine Litter Management in the Mediterranean in the Framework of Article 15 of the Land Based Sources Protocol;
- Amendments to Annexes I, II and IV to the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (LBS Protocol);
- Regional Plans on Urban Wastewater Treatment and Sewage Sludge Management in the Framework of Article 15 of the Land Based Sources Protocol;
- The Mediterranean Strategy for the Prevention, Preparedness and Response to Marine Pollution from Ships (2022-2031);
- The Ballast Water Management Strategy for the Mediterranean Sea (2022-2027);
- Amendments to the Annex to the Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea (Dumping Protocol);
- Amendments to the Annexes to the Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil (Offshore Protocol).

Circular economy and green business

- A set of Regional Measures to Support the Development of Green and Circular Businesses and to Strengthen the Demand for more Sustainable Products.

From UNEP MAP Website (to be completed)[110]

The organizational structure of the governance in the Mediterranean is coordinated by UNEP as follows:

A) In line with Article 17 of the Barcelona Convention, UNEP provides secretariat services to the Contracting Parties through its MAP Coordinating Unit, established in Athens in 1982 on the basis of a Host Country Agreement between Greece and UNEP.

The overall mission of the Coordinating Unit, is to promote and facilitate the implementation of the Barcelona Convention, its Protocols and Strategies, and of the Decisions and Recommendations of the Contracting Parties. It ensures the functioning of the MAP system and facilitates the work of the Contracting Parties to meet their commitments under the Barcelona Convention and its Protocols.

The UNEP/MAP Coordinating Unit:

- develops, implements and monitors the Programme of Work, organizes and provides secretariat services for the meetings of subsidiary bodies established within the MAP framework.
- provides through the UN Mediterranean knowledge platform (INFO/MAP) system effective reporting services to facilitate implementation Barcelona Convention and is entrusted with regularly reporting on the State of the Environment and Development in the Mediterranean and on the overall status of implementation of the Barcelona Convention and its Protocols.
- ensures the financial management of the MAP system and coordinating the implementation and periodic updating of the MAP information and communication policy.

In implementing its Programme of Work, the Coordinating Unit receives the technical support and assistance of the MAP Components in accordance with their individual mandates, and with specific decisions of the Contracting Parties.

B) Focal Points – They are appointed by the Contracting Parties to review the progress of work and ensure the implementation of recommendations at the national level.

C) Bureau – Six representatives of the Contracting Parties, elected in accordance with Article 19 of the Barcelona Convention provides guidance on the implementation of the Programme of work in the interim period between the biennial meetings.

D) Mediterranean Commission on Sustainable Development (MCSD) – the advisory body established in 1996 by the Contracting Parties to underpin the implementation of the Barcelona Convention was instrumental in integrating the Sustainable Development Goals (SDGs) into the Mediterranean Strategy on Sustainable Development (MSSD)—a strategic guiding document for all stakeholders and partners to translate the 2030 Agenda for Sustainable Development at the regional, sub-regional and national levels. MCSD brings together government representatives, local authorities, socio-economic actors, NGOs, the scientific community, IGOs, and parliamentarians.

E) Compliance Committee –. To facilitate and promote compliance with the obligations under the Barcelona Convention and its Protocols, the Barcelona Convention Compliance Mechanism: (1) establishes a Compliance Committee dedicated to help Parties to implement the Barcelona Convention and its Protocols; (2) establishes a procedure that is non-adversarial, transparent, preventive and non-binding in nature; (3) takes into account the specific situation of each Party; (4) considers specific situations of actual or potential non-compliance by individual Parties with a view to determining the facts

[110] Mediterranean | UNEP – UN Environment Programme

and causes of the situation; (5) promotes compliance and addresses cases of non-compliance by providing Parties advice and non-binding recommendations; and (6) considers, at the request of the Meeting of the Contracting Parties, general issues of compliance under the Barcelona Convention and its Protocols.

The work of the MAP—Barcelona Convention system is guided by a six-year Medium-Term Strategy (MTS) and implemented through two-year Programmes of Work and budgets adopted by the meetings of the Contracting Parties.

The UNEP/MAP Medium-Term Strategy (MTS) for 2022-2027 was adopted by the 22nd Meeting of the Contracting Parties to the Barcelona Convention and its Protocols (COP 22, 7-10 December 2021, Antalya, Turkey).

The strategy is aligned with the Rio+20 Outcome Document and the 2030 Agenda for Sustainable Development, and contributes to the achievement of the Sustainable Development Goals (SDGs) and their targets as part of the delivery of the UNEP/MAP mandate.

Underpinning the UNEP/MAP's role as an integrator of global processes at the regional level, the strategy encompasses contributions to the implementation of the Post-2020 Global Biodiversity Framework, the Paris Agreement, the UN Decade of Action for the SDGs, the UN Decade on Ecosystem Restoration and the UN Decade of Ocean Science for Sustainable Development.

The MTS 2022-2027 vision

"Progress towards a healthy, clean, sustainable and climate resilient Mediterranean Sea and Coast with productive and biologically diverse marine and coastal ecosystems, where the 2030 Agenda for sustainable development and its SDGs are achieved through the effective implementation of the Barcelona Convention, its Protocols and the Mediterranean Strategy for Sustainable Development for the benefit of people and nature."

Objectives:

- To drive transformational change and enhance the impact of the MAP-Barcelona Convention system and its contribution to the Mediterranean region;
- To ensure that the Good Environmental Status (GES) of the Mediterranean Sea and coast, the relevant SDGs and their targets, and the post-2020 global biodiversity goals (and associated targets) are achieved through concrete actions to effectively manage and reduce threats and enhance marine and coastal resources;
- To contribute to strengthening Mediterranean solidarity and peoples' prosperity;
- To contribute to the Building Back Better approach of the UN framework for the immediate socio-economic response to COVID-19 towards a green recovery of the Mediterranean by supporting new and sustainable business models, enabling a just and green transition to nature-based solutions and a circular economy.

Structure

The MTS 2022-2027 structure reflects:

- Legal commitments of the Contracting Parties to the Barcelona Convention and their Decisions and needs expressed at the regional and national levels;
- The Mediterranean Strategy for Sustainable Development (MSSD);
- The UNEP Strategy for 2022-2025.

The MTS 2022-2027 comprises:

Four thematic programmes:

1. Towards a Pollution and Litter Free Mediterranean Sea and Coast Embracing Circular Economy
2. Towards Healthy Mediterranean Ecosystems and Enhanced Biodiversity
3. Towards a Climate Resilient Mediterranean
4. Towards the Sustainable Use of Coastal and Marine Resources including Circular and Blue Economy

A foundational Programme on "Governance"

Two enabling Programmes:

1. Towards Monitoring, Assessment, Knowledge and Vision of the Mediterranean Sea and Coast for Informed Decision-Making
2. For Informed and Consistent Advocacy, Awareness, Education and Communication

Learn more

Implementation

The implementation of the MTS is envisaged to be a collective process, under which the MTS is used as a common platform for joint actions not only by the Contracting Parties and the UNEP/MAP-Barcelona Convention Secretariat, but also by other international and regional organizations and actors in the Mediterranean region, including MAP Partners and Members of the Mediterranean Commission on Sustainable Development (MCSD) and Civil Society Organizations at large.

The MTS implementation is structured in a way to be measurable, with a view to supporting efficient performance assessment and management and to providing assurance to Contracting Parties and donors that their efforts and resources are contributing to substantial impact. For this purpose, UNEP/MAP uses a performance framework approved by the Contracting Parties, which includes specific strategic outcomes and performance indicators and targets.

UNEP/MAP Key Achivements

MAP Achievements come in various forms and at different levels of action. There are achievements of a policy and regulatory nature that are complemented with concrete results on the ground pertaining to the implementation of the Barcelona Convention and its Protocols.

a) A uniquely comprehensive framework for regional cooperation

The MAP—Barcelona Convention system, including the seven Protocols, constitutes a uniquely advanced regulatory framework based on international law and integrating sustainable development with a focus on marine and coastal environment and their natural resources. This framework addresses the complexity of the issues being addressed with a comprehensive corpus of complementary strategic and regulatory instruments, including:

The Mediterranean Strategy for Sustainable Development (MSSD), which translates the SDG commitments at the regional level and provides a strategic policy framework for securing a sustainable future in the Mediterranean region.

The Strategic Action Programme to Address Pollution from Land-based Activities (SAP MED) adopted in 1997 with a timeline of actions and commitments until 2025.

The Strategic Action Programme for the Conservation of the Biological Diversity in the Mediterranean Region (SAPBIO). The MAP Regional Activity Centre SPA/RAC has initiated a regional, inclusive consultation for the preparation of a post-2020 SAPBIO.

The Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021). The Post-2021 Mediterranean Strategy for Prevention of and Response to Marine Pollution from Ships is currently under preparation; the MAP Regional Activity Centre REMPEC will submit a draft post-2021 Mediterranean Strategy for Prevention of and Response to Marine Pollution from Ships to the Fourteenth Meeting of its Focal Points in spring 2021.

Pioneering legal instruments, such as the Integrated Coastal Zone Management (ICZM) Protocol. Under the auspices of MAP, the Contracting Parties to the Barcelona Convention adopted the first ICZM protocol of its kind with the aim of enhancing the governance of coastal zones in an integrated manner.

Legally binding measures on marine litter management, including a Regional Plan on Marine Litter Management, adopted in the framework of Article 15 of the LBS Protocol of the Barcelona Convention. The Regional Plan on Marine Litter aims to minimize marine litter and its impacts in the Mediterranean by preventing it from entering the marine environment and removing existing litter where possible.

The Integrated Monitoring and Assessment Programme (IMAP), which was adopted by the Contracting Parties in 2016, has established a sound common basis for the definition of the Good Environmental Status (GES) of marine and coastal environment. IMAP is a crucial instrument that enables the coordinated and harmonised implementation of integrated monitoring and assessment programmes by the Mediterranean governments to assess GES and the effectiveness of measures taken for the implementation of the Barcelona Convention and its Protocols.

The establishment of an effective mechanism to promote compliance with Barcelona convention and its Protocols, notably through the articulation of a mechanism for the Compliance Committee to address communications from the public. Under Regional Seas, the Barcelona Convention is a pioneer in opening an avenue for civil society participation in environmental treaty compliance.

b) Enhanced knowledge for evidence-based policy-making

Assessments of the marine and coastal environment and studies of their interactions with development lie at the heart of the MAP mandate. Since 1996 MAP has delivered several assessment reports. The most recent ones include:

The first Quality Status Report for the Mediterranean – MED QSR (2017); work is underway for the production of the next edition of MED QSR in 2023.

Report on the State of the Environment and Development in the Mediterranean (SoED), which will be released in the second half of 2020.

MED 2050 Foresight Study providing scenarios for the future and prospective analysis of the interactions between environment and development at medium and long term. The report will be published in 2022.

c) Partnership and outreach to maximize benefits for the region

MAP has catalysed and strengthened regional ocean governance in the Mediterranean by pursuing effective partnership based on complementarities to maximise the benefits of joint action. MAP collaborates with a considerable number of partners, including UN entities, intergovernmental organizations and international financial institutions, as well as institutions operating in the fields of sciences, academia and civil society. Examples of concrete collaboration plans agreed bilaterally that are currently under implementation include—but are not limited to— agreements with with ACCOBAMS, EEA, IMO, IUCN, FAO/GFCM, the Black Sea Commission and the Union for the Mediterranean.

MAP is committed to supporting the UN Decade for Ocean Science and the UN Decade on Ecosystem Restoration. MAP is also following the post-2020 processes on biodiversity and climate change with the aim of aligning its strategic orientations and programmatic work in the Mediterranean on the global environmental agenda.

The MedProgramme, a new programme funded by the Global Environment Facility (GEF), epitomizes MAP accomplishments in the field of partnerships. The MedProgramme is a collaboration of regional and global partners focusing on the health and environmental security of the coastal ecosystems in the Mediterranean. It consists of an assortment of seven child projects that will deploy more than 100 coordinated actions at regional and national levels over the next five years (2020-2024) in ten beneficiary countries.

Establishment of a science-policy platform on climate change in the Mediterranean through the Network of Mediterranean Experts on Climate and Environmental Change (MedECC). Supported by the MAP Regional Activity Centre Plan Bleu and other institutions, MedECC constitutes an example of innovative cooperation mechanisms that strengthen engagement with key stakeholders to bolster the Science-Policy Interface. MedECC will publish the First Mediterranean Assessment Report (MAR 1) on climate change, which was developed with the support of MAP's Plan Bleu/RAC.

National implementation and actions on the ground

MAP has successfully facilitated efforts on the part of Contracting Parties at national level to formulate and implement necessary measures for the implementation of the Barcelona Convention, its Protocols and Decision adopted by the Contracting Parties. Under the auspices of MAP, the Mediterranean governments have taken and implemented major commitments in line with relevant global agendas to protect marine and coastal environment and promote sustainable development.

National Action Plans developed and updated by almost all Contracting Parties constitute important national policy instruments encompassing clear commitments to reduce and prevent marine pollution and address biodiversity protection. On coastal management, ICZM national strategies have been devised and are under implementation by several Contracting Parties.

References

CHAPTER 8. Scenario analysis and potential for long-term transformational change

The MED2050 initiative

The Mediterranean large Marine Ecosystem (LME) is subject to permanent movement and change. Within the causal chain analyses, the present TDA has identified a number of factors of change that are mainly human caused. Some of these factors of change are contemporary, ubiquitous and impacting indirectly the Mediterranean LME, such as contamination and pollution events. Other factors of change are structural and result from the general way the overall Mediterranean socio-economic-ecological system functions and the underlying long-term trends or disruptions in the way humans live within the Mediterranean LME (e.g., coastal artificialization, demography, fisheries decline, water abstraction, etc.). Exploring different long-term evolutions of the Mediterranean socio-economic-ecological system can be a powerful tool to lead to Strategic Action Programs that are suitable for different futures of the overall Mediterranean system. It can help develop sustainable Mediterranean horizons, or, contrarily, what is incompatible with a sustainable future, and therefore, support the identification of transition pathways to favor desirable outcomes and avoid undesirable ones.

Putting the Mediterranean LME into its systemic context via narratives of change can help to draw up pictures of what marine uses would look like and how they need to change, if the pressures they cause are to remain within the boundaries that allow for achieving a good environmental status. They can be a powerful tool to communicate on where fundamental changes are needed and where trade-offs need to be negotiated, and they can give an idea of what human wellbeing would be like if a good environmental status of the Mediterranean LME is achieved. Narratives of systemic change are also a way of communicating about the state of the Mediterranean LME and can potentially facilitate integration of ecological considerations into other policies and initiatives, highlighting better where trade-offs need to be arbitrated. Especially sectoral policies (energy, mobility, tourism, etc.) are likely to use language and metrics that are closer to those used to describe the uses of the sea than the ecological parameters.

In this sense, the Contracting Parties to the Barcelona Convention have entrusted Plan Bleu, Regional Activity Centre of UNEP/MAP, to carry out a new foresight exercise on the environment and development in the Mediterranean, with a horizon in 2050, entitled MED2050. This exercise is the third of its kind, following two initiatives that culminated in the foresight reports *« The Plan Bleu: the future of the Mediterranean basin »* of 1989 and *« Mediterranean – Plan Bleu perspectives on environment and development »* of 2005.

Following preparatory activities, the MED 2050 roadmap is organized around four main activity modules, each with its own specific utility and methodology:

Module 1 : building the foresight base – past and future trends, weak signals and disruptions, data sheets
Module 2 : compare and share contrasting visions for the Mediterranean by 2050 – with a focus on youth visions
Module 3 : designing scenarios – exploring possible futures to inform resilient policy development

Module 4 : co-constructing transition paths – guiding decision making towards alternative narratives of the future.

The preparatory phases of MED 2050, as well as Phases I (trends, weak signals, disruption)[111] and II (contrasting visions)[112] of MED2050 have informed the present TDA, through a synthesis of the results of the initiative regarding the main factors of particular interest to the LME. Concomitantly to the elaboration of the TDA the MED2050 is finalizing its work on Phase III (scenarios), and its Phase IV (transition pathways).

Mediterranean LME long-term global regulation

Within this context and supported by the GEF MedProgramme CP1.1. (TDA Component) the report "The Mediterranean Large Marine Ecosystem - Prioritization of the transboundary problems, analysis of impact and causes" was prepared by Plan Bleu. The term and scope of 'long-term global regulation' is understood to be the long-term maintenance of the physical, chemical or biological structural conditions related to the natural and systemic regulation and functioning of the Mediterranean LME. Under these conditions, the LME is naturally functioning and capable of providing the full spectrum of ecosystem services, which may be subject to transformations due to both natural and anthropogenic causes (e.g., climatic variability and change). Hence, "regulation" is not intended in terms of laws and legislation but rather in terms of system dynamics (ca. ecological parameters). Long-term global regulation processes can be associated with the regulation and maintenance-type ecosystem services and corresponding functions, as presented below (Table 44).

In line with the above definition, the qualification of the scope and components of the long-term global regulation problems facing the Mediterranean LME focused on the five following "sub-issues":

i. Changes in circulation patterns
ii. Seawater warming
iii. Acidification
iv. Changes in biogeochemical cycling
v. Waste overload

The selected sub-issues are fully in line with the concept of planetary boundaries. First introduced by Rockstrom et al. (2009), this approach defines "the safe operating space for humanity", maintained through the Earth's regulatory capacity, biophysical subsystems and processes. When human activities exceed a level that disrupts the systems that keep Earth in a desirable stable state, these boundaries are crossed leading to nonlinear and irreversible impacts and, in some cases, abrupt environmental changes and crises.

In a regional Mediterranean context these boundaries approach is assimilated by the achievement or maintenance of the Good Environmental Status, through the implementation and 6 year cyclic

[111] The consolidated results of MED2050's phase I can be accessed at kXK2kPVAn9UWwGHi (med2050.org)
[112] The consolidated results of the different Phases of MED2050 are published as available Plan Bleu - Des visions contrastées du futur de la Méditerranée - 080422 (med2050.org)

management of the IMAP, a marine monitoring and assessment program scientifically defined through a number of boundaries (ca. assessment criteria) within 11 selected Ecological Objectives monitored through Common Indicators to allow performing holistic assessments region wide. Nevertheless, the Plan Bleu report discusses some of the large scale and transboundary ecological key issues to maintain the long-term LME regulation and functioning. The five priority long-term LME issues further briefly described below:

Table 44. Overview of regulation and maintenance-type ecosystem services that are related to the long-term global regulation of the Mediterranean LME. Source: Adapted and elaborated from the Common International Classification of Ecosystem Services (CICES) framework (Haines-Young and Potschin, 2013).

Ecosystem service type	Function	Identified sub-issues
Mediation of flows (e.g. coastline stability, connectivity, habitats protection)	Water circulation	Changes in circulation patterns, including thermohaline circulation, marine cold engines, links to the hydrological cycle and oceanographic processes
Maintenance of physical, chemical and biological conditions (e.g. CO_2 sequestration, pH buffering)	Climate regulation, including carbon sequestration and storage	Seawater warming, including marine heat waves
		Acidification
	Biogeochemical regulation	Biogeochemical cycling, including sediment, nutrient and phytoplankton dynamics, oxygen depletion
Mediation of waste, toxics and other nuisances (e.g. bio-remediation, sound attenuation)	Dilution, absorption and breakdown of waste from sea- and land-based sources	Waste overload

Changes in circulation patterns: Water circulation is driven by ocean currents and the movement of water masses across the water column. It is the process that supports oceanographic connectivity, regulates water temperature and the exchange of oxygen, nutrients, sediments and other inorganic substances, setting the habitat conditions for living organisms.

During the past decade, the water masses of the Mediterranean Sea have experienced strong and fast increases in temperature and salinity, with deep water masses becoming saltier (MedECC, 2020). Deepwater is considered a stable medium, which allows for the precise quantification of trends in heat and salt content. Changes in temperature and salinity perturb the general thermohaline circulation and may also lead to the impairment of deepwater formation, the so-called cold-water engines (Boero, 2014). Seawater warming: Since the beginning of the 1980s, average sea surface temperatures have increased throughout the Mediterranean basin (García-Martínez et al., 2017; Pastor et al., 2020; MedECC, 2020). This increase is marked by large sub-regional differences and stronger warming in the Eastern basins (Adriatic, Aegean, Levantine and north-east Ionian Sea). In addition, over the last decades "marine heatwaves", defined as periods of extremely high sea surface temperature that persist from days to months and can extend up to thousands of kilometers, have become more frequent, intense and spatially extensive (MedECC, 2020; Juza et al., 2022). Temperature anomalies, even of short duration, can dramatically impact Mediterranean biodiversity.

Acidification: Carbon sequestration by the oceans (ca. biological pump) through the uptake of CO2 and its transport and storage in deep-sea compartments is an important ecosystem service related to climate regulation. Therefore, carbon sequestration and storage act as a sink for atmospheric carbon, slowing climate change. The ocean generally holds about fifty times more CO2 than the atmosphere (Bopp et al., 2017). The capacity of the Mediterranean Sea to absorb anthropogenic CO2 per unit area is relatively higher than the global ocean due to its higher alkalinity and the ventilation of deep waters over shorter timescales (MedECC, 2020). As the levels of CO2 in the atmosphere increase, the elevated uptake of CO2 by the oceans causes acidification. The average surface pH change for the Mediterranean Sea is −0.08 units, same as for the global ocean. However, deep waters of the Mediterranean Sea exhibit a larger anthropogenic change in pH than typical global ocean deep waters due to faster ventilation times (Palmieri et al., 2015).

Changes in biogeochemical cycling: The Mediterranean Sea is generally considered an oligotrophic basin, with primary productivity decreasing from the west to the east and some local regions of enhanced productivity e.g. the Alboran Sea or the northern zones of the Adriatic Sea. Primary productivity is influenced by circulation and vertical mixing that brings available nutrients to phytoplankton (Harley et al., 2006 in Richon et al., 2019). Changes in physical processes, such as the modification of vertical mixing, can have dramatic effects on the availability of nutrients to phytoplankton, on plankton community dynamics and ultimately on the productivity of the entire marine food webs. Temporal and spatial dynamics in marine productivity are also impacted by riverine and atmospheric inputs of nutrients. This implies that freshwater and wastewater management and agricultural practices, as well as damming and river discharge alterations could have downstream impacts on the total marine productivity of the Mediterranean Sea.

Waste overload: Oceans and seas provide the service of waste assimilation to some extent – the capacity to dilute, disperse, absorb, transform and remove harmful substances and waste (through biophysicochemical processes) when disposed into the marine environment. The concept of assimilative capacity was formulated around the use of the marine (or freshwater) environment to dispose of mainly organic wastes and associated effluents. Organic material, such as uncontaminated sewage sludge, inorganic forms of nutrients, and some acids, among other materials, may be neutralized by the sea (e.g. pH buffering). If this assimilative capacity exceeds the volume of waste received, the environment remains unharmed. If, however, the volume of waste exceeds the assimilative capacity, or the industrial and sewage wastes contain chemicals that are extremely toxic even at low concentrations (such as mercury, cryolite and DDT), including radioactive industrial wastes, this comes with significant harm to biodiversity and human health. At present, with many diverse pollution sources, ecosystems show a limited capacity to handle harmful substances and solid wastes (e.g. marine litter) and to assimilate them; therefore, leading to waste overloading with degradation and biodiversity loss as consequences. The establishment and application of different and specific legislation (e.g. emission limit values (ELVs) - the maximum allowable concentration of a pollutant in an effluent discharged to the environment) safeguard the receiving environment from controlled discharges.

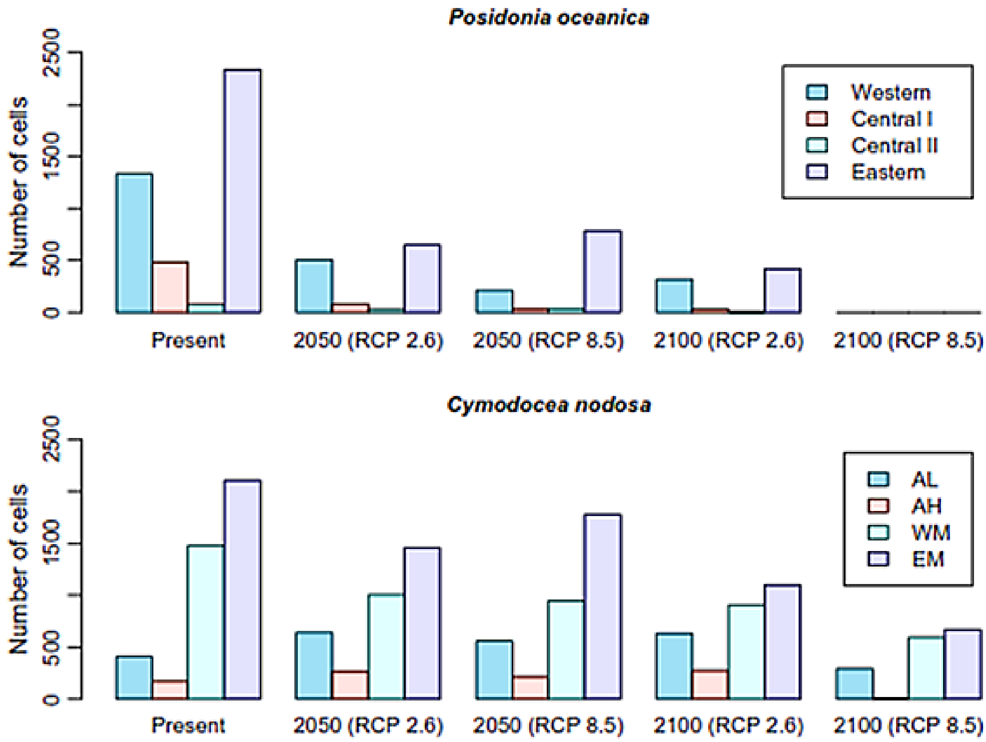


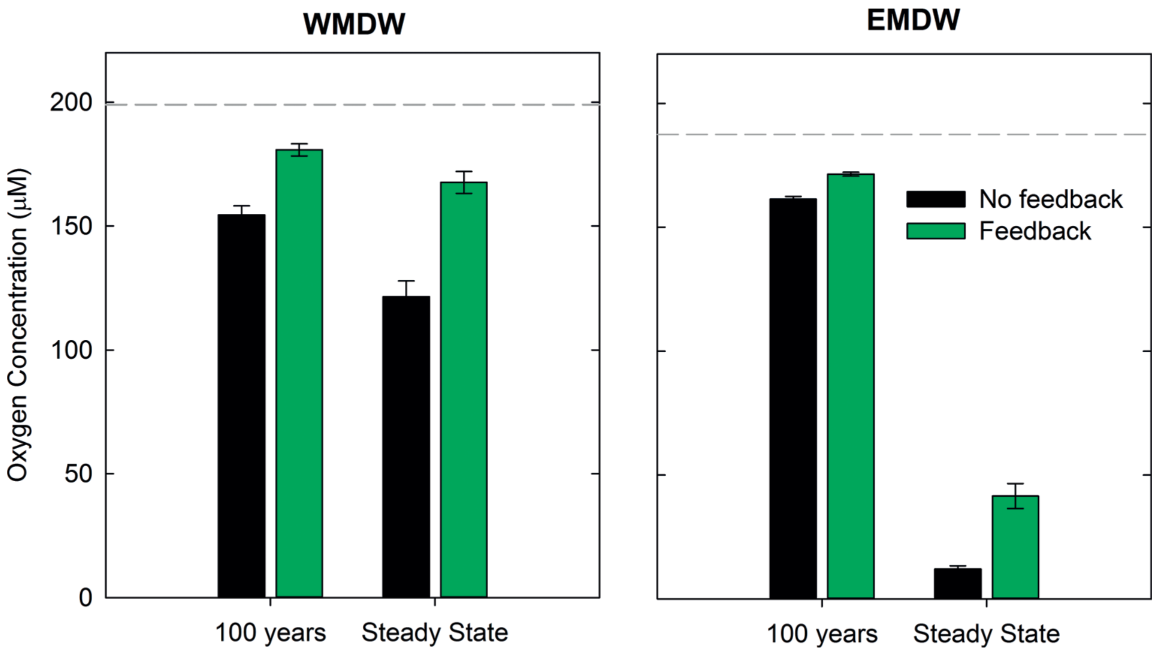
Figure 175. Posidonia oceanica and Cymodocea nodosa under present and future scenarios 2050 and 2100. The extension of the habitat is expressed as the number of cells (~9.2 km) found for each region after a binary classification (Chefaoui et al., 2019)

To exemplify the consequences of the ecological alterations in the long-term, a recent study predicted the disappearance of habitats under climate change IPCC scenarios. It would considerably affect all genetic regions identified for *Posidonia oceanica* even in the best-case scenario by 2050. Mediterranean warming will lead to significant population declines and genetic loss of *P. oceanica* and *Cymodocea nodosa*. This loss would be so severe that it may involve the complete loss of habitat and genetic diversity of *P. oceanica* by 2100, involving its functional and possibly species extinction, under the most severe scenario of climate change; and a 70% decrease in habitat under the best-case scenario by 2050 (Chefaoui et al., 2019). The authors also estimated that, by 2050, *C. nodosa* would increase by 37%–57% in the African Atlantic range (AL) region, and by 25%–59% in the Iberian Atlantic region (AH) region, depending on the scenario. In the Atlantic regions, C. nodosa could experience some increase in relation to its present suitable habitat, except under the scenario RCP 8.5 by 2100, under which the Iberian Atlantic region (AH) could disappear, and the African Atlantic range (AL) would decrease its extension.

It has been reported that the negative impact of climatic fluctuations on the Mediterranean ecosystem started much earlier than we expected and is larger than the prediction on the *P. oceanica* meadows. This was affirmed by Moullec et al. (2016) through their research on the effects of climate change on the ecosystem of the Catalan Sea (Northwestern Mediterranean). Their study underscored that, the common barracuda (*Sphyraena viridensis*) and the dolphinfish (*Coryphaena hippurus*) are good examples that have greatly extended their natural distribution range over the last 30 years. The SST trend increase in the Catalan Sea has been linked with the expansion of round sardinella (*Sardinella aurita*) and the decline of sardine (*Sardina pilchardus*). The potential impact of climate change on some essential habitats could severely affect the life cycle and the spatial distribution or redistribution of numerous marine species whether indigenous or not Moullec et al. (2016).

Thus, climate change is expected to modify migration patterns and periodicities with consequences for population dynamics and fisheries management. All these changes are shaping a different Mediterranean Sea in which living resources and human activities will need to adapt in a sustainable way.

Concerning climate and environmental influences on plankton assemblages in the Mediterranean, the variety of trophic regimes and the diversity of biological communities offer great opportunities to test hypotheses concerning climate change and its impacts on plankton. Benedetti, (2016) investigated the climate change impact on planktonic production in the Mediterranean Sea showing that nanophytoplankton account for 43% to 50% of the total primary production of the Mediterranean Sea. The Mediterranean Sea contains a wide range of plankton whose environmental preferences and functional roles remain to be fully determined. The patterns described above suggest differences between the ecological traits and environmental preferences of species. By altering the pelagic environment, anthropogenic climate change could alter plankton distribution, as well as their importance in the food web.



(Powley et al, 2017)

With regard to the social-economic-ecological system, demography is a key parameter. The population of the riparian countries bordering the Mediterranean Sea amounted to approximately 512 million inhabitants in 2018 (SoED, 2020) and the recent estimations account 531 and 541 million for 2021 and early 2023, respectively (see Chapter 1). Whilst the population has been stabilizing in the northern part of the Mediterranean since 1980 the population in the south and east of the basin has more than doubled (from 153 million in 1980 to 314 million in 2018), and is expected to increase by an additional 182 million people by 2050.

On the other hand, greenhouse gas emissions in the Mediterranean are currently making around 6% of the global emissions (MedECC, 2020). The Mediterranean carbon dioxide (CO_2) emissions reached 2,094 Mt in 2018 – 31% higher compared to 1990 and more than double the emissions in 1970. In the northern Mediterranean countries, carbon intensity decreased from 6 t of CO_2 per capita in 1990 to 5 t CO_2/ capita in 2018. A reverse trend was seen in the south where carbon intensity increased from 1.9 t CO_2/ capita in 1990 to 3 t CO_2/ capita in 2018 (OME, 2021). Carbon dioxide, among other parameters, are clear indicators to allow exploring different long-term evolutions of the Mediterranean socio-economic-ecological system.

The total emissions (ca. reference scenario) are expected to increase at the same pace as over the past three decades, reaching 2,686 Mt by 2050 (an increase of 28% compared to 2018 and 68% compared to 1990). Under alternative scenarios, with the help of carbon sequestration, CO2 emissions could be limited to 1,275 Mt (in the Proactive Scenario) and as low as 529 Mt in the (ProMED Scenario), the latter representing a decrease of 75% compared to the current, and 65% compared to 1990 emission levels. By 2050, the share of the emissions from the south Mediterranean countries is projected to increase to reach 67% of the total under the Reference Scenario, 73% under the Proactive Scenario and 86% in the ProMED Scenario in the region. In the ProMED Scenario, north Mediterranean CO2 emissions would fall below 76 Mt by 2050 – 11 times less than in 1970 (OME, 2021).

According to OME, fundamental restructuring and reshaping of the Mediterranean energy system is needed to reach the necessary level of decarbonisation by 2050. Depending on the considered scenario, the share of hydrocarbons in the primary energy is projected to decline from 76% in 2018 to between 37% and 73% by 2050, with the share of renewable energy increasing to between 19 and 57%. Wind and solar technologies, green gases (biomethane and hydrogen) and battery storage are expected to play crucial role in the transition (ca. long term transformational change). The OME report in 2021 concludes that achieving carbon neutrality in the Mediterranean by 2050 would not only require significantly faster deployment of clean energy technologies but also major behavioral changes.

As an output of the scenario analysis by OME, the level of investments needed to achieve transition over the next 30 years is estimated at between EUR 4 and 6 trillion (the higher figure corresponding with investments needed to achieve carbon neutrality), mainly for energy efficiency measures and for development of renewable technologies. The investment requirements are 55% higher in the ProMED Scenario and their structure is radically different: investments in energy efficiency, for example, are more than double compared to the Reference Scenario. Investments in energy supply would be in the range of EUR 2.5 and 2.9 trillion in the three scenarios, but with a much stronger emphasis on renewables in the ProMED Scenario where investment in renewable energy would account for 21% of total investment and 43% of energy supply investments (OME, 2021).

Regarding the Mediterranean LME scenario analysis in terms of environmental impacts, the main transboundary environmental changes linked to the production and use of energy are greenhouse gas emissions (ca. alteration of ecological key long-term parameters); underwater noise and accidental discharges stemming mainly from the offshore oil and gas production (ca. contamination and pollution events) and the transportation of fossil fuels also have high potential to cause negative environmental impacts (UNEP/MAP and Plan Bleu, 2020). It is imperative to employ scenario analysis in a multidimensional context accompanied by key indicators from different disciplines to perform foresight and forecast the future horizons for the Mediterranean LME.

References

CHAPTER 9. TDA (and SAP) indicators and their linkages to SDGs

It is unquestionable that after the publication of the 2005 Mediterranean TDA report by UNEP/MAP/MEDPOL in collaboration of GEF (see Preface), there has been an enormous and unpredictable reshaping of how we can both use and access data, information and knowledge being supported by an immense amount of new ICT technologies, which are in a non-stoppable global expansion phase (e.g. Internet of Things, Data science, Big Data, web-based Platforms, Application Programming Interfaces, etc.).

To this regard, these new ICT technologies and applications include sophisticated database architectures and quality management related to marine and maritime environmental data (see also Section 4.3.3), namely, digital bibliography, marine databases, geographical information systems and marine and maritime spatial planning frameworks to mention few. Many of them are already embedded into higher level structures, such as the IMAP Info System or EEA-Marine WISE platforms supporting the marine policies implementation in the Mediterranean region (i.e., UNEP/MAP IMAP and EU MSFD).

A further step in data management have generated several new scientific and policy applications through indicator-based assessments, providing additional digital management tools for data flows, data-driven and knowledge-based assessments of the major environmental concerns and socioeconomics impacts in the Mediterranean region. However, the consequent information and knowledge management generated to improve the integrated environmental management and governance still a challenge through the Mediterranean countries and requiring further developments, such as in other European Seas and globally. Within the UNEP/MAP system and from international frameworks, such as the Agenda 2030 and their Sustainable Development Goals (SDGs) a number of indicators coexists from a few databases of high relevance for the Mediterranean Sea:

- Integrated Monitoring and Assessment Programme (IMAP) data and indicators
- Shared Environmental Information System (SEIS) data and indicators
- Mediterranean Strategy for Sustainable Development (MSSD) data and indicators
- Sustainable Development Goals (SDG) data and indicators
- AQUASTAT – FAO's Global Information System on Water and Agriculture
- World Bank, UNSTATS, UNDESA, etc. databases for socio-economic data
- UNEP World Environment Situation Room (WESR) and associated cartographic tool MapX

Therefore, there exist a growing number of frameworks using indicators for the environment (ca. indicators-based ecosystem management) like the indicator-based economic management (ca. stock markets). Those for the environment are in its initial phase of implementation and have different properties (e.g., unidimensional, multidimensional, composite indicators, indexes, etc.).

To adequate the potential indicators for the TDA/SAP process, it is convenient to start from a top-down approach and introduce the overall Mediterranean framework, namely, the Mediterranean Strategy for Sustainable Development (MSSD) providing an integrative policy framework for all stakeholders, including MAP partners, to translate the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) at the regional, sub-regional, national and local levels in the Mediterranean region. The MSSD was adopted by all Mediterranean countries at the 19th Meeting of the Contracting Parties to the Barcelona Convention (COP 19) (Athens, Greece, 9-12 February 2016) (Decision IG.22/2). The MSSD is structured around six Objectives (Table 45) that feed into the Sustainable Development Goals (SDGs), including additional general indicators and multidimensional indicators.

Table 45. Link between MSSD and SDGs indicators (Note: 4. Quality Education and 5. Gender Equality are added intentionally in the last row).

MSSD Indicator Groups and Objectives	SDGs		
1. Sea and Coast (ensuring sustainable development in marine and coastal areas)			14 LIFE BELOW WATER
2. Rural and Resources (promoting resource management, food production and food security through sustainable forms of rural development)	2 ZERO HUNGER	15 LIFE ON LAND	6 CLEAN WATER AND SANITATION
3. Sustainable Cities (planning and managing sustainable Mediterranean cities)		11 SUSTAINABLE CITIES AND COMMUNITIES	7 AFFORDABLE AND CLEAN ENERGY
4. Climate change (addressing climate change as a priority)			13 CLIMATE ACTION
5. Green & Blue economy (transition towards a green and blue economy)	8 DECENT WORK AND ECONOMIC GROWTH	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	12 RESPONSIBLE CONSUMPTION AND PRODUCTION
6. Governance (Improving governance in support of sustainable development)		16 PEACE, JUSTICE AND STRONG INSTITUTIONS	17 PARTNERSHIPS FOR THE GOALS
Additional MSSD General potential indicators: Human Development index (HDI), Economy, Education, Gender, etc.		4 QUALITY EDUCATION	5 GENDER EQUALITY

Most Mediterranean countries have SDG Index[113] of 70 or higher (sdgindex.org), indicating a relatively high level of progress but also a high likelihood that that the goals will not be achieved by 2030 across the region. The countries with SDG Index of less than 70 are Morocco, Montenegro, Egypt, Lebanon and Syria (data not available for Libya, Monaco and Palestine). France, Slovenia and Spain have the highest SDGIs (close to 80 or higher) and are ranked among the top 20 countries in the world (Sachs et al., 2022)[114]. Performance on SDG 14 (Life below water) is worrying, as it was assessed that 16 Mediterranean countries are faced with major challenges for the goal's achievement. Similarly, the region is not on track to achieve SDGs 13 (Climate action) and 12 (Responsible consumption and production); major and/ or significant challenges towards the achievement of SGD 16 (Peace, justice and strong institutions) are typically found across the South and Eastern Mediterranean Countries (SEMC) but also in some of the NMC, including some of the EU countries (Sachs et al., 2022).

Nevertheless, the MSSD objectives no. 1(Sea and Coasts), 4 (Climate Change), 5 (Bleu and Green Economy) and 6 (Governance) (Table 47) are components aligned with the present TDA report and the indicators in place that should guide the overall monitoring and evaluation of the TDA/SAP process as well. *NOTE: for graphic presentation consider SDG dashboard data by country (included in the excel).*

Apart from the general list above, there are several Regional Plans within the UNEP/MAP Thematic Strategies which have developed and selected their own indicators for monitoring and assessment of progresses, such as the Regional Action Plan on Sustainable Consumption and Production (SCP) by Med Waves (SCP/RAC, UNEP/MAP) and the Mediterranean Observatory on Environment and Sustainable Development (Plan Bleu, UNEP/MAP) responsible for the MSSD Dashboard.

The Regional Action Plan on SCP in the Mediterranean is the first intergovernmental agreement in the Mediterranean basin to establish a regional action framework to promote the shift towards a more sustainable and circular economy, consumption patterns with lower environmental footprints, and greener production methods. It is structured around key economic sectors that are the main sources of environmental pressures on Mediterranean ecosystems. In this sense, they provide a tools for monitoring and valuation of the causes (direct, underlying and root causes) related to transboundary and shared challenges to correct the environmental degradation in the region. These SCP indicators are structured around six thematic areas and key economic sectors that are the main sources of environmental pressures on Mediterranean ecosystems. The Table 46 and 47 presents the comparability between the SCP and MSSD (and includes other comparable indicator sources such as SDG, as well as SEIS / Horizon 2020 Indicators, FAO, etc.).

On the other hand, the Mediterranean Sustainability Dashboard is a living set of indicators dedicated to the monitoring of the MSSD implementation. As international work on SDG Indicators progresses, the dashboard is regularly reviewed under the guidance of the MCSD Steering Committee, with the technical support of Plan Bleu Regional Activity Centre (UNEP/MAP). The indicators showcase observed trends, produce analytical factsheets, and prepare regional assessment and foresight studies on the interactions between environment and development.

[113] The index measures the total progress towards achieving all 17 SDGs. The score can be interpreted as a percentage of SDG achievement. A score of 100 indicates that all SDGs have been achieved.
[114] SDGI data and rankings available from https://dashboards.sdgindex.org/rankings

Further, to the analytical frameworks, it is worth noting that management processes also exist to promote and develop the indicator-based assessment for policy, such as the Simplified Peer Review Mechanism (SIMPEER): SIMPEER and peer learning experiences facilitate the transposition, implementation and monitoring of the MSSD and SDGs at the regional and national level, improving effective coordination between governmental departments. SIMPEER has the potential to support the preparation and follow-up of the Voluntary National Reviews (VNRs) presented by Contracting Parties at the UN High-Level Policy Forum (HLPF). SIMPEER helps Contracting Parties to identify common obstacles in the implementation of their national strategies on sustainable development. The UNEP/MAP Plan Bleu RAC coordinated the two first editions of SIMPEER with France, Montenegro and Morocco in 2016-2017, and Albania, Egypt and Tunisia in 2018-2019 .

As a conclusion, there exist in the Mediterranean region led by UNEP/MAP, a consolidated and ongoing validated mechanism to perform indicator-based assessments according to the global demands which require informing both policy and decision makers, through establishing indicators trends in the medium and long term. In this report the same indicators can be used in the opposite direction to close the loop on identified transboundary priorities and ensuring the findings in this TDA report are under the coverage of the existing indicators in the Mediterranean region.

Table 46. Comparative analysis of indicators within the Mediterrranean UNEP/MAP work between RP SCP, MSSD and SDGs.

	SCP Indicator Nº	Indicator's names	SCP AP Indicator number / Thematic issue	Plan Bleu MSSD's dashboard Indicator number / Goal	Link with SDGs
Specific SCP AP's indicators	1	Proportion of agricultural area under productive and sustainable agriculture	1ª / Land use		2.4.1
		Agricultural 378rea organic, total	1b / Land use	Indicator 16 / 2 – Rural & Resources	FIBL, FAO, Related (2.4)
	2	Global food loss index (and food waste index)	2 / Land use		12.3.1
	3	Index of sustainable forest management	3ª / Land use		15.2.1
		Area of Certified forest	3b / Land use		Related (15.2)
	4	Freshwater withdrawal as a proportion of available freshwater resources (also known as water withdrawal intensity)	1 / Water (Efficiency)	Indicator 12 / 2 – Rural & Resources	6.4.2
	5	Water Productivity or Water Use Efficiency	2 / Water (Efficiency)		6.4.1
	6	Degree of integrated water resources management (IWRM) implementation	3 / Water (Efficiency)		6.5.1
	7	Renewable energy share in the total final energy consumption	1 / Energy (Efficiency)	Indicator 22 / 4 – Climate change	7.2.1

	8	Energy intensity measured in terms of primary energy and GDP	2 / Energy (Efficiency)	Indicator 22 / 4 – Climate change	7.3.1
	9	Amount of fossil-fuel subsidies (production and consumption) per unit of GDP	3 / Energy (Efficiency)		12.c.1
	10	CO2 emission per unit of value added	1 / Pollution	Indicator 21 / 4 – Climate Change	9.4.1
	11	Countries signatory of 1 to 5 international multilateral environmental agreements (Minamata, Basel, Rotterdam and Stockholm conventions and Montreal Protocol) on hazardous waste and other chemicals	2 / Pollution		12.4.1
	12	Annual mean levels of fine particulate matter (e.g. PM2.5) in cities (population weighted)	3 / Pollution		11.6.2
	13	Material footprint (MF) per GDP	1ª / Resources		12.2.1; 8.4.1
	14	Domestic material consumption (DMC) per GDP	1b / Resources	Indicator 23 / 5 – Green/blue economy	12.2.2; 8.4.2
	15	Material footprint (MF) per capita	2ª / Resources		12.2.1; 8.4.1
	16	Domestic material consumption (DMC) per capita	2b / Resources	Indicator 23 / 5 – Green/blue economy	12.2.2; 8.4.2
	17	Proportion of fish stocks within biologically sustainable levels	3ª / Resources	Indicator 8 / 1-Sea and coast	14.4.1
	18	Marine Trophic Index (also called Mean Trophic Level (TL) of fisheries landings)	3b / Resources		14.4
	18	Countries with sustainable consumption and production (SCP) national action plans or SCP mainstreamed as a priority or target into national policies	1 / Behaviour	Indicator 24, 28 / 6- Governance	12.1.1
	20	SPP/GPP as a percentage of total public procurement (in terms of monetary value)	2 / Behaviour		12.7
	21	Green Patents (Development of environment-related technologies)	3 / Behaviour		OECD, Related, (12.7)
	22	Generation of waste	4 / Behaviour	Indicator 20 / 3 – Cities	11.6; 12.4
	23	Organic agriculture (retail sales, all million euro)	5 / Behaviour	Indicator 16 / 2 – Rural & Resources	FIBL, Related (12)
	24	Plastic waste generation (Index of coastal eutrophication and floating plastic debris density)	6 / Behaviour		UNEP MAP, Related 12

	25	Prevalence of overweight and obesity	7 / Behaviour		WHO, Related (2.2)
	Macro	Carbon Footprint (GHG emissions)	1 / Macro indicators		World Resources Institute, Related (9.4)
	Macro	Water Footprint	2 / Macro indicators		Water Footprint Network, Related (6.4)
	Macro	Ecological Footprint	3 / Macro indicators	Indicator 1 / General Indicator	Global Footprint Network, Related (12.2; 8.4)

Table 47. The MSSD indicators and goals and their relationship with the SDGs.

	Indicator's names (MSSD)	MSSD's dashboard Indicator number – Goal		Link with SDGs
Specific MSSD's indicators	Human Development Index	2- General indicators		No
	Gross Domestic Product	3-General indicators		Yes (SDG Indicator 8.1.1 "Annual growth rate of real GDP per capita")
	Youth literacy rate	4-General indicators		Yes (Indicator / target 4.4 "By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship" & 4.6 "By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy")
	Girl/Boy primary and secondary school registration ratio	5-General indicators		Yes (Target / indicator 4.1 "By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary

				education leading to relevant and effective learning outcomes”)
	Number of ratifications and level of compliance as reported by Barcelona Convention Contracting Parties	6- Sea and coast		No
	Coverage of protected areas in relation to marine territorial waters	7- Sea and coast		Yes (Indicator 14.5.1 “Coverage of protected areas in relation to marine areas”)
	Number of protected areas participating in the Green List initiative	9- Rural & Resources		Yes (indicator 15.1.2 “Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type”)
	Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems	10-Rural & Resources		Yes (SDG Indicator 15.a.1 “(a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments”)
	Global Food Security Index	11- Rural & Resources		No
	Water demand, total and by sector, compared to GDP	13- Rural & Resources		Yes (Goal 6)
	Proportion of population using safely managed drinking water service	14- Rural & Resources		Yes (SDG Indicator 6.1.1 “Proportion of population using safely managed drinking water services”)
	Proportion of population using (a) safely managed sanitation services	15- Rural & Resources		Yes (SDG Indicator 6.2.1 “Proportion of population using safely managed sanitation services, including a handwashing

				facility with soap and water")
	Red List Index	17-Rural & Resources		Yes (SDG Indicator 15.5.1 "Red List Index")
	Proportion of urban population living in slums, informal settlements, or inadequate housing	18- Cities		Yes (SDG Indicator 11.1.1 "Proportion of urban population living in slums, informal settlements or inadequate housing")
	Status of UNESCO world heritage sites	19- Cities		Yes
	Proportion of bank credit allocated to the private sector – Existence of alternative financing systems using bank credit	25- Governance		No
	Research and development expenditure as a proportion of GDP	26- Governance		Yes (SDG Indicator 9.5.1 "Research and development expenditure as a proportion of GDP")
	Number of countries that have clear mechanisms in place for ensuring public participation and guarantying public access to environmental information	27- Governance		Yes

References

CHAPTER 10. Findings for the Strategic Action Programme (SAP) development

Priority issue 1: Eutrophication (&coastal water quality)

Natural and anthropogenic eutrophication comprise among the major concerns as far as transboundary pollution is concerned around the Mediterranean Sea. This is particularly evident from the scientifically observed decadal trend anomalies in the Western Mediterranean (i.e., primary production) of satellite-derived Chl-a. On the other hand, related environmental and socioeconomic impacts in coastal water systems (i.e., bathing water quality, fish mortality) continue to pose pressure on the ecosystem; therefore, comprise a transboundary and shared issue for the Mediterranean countries. The situation is being addressed at a multilayer level (e.g., policy-governance, WWTPs installations, Regional Plans, etc.), but the eutrophication phenomena and random incidents still occur, along both the northern and southern Mediterranean coasts.

The key identified knowledge gaps are:

- Although the coastal watershed is the most appropriate geographical and analytical scale to assess pollution sources e.g., nutrients into the Mediterranean Sea, data is mainly available at the national scale.
- Significant gaps in wastewater data and not only related to countries lacking wastewater infrastructures (e.g., Libya)
- Discrepancies in data on wastewater management retrieved from global databases (e.g., UNSTAT)
- Lack of thorough evaluation of the relative contributions of the different sources (e.g., source apportionment assessment of point sources, riverine input, atmospheric deposition) to nutrient enrichment in the Mediterranean Sea
- Limited data and knowledge on the nutrient inputs through submarine groundwater discharge, despite studies showing its significance at the regional scale.
- The direct and indirect socio-economic impacts are difficult to quantify.

Final remarks:

- Eutrophication is generally restricted to coastal areas subject to anthropogenic land-based inputs and well-known natural eutrophication zones in the Mediterranean Sea under research.
- Multiple activities contribute to elevated nutrient levels, grouped as land-based or sea-based sources; point or diffuse sources. Studies indicate that loads of nutrients from diffuse sources (e.g., agriculture, atmospheric deposition, and mobile sources like shipping) commensurate with point sources (including municipal treatment plants or sewage outfalls, and industrial activities).
- Impacts may have transboundary implications by serving as a “source” for nuisance species (jellyfish, toxic algae, and their cysts) beyond the impacted local areas.
- The mechanism of local eutrophication is complex and depends on additional factors other than high nutrient inputs (e.g., temperature, depth, water circulation patterns, etc.).

- Inadequate wastewater treatment infrastructure is a key underlying cause for nutrient enrichment in coastal areas. Limited data on wastewater management hampers the assessment of the impacts of discharges of untreated wastewater. Excess use of fertilizers (i.e., agriculture) is a second major underlying cause.
- A comprehensive monitoring and modelling assessment framework that integrates nutrient inputs from different sources (point and diffuse) is essential to enhance our understanding of the drivers of eutrophication.
- Submarine groundwater discharges of nutrients are potentially an important additional source, which however, requires further quantification and substantiation.
- The factors contributing to eutrophication are determined by the upstream socio-economic activities, such as the development of wastewater infrastructure in relation to urbanization, fertilizer amounts use in agriculture and implementation of environmental policies to mention a few.
- Nutrients and chemical pollution share the same causes and sources, with potential links to other issues, such as climate change and biodiversity. The ecological effects, such as decline of seagrasses, may be attributed to nutrient enrichment but linked with other pressures like warming, extreme weather events, coastal development, free anchoring, and the presence of invasive species as well.
- Eutrophication phenomena and its environmental and socioeconomic impacts are known since early 20th century and still pose a disruption towards sustainable development and marine protection and conservation in some areas, despite large progresses with successful results (e.g., bathing water quality excellences) have been achieved in the Mediterranean Sea and achievements should be maintained, primarily, through governments and investment.

Priority issue 2: Chemical pollution (&emerging)

Well-known issues of legacy chemicals and emerging pollution remain a complex transboundary problem despite the positive policy successes (i.e., global leaded-fuel ban). The lifecycle management (i.e., monitoring-assessment-response) is in place for legacy chemicals with bans or disposal actions (e.g., GEF MedProgramme under CP1.1 Project). The coastal and marine hotspots of legacy pollution are controlled under national monitoring and assessment programmes; however, taking into account that the chemicals we know do not comprise more than 10% of the released chemicals; thus, a large number is not under control nor enough investigated. In fact, many different chemical groups of concern (both legacy and emergent) are well established in earlier policy documents in the Mediterranean region for industrial, water systems and the marine environment for monitoring programs (ca. MED POL). Unfortunately, only a very limited number of chemicals have been monitored and the issue remains not well-quantified. The coastal and marine environmental monitoring programmes (i.e., land, sea and atmospheric sources) of new/emerging substances require the same level of coordination to deliver successful legal and policy actions. Similarly, this is needed for the direct source contributions (ca. National Baseline Budget of Pollutants - NBB) to assess the pollutants lifecycles (ca. industrial, agricultural, etc.). As the number of chemicals is enormous, similar candidate lists of substances and surveillance approaches (e.g., HELCOM, EU, US-EPA, etc.) are highly complementary for the Mediterranean countries (ca. Barcelona Convention LBS Protocol (SAP-MED), and other UN Conventions).

The key identified knowledge gaps are:

- Chemical contamination remains not well-quantified. Data on targeted pollutant concentrations are available for specific locations but complete comparable regional datasets on all relevant substances at regular coherent intervals is not yet in place.
- Data on chemical loads from riverine inputs at the regional scale are very limited. The MEDPOL original objectives and coordination to this regard need renewed implementation as it is monitored and assessed by some countries.
- Industrial pollutants are under-reported. Data (concentrations and trends) on heavy metal and POPs discharges are lacking from different sources.
- Lack of information on the quantification of the transboundary dimension of the chemical pollution, mostly happening at cross-border mesoscales and via atmospheric long-range transport.
- Limited evidence of the direct relationships between exposure to pollutants and their effects on organisms under field conditions due to the existence of confounding factors (e.g., temperature, physiological status, etc.) exhibiting large uncertainties at molecular levels.
- The quantification of the impacts of contaminants on aquatic organisms and ecosystems is challenging due to the exposure to multiple sources and the complexity of ecosystems – cocktail effects.
- Only partial understanding of the CECs impacts on the Mediterranean marine ecosystem. The early knowledge from local studies cannot be extrapolated to the whole Mediterranean basin.

Final remarks:

- Trends and levels of legacy pollutants have generally decreased significantly in the most impacted areas in the Mediterranean Sea because of the implementation of environmental policy measures. However, legacy (e.g., industrial sources) pollution in coastal sediments remains an issue (i.e., hotspots).
- The limited availability of recent quality assured data with sufficient spatial geographical coverage (coastal and offshore) does not allow for the assessment of an accurate status in the Mediterranean Sea basin.
- However, there is sufficient evidence to qualify legacy pollution hotspots – harbors and coastal areas adjacent to industrial activities are most contaminated by the PAHs and PCBs, followed by transitional lagoons (e.g., wetlands).
- When it comes to impacts and bioaccumulation, the trophic status plays a role in the occurrence of POPs through bioaccumulation and biomagnification processes.
- The use of pesticides varies widely between Mediterranean subregions and in some countries exceeds the average global consumption pointing towards industrial agricultural practices and historical legacy from overapplication.
- The effects of chemical mixtures are largely unknown and difficult to investigate. Studies on the multitude of emerging contaminants (i.e., CECs) and their impacts are insufficient or nonexistent for a number of chemical substances.
- As the presence of emerging substances is being detected over the last three decades, more scientific evidence and monitoring approaches to enhance the understanding of the lifecycle of emerging contaminants, the ecotoxicological significance of chemical mixtures, and the cumulative and synergistic impacts on human health and the environment are needed.
- Removal of emerging contaminants by conventional wastewater treatment plants is limited. Additional causes for their ubiquitous presence relate to their disposal and reuse, pharmaceutical

manufacture and prescription, economic development level, industrialization, and demographic factors.

- The socio-economic costs of chemical pollution impact (e.g., mercury contamination on human health) has been investigated. The specific economic impact of other contaminants still needs to be properly evaluated (e.g., PAHs related to the provision of ecosystem services and welfare benefits).

Priority issue 3: Oil & HNS pollution

Pollution from oil and noxious substances is of great concern when it comes to chronic pollution (i.e., quantification and assessment of operational, illicit, and non-reported spills). However, it is not related to acute pollution events (ca. spills >7 tons or >50 m3 depending on the protocol). The number of oil related spills in the Mediterranean has plummeted progressively over the last decades due to regional and global (ca. IMO) policy response implementation (e.g., doble-hull tankers). In comparison, for HNS, there is not much evidence, and the regular operational discharges are less recognized and understood. Nevertheless, as shipping is a major issue in the Mediterranean Sea, the potential risk for a major accident is always present with known costly environmental and economic (ca. ecosystem services) losses. The recent scientific publications have reviewed the main Mediterranean databases to this regard from EMSA, REMPEC and other sources to provide an updated and a trend overview for the Mediterranean LME.

The key identified knowledge gaps are:

- The annual volume of oil entering the Mediterranean Sea is unknown when land-based and natural seep sources are also considered.
- Datasets on illegal discharges from ships (i.e., chronic oil pollution) are very limited.
- Limited information on the impact of pollution events on biota caused by shipping. Ship-generated pollution impacts are usually considered from a response perspective (i.e., the protection of sensitive areas and facilities).
- Limited access to information and reporting on operations related to oil and gas exploration.

Final remarks:

- Oil and HNS pollution are considered as a separate issue from chemical pollution due to the identification of shipping as a major cause of transboundary pollution in the Mediterranean Sea – the world's busiest waterway.
- The CCA for oil and HNS pollution identifies three types of spills which represent the main direct sources of oil pollution: accidental, operational, and illicit.
- The major source of oil pollution is from shipping while oil and gas production and exploration are relatively less important relative to other areas in the world.
- Despite the increase in maritime traffic, global statistics show a clear downward trend in the frequency of spills greater than 7 tons, coherent with the trend in the Mediterranean Sea.
- Although the frequency of oil spills is decreasing, chronic inputs at sea from operational discharges remain an worrying issue. Their composition and occurrences are largely unknown.

- The regional overview of incidents shows that causalities involving small volumes of oil and other pollutants are still numerous in the Mediterranean Sea and require continuous monitoring and reporting.
- Quantitative estimations of illicit discharges and related volumes show large differences and a high uncertainty. Surveillance and monitoring of illicit discharges remain critical issues, resulting in limited structured data to quantify the issue and reconstruct historical trends.
- Chronic pollution is generally overlooked, although it generates cumulative and long-term changes in marine ecosystems and their services. These differ substantially from the effects on marine ecosystems that take place as a result of acute pollution caused by accidental spills.
- The expected impacts of oil from offshore oil installations in the marine environment remain uncertain, primarily due to difficulties associated with conducting research at great depth.
- The ecological impacts of regular HNS discharges are less recognized and understood than those involving oil pollution.

Priority issue 4: Marine litter and microplastics (wastes)

Anthropogenic solid waste, comprising to a great extent of plastic materials, have been monitored and assessed over the last decade. These lightweight items/particles can be transferred around the Mediterranean (e.g., oceanographic conditions, water circulation); thus, can be only addressed at regional level with multiple environmental, economic, social and health impacts. Nowadays, numerous research publications, policy reports and relevant information are available mainly focusing on the quantitative and qualitative characteristics, including the pertaining impact on the environment and its biota (e.g., ingestion and entanglement). Regional policy instruments are in place, including the updated Regional Plan on Marine Litter Management in the Mediterranean (adopted 2013 and updated in 2021) and multi-stakeholder partnerships and platforms.

Priority issue 5: Nanolitter and chemicals leaching (&toxicity)

Marine litter, when at sea, is fragmented into smaller sized particles (e.g., micro- and nano-sized particles), which in turn release several chemical substances, therefore, leading to chemical pollution and toxicity issues mainly related to the unknown emerging compounds pool yet to be fully investigated and environmental impacts to be understood. At present, these transboundary issues are only addressed at science/research level.

The key identified knowledge gaps are:

- Limitations in approaching the causality analysis (ca. CCA) of marine litter and microplastics and down to nanolitter quantitatively using a source-to-sea paradigm due to the data gaps along the continuum.
- The identification of marine litter sources (e.g., rivers, diffuse inputs) is hampered by inconsistent and incomplete information and data at the regional scale.

- A general lack of available data on the transboundary impacts of marine litter and microplastics on Mediterranean ecosystems and biota.
- Despite the surge in the number of scientific publications on marine litter in the Mediterranean Sea over the past decade, uncertainties and knowledge gaps exist related to the amounts, fate in the marine environment and both environmental and socioeconomic impacts of marine litter.
- Impacts of marine litter, microplastics and in particular nanoplastics (ca. nanoparticles) on environmental and human health are still not sufficiently addressed.
- Limited data and information to quantify the socio-economic impacts.

Final remarks:

- It is often suggested that the Mediterranean Sea is a marine environment with one of the highest levels of plastic pollution worldwide.
- The distribution of plastic debris in terms of abundance, mass and size at the surface of the Mediterranean Sea is uneven and marked by regional differences.
- The transboundary component of marine litter in the Mediterranean was estimated to be as high as 30%.
- Multiple point/diffuse and land-/sea-based sources make the identification of sources a complex task, as marine litter enters the sea.
- One of the key underlying causes is the inadequate waste collection and treatment infrastructure, which fails to keep up with the increasing waste generation rates, in the south Mediterranean countries.
- Marine litter and microplastic pollution cause serious impacts on the economic sectors in the Mediterranean basin that are quantifiable in monetary terms for the tourism and fisheries economic sectors.
- More data and information on the occurrence of microplastics are required to fully understand the distribution, fate and impacts of microplastics.
- Coastal population and tourism, associated with take-make-waste economic models, are the main drivers of plastic-waste generation and marine litter in the Mediterranean Sea. Fundamental changes in the socio-economic drivers (root and underlying causes) and prevalent lifestyles are required to combat litter pollution.

Priority issue 6: Fisheries harm (overfishing and trawling)

Fisheries and its socioeconomic transboundary concerns were reported in the 2005 TDA. Similarly, like the water quality issues (n°1) or chemical pollution issues (n°2), and despite the improvement of the fisheries overexploitation management, the problems and declining trends persist according to both scientific and policy studies. Therefore, unsustainable fisheries and its impacts remain a priority issue with costly socioeconomic and environmental bills (ca. biodiversity), having also side effects on pollution generation (e.g. marine litter generation). Primarily, over the last two decades, scientific research linked to national and regional coordinated monitoring programmes in most of the Mediterranean countries has improved to provide responses to fisheries management; however, it is still seen as a potential economic sector along the aquaculture sector. Environmental harm and damage from fisheries exploitation models are obvious (ca. scientific evidence) in both overfishing and trawling practices and continue to be examined by Mediterranean scientists and stakeholders.

Remarks:

- The unsustainably high level of fishing pressure, combined with seafood consumers preference by carnivore fish species (e.g., tuna, hake, turbot, swordfish), and the weak monitoring and enforcement have all combined to a situation of overfishing, which affects especially the species with higher trophic level. In turn, the overfishing of predator fish species may result in cascade effects throughout the marine trophic levels and can trigger ecosystem shifts towards ecosystems dominated by species with lower trophic level. This process, termed "*Fishing down the food web*" (Pauly, 1998) was demonstrated to be happening in the Mediterranean by Piroddi *et al*. (2017). These authors evidence that across the Mediterranean basin there has been a reduction in abundance of important fish species (~34%, including commercial and non-commercial) and top predators (~41%), and an increase of the organisms at the bottom of the food webs (~23%). In detail, Piroddi *et al*. (2017) found that there was a clear decline of small pelagics (-41%), demersal fish (-49%) and elasmobranch (-60%) biomasses in the Western and Adriatic Seas.

- Piroddi *et al*. (2017) conclude stating that, with anthropogenic pressures rapidly expanding in the Mediterranean Sea, there is a serious risk that these may push the system beyond the "point of no-return", with consequences for marine biodiversity and the economies that depend on it, seriously constraining the ecosystem service options available to future generations. Ecosystem modelling tools can support the analysis and identification of the potential suitable options for ensuring the coexistence of sustainable human activities and the protection of healthy marine ecosystems. Since climate variability and climate change in combination with fishing pressure is expected to intensify in the region, modelling approaches are necessary in predicting the effect of changes of the above-mentioned pressures on the marine food web.

Priority issue 7: Biodiversity decline (by-catch, key species & NIS)

Biodiversity is under threat by several pressures (ca. cumulative pressures). In terms of species, issues originate directly or indirectly by our societal and economic models. A major pressure (ca. collateral impact from fisheries, nº6) is by-catch of non-target species, discards and mortality of non-commercial species leading to the degradation of the pelagic, demersal and benthic habitats. Furthermore, key emblematic species (ca. long-lived species) (ca. turtles, monk seal, fan shell, etc.) in the Mediterranean are also threatened, but most if not all, the transboundary issues and their causes related to biodiversity decline have been identified (including from nº1 to nº12). Non-Indigenous Species (NIS) phenomena is both an old and current issue being mostly problematic when affecting species displacements and ecosystem functioning, either exploited or not (ca. faster succession changes interfering with natural distributions and evolution). The large and complex cumulative pressures and impacts within the Mediterranean marine biodiversity provoke many socioeconomic challenges, as well as result in worrying uncertainties when related to the future climate change (ca. species extinctions) according to scientific forecasted studies.

Some mortality figures from Carpentieri et al. (2021) illustrate the magnitude of the bycatch problem:

Sea turtles

- Set nets, bottom trawling and pelagic longline are the main gears catching sea turtles.
- Each year, small-scale fisheries using set nets kill at least about 16,000 turtles.
- Bottom trawling (BT) fleets catch 51,000 turtles per year, of which about 9,000 die (these mortality estimates refer only to turtles that are already dead at the time of hauling; they do not include post-release mortality).
- Between 27,000 and 56,000 turtles are caught annually by pelagic longlines, with 20% direct mortality rate.
- In total, the estimated range is 121,000-150,000 turtles caught and 33,000-39,000 deaths per year.

Elasmobranchs

- Elasmobranchs or chondrichthyans (sharks, skates, rays, chimaeras and guitarfishes) are globally threatened by overfishing, finning and habitat loss.
- The Mediterranean and Black Sea contribute about 7% of global elasmobranch diversity, with at least 48 species of sharks, 38 species of batoids (rays and skates) and two species of chimaeras.
- Between 53 and 71% of Mediterranean elasmobranch species are at risk.
- Only 28% of Mediterranean and Black Sea elasmobranch species (the 24 species included in Annex II of the SPA/BD Protocol) have legal protection.
- Bycatch in fisheries presents the main threat to elasmobranch populations in the Mediterranean Sea, with all species potentially affected. All species may be caught in bottom trawlers, almost all (94%) in various types of nets, and two thirds (67%) are vulnerable to bycatch by longliners.

Seabirds

- About 50% of the available literature and records in the Mediterranean on seabird bycatch refer to longline fisheries, followed by set nets (gillnets and trammel nets, 16.7%) and bottom trawls (14%). This dynamic is consistent with data available from other regions of the world.
- Available data on seabird bycatch in Mediterranean and Black Sea fisheries is scarce and unequally distributed, with data mainly gathered in the western Mediterranean (68% of records).
- Of the 15 seabird species present in the Mediterranean, three have high susceptibility to bycatch: the Balearic shearwater (Puffinus mauretanicus) and the Yelkouan shearwater (Puffinus yelkouan) are predominantly caught in set nets, and Scopoli's shearwater in pelagic and demersal longline.

Marine mammals

- The use of large-scale driftnets targeting tuna and swordfish during the 1980s-1990s killed 10,000 cetaceans per year in the Mediterranean Sea. Driftnets larger than 2.5 km are now under an international moratorium. Cetacean bycatch in the Mediterranean has decreased drastically.
- Even though large-scale driftnets are banned, there is anecdotal evidence (e.g. stranded cetaceans showing typical signs of entanglement in large driftnets, images and videos on social networks, or online news sources) that this activity is illegally practiced in some areas.
- Also, cetacean mortality due to interactions with small-scale fishing gear may be underestimated and partially unrecorded, due to the low level of monitoring.
- As for the Mediterranean monk seal (Monachus monachus), the only pinniped species native of the Mediterranean, interactions with set net fisheries often lead to accidental deaths. Most interactions involve small-scale fisheries that overlap with monk seal habitat.

- A study about monk seal mortality in Greece identified net entanglement as the cause of death in 65% of the recorded cases.

Non-Indigenous Species (NIS)

There are several main pathways by which non-indigenous species (NIS) reach the Mediterranean marine ecosystems. The main currently identified pathways are corridors and shipping (biofouling and ballast water). The relative importance of corridors has increased since the enlargement of the Suez Canal in 2015. Further monitoring is needed regarding the identification of the NIS, their abundance levels, and the possible negative interactions with native species and the wider marine ecosystem. It is also necessary to take into account that not all non-indigenous species (NIS) are also invasive. The impacts of such NIS that are invasive and able to outcompete native species are probably enhanced by stressors such as habitat degradation, pollution, and climate change. Therefore, it is very difficult to isolate the specific impacts caused by NIS to the Mediterranean species and habitats.

Priority issue 8: Habitat changes (contamination, damage & loss)

The coastal land-sea transitions and the marine seafloor in the Mediterranean basins are rich in geomorphologies responding to a rich diversity of habitats and species of the Mediterranean Sea. Mediterranean transboundary habitats (ca. and transboundary species distributions) from inland down to the deep sea habitats, including wetlands, coastal lagoons, mesophotic habitats/communities (ca. seagrass meadows, coralligenous formations, maërl) and seafloor are threatened by a large list of anthropogenic causes (ca. pressures) with growing evidences of polluted, partially damaged or already lost ecosystems in some parts of the Mediterranean by multiple stressors over the lasts decades, whilst policy responses continues (ca. Coastal and Marine Protected Areas) accompanied by new tools, such as the global System of Environmental-Economic Accounting (ca. SEEA), to address the conservation needs.

Regarding habitats, from the results of the literature review it can be inferred that several of the most important marine habitats in the Mediterranean are experiencing a reduction in their distributional range, due to both direct destruction and cumulative impacts. The coastal areas covered by wetlands and seagrass meadows, especially of Posidonia oceanica is receding, while other infralittoral like vermetid or polychaete reefs are poorly studied (however, some massive mortalities events have been recorded). Circalittoral, mesophotic and deep-water habitats are more difficult to monitor and assess; however, the available information points out to significant reduction of habitats, such as coralligenous formations, maërl/rhodolith beds, mesophotic stony corals, hard-bottom coral gardens, soft-bottom coral gardens, sea pen fields, and sponge aggregations. Besides the net loss in total geographical extent of these habitats, the information available points out to a decrease in habitat quality i.e. a poorer overall condition of the habitats for which there is relevant information (e.g. seagrass meadows, polychaete reefs, coralligenous formations).

Priority issue 9: Atmospheric emissions (&pollutants)

Atmospheric chemicals, chemical processes and their relationships with the marine environment are transboundary by nature (ca. the atmosphere over the sea) and bidirectional exchanges and fluxes occur for particles, compounds and gases at the sea surface. As such, particles (ca. dust), chemicals (ca. NOx, SOx) and gases (ca. CO2) displaced from the equilibrium pose a threat to the natural steady state and biogeochemistry cycles with secondary long-term consequences due to phenomena, such as sea acidification with potential environmental and socioeconomic impacts. Most of the research in this topic has been separately addressed by science in the Mediterranean region not always linked to the marine environment and the interactions observed, whilst recent policy has been established to that extent (ca. SECA-REMPEC).

Priority issue 10: Marine anomalies (SST-heat waves)

Climate change led to an increase in the frequency and intensity of marine heatwaves (MHWs) in the Mediterranean Sea related to the displacements of the steady state responding to altered heat exchanges between the atmosphere and the sea surface. Evidence of mortality events (MMEs) of marine organisms are one of their main ecological impacts, as it is currently investigated. The Mediterranean Sea is experiencing exceptional thermal conditions variabilities to be yet well understood, add to that the yearly summer heat waves and forest fires expected to worsen according to climate forecasting studies. This sums another factor to the occurrence, distribution of chemical compounds and pollutants in the environment and their effects.

Priority issue 11: Coastal water systems (pollution&flooding)

Land-sea and sea-land flooding processes are the result of complex combinations of environmental factors (ca. storm surge, sea level rise, geomorphology, water stressors, etc.) with highly socioeconomic and environmental impacts varying among the different Mediterranean coastal areas. In terms of pollution issues (from nº1 to nº5), uncertainty is high as it is a collateral effect and depends on the flows variabilities during the events and the coastal-water systems (both surface and groundwater flows and reservoirs). Chemical and litter pollution of land, transitional, groundwater and coastal freshwater flows have a clear impact in the marine environment (ca. LBS Protocol) with direct and indirect ecosystem services costs, yet to be fully accounted and understood.

Priority issue 12: Coastal planning (assets&drought)

Climate change and its multiple impacts, such as droughts, pose a systemic challenge to Mediterranean assets, such as freshwater and drinking water resources and other ecosystem services maintenance. Therefore, coastal planning is a major challenge in the Mediterranean at transboundary level. The Mediterranean region with a population of 531.7 million inhabitants is considered one of the regions of the globe with the highest socioeconomic exposure to drought that is likely be exacerbated in the future (ca. water abstraction, rain/moisture patterns variability, etc.). Coastal and marine ecosystem services; both transboundary and shared (ca. by countries), are interlinked with many transboundary issues. New digital tools, such as Marine and Maritime Spatial Planning, along socioeconomical transitions could be the way forward.

CHAPTER 11. Summary, conclusions, and recommendations

SUMMARY/CONCLUSIONS ON POLLUTION

EUTROPHICATION

- Local unnatural eutrophication is not commonly observed in the basin except for few restricted problems in areas subject to land-based and untreated wastewater inputs.
- A few coastal areas are historically known to be influenced by natural and/or anthropogenic inputs of nutrients (e.g., Alboran Sea, Gulf of Lion, Gulf of Gabès, Adriatic Sea, Northern Aegean and the Nile-Levantine) with some trend off-coast anomalies detected recently.
- Impacts in these areas could have transboundary implications.

CHEMICAL POLLUTION

- Trends and levels of pollutants have generally decreased significantly in the most impacted areas in the Mediterranean Sea after the implementation of environmental measures.
- Although levels of cadmium, mercury and lead in coastal waters show an acceptable environmental status, the contamination of coastal sediments remains an issue.
- Harbors and industrial coastal areas were the most contaminated by PAHs and PCBs in almost all studied sites, followed by coastal lagoons. PCB in seawater showed a significant spatial variability in dissolved concentrations with lower levels offshore.
- Concentrations of dissolved PAHs measured during two sampling cruises were found higher in the Eastern Mediterranean than in the Western Mediterranean, reflecting different pollutant loads, trophic conditions and cycling. In a separate review study, higher concentrations of PAHs and PCBs were reported in northwestern countries, where most study sites were located.
- PBDEs and PCDD/Fs tend to bioaccumulate in lower trophic levels (phytoplankton and zooplankton) whereas PCBs preferentially bioaccumulate in the higher trophic levels (fish and cephalopods)
- Although banned for years, the levels of organochlorine pesticides and PCBs were still elevated compared to common cetacean toxicological thresholds in the northwestern Mediterranean.
- Recent scientific studies on contaminants of emerging concern (CEC) highlight the ubiquitous occurrence of a myriad of substances contained in pharmaceuticals, personal care products (antiseptics, sun lotions, cosmetics, etc.).

OIL AND HNS POLLUTION

- The number of oil pollution accidents (acute pollution events) in the Mediterranean Sea is decreasing, in line with decreasing trend observed at the global level.
- Geostatistical analysis of oil spill data show that at the regional level the Aegean Sea had the highest concentration of oil spills.

- Despite the clear reduction of accidental and acute pollution events, continuous chronic oil pollution from operational discharges remains an issue.
- Offshore operations, such as the oil and gas exploitation present another source of chemical pollution to the marine environment ranging from accidental spills to operational discharges in the drilling fluids and produced water. The quantity and composition of such discharges is largely unknown with a few research studies tackling this issue.

MARINE LITTER, MICROPLASTICS, NANOLITTER AND TOXICANTS

- Because of the distinguishing semi-enclosed morphology of the Mediterranean Sea, and different plastic waste generating activities originating from surrounding countries, the Mediterranean Sea is highly vulnerable to marine litter and microplastic pollution.
- Although the Mediterranean Sea is extensively polluted by marine litter and microplastics, it lacks zones of high plastic concentration, i.e. permanent accumulation zones.
- Model simulations showed that the amount of transboundary litter in Mediterranean countries could be as high as 30 %, although both regional and seasonal differences could be significant.
- The distribution of plastic debris in terms of abundance, mass and size at the surface of the Mediterranean Sea is uneven and marked by regional differences. Areas of very high and low abundance reflect the high temporal and spatial variability of the currents.
- The total annual load of plastic is estimated at 17,600 metric tons, whereas approximately 3,760 metric tons of plastic is assumed to be floating on the Mediterranean Sea. This so-called "missing" plastic issue to close the regional plastic budget remains unsolved.
- Higher microplastics presence is generally related to areas under high anthropogenic pressure and proximity to land-based sources nearer to the shore, although hydrodynamic conditions and wind-driven processes influence their redistribution, even far from their sources.
- Microplastics are a ubiquitous and dominant constituent of beach litter. Microplastics can decompose in nanosized particles made of plastic and other components, as well as undertake leaching processes releasing chemical contaminants into the biota and marine waters.
- Despite the increasing number of scientific studies on microplastics, the discrepancies in the methodologies and lack of standardization limit the overall interpretation and intercomparison of published data to some extent.

RECOMMENDATIONS

The overall report update and renewed findings validation of the major transboundary concerns and prioritized analysis undertaken in this TDA update report at Mediterranean Sea scale also needed to observe other relevant regional reporting and the UNEP/MAP System existing regular processes to provide the present report with the necessary robustness for its future uses (see Annex A comparative analysis of the main relevant latests reports from UNEP/MAP and collaborators).

Undoubtedly, there have been a need to observe the H2020 joint EEA-UNEP/MAP Report recently published graping a decade of cooperative work in the Mediterranean to address pollution, as well as the state reports resulting from three different science-based (natural and social sciences) processes, namely the *Climate and Environmental Change in the Mediterranean Basin – Current situation and risk for the future – Report* produced by the Mediterranean Experts on Climate and environmental Change (MedECC, 2020) being the 1st Mediterranean Assessment Report fully tackling Climate Change (MAR1), and the new of its collection of the *State of the Environmenta and Development in the Mediterranean* – SoED Report (Plan Bleu, 2020). Addtionally, the alingment with the Post-2020 SAPBIO content (*Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region (SAPBIO, SPA/RAC, 2020)* and UNEP/MAP COP22 decision (IG.25/11) was also considered, being a triad of both relevant and recent reports on Climate Change, Economy and Biodiversity, respectively. Therefore, beyond the update and focus of this report on pollution issues and advancements here integrated within ecosystem, particularly, the water component (and the reason why UNEP/MAP/MEDPOL is in charge as for the older TDA versions), the above mentioned existing regional related publications, as well as a number of diferent relevant publicaitons in many fields have been considered up to early 2023.

Therefore, aspects form all the knowledge dimensions to elucidate the causes of transboundary environmental concerns have served to establish the deep connections among the issues (or changes observed) in the environment and the casues (or challenges pending to address). Further, the integrative *UNEP/MAP Mediterranean Quality Status Report (QSR) 2017 (UNEP/MAP, 2017)* and the alignment with the ongoing *UNEP/MAP Mediterranean Quality Status Report (QSR) 2023* were considered during the time of preparation of this report over 2021 and 2022 and has been also a priority and should be a continuous support for any reporting process to ensure coherence and avoid disparate interpretations, or at least contradictory (ca. knowledge gap), related to the Mediterranean Sea ecosystems and their funtioning and GES achivement (or deterioration status) for these high-level policy type documents.

There is no doubt that after the second GEF TDA report in 2005, this *UNEP/MAP GEF Mediterranean Sea and Coast (Pollution & Ecosystems) Transboundary Diagnostic Analysis Report update by 2023,* serves the GEF IW global framework TDA/SAP approach, as well as the future endevours in the Mediterranean region through providing further transboundary cooperation and funding opportunities for Contracting Parties that should not be missed.

Annex A. UNEP/MAP and Mediterranean reports comparison analysis

The scientific evidences presented in this report and the earlier research findings and previous assessments of the Mediterranean Sea region in a nunber of envionmental thematics at both local, national, and regional scales can be depicted following the main prioritization of the transboundary changes and challenges across the Mediterranean countries.

Therefore, with reference to the a prioritization based transboundary relevance the following could be stated for the different transboundary thematics (below). Further, based on national thematic assessments the basic findings to further contribute to develop a Strategic Action Programme on a ountry basis could be also summarised.

1.Reversing Pollution (environment)	4.1. on Land and sea-based chemical, biological and physical pollution in transitional waters, coasts and offshore

This report – TDA update 2023 (focus Pollution)	MAR1 2020 (Climate Change) Key findings	SAPBIO 2020 (Biodiversity) Goals and Targets	SoED 2020 (Development) – Key messages	Strategic Action Programme
TP1-2. Chemical legacy pollution and man-made local eutrophication still a concern, altough notable achievements and control through policy/law	2.2 Across the Mediterranean Basin, ocean and inland pollution are transboundary, ubiquitous, diverse and increasing in both quantity and in the number of pollutants, due to demographic pressure, enhanced industrial and agricultural activities, and climate change (high confidence)	ADDRESSING PRESSURES T1.3 on pollution control, particularly plastics, nutrient leakage, and noise	13. Pollution sources: investments and collaborations have addressed some major pollution sources and health hazards.	KM1(SOED). Enforcement: ensuring the effective enforcement of common, agreed objectives and commitments.
TP2. Emerging chemical pollution (MEDPOL List) and microbiological pollution are uder the scope of research for applied science to policy solutions.	2.2.2.3 Emerging contaminants (related to recently discovered chemicals or materials) are prevalent across the Mediterranean Basin, and enhanced by increasing inflow of untreated wastewater. These substances may cause disorders of the nervous, hormonal and reproductive system (high confidence)			KM3(SOED). Local action: translating national and international commitments into local action, adapted to the territorial context.

	2.2.2.4 The increasing frequency of extreme precipitation events in the north of the Mediterranean increases the supply of faecal bacteria and viruses to the coastal zone (medium confidence)			KM4(SOED). Fostering transitions towards sustainability: upgrading and diversifying the policy mix.
TP9. Atmospheric emissions of chemical pollutants, including GHG, altough notable achievements and control through policy/law (e.g. SECA)	2.2.3.1 The Mediterranean Basin is among the regions in the world with the highest concentrations of gaseous air pollutants (NO2, SO2 and O3).			KM5(SOED). Networking and co-construction: developing permanent collaboration frameworks.
TP9. Atmospheric emissions of chemical pollutants, including GHG, altough notable achievements and control through policy/law (e.g. SECA)	2.2.3.2 Ships are among the major emitters of SO2 and NOx, along with road traffic. Their contribution to transport sector emissions and general air pollution in the Mediterranean Basin is increasing (medium confidence).			(SAPBIO2020) 3. MARITIME TRAFFIC 7. LITTER 8. EIA/SEA 9. WIND ENERGY 10. MINERALS 11. SPATIAL PLANNING 32. IMAP REFINEMENT 33. IMAP IMPLEMENTATION
TP9. Atmospheric emissions, including northward and western fluxes of Shaara dust and its associated content a concern.	2.2.3.4 Particular meteorological conditions and natural sources, including the proximity of the Sahara Desert, create specific patterns of aerosol concentrations that may influence particulate matter (PM) concentrations.			
	4.1.3 Adaptation strategies to reduce environmental change impacts on marine ecosystems need to occur in conjunction with climate mitigation and pollution reduction policies and actions			

2.Stopping Litter (environment)	4.2. Sources and fate of litter and waste pollution, including coasts and offshore seafloor

This report – TDA update 2023 (focus Pollution)	MAR1 2020 (Climate Change) Key findings	SAPBIO 2020 (Biodiversity) Goals and Targets	SoED 2020 (Development) – Key messages	Strategic Action Programme
TP4. Marine litter concenrtations and impact affects the entire coastal and marine ecosystems of the Med region. Land-based plastic sources are the major concern.	2.2.2.5 The Mediterranean Sea is one of the most polluted large water bodies globally in terms of plastic and the level of this pollution is expected to increase in the future *(medium confidence)*	ADDRESSING PRESSURES T1.3 on pollution control, particularly plastics, nutrient leakage, and noise		KM1(SOED). Enforcement: ensuring the effective enforcement of common, agreed objectives and commitments.
	4.1.3 Adaptation strategies to reduce environmental change impacts on marine ecosystems need to occur in conjunction with climate mitigation and pollution reduction policies and actions			KM3(SOED). Local action: translating national and international commitments into local action, adapted to the territorial context.
				KM4(SOED). Fostering transitions towards sustainability: upgrading and diversifying the policy mix.
				KM5(SOED). Networking and co-construction: developing permanent collaboration frameworks.
				(SAPBIO2020) 3. MARITIME TRAFFIC 7. LITTER

3.Enhancing Nature (environment)	4.3. on Nature value loss, focusing on marine habitats, biodiversity, and ecosystems

This report – TDA update 2023 (focus Pollution)	MAR1 2020 (Climate Change) Key findings	SAPBIO 2020 (Biodiversity) Goals and Targets	SoED 2020 (Development) – Key messages	Strategic Action Programme

TP8. Habitats loss and degradation	2.4.1 The Mediterranean Sea (and particularly the Levantine Basin) is a hotspot for the establishment of many non-indigenous species *(high confidence)*	ADDRESSING PRESSURES T1.1. on specific and urgent pressures over protected species and habitats T1.2 on alien invasive species, sharing databases and controlling introduction pathways, and impacts in the most vulnerable areas	7.Ecosystem services and cumulated impacts: multiple human-induced pressures combine to threaten critical resources, biodiversity components and ecosystem services.	KM1(SOED). Enforcement: ensuring the effective enforcement of common, agreed objectives and commitments.
TP8. Habitats loss and degradation	4.1.1 Mediterranean marine ecosystems are unique due to their high number of endemic species, but they are also highly vulnerable to local and global pressures including environmental change	MARINE AND COASTAL PROTECTED AREAS1 T1.4. on effective systems of MCPAs and OECMs T1.5. on areas with enhanced protection levels		KM3(SOED). Local action: translating national and international commitments into local action, adapted to the territorial context.
TP8 and TP10, 11, and 12.	4.1.2 The combination of various ongoing climate drivers of environmental change (e.g., sea warming, ocean acidification, and sea level rise) has numerous detectable effects on marine organisms acting at individual, population, and ecosystem scales. Expected future impacts include major reorganizations of the biota distribution, species loss, decrease in marine productivity, increase in non-indigenous species, and potential species extinctions (medium confidence)	ECOSYSTEM HEALTH T1.7. on the achievement of the Good Environmental Status		KM4(SOED). Fostering transitions towards sustainability: upgrading and diversifying the policy mix.
	4.1.3 Adaptation strategies to reduce environmental change impacts on marine ecosystems need to occur in conjunction with climate mitigation and pollution reduction policies and actions			KM5(SOED). Networking and co-construction: developing permanent collaboration frameworks.
				(SAPBIO2020) 1. SPECIES PLANS 2. URGENT SPECIES RECOVERY 3. MARITIME TRAFFIC 4. NIS/IAS COMMITMENT 5. NIS/IAS CAPACITY 6. NIS/IAS CONTROL AND MONITORING 7. LITTER

				8. EIA/SEA 9. WIND ENERGY 10. MINERALS 11. SPATIAL PLANNING 12. RESTORATION 13. CLIMATE CHANGE 14. GOOD ENVIRONMENTAL STATUS 15. EFFECTIVE SYSTEMS OF MCPAs AND OECMs 16. BIODIVERSITY PLATFORM 17. INVERTEBRATES (status) 18. VERTEBRATES (status) 19. HABITATS 21. OVERFISHING and IUU 22. BY-CATCH AND FISHERIES PLANNING 23. SMALL SCALE FISHERIES (incl. recreational) 32. IMAP REFINEMENT 33. IMAP IMPLEMENTATION 34. Post-2020 SAPBIO MONITORING
TP5, 6 and 7 (Fisheries)				

4.Fighting Climate (environment)	4.4. on Climate change adaptation, mitigation, and socio-ecological resilience

This report – TDA update 2023 (focus Pollution)	MAR1 2020 (Climate Change) Key findings	SAPBIO 2020 (Biodiversity) Goals and Targets	SoED 2020 (Development) – Key messages	Strategic Action Programme
TP 11 and 12.	2.1. Anthropogenic climate change has been observed for many variables in the Mediterranean Basin during recent decades. For the future, the region is expected to remain among the regions most affected by climate change, particularly when it comes to precipitation and the hydrological cycle	ECOSYSTEM HEALTH T1.8. on climate change mitigation, adaptation, and nature-based solutions	9.Climate change impact: Climate change is already affecting the Mediterranean, exacerbating pre-existing challenges.	KM1(SOED). Enforcement: ensuring the effective enforcement of common, agreed objectives and commitments.
TP11.	3.1.3 Disastrous flash floods are frequent in many countries including Italy, France			KM3(SOED). Local action: translating national and international

	and Spain, affecting mainly the coastal areas, in particular, where population and urban settlements are growing in flood-prone areas. These will likely become more frequent and/or intense due to climate change and surface-sealing (medium confidence)			commitments into local action, adapted to the territorial context.
TP12.	3.1.4 Climate change, in interaction with other drivers (mainly demographic and socio-economic developments including unsustainable agricultural practices), is likely to impact most of the Mediterranean Basin, through reduced runoff and groundwater recharge, increased water requirements for crops, increased conflicts among users, and increased risk of overexploitation and degradation (high confidence)			KM4(SOED). Fostering transitions towards sustainability: upgrading and diversifying the policy mix.
	5.2.1 Environmental change has already led to a wide range of impacts on human health in Mediterranean countries, and most trends are likely to continue			KM5(SOED). Networking and co-construction: developing permanent collaboration frameworks.
TP10.	5.2.2 Heat waves are responsible for high mortality rates causing tens of thousands of premature deaths, especially in large cities and among the elderly. Heat-related morbidity and mortality has been partially reduced in recent years by more ef-ficient protection of people (high confidence)			(SAPBIO2020) 2. URGENT SPECIES RECOVERY 3. MARITIME TRAFFIC 4. NIS/IAS COMMITMENT 5. NIS/IAS CAPACITY 6. NIS/IAS CONTROL AND MONITORING 7. LITTER 8. EIA/SEA 9. WIND ENERGY 10. MINERALS 11. SPATIAL PLANNING 12. RESTORATION 13. CLIMATE CHANGE 14. GOOD ENVIRONMENTAL STATUS 15. EFFECTIVE SYSTEMS OF MCPAs AND OECMs 16. BIODIVERSITY PLATFORM 17. INVERTEBRATES (status) 18. VERTEBRATES (status)

				19. HABITATS 20. NIS/IAS (data bases) 21. OVERFISHING and IUU 22. BY-CATCH AND FISHERIES PLANNING 23. SMALL SCALE FISHERIES (incl. recreational)
TP10 and TP2.	5.2.3 Despite the rise in mean temperature, cold waves are not likely to disappear (high confidence). Moderate cold-related risk will remain a temperature-related risk throughout the 21st century, in combination with risks due to pathogenic agents (low confidence)			24. AQUACULTURE 25. TOURISM 26. INTEGRATING BIODIVERSITY 27. STREAMLINE Post-2020 SAPBIO 28. POLITICAL WILL AND COORDINATION 29. STAKEHOLDER PARTICIPATION 30. UP-DOWN BOTTOM-UP INTERNATIONAL COMMITMENTS 31. COMPLIANCE AND ENFORCEMENT
TP10 and TP8.	5.2.4 Environmental changes in the Mediterranean Basin will likely exacerbate risks for vector-borne disease outbreaks in the Mediterranean region, since warmer climate and changing rainfall patterns (together with landscape management) may create hospitable environments for mosquitoes, ticks, and other climate-sensitive vectors, particularly for the West Nile Virus, Chikungunya and Leishmaniasis (medium confidence)			32. IMAP REFINEMENT 33. IMAP IMPLEMENTATION 34. Post-2020 SAPBIO MONITORING 35. SUPPORT TO RUN the Post-2020 SAPBIO 36. CAPACITY BUILDING FOR THE Post-2020 SAPBIO AT NATIONAL LEVEL 37. NETWORKING AND COMMON KNOWLEDGE 38. AWARENESS 39. OUTREACH AND EDUCATION 40. EMPLOYMENT 41. SUSTAINABLE FUNDING 42. COOPERATION

5.Sustaining assets and Switching livelihoods (welfare)	4.5. on Coastal belts degradation, sustainability, and restoration; and, 4.6. on Socio-economic drivers of transformation, green recovery, and sustainable blue finance

This report – TDA update 2023 (focus Pollution)	MAR1 2020 (Climate Change) Key findings	SAPBIO 2020 (Biodiversity) Goals and Targets	SoED 2020 (Development) – Key messages	Strategic Action Programme

Sustaining assets (coastal ecology) and Switching livelihoods (environmental economy)	2.3.1 Landscapes and their use have changed over millennia in the Mediterranean Basin, however the rate of change has increased substantially since the second half of the 20th century (high confidence)	ECOSYSTEM HEALTH T1.6. on ecosystem restoration, most of those with the highest relevance and potential	1.Demographic trends: the population continues to grow in coastal and urban areas of the Mediterranean region, with a younger population in SEMCs.	KM2(SOED). Institutional capacity: raising the profile of environmental institutions and stakes.
Sustaining assets (fisheries)	2.3.2 Marine resource overexploitation and unsustainable fishing practices are the main driver of marine species population decline	SUSTAINABLE FISHERIES T2.4. on halting by-catch and illegal, unreported and unregulated fishing T2.5. on small-scale fisheries (professional, recreational), particularly in MPAs T2.6. on sustainable and biodiversity-friendly aquaculture.	2.Human development: while considerable progress has been made in education and health in the South and East of the basin, large North-East/South divides remain, driven by persistent GDP gaps and aggravated by conflicts.	KM3(SOED). Local action: translating national and international commitments into local action, adapted to the territorial context.
Sustaining assets (coastal ecology)	2.4.2 On land, there is a high number of non-in-digenous species in human-modified ecosystems and in regions with high infrastructure develop-ment *(high confidence)*	MAINSTREAMING BIODIVERSITY T2.7. on the ecosystem approach, and marine and coastal spatial planning T2.8. on cross-sectoral integration, including tourism, mining, energy T2.9. on reinforced governance, compliance, and stakeholder participation	3.Macroeconomic situation: Mediterranean countries are increasingly vulnerable to external conditions and shocks, including environmental shocks.	KM4(SOED). Fostering transitions towards sustainability: upgrading and diversifying the policy mix.
Sustaining assets (water resources and abstraction)	3.1.2 Due to the general scarcity of water resources, conflicts arise from different sectors of water use (agriculture, tourism, industry, people, also biodiversity conservation) (medium confidence)	MOBILIZING SUFFICIENT RESOURCES T3.8. on employment, notably public, in direct relation to biodiversity conservation T3.9. on sustainable funding, national commitments and innovative sources T3.10. on international cooperation and increased north/south financial flows	4.Good Environmental Status: Mediterranean economies are dependent on environmental integrity, particularly in coastal areas.	KM5(SOED). Networking and co-construction: developing permanent collaboration frameworks.
Sustaining assets (coastal ecology)	3.1.3 Disastrous flash floods are frequent in many countries including Italy, France and Spain, affecting mainly the coastal areas, in particular, where population and urban settlements are growing in flood-prone areas. These will likely become more frequent and/or intense due to climate change and surface-		5.Environmental pressures from economic sectors: despite the emergence of low-impact solutions, economic sectors are exerting increasing pressures on the environment, driven by rapid growth in polluting sectors and a diversification of	KM6(SOED). Foresight: anticipating the transformation of coastal and marine areas, activities and landscapes.

	sealing (medium confidence)		economic activities in marine areas.	
Sustaining assets (coastal ecology and water abstration)	3.1.5 The combined dynamics of climate and socio-economic changes suggest that despite an important potential for adaptation to reduce freshwater resource vulnerability, climate change exposure cannot be fully and uniformly counterbalanced. In many regions, socio-economic developments will have greater impact on water availability compared to climate-induced changes (low confidence)		6.Land-cover and land-use change: ambitious objectives and disparate policy measures have not been sufficient to preserve natural land cover and agricultural land use, particularly in coastal areas.	KM9(SOED). Transparency: documenting and communicating the stakes of environmental degradation and socioeconomic inequalities.
Sustaining assets (coastal ecology and water abstration)	3.2.1 Warmer and drier climate conditions, with more frequent and intense extreme events, in combination with higher soil salinization, ocean acidification and land degradation, sea level rise and the emergence of new pathogens pose a threat to most elements of the food production system in the Mediterranean Basin (high confidence)		8.Human health: while health has globally improved in the region, pollutants, climate change, new lifestyles and consumption patterns are raising increasing health concerns.	KM10(SOED). Learning by doing: learning from experience sharing and peer review mechanisms for adaptive policies.
Sustaining assets (coastal water-systems)	3.2.1 Warmer and drier climate conditions, with more frequent and intense extreme events, in combination with higher soil salinization, ocean acidification and land degradation, sea level rise and the emergence of new pathogens pose a threat to most elements of the food production system in the Mediterranean Basin (high confidence).		10.Progress on policy challenges: cooperation on environmental matters remained active despite unfavourable geopolitical circumstances.	1. SPECIES PLANS 2. URGENT SPECIES RECOVERY 3. MARITIME TRAFFIC 4. NIS/IAS COMMITMENT 5. NIS/IAS CAPACITY 6. NIS/IAS CONTROL AND MONITORING 7. LITTER 8. EIA/SEA 9. WIND ENERGY 10. MINERALS 11. SPATIAL PLANNING 12. RESTORATION 13. CLIMATE CHANGE 14. GOOD ENVIRONMENTAL STATUS 15. EFFECTIVE SYSTEMS OF MCPAs AND OECMs 16. BIODIVERSITY PLATFORM 17. INVERTEBRATES (status) 18. VERTEBRATES (status) 19. HABITATS 20. NIS/IAS (data bases) 21. OVERFISHING and IUU

				22. BY-CATCH AND FISHERIES PLANNING 23. SMALL SCALE FISHERIES (incl. recreational)
Switching livelihoods (environmental economy)	3.2.3 The food production system on land has the capacity to contribute to greenhouse gas mitigation strategies through nitrogen fertilization optimization, improved water management, better storage of soil organic carbon and carbon sequestration, management of crop residues and agroindustry by-products (high confidence)			24. AQUACULTURE 25. TOURISM 26. INTEGRATING BIODIVERSITY 27. STREAMLINE Post-2020 SAPBIO 28. POLITICAL WILL AND COORDINATION 29. STAKEHOLDER PARTICIPATION 30. UP-DOWN BOTTOM-UP INTERNATIONAL COMMITMENTS 31. COMPLIANCE AND ENFORCEMENT
Switching livelihoods (environmental economy)	3.3.3 Climate change in the Mediterranean is expected to impact energy production (due to impacts on infrastructure) and energy use (by decreased heating demand and increased cooling needs)			32. IMAP REFINEMENT 33. IMAP IMPLEMENTATION 34. Post-2020 SAPBIO MONITORING 35. SUPPORT TO RUN the Post-2020 SAPBIO 36. CAPACITY BUILDING FOR THE Post-2020 SAPBIO AT NATIONAL LEVEL 37. NETWORKING AND COMMON KNOWLEDGE 38. AWARENESS 39. OUTREACH AND EDUCATION 40. EMPLOYMENT 41. SUSTAINABLE FUNDING 42. COOPERATION
Sustaining assets (coastal ecology) and Switching livelihoods (environmental economy)	4.2.1 The coastal zone, i.e. the area in which the interaction between marine systems and the land dominate ecological and resource systems, is a hotspot of risks, especially in the MENA region (high confidence)			
Switching livelihoods (environmental economy)	4.2.3 Developing more integrated approaches would support adaptation policies for the entire Mediterranean, involving ecosystem-based management of coastal areas, identifying synergies and conflicts, as well as			

	integrating local knowledge and institutions			
Switching livelihoods (environmental economy)	4.3 Terrestrial ecosystems; 5.1 Development; 5.3 Human security			

6.Integrating knowledge and Boosting digitalization (welfare)	4.7. on Observing infrastructures, including joint IMAP national monitoring data flows, regional and global indicators; and, 4.8. on Environmental digitalization, marine literacy and forecasting research

Therefore, we could list:

This report – TDA update 2023 (focus Pollution)	MAR1 2020 (Climate Change) Key findings	SAPBIO 2020 (Biodiversity) Goals and Targets	SoED 2020 (Development) – Key messages	Strategic Action Programme
Switching livelihoods (environmental economy)	3.3.1 From 1980 to 2016, primary energy consumption in the Mediterranean Basin steadily increased by approx. 1.7% yr-1, mostly due to changing demographic, socio-economic (lifestyle and consumption) and climate conditions (high confidence)	IMPROVED KNOWLEDGE T2.1. on the distribution and status of species protected under the SPA/BD Protocol T2.2. on sea-floor cartography, status and integrity of threatened habitats T2.3. on knowledge sharing (Mediterranean Biodiversity Platform)	11.Regional cooperation for common objectives: Mediterranean countries have adopted common objectives and cooperation frameworks, setting a shared path towards sustainable development.	KM2(SOED). Institutional capacity: raising the profile of environmental institutions and stakes.
Switching livelihoods (environmental economy)	3.3.2 Projected trajectories for energy demand over the next few decades in the Mediterranean Basin differ significantly between the northern and the eastern/southern rim countries (high confidence)	IMPLEMENTATION, MONITORING AND REPORTING T3.1. on the IMAP refinement and full compliance T3.2. on the Post-2020 SAPBIO assessment and reporting mechanisms T3.3. on adequate means to run the Post-2020 SAPBIO.	12.EcAp, ICZM, and MSP: Integration and system-based approaches are increasingly recognized as the most efficient way to address systemic factors, combined pressures and cumulated impacts.	KM3(SOED). Local action: translating national and international commitments into local action, adapted to the territorial context.
Integrating knowledge (research and policy)		CAPACITY BUILDING AND NETWORKING T3.4. on capacity building, particularly in the less developed countries T3.5. on networking and knowledge sharing (NIS, migratory species, MPAs, GES...).	14.Adaptive policies: capacity to generate knowledge is increasing based on common assessment frameworks and data for decision-making.	KM4(SOED). Fostering transitions towards sustainability: upgrading and diversifying the policy mix.

Integrating knowledge (research and policy)		OUTREACH AND AWARENESS T3.6. on raising awareness, targeting decision-makers, media, and general public T3.7. on integrating marine biodiversity into school, higher education, and professional training.		KM5(SOED). Networking and co-construction: developing permanent collaboration frameworks.
Integrating knowledge (research and policy)				KM7(SOED). Useful knowledge: putting existing knowledge to use.
Integrating knowledge (research and policy)				KM8(SOED). Monitoring: implementing, sustaining and expanding common monitoring frameworks.
Integrating knowledge (research and policy)				KM10(SOED). Learning by doing: learning from experience sharing and peer review mechanisms for adaptive policies.
Integrating knowledge (research and policy) and Boosting digitalization (technology)				1. SPECIES PLANS 2. URGENT SPECIES RECOVERY 3. MARITIME TRAFFIC 4. NIS/IAS COMMITMENT 5. NIS/IAS CAPACITY 6. NIS/IAS CONTROL AND MONITORING 7. LITTER 8. EIA/SEA 9. WIND ENERGY 10. MINERALS 11. SPATIAL PLANNING 12. RESTORATION 13. CLIMATE CHANGE 14. GOOD ENVIRONMENTAL STATUS 15. EFFECTIVE SYSTEMS OF MCPAs AND OECMs 16. BIODIVERSITY PLATFORM 17. INVERTEBRATES (status) 18. VERTEBRATES (status) 19. HABITATS 20. NIS/IAS (data bases) 21. OVERFISHING and IUU 22. BY-CATCH AND FISHERIES PLANNING

				23. SMALL SCALE FISHERIES (incl. recreational)
Integrating knowledge (research and policy) and Boosting digitalization (technology)				24. AQUACULTURE 25. TOURISM 26. INTEGRATING BIODIVERSITY 27. STREAMLINE Post-2020 SAPBIO 28. POLITICAL WILL AND COORDINATION 29. STAKEHOLDER PARTICIPATION 30. UP-DOWN BOTTOM-UP INTERNATIONAL COMMITMENTS 31. COMPLIANCE AND ENFORCEMENT
Integrating knowledge (research and policy) and Boosting digitalization (technology)				32. IMAP REFINEMENT 33. IMAP IMPLEMENTATION 34. Post-2020 SAPBIO MONITORING 35. SUPPORT TO RUN the Post-2020 SAPBIO 36. CAPACITY BUILDING FOR THE Post-2020 SAPBIO AT NATIONAL LEVEL 37. NETWORKING AND COMMON KNOWLEDGE 38. AWARENESS 39. OUTREACH AND EDUCATION 40. EMPLOYMENT 41. SUSTAINABLE FUNDING 42. COOPERATION

Annex B. EU Mediterranean layers [Chemistry (incl.Pollution), Biology, Physics, Geology, Bathymetry, Seabed Habitats and Human Activities]-European Atlas of the Seas

EMODnet data layers catalogue within the European Atlas of the Seas

European Marine Observation and Data Network (EMODnet)

https://emodnet.ec.europa.eu/en/emodnet-data-layers-catalogue-within-atlas

Chemistry (inlc. Pollution)

- Concentration of chlorophyll-a (winter 2012-2017)
- Concentration of chlorophyll-a (spring 2012-2017)
- Concentration of chlorophyll-a (summer 2012-2017)
- Concentration of chlorophyll-a (autumn 2012-2017)
- Beach Litter - Composition of litter according to material categories - Official monitoring
- Beach Litter - Median total number of litter items per 100m & to 1 survey - Official monitoring
- Beach Litter - Median number of Cigarette related items per 100m & to 1 survey - without UNEP_MARLIN - Official monitoring
- Beach Litter - Median number of fishing and aquaculture related plastic items per 100m & to 1 survey - Official monitoring
- Beach Litter - Median number of Plastic bags related items per 100m & to 1 survey - Official monitoring
- Seabed litter - Density (Nb. Items/km2)
- Seabed Litter - Material categories percentage per year
- Seabed litter - Fishing related items density (Nb. Items/km2)
- Seafloor litter - Plastic bags density (Nb. items/km2)
- Water body ammonium 2010 in winter
- Water body ammonium 2010 in spring
- Water body ammonium 2010 in summer
- Water body ammonium 2010 in autumn
- Water body dissolved oxygen concentration 2012-2017 in winter
- Water body dissolved oxygen concentration 2012-2017 in spring
- Water body dissolved oxygen concentration 2012-2017 in summer
- Water body dissolved oxygen concentration 2012-2017 in autumn
- Water body phosphate 2012-2017 in winter
- Water body phosphate 2012-2017 in spring
- Water body phosphate 2012-2017 in summer
- Water body phosphate 2012-2017 in autumn
- Water body silicate 2012-2017 in winter
- Water body silicate 2012-2017 in spring
- Water body silicate 2012-2017 in summer
- Water body silicate 2012-2017 in autumn

Biology

- Zooplankton (Acartia) abundance in winter
- Zooplankton (Acartia) abundances in spring
- Zooplankton (Acartia) abundances in summer
- Zooplankton (Acartia) abundances in autumn
- Zooplankton (Calanus finmarchicus) abundance in winter
- Zooplankton (Calanus finmarchicus) abundance in spring
- Zooplankton (Calanus finmarchicus) abundance in summer
- Zooplankton (Calanus finmarchicus) abundance in autumn
- Zooplankton (Temora longicornis) abundance in winter
- Zooplankton (Temora longicornis) abundance in spring
- Zooplankton (Temora longicornis) abundance in summer
- Zooplankton (Temora longicornis) abundance in autumn
- Marine species observed per sea region
- Marine bird observations

Physics

- Sea water velocity
- Drifting buoy temperature tracks (Monthly)
- Sea level anomalies
- Relative sea level trends
- River runoff trends
- Global sea-basins
- Underwater noise indicator
- Argo floats
- Drifting buoys
- Ferrybox
- Underwater glider
- High Frequency Radar
- River gauging stations
- Mooring platforms
- Drifting buoy tracks (Monthly)

Geology

- Coastline changes based on satellite data (2019)
- Tsunamis origin points
- Coasts affected by tsunamis
- Submarine landslides
- Submarine fluid emissions
- Tectonic lines
- Submarine volcanoes
- Hydrocarbon reservoir
- Seabed substrates
- Seafloor lithology
- Seafloor stratigraphy
- Seabed sediment accumulation rates
- Submerged landscapes

Bathymetry

- Underwater depth contours
- Mean underwater depth

Seabed Habitats

- Coralligenous Habitats
- Maerl Habitats
- Posidonia oceanica distribution (seagrass species)
- Habitat classification by EUNIS 2019
- Predictive habitat map (MSFD)
- Habitat Descriptors - Biological zones

Human Activities

- Macroalgae production facilities
- Microalgae production facilities
- Seawater finfish farms
- Freshwater finfish farms
- Shellfish farms
- Ocean energy - Project locations
- Ocean energy - Test sites
- Offshore installations (oil & gas)
- Locations of wind farms
- Locations of wind farms (polygons)
- Coastal nuclear power plants
- Marine Natura 2000 sites
- Advisory Councils (Aquaculture)
- Exclusive Economic Zone
- Dredge spoil dumping (points)
- Dredge spoil dumping sites (polygons)
- Dumped munitions (polygons)
- Waste discharged in ports
- Dumped munitions (points)
- Telecommunication cables - Germany
- Telecommunication cables - schematic routes)
- Pipelines and cables - landing stations
- Telecommunication cables - Malta
- Offshore pipelines routes
- Telecommunication cables - SIGCables routes
- Active offshore hydrocarbon licences
- Marine sediment extraction
- Dredging areas
- Offshore hydrocarbon extraction boreholes
- Lighthouses
- State of bathing waters
- First Sales of Fish (Cod)
- First Sales of Fish (Alaska Pollock)
- First Sales of Fish (Herring)
- First Sales of Fish (Mussel)
- First Sales of Fish (Salmon)
- First Sales of Fish (Shrimps)
- First Sales of Fish (Tuna)
- Main ports (goods traffic)
- Main ports (locations)
- Main ports (passengers traffic)
- Main ports (vessels traffic)
- Vessel density 2019 (all)
- Vessel density 2019 (other)
- Vessel density 2019 (fishing)
- Vessel density 2019 (service)
- Vessel density 2019 (dredging or underwater ops)

- Vessel density 2019 (sailing)
- Vessel density 2019 (pleasure craft)
- Vessel density 2019 (high speed craft)
- Vessel density 2019 (tug and towing)
- Vessel density 2019 (passenger)
- Vessel density 2019 (cargo)
- Vessel density 2019 (tanker)
- Vessel density 2019 (military and law enforcement)
- Vessel density 2019 (unknown types)