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DRAFT INITIAL INTEGRATED ASSESSMENT OF THE MEDITERRANEAN SEA: FULFILLING STEP 3 OF THE ECOSYSTEM APPROACH PROCESS

UNEP/MAP
Athens, 2011

Note from the Secretariat

1. This report represents an initial assessment of information on ecology, status, and pressures affecting coastal and marine ecosystems of the Mediterranean, based on existing information available either at the regional level, or available throughout each of the four subregions that were delineated by agreement of the Contracting Parties to the Barcelona Convention. The assessment was prepared in line with the decision taken by the First Meeting of Technical Experts on the Application of the Ecosystem Approach by MAP, in Rome 8-9 April 2010, which stipulated that the integrated report should follow the Table of Contents proposed and adopted by the Second meeting of Government Designated Experts on the Application of the Ecosystem Approach by MAP, in Athens 9-10 July 2008. In addition to a standard format for each of the subregions, this integrated report contains an Introduction that describes this initial assessment in the context of the ecosystem approach process, a basin-wide overview of what is currently known about pressures and states of marine and coastal ecosystems across the Mediterranean, and a concluding section identifying priority issues, as well as critical gaps in understanding that need to be filled in order to advance the Ecosystem Approach process.

2. The Secretariat has submitted the draft for consideration and review to the Second meeting of technical experts on the Application of the Ecosystem Approach by MAP held in Barcelona in July 2010. The report was also subject to comments by the Contracting parties through the second half of 2010. Comments from Croatia, Greece, France, EC, Israel, Morocco, Spain and Turkey were received and incorporated.

3. After the decision of the Bureau of the Contracting Parties the second draft version, including the comments received, was submitted to GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environment Protection) for peer review in March 2011. The review process is ongoing at this moment and the review comments recently received from GESAMP are being considered and incorporated. GESAMP review comments to the report were compiled in a table and summarized in a letter reflecting the most substantive feedback that are made available to the Contracting Parties as information document UNEP(DEPI)/MED WG.360/Inf.4.

4. The present version of the report includes therefore the comments received by the Contracting Parties on the previous version and the most substantive comments and suggested changes provided by GESAMP regarding the report restructuration by moving forward the Mediterranean-wide synthesis, the improvement of the connection between the subregional sections, the Mediterranean-wide synthesis and the executive summary and the further elaboration of the background information on the framework for the elaboration of the assessment and the report with regards to the application of the Ecosystem Approach.

5. The definitive version of the report will be prepared, following the feedback received during the meeting and incorporating the rest of technical and editorial comments received from GESAMP, in order to be submitted to the Meeting of Focal Points in September 2011 so it can be endorsed for submission to the next Meeting of the Contracting Parties.

6. Besides the comments on the specific content of the report GESAMP provided also some comments regarding the assessment process followed to compile the information of the report and the alignment of this assessment with the recommendations and guidance issuing from the Assessment of Assessments that should be taken in consideration by the Contracting Parties in future assessment efforts in the Mediterranean Region. In particular GESAMP emphasized that, even if the initial assessment integrated information across sectors and ecosystem components, there is a need to better reflect the relevant social and economic aspects of the Mediterranean in order to produce fully integrated assessments for which the Mediterranean Action Plan/Barcelona Convention are in a privileged position.

7. This initial assessment report has been prepared under the auspices of UNEP/MAP Coordinating Unit with the contributions of lead consultant Dr. Tundi Agardy, as based on the subregional reports prepared by UNEP/MAP components, MED POL and SPA/RAC, along with contributions of regional and

national consultants, and with the regional UNEP/MAP- BP/RAC report on the "Economic Value of Sustainable Benefits Rendered by Mediterranean Marine Ecosystems".

8. Many portions or the text originate from consultant subregional reports, especially the sections on biodiversity pollutants, pressures and impacts. Additional material was derived from national reports and from comments and contributions provided by Contracting Parties representatives. Important additional sources of information include the UNEP/MAP-EEA reports, and the Transboundary Assessment of the Mediterranean, as well as cumulative impacts mapping prepared under the auspices of the National Center for Ecological Analysis and Synthesis by Fiorenza Micheli.

9. Regional consultants engaged by UNEP/MAP-MED POL who provided text and information include:

Dr. François Galgani (Western Mediterranean), Prof. Victor Axiac (Central Mediterraenan and Ionian), Dr. Monica Peterlin (Adriatic) and Dr. Nikos Streftaris (Eastern Mediterranean).

10. Regional and national consultants engaged by UNEP/MAP – SPA/RAC who provided text and information include:

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Executive Summary

1. The Mediterranean Action Plan (MAP) / Barcelona Convention and its 7 associated protocols offer an excellent foundation for coordinated and effective management of the Mediterranean Sea and its coastal areas. Contracting Parties have committed to the progressive application of the Ecosystem Approach (EA) to the management of human activities, and have moved forward towards laying the groundwork for policy formulation that addresses priority threats and improves understanding of management needs. Their commitment to a seven step EA process is rational and strategic, involving the following: 1) establishing the vision for an ecosystem approach throughout the Mediterranean; 2) elaborating three strategic goals to achieve this vision; 3) undertaking an initial assessment to determine priority issues, information availability as well as gaps that need to be filled; 4) deciding on ecological objectives; 5) determining operational objectives and associated indicators and identifying targets or thresholds for those indicators; 6) developing a monitoring strategy; and 7) elaborating specific management plans and actions that will ensure that ecological objectives and strategic goals are met, moving the Mediterranean countries effectively towards their vision for marine and coastal management.

2. This initial assessment report represents step 3 in the EA process: collating information on the overall nature of ecosystems in the Mediterranean, including physical and ecological characteristics, drivers and pressures that affect the state of the marine environment, conditions or state of the coastal and marine ecosystems, and expected response of ecosystems if trends continue, where feasible. The goals of the initial assessment were to define the major basin-wide priority issues to be addressed by the EA and to determine where information that is being gathered within MAP/Barcelona Convention system, combined with published studies, could eventually suffice to elucidate management priorities. The converse of this goal is also important: determining where gaps exist, in order to improve scientific research and monitoring being undertaken by Mediterranean countries so as to provide an adequate foundation for effective and efficient ecosystem-based management going forward.

3. The Contracting Parties provided information, in snapshot as well as longer-term time series, on the physical, chemical, and biological features of the Mediterranean Sea. This information was combined with information from international bodies on uses, pressures, and impacts, to first develop four sub-regional and thematically-oriented assessments, and subsequently an over-arching assessment that attempts to synthesize information from the four subregions. The focus of information gathering and analysis was on status and trends in pressures already identified as important, and reflected in the foci of the Convention's protocols, with the aim of harnessing this information to further an ecosystem approach to coastal and marine management throughout the Mediterranean.

4. The four subregions of the Mediterranean, as defined by the Contracting Parties for practical reasons and the unique purpose of this initial assessment, present a conglomerate of linked coastal and marine ecosystems, with many shared resources, species and common approaches to both environmental monitoring and management. Each of the major pressures or classes of threat identified by national monitoring, the research undertaken by scientific institutions, and the analysis of multilateral agencies and programs such as MAP, occur across all four subregions – but the priority issues are different in each. This is partly based on the underlying physical and biological characteristics of each subregion, and the degree to which various impacts are being felt by the marine ecosystems within them.

5. The Western Mediterranean subregion is characterized by exchange with the North Atlantic through the Straits of Gibraltar, and complex physic-biological dynamics. There is a high level of industrialization and coastal development-related habitat loss and alteration in this region – especially on the north coasts. Tourism drives much of the coastal development and pressure on resources, and tourism is behind much of the degradation of coasts and nearshore waters. In addition to the physical alteration of the environment and the degradation caused by pollution and loss of key habitats, growth in tourism and urbanization drive increasing pressure on resources, including freshwater (limiting availability in wetlands and estuaries and increasing the need for desalination, with its attendant pollution impacts) and fisheries. In the southern portion of this subregion, population growth along the coast has led to degradation from sewage inputs and run-off. Maritime industries, including shipping, energy development, and aquaculture also degrade the environment and impact biodiversity, causing localized pollution as well as broader impacts on the delivery of ecosystem services due to trade-offs.

6. The Central Mediterranean and Ionian subregion experiences some of the same pressures and drivers, though the major impacts are somewhat different from the western Mediterranean, in part because of the differing physical characteristics of this subregion. There is no direct exchange with waters of the Atlantic, and in contrast to the wide open basin of the western subregion, the central subregion has complex bottom topography and numerous straits through which water masses and species pass. Coastlines are generally not as highly developed as in the Western Mediterranean, though urbanization is a factor in some localized areas. Fishing is a primary pressure on species and ecosystems, both due to over-exploitation and incidental catch or by-catch, and due to the use of destructive fishing methods, including dynamite fishing, bottom trawling, and destructive removal of deep corals. Shipping pressures are concentrated in the straits between the African continent and the southern Sicilian coast, and nutrient over-enrichment from sewage and run-off puts the southeastern portion of this subregion at risk of hypoxia.

7. The Adriatic Sea is a semi-enclosed sea within a semi-enclosed sea; given its limited water exchange, agricultural inputs and urbanization along its western flank, and its relative shallowness, eutrophication is a major issue. Although point source pollution by toxic contaminants has been largely controlled and toxic pollution is confined to a few localized industrial areas, run off and inadequately treated sewage continues to upset the nutrient balances of the narrow sea, leading to algal blooms, mucilages, and spreading hypoxia. Climate changes may be exacerbating the impacts of these pressures, as well as compounding the effects of invasive species in the subregion. Fisheries over-exploitation is also identified as a pressure, especially in the northern reaches of the central Adriatic. Yet despite the pressures, the Adriatic Sea is remarkably diverse and productive, with a variety of ecosystems providing valuable ecosystem services. Tourism is important to the region, as are fisheries. The Adriatic is also noteworthy in that several of the countries within this subregion have been exploring ways to coordinate research and management, setting the stage for a facilitated movement towards an ecosystem approach.

8. The Eastern Mediterranean subregion is perhaps the least known of the four subregions delineated for the initial assessment of the EA. This subregion is also very diverse in large-scale biodiversity: extensive archipelagos exist in the north, while a wide shelf with alluvial sediments is found around the Nile Delta to the south. The coastline and bottom topography is highly varied, as are the human uses of coasts and seas. While all the pressures that exist throughout the Mediterranean are found within this subregion as well, invasive species and climate change are the top issues of concern. Spreading hypoxia and lowered water quality result from untreated sewage inputs, desalination effluents, and urban run-off. The trends in water quality, invasive species spread, and tropicalization from climate change have not yet devalued this subregion. The northern portion remains one of the

primary coastal tourist destinations in the world, and coastal communities throughout the region continue to depend on marine resources.

9. To the extent this information synthesis provides a common approach to assessment, it has begun to highlight how different threats or pressures have differing levels of importance in each region. Thus pressure-state-impact-response varies, and this initial assessment can only begin to tease out why these responses may be different in different areas. It is recognized that this approach will allow the development of strategic activities at a variety of scales: 1) at the basin level, where a standardized approach to monitoring and future assessment will create a common knowledge base; 2) at the national level, where countries can use a common approach to establish their own priorities; and 3) at the site level, where the tools of management can be harnessed, either unilaterally or multilaterally, to address key marine issues.

10. An overview of all four subregions, taken together with a review of literature on Mediterranean ecology overall, suggests that commonalities may be more pervasive than are differences between subregions. Common to all regions is the recognition that certain coastal and marine habitats deliver extremely valuable ecosystem services that benefit all Mediterranean inhabitants. In an attempt to prepare a preliminary analysis of the known economic value of some of these services, MAP produced an initial Mediterranean marine ecosystem services valuation report. The study concludes that across the Mediterranean region, ecosystem service benefits may exceed 26 billion euros annually. The bulk of these estimated economic benefits (more than two thirds) come from tourism and the value of nature supporting such tourism. Other valuable services supported by the studied habitats include provisioning of seafood, waste assimilation, coastal stabilization and erosion prevention, and carbon sequestration, which contribute to the total value with amounts within the same order of magnitude. While the findings of the study are under review, the magnitude of the value estimates for the different ecosystem services studied suggest the relative importance of certain types of habitats and resources in supporting human well-being throughout the basin. As countries discuss how to move forward together toward a more ecosystem-based approach to marine management, priorities may center on those habitats that provide the bulk of these economically, ecologically, and culturally valuable services.

11. Despite the emerging science of valuation that highlights the value of Mediterranean coastal and marine environments, degradation continues due to direct uses and indirect impacts on ecosystems. The pressures and impacts that are common to all four subregions include:

- **coastal development and sprawl,** driven by urbanization and tourism development, leading to habitat loss and degradation, and erosion/ shoreline destabilization

- **overfishing**, and incidental or by-catch, affecting community structure, ecological processes, and delivery of ecosystem services

- **destructive fishing**, including bottom trawling and fishing methods resulting in benthic disturbance

- **contamination** of sediments and biota caused by pollution, primarily from urbanization and industry, but also from anti-foulants and atmospheric inputs of hazardous compounds

- **nutrient over-enrichment**, leading sometimes to eutrophication and hypoxia, more regularly leading to ecological imbalances (reduced water quality and growth of algae)

- **disturbance and pollution caused by maritime industries**, including shipping, energy, aquaculture, and desalination (operational as well as disaster-related)

- **invasive species** spread, in many cases mediated by climate changes

- **degradation of transitional or estuarine areas**, which serve as critical nursery areas for commercial fisheries and also support unique assemblages of species

12. Additionally, the initial assessment provides some information on ecologically important, biologically diverse, or vulnerable areas, and the potential biodiversity loss (inferred but not yet quantified) that emerges as a priority issue across the whole of the Basin.

13. Since the 2006 UNEP/MAP - EEA report on Priority issues in the Mediterranean environment, some changes in condition are apparent. Improvements in water quality are discernable in many places, thanks to strategic efforts to reduce pollutant loading. Quantities of hazardous substances such as DDT and heavy metals are declining in most areas. New issues, however, are emerging which warrant attention. Desalination and its effects, particularly with respect to brine release, should be better investigated. The increasing uses of coastal and ocean space for aquaculture, including the grow out operations for bluefin tuna, bring with them the threat of increased pollution, eutrophication, invasive species and pathogen releases, and increased conflicts over reduced access and availability of space for other uses.

14. Increasing and multiple uses of ocean space also mean that any threats that act synergistically with others to cause even greater impact than if acting alone should be monitored. One example is how the combined effect of nutrient over-enrichment, over-fishing of certain functional groups like grazing fishes, and climate change can act together to cause imbalances in nearshore ecosystems, and loss of ecosystem services.

15. It should be emphasized that this initial assessment is not a compilation of all scientific information on the Mediterranean Sea and its uses. Since the assessment will guide a coordinated regional approach to ecosystem-based management, care was given to balance the assessment across the significant variability that exists in availability of information, and across sometimes incompatible datasets. Furthermore, because knowledge was derived from information already being collected for other purposes (for instance to meet obligations under the Convention's protocols), and not from the sort of comprehensive and systematic monitoring program for integrated management that will eventually be adopted under EA, the initial assessment is important not just for summarizing the state of the art, but also for highlighting gaps in data and information.

16. One such gap concerns the ability to uniformly assess pressures and states, in order to formulate responses. With the exception of localized pollutants and nutrient and organic matter enrichment, data for some countries is limited, whereas for others it is more extensive. Some countries have begun to assess climate change impacts and have research oriented towards emerging issues such as noise pollution and cumulative impacts assessments, whereas other countries with more limited human and financial resources are focusing at the national level on their obligations under the various Barcelona Convention protocols. It is expected that the rationalized monitoring program that will flow from selection of ecological and operational objectives will overcome these barriers to understanding pressure-state-impact-response across a wide span of inter-related impacts from human activity.

17. A further gap that the assessment points to is the strong bias towards understanding the ecology and human impacts on shallow water environments, particularly rocky bottoms and intertidal areas, as well as seagrass meadows. While some descriptions of biodiversity and the ecosystem services that flow from other habitats is available, systematic information on pressures and state have not been compiled – with the exception of special transitional and marine areas (such as within protected areas, in Natura 2000 sites in EU countries, etc.). A rationalized system of monitoring using key indicators will overcome these discrepancies in focus.

18. It is difficult to make general statements about the Mediterranean as a whole when only certain aspects are currently being monitored in certain areas. For instance, tailoring the pollution monitoring to assessing levels of contaminants (of all sorts) at trouble or hot spots is logical in that these worst-case scenarios point to where management is most needed. However, painting the Mediterranean picture based on this sort of sampling regime cannot be expected to represent true overall conditions in the Sea. Furthermore, trends in levels of contaminants say nothing about how ecosystems are responding to such threats, and even less about how such threats are acting in negative synergy with other threats to lower the status of heavily-impacted areas, or to impact delivery of services and human well-being.

19. In line with the Ecosystem Approach, every attempt was made to focus on ecosystem services in coastal and marine areas that are of value to the Mediterranean countries. However, because the study of ecosystem services is still in its infancy everywhere in the world, the assessment has utility in pointing to gaps in information about how communities and nations depend on and value these ecosystems – gaps which if filled could steer Mediterranean countries towards an effective, efficient, coordinated response to the growing pressures being exerted on Mediterranean coasts and marine ecosystems. The conclusions arising from the assessment also have implications for how to raise awareness about the value of Mediterranean ecosystems and their services, with the eventual outcome of improved management.

20. There may be other drivers of change to ecosystems and attendant delivery of ecosystem services that have not been highlighted as basin-wide in the assessment, due to lack of information available across the whole of the Basin. This includes anthropogenic impacts from changing hydrodynamics and sediment delivery (through dams, freshwater diversion, etc.) from watersheds, as well as coastal constructions, which both contribute to changes to shoreline stability and potentially exacerbate sea level-induced erosion.

21. The subregional assessments and the integrated Mediterranean-wide synopsis highlight gaps in knowledge, some variability in data collection and data management, and inconsistencies in periodic monitoring for the purposes of deriving trends information. But, importantly, the initial EA assessment also points to important opportunities to take the information currently available and begin to harness it to guide an effective set of management responses. One major opportunity that exists concerns mapping the information currently available on species, habitats, and human uses and their impacts. The Mediterranean countries and MAP are well-positioned to harness Geographic Information Systems to their fullest potential across the Mediterranean Basin, allowing the creation of graphics that are compelling and tell a complex story in ways that the public and decision makers can fully grasp. Future assessment can and should be populated with a series of maps showing not only basic information on the changing conditions in coastal and marine ecosystems of the Mediterranean, but also graphic displays of ecosystem services -- clearly showing the high values attached to natural coastal and marine habitats in different areas of the Mediterranean.

22. The initial assessment process has helped to highlight commonalities, and possible priorities that should serve as foci for subsequent steps in the Ecosystem Approach. It has also been extremely useful in highlighting information gaps serving as the foundation to

support the next steps in the EA process. These steps include the determination of ecological objectives that reflect common issues for marine management at the regional scale, the determination of operational objectives, indicators, and targets, which will help steer future monitoring and guide decision-making; and the development of management plans at sub-regional, national, or local levels, based on the robust information that will flow from an integrated monitoring regime in the future.

CHAPTER 1: INTRODUCTION - THE ECOSYSTEM APPROACH AND ASSESSMENT OF EXISTING INFORMATION

1. The Mediterranean Sea is complex in its ecology and its social dimensions. Twenty one countries border the basin of this heavily used and highly valued sea, and all have agreed in principle to improve the management of activities that impact it. The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (known as the Barcelona Convention) provides a critical framework for the sharing of information necessary for such management, as well as the setting of standards and targets acceptable to all the Contracting Parties. The Barcelona Convention was adopted on 16 February 1976 and amended to its present text on 10 June 1995; Contracting Parties currently include the 21 nations bordering the Sea, as well as the European Union.

2. The process of implementing an Ecosystem Approach in order to move towards the goal of “a healthy Mediterranean with marine and coastal ecosystems that are productive and biologically diverse for the benefit of present and future generations” was launches at the July 2008 meeting of the Barcelona Convention Contracting Parties held in Almeria Spain (Decision IG 17/6). This ECOSYSTEM APPROACH process among all Mediterranean Contracting Parties is abbreviated as EA.

3. The Mediterranean countries view the ecosystem approach as a tool; providing a framework that can be used to implement the objectives of the Convention on Biological Diversity, including the work on, inter alia, protected areas and ecological networks. As stated by the Mediterranean Action Plan, which helps to coordinate activities under the Barcelona Convention, there is no single correct way to apply the ecosystem approach to management of land, water, and living resources. The principles that underlie the ecosystem approach can be translated flexibly to address management issues in different social, economic and environmental contexts.

4. The Contracting Parties did however agree to a common process for moving towards an Ecosystem Approach in the Mediterranean – one which would recognize the diversity of approaches that countries within the region are taking to management, and build on the activities that Contracting Parties are already obliged to do under the various protocols of the Convention. This EA process, described in detail in the following paragraphs, articulates seven steps towards an Ecosystem Approach, which ultimately results in management action, plans ,and programmes that arise from a strategic and objective determination of management priorities.

5. To further Ecosystem Approach implementation, the Contracting Parties to the Barcelona Convention have enumerated three strategic goals for Mediterranean marine and coastal areas (UNEP(DEPI)MED WG 326/3 Annex 1 page 2):

1) To protect, allow recovery, and where practicable, restore the structure and function of marine and coastal ecosystems – thus also protecting marine biodiversity – in order to achieve and maintain good ecological status allowing for sustainable use.
2) To reduce pollution in the marine and coastal environment so as to ensure that there are no significant impacts or risks to human and/or ecosystem health and/or on the uses of the sea and the coasts.
3) To preserve, enhance, and restore a balance between human activities and natural resources in the sea and the coasts and reduce their vulnerability to risks.

6. A roadmap to achieve these strategic goals was discussed and adopted by the Contracting Parties; it articulates five additional steps that need to be taken, in addition to setting the ecological vision for the Mediterranean and articulating the strategic goals above, including:

a) Identification of important ecosystem properties and assessment of ecological status and pressures;
b) Development of a set of ecological objectives corresponding to the Vision and strategic goals;

c) Derivation of operational objectives with indicators and target levels;
d) Revision of existing monitoring programmes for ongoing assessment and regular updating of targets;
e) Development and review of relevant action plans and programmes.

7. Together these seven steps constitute the EA process, to which all Contracting Parties are committed, and which they will continue to work towards in the coming three-five years. This initial assessment represents the culmination of Step 3 of the EA, collating the available information of ecosystem properties and status, and identification of priority pressures that merit further monitoring and eventual management responses that will be designed after the completion of the subsequent strategic steps, which include the identification of ecological objectives and the determination of operational objectives and associated indicators and targets.

8. A critical feature of the initial assessment is the identification of gaps in information needed to eventually inform management (the final section of chapter describes these gaps in detail). In order to move towards a systematic ecosystem approach these gaps will need to be addressed through a comprehensive monitoring program – but one which does not put undue burden on States. Only after an improved monitoring regime is put in place, and information on key pressures and their impacts is made available to management authorities, will periodic assessment for the purposes of ecosystem-based management be possible at the regional scale.

9. Thus this initial assessment represents a stock-taking of available information, and an analysis ot that information to begin the process of identifying focal areas for future management, as well as monitoring and research needs. Both these sets of information: initial priorities and information gaps, serve as a foundation for establishing ecological objectives for the regional sea, and a future monitoring regime that will guide management and steer it towards a regional ecosystem approach. Figure 1.1 shows the cyclic nature of this information gathering and assessment process.

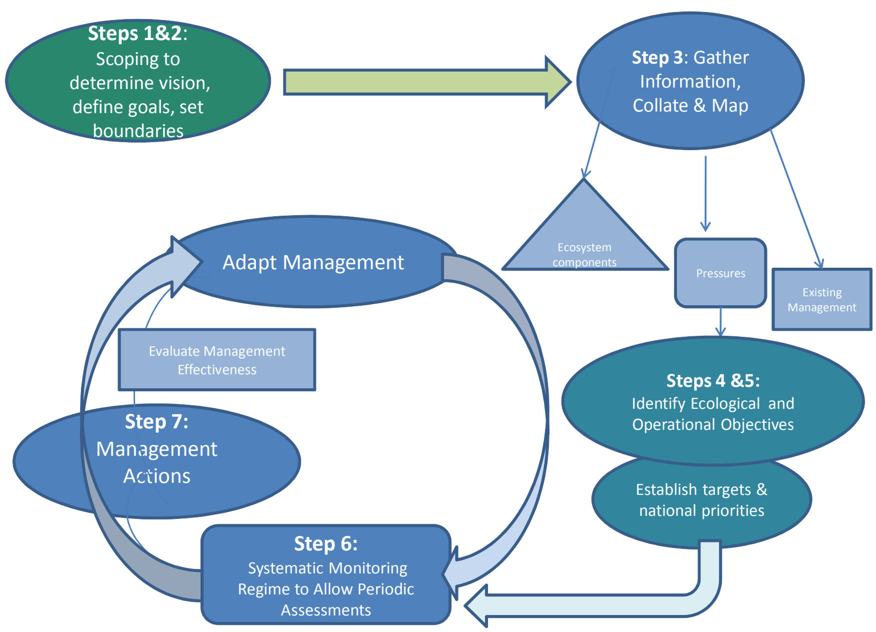


Figure 1.1 Schematic of the EA process. Step 3 describes the initial assessment which this integrated report summarizes.

10. UNEP/MAP has overseen the process of undertaking a Mediterranean-wide assessment, building on previous studies done under its auspices and other institutions, as well as national data coming in from focal countries which undertake monitoring to meet the obligations of the Barcelona

Convention and its protocols. The methodology for preparing this initial assessment report follows a decision made by the Contracting Parties to subdivide the Mediterranean region into four loosely defined geographic areas – solely for the purpose of analysis. These geographic areas, or subregions, are:

- Subregion #1: **Western Mediterranean**
- Subregion #2: Ionian Sea and **Central Mediterranean**
- Subregion #3: **Adriatic** Sea
- Subregion #4: **Eastern Mediterranean**

Figure 1.2 shows these subdivisions created for the purposes of assessing conditions in a detailed fashion.

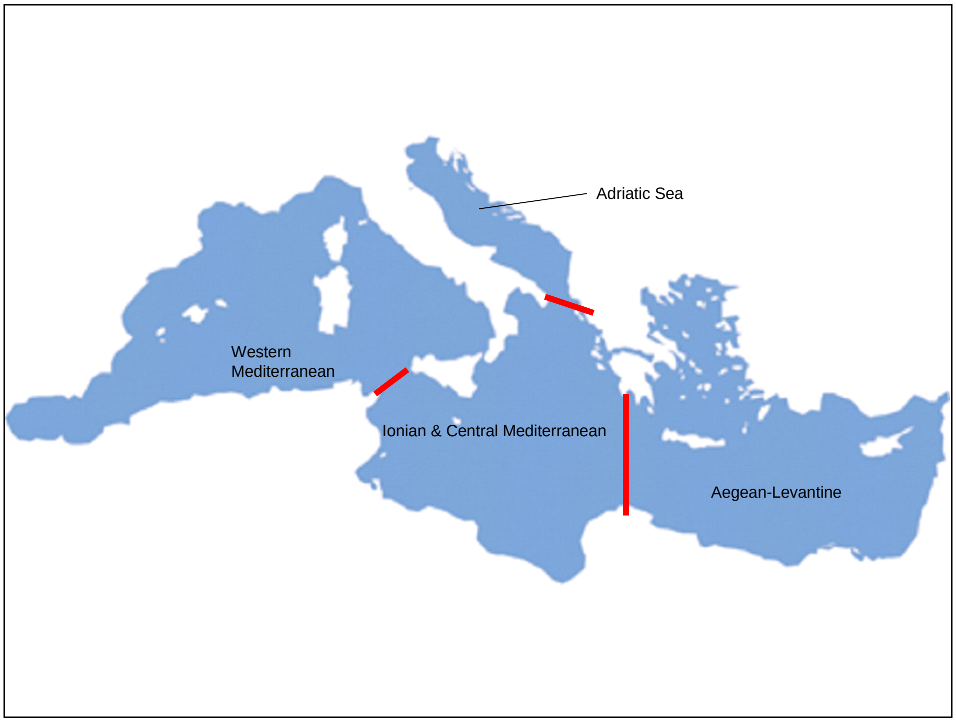


Fig 1.2 The Mediterranean divided into four regions

11. The reasons for subdividing the Mediterranean Sea into four subregions are varied. First, the sheer scale of the semi-enclosed sea is such that systematic collation of information on ecology and anthropogenic impacts is difficult at the basin-level. Second, it was felt that there are commonalities in both the ecology and the human dimension of the subregions, such that a scaling down would make sense. Many of the neighboring countries within a subregion have similar capacities for monitoring and management, share transboundary resources or species, and have already begun to exchange lessons learned about marine management.

12. In coordinating these assessments, UNEP/MAP, through its technical components MED POL and SPA/RAC, identified national consultants and sub-regional coordinators that correspond to the working divisions outlined above. UNEP/MAP - SPA/RAC, in close collaboration with national authorities, selected national biodiversity experts in 17 countries. In addition, UNEP/MAP - SPA/RAC engaged four international consultants to coordinate the compilation of biodiversity information within each subregion, and to give guidance and technical support to the national consultants. UNEP/MAP - MED POL also contracted four sub-regional coordinators, in order to oversee the preparation of reports dealing with pollution of the marine environment and land-based sources of pollution in the four subregions. These subregional consultants worked to harmonize the data and coordinate the merging of input; collate, revise, and provide coherence to additional inputs obtained from other

UNEP/MAP components; prepare a document for each respective subregion; and prepare draft and final reports submitted to UNEP/MAP - MED POL.

13. UNEP/MAP - BP/RAC completed a Mediterranean-wide analysis of the value of marine ecosystems of the Mediterranean, focusing on goods and services which included fisheries resources, carbon sequestration potential, waste processing, erosion control, and recreational value. The focus of the study was on five distinct Mediterranean ecosystems: *Posidonia* meadows, coralligenous communities, rocky bottoms with macroalgae, soft bottom communities, and open sea pelagic systems over 100 meters in depth.

14. UNEP/MAP - IMO/REMPEC contributed databases on shipping traffic, oil spills and other shipping accidents, and ports. UNEP/MAP - Info/RAC began assembling an inventory of databases on the Mediterranean environment and has determined which datasets could be digitized in order to determine priorities for an Ecosystem Approach. This process has highlighted some remaining challenges concerning data sharing and data compatibility – challenges which all parties committed to the ecosystem approach process should work to address.

15. The subregional reports that formed the basis of section III of this assessment present the best available information on environmental characteristics, quality, and priorities for the marine and coastal ecosystems within those subregions. The concluding section of this assessment (Section VI) identifies commonalities in the four subregions, suggests Mediterranean-wide priorities based on those commonalities, and briefly discusses options for next steps in the ecosystem approach process.

16. The scale of the ecosystem(s) under consideration is significant, such that the larger the geographic and sectoral scales, the greater the need for a hierarchical or integrated strategy to maintain linkages between scales. In the case of the Mediterranean Sea, the division into four loosely defined areas makes sense for practical and operational purposes, but may raise questions of whether these regions are biologically or ecological separate, what to do about inconsistent data availability across all four regions, and how to aggregate analyses in order to achieve a truly effective Ecosystem Approach.

17. Although the compilation of information was done at the subregional level, the findings of the initial assessment suggest that pressures that are common to all regions will need to be more systematically tracked in order to gain the sort of scientific foundation needed for an Ecosystem Approach. By determining Mediterranean-wide ecological objectives (step 4 in EA), and subsequently setting operational objectives, the Mediterranean countries will be able to advance towards an Ecosystem Approach across the whole of the region. Steps 4 through 6 will thus likely result in a blurring of the subregional divisions, leading to an information-generating system for the whole of the Mediterranean, providing the necessary science to support management. That management, however, will be brought down to the more localized scale in the final step of the Ecosystem Approach process – with some management responses that are specific to a subregion, nation, or even special area within a nation.

18. Assessment for the purpose of furthering an Ecosystem Approach is not a one-step process, but an iterative one. This initial integrated assessment report represents one phase of the assessment process – an initial scoping of available information, the characterization of subregions according to information on pollution, biodiversity condition, and other ecological features, and an analysis of Basin-wide commonalities. It should be noted that given the history of the Barcelona Convention, with its initial emphasis on pollution, and given the variability in resources and capacity of various Mediterranean countries to conduct periodic monitoring, the information available to assess current status, and to establish management priorities, is very patchy. For this reason, Mediterranean countries are heeding the findings of the initial assessment to support an improved monitoring scheme that will better allow information to be collected on trends in pressures and status, and allow mangers to use that information to determine management priorities.

19. Future assessments will utilize standardized methodologies that determine trends in pressures (resulting from direct and indirect human uses, against the backdrop of large scale changes such as those wrought by climate change); changes in the status of ecosystems and their ability to deliver ecosystem services of value to human beings; and effectiveness of existing management. In other words, in order to know whether EA is being achieved, it will be necessary to further supplement basic

knowledge about how the ecosystem operates, what values it provides human beings, how it is being used and impacted, and how it is performing under existing management. Section VI of this report thus begins the discussion of options for future monitoring and assessment, as is needed to steer Mediterranean marine management in a more effective and efficient ecosystem-based direction.

20. The initial assessment process has helped to highlight commonalities, and possible priorities that should serve as foci for subsequent steps in the Ecosystem Approach process. It has also been extremely useful in highlighting information gaps. Though peer-reviewed by GESAMP, this report is not intended for publication. Rather it serves as the foundation to support the next steps in the EA process: the determination of ecological objectives that reflect common issues for marine management at the regional scale, the determination of operational objectives, indicators, and targets, which will help steer future monitoring and guide decision-making; and the development of management plans at sub-regional, national, or local levels, based on the robust information that will flow from an integrated monitoring regime in the future.

CHAPTER 2. MEDITERRANEAN COASTAL AND MARINE ECOSYSTEMS: PRESSURES AND EXISTING CONDITIONS, BASED ON AVAILABLE KNOWLEDGE

2.1 Region-wide perspective on ecosystem condition

2.1.1 Physical, chemical, and biological characteristics of the Mediterranean Basin

21. The semi-enclosed Mediterranean Sea encompasses a large, rich, and diverse set of coastal and marine ecosystems. Twenty one countries border the Mediterranean Sea, in Europe, the Middle East, and northern Africa (see Figure 2.1 below). There are connections between the Mediterranean and the Atlantic through the Straits of Gilbralter, and between the Mediterranean and the Black Sea through the Strait of Istanbul, the Strait of Çanakkale and the Sea of Marmara. In general the Mediterranean has narrow shelf areas, relatively narrow littoral zones, and somewhat small drainage basins (with the exception of some large watersheds in the southern portion). The Basin has water depths of over 4 kilometers, and the 400 meter deep Sicilian Channel acts to delineate the eastern basin from the western.

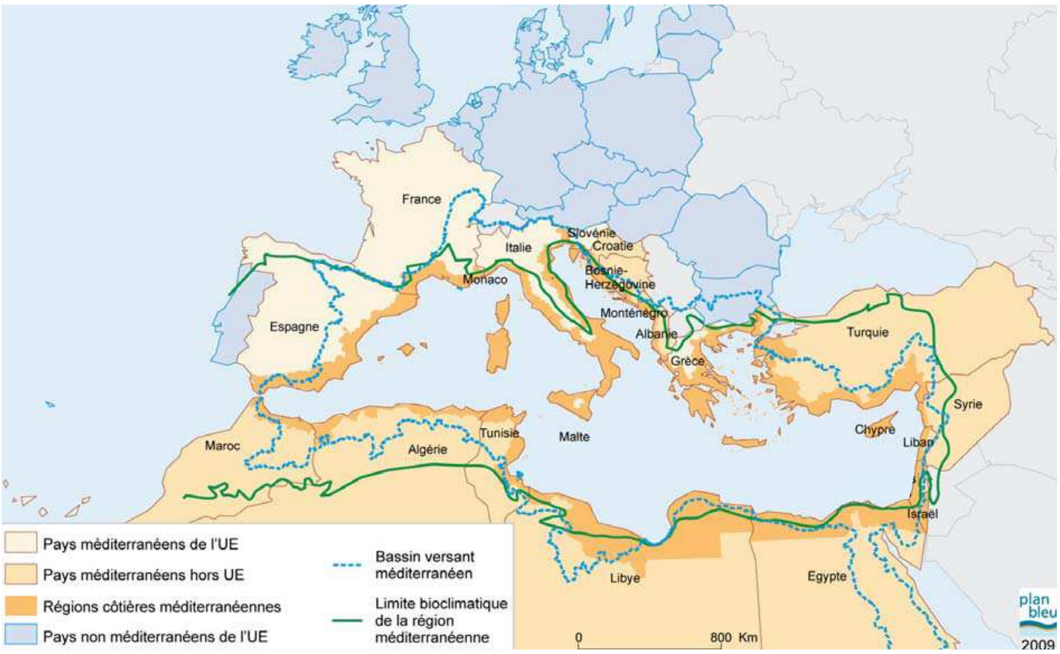


Figure 2.1. Countries bordering the Mediterranean Sea, showing coastal zones (shaded dark beige) and major watershed (in blue dotted lines) ((UNEP/MAP - BP/RAC, 2009)

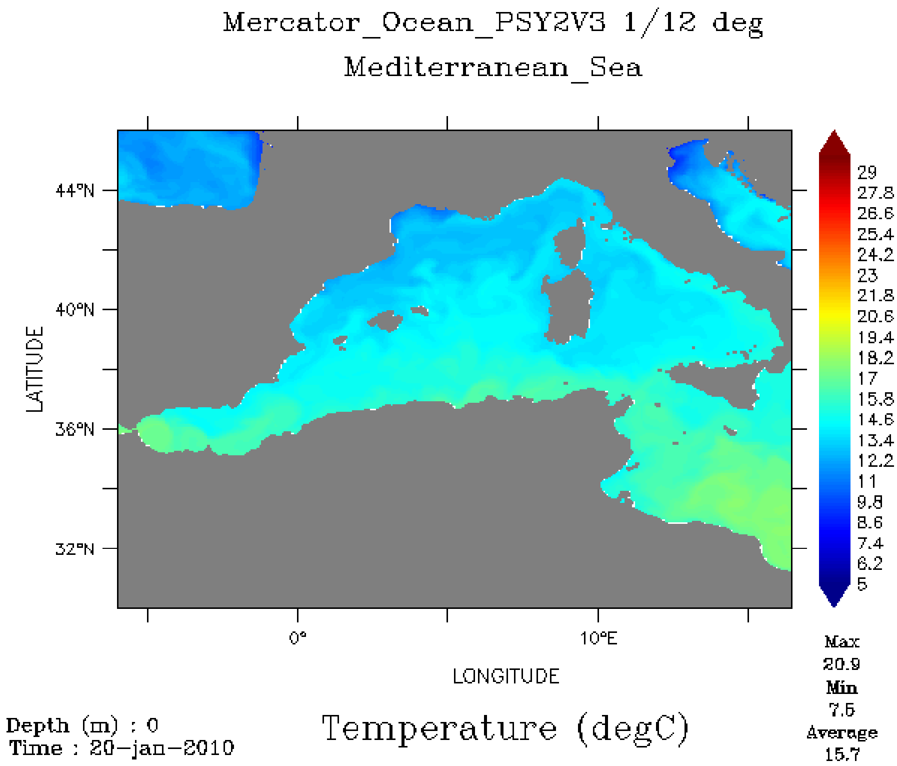
22. The Mediterranean is oligotrophic, with relatively few nutrients, low primary productivity, and low phytoplankton biomass – characteristics that contribute to the clarity of the waters and the light penetration that has made the Sea so aesthetically pleasing to humans. Yet there are regions with relatively high productivity, driven either by frontal systems and upwelling, or by delivery of nutrients from river systems.

23. Climatically, the Mediterranean is characterized by warm temperatures, winter-dominated rainfall, dry summers and a profusion of microclimates due to local environmental conditions (Ludwig *et al.*, 2003). Mean annual temperature follows a marked north to- south gradient to which local orographic effects are superimposed. Lowest average temperatures of <5℃ are found in the higher parts of the Alps, whereas temperatures of >20 ℃ are typical for southern part. Mean annual precipitation has a general decreasing north-to-south gradient. Annual precipitation values of 1500–2000mmyr-1 and more exist in the alpine and Pyrenean headwater regions of the Rhone and the Ebro Rivers.

24. The strong summer–winter rainfall contrast is the major characteristic of the Mediterranean climate. This contrast increases from north to south and from west to east (Ludwig *et al.*, 2003). Precipitation mainly occurs during winter and autumn, and often less than 10% of the annual precipitation falls during summer. High precipitation during autumn is typical for the coasts of Spain, France and Italy. The Rhône and Ebro rivers alone account for more than 20 % of Mediterranean riverine inputs.

25. Altimetric measurements have shown that the sea surface height has changed for the last decade over the Mediterranean basin. Over the past 25 years the rate of increase in sea surface temperature in all European seas has been about 10 times faster than the average rate of increase during the past century. In the Mediterranean, the warming occurs three times faster than the global average over the past 25 years. Deep waters in the Western basin have also been evolving slowly since 1970 with increasing temperature and salinity (Rixen *et al.*, 2005), whereas the SST has increased in annual mean by about 1℃ in 30 years, mainly due to warmer wintertime temperature. Also, the dense water formed in winter on the continental shelf of the Gulf of Lions could contribute significantly to the modification of the characteristics of the western deep waters.

26. Hydrological processes are largely variable both in time and space due to the high variability of rainfall regime, the influence of topography and the spatial distribution of soil and land use. The temporal variability of precipitation within and between years is one of the specific characteristics of this climate characterized by a succession of dry and flash-flood periods that locally affect salinity. The improvement of sensors has made possible the observation of these changes, which could be related to climate or to natural variability associated to the North Atlantic oscillation. Actually temperature and salinity are monitored on regular basis and data from various sensors are available online (see for examples GMES project, http://www.gmes.info/index.php; MOON project, http://www.moon-oceanforecasting.eu/) and from database at both regional or sub regional scale including participants from all countries surrounding the western basin (MEDAR project, http://www.ifremer.fr/medar/ ; http://medar.ieo.es/). Figure 2.2 and 2.3 shows typical values.



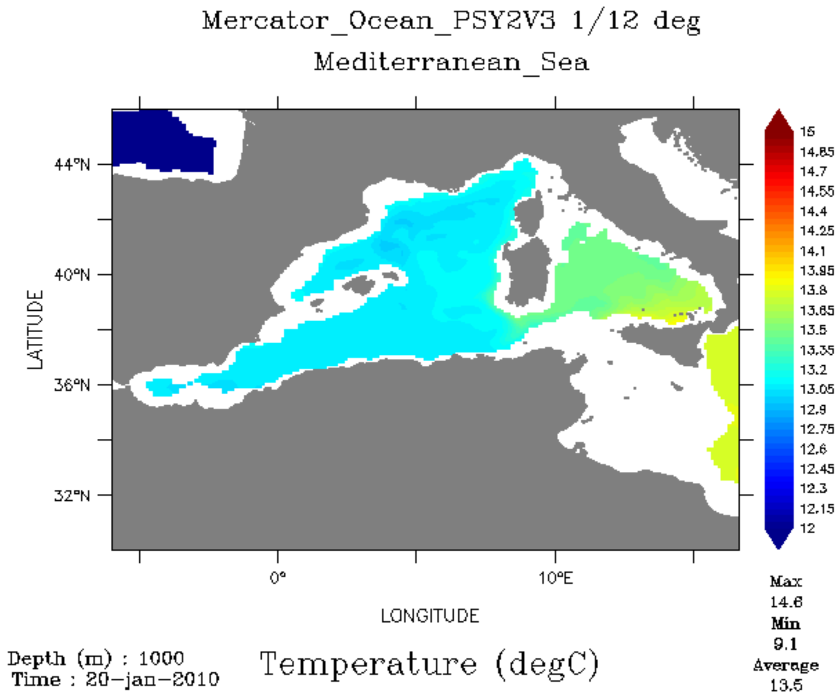


Figure 2.2 : Examples of temperature measurements at the occidental basin scale (http://bulletin.mercator-ocean.fr/)

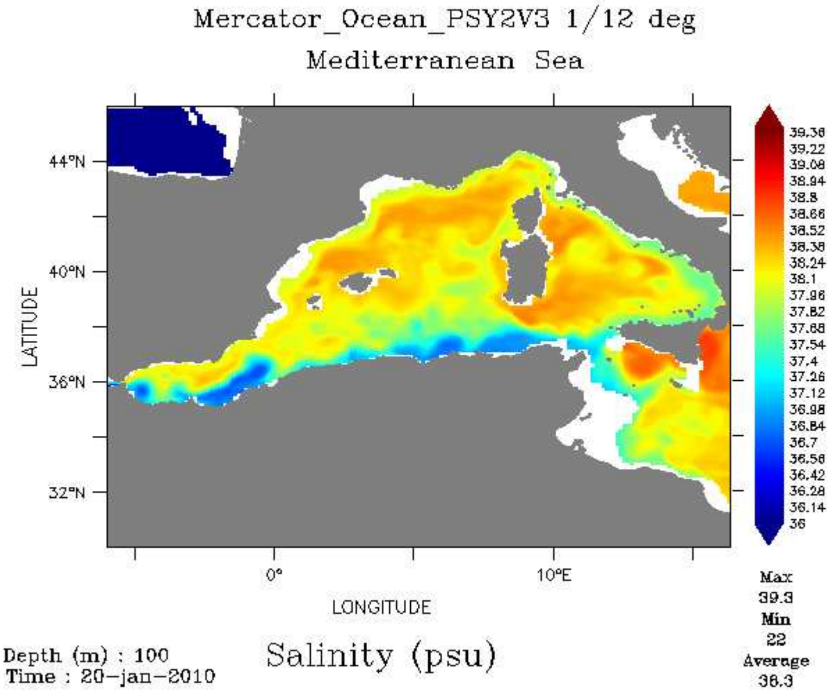


Figure 2.3: Surface Salinity of the occidental basin scale (20/01/2010) and salinity profile along a Sete – Tunis transect (mean values for the period from 28/07 - 04/08/2009, http://bulletin.mercator-ocean.fr/)

27. A large thermohaline cell encompasses the whole Mediterranean and is mainly driven by water deficit and by heat fluxes, compensated by the exchanges through the Straits of Gibraltar. The formation and subsequent spreading of the intermediate water, together with the inflow of the Atlantic Water through the Straits of Gibraltar, contributes to this thermohaline circulation. Besides the main thermohaline circulation, several local features characterize the Mediterranean circulation, such as gyres and fronts. Atlantic Water is present almost everywhere in the basin. It forms two anticyclonic gyres in the Alboran Sea, constrained by the bathymetry, and then bifurcates around the Sardinia Island in two different branches: one into the Tyrrhenian Sea as the source of the large-scale cyclonic circulation occurring in the north-western Mediterranean. The other crosses the Sicilian Channel and penetrates in the Ionian Sea. The water from the Tyrrhenian produces a large cyclonic circulation in the western Mediterranean, with the central gyre between the Balearic Islands and the Sardinia being the region of deep water convection. Figure 2.4 shows the major currents while Figure 2.5 highlights permanent fronts associated with this regional thermohaline circulation.

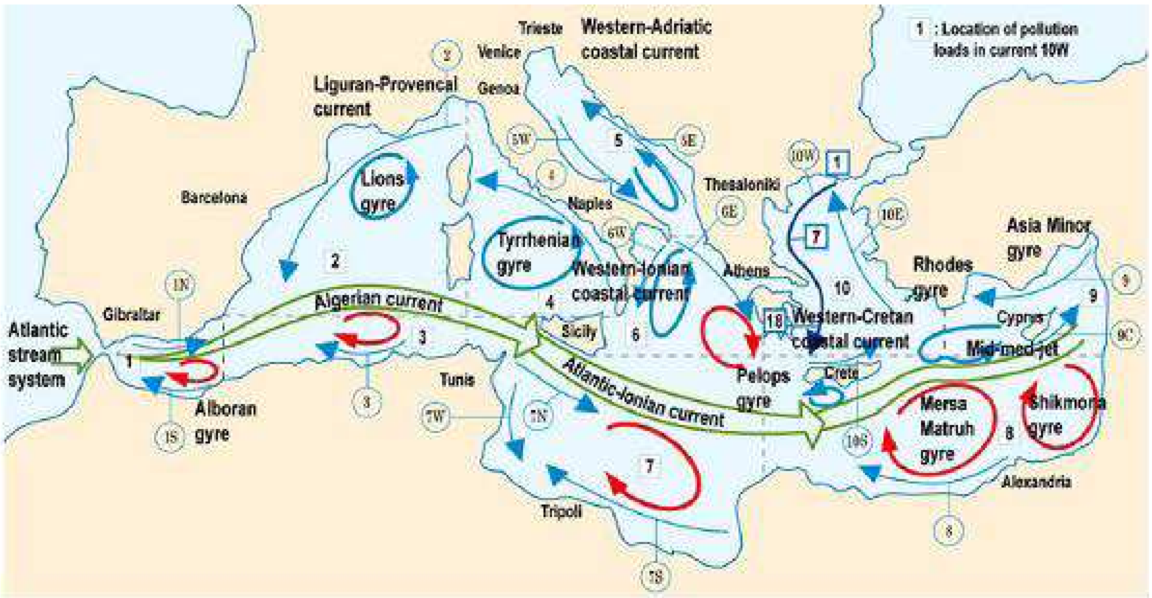


Figure 2.4. Major areas of the Mediterranean Sea and the 18 coastal currents (Reprinted from Stamou and Kamizoulis, 2009)

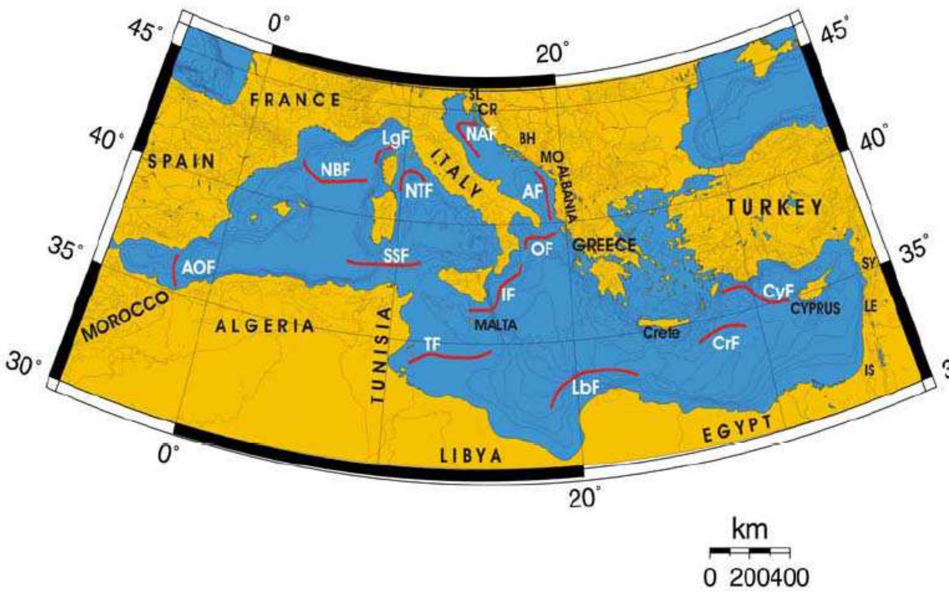


Figure 2.5: Fronts in the Mediterranean Sea (source: Belkin *et al*., 2008, in Sea Around Us, 2009). AF=Albanian Front, AOF=Almeria-Oran Front, CrF=Crete Front, CyF=Cyprus Front, LbF=Libyan Front, LgF=Ligurian Front, NAF=North Adriatic Front, NBF=North Balearic Front, NTF=North Tyrrhenian Front, OF=Otranto Front, SSF=Sardinia-Sicily Front, TF=Tunisian Front. Countries: BH=Bosnia-Herzegovina, CR=Croatia, IS=Israel, LE=Lebanon, MO=Montenegro, SL=Slovenia, SY=Syria

2.1.2 Key features supporting ecosystem services

28. Coastal ecosystems are among the most productive systems of the global environment, supporting not only marine and terrestrial food webs but also providing key services for humankind. Coastal communities and industries exploit coastal resources of all kinds, including fisheries resources; timber, fuel wood, and construction materials; oil, natural gas, strategic minerals, sand, and other nonliving natural resources; and genetic resources. In addition, people increasingly use ocean

areas for shipping, security zones, recreation, aquaculture, and even habitation. Coastal zones provide far-reaching and diverse job opportunities, and income generation and human well-being are currently higher on the coasts than inland.

29. There are less well known, yet equally important services that coastal ecosystems provide human communities. Wetlands maintain hydrological balances, recharge freshwater aquifers, prevent erosion, regulate flooding, and buffer land from storms. Coastal areas and continental shelves support many regulatory services that keep the planet productive and in balance. Continental shelves account for at least 25% of global primary productivity, 90–95% of the world's marine fish catch, 80% of global carbonate production, 50% of global denitrification, and 90% of global sedimentary mineralization. Coastal ecosystem services present many of the "pull" factors that resulted in initial settlement along coasts as well as subsequent migration to them. Forty percent of the global population now lives within the thin band of coastal area that is only 5% of the total land mass, and dependence on these coastal systems is increasing.

30. Coastal and marine ecosystems in the Mediterranean provide a complex set of valuable ecosystem services. Clearly individuals and communities value the coast, as burgeoning population growth and resource use in coastal areas of the Mediterranean attest. Dependence on coastal zones is increasing around the world, even as costs of rehabilitation and restoration of degraded coastal ecosystems are on the rise. Resident populations of humans in coastal areas are rising, but so are immigrant and tourist populations.

31. Mediterranean ecosystems support many marine capture fisheries. Coastal areas also provide the foundation for the mariculture (marine aquaculture) industry, which uses coastal space or relies on wild stock to produce valuable fisheries products, from oysters to bluefin tuna. Human reliance on farmed fish and shellfish is significant and growing. Global annual per capita consumption of seafood averages 16 kilograms, and one third of that supply currently comes from aquaculture. Globally, aquaculture is the fastest-growing food-producing sector, with production rates doubling in weight and value from 1989 to 1998. The resource rent relating to the production of food resources of Mediterranean origin was recently valued at almost 3 billion Euros annually (UNEP/MAP - BP/RAC, 2010).

32. In addition to marketed goods and products, landscape features and ecological processes within the coastal zone also provide ecosystem services that contribute to human well-being and have significant economic value. These nonmarket values often exceed market values. Much of what people value in the coastal zone—natural amenities (open spaces, attractive views), good beaches for recreation, high levels of water quality, protection from storm surges, and waste assimilation/nutrient cycling—is provided by key habitats within coastal systems. Open space, proximity to clean water, and scenic vistas are often cited as a primary attractor of residents who own property and live within the coastal fringe. Coastal housing values are strongly correlated to characteristics such as ambient environmental quality (proximity to shoreline, for example, or water quality).

33. These coastal values also underlie much of the world's coastal and marine tourism. The link between tourist visits and the revenues from and condition of the coastal system has not been analyzed at the Mediterranean level, but case studies from elsewhere in the world point to a strong correlation between value and condition. In the Mediterranean, estimates of the value of marine habitats supporting recreational activities including tourism (estimated as the resource rents related to the provision of amenities and support to the recreational sector) is in excess of 17 billion Euros (2005 values, based on the UNEP/MAP - BP/RAC report 2010).

34. Mediterranean marine ecosystems also sequester carbon and play a large role in climate regulation. UNEP/MAP - BP/RAC has estimated the carbon sequestration value of the 5 marine ecosystems studied at 2.219 billion Euros annually, although is thought to be an underestimate. Further ecosystem services values which were estimated in the UNEP/MAP - BP/RAC study include the value of protection against coastal erosion 527 million Euros annually) and the value of waste assimilation (estimated at 2.7 billion Euros annually). The aggregate value of all five services studied (fisheries production, recreation, climate regulation, erosion control, and waste treatment) was assessed conservatively at over 26 billion Euros annually (PB, 2010).

35. In summary, ecosystem services are critical to the functioning of coastal and marine systems and also contribute significantly to human well-being. Substantial positive economic values can be attached to many of these services. Details of these values are now being derived; some of these details are provided in the synopsis of the UNEP/MAP - BP/RAC valuation work described in Section 2.2.

2.1.3 Mediterranean Biodiversity

36. The Mediterranean Sea, probably due to the many marine research stations set up within its bounds, is one of the most studied seas in the world. The most recent estimates of Mediterranean marine species, taken from compilations of former works, show 10,000-12,000 species (about 8,500 species of macroscopic fauna, over 1,300 plant species and about 2,500 other taxonomic groups (Zenetos *et al*., 2002; UNEPMAP- SPA/RAC, 2003; Boudouresque, 2004; Bianchi, 2007; Briand & Giuliano, 2007; Boero, 2007; UNEP/MAP, 2009). This corresponds to 4-18% (according to taxonomic group) of the world's known marine species. With about 0.82% and 0.32% of the surface area and volume of the world ocean respectively (Bianehi & Morri, 2000), the Mediterranean Sea constitutes one of the 25 biodiversity centres that are recognized on a planetary scale (Meyers *et al*., 2000). This is also true for the continental domain of the Mediterranean basin, which, although only constituting 1.6% of the surface area of the continents, contains 10% of world biodiversity.

37. Biodiversity hotspots are characterized by both exceptionally high levels of endemism and critical levels of habitat loss, and it is thus on them that conservation efforts mainly focus. High endemism, referring to species that live in only in the Mediterranean, is another marked feature of marine biodiversity of the region. The levels of endemism are greater in the Mediterranean than in the Atlantic (Bianchi & Morri, 2000). At the biogeographic level, Mediterranean biota include 55-77% of Atlantic species (present in the Atlantic and the Mediterranean), 3-10% of pan-tropical species (species from the globe's hot seas), 5% of Lessepsian species (species from the Red Sea which entered the Mediterranean via the Suez Canal) and between 20 and 30% of endemics. This ratio of endemism, relatively high compared to other seas and oceans, varies according to taxonomic group. It is 18% for decapodal crustaceans, 27% for hydras, 40% for Rhodobionta (Plantae), 46% for sponges, 50% for ascidians, 90% for nesting sea birds (Metazoa) (Zenetos *et al*., 2002; Boudouresque, 2009). These are basically neo-endemics like the *Cystoseira* genus (Chromobionta, Stramenopilous) with over thirty species known in the Mediterranean, 20 of them endemic, and to a lesser extent, paleo-endemics like species of the *Rodriguezella* genus (Rhodobionta, Plantae), the red coral *Corallium rubrum* (Metazoa, Opisthochonta) and the seagrass *Posidonia oceanica*.

38. This high biological diversity may be related to the specific geomorphological and hydrographical features of the Mediterranean basin, its geological history and its position as interface between temperate and tropical biomes that allow it to host both cold- and hot-affinity species (UNEP/MAP - BP/RAC, 2009).

39. The Mediterranean Sea's flora and fauna are differently distributed among its various basins: 87% of the known forms of life in the Mediterranean are present in the western Mediterranean, 49% in the Adriatic and 43% in the eastern Mediterranean. However, many species are present in two or three basins (Boudouresque, 2009). Also, endemic species are more numerous in the western Mediterranean.

40. It is estimated that there are about 5,942 benthic invertebrate species in the Mediterranean (622 sponges, 420 cnidarians, about 500 bryozoa, 1,000 annelids, 2,000 molluscs, 154 echinoderms, 6 echiurians, 3 priapulidae, 33 siphuncles, 15 brachiopods, 1 pogonophore, 4 phonorids, 5 hemichordata and about 1,935 arthropods) (Zenetos *et al*., 2002, 2003). The differing distributions of these taxa around the Mediterranean basin reveal a gradient that drops from the west to the east (Zenetos *et al*., 2003).

2.1.4 Flagship species

41. Flagship species are those organisms that attract public attention and are used as symbols for education or advocacy campaigns. In general, flagships species tend to be charismatic megavertebrates – commonly large mammals with attractive physical features or interesting social

organization. In the marine realm, flagships are not necessarily ‘warm and fuzzy’ – they can be iconic marine species such as sharks or bluefin tuna. Flagship species are sometimes so-called “umbrella species”, in that their protection can lead to protection of the wider food webs and ecosystems of which they are a part.

42. Mediterranean flagship species include the monk seal, fin whale, common dolphin, bottlenose dolphin, loggerhead turtle, bluefin tuna, and many shark species identified as species of concern, among others. Seabord species are also flagships, and as umbrella species can integrate management by linking coastal lands important as breeding grounds to marine feeding areas. All these species, and many others that might be considered flagship species, are vulnerable to direct and indirect pressures, and many have populations in decline. Action plans have been or are being developed for certain groups, like the elasmobranchs.

2.1.5 Populations of Fisheries Species

43. In many Mediterranean nearshore areas, including in coastal lagoons and estuaries, fishing is the most extensive use of resources. The main species of fish of commercial interest in the lagoons belong to the Sparidae, Mugilidae, Anguillidae and Moronidae families (Kapetsky & Lasserre, 1984), which are present in over 75 Mediterranean lagoons (Pérèz-Ruzafa *et al*., 2010a). However, other invertebrate species are used for commercial purposes, particularly natural deposits of some mollusc species.

44. In coastal waters, the abundance of biological resources that are exploited (fishes, crustaceans etc.) fluctuates enormously with depth. But the continental shelf, because of its high biological production, remains the preferred habitat for commercially exploited species. Fishing in the Mediterranean is basically coastal in nature, and halieutic production is today in the range of 1,500,000 to 1,700,000 tons/year, 85% of which is produced by Italy, Turkey, Greece, Spain, Tunisia and Algeria (UNEP/MAP - BP/RAC, 2009).

45. The main species of fish exploited in the coastal areas are sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicholus*) among the small pelagics, and hake (*Merluccius merluccius*), mullet (*Mullus* spp.), whiting (*Micromesistius poutasou*), angler fishes(*Lophius* spp.), sea bream (*Pagellus* spp.), octopus (*Octopus* spp.), squid, *encornet* squid (*Loligo* spp.), and red shrimp (*Aristeus antennatus*) among the demersals, and big pelagics like bluefin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*). These species represent 70-80% of the total landed in the Mediterranean. However, other species of invertebrate are exploited like the red coral (*Corallium rubrum*), many sponge species (*Spongia* spp., *Hypospongia* spp.), natural beds of bivalves (*Lithophaga lithophaga, Acanthocardia* spp., *Callista chione*, etc.).

46. Fisheries also exploit Mediterranean deep seas, essentially target decapodal crustaceans. The main biological resources exploited are the deep sea pink shrimp *Parapenaeus longirostris* and the Norwegian lobster *Nephrops norvegicus*, to which are associated other species like *Merluccius merluccius*, *Micromesistius poutassou, Conger conger, Phycis blennoides* and, to a lesser extent, *Lophius* spp. and the cephalopod *Todarodes sagittatus*. The deeper fisheries (going down to approximately 400-800 m) almost exclusively target the shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* (IUCN-WWF, 2004). Over-exploitation is also becoming apparent in these deep sea areas, where shrimp stocks are already showing signs of overexploitation. Stocks of *Aristeus antennatus* have either collapsed (Liguria: Orsi Relini & Relini, 1988), are showing signs of overexploitation (Carbonell *et al*., 1999) or are underexploited (Demestre and Lleonart, 1993; Bianchini and Ragonese, 1994). *Aristaeomorpha foliacea* has significantly dwindled in catches in many regions (Gulf of Lions: Campillo, 1994; Catalan Sea: Bas *et al*., 2003; Tyrrhenian Sea: Fiorentino *et al*., 1998) and is considered to be overexploited in Italian water (Matarrese *et al*., 1997; D’Onghia *et al*., 1998).

47. Species targeted by offshore fisheries are usually those whose stocks straddle the high seas and the coastal areas. These are bony fishes, elasmobranchs, crustaceans, cephalopods and big migratory pelagic fish like tuna and swordfish in particular (PNR-UNEP/MAP - SPA/RAC, 2003). In high seas pelagic areas, populations of big sharks (e.g. *Mustelus mustelus, Scylliorhinus stellaris* and *Squalus blainvillei*) are dwindling rapidly in the Mediterranean Sea. These species are threatened with extinction because of over-fishing, the degradation of their habitat and slow population renewal. This

situation is worrying because these predators play a key part in the balance of the high sea marine ecosystems.

48. Much of Mediterranean waters are high seas. The Mediterranean high seas contain a great diversity of habitats, both pelagic and demersal (high sea). Not much is known about these habitats as regards the coastal ecosystems and continental shelves, which are more easily studied, while there is good knowledge of the state of stocks of the commercial species they shelter, thanks to studies done on commercial fishing and catch. The protection of the fauna in these areas is important for fishery and the conservation of the ecosystem, for the organisms can determine the health of an ecosystem. The sessile benthic fauna has an important role as organisms that structure the habitats providing a refuge for many marine species (e.g. cold water coral reefs, deep sea sponges, crinoid beds).

49. The ocean depths consist of large stretches of loose sediment interrupted by geological features like underwater canyons, brine lakes, seamounts, hydrothermal events, cold seeps and mud volcanoes, which create a special habitat that shelters great diversity and endemism; many of these habitats have only recently been discovered and must be protected under the Precautionary Approach.

50. The demersal fisheries practiced in the Mediterranean high seas may be summed up as follows: bottom trawling, long line and mesh net. Fishing in the high seas is currently done over the continental shelf and some slopes, down to depths below 800 m. Bottom trawling is an extremely harmful practice that was forbidden in 2005 to Mediterranean sea beds that were deeper than 1,000 m in order to protect the vulnerable deep sea fauna.

51. In the Mediterranean deeph sea benthic habitats, the elements that are extremely vulnerable to fishery are the coralligenous facies, the crinoid echinoderm *Leptometra phalangium*, the cnidarian *Funiculina quadrangularis* and *Isidella elongata*, facies of sessile organisms so far spotted over the continental shelves and the rift of the continental slope of the western basin, although the siting and extent of these habitats in the region as a whole are still very little known.

52. In the deep water are many areas that possess a considerable abundance of cold water coral reefs that are extremely vulnerable, mainly found on the continental slopes, the seamounts and the walls of underwater canyons (e.g. off Cape Santa Maria di Leuca, in the central basin, or in the many canyons and seamounts distributed throughout the Sea of Alboran, in the western basin). Several abyssal plains, containing a deep sea fauna that is vulnerable and badly known, exist throughout the entire Mediterranean, the deepest being in the central basin (e.g. the Calypso plain in the Ionian Sea, south-west of Greece). Other geological types can be more vulnerable to fishery in that they are key regions in terms of diversity and the habitat of a vulnerable fauna like the cold water corals. The vast Eratosthenes Seamount in the eastern basin (south of Cyprus) and the many seamounts dispersed around the Sea of Alboran and the southern Tyrrhenian Sea; cold seeps, brine basins and hydrothermal events have mainly been spotted in the eastern basin of the Mediterranean (south of Cyprus and Turkey, and near Egypt). The western basin of the Mediterranean contains many underwater canyons that are EFHs for red shrimp, like the many canyons in the Gulf of Lions that contain big resources of red shrimp, Norwegian lobster, hake and angler fish among other commercially important species; the hake nursery areas are mainly found in the vast stretches of the continental shelves or shores, scattered around the south of Sicily, the central Adriatic Sea in the Jabuka rift, and the Thracian Sea, whereas the hake spawning areas seem to be found in canyons in a rift between one continental slope and another continental slope, the most obvious being that of the Gulf of Lions.

53. Big pelagic species that inhabit the high seas, essentially the Mediterranean bluefin tuna, swordfish and albacore, and also the pelagic sharks (blue shark and porbeagle) present a great interest at conservation level and has long been overfished by pelagic fishing gear. The main fishing gears used for fishing the big pelagic fishes are running seines and pelagic *palangres*. The fleets using pelagic *palangres* to fish in Mediterranean water are both local fleets of the states bordering on the Mediterranean and big foreign commercial fleets; the latter are extremely mobile and cover almost the entire Mediterranean basin. Driftnets were forbidden in the Mediterranean in 2005, but despite this the activity is still practiced. The high seas in the Mediterranean are also the habitat of cetaceans and turtles that are disappearing, and that frequently constitute by-catch of pelagic fishing and deserve to be specially protected. EFHs important for big pelagic species are essentially determined by

oceanographic type, like upwellings or gyres, creating productive areas that are important for feeding and spawning; these areas, which act as EFHs, must be identified to determine measures of protection for the pelagic species. The main spawning areas of the Mediterranean bluefin tuna are located south of the Balearic Islands, in the Sea of Alboran and in the Strait of Sicily, while those of the swordfish are found pretty well throughout the Mediterranean and those of the albacore partially coincide with the spawning areas of the Mediterranean bluefin tuna.

54. High levels of fishery resource extraction in Mediterranean fisheries have led to over-exploitation, or, in the best cases, optimum exploitation (UNEP/MAP - SPA/RAC 2003). Indicative of this situation is the fact that several stocks of target species in the Mediterranean are dominated by juveniles. Some of the most known target species threatened by fishing are eel (*Anguilla Anguilla*), grouper (*Epinephelus marginatus*), brown meagre (*Sciaena umbra*), bluefin tuna (*Thunnus thynnus*), Albacore tuna *(Thunnus alalunga),* swordfish (*Xiphas gladius*), red mullet (*Mullus barbatus*), striped red mullet (*Mullus surmuletus*), fourspotted megrim (*Lepidorhombus boscii),* potted flounder (*Citharus linguatula),* hake (*Merluccius merluccius*), atlantic bonito (*Sarda sarda*), several cartilaginous fishes, crustacean species like *Homarus gammarus, Palinurus elephas and Scyllarides Latus,* some sponges (e.g. *Hypospongia communis*, *Spongia* spp.), red coral (*Corallium rubrum*). Overfishing has also caused changes in the nearshore ecology, such as in coastal lagoons. These over-exploitation effects are explored habitat-by-habitat below.

2.1.6 Major Habitat Types and Condition

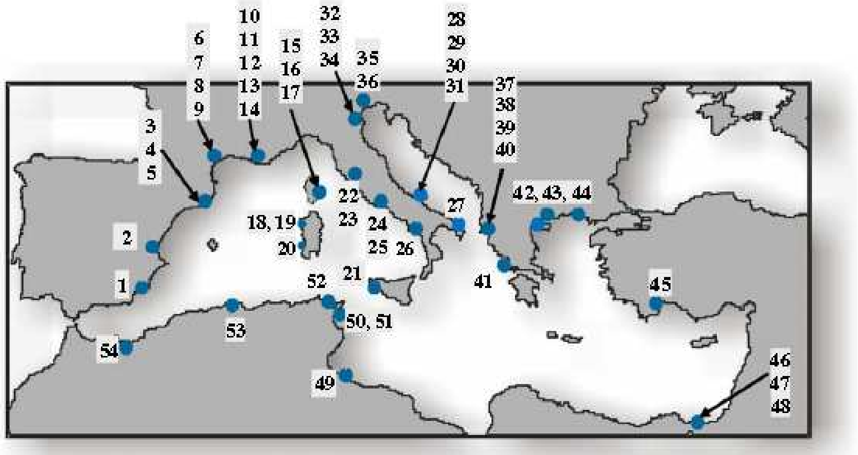
Coastal Habitat Diversity: Sand Dunes

55. Sand dunes and coastal wetlands support a wide variety of species. Dunes play a major part in preserving beaches and protecting the forests, biological communities and facilities that lie behind them. Various kinds of dune exist in the Mediterranean: white, grey, etc. The decline of the Mediterranean dunes has become severe since the 1900s and losses have been estimated at over 70% of the dunes. Few dunes have remained intact around the Mediterranean. Dunes are exclusive habitats for many animal (gastropods, arthropods, reptiles, etc.) and plant species. These are highly fragile ecosystems containing a considerable endemic flora. One-third of the dune flora is endemic to the Mediterranean. The indigenous vegetation of the dunes in this region is threatened by the invasion of exotic species, like the species *Ammophila arenaria*, introduced to stabilize the dunes. Dune developments, particularly to develop seaside tourism, constitute an undeniable threat to these formations in many countries around the Mediterranean.

Coastal Habitat Diversity: Coastal Wetland, Estuaries, and Lagoons

56. Coastal wetlands, especially lagoons, estuaries and deltas, have physical, economic and social features that are common to any coastal area. These are extremely dynamic, highly productive ecosystems. These transitional waters are usually characterized by low biodiversity and contain species that are well adapted to the wide, stressful variations in environmental conditions (Elliott & Quintino, 2007). These aquatic transitional areas provide important services (fighting against floods, stabilizing shores, conserving sediment and nutritive elements, locally reducing climate change, water quality, biodiversity and biomass reservoirs, recreation and tourism, cultural value (Levin *et al*., 2001). Their potential economic value is more than 22,000 dollars/hectare-1/year-1 (Constanza *et al*., 1997). In the Mediterranean, the biggest coastal wetlands are found in delta areas like that of the Po (Italy), Nile (Egypt), Rhône (France) and Ebro (Spain) rivers. Small tides associated with low-speed currents have encouraged the establishment of lagoon systems (Britton & Crivelli, 1993; Ibanez *et al*., 2000; De Stefano, 2004).

57. Mediterranean estuaries and coastal lagoons offer a diversity of habitats for many species. The location of major lagoons is given in Figure 2.6. They act as nursery areas and feeding sites for many coastal fishes. These environments contain a high biodiversity. Over 621 macrophyte species and 199 fish species are present in the Atlantic-Mediterranean lagoons (Pérèz-Ruzafa *et al.*, 2010a). In the Mediterranean, there are more than 50 lagoons for which hydrological and ecological data exist in the scientific literature (Pérèz-Ruzafa *et al.*, 2010b), but these are just the best known lagoons (Fig. 4). In Greece, there are at least 40 lagoons devoted to fish farming (Schmidt & Spagnolo, 1985). Sabetta *et al*. (2007) list 26 lagoons in Italy alone, not including Sardinia.



1 Mar Menor	15 Biguglia	29 Margherita de Savoia	43 Vistonis
2 Albufera	16 Diana	30 Lesina	44 Porto-Lagos
3 Encañizada	17 Urbino	31 Varano	45 Koycegiz-Dalyan
4 Tancada	18 Cabras	32 Scardovari	46 Bardawil
5 Buda	19 Mistas	33 Comacchio	47 Manzala
6 Thau	20 S' Ena Arrubia	34 Pialassa Baiona	48 Burullus
7 Salses-Leucate	21 Stagnone di Marsala	35 Venecia	49 Biban
8 Vaccarès	22 Burano	36 Sacca di Goro	50 Korba
9 Canet-Saint-Nazaire	23 Orbetello	37 Patok	51 Kélibia
10 Arnel	24 Fogliano	38 Butrinti	52 Tunis
11 Berre-Vaine	25 Caprolace	39 Karavastas	53 Mellah
12 Prevost	26 Fondi	40 Narta-Valona	54 Mar Chica
13 Mejean	27 Alimini	41 Messolongui	
14 Mauguio	28 Cesine	42 Agiasma	

Figure 2.6: Main coastal lagoons in the Mediterranean basin related to the availability of hydrological, geomorphological and ecological data in the scientific literature (Pérère-Ruzafa *et al.*, 2010b)

58. The variability between Mediterranean lagoons in terms of biodiversity (number of species) and ecological processes is mainly a function of the lagoon's size, degree of communication with the sea, and trophic state of the water column (Pérère-Ruzafa *et al*., 2007). Within each lagoon the benthic assemblages are not homogeneous and show differences that depend on the type of substratum and vertical zoning, as in all marine communities. The spatial organization of communities, specific richness, phytoplanktonic vs. benthic, productivity and algal biomass depend on a gradient of confinement related to the distance of communication with the sea and the rate of water renewal or the degree of colonization within each site (Guelorget and Perthuisot, 1983; Mariani, 2010; Pérèz-Ruzafa & Marcos, 1992, 1993). However, confinement is not the main factor that determines the distribution of plant species, suggesting that vertical gradients in environmental variables, type of substratum, radiation, hydrodynamics and stress due to the fluctuations of environmental parameters are more important in structuring algal assemblages than the rate of colonization and confinement-linked dispersion (Pérèz-Ruzafa *et al*., 2008). Mediterranean coastal lagoons are well-known for their richness in nutritive salts. Primary production there is very much greater than in the sea. Benthic invertebrates exhibit relatively low densities in eurythermal-euryhaline lagoon communities (shallow lagoons <3 m) but greater species richness in deeper benthic communities which form on silty sand in calm conditions.

59. Very few fishes are resident in Mediterranean lagoons, i.e. pass the whole of their life cycle there. Mullet, eel, sea bass, gilt-head bream, sardine, common two banded-seabream, bogue, saupe and sole are migratory species common to the lagoons, whereas saddled seabream, red mullet, surmullet, mackerel, Mediterranean horse mackerel, anchovy, gurnard, and common searobin are occasionally migrant species. Siphonostome, pipefish, sea horse, grey wrasse, corkwing wrasse, goby, peacock blenny and atherine are common resident species.

60. Macroalgal biomass in lagoon environments is generally high. A rich and varied avifauna uses these ecosystems as stopover or wintering sites since they find favorable ecological conditions there.

Many coastal lagoons are now listed on the Ramsar Convention List as sites of global significance for birds.

Nearshore or Neretic Marine Areas

61. In the coastal waters, the distribution of Mediterranean fauna and flora differs greatly according to distance from the coast, longitude and depth. The marine biodiversity is basically concentrated within the shore area (between 0 and 50m), which contains about 90% of the known plant species and 75% of the fish species of the Mediterranean. The photosynthetic flora disappears at between 50 and 200 m down (according to the region and the transparency of the water).

62. The phytoplanktonic element remains little studied in many Mediterranean countries. Primary production is on average three times lower in the eastern basin than in the western (Tutley 1999 in Zenetos *et al*., 2002) (Fig. 5). In the euphotic area, primary production is 40, 78 and 155 (mgC/sq.m) in the eastern, central and western basins respectively. Low primary production, linked to low development of the higher levels of the trophic chain, including low production of fishes, are the main features that characterize the Mediterranean. Some 470 species of zooplankton have been listed in the Mediterranean (coastal waters and open sea). The increase in oligotrophy from the west to the east of the Mediterranean basin is reflected in the abundance of the zooplanktonic biomass.

63. The coastal benthic systems are better studied. The Mediterranean continental shelf possesses rich and important benthic habitats. In the context of the tools developed by the Regional Activity Centre for Specially Protected Areas (UNEP/MAP - SPA/RAC), a reference list of 27 major types of benthic habitat was made, to help the Mediterranean states in drawing up inventories of natural sites of conservation interest (UNEP/MAP – SPA/RAC, 2002). The SAP BIO Programme (UNEP/MAP – SPA/RAC, 2003) had identified among its priority actions the making of a complete, integral inventory of its Mediterranean habitats, including mapping their spatial distribution and the cohort of species associated with each habitat.

64. The Mediterranean marine macroflora is estimated to be about 1,000 macroscopic species, five of these being marine phanerogams. It is generally distributed in the shallow areas that constitute less than 10% of the surface area of the Mediterranean. Near the shoreline are *Lithophyllum byssoides* (e.g. *L. Lichenoides*) rims in the medio-littoral stage, *Posidonia oceanica* meadows and Fucal forests (biocenoses with *Cystoseira*) in the infra-littoral, and the coralligenous in the circa-littoral (Zenetos *et al*., 2002; Boudouresque, 2004). Additional coastal habitats include the Vermetid platforms and the *Neogoniolithon brassica-florida* concretion (Boudouresque, 2004) (see below).

Seagrass Meadows

65. The *Posidonia oceanica* meadows are considered to be one of the Mediterranean Sea’s most important ecosystems. The most extensive meadows are those in the Gulf of Gabès (Tunisia), Hyères and Giens bays (France), the eastern coast of Corsica, and the western coast of Sardinia and Sicily (Boudouresque, 2004). The meadows are present on most of the Mediterranean shores (except for Israel, Palestine and perhaps Lebanon). National reports suggest *Posidonia* occurs in Albania (essentially in Vlora Bay on the Adriatic) (Dedej, 2010); in Algeria [El Tarf (El Kala), Annaba (Cap de Garde), Jijel (Kabyle Bank, Aouana), Tizi Ouzou (Sidi Slimane, Tigzirt District), Boumerdès, Algiers (Sidi Fredj, Ain Benian, Raïs Hamidou, Ras Matifou), Tipaza (Kef El Haouaci, Mostaganem Cove), Kef El Aoua, Kef El Asfer, Kef Oumer, Kef Bou Ghetar, Ras Ouillis (Sidi Abdelkader, Kef Kharouba), Oran (Baie des Andalouses), Témouchent (Rachgoun), Tlemcen (Ras Tarsa Cove, Honaine Bay, Ioubar Damah, Ronde Island, Sidi Madani Cove)] (Grimes, 2010); in Egypt, where the Posidonia meadows seem thickest in the western part of the country compared to those of Alexandria (Halim, 2010); in the Aegean Sea and the Ionian Sea, where it seems very common (Zenetos *et al*., 2010a); in Libya (Bamabah Bay, Farwa, Ain Elghazala and El-Bardyya, Al Elghazalaha Bay) (Shakhman, 2010); and in Morocco near the Chafarin Islands (Bazairi, 2010). In Syria, Posidonia has probably disappeared, but it is thought that a few insignificant meadows do still exist there (Ibrahim, 2010).

66. The Cymodocea *nodosa* meadows are second most significant seagrass habitat in the Mediterranean after *Posidonia*. Without being strictly endemic to the Mediterranean, the species also lives in the Atlantic, from Morocco to Senegal. It has been reported in the context of the ecosystem approach process in Albania (Kasmil, Saranda Bay and Vlora Bay) (Dedej, 2010); Algeria (Grimes,

2010); Bosnia-Herzegovina (Neum-Klek Bay but restricted in area) (Vučijak, 2010); in the Aegean and Ionian Seas, where it is widely found on loose substratum (Zenetos *et al*., 2010a and b); in Libya (Al Elghazalaha Bay) (Shakhman, 2010); in Slovenia (Lipej & Mavrič, 2010); in Syria (Ibn Hani area, Oum Altiur site) (Ibrahim, 2010); and in Tunisia (Romdhane, 2010).

67. Another Mediterranean seagrass -- *Zostera marina* – also forms meadows. This is a species that is widespread throughout the northern hemisphere but rare, only growing very locally in the Mediterranean (mainly the north-western Mediterranean, the Adriatic, and the Aegean Sea). It was reported in Algeria (Bou Ismail (Grimes, 2010); Morocco, in the Nador lagoon (Bazairi, 2010) and in Bosnia-Herzegovina (Vučijak, 2010). In addition, *Zostera noltii* meadows -- widespread throughout the North Atlantic (from Sweden to Mauritania) – are rarer and more localized in the Mediterranean (western Mediterranean, the Adriatic, Greece and Egypt). This seagrass was reported in Algeria on the Mostaganem coast (Santa & Simonet, 1961); in Morocco in the Smir and Nador lagoons (Bazairi, 2010); in Syria (Ibrahim, 2010); and in Bosnia-Herzegovina (Vučijak, 2010). Finally, *Halophila stipulacea* meadows occur but are restricted to specific areas. They are reported to occur in Greece (Zenetos *et al*., 2010a and b); in Syria (Ibrahim, 2010); and in Tunisia in the Gulf of Gabès (Romdhane, 2010), as well as the Port of Palinuro (Salerno, Tyrrhenian Sea, central Italy).

68. Collectively these seagrass habitats are among the most productive ecosystems in the marine environment. Their economic value is estimated at over 15000 Euros per hectare, i.e. 100 times greater than that of their terrestrial equivalents (UNEP/MAP - BP/RAC, 2009). The five species of marine phanerogam described above (*Cymodocea nodosa*, *Halophila stipulacea*, *Posidonia oceanica*, *Zostera marina* and *Zostera noltii*) form vast underwater meadows at between zero and 50 m down in the open sea and in lagoons. Generally speaking, the available data on these habitats are very heterogeneous, and in certain countries do not exist. The efforts made to map these habitats have mostly been in the north-western basin.

Coralligenous Communities

69. Coralligenous communities -- biogenic constructions made by calcium carbonate forming organisms, are the second most important hotspot of species biodiversity in the Mediterranean (Boudouresque, 2004). Very recently the coralligenous habitats and bioconcretions (pre-coralligenous populations, shelf coralligenous, associations with rhodoliths – maërl facies, association with rhodoliths – *pralines* facies, association with rhodoliths – *Lithothamnion minervae* facies, association with *Peyssonnelia rosa-marina* – free Peyssonneliaceae facies and big bryozoan facies of the coastal detrital bottoms) were the subject of a regional summary whose aim was to establish the state of current knowledge and map the geographical distribution of these habitats on a Mediterranean scale (UNEP/MAP – SPA/RAC, 2009c). The available data highlight the fact that these habitats are best studied in the western Mediterranean and to a lesser degree in the Ionian Sea; little data exists in the Adriatic, Aegean and Levantine regions. Even though relatively widely represented in the Mediterranean, data on the coralligenous communities are usually qualitative and the habitats have only been mapped in the western basin. Coralligenous communities have been recorded in Tunisia (from El Haouaria to La Chebba) (Romdhane, 2010); in Israel (north of Haifa Bay) (Galil, 2010); in Algeria on many stretches of the Algerian coast but mainly in El Kala, Taza, Gouraya, Habibas, Rachgoun, Mostaganem (Grimes, 2010); in the Principality of Monaco, basically in the Tombant des Spélugues Reserve (15-40 m) and the Saint-Nicolas rocks (50-70 m off the port of Fontvieille) and further out to sea in the Saint Martin shallows (50-70 m) (Pérèz *et al*., 2010); and in Morocco (Sebta, Ben Younech, Cabo Negro, Jebha, Al Hoceima National Park, Cap des Trois Fourches, the Chafarin Islands) (Bazairi, 2010).

Cystoseira Forests

70. Forests of macroalgae of the genus *Cystoseira* can occupy large areas in the marine ecosystems, where they form highly productive communities with remarkable biodiversity. Species of the *Cystoseira* genus are in a speciation process which has led to many varieties within a single species. Furthermore, these algae present significant morphological variability. Outstanding Cystoseira forests have been reported in Cap Mitjá and Cap d'en Roig (Costa Brava, Spain: *C. mediterranea*), in Harri Bolas (Vizcaya, Spain: *C. baccatta* and *C. tamariscifolia*); in Tuzla-Vama (Romania: *C. barbata*); in the Black Sea (*C. crinite*); in Port-Cros National Park (France: *C. zosteroides*); in Porto Cesareo (Ionian Sea, Italy: *C. amentacea, C. barbata* and *C. compressa*); on

Alboran Island (Spain: *C. amentacea*, *C. tamariscifolia*, *C. mauritanica*, *C. foeniculacea*, or *C. usneoides*); in Ile Verte (Bouches du Rhône, France: *C. foeniculacea* and *C. sauvageauana*); in the Gulf of Evoikos (Greece: *C. amentacea*); in the Bay of Biscay (Spain: *C. baccatta, C. humilis, C. tamariscifolia* and *C. usneoides*); in Torre del Serpe (Apulia, Italy: *C. squarrosa*); in Corsica (France: *C. spinosa*, *C. amentacea* and *Sargassum vulgare*); in Linosa Island (Sicily, Italy: *Cystoseira brachycarpa, C. sauvageauana, C. spinosa*, *C. zosteroides, Sargassum acinarium* and *S. trichocarpum*); in Ramla Bay (Gozo, Malta: *Sargassum vulgare*). National reports confirm the presence of these habitats in Albania (Dedej, 2010); in Bosnia-Herzegovina (Vučijak, B., 2010); in Morocco (Bazairi, 2010); in the Aegean and Ionian Seas (Zenetos *et al.*, 2010a and b); in Algeria (Grimes, 2010); and in Tunisia (Romdhane, 2010).

Lithophyllum Rim Habitats, Vermetid Platforms, and other Hard-Bottom Habitats

71. *Lithophyllum* rim habitats are common in the northern and central parts of the western Mediterranean and in the Adriatic Sea. The rims are rare in the southern part of the western Mediterranean and in the eastern Mediterranean (Boudouresque, 2004). The most spectacular rims are those of the Grand Langoustier and Porquerolles (France), and Punta Palazzu (Scandola Reserve, Corsica), where they can be as wide as 2 meters (Boudouresque, 1996). This habitat has been recorded in Spain (Medes Islands), Italy (Sicily), the Adriatic (Pelagosa Island) and Yugoslavia (UNEP/IUCN/GIS Posidonie, 1990). This habitat is present in Tunisia (Sidi Mechreg, the Lakhouet Islets, Bizerta) (Romdhane, 2010); in Albania (typically in the north-western area and the median area of the Adriatic) (Dedej, 2010); in the Principality of Monaco (Pérèz *et al*., 2010); and in Morocco (Al Hoceima National Park, Cirque de Jebha and Cap des Trois Fourches) (Bazairi, 2010).

72. Vermetid platforms are basically built up by the association of *Dendropoma petraeum* (gastropod) and a crusting coralline alga *Neogoniolithon brassica-florida*. Vermetid platforms are usually formations that are typical of the hot parts of the Mediterranean. The best developed are in Sicily, Algeria, Tunisia, Crete, Lebanon and Israel. They are also present in the southern part of Spain and Italy (Boudouresque, 2004). In the context of the ecosystem approach process, these habitats were described in Tunisia (Sidi Mechreg, Lakhouet Islets, Bizerta) (Romdhane, 2010); in Algeria, where they present discontinuous distribution on all the low rocky coasts of the Algerian coast (Cherchell-Ténès region, particularly in the Cherchell-Hadjaret Ennous sector, Sidi Ghiles and the Sefah cove, particularly between Sidi Ghiles and Hadjaret Ennous) (Grimes, 2010):.in Israel (Galil, 2010); in Syria (northern part of the Syrian coast from Lattakia up to the border with Turkey) (Ibrahim, 2010); and in Morocco (Chafarin Islands, Sebta) (Bazairi, 2010).

73. Hard bottom formed by *Neogoniolithon brassica-florida* are known from the hypersaline lagoon of Bahiret-el-Bibane in the south of Tunisia (where at 31 km it has no parallel elsewhere in the Mediterranean). Other more localized reefs, less spectacular than the Tunisian one, are mentioned in the eastern Mediterranean, e.g. in Greece and Turkey. The only data from the national ecosystem approach reports concerns Albania (from Karaburun to Porto Palermo (Dedej, 2010).

Other Coastal Habitats

74. Beyond these relatively well-studied habitats, the available knowledge on other sorts of marine habitats is extremely fragmentary and very variable in the Mediterranean basin (UNEP/MAP - BP/RAC, 2009). In the context of the ecosystem approach process, the national reports, presented the following additional information:

75. In the supra-littoral area, the washed-up phanerogam biocenoses , widespread throughout the Mediterranean, have been sighted in Greece (Zenotos *et al*., 2010a and b); in Morocco between Cap des Trois Fourches and Cap de l'Eau (Bazairi, 2010); and in Tunisia. In the medio-littoral area, facies with *Pollicipes cornucopiae* is a habitat that is very rare in the Mediterranean. The characteristic species *Pollicipes cornucopiae* prefers well exposed rocky substrata. It has been mentioned in Morocco in Cap des Trois Fourches, Al Hoceima National Park and Cirque de Jebha (Bazairi, 2010); and in Algeria. The association with *Fucus virsoides* , an emblematic species of the Adriatic Sea, was mentioned in the Vigo estuary (Spain), the Gulf of Trieste (Italy) and the Venice lagoon, where it has become particularly abundant. In the ecosystem approach context, this habitat was reported in Slovenia (Lipej & Mavrič, 2010). Maërl bottoms are responsible for much of the biogenic sediment of the coastal area. They have been reported in Spain (in the Balearics, Fornos *et al*., 1988); in France

(Hyères Islands, near Marseilles and in Corsica); in Algeria (off the El Aouana Islands) (Grimes, 2010); in Greece (Zenotos *et al*., 2010a and b); and in Morocco (Al Hoceima National Park) (Bazairi, 2010). Lastly, the facies with *Corallium rubrum* in the circa-littoral stage is mainly localized in the western Mediterranean, where its populations seem to be continuous. Its distribution in the eastern Mediterranean seems to be occasional (Adriatic Sea, Aegean Sea). It has been cited in Algeria (essentially El Kala) (Grimes, 2010); in Morocco (AHNP, Sidi Hsain, C3F) (Bazairi, 2010); in Greece (Zenetos *et al*., 2010a and b); in Turkey (Öztürk, 2010); and in Tunisia (Romdhane, 2010).

Deep Sea

76. The term deep sea usually refers the marine depths from which photosynthetic organisms are absent. According to some authors, the term applies to areas lying outside the continental shelf. Deep sea ecosystems are considered to be extremely stable when compared to coastal environments. Their important feature is linked to the temperatures and salinity that do not usually fluctuate much (George *et al*., 1991). The deep seas extend downwards from the continental shelf break, i.e. waters deeper than 200 m to its maximum depth.

77. In the Mediterranean, as elsewhere, these deep waters remain largely unexplored. The data available for the Mediterranean are fairly weak, but preliminary work has already enabled a qualitative inventory to be made of these ecosystems, even if the data on biogeography is still lacking (Rais, 2008). Work recently published by WWF and IUCN (WWF/IUCN, 2004) draws the broad outlines of deep sea ecosystems in the Mediterranean.

78. The bathyal and abyssal domains cover respectively about 60% and 10% of the surface area of the Mediterranean Sea, while the continental shelves represent about 30%. Unlike the Atlantic, the Mediterranean deep waters are characterized by the absence of typical deep sea species (bathypelagic species like the foraminifers *Xenophyophora*, the sponges *Haxactinellidae*, the sea-cucumber of the *Elasopodida* order, etc.) (Zenetos *et al*., 2002; WWF-IUCN, 2004). Mediterranean deep sea life forms are essentially eurybathic species. Other faunistic groups (decapodal stropods) are weakly represented in the deep sea. The deep substratum macrobenthic fauna is poor in terms of abundance, species richness and endemism. Longitudinal comparison shows a declining west-east Mediterranean gradient, especially for the deep benthos.

79. The macrofauna of the Mediterranean deep sea is dominated by fishes and decapodal crustaceans. Differences exist between the western and eastern Mediterranean in both specific composition and abundance. The species of macrofauna are typically smaller than those of the Atlantic. The meiofauna is less abundant in the eastern Mediterranean. In the deep sea, the rate of endemism for many taxa (i.e. 48% for amphipods) is clearly higher than the average endemism rate in the Mediterranean. In the Mediterranean high sea benthic habitats, the elements that are extremely vulnerable to fishery are the coralligenous facies, the crinoid echinoderm *Leptometra phalangium*, the cnidarian *Funiculina quadrangularis* and *Isidella elongata*, facies of sessile organisms so far spotted over the continental shelves and the rift of the continental slope of the western basin, although the siting and extent of these habitats in the region as a whole are still very little known.

80. In the deep water are many areas that possess a considerable abundance of cold water coral reefs that are extremely vulnerable, mainly found on the continental slopes, the seamounts and the walls of underwater canyons (e.g. off Cape Santa Maria di Leuca, in the central basin, or in the many canyons and seamounts distributed throughout the Sea of Alboran, in the western basin). Several abyssal plains, containing a deep sea fauna that is vulnerable and badly known, exist throughout the entire Mediterranean, the deepest being in the central basin (e.g. the Calypso plain in the Ionian Sea, south-west of Greece). Other geological types can be more vulnerable to fishery in that they are key regions in terms of diversity and the habitat of a vulnerable fauna like the cold water corals. The vast Eratosthenes Seamount in the eastern basin (south of Cyprus) and the many seamounts dispersed around the Sea of Alboran and the southern Tyrrhenian Sea; cold seeps, brine basins and hydrothermal vents are mainly in the eastern basin of the Mediterranean (south of Cyprus and Turkey, and near Egypt), many of these have been identified as ecologically significant areas.

High Seas Systems

81. In the Mediterranean, the High Seas (seas lying outside the territorial waters of the Mediterranean countries), form a large part of the Mediterranean basin, i.e. 2.5 million sq. km. The High Seas support a big selection of marine life and have pockets of relatively high productivity (gyres, upwellings and fronts). Only one Marine Protected Area that straddles High Seas is known in the Mediterranean: the Pelagos Sanctuary for Mediterranean marine mammals (UNEP/MAP – SPA/RAC, 2009a).

82. Generally speaking, the High Seas possess a diversified fauna belonging to various zoological groups. It is obvious that not all the species described in the Mediterranean are found in the high seas area outside 12 nautical miles, which constitutes the current boundary of the territorial waters, but many forms of life frequent the high seas. These are essentially high marine predators, known as charismatic macrofauna, which have special conservation importance as umbrella species. These include the chondrichthyan fishes, cetaceans, marine turtles, and seabirds.

83. An exercise recently undertaken by CIESM called CHOMP (Critical Habitats of Mediterranean Predators) focused on marine top predators and charismatic species (cetaceans, monk seals, marine birds, marine turtles, sharks and large pelagic fishes), due to their qualities of umbrella and flagship species, and as ecological indicators. This critical habitat mapping follows on a process initiated at the IUCN World Conservation Congress in Barcelona (Hoyt and Notarbartolo di Sciara 2008), where a first attempt was made to overlay the different species' habitat to detect location of special faunal importance. *CHOMP* carried the effort forward in much greater detail, bringing together specialists from diverse zoological groups to facilitate joint multi-species proposals of place-based protection, rather than single-taxon MPA proposals that present unrealistic scenarios for the region's biodiversity conservation. The mapping effort combined a Delphic process, based on expert knowledge, and analytical approaches. Figure 2.7 shows some of these data on major mega-vertebrates, showing areas of high overlap in the Mediterranean pelagic environment.

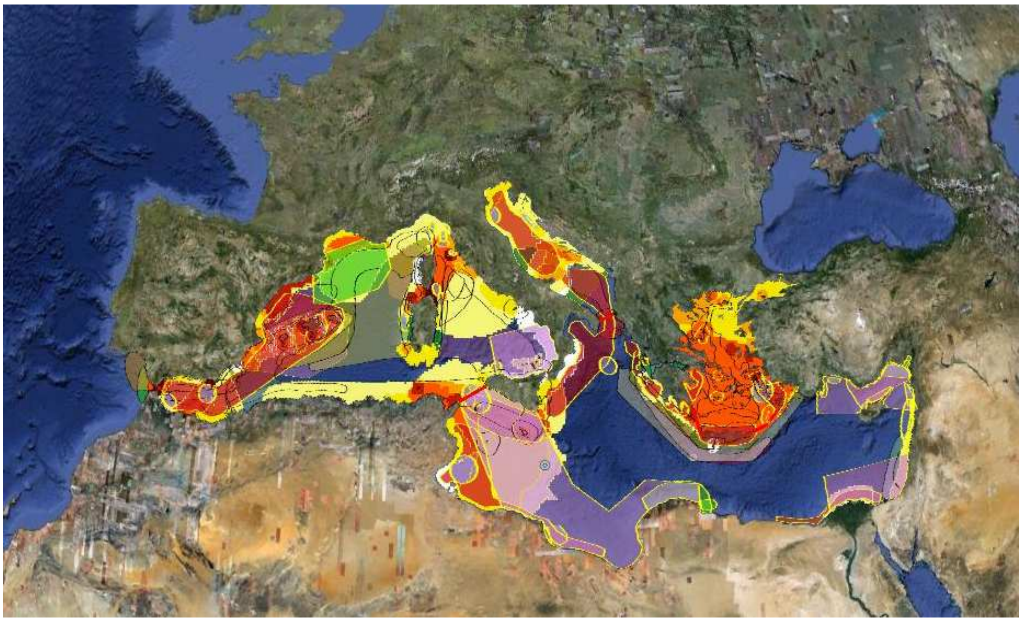


Figure 2.7. Main areas of ecological importance for select Mediterranean mega-vertebrates, as provided by the CHOMP exercise.

84. Pelagic systems of the Mediterranean include distinct features such as upwellings, gyres and fronts. Thermal fronts correspond to areas of contact between two masses of water of different temperatures. These regions are often the site of vertical mixtures likely to bring to the surface mineral salts that encourage plankton development and help install a food chain. Upwellings are considered as being among the most productive ecosystems in the marine environment.

85. The seafloor in offshore areas has unique life forms. Features include the hydrothermal vents, the seamounts and the deep sea coral reefs, underwater canyons, seamounts, and brine pools.Deep sea canyons are of major importance in the Mediterranean since they represent, for many species, places for reproduction and feeding (fishes, cetaceans like *Grampus griseus* and *Physeter macrocephalus*) and are a remarkable reservoir of endemism. Chemosynthetic communities associated with hydrothermal vents are characterized by symbiosis between invertebrates and chemotrophic bacteria are rare in the Mediterranean, being found in southern Crete, southern Turkey (Anaximander Seamounts) and off Egypt and Gaza (ICSEMS, 2004).

86. Cold water corals are habitats of great ecological value and high diversity, which are threatened by deep sea trawling and by the effects of global warming (ICSEMS, 2004). Seamounts are underwater mountains that emerge from the seabed and constitute singular habitats in the marine environment. They represent essential habitats for the life-cycles of several species and contain high density levels of macro- and megafauna. Seamounts are characterized by a high rate of endemism (i.e. hydrozoa). They are also feeding places for many species of marine vertebrates. The Sea of Alboran (Spain), the Balearic Sea (Spain), the Gulf of Lions (France) and the abysses of the Ionian Sea are of special interest for these habitats.

87. Deep hypersaline habitats or brine pools show high biodiversity, particularly in bacterial and metazoan meiofaunal assemblages (IUCN-WWF, 2004). Little data exist on these habitats but they are considered to be important environments because of their specific Mediterranean feature (ICSEMS, 2004).

2.1.7 Locations of SPAMIs and other MPAs

88. Marine and coastal protected areas abound in the Mediterranean. Coastal protected areas include national and local designations (Specially Protected Areas; SPAs), as well as Natura 2000 sites. Marine protected areas (MPAs) include national designations (SPAs), and multilateral designations (Specially Protected Areas of Mediterranean Importance; SPAMIs) (e.g. the Pelagos Sanctuary for Mediterranean Marine Mammals).

89. Figure 2.8 shows the location of Mediterranean Specially Protected Areas (SPA) and Specially Protected Areas of Mediterranean Importance (SPAMI) up to end 2009.

Figure 2.8: Specially Protected Areas (SPA) and Specially Protected Areas of Mediterranean Importance (SPAMI) up to end 2009. Pelagos Sanctuary is a SPAMI embracing High Seas.

90. The Specially Protected Areas of Mediterranean Importance (SPAMIs) are sites recognized under the Barcelona Convention Protocol to conserve amongst other things: *"the components of biological diversity in the Mediterranean, ecosystems specific to the Mediterranean area or the habitats of endangered species, are of special interest at the scientific, aesthetic, cultural or educational levels".* 1 The Protocol to which the Parties to the Barcelona Convention acceded in 1984 and to which amendments were made in 19992, protects natural resources and certain natural sites, preserves the diversity of the gene pool, and safeguards cultural heritage in the Mediterranean region by creating a series of Specially Protected Areas of Mediterranean Importance (SPAMIs). These listed SPAMIs are aimed to be representative of the region coastal and marine ecosystems, habitats and biodiversity. They safeguard habitats which are intrinsically restricted in areas or are in danger of disappearing in the Mediterranean, as well as those critical to the survival, reproduction and recovery of endangered, threatened or endemic species of flora or fauna (www.biodiversitya-z.org/areas/31.pdf). The Mediterranean Action Plan tracks SPAMI designations by country.

2.2 Ecosystem Services and their Values

91. The recent economic study completed under the auspices of UNEP/MAP - BP/RAC is entitled "The Economic Value of Sustainable Benefits Rendered by the Mediterranean Marine Ecosystems", prepared by A. Mangos, J-P. Bassino, and D. Sauzade (2010). A full version of the report is available on the UNEP/MAP - BP/RAC website http://www.planbleu.org/themes/intro_marinUk.html).

92. The report sets out an economic evaluation of the sustainable benefits relating to the ecosystem services provided by the marine ecosystems in the Mediterranean in 2005. The results illustrate the economic potential of marine ecosystems as regards the sustainable development of the riparian states. The analysis looks at the value of the flows produced by the environmental assets constituting marine natural capital, without making any attempt to estimate the value of the stock of natural capital.

93. The methodological framework for the valuation study was established on the basis of a bibliographical analysis of numerous studies which addressed the economic evaluation of the services provided by ecosystems. The main types of Mediterranean marine ecosystems were characterised and considered according to their role in producing resources, as a regulator and in cultural terms, as defined by the *Millennium Ecosystem Assessment* (MEA, 2005). For each of these three categories, various services provided by the ecosystems under consideration were identified in respect of the human uses they allow or to which they contribute. In this study, the methods used to assess the benefits derived through the use of ecosystem services have been drawn from the framework established by the United Nations in the System for integrated Environmental and Economic Accounting (UN, 2003). A sustainability criterion for the usages of the ecosystem services was introduced, in line with concerns expressed about sustainable development in the Mediterranean.

94. Five ecosystems have been considered as a basis for this study: Posidonia meadows (*Posidonia oceanica*), corallogenic concretions, rocky sea-beds with photophilic algae, sea-beds with a soft substrate and the open sea (over 100 m in depth). Area covered by each ecosystem was estimated using available data and expert reviews. The benefits assessed fall into three groups of services provided by the ecosystems, as set out in the following table:

<table>
<tr><th>Categories of ecosystem services :</th><th>Ecosystem services:</th><th>Benefits assessed:</th></tr>
<tr><td>Provisioning services</td><td>Production of food resources</td><td>Resource rent relating to the production of food resources of marine origin</td></tr>
<tr><td rowspan="2">Cultural services</td><td>Amenities</td><td rowspan="2">Resource rent relating to the provision of amenities and recreational supports</td></tr>
<tr><td>Support for recreational activities</td></tr>
<tr><td rowspan="3">Regulating services</td><td>Climate regulation</td><td>Value of man-made CO_2 sequestration</td></tr>
<tr><td>Mitigation of natural hazards</td><td>Value of protection against coastal erosion</td></tr>
<tr><td>Waste processing</td><td>Value of waste treatment</td></tr>
</table>

95. In this study, the economic value of the benefits rendered by ecosystems has been assessed as either a more or less important part of the value added created in various economic activities or an equivalent to avoided expenditure or even as a reference value, when facing collective benefits.

96. Each type of benefit was individually assessed. Benefits relating to the production of food resources were assessed using fisheries and marine aquaculture related data. Benefits relating to the provision of amenities and recreational supports were assessed on the basis of data on real estate rents, hotel and restaurant service activities, and tourism. Benefits relating to climate regulation were assessed on the basis of the marine environment's capacity to absorb anthropogenic CO_2 valued at the price per tonne of CO_2 in force under the European Emission Trading Scheme in 2005. Benefits relating to the mitigation of erosion were evaluated on the basis of the proportion of the coastline exposed to this hazard and where Posidonia meadows are also supposed to be both present and efficient, the benefits being valued according to the replacement cost of defence structures. Finally, the benefits relating to waste processing by the marine ecosystems were valued by observing a reference value corresponding to a situation where waste disposal meets environmental standards.

97. Aggregation of these results provides a first indication of the overall value of the benefits resulting from the Mediterranean marine ecosystems. At the regional level, the benefits are estimated to be over 26 billion Euros for 2005 (which represent almost 120% of Tunisia's GNP during the same year), more than 68% of which comes from the benefits stemming from the provision of amenities and recreational supports. The benefits relating to the production of food resources account for 11% of the overall estimated benefit. The study also provides a breakdown of the benefits relating to the production of food resources by ecosystem type. Thus for fisheries, the open seas account for over 70% of the value of the benefit in proportion to the volume of catches involved. On the other hand, basing itself on catch quantity, the study demonstrates that it is the Posidonia meadows and the rocky substrate which provide the best fishing productivity by area unit.

98. This exploratory study represents a preliminary attempt to assess the contribution made by the marine ecosystems in the Mediterranean on an economic basis. The constraints under which it was drawn up, whether these be the application of the sustainability criterion for assessing the benefits considered or the lack of sound data for certain benefits, which consequently could not be included in the study, have led to what is probably a low initial assessment of the annual value of the sustainable benefits from marine ecosystems. Further studies will thus be undertaken. In addition, current and future research into the costs of degradation will be undertaken; this information will be critical to making informed management decisions.

99. Nevertheless, the report and the attention which will be focused on Mediterranean marine ecosystem services that flow from it will contribute to the ecosystem approach process andf will help catalyze the move from conventional management to an Ecosystem Approach.

2.3 Pressures and Impacts: Pollution

100. Marine pollution takes many forms, including hazardous substances such as heavy metals and POPs; excessive nutrients (discussed above); petrochemicals; and debris. Other marine pollutants impacting marine species and ecosystems are chemical and microbiological. Many different kinds of pollutants enter Mediterranean waters via discharge points and dumping grounds, from river and run-off, and through atmospheric deposition. Known pollution hotspots are shown in Figure 2.9.

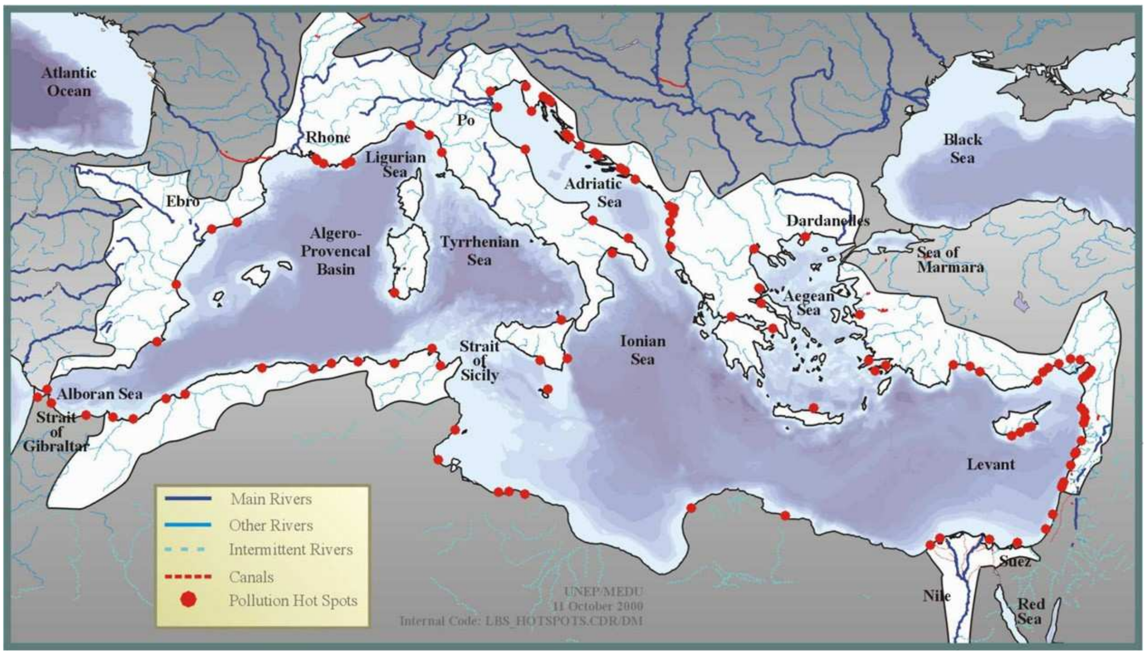


Figure 2.9 Pollution hotspots as identified by UNEP/MAP - MED POL

101. In addition to run-off and atmospheric pollution, dredge spoil and other forms of dumping can lead to high concentrations of heavy metals and organic matter, and these can accumulate in deeper waters. These compounds also enter the marine ecosystem through river discharges, via run-off, and by atmospheric deposition. The magnification of chemical pollutants in deep trophic food web can have consequences on both marine species and human health. The influence on recruitment success and the effects of the incorporation of certain materials in trophic webs is partially unknown.

<u>2.3.1 Contamination by hazardous substances (heavy metals, halogenated and petroleum hydrocarbons, antifoulants, chemicals and pharmaceuticals, etc. from all sources as well as radionuclides)</u>

102. Many hazardous compounds enter the marine environment via the atmosphere. For instance, the major source of anthropogenic radionuclides to the Mediterranean Sea is the global fallout from atmospheric weapons testing and accidents such as Chernobyl in 1986 (EEA, 2006). The input deriving from the nuclear industry is considered very small compared to other sources. According to the EEA (2006) the overall total inventory of radionuclides in the Mediterranean Sea is declining.

103. UNEP (2002) made a Mediterranean-wide assessment of toxic and persistent organic compound including halogenated hydrocarbons. The report concluded that apart from areas of intense local contamination, compounds of regional concern are PCBs, DDT, HCHs, and HCB, amongst others. Other compounds, e.g., phthalates, alkylphenols and PBDE/PBBs, are suspected to be ubiquitous but data were lacking. Most of these compounds enter the marine environment via river discharge and inputs from urban environments and industrial centers.

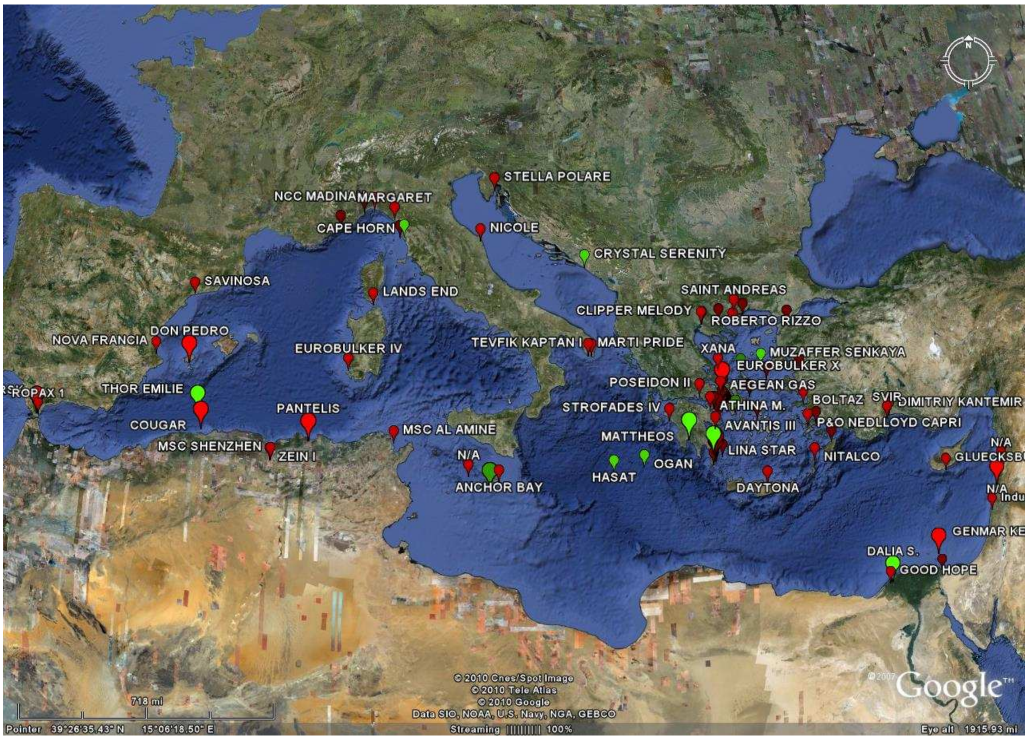
104. Toxicological studies have found that PCB levels in deepwater fishes (*Alepocephalus rostratus*, *Bathypterois mediterraneus*, *Coryphaenoides guentheri* and *Lepidion lepidion*) were lower than in coastal fishes, close to the pollution sources, but much higher than that of fish living on the continental shelf to upper slope (*Micromesistius poutassou*, *Phycis blennoides* and *Lepidorhombus boscii*). PCB levels recorded were within the same range as that of top predators like tuna (Porte *et al.,* 2000; Solé *et al.,* 2001). Levels of TPT (triphenyltin) resulted higher in two bathyal species (*Mora moro* and *Lepidion lepidion*) than in bivalves and fishes of harbours and coastal areas (Borghi & Porte, 2002).

105. The Mediterranean is one of the world's busiest waterways, accounting for 15% of global shipping activity; more than 325,000 voyages occur annually representing a total capacity of 3.8 billion tonnes. Shipping leads to polluted waters, both in the course of normal operations and via disasters. While maritime activities within the Mediterranean have always been a characteristic and essential element of human presence, according Abdulla and Linden (2008), between 1985 and 2001, a 77% increase was recorded in the volume of ship cargo loaded and unloaded in Mediterranean ports. An estimated total of 200,000 commercial ships cross the Mediterranean Sea annually and approximately 30% of international sea-borne volume originates from or is directed towards the 300 ports in the Mediterranean Sea. These values are expected to grow three or four fold in the next 20 years. This growth is due mainly to ship traffic and to an increase in the size of ships.

106. Marine transport is one of the main sources of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbon (PAH) pollution in the Mediterranean Sea. It is estimated that about 220 000 vessels of more than 100 tonnes each cross the Mediterranean each year discharging 250 000 tonnes of oil. This discharge is the result of shipping operations (such as ballast water discharge, tank washing, dry-docking, fuel and oil discharge, etc.). The PAH input varies according to the type of oil discharged and its range is estimated at between 0.3 and 1,000 tonnes annually (UNEP Chemicals, 2002). Illicit vessel discharges can be detected through the interpretation of ERS SAR (Synthetic Aperture Radar) satellite images.

107. Shipping and boating is also tied to pollution by organotins. These toxins have been used for a wide range of applications, generally for their biocide effects. One of the best known is tributyltin (TBT) which has until recently been used as an antifouling agent; the effects of TBT are still being studied but the impacts seem to be extensive across ecosystems.

108. In addition, 80,000 tonnes of oil have been spilled in the Mediterranean Sea and its immediate approaches because of shipping accidents (taking into account accidents resulting in releases of more than 700 tonnes. The bulk of these spills have occurred in the western Mediterranean subregion, though nearly a third of significant spills (>100t) occurred in the central Mediterranean in the period between 2000-2009 (see Figure 2.10).



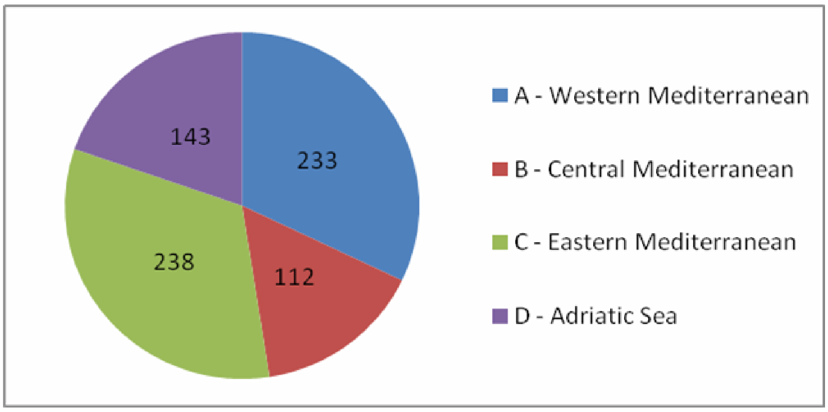


Figure 2.10 Location of major tanker oil spills (> 700 tonnes) 1990–2005 (reprinted from EEA 2006) and number of accidents leading to a significant spill (>100t) in 2000-2009 in each subregion (REMPEC)

109. The negative effects of oil effects do not result solely from shipping accidents, however. Incidents at oil terminals and routine discharges from land-based installations have been estimated at 120,000 tonnes/year (EEA, 2006).

110. REMPEC (2008) recently reviewed the maritime traffic in the Mediterranean region, providing information on routine operations, as opposed to disaster-related data (Figure 2.11). In 2006 around 10,000, mainly large, vessels transited the area en-route between non-Mediterranean ports. Merchant vessels operating within and through the Mediterranean are getting larger and carrying more bulky cargo. Vessels transiting the Mediterranean average 50,000 DWT and are, on average, over three times larger than those operating within the Mediterranean. Overall vessel activity within the Mediterranean has been rising steadily over the past 10 years and is projected to increase by a further 18 per cent over the next 10 years.

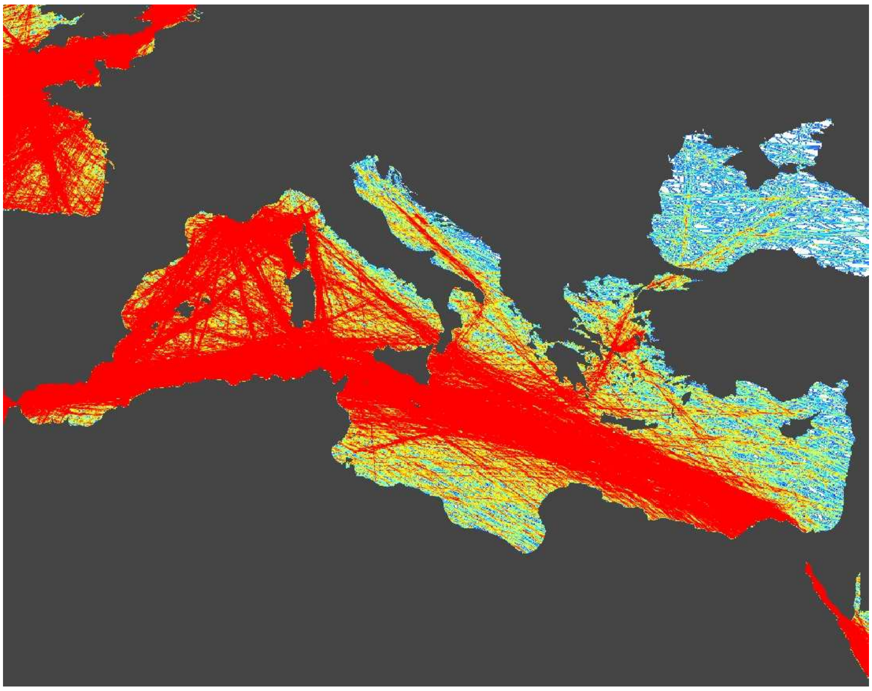


Figure 2.11 Maritime traffic (from data supplied by REMPEC)

111. Maritime traffic has direct impacts on biota, as for instance in ship-strike mortality of cetaceans and sea turtles, but it also has indirect (and as yet, unquantified) effects. These effects include the generation of underwater noise (see section 2.5.5), and hydrocarbon pollution resulting from operations and ballast discharge. Ballast water discharge is also implicated in the release of alien, and sometimes invasive, species.

112. REMPEC has analyzed ballast water discharges by assessing the location of major crdue oil ports throughout the Mediterranean. Crude oil loading ports, and thus potential ballast water impacts, are concentrated in the eastern and central Mediterranean (39% and 38% of total respectively, using 2006 figures from the 20 top ports in each subregion).However, it must be noted that 74% of this traffic originates within the Mediterranean Sea, therefore only about a quarter of the ballast discharges could potentially release non-Mediterranean species.

2.3.2 Nutrient and organic matter enrichment, eutrophication, and anoxia

113. Excessive nutrients (nitrogen and phosphorus) are a major pollution problem in many developed coastal areas. The sources of these nutrients include untreated human sewage, animal waste, fertilizers used in agriculture and in landscaping (and golf courses), and industrial discharges

(fish processing plants, etc.). Coastally-based aquaculture is a growing driver behind eutrophication as well. The level of nutrients entering the Mediterranean has been rising over the last decades, as illustrated in the bar graph below (Figure 2.12).

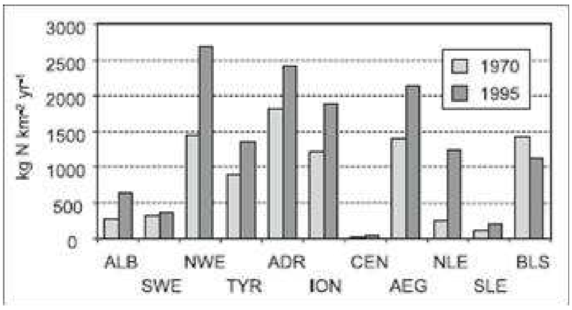


Figure 2.12. Fertilizer use in drainage basins of the Mediterranean and Black Seas in 1975 and 1995 (source: Ludwig et al 2009)

114. An EEA report (2009) recently assessed the nitrogen loadings/emissions in the member states of the EU. Agriculture and transport were given as the main sources of nitrogen pollution. When this pollution exceeds certain levels ('critical load'), it is damaging to biodiversity through eutrophication, etc. Across the EU countries, approximately 47 % of (semi-) natural ecosystem areas were subject to nutrient nitrogen deposition leading to eutrophication in 2004. The extent to which critical loads are exceeded varied significantly across Europe. In some cases over-enrichment leads to hypoxia or anoxia. The distribution of hypoxic areas has been modeled by Micheli (2011); a map of hypoxic zones will be available at http://globalmarine.nceas.ucsb.edu/mediterranean/.

115. The UNEP/MAP - BP/RAC, 2009 report provides further detail, assessing the relative importance of different sources of releases for nutrients, organic matter and total suspended solids in the Mediterranean. This assessment was based on the NBB received from different Mediterranean countries. The assessment concluded that for nitrogen (N), the largest emitters are urban waste water treatment (31%), livestock farming (19%) and metal industry (11%); for phosphorous, the manufacture of fertilizers accounts for the majority of phosphorus emissions (63%), followed by the livestock farming (20%) and urban waste water treatment (8%).

116. Localized enrichment by nutrients and organic matter may often lead to increased primary productivity and eventually also to algal blooms. These phenomena may or may not be associated with eutrophic conditions. Though some of such blooms are often due to natural conditions, others are at least partly due to anthropogenic releases. Such increased algal phenomena are often easily detectable from space.

117. When marine algae occur in significant numbers and produce biotoxins they are termed Harmful Algal Blooms (HABs). HABs are a global phenomenon, and have also affected the Mediterranean Sea (Smayda, 1990). They may cause harm through the production of toxins or by their accumulated biomass, which can affect co-occurring organisms and alter food-web dynamics. Impacts include human illness and mortality following consumption of or indirect exposure to HAB toxins, substantial economic losses to coastal communities and commercial fisheries, and HAB-associated fish, bird and mammal mortalities.

118. The presence of the toxic tropical dinoflagellate *Ostreopsis ovata* in various areas such as North Aegean raises concern as it was found to produce a toxin, analog of palytoxin (putative palytoxin, p-PLT) (Aligizaki & Nikolaidis, 2008). The detection of *Gambierdiscus* sp. cells on the west coasts of Crete in September and October 2007 is the first record of the causative agent of ciguatera in the Mediterranean Sea. Periodic mollusk poisoning caused by blooms of toxic dinoflagellates have been observed in Spain, France, Italy, Morocco, Algeria and Turkey.

119. Temporal changes in abundance of non-toxic indigenous species can also have a disruptive effect on ecology. For example, regular blooms of Scyphozoa jellyfish are also very common in the Mediterranean (CIESM, 2001) but seem to have become more frequent over the past few years. The most spectacular events were those of *Pelagia noctiluca*. High densities of *Pelagia* have been observed regularly over the past 12 years in the whole of the Mediterranean (Ramsak & Stopar, 2007). The common jellyfish *Aurelia aurita* is usually present in winter/spring in the Adriatic Sea but recently its proliferation has become very clear, especially in the coastal regions of the northern Adriatic. This is also so for the jellyfish *Rhizostoma pulmo*, which proliferates during autumn/winter in the northern Adriatic. Many hypotheses have been advanced to explain these frequent blooms throughout the world, which also apply to the Mediterranean: climate fluctuations, eutrophication, overexploitation, translocation of jellyfish via maritime transport (Mills, 2001; Lynam *et al*., 2004; Purcell *et al*., 1999).

2.4 Biological disturbance

2.4.1 Non-indigenous and invasive species distribution and impacts

120. The number of exotic species found in the Mediterranean is currently about 1,000 and their rate of introduction there is currently thought to be one species every 1.5 weeks (Zenetos, 2010). Their number in the Mediterranean has increased spectacularly since the start of the last century (Fig.2.13). These species are represented by 13 branches dominated by mollusks (216 species), followed by fishes (127 species), benthic plants (124 species) and crustaceans (106 species).

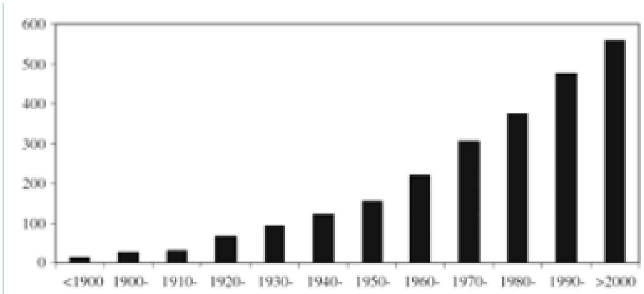


Figure 2.13. Number of species introduced to the Mediterranean Sea in the 20th Century.

121. Among these exotic species, over 500 are well established in the Mediterranean (UNEP/MAP - BP/RAC, 2009). This is so for the two fishes originally from the Red Sea, *Siganus luridus* and *S. rivulatus* (sunfish), which today constitute remarkable populations in the Levantine basin. Other species are one-off observations, like the spiny lobster *Palinuris ornatus*, seen once on the Israeli coast in 1989. Moreover, not all the non-native introduced species in the Mediterranean are invasive species.

122. The distribution of non-native species varies from country to country. Non-native species are more preponderant in the eastern basin that the western (Fig.2.14). Also, the origins of the introduction differ for the two basins. Non-native species in the western basin are mostly species that have been introduced by maritime transport and fish farming, whereas the species in the eastern basin are Lessepsian species that have entered the Mediterranean through the Suez Canal (Figure 2.14).

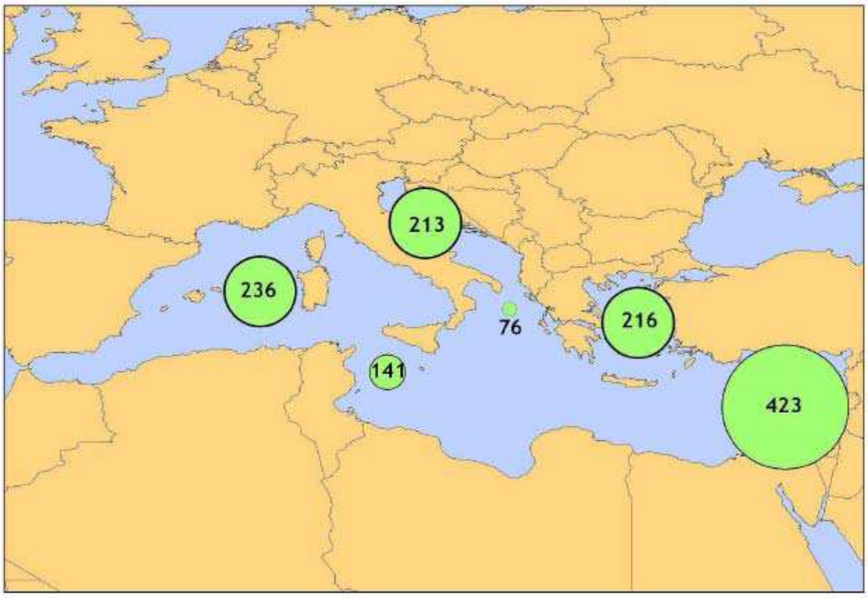


Figure 2.14 Distribution of exotic species in the Mediterranean basins (Zenetos & Streftaris 2008)

123. Exotic invasive species are considered by several authors one of the biggest cause of loss of biodiversity. Non-native species represent a growing problem mainly due to the unexpected and harmful impacts that these species can have on the ecosystems and consequently on the economy and human health (EEA, 2006). Yet it is important to recognize that: not all the non-indigenous species are also invasive (i.e. in the Aegean Sea of the 172 alien species reported, only 26 are classified as Invasive alien species); some non-indigenous species have increased the biodiversity of the Eastern Mediterranean; a significant number of exotic species have become valuable fishery resources in the Levantine area.

124. Drawing this distinction, the pressure and impacts of non indigenous and invasive species have been reported in several reports and papers and in some cases their ecological, economic and health threats have been documented. Although no extinctions of native species are known, rapid declines in abundance and local extirpations (sometimes concurrent with proliferation of invasive non indigenous species) have been recorded.

125. Even if local population losses and niche contraction of native species may not induce immediate extirpation, the pressure of the presence of invasive species lead to reduction of genetic diversity, loss of functions, processes, and habitat structure, increase the risk of decline and extinction. The final effect often is biotic homogenization and biodiversity reduction.

126. Invasive species can change the structure and functioning of the ecosystem; for example the invasion of an herbivore species can change the structure of rocky coast inhabited by algae. Along the Turkish coast the presence of the invasive rabbitfish (*Siganus luridus*) has caused in several rocky areas the modification of marine landscape with the formation of substrates without macro algae (barren areas). The clam *Ruditapes philippinarum*, besides out-competing native species, has impacted the physical environment because their harvesting has led to increased loads of suspended material (Occhipinti Ambrogi, 2002).

127. Health problems in local populations of eels (*Anguila anguilis*) have been caused by the introduction of *A. japonica* and *A. australis*. An example of hybridization is that encountered by the White-headed Duck (*Oxyura leucocephala*) after the introduction of the North American Ruddy Duck (*O. jamaicencis*). The Thau Lagoon (France) is revealed to be one of the major hot spots of marine species introduction in the Mediterranean Sea, Europe, but also in the world. The hard substrates of

the Thau Lagoon are clearly dominated by the introduced species (mainly vegetal) to the detriment of indigenous flora. A highly probable vector of macroalgae introductions is the transfer of oysters.

128. In some cases a given impact affects not only the ecosystem but also has direct consequences for the human activities. One example comes from the Thau lagoon, where the algae *Sargassum muticum* develop fronds longer than 4 m which form a sort of carpet on the lagoon surface and limit navigation in the area.

129. Several examples of invasive species impacts on coastal ecosystems can be reported. One of the most famous is the *Caulerpa* species spread, mainly *C. taxifolia* and *C. racemosa*. *Caulerpa-taxifolia* invasions have caused some ecological damage in the Mediterranean ecosystems mainly by competing with other species for space and light. This results in the displacement of native communities, and the creation of dense uniform mats that can impact benthic communities and can reduce important fish habitat for spawning and feeding. *Caulerpa taxifolia'*s spectacular average growth rate and its chemical defense mechanism (the alga produces repellent toxins) make it unpalatable to generalist herbivores, facilitating this biological invasion. The co-genus *C. racemosa* thanks to its fast growing stolons can overgrow other macroalgae, mainly turf and encrusting species, and restrain species number and percent cover of the macroalgal community. *C. racemosa* has been reported to grow on soft bottom casing serious problems to the fishing activities because both fix net and trawlers collect huge amount of algae.

130. The change in the composition of the phytobenthos can brought about a modification of the macro-zoobenthos. For instance, some studies indicate a proliferation of polychaetes, bivalves and echinoderms and a reduction in the numbers of gastropods and crustaceans. Other researches, focused on Porifera, indicate that the spread of the *C. racemosa* can be related with a significant decrease in the percentage of sponge cover. Nevertheless no major changes have affected the specific composition of the sponge assemblages, suggesting that, at list, at the first stage of colonization, the algal spread has not produced a loss of sponge biodiversity (Baldacconi & Corriero, 2009).

131. Niche contraction and rapid decrease of indigenous species have also been described as a result of competition with non indigenous invasive species. For example in Israel where the populations of the starfish *Asterina gibbosa*, the prawn *Melicertus kerathurus* and the jelly fish *Rhizostoma pulmo* decreased, whereas the non indigenous invasive species *Asterina burtoni* (starfish), *Marsupenaeus japonicus* (prawn), and *Rhopilema pulmo* (jelly fish) have increased their population (EEA, 2006). In some situations the competition for space can force native species to move to deeper water like in the cases of fish populations of red mullet (*Mullus barbatus*) and hake (*Merluccius merluccius*) which have migrated to deeper waters because of the presence of exotic species *Upeneus moluccensis* and *Saurida undosquamis* respectively (Galil and Zenetos, 2002).

132. For some coastal invasive species, a direct impact on human health has been demonstrated. This is the case of the silverstripe blaasop *Lagocephalus sceleratus*, a toxic fish that originates in the shallow waters of the Indo-Pacific on sandy and muddy substrates. This fish has dramatically spread in the eastern Mediterranean (10 % of fish catches in Turkey). First discovered in 2003 in Southern Turkey, it has now has spread rapidly in the Levantine Sea reaching also the north Aegean. This species contains tetrodotoxin that may cause food poisoning. During 2005-2008, thirteen patients were hospitalized in Israel after consuming *L. sceleratus* (Bentur *et al*., 2008). Other examples of direct impact on human health determined by non indigenous invasive species concern toxic algae (i.e. *Ostreopsis ovata*, *Alexandrium catenella*); these impacts are described better in the section below dedicated to the microbial pathogens.

133. Several examples of economic losses caused by invasive species have been described in coastal waters, where the main part of human activities and the pressures are concentrated, including the macroalgae *Womersleyella setacea* and *Acrothamnion preissii* clogging up fishing nets in France and Italy (Verlaque, 1989; Cinelli *et al.,* 1984). Another example is the jellyfish *Rhopilema nomadic,* today distributed along the eastern Mediterranean coast and as far north as the southeastern coast of Turkey where it impacts tourism, fisheries and coastal installations (Galil and Zenetos, 2002). Another case is this of the prawn *Metapenæus monoceros,* which has partially replaced the indigenous prawn *Penæus kerathurus* in Tunisia. Globally the fishery of prawn has not decreased and 50% is composed

by the non-indigenous species; the economic loss is due to the fact that the commercial price of the new species is 7 times less than that of the indigenous prawn.

134. However, the economical impact of the non indigenous species is not always negative. A significant number of exotic species have become valuable fishery resources in the Levantine area for coastal fishery. Some of the most notable are: the conch *Strombus persicus;* the prawns *Marsupenaeus japonicus, Metapenaeus monoceros* and *M. stebbingi*; the crab *Portunus pelagicus* and a few fish species, such as the mullids (*Upeneus moluccensis* and *U. pori*), the lizard-fish *Saurida undosquamis,* the Red Sea obtuse barracuda (*Sphyranea chrysotaenia*), clupeids (*Dussummieria acuta, Herklotsichthys punctatus*) and rabbitfish (*Siganus rivulatus*) (EEA, 2006). Forty-three percent of the halieutic resources of Turkey come from alien species.

135. The importance of the impact of an alien invasive species cannot be understood without considering the consequences at level of the ecosystem functioning. The vulnerability of an ecosystem towards invasive species seems to be related also to the environmental status: polluted or physically degraded environments are more prone to invasion than pristine sites. For example the cosmopolitan serpulid worm *Hydroides elegans* that dominated the fauna in the polluted marina was only infrequently found in the non-polluted marina (Kocak *et al.,* 1999). The response of exotic species to pollution is so clear that in some cases makes them good candidates for assessing Ecological Quality Status.

2.4.2 Pathogen spread and the occurrence of new microbial pathogens

136. In recent years mass mortalities due to disease outbreaks have affected many taxa in the Mediterranean Sea. For closely monitored groups like corals and marine mammals, reports of the frequency of epidemics and the number of new diseases have increased recently. Despite the growing number of cases reported out, very little is known about the infection agents that can act in temperate ecosystems. The main problem lies in the effort needed to ascertain the infectious agent responsible (UNEP/MAP - SPA/RAC 2008). Undisputable is the fact that both climate and human activities may have accelerated global transport of species, bringing together pathogens and previously unexposed host populations (Harvell et *al*, 1999).

137. A pathogenic agent is defined as “any organism, which in living on or within another organism (the host) causes disease in the host” (FAO, 1998). In general, microbial pathogens are agents of waterborne diseases including viruses, bacteria, and protozoa (Gerba, 1996). While many species of microbial pathogens are known as occurring naturally in water or derived from faecal contamination sources, others may appear and increase due to the invasion of non indigenous and invasive species and due to the happening of climate change.

138. In addition to those occurring naturally in marine waters, such as the cholera bacterium (*Vibrio cholerae*), pathogens are carried into waterways via sewage effluent, agriculture and storm water runoff, ship waste discharges, recreational aquatic activities, industrial processes, septic tanks closed to the shore and wildlife (WHO, 2003). The sewage collection systems are often only connected to parts of the urban population, which lead to direct discharge of untreated wastewater into the sea through other outfalls (EEA, 2006). The rapid growth of many coastal cities, especially in the southern Mediterranean, makes the problem even more acute; coastal beaches are subject to heavy human activity and susceptible to microbial contamination as well.

139. The survival of pathogens depends on factors such as water quality, nutrient supply, salinity, exposure to sunlight, and related hazards identification is crucial for an analysis of the associated risks. These issues are regulated by the EU Water Framework Directive (WFD) (2000/60/EC) and by the EU Marine Strategy Framework Directive (MSFD) (2008/56/EC), which suggest strategies to prevent and to reduce pollution of water.

140. Recreational waters generally contain a mixture of pathogenic and non-pathogenic microorganisms. Consequences of pathogens on human health frequently include gastrointestinal illness (Kay *et al.*, 1994) and skin rashes, fever, acute febrile respiratory illness caused by pathogenic

bacteria and protozoa (Fleisher *et al.*, 1996a), salmonellosis, meningo-encephalitis, cryptosporidiosis, and giardiasis (Prüss, 1998).

141. Impacts of microbial pathogens on marine environment may also represent losses on biodiversity. For instance, *Aeromononas spp.* infections are responsible for hemorrhagic septicemia, a disease affecting a wide variety of freshwater and marine fish as well as causing food born diseases in humans (Popoff, 1984).

142. While “classic” pathogens – related pressures and incidences are already known, the concern for “new” pathogens is recently increasing. The explanation of such rises is mostly linked up to two main causes, invasion of alien or invasive species and climate change, that have been implicated in the decline and even collapse of several marine ecosystems (Harris and Tyrrell, 2001; Stachowicz *et al.*, 2002; Frank *et al.*, 2005).

143. Whether intentional or non-intentional, alien species present a growing problem due to the fact that they are importing subset of their parasitofauna, thus releasing themselves from the parasites of their native habitat into the new environment. The introduction of new species on endemic populations, a process termed “pathogen pollution”, lead to the co-introduction of parasites through the alteration of pre-existing infectious disease dynamics (Daszak *et al.*, 2000). Pathogenic microbes can devastate populations of marine plants and animals, causing loss of biodiversity. Yet, many sessile organisms such as seaweeds and sponges suffer remarkably low levels of microbial infection, despite lacking cell-based immune systems.

144. A recent study of the rabbitfish (*Siganus rivulatus*) has shown the prevalence of its Erythrean monogenean ecto-parasite *Polylabris cf. mamaevi* off the Mediterranean coast is three times as high as the one found in the Red Sea population. These authors ascribe the heavier infection to “changes in the natural environment and impact of anthropogenic factors encountered by the rabbitfish in their new Mediterranean habitats” (Pasternak *et al.*, 2007).

145. Another issue complicating the picture of pathogen spread is climate change. Climate-mediated and physiological stresses may compromise host resistance and increase frequency of opportunistic diseases (Harvell et *al*, 1999). Where documented, new diseases typically have emerged through host or range shifts of known pathogens. Marine invertebrates, particularly sponges, gorgonians and corals, are known to produce secondary metabolities and an attack on a secondary metabolism after a temperature stress can encourage the action of pathogen agents. For example, Kushmaro *et al.* (1996, 1998) showed experimentally that sea-water warning would significantly increase the virulence of the bacterium *Vibrio shiloi* causing the blenching of the coral *Oculina patagonica.*

146. Some authors advance the hypothesis that the growth of thermo-dependant pathogens is encouraged by the Mediterranean warming (Bally and Garrabou, 2007; Sussman *et al.*, 2003). Pérez (2008) also reported the outburst of diseases as a potential impact of climate change on marine benthic fauna. Such diseases may lead to mortalities of benthic invertebrates, either due to their lower tolerances induced by changes in environmental variables or due to the fact that some of the pathogens are more harmful at higher temperatures.

2.4.3 Impact of fisheries on target species and on food webs/biodiversity

147. The pressures of fishery activities stem from commercial fisheries, recreational fisheries, and aquaculture. Commercial fisheries include both artisanal (mainly trammel, traps, gillnets, longlines, etc.) and industrial fisheries (mainly trawlers and purse seine, large loglines, driftnet). The MEDITS survey programme, started in 1993, produces basic information on benthic and demersal species in term of population distribution as well as demographic structure, on the continental shelves and along the upper slopes at a global scale in the Mediterranean Sea, through systematic bottom trawl surveys.

148. Generally small-scale fishing is socioeconomically more important to coastal communities and countries than industrial fishing and its impacts on biodiversity are less significant. In any case, the heterogeneity of gears and target species of artisanal fisheries makes it difficult to reach any general

conclusions as regards the impact of these small-scale practices on the ecosystem. While on the one hand the higher selectivity of some artisanal gears is documented, on the other, the negative effects of other artisanal practices are known.

149. Fishing activity impacts both benthic and pelagic species (and habitats). Impacts stem from direct over-exploitation of commercial species, as well as indirect ecosystem effects. The impact of fisheries on biodiversity depends on several factors such as fishing technique, water depth, sea bottom characteristics, and season. Some fishing practices banned by law in several Mediterranean countries have particularly negative effects on the ecosystem but are conducted regardless (i.e. illegal trawling in shallow water, dynamite, large driftnets, illegal mesh sizes). The large variety of small-scale fishing gears used and diversity of species landed make the management of Mediterranean fisheries extremely complex. More than 45 fishing techniques are used within the Mediterranean fisheries. Approximately 63% of fishing vessels are owned by countries of the Western and Central Basins and 53 % by EU countries (Spain, France and Italy).

150. Recreational or sports-fishing activities are mainly associated to gears such as angling, handline, spearing, longline, rod-and-reel. The impacts of recreational fishing activities are unknown due of a lack of catch control. Angling and handline fishing threaten juveniles of most littoral, demersal fishes, because they are practiced on nursery areas such as shallow rocky bottoms and seagrass beds. Spear fishing, on the other hand, has an impact mainly on endangered species such as groupers (*Epinephelus* spp) and brown meagre (*Sciaena umbra*). Rod-and-reel and longline recreational fisheries impact populations of swordfish and blue shark and affect other species of commercial interest such as tunas (Thunnidae) and dolphin fish (Coryphaenidae).

151. The indirect effects of fishing on biodiversity include the impact on non-commercial species (discards), habitats, ecosystem structure and functioning. Consequently, because of the deterioration of the environment, the indirect effects can also cause further pressures and negative impacts on target species. Some indirect effects of fishing include: decreases in populations (either commercial or not), due to by-catch, discarding, ghost fishing, etc; decreases in populations of non-commercial endangered and protected species such as cartilaginous fishes, sea turtles, sea birds and marine mammals accidentally injured by fishing engines; disturbance or destruction of habitats such as *Posidonia oceanic* meadows, coralligenous and maërl beds; this impact is especially due to trawling, often practiced illegally in shallow waters, dragnets for catching shellfish, gathering of algae (used for cosmetic and pharmaceutical purposes) and some illegal practices such as gathering date shells (*Lithophaga lithophaga*); alteration of functioning and structures in other marine habitats such as muddy and sandy bottoms (as synthesized by Pranovi *et al*. (2000), with trawls and dredges that scrape or plough the seabed, resuspend sediment, change grain size and sediment texture, destroy bedforms, and remove or scatter non-target species.

152. At present, data are insufficient to determine how fishing in the Mediterranean impacts food webs, since most countries collect catch and catch per unit information on target species, and both by-catch rates and underlying population dynamics of target species are largely unknown. For this reason, determining the ecological impact of fisheries in the heavily-exploited Mediterranean emerges as a priority for future monitoring/research.

Over-exploitation

153. Overall, over-fishing in the Mediterranean over the past ten years is the result of grown in the industry (by about 12%), with highest exploitation of stocks of demersal species and big pelagics (tuna and swordfish) (Zenetos *et al*., 2002). Over-fishing has caused a collapse of beds of the red coral *Corallium rubrum*, the date shell *Lithophaga lithophaga*, some sponges (*Hypospongia communis, Spongia* spp., etc.), some species of decapodal crustaceans (i.e. *Homarus gammarus, Palinurus elephas*). Several other species of fish are overexploited (*Anguilla anguilla, Epinephelus marginatus, Sciaena umbra, Thunnus thynnus, Xiphias gladius*, etc.).

154. The results of the MEDITS (International Bottom Trawl Survey in the Mediterranean) show that over-exploitation has led to a serious decline in many fish stocks. In addition, the GFCM (2008) concurs that many species of commercial interest are currently being over-fished. This is so for the hake (*Merluccius merluccius*), the mullet (*Mullus barbatus*) and the deep sea pink shrimp

(*Parapenaeus longirostris* in the north of the Sea of Alboran, the Balearic Islands, northern Spain, the Gulf of Lions, the Ligurian Sea and southern Sicily), the sole (*Solea solea* in the northern Adriatic Sea), the sardine (*Sardina pilchardus*) and the anchovy (*Engraulis encrasicholus* in the north of the Sea of Alboran, in northern Spain, in the Gulf of Lions, in southern Sicily and the northern Adriatic Sea). The situation is also very worrying for the bluefin tuna (*Thunnus thynnus*), widely overexploited in the Mediterranean. These trends are becoming common to the entire Mediterranean and for all the stocks of fish that are exploited with ever-growing catches (Sea Around Us, 2009).

155. A number of studies have established that intensive fishing strongly impacts all levels of biological organization of marine life (EEA, 2006). Negative impacts of inappropriate fishing activities on marine biodiversity are recorded in the national report elaborated within national/regional processes (i.e. SAP/BIO project) of most of the Mediterranean countries.

156. The demersal fishery practiced in the Mediterranean high seas may be summed up as follows: bottom trawling, long line and mesh net. Fishing in the high seas is currently done over the continental shelf and some slopes, down to depths below 800 m. Bottom trawling is an extremely harmful practice that was forbidden in 2005 to Mediterranean sea beds that were deeper than 1,000 m in order to protect the vulnerable deep sea fauna.

157. Big pelagic species that inhabit the high seas, essentially the Mediterranean bluefin tuna, swordfish and albacore, and also the pelagic sharks (blue *requin-taupe*, blue shark and common *requin-taupe*) present a great interest at conservation level and has long been overfished by pelagic fishing gear. The main fishing gears used for fishing the big pelagic fishes are running seines and pelagic *palangres*. The fleets using pelagic *palangres* to fish in Mediterranean water are both local fleets of the states bordering on the Mediterranean and big foreign commercial fleets; the latter are extremely mobile and cover almost the entire Mediterranean basin. Driftnets were forbidden in the Mediterranean in 2005, but despite this the activity is still practiced. The high seas in the Mediterranean are also the habitat of cetaceans and turtles that are disappearing, and that frequently constitute by-catch of pelagic fishing and deserve to be specially protected. EFHs important for big pelagic species are essentially determined by oceanographic type, like upwellings or gyres, creating productive areas that are important for feeding and spawning; these areas, which act as EFHs, must be identified to determine measures of protection for the pelagic species. The main spawning areas of the Mediterranean bluefin tuna are located south of the Balearic Islands, in the Sea of Alboran and in the Strait of Sicily, while those of the swordfish are found pretty well throughout the Mediterranean and those of the albacore partially coincide with the spawning areas of the Mediterranean bluefin tuna.

By-Catch and Discards

158. Another major impact of fishing arises from the fact that many fishing practices lead to incidental catch (known as by-catch), and discards. Despite the adoption of some legal limitations for the more impacting fishery practices and the reduction in fleets in some countries, the problem of fishing impact on marine biodiversity is likely to increase due to continuous improvements in fishing and navigation technology.

159. Several fishing gears used by commercial fisheries have harmful effects: "tonailles" (nets for tuna), long lines and driftnets, especially used for tuna and swordfish fishing, as well as fine-mesh fixed nets set for over-long periods (often at night), dragged beach seines and bottom trawling. All these have high levels of incidental catch or by-catch, and some are responsible for physical damage to the seabed and the degradation of associated communities (see below).

160. Another key issue regards discards. Discard rates vary with fishing depth, gear used and targeted species. Discards by unselective Mediterranean trawling fleets are significant. For example, out of the 162 species caught by trawling in the eastern Mediterranean, two were the target species, 34 were by-catch of variable commercial value and the remaining 126 unwanted species (D'Onghia *et al.*, 2003). The effect of discards on marine communities includes both single-species levels, where the population dynamics of a species is altered, and ecosystem levels, where profound changes occur because of the disruption to food webs, favoring scavengers, etc.

161. The available information on discards in Mediterranean trawl fisheries confirms the magnitude of the problem. For example, total annual discards in Sicily during the 1980s were estimated around

70,000 t, accounting for an average of 44-72% of total catch (Charbonnier 1990); A regional study on discards in the western Mediterranean gave discard estimations of 23-67% of total catch at depths of less than 150 m; 13-62% at depths of 150 -350 m and 14-43% at more than 350 m depth. The amount discarded, however, peaked at 75.4% and 66.6%, respectively, in the case of larger boats operating in spring and smaller ones operating in summer on shelf bottoms (< 150-m depth) (*Carbonell et al. 1998).* Discarding can also involve commercial species of the smallest size classes.

Illegal Fishing and Fishing in Areas Beyond National Jurisdiction

162. Illegal fisheries have broad impacts across the Mediterranean. Illegal trawling on seagrass beds impacts ecosystems both by suspending sediments and directly damaging vegetal mass. Sediment suspension affects macrophyte photosynthesis by decreasing light intensity. This pressure is believed to have contributed to the disappearance of seagrass meadows, and to affect fish recruitment and the quality of juvenile feeding areas in the Mediterranean Spanish coast (Sánchez-Jerez and Ramos-Espla 1996).The effects of trawling on Posidonia include changes in the structure of demersal fish communities, reduction or elimination of species typical of hard bottoms and their replacement by ubiquitous species and others typical of sandy/muddy bottoms, increased numbers of active filter feeders and sedimentivorous species.

163. Another illegal coastal practice widespread in several Mediterranean areas is date mussel (*Lithophaga lithophaga*) fisheries, based on the demolition of substrates by commercial divers. The consequence of this pressure is the desertification of long stretches of rocky shore caused by the destruction of habitats and the associated communities, combined with grazing by sea urchins (Fanelli *et al.* 1994). A further illegal fishing problem is caused by the St Andrew Cross, which is an iron bar hung with chains, used for harvesting red coral; this tool known for its strong impact on coralligenous benthos assemblages. The use of this gear has been banned in EU waters since 1994 (Council Regulation No 1626/94).

164. Deep-sea fisheries could affect open ocean and deep sea ecology, but studies and modelling of these effects are sparse. Fisheries currently only operate at depths of less than 1000 m in the Mediterranean, but seamount fisheries could be exhausted in a period of time as short as three to four years if deeper technologies are adopted (Johnston and Santillo, 2004). The potential fishing interest of the currently unexploited bottoms below 1000 m depth (towed gears banned by GFCM, 2005) is very limited. This is so because the overall abundance of crustacean species is considerably lower, and fish communities are largely dominated by fish either of non-commercial interest (like the smooth head *Alepocephalus rostratus*) or of a small size (such as the Mediterranean grenadier *Coryphenoides guentheri*). If these species ever become of economic interest and trawlers could reach deeper areas, then the ecosystem could be rapidly deteriorated by fishing.

165. Industrial pelagic fishing generally takes place mainly in international waters and even non-Mediterranean countries can be involved (Cacaud, 2005). Most information on the activity of the fishing fleets in the Mediterranean comes from the working group STECF and the GFCM Demersal Working Group, of the Subcommittee on Stock Assessment, and ICCAT for large pelagics, which relates the activity of the fleets from member countries. Therefore, there is a lack of reported information of fishing activity of EU non-member countries (e.g. North Africa) in STECF, although GFCM task 1, and the cooperation projects (Medfisis, COPEMED II, ADRIAMED and EASTMED) work on this direction.

166. Most of the Mediterranean waters are high seas. The Mediterranean high seas contain a great diversity of habitats, both pelagic and demersal (high sea). Not much is known about these habitats as regards the coastal ecosystems and continental shelves, which are more easily studied, while there is good knowledge of the state of stocks of the commercial species they shelter, thanks to studies done on commercial fishing and catch. The protection of the fauna in these areas is important for fishery and the conservation of the ecosystem, for the organisms can determine the health of an ecosystem. The sessile benthic fauna has an important role as organisms that structure the habitats providing a refuge for many marine species (e.g. cold water coral reefs, deep sea sponges, crinoid beds).

167. Fishing on high seas (areas outside national jurisdiction) targets a restricted number of resources, such as red shrimp, Norwegian shrimp and few demersal fishes (i.e. hake), small pelagic fishes (mainly on sardine and anchovy) and pelagic fishes, especially tuna and swordfish. The little

information available about the effects of deep sea trawling on demersal species emphasize the vulnerability of deep muddy bottom communities to external disturbance, principally due to their sensitivity to physical disturbance and to the low adaptability of deep fauna to changes in sedimentation regime and external disturbance. D'Onghia *et al.* (2003) found that in deep sea trawling, discard rates increase with total catch and depth. *Isidella elongata* facies distributed in bathyal muddy assemblages constitute an example of deep habitats greatly affected by fishing. Several deep sea demersal species are particularly sensitive because of their low fecundity and low metabolic rates.

168. Pelagic ecosystems are mainly impacted by purse seine, drift longlining and driftnet. Purse seine is strongly impacting, mainly on bluefin tuna population. In the Mediterranean Sea, excluding a few cases, differently than in other seas, this practice seems not to have a particular interaction with cetaceans. Pelagic longlining impact target species such as swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) and inflicts significant mortality on elasmobranchs, marine turtles and seabirds taken as by-catch.

169. Driftnet fisheries have long been the object of discussion in several Mediterranean countries because the gears are particularly unselective and consequently responsible for heavy impacts on many vulnerable groups inhabiting the pelagic ecosystem; particular important are the by-catch of cetaceans and elasmobranches. During the last two decades some Mediterranean governments have reduced the number of fleets fishing with driftnet, and this practice was prohibited by ICCAT and GFCM in 2003. However this practice (often under different names) is far for being eradicated in the Mediterranean.

170. The degradation of the ecosystems caused indirectly by fishing affects the commercial species if the habitat ceases to be suitable for these species. In this context, it is necessary to regulate fishing activities in order to lessen the degradation of the ecosystems by creating an Ecosystem Approach to Fisheries (EAF) that takes into account not only protection of the target species but also the ecosystem as a whole. As part of the EAF, the Precautionary Approach studies the most restrictive measures for managing fishery (the setting up of areas that are closed to fishing, or Marine Protected Areas) in a context where knowledge on how the many ecosystems that maintain the halieutic resources function is generally absent.

171. The following sites are deemed to be critical areas in the sub-region as regards impacts of high sea fishing in the Mediterranean, notably demersal and pelagic ecosystems.

<u>In the Western Mediterranean</u>

Potential priority demersal areas include:

- The Gulf of Lions slope: a demersal ecosystem to protect many commercial species (including hake, shrimp, angler fish), a spawning area that is sensitive to demersal fishery activities. Already adopted as a FRA by the GFCM
- The Alboran Seamount: this area contains cold water coral reefs and underwater canyons and is very sensitive to bottom fishery

Potential priority pelagic areas include:

- South of the Balearic Islands: a spawning area that is important for the bluefin tuna in the Mediterranean and for cetaceans and sharks
- Straits of Gibraltar and Sea of Alboran: an important migration route for bluefin tune and cetaceans

<u>In the Central Mediterranean</u>

Demersal priority areas:

- South of Sicily, Adventure and Malta banks. Demersal ecosystem important as hake nursery areas where bottom fishing activities, specially trawling, should be restricted.

- Cold coral reefs (Lophelia pertusa) off Cape Santa Maria di Leuca. SH highly vulnerable to any physical disturbance inflicted by bottom trawling. Already adopted as FRA (Fishery Restricted Area) by GFCM.

Pelagic priority areas:

- Strait of Sicily. It is an important migratory route for tuna-like species.

In the Adriatic

Demersal priority area:

- Fosa di Pomo/Jabuka Pit. This important nursery area for hake in the central Adriatic should be protected from demersal fishing activities, mainly trawling. . Besides that, Pomo/Jabuca Trench has cold seeps.

Pelagic priority areas:

- The Northern Adriatic. Spawning grounds for anchovies and pilchards.
- The Central Adriatic.

In the Eastern Mediterranean

Demersal priority areas:

- Thracian sea. Demersal ecosystem at Strymonikos gulf and Samotraki plateau as important spawning grounds for hake where bottom fishing activities, mainly trawling should be restricted.
- Eratosthenes Seamount. Important SH vulnerable to bottom fishing activities. Already adopted as FRA (Fishery Restricted Area) by GFCM.
- Nile Hydrocarbon cold seeps. SH being a unique environment in the Eastern Mediterranean basin that needs to be protected from damaging bottom fishing activities. Already adopted as FRA (Fishery Restricted Area) by GFCM.

Mediterranean-wide

Potential priority pelagic and demersal areas include:

- Mediterranean seabed below 1,000 m. The habitat of a little known vulnerable fauna found in the four Mediterranean sub-regions. In these areas, fishery using towed gear has been banned by the GFCM.

2.4.4 Impacts of desalination and aquaculture

Desalination

172. Desalination is an emerging issue in the Mediterranean, as it is in other parts of the world due to a rapid proliferation of desalination plants and an increasing dependence on the sea for freshwater. The impacts of desalination are not fully studied. In the Mediterranean, some studies have shown impacts on marine ecology, but most information on impacts currently comes from studies in other regions. For instance, the Californian Coastal Commission lists these potential impacts of desalination plants on the environment: potential coastal zone impacts, air quality, commercial and recreational fishing, construction impacts on land and marine species and habitats, energy use, growth-inducing effects, marine resources impacts from feedwater intake and ocean discharge, navigation, noise, potential hazardous releases from accidents, public access, recreation, visual quality, water quality, water quantity (e.g., effects of drawdown or saltwater intrusion of groundwater wells), and cumulative impacts (www.cleanocean.org).

173. The discharge of concentrated brine has undeniable impacts on marine biota. Brine is not only concentrated salt, but also includes industrial chemicals and heavy metals that originate from the plant and are released by the corrosive effect of the salts. As heavy brine flows along the benthos, it can directly affect organisms, and interfere with oxygen transport and delivery to the sediments.

174. Though desalination development is rapidly expanding throughout the arid regions of the Mediterrnaean basin, the greatest impacts will likely be occurring in the western portion of the Western Mediterranean subregion, and the easternmost portion of the Eastern Mediterranean subregion (i.e. Middle East).

Aquaculture/mariculture

175. Fish farming is a relatively ancient practice in the Mediterranean basin. But it has expanded enormously since the 1990s, particularly marine fish farming. This involves farming the gilthead sea bream *Sparus aurata*, the sea bass *Dicentrarchus labrax*, the mussel *Mytilus galloprovincialis* and the flat oyster *Crassostrea gigas*. 58% of production comes from the western European countries, but Greece is the first offshore marine fish farming producer country with over 120,000 tons per year of sea bass and gilthead sea bream. As for the raising of bivalve mollusks, mussels and flat oysters hold respectively first and second place, with an annual joint production of about 500,000 tons for Spain and France. Fish farming in Mediterranean lagoons target typical 'lagoon' species like the sea bass *Dicentrarchus labrax* and the gilthead sea bream *Sparus aurata*. Global production in 2008 was 66,738 tons (US $ 496,898) for sea bass and 113,062 tons for sea bream. Most of the production of gilthead bream takes place in the Mediterranean: Greece (49%), Turkey (15%), Spain (14%) and Italy (6%) are the most productive countries (FAO, 2010).

176. Regarding aquaculture, the harvesting wild populations of bluefin tuna (*Thunnus thynnus*) to be fattened in cage-farming facilities, is greatly contributing to the collapse of tuna stocks. In addition small species caught to feed tuna (e.g. mackerel) are also likely to be over-exploited (UNEP/MAP - SPA/RAC 2003).

177. Fisheries can have cascading effects on the trophic structure of the marine ecosystem by the harvesting of top predators, either pelagic or demersal species (sometimes called '*fishing down marine trophic food webs*'). Over-fishing reduces the populations of more valuable large-sized fish that are at higher trophic levels, such as piscivorous, as a result average trophic levels of landings are reduced according to the degree of fishing effort. According to FAO fishery statistics, the mean trophic level of Mediterranean fisheries declined one level in the last 50 years (Pauly *et al.,* 1998). Population explosions of undesirable organisms such as jellyfish may be the consequence of overfishing, as preyare "released" from predation when predators are removed. However, recent research indicates that fisheries also causes significant ecological changes at lower trophic levels among fish of small body size (Pinksy et al., 2011).

2.5 Physical disturbance

2.5.1 Effects from coastal constructions, infrastructure, and urbanization

178. Coastal development and urbanization exerts great pressures on the Mediterranean environment. Habitats are lost and degraded by constructions, placement of infrastructure, and 'reclamation of' coastal lands. Sand-mining and other extractive activities can lead to major changes in habitat and loss of services. Freshwater diversion from estuaries changes the brackish water nature of these ecosystems and diminishes the delivery of services they provide. Coastal constructions, such as breakwaters, causeways, groins, and armoring, affect not only the area where they are installed, but also wide swaths of the coast, due to the changes they cause in coastal currents and processes. And the increase in non-permeable surfaces associated with urbanization and development leads to significantly more run-off of pollutants in nearshore areas.

179. Population pressures have lead to increased use of resources and habitats, and indirect degradation as well. Habitat loss is one of the greatest drivers of biodiversity loss and decline in ecosystem services (MA, 2005). Paradoxically, tourism – an industry of great importance to the Mediterranean region – drives much of the habitat loss as well as indirect degradation (UNEP, 2009).

The loss of Mediterranean marine and coastal biodiversity is due to concomitant causes and several pressures which act in synergy: fisheries overexploitation and fishing-related environmental degradation; the biological invasions of non indigenous species are often linked to climate change and other environmental disturbances, including fishing pressure; pollution; and the spread of pathogens. Climate change is the background against which all these changes play out – sometimes speeding the changes, sometimes causing irreversible alterations.

180. Coastal development, and associated infrastructure placement, use and rerouting of freshwater, and increases in non-porous surfaces within coastal zones can all exacerbate erosion of shorelines. A recent cumulative impacts study derived erosion potential through modeling (Micheli, 2011). By also modeling Basin-wide potential impacts of coastal engineering and combining this with shoreline stabilization, it identified areas of maximum development pressure throughout the Mediterranean region.

2.5.2 Offshore constructions and dredging activities/ impacts

181. Offshore constructions include oil rigs, wind farms, and other energy sector infrastructure, as well as facilities for scientific research. The impacts of these constructions have not been systematically evaluated for the Mediterranean Sea, but this may be an emerging issue that warrants significant attention. There are potential implications for the benthic communities immediately impacted by the construction footprint; for benthic ecology more generally caused by indirect effects of construction and operation of offshore infrastructure; for benthic-water column coupling; and for behavior and ecology of pelagic organisms avoiding the installations or affected by changes in currents.

182. Since the main sources of oil pollution in the Mediterranean originate from maritime transport, both through accidental and deliberate discharges, atmospheric deposition (from military activities and commercial jet flights), coastal refineries and offshore installations, as well as land-based activities (either discharging directly or through riverine inputs) (GESAMP, 2005; GESAMP 2007; Redondo *et al.*, 2008), installation and operation of offshore constructions may pose a significant threat.. Marine transport is one of the main sources of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbon (PAH) pollution in the Mediterranean Sea (UNEP/MAP-EEA, 2006).

183. Oil discharges and spills to marine areas can have a significant impact on marine ecosystems in this and other subregions of the Mediterranean. The consistency of oil can cause surface contamination and smothering of marine biota, and its chemical components can cause acute toxic effects and long-term accumulative impacts. The damage of oil spills is not restricted to the environment but also has socio-economic component. Oil spills in fishing (catching, spawning and feeding) or aquaculture areas or coastal locations which rely upon tourisms can be severely impacted. Fisheries may close and tourism decline with the associated loss of income and livelihoods. Even if there is little or no actual environmental damage the perception that an oil spill has affected the coastline can still have impact (UNEP/MAP-EEA, 2006).

2.5.3 Fisheries Impacts on the Seabed

184. The use of bottom gear can cause a series of cascade effects on the ecosystem. Eutrophication processes may be enhanced, leading to hypoxia in sensitive soft bottom areas (as in the northern Adriatic) and the quantity of hydrogen sulfide released from sediments may increase (Caddy 2000). For example the re-suspension of sediment enriched in organic matter can reduce macrophyte, zoo-benthos and demersal fishes, on the other hand species adapted or tolerant to hypoxic conditions can increase. Trawling and dredging can also influence the intensity and duration of naturally occurring seasonal hypoxic crises. For example, in the Adriatic these conditions can worsen the summer mortality rate of young shellfish.

185. Trawling can also remove large-bodied, long-lived macrobenthic species and subsequently reduce the bioturbation zone (Ball *et al*. 2000). Such reduction can contribute to increasing the eutrophication risk. Fishing disturbance may cause shifts in the benthic community structure that particularly affect mobile scavenging species, probably the most food-limited group in muddy seabed

environments (UNEP/MAP - SPA/RAC 2003). Trawling is also responsible for changing grain size distribution and sediment texture and for destroying bedforms. Coralligenous and maerl communities are mainly endangered by trawling, responsible for the disappearance of maerl in large Mediterranean areas (UNEP/MAP - SPA/RAC, 2008a).

2.5.4 Freshwater Diversion

186. The diversion of freshwater from estuarine and lagoonal areas causes significant impacts not only on the coastal ecology, but also potentially on the ecology of the marine environment, since nursery areas can be lost by freshwater diversion. Alteration of flows also effects sediment delivery to the coast – when river flows are altered, coastal erosion can be the unintended consequence. Although some information exists on the global scale suggesting that dramatic losses in flows have occurred in the region as a whole (see for instance Milliman and Farnsworth 2011), diversion from irrigation and water use in the catchment basins has not been systematically studied in the context of the ecology of the Mediterranean, and warrants further attention.

2.5.5 Environmental Pressures in the Water Column: Underwater Noise, Marine Litter

187. Underwater noise is a growing concern, especially as it affects the communication and behavior of marine mammals (especially beaked whales) and certain fishes. With the immense pressures posed from maritime traffic in the Mediterranean, the potential for noise impacts to be significant is quite large, though not yet quantified. CIESM and other scientific groups have indicated that a priority for future research is to determine the distribution of sensitive species and the degree to which shipping lanes and area of seismic exploration coincide with critical habitat for such species. To this end, the mapping of information, as called for in the final chapter of this report, could be very useful.

188. Associated in part with the high degree of shipping in the Mediterranean Basin, but also originating from other sources, marine litter remains an issue for many Mediterranean areas. The bulk of this litter apparently originates in households, with direct disposal to the sea. Tourist infrastructure also contributes, as does river-based input, littering from boats and ships, and disposal by municipalities (see Figure 2.15). The ecological impacts of litter on beaches, shorelines, and in marine waters, and the effects of microplastics in water column, have not been determined in the Mediterranean.

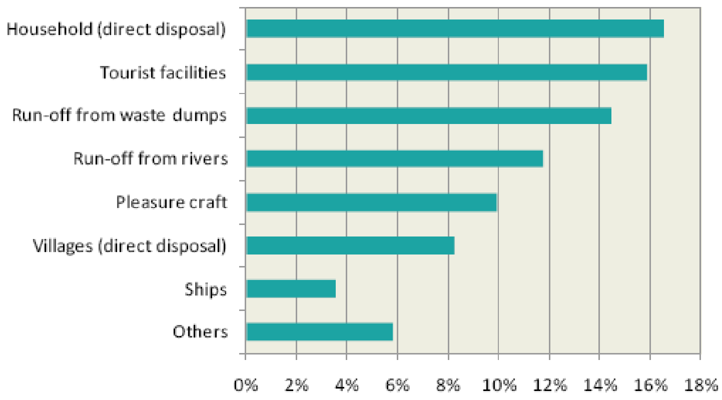


Figure 2.15. Sources of marine litter (UNEP/MAP - BP/RAC, 2009)

189. The dumping of derelict ships, harbor mud, and other dangerous materials offshore represents another risk for Mediterranean ecosystems. Accidental discharges as occur with shipping accidents and oil spills constitute a serious danger for marine organisms. Petroleum and gas exploration, including the use of seismic arrays, may have profound consequences on marine organisms. Associated activities, such as laying of pipelines, can have additional effects.

190. Oceans are sites of accumulation of solid, liquid, and atmospheric wastes. This seems obvious in the nearshore, but even deep sea areas are affected. Seventy percent of the deepwater research trawl hauls contain litter, such as plastic and glass bottles, metal cans, nylon rope and plastic sheeting (Galil *et al.,* 1995). Refuse generated by vessels is considered the major source of litter in the Mediterranean. Although disposal of all litter (except food waste) is prohibited in Mediterranean waters, these regulations are not routinely enforced.

2.6 Climate Change and Emerging Issues

191. Climate change is the backdrop against which all of the human-induced changes and pressures play out. Much has been written about the predicted effects of climate change on the marine ecosystems of the Mediterranean, as well on the alteration of carbon and nitrogen cycles. In fact, the evidence that climate change has already had an impact on Mediterranean ecology is compelling. The cumulative impacts assessment by Micheli (2011) highlights the significance of temperature changes (sea surface and other), and related changes in sea level that climate change drives in the Basin (see next section). Sea surface temperature (SST) modeling indicates there may be potential hotspots for climate change impacts, especially in the waters off Crete, around the island of Rhodes, and west of Cyprus in the eastern Mediterranean, and portions of the southern Adriatic subregion and the southern Central subregion.

192. In addition to the direct effects that rising temperatures are expected to have on biota and on ecological processes, climate change is also expected to cause changes in sea level, increasing acidification of seawater, and changes to physical oceanography. These impacts in turn will cause changes in pollution loading (sediments as well as contaminants released from coastal and marine substrates), and will affect the physiologies of individual organisms as well as the adaptability and survivability of species and taxonomic groups.

193. Climate forcing will also affect riverine freshwater fluxes to the sea. The work of Ludwig *et al.* 2009, suggested that climate change alone could provoke a water discharge reduction of more than 20% over the entire Mediterranean. Strongest reductions appear for the Alboran (-64%), Southwestern (-31%), Southern-Levantine (-25%), Aegean (-24%) and Adriatic (-17%) seas. Such reductions in only 40 years are highly remarkable (Ludwig *et al.*, 2009). This underlines why the Mediterranean region was identified as one of the most prominent ‘‘hot-spots” in future climate change projections (Giorgi, 2006).

194. These reductions in river flow may have hydrological implications affecting the circulation in the basin. Skliris *et al.* (2007) demonstrated by modeling that reductions in the riverine freshwater inputs can cause greater deep water formation rates in the Mediterranean Sea. Data show that during 1985–1994the river discharges to the Aegean Sea were suddenly reduced by more than 30% compared to the previous years (1960–1984). This may have contributed to higher salinities in the surface waters, favoring the formation of deep waters and the onset of the Eastern Mediterranean Transient.

195. Deep sea issues are also emerging. Much focus concerning the Mediterranean environment has been on coastal development, urbanization, nearshore pollution and overexploitation. But the Mediterranean deep sea is considered by some authors to be among the most heavily impacted deep-sea environments in the world, and at the same time among the least known areas in terms of biodiversity (UNEP/MAP - SPA/RAC, 2010): the risk is that a significant loss of biodiversity occurs before scientists have had time to document its existence (Briand 2003, Cartes *et al.* 2004).

CHAPTER 3: WESTERN MEDITERRANEAN

3.1 Introduction

196. The Western Mediterranean Sea is bordered by Spain, France, Monaco, Italy, Algeria, and Morocco. It is perhaps the most impacted of the four subregions, with intensive maritime activities that include extensive shipping, commercial fishing, and tourism, among many others. As well, this subregion may be the most thoroughly studied, despite the fact that it appears to support the most complex oceanographic and ecological processes of any of the four Mediterranean subregions.

197. The Western Mediterranean subregion supports the largest portion of known Mediterranean species diversity: 87% of the known forms of life in the Mediterranean are present in the western Mediterranean. This subregion also as a high degree of habitat diversity, with numerous well-developed coastal wetlands / marshes, extensive seagrass meadows, rocky shorelines and reefs, well-studied coralligenous communities, and highly productive frontal systems, *inter alia*. This biodiversity, and the region's relatively high productivity, supports commercial and recreational fisheries, as well as tourism. These individual pressures, and the increasing conflicts around various uses in some areas have already had impacts on marine ecosystems and the delivery of ecosystem services. The loss of Posidonia meadows throughout the region is one example.

3.2 Physical and chemical characteristics

3.2.1 Topography, bathymetry and nature of seabed

Topography

198. This subregion can be divided into morphological units (Rehault et al, 1984), based on bottom togography. The *bathyal plain,* surrounded by the 2700 m isobath, lies in the deepest central part of the basin with a maximum depth (up to 2850 m) reached southwest of Corsica, in the Sardo--Balearic plain . The tops of some buried salt domes occur as knolls, 50 to 100 m high, dotting the flat Ligurian and Algerian bathyal plains. The *continental rise and the deep-sea fans* (between 2000 and 2700 m) are widely developed in the northern part of the basin, where there are three main gravitative sedimentary bodies. The Rhone deep-sea fan, including numerous elementary lobes, has the largest extension with a deep-sea channel and lateral branches as collector. In the Ligurian Sea, sedimentary supplies from the Var and Roya rivers and other canyons build up a coalescent deep-sea fan. Finally, the main part of the Valencia Gulf, deeper than 1000 m, belongs to the continental-rise geomorphological province. The Ebro canyon and numerous smaller submarine cut the continental slope and merge in a complex coalescent fan, including numerous juxtaposed sedimentary bodies. Elongated salt ridges and walls are observed, trending NE--SW or NW--SE (Liguro--Provencal Basin), N--S (southern Gulf of Lion) and E--W (Algerian Basin). Compared to the Provencal or Catalan rises, the Corsican, Sardinian, Balearic and Algerian rises are still very narrow.

199. This asymmetry of the basin is a consequence of a different sedimentary supply from the two borderlands of the Mediterranean: to the north, continental rise and deep-sea fan are fed by the sedimentary influxes by such large European rivers as Roya, Var, Rhone and Ebro; rivers are however minor in Corsica, Sardinia, the Balearic Islands and Algeria, and consequently margins are starved.

200. The *Alboran Sea* must be described separately. The western Algerian Basin is delimited by the 2000-m isobaths. The Alboran Basin can be divided into three morphological units including the middle part, the Alboran ridge, bounded by the 1000m isobaths, trends NE--SW, that separates two basins, respectively 1500 m (to the north) and 1100 m (to the south) deep. Southward and northward, the wide Moroccan and Spanish Plateaus (1000 m) are seaward extensions of the African and Iberian borderlands. Eastward, depth gently decreases from 1000 m to the shore. Resting upon oceanic crust,

the sedimentary column is very thick (up to 7 km) and can be divided into three layers: a detrital lower formation, an evaporitic middle one, and a turbiditic upper one.

Bathymetry

201. Except of the Gulf of Lion, western Sardinia, the southern Menorca promontory and the Ibiza Plateau, continental shelf and slope regions are narrow in the whole Western Mediterranean Basin (Figure 3.1). Most continental shelves are Pliocene and Quaternary small progradational prisms, built up on Messinian erosional surfaces, But the Rhone and Ebro rivers feed a wide and thick prograded platform in the Gulf of Lion and the Valencia Gulf. The depth of the shelf break is variable: off Provence, Corsica, the Balearic Islands and Algeria, it is no more than 100 to 125 m deep. It is deeper off Tuscany (130--150 m) and reaches 200 to 235 m depth off western Sardinia .As shown by recent computerized bathymetry (*http://www.ifremer.fr/caraibes*), the slope is steep (6 ° up to 10°), rocky or overlapped by a thin sedimentary sheet, and split into successive steps. When the coast is mountainous (Provence, Ligurian Alps, Corsica, Algeria, South Balearic Islands), the slope is locally more than15°.

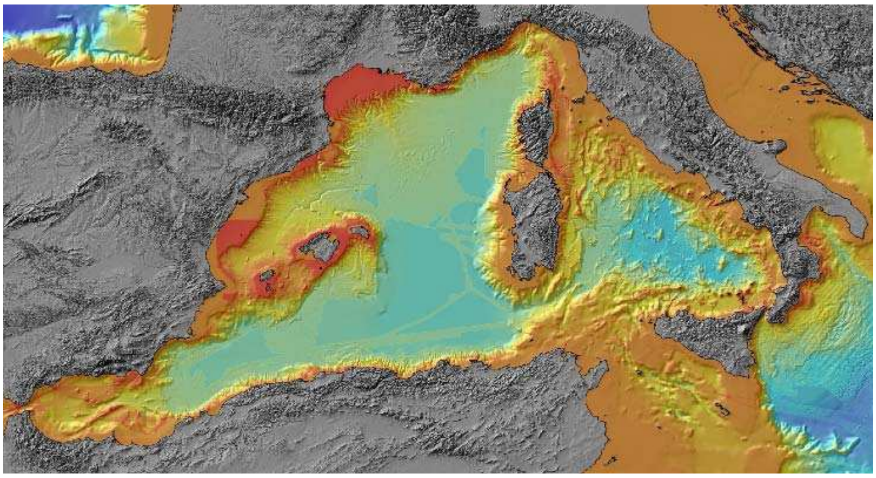


Figure 3.1. : Bathymetry of the western basin of the Mediterranean sea (from Geosciences Azur, IFREMER, CIESM, 2008) and sea beam data from surrounding countries)

202. The continental shelf in this subregion is fragmented and discontinuous. Extremely small, it disappears along coastal mountains and develops off the coast near major rivers including the Rhone, Ebro, and Tevere, and in the large gulfs (Gulf of Lions) or bays (Algiers, Algeciras, Tunis etc.).

Nature of the Seabed

203. The sedimentary processes contributing to the make-up of the seabed are complex, with sediment delivery being influenced by river discharge, currents, tectonics, and other factors. The origin of the material, on the other hand, is of dual origin: biogenic from planktonic or benthic organisms and terrigenous from river sediments (fine, coarse). The latter is most important.

204. Distribution of terrigenous sediments on the sea floor is made on a bathymetric gradient or a gradient of silt from the coast to sea with a characteristic succession of sedimentary faces: fine sand, silty fine sands, sandy muds and true vases. The fine sand silt and sandy muds are transition sediments enabling changes from coastal fine sand to pure vases offshore. In capes around bays and gulfs of the African coast, sea floor is rough (very coarse sand, gravel). Then the following distribution of sedimentary faces is a general model for southern shores. The fine sands are located in shallow waters where they form a narrow coastal strip. Vases are sometimes pure and occupy almost the entire continental shelf (Gulf of Al-Hoceima, Bay of Arzew, Bou Ismail, Gulf of Bejaia, Skikda, Bay of

Tunis), while the absence of river and oueds (Bay of Oran) promotes coarse sands and gravels. Direct inputs of sediments influenced by tectonic movements have been described for the occidental basin. They act as important sources of natural trace metals and complete other sources from bio-geochemical cycles (Rajar *et al.*, 2008). Inputs linked to tectonics are important in volcanic areas and around geothermal sources such as the southern Tyrrhenian. These contributions explain important natural levels of metals around some islands (Aeolians, Sardinia, Palmarola). The presence of mines located upstream of rivers or streams in the basin (Almaden, Spain, Monte Amiata in Tuscany) is also a source of enriched sediments (UNEP/MAP, 1996).

205. Natural resuspension of sediments is dominated by waves of short duration down to 40m depth. The coastal winds (Mistral, Tramontana on the north shore and Sirocco in the south) have no effect on the resuspension but control the dispersion of turbid waters seaward. This natural phenomenon allows a release of nutrients dissolveded in sediment pore waters. The effects of bottom trawling are very comparable to localized severe storms, and affect resuspension of fine se*diment*s from the continental shelves (50 m to 200 m depth) where effects of waves and currents are negligible. At the scale of the fishing fleet from the Gulf of Lions, the resuspended volume of sediment (5 million tons, approximately 3% of storm inputs) is equivalent to particles inputs from the Rhone (Ferre *et al.*, 2008). Then, the resuspended nutrients are in quantities several orders of magnitude larger than those from natural fluxes and bioturbation. They must then be considered for the evaluation of biogeochemical cycles.

3.2.2 Salinity, temperature regime; currents, sediment transport, etc.

Salinity and Temperature Regimes

206. Hydrological processes are spatially and temporally dynamic due to the high variability of rainfall regime, the influence of topography and the spatial distribution of soil and land use. The temporal variability of precipitation within and between years is one of the specific characteristics of this climate characterized by a succession of dry and flash-flood periods that locally affect salinity.

207. The improvement of sensors has made possible the observation of these changes, which could be related to climate or to natural variability associated to the Noth Atlantic oscillation. Actually temperature and salinity are monitored on regular basis and data from various sensors are available online (see for examples GMES project, http://www.gmes.info/index.php; MOON project, http://www.moon-oceanforecasting.eu/) and from database at both regional or sub regional scale including participants from all countries surrounding the western basin (MEDAR project, http://www.ifremer.fr/medar/ ; http://medar.ieo.es/) (see Figure 3.2).

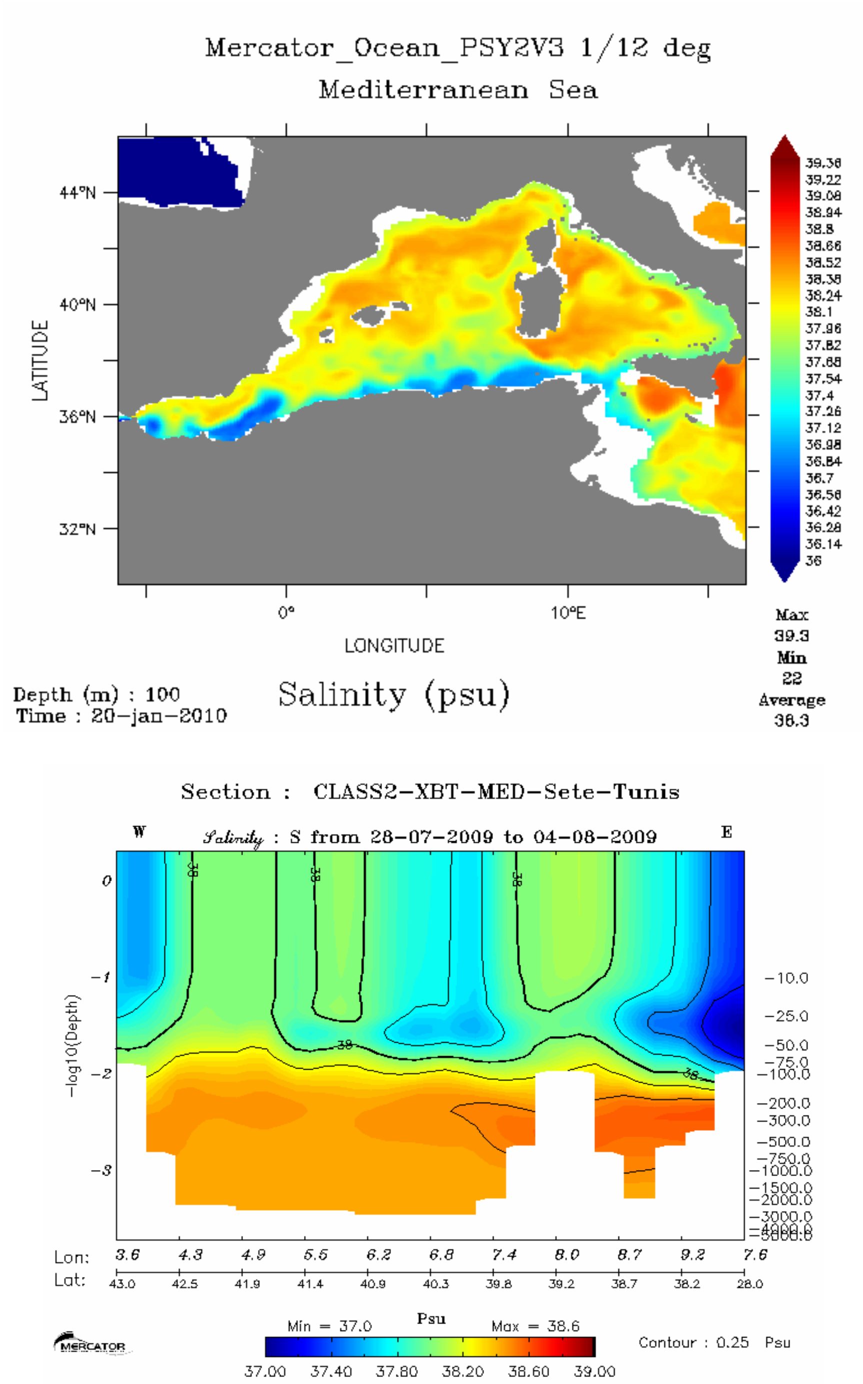


Figure 3.2. Surface salinity of the occidental basin scale (20/01/2010) and salinity profile along a Sete – Tunis transect (mean values for the period from 28/07 - 04/08/2009, http://bulletin.mercator-ocean.fr/)

208. Climatically, the Mediterranean is characterized by warm temperatures, winter-dominated rainfall, dry summers and a profusion of microclimates due to local environmental conditions (Ludwig *et al.*, 2003). Mean annual temperature follows a marked north-to-south gradient to which local orographic effects are superimposed. Sea surface temperatures are generally higher in the southern portions of the Basin (see Figure 3.3). Mean annual precipitation has a general decreasing north-to-south gradient. Annual precipitation values of 1500–2000mmyr-1 and more exist in the alpine and Pyrenean headwater regions of the Rhone and the Ebro rivers.

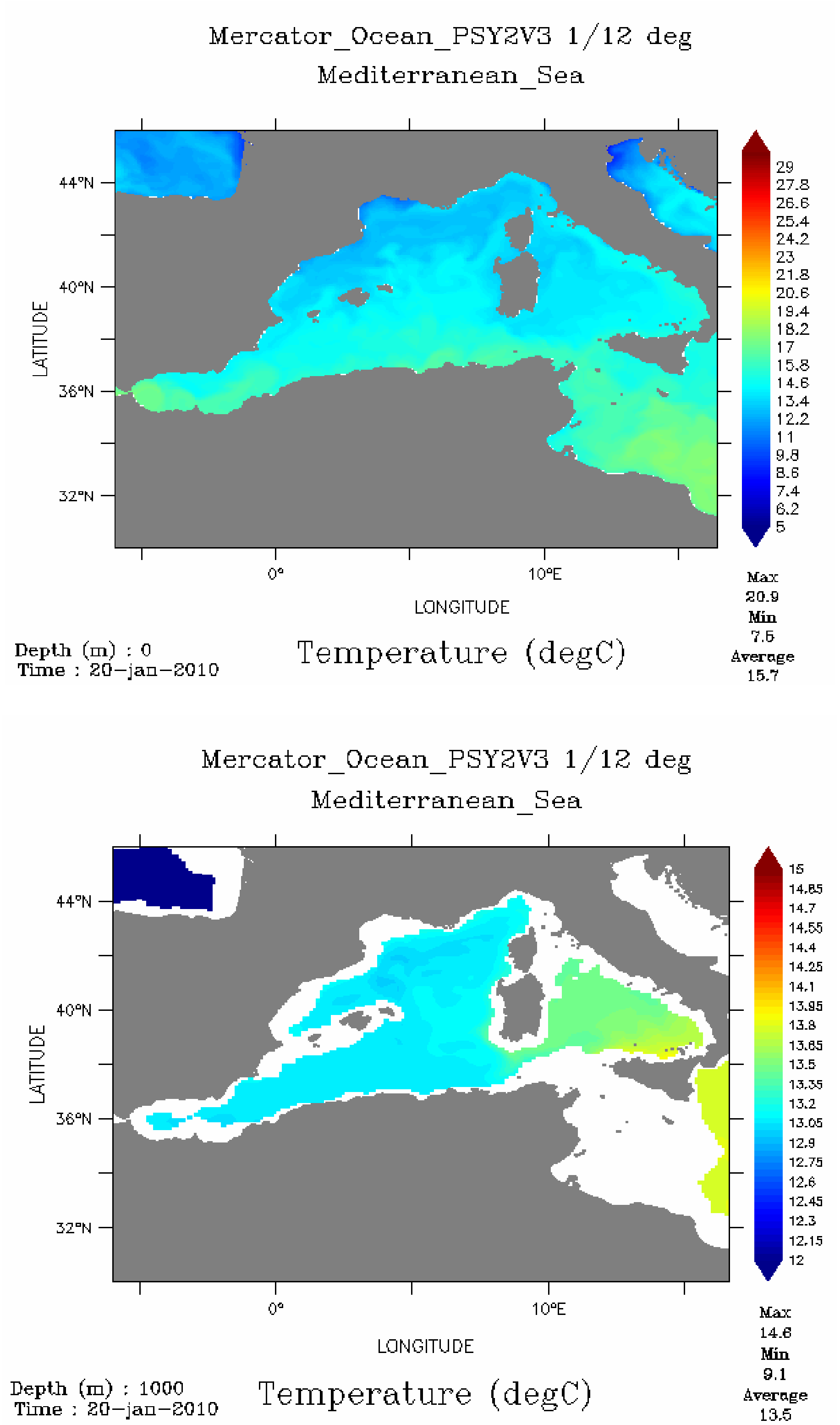


Figure 3.3 Examples of temperature measurements at the occidental basin scale (http://bulletin.mercator-ocean.fr/)

209. The strong summer–winter rainfall contrast is the major characteristic of the Mediterranean climate. This contrast increases from north to south and from west to east (Ludwig *et al.*, 2003). Precipitation mainly occurs during winter and autumn, and often less than 10% of the annual precipitation falls during summer. High precipitation during autumn is typical for the coasts of Spain,

France and Italy. The Rhône and Ebro rivers alone account for more than 20 % of Mediterranean riverine inputs.

210. Altimetric measurements have shown that the sea surface height has changed for the last decade over the Mediterranean basin. Over the past 25 years the rate of increase in sea surface temperature in all European seas has been about 10 times faster than the average rate of increase during the past century. In the Mediterranean, the warming occurs three times faster than the global average over the past 25 years. Deep waters in the Western basin have also been evolving slowly since 1970 with increasing temperature and salinity (Rixen *et al.*, 2005), whereas the SST has increased in annual mean by about 1℃ in 30 years, mainly due to warmer wintertime temperature. Also, the dense water formed in winter on the continental shelf of the Gulf of Lions could contribute significantly to the modification of the characteristics of the western deep waters.

211. Rivers are important sources of freshwater and nutrients for the Mediterranean Sea. A reconstruction of the spatial and temporal variability of these inputs since the early 1960s, based on available data on water discharge, nutrient concentrations and climatic parameters was performed recently (Ludwig *et al.*, 2009). Results demonstrated rivers suffer from a significant reduction in freshwater discharge, estimated to be at least about 20% between 1960 and 2000. Recent climate change and dam construction may have reduced discharge even further. Rivers do play a particular role in sustaining the marine productivity in the Mediterranean Sea. The latter is a semi-enclosed ocean basin and does have a high value of drainage area to surface area compared to the open ocean. The importance of the strong connection to the river inputs is related to the oligotrophic character of the Mediterranean Sea.

212. Because nutrients are exported to the Atlantic Ocean, they are lost for the basin internal primary production. Zones of high productivity are therefore mainly restricted to the coastal waters in the vicinity of major freshwater inputs, as this is shown by satellite images on chlorophyll concentrations in surface waters (Bosc *et al.*, 2004).

213. Estimates of total riverine freshwater flux into the Mediterranean have been established through inventories of major rivers, mapping of average runoff depths, modeling or country-based inventories of water resources. Most of them vary around 400– 450 km3 yr-1 for the Mediterranean. Precise quantification of the reduction is complicated by the fact that the evolution is also superimposed by the cycles of humid and dry periods. Long-term series of precipitation and discharge (e.g., in the Rhone rivers) show that in the northern part of the Mediterranean, these cycles occur in intervals of about 20 years (Zanchettin *et al.*, 2008). A decrease of the total freshwater discharge of 80–100 km3 yr-1 by rivers is therefore a realistic estimate for the last 40–50 years in the whole Mediterranean Sea. The results of analyses reveal strong negative trends for half to two third of the Mediterranean rivers. The strongest negative trends appear for rivers that were affected by the construction of dams, such as the Ebro River in Spain and the Moulouya River in Morocco. The Rhone River does not follow the general trend. Its water discharge remains about constant as affected by the non Mediterranean climate in the northern part of the basin.

214. Both climate monitoring and modeling studies revealed a general trend toward drier and warmer conditions, which already started in the last century, and which is supposed to worsen even further in the future (Giordi and Lionello, 2008). Strong repercussions for riverine water discharges can be expected and changes in Mediterranean riverine inputs are therefore potential drivers for long-term changes in the marine ecosystems. For drainage basins of the Western basin, there is a highly significant negative trend for precipitation with an average decrease by about 11%. The decrease is particularly important for the Alboran Sea (34%). Also the Southwestern Sea seems to be affected by a precipitation decrease. Temperature, on the other hand, strongly increased. Lespinas (2008) reported an average temperature increase of about 1.5 ℃ for the period 1965–2004 in a regional study on the coastal river basins in the Gulf of Lions. Although annual precipitation remained approximately constant, they showed that water discharge decreased in this region, mainly by a temperature related reduction of the basin internal water storage in the snow, soil and groundwater reservoirs.

215. Reservoirs can reduce the natural water discharge of rivers, in particular when they allow water extraction for irrigation of the fields. The Ebro River in Spain is a typical example where damming was continuously developed for agricultural purposes. This river counts nowadays about

more than 130 dams in its basin and the strong and continuous reduction of its water discharge is commonly attributed to anthropogenic water use (Ludwig *et al.*, 2009). Another interesting example is the Moulouya River in the drainage basin of the Alboran Sea. Here, climate induced water stress was great in this Mediterranean region and a major dam (Mohamed V) was constructed in 1967 (Snoussi *et al.*, 2002). The predicted runoff decrease of this river (72%) is almost fully reproduced by trend analyses and observed discharge before and after the dam construction suggests that water extraction may have reduced the river discharge by about 20%.

Ocean Circulation / Currents

216. The Western Mediterranean Sea has a negative water budget: the loss to the atmosphere by evaporation is larger than the gains by precipitation, runoff from the main rivers, and input from the Black Sea. Since the basin is limited by the shallow Gibraltar and Sicily Straits, the warm surface inflow of Atlantic water transformed into dense Mediterranean waters remains mostly trapped in deeper areas.

217. The general circulation (residual currents) has been extensively studied during last decades (see Figure 3.4). The experiments MEDIPROD (1986-1987), PRIMO-0 (1990-1991) in the channels of Corsica and the Balearic Islands, PRIMO-1 (1998-1999) in the channel of Tunisia and Sardinia, the experiments THETIS-MAST-2, ALGIERS and ELISA-MAST-3 and historical series helped to give a consistent pattern of movement. Since the 2000s, the development of models and their validation has clarified the mechanisms of the general circulation and developed particularly in the southern basin, and remains valid in its general scheme (Millot, 1999).

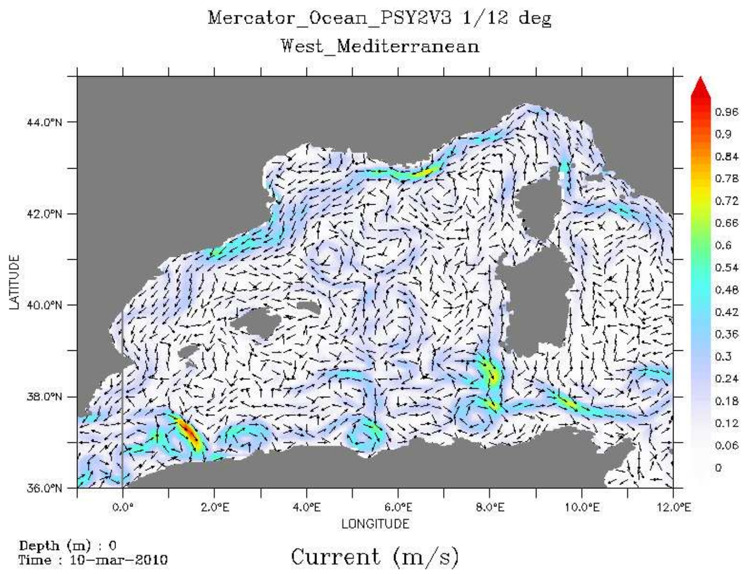


Figure 3.4: Large scale General circulation in the occidental Mediterranean basin on March 10th (Mercator, http://www.mercator-ocean.fr/) and March 21st (http://www.cnr.it/sitocnr/home.html)

218. A large thermohaline cell encompasses the whole Mediterranean and is mainly driven by the water deficit and by the heat fluxes, compensated by the exchanges through the Straits of Gibraltar. The formation and subsequent spreading of the intermediate water, together with the inflow of the Atlantic Water through the Straits of Gibraltar, contributes to this thermohaline circulation. While progressing eastwards, Atlantic water gets progressively denser before being transformed into dense water along the North African coasts (Bethoux *et al.*, 2002, Gasparini *et al.*, 2005). The contribution of the water formed in the Eastern basin (the Levantine Intermediate Water) is also essential to the formation of deep water in Western basin through the Sicilian-Tunisian channel. Deep circulations in the two main sub-basins, separated by the Sicilian Straits, are decoupled and are composed by two

minor thermohaline cells forced by events of dense water formation occurring in the Gulf of Lions for the western Mediterranean.

219. The principal oceanographic feature of this subregion is the strong current (the Liguro-Provencal Current), which leaves the Italian coast and moves south-westward along the continental margins, and an intense front spanning from the Balearic Islands to the Sardinia. Favourable hydrographic conditions cause bottom and intermediate water formation, which in Mediterranean occurs where strong winds and cyclonic structures are recurrently observed.

220. The Levantine Intermediate water in the eastern Mediterranean is characterized by maximum in salinity and in temperature and represents the most important player of the Mediterranean thermohaline circulation and is in fact the principal component of the eastern Mediterranean waters flowing in the Western basin through Sicilian Channel. In addition, it represents the main component of the Mediterranean outflow at Gibraltar which is essentially driven by the difference of density between both sides of the strait. Northern winds and permanent circulation force the formation of the deep water, which takes place in the Gulf of Lions during the wintertime. The characteristics (density, temperature and salinity) of the deep waters are determined by the long time accumulation of the dense waters formed during successive winters up to a level above the sills. Upon exiting the Straits of Gibraltar, the outflow of Mediterranean water (saltier) dives along the slope in the Atlantic Ocean with a flow rate 10 to 20 times larger than the Mediterranean inputs, and affects the deep layer and thermohaline circulation in the Atlantic Ocean. The volumes of water exchanged at Gibraltar are mainly fixed by local conditions near the straits.

221. Besides the main thermohaline circulation, several local features characterize the Mediterranean circulation, such as gyres and fronts. The Atlantic Water is present almost everywhere in the basin. It forms two anticyclonic gyres in the Alboran Sea, constrained by the bathymetry, and then bifurcates around the Sardinia Island in two different branches, one going into the Tyrrhenian Sea as the source of the large-scale cyclonic circulation occurring in the north-western Mediterranean; the other crossing the Sicilian Channel and penetrates in the Ionian Sea. The water from the Tyrrhenian produces a large cyclonic circulation in the western Mediterranean, with the central gyre between the Balearic Islands and the Sardinia being the region of deep water convection. Principal feature is the strong current (the Liguro-Provencal Current), which leaves the Italian coast and moves south-westward along the continental margins, and an intense front spanning from the Balearic Islands to the Sardinia.

222. Atlantic water inflow in the Alboran Sea or the Northern Current in the Ligurian Sea, exhibit vertical motions that induce significant exchanges of properties between the surface layer and the deeper layers. These vertical motions have an important role on heterogeneous nutrient inputs in the mixed layer and affect the distribution of marine aggregates.

223. In the southern part, the Algerian currents are unstable and generate (50-100 km) eddies with vertical extents to the bottom at around 3000m and lifetimes in the months-year range. Eddies usually propagate eastward along the continental slope at few km/day. They can detach and drift in the open basin. This intense mesoscale activity is responsible for the dispatching of water masses at surface, intermediate and deep levels. In the northern parts, the mesoscale current has a clear seasonal signal and is associated to deep water formation. During wintertime the current is stronger and faster. Eddies generate significant upwelling and subduction. Along the continental slope, currents follow submarine canyons producing topographically-controlled up- and down-wellings which affect the cross-slope transfers of particulate and biogenic matter. This process can be enhanced by concomitant storms that flush the shelf water or hinder by intense freshwater discharge (Ulses *et al.*, 2008). Shelf regions are affected by river plume dynamics, wind-driven meso-scale circulation and dense water transport that control the exchanges of water and biogeochemical elements from the enriched coastal areas to the interior of the basin. Freshwater discharges from large rivers (e.g., Rhône, Po) produce highly stratified buoyant flows sometimes beyond the shelf. Finally, altimetric measurements have shown that the sea surface height has changed for the last decade over the Mediterranean basin. The improvement of the sensors that monitor the Mediterranean region at higher temporal resolution has made possible the observation of these changes, which could be related to climate change.

224. Interactions between different constraints affecting the current such as ocean-atmosphere interactions (Korres *et al.*, 2000), the formation of deep water, the influence of topography (Beranger *et al.*, 2005) implies high-resolution models. In recent years, the improvement of methods enabled to characterize seasonal variations (Bethoux *et al.*, 2002), the formation and variability of gyres (Testor *et al.* 2005; Demirov and Pinardi, 2007, Hu et al, 2009). More recently, models were made available to the scientific community. Systems such as the "Mediterranean Forecasting System (MFS) using a 5-7 km resolution was demonstrated to be sufficiently accurate to study the variability of mesoscale gyres. The altimetry has also demonstrated the importance of varying forces on currents. Despite the properties of the geoid, which must be considered, this approach is very useful to characterize the variability of gyres (Vigo *et al.*, 2005, Pascual *et al.* 2007; Aldeanueva-Criado *et al.*, 2008). A high resolution (3-4 km) and a comparison with altimeter data enabled estimation of mean currents during a 12 years period with a permanent atmospheric forcing (Jordi and Wang, 2009). This model reproduces most of the major currents and eddies and confirms the importance of meso-scale. The Mediterranean ocean forecasting system (MFS) has started operational activities in January 2000. Presently it produces daily analyses and 10-days forecasts of currents and temperature and salinity fields for the entire Mediterranean at approximately 10 km resolution. At INGV, weekly forecasts Bulletins are disseminated through the MFS (http://www.bo.ingv.it). Confirmed by observations particularly since the development of VHF radar images, drifting buoys followed more recently by gliders (Molcar *et al.*, 2009; Rubio *et al.*, 2009; Ruiz *et al.*2009) and largely modelled with improved resolution, the general pattern of the circulation was confirmed.

225. The north-westerly winds (Mistral, Tramontana) overlooking the north shore of the western basin of the Mediterranean influence the currents generated in the northern basin. Although of secondary influence to the whole basin, the upwelling generated by these North West winds and currents cause complex physical phenomena that promote the redistribution of dissolved elements, particles and nepheloids and the recovery of nutrients to water surface. This mixing causes the homogenization of the water, including mixing with waters of large rivers such as in the Rhone delta and Ebro estuary. The arid period from 1990 to 2000, the significant decrease in water inflows, the trapping of sediments in dams are the mains reasons for the decrease in the flow of materials from rivers. Studies by the National Agency of Water Resources (ANRH) of Algeria have clearly highlighted the link between sediment yield and discharge rates. The volumes of sediment trapped in dams located in coastal areas deprive beaches of solid particles inflows. This is illustrated by the case of oueds representative of the North African coast.

Sediment Transport and Fluxes

226. Natural resuspension of sediments is dominated by waves of short duration down to 40m depth. The coastal winds (Mistral, Tramontana on the north shore and Sirocco in the south) have no effect on the resuspension but control the dispersion of turbid waters seaward. This natural phenomenon allows a release of nutrients trapped in sediment pore waters. The effects of bottom trawling are very comparable to localized severe storms, and affect resuspension of fine sediments from the continental shelves (50 m to 200 m depth) where effects of waves and currents are negligible. At the scale of the fishing fleet from the Gulf of Lions, The resuspended volume of sediment (5 million tons, # 3% of storm inputs) is equivalent to particles inputs from the Rhone (Ferre *et al.*, 2008). Then, the resuspended nutrients are in quantities several orders of magnitude larger than those from natural fluxes and bioturbation. They must then be considered for the evaluation of biogeochemical cycles.

227. On the south shores, atmospheric particles from the Sahara-Sahel Corridor (Western Sahara, Algeria, Chad and Niger) are natural sources of aluminum and iron and most trace metals, and contain elevated levels of anthropogenic molecules (Zn, Pb, Cd) or chemicals leached after abrasion of natural rocks (chrome, nickel). All the coasts of southern basin are concerned (Castillo *et al.*, 2007). In some areas such as Annaba (Algeria), the particle flux and atmospheric winds are responsible for air intakes of lead, chromium, manganese, nickel, cadmium and cobalt associated with the presence of industrial activities (Khoja ali et al, 2008).

228. Behaviour of particles at sea has become an important process for sediment budget evaluation. Although this process is not sufficient to completely explain the space and time variations of observed particle fluxes, especially at depth, particle exchange across the margins and fluxes, variable annually, in canyons are largely resulting of the effect of the general current and by dense

water formation in winter rather than variations in the sources of matter (Guarracino *et al.*, 2006). Smaller aggregates are more abundant in coastal waters, as a result of continental input, cross-slope export, and re-suspension along the slope. With a relative proportion of large cells increased with the magnitude of the upward velocity, mesoscale vertical motion controls directly the size structure of phytoplankton in the ocean. CTD-video packages experiments demonstrated that large particulate matter spatial heterogeneity generated by the upper layer mesoscale hydrodynamics extends into deeper layers and may significantly contribute to the biogeochemical cycling between the upper and meso-pelagic layers (Gorsky *et al.*, 2002). The layers that contain very high concentrations of small aggregates are observed from surface down to 1000 m, and extend from the continental slope to the fronts (Stemann *et al.*, 2008). Even if the particles are derived from the atmosphere or internally produced by biological processes, their transference from the upper to the deeper ocean is controlled by the stabilization of the water column and the distribution of the water masses. Concentrations of sediments and large aggregates are highest in and under frontal zones probably as a result of physical coagulation, and/or biological transformations with limited cross-slope transport. This processes, which takes place in sub-mesoscale zones (5–10 km wide) are widely distributed amongst the occidental basin and have consequences for the transport of continental particles to the ocean's interior.

229. A budget evaluation of particulate organic carbon (POC) fluxes carried out in the deep part of NW basin (Ziga *et al.* 2008) demonstrated the low Particulate organic carbon input in both Thyrrenean deep waters and Algero Balearic basin mainly related to the spreading of dense cold water along the whole basins that supplied Particles at depths higher than 2000 m. The size structure of phytoplankton may also depend more directly on hydrodynamic forces than on the source of available nitrogen (Rodriguez *et al.*, 2001) and drifting sediment trap measurements showed highly variable fluxes of planktonic and terrigeneous lipids at 200 m in the NW Mediterranean and pulses to be depending on the intensity of particle dry weight, plankton and aggregation processes (Mejanelle and Dachs, 2009).

230. Strong gradients for many physical and chemical parameters are occurring in estuaries (Chapman and Wang, 2001) and affect the quantity and composition of dissolved organic matter and colloidal particles, which play an important role in the transfer of contaminants and their transformation as the ionic strength and precipitation phenomena are affecting the bio availability of contaminants. Due to salinity gradients, stratification of water is common, causing density currents whose depends on the topology in the case of the Rhone and the Ebro rivers. The time series analysis of climate, currents and particulate matters fluxes (Durrieu de Maderon *et al.*, 1999) showed that the particles transported to the bottom could be linked to sediment exchanges between the continental margin and greater depths rather than only atmospheric inputs or transportation from major rivers. In this case, the vertical oscillations of flow on the continental slope govern much of the contributions to the bottom and undergo significant seasonal variations due to fluctuations in vertical temperature.

231. Isopicnal currents are likely to support a very important contribution of transport in the deep adjacent canyon up to distances of more than one hundred kilometers to reach distal lobes. Under these conditions, transport of contaminants associated with sediment particles into the abyssal plains must be considered. Finally, the contributions related to accidental flooding or storms are linked to exceptional climatic events. They affect sediment transport in rivers, including small ones (Gremare *et al.* 2003). In this case, a significant contribution of sediment but also dissolved substances or contaminants is taken up by the local hydrodynamic and contributes to coasts and canyons enrichment. The role of waves and currents driven by onshore and off-shore wind regimes has been determined as dominant mechanisms for the dispersal of river plumes, resuspension of shelf sediment, and off-shelf sediment export (Canals *et al.*, 2006, Palanques *et al.*, 2008).

232. *In situ* observations combined with 3D modeling to quantify the suspended sediment transport in the Gulf of Lions revealed (Ulses et al, 2008) that most of the particulate matter delivered by the Rhone was entrapped on the pro-delta, and that marine storms played a crucial role on the sediment dispersal on the shelf and the off-shelf export. Erosion is controlled by waves on the inner shelf and by energetic currents on the outer shelf. Sediment deposition takes place in the middle part of the shelf, between 50 and 100 m depth. Resuspended sediments and river-borne particles are transported to the south-western end of the shelf by a cyclonic circulation induced by these onshore winds and exported towards the Catalan shelf and into the Cap de Creus Canyon which incises the slope close to the shore

233. Observations from a submarine canyon on the Gulf of Lions margin demonstrated that these flows can also be triggered by dense shelf water cascading, a type of current that is driven solely and seasonally by seawater density contrast. It not only transports large amounts of water and sediment but also reshapes submarine canyon floors and rapidly affects the deep-sea environment. One study measured the resuspension particulate matter in these areas. From the evaluation of particulate flow, sedimentation rates and different terms of inputs (rivers, atmosphere, primary production) and output (degradation in the water column and at the interface of water and sediment), a first assessment of particulate organic carbon fluxes has been established. This assessment indicates that less than 10% of the particulate material brought to the Gulf of Lions is exported to the North Mediterranean basin.

3.2.3 Spatial and temporal distribution of nutrients, dissolved oxygen and pH

234. The Mediterranean basin is characterized by low quantities of nutrients and a reduced biomass of phytoplankton. In large part this is because riverine inputs of nutrients are relatively low; with a few exceptions, all river systems discharging in the Mediterranean Sea are small. The most eutrophic waters in the western basin are located on the north shore, at the mouth of the large rivers Rhone and Ebro (with catchment areas of 96,000 and 84,000 km2 respectively). However, it should be noted that besides nutrients inputs, the primary productivity at local scale is also controlled by additional factors such as the stratification of the water column, transparency, and surface local currents.

235. The total estimated loads are about 304,000 ton/year N and 22,000 ton/year P. Both nitrogen and phosphorus are deposited in water and soil in different forms: nitrogen as ammonia which has evaporated from animal manure, and as NOx coming from combustion of fossil fuels, i.e. power plants and transportation; phosphorus as dust, falling leaves and bird faeces. The highly productive areas are located near river deltas or large urban agglomerations while offshore waters are generally oligotrophic.

236. According to UNEP (EEA 1999) there are numerous factors governing the transfer of nutrients. The total nitrogen (N) is largely rejected by urban wastewater treatment(31%), livestock (19%) and metals industry (11%), while fertilizer production represents the majority of emissions of total phosphorus (P) (63%), followed by livestock (20%) and urban wastewater treatment (8%). These factors illustrate how a small group of industries is responsible for the main emissions/discharges of nutrients and transportation to the sea in the Mediterranean region. It appears that large cities also play an important role in the contributions to organic matter and nutrients inputs.

237. Even if other sources must be considered (atmospheric inputs, nitrogen biological fixation, Atlantic inputs), the origin of nutrients is largely due to the presence of rivers. In the western Mediterranean, all water systems are small except for the Rhone and the Ebro Rivers. They there are important for understanding the geochemical budgets at larger scales, made possible by more or less complete reconstructions of their nitrate and phosphate fluxes during the last 40 years. Nitrate fluxes in the Rhone and Ebro rivers increased steadily from the beginning of the 1970s up to the 1990s, before they remained approximately constant, or even decreased during recent years. These large rivers have support a variety of human activities at regional scales, making them more relevant to integrated ecosystem-based management than smaller river basins.

238. The inputs of nutrients are however important in small rivers too collecting rich effluents in large quantities. This is the case in most north African oueds (Djemai & Mesbah, 2008) but also in rivers of the north shores where after heavy rains following dry periods, metals, nitrates and organic carbon reach concentrations that could affect biological populations (Nicolau et al, 2006). Fluxes of nitrogen (N) were strongly enhanced by anthropogenic sources during last decades when phosphorous only increased up to the 1980–1990s, and then rapidly dropped down to about the initial values of the 1960s limiting primary production (Ludwig *et al.* 2009) .Silica (Si), strongly controlled by water discharge, was decreased during the same period and has become a limiting element for siliceous primary producers such as diatoms, since the early 1980s. However, gross primary production sustained by rivers (PPR) represents only less than 2% of the gross production in the Mediterranean. Possible ecological impacts of the changing river inputs should therefore be visible

only in productive coastal areas, such as the Gulf of Lions, where primary production can reach more than two thirds of primary production.

239. Nitrogen, phosphorus and silica exist in rivers in various dissolved, particulate, organic and inorganic forms. When considering the proportions of specific nutrient forms in more densely populated regions, such as the Mediterranean, the dissolved forms and especially nitrates are the dominant forms in the total nitrogen (TN) fluxes when other DIN species (NO2- and NH4+) are only abundant when rivers suffer from organic pollution reducing the oxygen levels. For phosphorus, however, the particulate forms cannot be neglected and monitoring programs often also determine the total phosphorus (dissolved and particulate P species) content in rivers that is also dependent on suspended solids. Then, although phosphate is not necessarily the dominant P form, average values might be more suitable for an assessment of phosphorus enrichment in rivers.

Table 3.1: Average nitrate and phosphate levels in Mediterranean rivers

River	Country	av. N–NO3 (Period) (mg l^{-1})	av. P–PO4 Q (period) (mg l^{-1})	Flux–NO3 (kg N km^2 $yr^{-1)}$	Flux–PO4 (kg P km^2 yr^{-1})
Arno	Italy	2.39 (01–05)	0.149 (01–05)	255	609 38
Aude	France	1.51 (00–05)	0.107 (00–05)	290	437 31
Ebro	Spain	2.39 (00–05)	0.065 (00–03)	110	263 7
Herault	France	0.58 (00, 06)	0.023 (00--06)	590	340 13
Jucar	Spain	4.01 (00–05)	0.080 (05)	58	233 5
Llogrebat	Spain	2.19 (01–04)		95	208
Rhone	France	1.44 (00–05)	0.050 (00–05)	564	812 28
Tevere	Italy	2.10 (03–04)		446	937
Turia	Spain	3.22 (00–05)	0.235 (05)	42	135 10

Average concentrations were taken from EEA (2007) and Ludwig et al (2009).

240. Monitoring of water quality parameters in rivers has been developed at national levels but only for recent years these data became widely available. Data on many of the largest European rivers is now centralized in the Waterbase database at the European Environmental Agency (EEA, 2007), allowing the nitrate and phosphate levels in western European countries to be quantified. African countries are not considered in this database, which can bias the general picture.

241. For nitrate, data (Table 3.1) demonstrated relative moderate specific fluxes in river basins, indicating that nitrogen pollution is still low compared to what is commonly reported for the large European rivers further to the north, such as the Seine and Rhine rivers. Phosphorus pollution often originates from point sources, such as urban waste waters. The north to south decreasing trend that is typical for nitrate in Europe is overprinted for phosphate by an upstream to downstream increase, following the distribution of population densities. Phosphate levels reported in scientific studies are often clearly lower but observations mostly refer to scientific studies that were limited in time (Ludwig *et al.*, 2003), making it difficult to catch the long-term evolutions.

242. Eutrophication is discussed in the pressures section, however the naturally occurring nutrient levels and their relation to eutrophication also merit attention here. Phenomena of eutrophication in freshwaters and coastal waters are not only depending on the degree of anthropogenic nutrient enrichment, but also on the relative nutrient composition. In particular the unbalance of nitrogen and phosphorus with respect to silica seems to play a crucial role, as it can provoke a shift in primary production from diatoms to non-siliceous algae, often harmful for the ecological equilibrium.

243. The Mediterranean is positioned between the temperate and subtropical climates, and temperatures are generally higher than in the pure temperate climate further to the north. Consequently, Billen and Garnier (2007) found higher Si values in Mediterranean rivers compared to

temperate climate using however a general approach that cannot account for the influence of other controlling factors, such as the nature of the weathered rock types in the drainage basins and anthropogenic factors that can modify the natural riverine silica loads. When eutrophication conditions are favourable for diatom growth, silica retention can also occur in large rivers (Sferratore *et al.*, 2006). Several modeling approaches have been published in order to predict the spatial variability of DIN fluxes on the basis of economic and demographic input data (e.g., fertilizer spreads). The NEWS-DIN model of Dumont *et al.* (2005) (after adjusting and recalibrating it for rivers) shows that particulate river loads are spatially more variable than dissolved loads.

244. Budgets strongly depend on the estimates of the nutrient levels in the incoming Atlantic waters. These budgets should also include the nutrient inputs from other sources such as wastewaters of coastal cities that are directly discharged into the sea (UNEP/ WHO, 1999) and recent data on European rivers, showing that the strong reduction of anthropogenic P continues and probably will in the near future. A prospective scenario corresponding to the application of the European Water Framework Directive (WFD, 2000) may involve a 90% abatement of phosphorus from all urban wastewater inputs by 2015. This means that the phosphorus levels in the Mediterranean could fall below the 1960 levels. However, statistical modeling applied to a large number of historical nutrient data to assess the significance of human perturbations in the Mediterranean Sea (Karafistan *et al.*, 2002) does not indicate any particular trend in time for the last 30 years. Average horizontal space distributions of the phosphate data over the whole Mediterranean clearly demonstrated oligotrophy was mainly affecting the Levantine basin. Besides rivers, the main sources of nutrients are soil erosion and excess nutrients from over-fertilization and livestock. Among the first areas of drainage, soil erosion and nutrient loss in the Mediterranean, 3 are located in the western basin (Sicily, Sardinia, Spain; EEA / UNEP 1999). More locally, intensive marine aquaculture, although undeveloped in open seas and mainly located on the north, largely participate in waters inputs of organic matter and nutrients (Doglioli *et al.*, 2004). In the area influenced by the plume of the Rhone, the organic enrichment and quantities phaeopigments suggest an organic matter of detrital and terrestrial origin. (Alliot *et al.*2003).However, the marine origin of nutrients and organic matter is also important (Di Leonardi *et al.* 2009).

245. In 25 years, nitrate concentrations in the wat*ers of* the Ebro (Spain), which has a basin of 85,566 km2, increased in 46% of the 65 sampled sites in parallel of increase of agricultural activities (R2 = 82, Lassaletta *et al.* 2009). At the estuary, the Ebro is highly stratified and shows a positive balance of nitrogen and phosphorus inputs due to its superficial layer of fresh water, the presence of dissolved and particulate compounds, the reduction of uptake by phytoplankton (as shown by a decrease in chlorophyll in the estuary), the high turbidity, and to a lesser extent, the effects of sewage. The annual burden is among the highest in the Mediterranean for nitrates and silicates (# 10 000 tons) while the phosphorus is released at relatively low concentrations (approximat*ely 20*0 t year-1) even above needs (Falco *et al.* 2010). By comparison, the Rhone with its higher flow produces a total load of 77,500 tonnes of inorganic nitrogen and 2,500 tonnes of phosphorus annually.

246. In the sediments at the mouths of rivers, the levels of nutrients appear to be decreasing (Denis and Grenz, 2003). Under these conditions, sediments act as a reservoir that plays an important role in the biogeochemical cycles of the Gulf of Lions, mainly for inorganic phosphorus.

Table 3.2: Comparison of intakes of nutrients in the Gulf of Lion. (DIN, DIP and DSi: Total nitrogen, phosphorus and dissolved silicates) (After Denis and Grenz, 2010)

	RHONE (Kt y-1)	NW CURRENT	SHELF SEDIMENTS	CONSUMPTION (kty-1)
DIN	99.9-104.3	75 (nitrates)	14.1	299
DIP	2.7-3	6	2.9	41
Dsi	135-139	nd	165	600

247. Beside nutrients inputs, the primary productivity at local scale is also controlled by additional factors such as the stratification of the water column, transparency, surface local currents.

248. According to national assessments measuring inputs of nutrients on the Algerian coast, the transfer of nutrients from the terrestrial system to the marine system occurs in agricultural areas, including intensively farmed coastal lowlands (Annaba, Mitidja Algerian Sahel, Mostaganem area) where' use of nitrogenous and phosphates fertilizers have multiplied inputs to the coast (UNEP/MAP, 2003). Levels of nutrients in Mitidja indicate peaks of 200 mg / liter of nitrate (standard 50 mg / l). On the hills of the Sahel and other coastal areas (Skikda, plain, Saf Saf Mostaganem) nitrate is delivered by runoff and transferred directly to the sea. In the Gulfs of Arzew and Algiers, the distribution pattern of organic carbon shows sedimentation in middle of bays and nearby ports. These maxima are related to increasing population and industrial activities (Buscail *et al.*, 1998). Nutrient concentrations in sediment are higher in harbours than those measured in the vicinity and correlated to levels of organic pollutants. Djijell, Algiers and Annaba are the most affected. In some areas with a continental influence, high levels of nutrients can be observed (Freha et al, 2007). In the Oued Aissi water basin, situated in the South-East of Tizi-Ouzou, significant surface and underground water resources are generated by irregular precipitations (annual average pluviometry = 910 mm). Following the increase in population, the industrial development and the increased use of fertilizers, concentrations of pollution parameters like ammonium (0.8 mg/l), the nitrites (0.095 mg/l), phosphorus (0.408 mg/l) and the ferrous-iron (0.326 mg/l) arise in concentrations higher than the standards of quality of water surface (Mohammed and Mohamed, 2008).

249. In Morocco, the Oued Martil estuary, where urban and industrial wastes are discharged, is affected by excessive levels of nutrients with maximum nitrate concentrations ranging from 400 to 500 µg/l.

250. The Spanish coast is characterized both by natural enrichment due to upwelling and an induced eutrophication caused by human discharge. The high productivity of the Alboran Sea appears to be related to the upwelling created by the anticyclonic circulation generated by the flow of Atlantic waters entering the Mediterranean through the Straits of Gibraltar. Other areas affected by nutrients appear to be coastal areas close to Valencia and the Ebro delta. As monitored by concentrations of nutrients, Localized events of eutrophication in the Mediterranean coasts of Spain have been reported in several cases (UNEP/MAP, 2008). Finally, the bay of Tunis is an enclosed gulf where the urban areas around the Lac de Tunis have caused serious nutrients inputs.

251. In Italy, nutrients are mainly related to effluent discharges from urban agglomerations on or near the coast (Foce Torrente Lerone, Marinella - Foce Magra, Napoli) and only in a few cases from inputs of major rivers (Sarno, Arno, Tevere).

252. The remineralization of organic matter, measured by the kinetics of total organic carbon or dissolved is recognized as an important source of inorganic nutrients in coastal systems. It increases the production of endogenous nutrients. Whether in offshore waters or in coastal areas in winter, levels of certain nutrients, including phosphates may limit primary production. An experimental and numerical study of the spatial distribution of aerosols over the western Mediterranean basin (Salameh *et al.* 2007) showed the influence of northerly winds (Mistral and Tramontana) in the Rhone valley and the Gulf of Lion. The transport of natural and anthropogenic aerosols at sea may affect the whole north-western basin. These winds are responsible for the transport of particles containing ammonium nitrates and sulphate in an advective pattern from the northern region of Fos / Berre / Marseille to North Africa and Italy. They are also influencing and generating currents in the northern basin. Although of secondary influence in the Mediterranean, the upwellings generated by these persistent north-west winds and currents cause complex physical phenomena that promote the redistribution of dissolved and particulate elements and the recovery of nutrients to surface waters. This mixing causes the homogenization of the water, mixing with waters from large rivers in the delta of the Rhone and near the estuary of the Ebro and changes in concentration of chlorophyll in the sea surface as described since for many years (El Sayed *et al.*, 1994).

3.2.4 Relationship of catchment area to subregion

253. Extensive catchment basins influence this subregion, particularly in its northern reaches. Significant land areas form watersheds draining into the western Mediterranean, including the bulk of eastern Spain, southeastern France, all of Monaco, most of western and much of northern Italy, and large portions of northern Morocco, Algeria, and Tunisia (see Figure 3.5).

Figure 3.5 Catchment basins (indicated by dotted blue lines) in the countries bordering the western Mediterranean subregion (from Blue Plan)

3.3 Biological characteristics

3.3.1 Description of water column biological communities including the species and seasonal and geographical variability

254. As is the case for the entire Mediterranean basin, the western subregion is characterized by a reduced biomass of phytoplankton, which causes a high water clarity and deep penetration of light in the water column. The richest waters in the western basin are located on the north shore. Inversely, the offshore waters are generally oligotrophic, except in cases of deep nutrient-rich upwelling.

255. Due to oligotrophy, phytoplankton biomass as Chl-a, generally displays low values (less than 0.2 µg chl-a l -1) over large areas, with a modest late winter increase. A large bloom (up to 3 µg chl-a l -1) throughout the late winter and early spring is only observed in the NW area (Siokou-Frangou *et al.*, 2009). Relatively high biomass peaks are also recorded in fronts and cyclonic gyres. A deep chlorophyll maximum is a permanent feature for the whole basin (except during the late winter mixing). It progressively deepens from the Alboran sea (30 m) to the west. Primary production reveals a similar west-east decreasing trend and ranges from 59 to 150 g C m-2 (in situ measurements). Overall the basin is largely dominated by small-size autotrophs, microheterotrophs and copepod species. The phytoplankton and the microbial (autotrophic, heterotrophic and probably diazotrophic) reveal a considerable diversity and variability over spatial and temporal scales.

256. In the Spanish portion of the western Mediterranean, phytoplankton communities in the coastal zone are characterized by a late winter bloom (February-March) that triggers the spawning of many benthic species, and a late summer or early fall bloom (Duarte 1996, Duarte et al 1999). These blooms are dominated by diatom species (*Scheletonema, Chaetoceros*, etc.) and dinoflagelates, respectively. The interval in between these blooms is characterized by an oligotrophic phase, with low chlorophyll and nutrient concentrations, and phytoplankton communities dominated by picoplankton, mostly Synechoccocus species. Chlorophyll a concentrations reaches maximum values in the order of 2-4 µg Chla L^{-1}, and the values during the oligotrophic phase are typically < 0.5 µg Chla L^{-1} (Duarte 1996, Duarte et al 1999). These values can be exceeded in eutrophied areas, such as harbours and eutrophied coastal lagoons and bays, with chlorophyll a values in excess of 10 µg Chla L^{-1}, in the

most eutrophic areas. Toxic dinoflagellates, of the genera *Alexandrium* and *Gymnodinium*, have also been reported in eutrophied coastal waters and coastal lagoons along the Spanish Mediterranean coast.

257. Data on pelagic primary production in the Spanish Mediterranean is sparse with estimates, derived from a 7-year time series in the Bay of Blanes (NE Spain) indicating an average gross primary production of 2.56 µmol C L^{-1} day^{-1} (Duarte *et al.* 2004). And the annual gross primary production at Bay of Palma (Mallorca, Balearic Islands, Spain) has been estimated at 3.19 µmol C L^{-1} day^{-1} (Navarro *et al.* 2004). The mean gross primary production for the Mediterranean Basin has been estimated to be 4.5 µmol C L^{-1} day^{-1} (Regaudie de Gioux et al 2009).

258. Zooplankton communities are typically dominated by copepods of the genera *Acartia* , *Ohitona*, *Penilia and Paracalanus,* with important contributions of doliolids, gelatinous organisms, during summer, as these organisms are able to graze on the pico-sized organisms that dominate in summer. These organisms exert an important grazing pressure on phytoplankton. Microzooplankton, dominated by ciliates of the genera *Tontonia, Mesodinium, Halteria, Sormbidium and Strobilidium* are also an important component of the plankton biomass and are responsible for a sizeable fraction of the losses of pico-sized plankton, both autotrophic and heterotrophic. Microzooplankton are, in turn, predated upon by copepods (from Malba and Duarte, 2010).

259. The Pelagos Sanctuary for the Protection of Mediterranean marine mammals is another well-studied region within this subregion. Compared to the rest of the Mediterranean, this marine area is characterized by very high levels of offshore primary productivity, caused by the interplay of oceanographic, climatic and physiographic factors (Notarbartolo di Sciara *et al.*, 2007). High levels of primary production, with chlorophyll a concentrations exceeding 10 g m^{-3} (Jacques, 1989), support a conspicuous biomass of highly diversified zooplankton fauna, including gelatinous macrozooplankton and swarming *Meganyctiphanes norvegica* euphausiid crustaceans (krill) (Sardou *et al.,* 1996). Zooplankton concentrations, in turn, attract to the area various upper-trophic level predators, including krill-eating, fish-eating, and squid-eating cetaceans (Forcada *et al.* 1995; 1996; Gordon *et al.* 2000).

3.3.2 Information on invertebrate bottom fauna macro-algae and angiosperms

Invertebrate Fauna

260. Benthic communities are both productive and diverse in species in the western Mediterranean subregion. Rocky intertidal and benthic areas, *Posidonia* meadows and habitats formed by macroalgae, coralligenous communities, and soft bottoms all support a wide variety of sponge, corals and anemones, mollusks, crustaceans, and echinoderms. Many of these species are classified as threatened; for invertebrate species of particular interest to conservation, Table 3.3 provides information on occurrences of species in the western Mediterranean subregion.

Table 3.3 List of invertebrate species of conservation interest, with occurrences in the Western Mediterranean

Porifera	**Annex Protocol SPA and Biodiversity**
Axinella polypoides Schmidt, 1862	II
Spongia lamella (Schulze, 1879)	III
Spongia officinalis officinalis Linnaeus, 1759	III
Spongia zimocca Schmidt, 1862	III
Cnidaria	
Astroides calycularis (Pallas, 1766)	II

Savalia savaglia Nardo, 1844	II
Corallium rubrum (Linnaeus, 1758)	III
Mollusca	
Charonia lampas lampas (Linnaeus, 1758)	II
Dendropoma petraeum (Monterosato, 1884)	II
Erosaria spurca (Linnaeus, 1758)	II
Lithophaga lithophaga (Linnaeus, 1758)	II
Luria lurida (Linnaeus, 1758)	II
Mitra zonata Marryat, 1818	II
Patella ferruginea Gmelin, 1791	II
Patella nigra (da Costa, 1771)	II
Pholas dactylus Linnaeus, 1758	II
Pinna nobilis Linnaeus, 1758	II
Pinna rudis (Linnaeus, 1758	II
Schilderia achatidea (Gray in G.B. Sowerby II, 1837)	II
Tonna galea (Linnaeus, 1758)	II
Crustacea	
Homarus gammarus (Linnaeus, 1758)	III
Maja squinado (Herbst, 1788)	III
Palinurus elephas (Fabricius, 1787)	III
Scyllarides latus (Latreille, 1803)	III
Scyllarus arctus (Linnaeus, 1758)	III
Echinodermata	
Centrostephanus longispinus (Philippi, 1845)	II
Ophidiaster ophidianus (Lamarck, 1816)	II
Paracentrotus lividus	III

261. Information provided for the Spanish Mediterranean by Marba and Duarte (2010) can inform much of the rest of this subregion (following paragraphs taken from their report). The fauna living on soft bottoms is dominated by polychaeta and echinodermata (Pérès and Picard 1962). In seagrass meadows, polychaeta dominate in biomass and species richness the associated invertebrate community (Luque and Templado 2004). However, amongst the large number of invertebrates inhabiting seagrass meadows, it is worth to mention the mollusk Pinna nobilis, typically growing in Posidonia oceanica and, occasionally, *Cymodocea nodosa* meadows. This mollusk is the largest bivalve growing in the Mediterranean, with shells up to 100 cm long. One third of the shell is buried in the sediment and seagrass rhizomes. The abundance of P. nobilis ranges from 1 to 10 individuals m-2, and some individuals can become older than 35 years (Garcia-March and Márquez-Aliaga 2007). Maërl beds also host a highly diverse invertebrate community. In a maërl bed at the Alicante coast (Spain), about 200 species of invertebrates, mostly belonging to crustacea, mollusca and annelida, have been recorded (Barbera et al 2003).

262. The list of characteristic invertebrates growing on rocky substrates and forming reefs along the Spanish Mediterranean is extensive (Table 2). Amongst them, there are the animal builders of the coralligenous and bioeroders. At the region of Marseilles (France), Hong (1980) identified 124 species

of coralligenous animal builders, being most of them bryozoans (62 %) and serpulid polychaetes (23 %), while cnidarians, molluscs, sponges and crustaceans only accounted for 4 %, 4%, 4 % and 1.6 % of the species. The sponge *Clionia viridis*, the bivalve *Lithophaga litophaga* and several annelids, amongst others, erode the calcareous concretions. The composition of animal assemblages in the coralligenous is diverse and it varies among plant associations, sites and geographical areas. The biomass of invertebrate assemblages of the coralligenous has only been quantified at the region of Marseilles (True 1970). At Marseilles, the biomass of the entire invertebrate assemblage dominated by *Eunicella cavolini*, that included 146 invertebrate species, was 1563 g DW m-2. *E. cavolini* biomass in this assemblage accounted for 304 g DW m-2 (True 1970). At the same region, the assemblage dominated by Paramuricea clavata contained 111 invertebrate species, its total weight was 3175 g DW m-2, and biomass of *P. clavata* was 746 gDW m-2 and that of other cnidaria (*Caryophyllia smithii, Hoplangia durotrix* and *Corallium rubrum*) 462 g DW m-2 (True 1970). At Medes Islands (Spain), the total cnidarian biomass in coralligenous concretions dominated by *P. clavata* was 430 g DW m-2 (Gili and Ballesteros 1991). The biomass of the invertebrate assemblage of red coral at Marseilles, dominated by Corallium rubrum, was 3817 g DW m-2 and encompassed 63 specie (True 1970).

263. The coralligenous community as a whole does not exhibits very pronounced seasonality (Ballesteros 2003). However, the dynamics of most dominant benthic animal species of the coralligenous (e.g. hydrozoans, anthozoans) varies seasonally (Ballesteros 2003). Species of large sponges and cnidaria dominate the circalitoral community developing from 80 m down to the upper bathyal region (250 m- 300 m) of the Spanish Mediterranean (Templado et al 2009). On detritic seabeds at 90-250 m depth the bivalve *Neopycnodonte cochlear* often dominates. Bathyal rocky bottoms of 200 m to 400 m depth, and elevations of the bathyal region, can be colonized by the *Dendrophyllia cornigera* community, which in addition to this coral species it contains several species of sponges, hydrozoa and briozoa (Templado et al 2009).. Bathyal rocky floors can also be colonized by bathial octocoral communities and bathial communities of sponges (Templado et al 2009). The Spanish Mediterranean rocky seafloor deeper than about 300 m can be occupied by relict communities of white corals (Templado et al 2009), mostly of the colonial corals *Lophelia pertusa* and *Madrepora oculata*. However, the presence of white coral communities in the Mediterranean seafloor is poorly documented (ZibroWius 2003).

264. The number of individuals in *Pinna nobilis* populations has been severely reduced, and at present its abundance is low in most *P. oceanica* meadows of the Spanish Mediterranean. *P. nobilis* populations in best conservation status can be found along Almería, Alicante and Balearic Islands coasts. On rocky bottoms and the coralligenous, the mollusc *Lithophaga lithophaga* is also considered an endangered species (Boudouresque et al 1991) although it still abounds (Ballesteros 2003). Harvesting of these species and, for *P. nobilis*, changes in coastline are identified the main threats.

265. Boudouresque et al (1991) also list the sea urchin *Centrostephanus longispinus* as endangered species. The abundance of *Scyllarides latus* (slipper lobster) has sharply declined in many Mediterranean regions due to high fishing pressure on this priced resource. In the Spanish Mediterranean it is more common in the Balearic Islands, where the seawater is the warmest.

266. Colonies of suspension feeders (sponges and gorgonians) in the Northwestern Mediterranean growing above 40 m depth have experienced mass mortality events following heat waves (Garrabou et al 2009). In addition to temperature stress, low food abundance and pathogenic infections during those periods contributed to mass mortality (Coma et al 2009, Bally and Garrabou 2007). Excess of sediment deposition is also an important threat to the filter-feeders of the coralligenous (Templado et al 2009).

267. The extension and conservation status of circalitoral and bathyal communities are little known. Trawling represents the main threat to these communities.

Benthic flora: macroalgae and angiosperms

268. The Mediterranean marine macroflora is estimated to be about 1,000 macroscopic species, five of these being marine phanerogams. It is generally distributed in the shallow areas that constitute less than 10% of the surface area of the Mediterranean. Near the shoreline are *Lithophyllum byssoides* (e.g. *L. Lichenoides*) rims in the medio-littoral stage, *Posidonia oceanica* meadows and Fucal forests (biocenoses with *Cystoseira*) in the infra-littoral, and the coralligenous in the circa-littoral

(Zenetos *et al*., 2002; Boudouresque, 2004). Additional coastal habitats include the Vermetid platforms and the *Neogoniolithon brassica-florida* concretion (Boudouresque, 2004).

269. The *Posidonia oceanica* meadows are considered to be one of the Mediterranean Sea's most important ecosystems; the most extensive meadows in the western subregion can be found in France (Hyères and Giens bays and off the eastern coast of Corsica), Italy (western Sardinia and Sicily especially) and Tunisia, though less extensive meadows can be found scattered across the region. Posidonia and other marine angiosperms form valuable habitats from an ecosystem services perspective; because of this, localized areas have been well studied and mapped (see for instance, Figure 3.6).

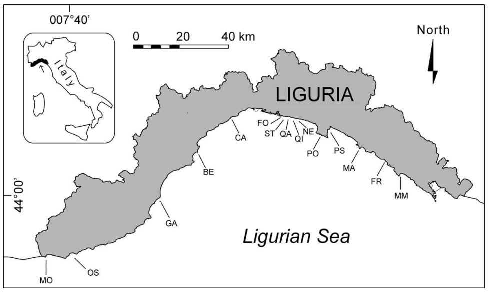


Figure 3.6 Location of 15 Posidonia beds investigated by Montefalcone *et al.*, 2009)

270. The *Cymodocea nodosa* meadows are second most significant seagrass habitat in the Mediterranean after *Posidonia*. Without being strictly endemic to the Mediterranean, the species also lives in the Atlantic. In the western subregion, assemblages are found primarily in Morocco and Algeria.

271. Detailed information is available from the Spanish Mediterranean, due to the 2010 report provided by Malba and Duarte. Four species of seagrasses, i.e. clonal angiosperms that can only complete their life cycles in the sea, colonize the sandy bottoms of the Spanish Mediterranean: *Posidonia oceanica, Cymodocea nodosa, Zostera noltt*i and occasionally *Z. marina*. In shallow waters, *P. oceanica* can also grow on rocky bottoms while *C. nodosa* and *Zostera* sp. can also colonize muddy sediments. Because the high light requirements (Duarte 1991, Gattuso et al 2006), seagrasses are restricted to the infralitoral zone where light irradiance is at least 11 % of sea surface irradiation. *P. oceanica*, the only Mediterranean endemic seagrass, extends between 0 and 45 m depth, the deepest meadows being recorded in the clear waters of the Cabrera Archipelago National Park (Marbà et al 2002). *C. nodosa* grows between 0 and about 30 m depth in areas or patches devoid of *P. oceanica* but it can grow mixed with *Zostera* species (Luque and Templado 2004). Zostera noltii colonizes shallow bottoms of 0-5 m depth whereas *Z. marina* can reach 18 m depth (Luque and Templado 2004).

272. *Posidonia oceanica* is the dominant seagrass and forms lush meadows along the Spanish Mediterranean (including Balearic Islands) down to Cabo de Gata (Almería), the western geographic distribution limit for this species in the European Mediterranean coast. Between Cabo de Gata and Gibraltar Straight *P. oceanica* is only present at some localities, forming isolated patches in shallow waters (Luque and Templado 2004). The westernmost *P. oceanica* population of the Spanish Mediterranean has been recorded at Punta Chullera-Cala Sardina (Luque and Templado 2004). Cabo de Gata also sets the eastern geographic limit of *Zostera marina* penetration from the Atlantic into the European Mediterranean coast (Luque and Templado 2004). While extensive meadows of *Z. marina* are common on the west of this biogeographical barrier, it rarely grows along the rest of the Spanish Mediterranean. Between eastern Cabo de Gata and the Cap de Creus (NE Spain), two small patches *Z. marina* were observed at Cala Jonquet in the early 90's (Costa Brava, Spain, Marbà et al 1996) but they were lost by the end of that decade. *C. nodosa* and *Z. noltii* distribute along the entire Spanish Mediterranean (including Balearic Islands), from Cap de Creus to Gibraltar Straight.

273. The architectural pattern of seagrasses is very similar, but they exhibit a wide repertoire of sizes and growth rates, already evident among those growing in the Spanish Mediterranean coast. *P. oceanica* is one of the planet's biggest and slowest-growing marine angiosperms, with shoots weighing more than 700 mg (Duarte 1991) and rhizome extension rates of 1 – 6 cm yr^{-1} (Marbà and Duarte 1998). The other seagrass species growing in the Spanish Mediterranean have smaller shoots, ranging from 250 mg shoot-1 (*Z. marina*) to 6 mg $shoot^{-1}$ (*Z. noltii*, Duarte 1991) and their rhizomes spread at faster rates, 20-30 cm yr^{-1} for *Z marina*, 10-127 cm yr^{-1} for *Z noltii* and 7-200 cm yr^{-1} for *C nodosa* (Marbà and Duarte 1998). Average shoot life span of these seagrass species ranges from less than 100 days (*Z. noltii*) to more than 4300 days (*P. oceanica*, Marbà et al 2007), although shoots older than 30 yr are present in relatively pristine Spanish Mediterranean meadows (Marbà et al 2002). Similarly, sexual reproductive effort differs across these species. *P. oceanica* produces hermaphrodite inflorescences that annually emerge from less than 3 % of the shoots (Borum et al 2004), although flowering intensity widely fluctuates between years. Massive flowering events (when more than 10 % of the shoots flower) of *P. oceanica* have been observed after extremely warm summers (Díaz-Almela et al 200X). On average, about 10 % of shoots of the other seagrass species annually flower, besides flowers are contained in terminal hermaphrodite inflorescences (*Zostera* sp) or segregated in flowers standing in shoots of male or female clones (*C. nodosa*). The little investment and low success of sexual reproduction, combined with the extremely slow clonal spread of *P oceanica* explains the long colonization (centuries) and recovery time for this species (Duarte 1995). Conversely, the biological characteristics of the other seagrass species present in the Spanish Mediterranean indicate that they would be able to develop, and thus to recover, a meadow in some decades (Duarte 1995) if disturbance triggering losses ceases and seagrass growth conditions are favourable.

274. As important as the angiosperms are for biodiversity and productivity, macroalgae species account for most flora diversity in benthic marine environments. Most autochtonous benthic macroalgae species growing in the Mediterranean Sea colonize rocky bottoms. However, the stoloniferous macroalgae *Caulerpa prolifera*,calcareous rhodophytes that form maërl beds, and free-Peyssonnelia beds, grow on soft bottoms. Macroalgae can grow at water depth where light irradiance is at least 0.02 % of surface irradiance (Gattuso et al 2006). These low light requirements for growth allow macroalgae species in the Western Mediterranean to distribute from 0 m down to 100 m depth (Barbera et al 2003).

275. *Caulerpa prolifera* grows between 0 m and 40 m depth. *Caulerpa prolifera* forms dense meadows, often on muddy areas with long water residence times, such are coastal lagoons, enclosed bays and harbours. It is common along the entire Spanish Mediterranean coasts in shallow areas but it can grow down to 20 m depth (Luque and Templado 2004). *C. prolifera* may grow monospecifically or mixed with seagrasses and other macroalgae species. *C. prolifera* has stolons of 1-2 mm diameter that extend at rates of about 80 cm yr^{-1} (Marbà unpublished data). From the dense networks of stolons, fronds between 1 cm and 25 cm long emerge (Luque and Templado 2004). The biomass of *C. prolifera* meadows exhibits strong seasonality, mostly forced by temperature, and during summer, when it peaks, can be 180 g DW m^{-2} to 280 g DW m^{-2} (Luque and Templado 2004).

276. In Western Mediterranean, maërl and free-Peyssonnelia beds are found in the circalitoral zone, between 40 and 80-100 m depth (Barbera et al 2003, Canals and Ballesteros 1997). Macroalgae diversity in maërl beds is very high, as reflects the 168 macroalgae species reported for one of them located in the area of Alicante (Spanish Mediterranean, Barbera et al 2003). However, *Lithothamnon corallioides, L. valens, Phymatolithon calcareum* and *Peyssonnelia* species account for most of macroalgae abundance (Canals and Ballesteros 1997). These are extremely slow-growing species, the tips of the branches elongating less than 1 mm yr^{-1} (Blake and Maggs 2003). The macroalgae forming these communities in the Balearic Islands contain 2562 g of total carbonate m-2 (Canals and Ballesteros 1997), the largest amount of total carbonate per area standing on marine vegetation.

277. The characteristic macroalgae taxons inhabiting rocky bottoms of the Spanish Mediterranean include habitat structuring species, such those of the genus Cystoseira, large kelps, and the coralligenous algae builders (Templado et al 2009). Most of the species of the genus Cystoseira grow in the Mediterranean Sea. Mediterranean *Cystoseira* spp. form highly prominent canopies and grow in the infralitoral zone, although the densest belts of Cystoseira taxons occupy the shallowest areas of the sublitoral that are exposed to high hydrodynamism. The biomass of Cystoseira populations can be very high. For instance, at sea level a population of *Cystoseira mediterranea* attained a biomass of

1913 g dry mass m−2 (NW Spain, Ballesteros, 1988) and one of *Cystoseira stricta* 1860 gDW m-2 (SE France, Bellan-Santini 1968). In shallow waters the biomass of *Cystoseira caespitosa* was 1090 g dry mass m−2 (1406 g dry mass m−2 if *Cystoseira compressa* is included, Ballesteros, 1990a), that of a community of *Cystoseira crinita* 910 g DW m-2 (SE France, Bellan-Santini 1968). The biomass of Cystoseira species decreases with increasing water depth, but still at 27 m depth the aerial biomass of a *Cystoseira spinosa* population was 454 g DW m−2 (Ballesteros et al 1998) whereas that of *Cystoseira zosteroides* reached 112 g DW m−2 at a depth of 18 m (Ballesteros, 1990b). The biomass of Cystoseira stands fluctuates seasonally, and it peaks in summer.

278. In the Spanish Mediterranean, kelp forests are represented by few species growing in the circalittoral zone. *L. ochroleuca* is restricted the Alboran Sea where it grows down to 60 m depth, and *Laminaria rodriguezi*, a Mediterranean endemic, is present at 50-70 m water depths in areas with very clear waters of Columbretes Islands, Balearic Islands and occasionally in the Murcia region (Templado et al 2009).

279. Coralligenous communities -- biogenic constructions made by calcium carbonate forming organisms, are the second most important hotspot of species biodiversity in the Mediterranean after seagrass meadows (Boudouresque, 2004). These communities have been documented in the western subregion as occurring primarily in Morocco, Algeria, Tunisia, and the Principality of Monaco. *Lithophyllum* rim habitats are common in the northern and central parts of the western Mediterranean, though they are rare in the southern part of the western Mediterranean (Boudouresque, 2004).

280. Coralligenous concretions of the Mediterranean host more than 300 macroalgae species, that 33-48 % of them are them Mediterranean endemics (Ballesteros 2003). Coralline algae are the main builders of the coralligenous (Ballesteros 2003) and they encompass several rodophytes *as Lithophyllum lichenoides, L. byssoides, L. frondosum, L. cabiochae, Mesophyllum alternans, Neogoniolithon brassica-florida*, or *Neogoniolithon mamillosum*, among others (Templado et al 2009). They form sciaphilic communities, growing in dim light conditions that range between 0.05 % and 3 % of surface irradiance (Ballesteros 2003). Hence, they grow on almost vertical walls and deep channels between 20 m and 60 m depth in the North Spanish Mediterranean and between 50 m and 100 m depth in the clear waters of the Balearic Islands (Ballesteros 2003). Relative growth rates of two important coralligenous alga builders growing between 15 and 30 m depth at Medes Islands (N Spanish Mediterranean) ranged between 0.16 month-1 (*M. alternans*) and 0.09 month-1 (*L. frondosum*) and shrinkage rates from 0.09 month-1 (*M. alternans*) and 0.04 month-1 (*L. frondosum*, Garrabou and Ballesteros 2000). These growth rates did not vary seasonally. Coraligenous algal dominated communities are the Mediterranean communities that produce the largest amount of total carbonate per unit of area (464 g total carbonate m-2 yr-1, Canals and Ballesteros 1997). Coralligenous algal dominated communities contain large amounts of total carbonate, that in the Balearic Islands it has been estimated to be 1585 g of total carbonate m-2 (Canals and Ballesteros 1997), In addition to the coralline algae, the clorophyte *Halimeda tuna* can also contribuye significantly to the calcium carbonate production of shallow coralligenous concretions (Ballesteros 2003). Annual organic matter and calcium carbonate production by *H. tuna* growing at 18 m depth in the North Western Mediterranean has been estimated to be 680 g DW m-2 yr-1, equivalent to 114 g organic carbon m-2 yr-1 and 314 g Ca C03 m-2 yr-1 (Ballesteros 2003), which is similar to the calcium carbonate production of coralline algae (Ballesteros 2003). Growth of *H. tuna* exhibits strong seasonality and it mainly occurs in summer (Ballesteros 2003).

281. Sharp reduction of macroalgae species structuring habitats in the Western Mediterranean have been reported for some Fucales. Five species of Cystoseira (*Cystoseira crinita, Cystoseira barbata, Cystoseira foeniculacea f. tenuiramosa, Cystoseira spinosa, Cystoseira spinosa var. compressa*) and two Sargassum species (*Sargassum hornschuchii* and *Sargassum vulgare*), that at the end of the 19^{th} century grew at Albères Coast (France, NW Mediterranean), have become extinct at that region (Thibaut et al 2005). Also, *C. mediterranea*, a species that at the end of 19^{th} century formed a continuous belt along the shores of the Albères coast, is currently restricted to few sites along that coast (Thibaut et al 2005). Along the Spanish Mediterranean, *Cystoseira mediterranea* is only found in relatively undisturbed sites, and its presence is used as an indicator of good coastal quality of water masses for the European Water Framework Directive (Pinedo et al 2007). Overgrazing by sea urchins, outcompetition by mussels, habitat destruction, and pollution have been identified as the major threats to these populations of Fucales living in shallow waters, while the increase in water

turbidity, and, probably, pollution and net fishing are the main causes of *Cystoseira* declines in deep-water (Thibaut et al 2005).

282. Maërl beds have been also reported to be strongly threatened by human activity. Recent studies on the fishing intensity and area swept by fishing gear, indicate that most sedimentary benthic systems on the continental shelf of Europe have been modified by fishing activities in the last 100 years (Barbera et al 2003). Otter trawling can cause physical and biological degradation of benthic habitats (Sánchez-Lizaso *et al.*, 1990) and in the Spanish Mediterranean is carried out illegally in some inshore waters, including maerl beds off Alicante (Bordehore *et al.*, 2000) and Mallorca (Massutí *et al.*, 1996). However, the degree to which maerl beds are fished is unknown in most areas (Barbera et al 2003) preventing estimations of the magnitude of losses of key species.

283. Amongst the macroalgae that live in the coralligenous, Boudouresque et al (1980) identifies 8 that can be considered endangered: *Chondrymenia lobata, Halarachnion ligulatum, Halymenia trigona, Platoma cyclocolpa, Nemastoma dichotomum, Ptilophora mediterranea, Schizymenia dubyi* and *Laminaria rodriguezii*. In addition, Ballesteros (2003) adds the following ones to the list: *Aeodes marginata, Sphaerococcus rhizophylloides, Schmitzia naepolitana, Ptilocladiopsis horrida, Microcladia glandulosa, Rodriguezella bornetii, R. pinnata and Lomentaria subdichotoma.* Pollution and increased sedimentation rates are the main threats to these species. *L. rodriguezii* it is now mainly restricted to the coralligenous since it has almost disappeared from maërl beds, the best habitat for its development, due to trawling activities (Ballesteros 2003).

3.3.3 Marine mammals, reptiles and seabirds

Marine Mammals

284. The western subregion supports the richest array of marine mammal, sea turtle, and seabird species of the entire Mediterranean Basin. In part this is because the proximity to the Atlantic means some incursions of Atlantic species into the western portion of the Basin – but it is also due to the subregion having seasonal frontal and upwelling systems that provide nutrients to support an extended food web. The Pelagos Sanctuary is one such location, containing habitat suitable for the breeding and feeding needs of the entire complement of cetacean species regularly found in the Mediterranean Sea (Notarbartolo di Sciara, 1994; Beaubrun, 1995). The two most abundant species in the Sanctuary, the fin whales and striped dolphins, accounted for over 80% of all cetacean sightings made during summer cruises conducted in the area between 1986 and 1989 (Notarbartolo di Sciara, 1994). About 3,500 fin whales are found in the western Mediterranean, most of which concentrate in the Corsican-Ligurian-Provençal Basin in summer to feed on krill (Forcada *et al.,* 1996), although whales can be observed there year-round (Notarbartolo di Sciara *et al.,* 2003). Striped dolphins are the most abundant cetaceans throughout the Mediterranean offshore waters (Aguilar, 2000); in the Sanctuary their numbers are 20,000-30,000 (Forcada *et al.,* 1995), and accounted for 60% of all cetacean sightings in 1986-89 (Notarbartolo di Sciara, 1994).

285. The remaining species are also regular components of the Sanctuary's cetacean fauna; these include deep-diving teutophagous odontocetes such as sperm whales *Physeter macrocephalus*, long-finned pilot whales *Globicephala melas*, and Risso's dolphins *Grampus griseus*, frequenting both offshore and slope waters (Di-Méglio *et al.,* 1999; Gordon *et al.,* 2000), and Cuvier's beaked whales *Ziphius cavirostris*, favouring specific slope areas overlying submarine canyons (Nani *et al.,* 1999); now rare and endangered short-beaked common dolphins *Delphinus delphis*, found both in coastal and offshore waters particularly in the southern part of the Sanctuary (Bearzi *et al.,* 2003); and predominantly coastal bottlenose dolphins *Tursiops truncatus*, frequenting mostly the shelf areas surrounding Corsica, northern Sardinia, the Tuscan Archipelago, and continental France (Nuti *et al.,* 2004; Ripoll *et al.,* 2004). The only other marine mammal found in the Mediterranean, the monk seal *Monachus monachus*, was extirpated from the Sanctuary area in the mid 20th century (Notarbartolo di Sciara and Demma, 1997), but could theoretically re-colonise its shores if its population numbers were to increase, and human encroachment of its critical breeding habitat were lowered to levels acceptable to this shy mammal.

286. The Spanish Mediterranean is also a key area for marine mammal, sea turtle, and seabird species. The Alboran Sea and Balearic Islands are particularly important for aging and staging areas for marine mammal species and, to a lesser extent, sea turtles (primarily loggerhead turtles, though occasional sightings of leatherback turtles confirms that members of the Atlantic population occasionally enter the Mediterranean through the Straits of Gibraltar). Further information on these megafauna in the Spanish portion of the western Mediterranean, as provided by Marba and Duarte (2010) follows, with information derived from Ministerio de Medio Ambiente, y Medio Rural y Marino (www.marm.es).

287. The fin whale *Balaenoptera physalus* is relatively abundant in the Mediterranean Sea, concentrating in upwelling areas such are the Gulf of Lions and the Liguran Sea. There are no robust estimates of population size of this species in the Mediterranean but it could range between 1000 and 3000 individuals. The main threat is hunting for commercial explotation and collision with ships in areas with intense maritime trafic. The humpback whale *Megaptera novaengliae* is a rare species in the Mediterranean, and when observed probably they are wandering individuals from Atlantic population.

288. The sperm whale *Physeter macrocephalus* is relatively frequent in the Spanish Mediterranean, particularly in productive waters although it can colonize any water mass where food availability suffices. Commercial exploitation has impacted intensively the large global stocks of this species. Several individuals have been accidentally catched by fishing nets in the Mediterranean, but it is unknown how much it enhances mortality at population level.

289. *Stenella coeruleoalba* is the most abundant marine mammal in Spanish waters, both in the Atlantic and Mediterranean coasts. It is a pelagic species that inhabits waters with sea temperature ranging between 18 and 25 ^{O}C, although in the Mediterranean it is abundant in the continental shelf deeper than 100-200 m or at about 10 nautical miles away from the coastline. In 1990, an important but undefined part of the population died as a consequence of an epizootia. It has been suggested that the population of this species in the Western Mediterranean has been expanding for the last decades, but this trend has not been quantified.

290. The bottlenose dolphin *Tursiops truncatus* is present along the entire Spanish Mediterranean, but the distribution of the population is fragmented along the region.Its population size along the Spanish Mediterranean is unknown, but during the last decades it has experienced strong declines, particularly in the areas of Catalunya and Comunidad Valencia, probably due to accidental fishing, pollution and degradation of coastal ecosystems. The population in the Balearic Islands, with 400-800 individuals, ranks amongst the most abundant in the Spanish Mediterranean.

291. The common dolphin, *Delphinus delphis*, used to be present along the entire Spanish Mediterraean (including the Balearic Islands) coast but its distribution range along this coast has been reduced and currently it is only found south of the Nao Cape. This distribution change is not restricted to the Spanish Mediterranean since at present it is very rare in the French Mediterranean and North Italian coasts. The pilot whale, *Globicephala melas*, is relatively common along the coast of Almería, Granada, and Murcia region. Its abundance decreases along Valencia region, Catalunya and the Balearic Islands. Genetic studies revealed that Atlantic and Mediterranean populations are different, and lower genetic variability in the Mediterranean one. In the Spanish Mediterranean, the highest encounter rate occurs in the Alboran Sea. Above Vera Gulf, the number of individual observations decreases. The encounter rates of groups and individuals of this species in these regions are stable, although with some fluctuations between 1992 and 2006 and an increase during 2007 and 2008.

292. The killer whale *Orcinus orca* lives in coastal and open waters and has been observed several times near the Balearic Islands but it is not abundant in Spanish waters. Another rare species is *Grampus griseus,* observed in the north of Mallorca and Menorca (Balearic Islands), south of Gulf of Lions and from Alboran Sea to Gata Cape and Vera Gulf (Almería). Overall abundance estimates for this species are lacking, and the distribution in the western Mediterranean has not been ascertained.

293. The monk seal *Monachus monachus* also inhabits the western Mediterranean, but is rare. The global historical distribution of this species encompasses the coasts of the whole Mediterranean and in the Atlantic the coast of north Africa and Portugal. In 1991 there was only one individual living at Chafarinas Islands. Until 1960-65, there were small groups living at Gata Cape and other small groups

in the Balearic Islands. Since then, it has been observed occasionally in the Balearic Islands (Ministerio de Medio Ambiente, y Medio Rural y Marino, www.marm.es). The main threats to this species are the hunting by humans to prevent competition with fisheries, accidental capture by fishing nets, coastal habitat destruction, pollution, population fragmentation and size.

Sea Turtles

294. The species of sea turtles present in Mediterranean Spanish waters are *Caretta caretta, Chelonia mydas, Dermochelys coriacea* and occasionally *Lepidochelys kempii* (Ministerio de Medio Ambiente, y Medio Rural y Marino, Atlas y Libro Rojo de los Anfibios y Reptiles de España). *Caretta caretta* is the most common sea turtle in the Spanish waters. In Spain, it is more common in the Mediterranean, particularly in the regions of the Balearic Island and Alborán Sea, than in the Atlantic. Individuals are often observed in open waters of the Mediterranean mostly in spring and beginning of autumn. The Mediterranean population shows higher stability in terms of annual nests than the Atlantic one but it is highly threatened on beaches (due to tourism and pollution) and open sea (fisheries, pollution, maritime traffic). In 1992 sea turtles were considered extirpated in the Spanish Mediterranean (Blanco and González 1992), but subsequently some individuals were recorded (Delta del Ebro, Almería).

295. The green sea turtle *Chelonia mydas* is a rare species in the Spanish Mediterranean. Individuals have been observed in the Chafarinas Islands, Valencia and Murcia regions, Balearic Islands and the north of Alboran Sea. The main threat for this species is the human consumption of its meat, eggs and fat. The exploitation of this species between 1930 y 1982 caused major declines of the Mediterranean reproductive stocks. Moreover, the loss of seagrass meadows, feeding grounds for adult individuals, may have contributed to the decline of this sea turtle species in the Mediterranean. The occupancy of Mediterranean beaches by humans is threatening the reproduction of this species. The small size of the population, pollution and accidental fishing are also identified as threats to this species in the Mediterranean.

296. The leatherback turtle *Dermochelys coriacea* is present, but no records of nesting in the Basin occur. It is present in the entire Spanish Mediterranean but it is more frequent observed South Balearic Islands, Alboran Sea, Ceuta and Melilla. The Kemp's ridely turtle, *Lepidochelys kempii*, is an even more rare species in the Spanish Mediterranean, where it has been cited only once in Valencia (October of 2001, J. TOMÁS, com. pers.).

297. The Pelagos Marine Sanctuary and surrounding waters also support significant numbers of loggerhead turtles, as well as occasional leatherback turtles (G. Lauriano, pers. comm.).

Seabirds

298. The western Mediterranean is a critically important seabird area as well. Of the list of Mediterranean seabird species of conservation concern, many species are resident or stage in this subregion (Table 3.4).

Table 3.4 Seabird species and status in the protocol

Species	**Annex Protocol SPA and Biodiversity**
Ceryle r. rudis (Linnaeus, 1758)	II
Charadrius alexandrinus (Linnaeus, 1758)	II
Charadrius leschenaultii columbinus (Lesson, 1826)	II
Larus genei (Breme, 1839)	II
Larus melanocephalus (Temminck, 1820)	II
Puffinus mauretanicus (Lowe, PR, 1921)	II

Sterna caspia (Pallas, 1770)	II
Sterna nilotica (Gmelin, JF, 1789)	II
Calonectris diomedea (Scopoli, 1769)	II
*Falco eleonorae (*Géné, 1834)	II
Hydrobates pelagicus (Linnaeus, 1758)	II
*Larus audouinii (*Payraudeau, 1826)	II
*Numenius tenuirostris (*Viellot, 1817)	II
Pandion haliaetus (Linnaeus, 1758)	II
Pelecanus onocrotalus Linnaeus, 1758	II
Phalacrocorax aristotelis (Linnaeus, 1761)	II
Phoenicopterus ruber (roseus) Linnaeus, 1758	II
Puffinus puffinus yelkouan (Brünnich, 1764)	II
Sterna albifrons Pallas, 1764	II
Sterna bengalensis Lesson, 1831	II
Sterna sandvicensis Latham, 1878	II

299. Seabird ecologists have flagged five large areas in the western Mediterranean as priorities for seabird conservation, including the Alboran Sea, waters surrounding the Balearic Islands, the Catalan coastal and offshore area, Gulf of Lions, and the greater Ligurian (Pelagos Marine Sanctuary) (C. Carboneras, pers. comm.).

300. Beyond these discreet areas, the Spanish Mediterranean hosts probably the most diverse community of breeding and migratory seabirds in Europe (Arcos et al 2009). It is also at present the only country in which all the three endemic species of seabirds nest (Marba and Duarte, 2010).

301. Ten species of gulls and terns place their main colonies along the Spanish coasts, and 4 species of procellariformes breed in the Balearic Islands and small islands near the Spanish mainland (Arcos et al 2009). Among these species, the Balearic shearwater *Puffinus muritanicus*, the Yelkouan shearwater *Puffinus yelkouan* and the Audouin's gull *Larus audouinii* are endemic of the Mediterranean basin. With a population of c. 2000 breeding pairs, the Balearic shearwater is the most threatened seabird of the Mediterranean region and it breeds exclusively along the coasts of the Balearic archipelago. The distribution of the closely related Yelkouan shearwater ranges from the island of Menorca, the only site known in Spain, to the eastern part of the Mediterranean Sea. Its populations are not considered as vulnerable, but the number of breeding pairs had recently declined. The Spanish coast hosts c. 90 % of reproductive population of Audouin's gull. The largest colony is located at the estuary of the river Ebro along the eastern coast of the country, but other breeding sites have been found along Valencia region, the island of Majorca, Alborán and the archipelago of Chafarinas. Also, the Cory's shearwater *Calonectris diomedea* breeds in large numbers in the Balearic and Chafarinas islands. The 40 % of the Mediterranean reproductive population of petrel *Hydrobates pelagycus* is distributed along the Spanish Mediterranean, mostly in the islands of Ibiza and Formentera and on the small islands off the coast of Alicante and Murcia. The Common shag *Phalacrocorax aristotelis* also has important populations along the south coast of Spain (Girona, Alicante y Murcia areas) and in the islands of the Balearic archipelago. Terns, such as the Little tern *Sterna albifrons,* the Common tern *Sterna hirundo,* The Sándwich tern *Thalasseus sandviensis* and the Gull-billed tern *Gelochelidon nilotica* are mainly concentrated on the wetlands of the Ebro Delta, on the region of Valencia and along the southern coast of Spain (Murcia and Alicante). Their populations are currently declining due to a rapid loss of wetlands along the Mediterranean coast (Martí & Del Moral, 2003). In contrast, the Spanish population of the Yellow Legged gull *Larus cachinnans* is probably the largest in the world (Martí & Del Moral, 2003), with breeding colonies along the entire coast of Spain and islands.

302. Large populations of wintering species are also present along the Mediterranean coast. Some of them, such as the Mediterranean gull *Larus melanocephalus,* may have the main global sites for wintering located in eastern Mediterranean coast of Spain (Arcos et al 2009).

303. With the exception of few species, such as the Yellow legged gull, almost all breeding seabirds of the Spanish Mediterranean are threatened or considered vulnerable. Most species of these seabirds are listed in the Annex I of the EU Bird Directive due to their small population size and/or sharp declines in abundance.

3.3.4 Exotic, non-indigenous and invasive species

304. Rocky areas and soft-bottom communities in this region are productive and diverse, yet are beginning to be impacted by human activity, in direct and indirect ways. According to Badalmenti *et al.*, 2008, catastrophic mortality events of populations of sessile invertebrates, such as several gorgonians and sponges, have been documented in the Ligurian Sea (Cerrano *et al*., 2000; Rodolfo-Metalpa *et al*., 2000, 2005, 2006), but they have likely also occurred in other Italian seas. Warm episodes recorded in the late 1990s and early 2000 have likely resulted in increasing population sizes of warm-water Mediterranean species and widespread colonization of invasive species of Atlantic and Red Sea origin (e.g. *Caulerpa racemosa, Caulerpa taxifolia, Percnon gibbesi, Cerithium scabridum* among several others).

305. In addition to these well-documented expansions/invasions, an intriguing observation is the existence of extensive mussel beds, mainly composed of the Eritrean mussel *Brachidontes pharaonis* on many vermetid platforms, *Dendropoma petraeum*, of north-western Sicily (Milazzo unpublished data). *B. pharaonis* is common in the Levantine Basin, where it entered 6 years after the opening of the Suez Canal. This species was found in Sicily in the late 1960s (Di Geronimo, 1971), successively spreading to some hyperhaline habitats (saltwork systems) in the late 1980s (Gianguzza *et al*., 1998; Sarà *et al*., 2006). It now has colonised several vermetid platforms along the Sicilian coast (Badalmenti *et al.*, 2008).

306. It seems reasonable to suppose that the northern extension (Ligurian- Tyrrhenian system) of the 15 degree isotherm may cause an increase in the range of thermophilic species, including those species of tropical Atlantic origin (e.g., *Sparisoma cretense*) that penetrated into the Mediterranean Sea during warmer interglacial periods to remain confined in the southeastern sector with subsequent cooling (Bianchi, 2007). In their shift northwards these species will come into contact with the flora/fauna of the north-western Mediterranean which is very different from the rest of the Mediterranean. In fact here are found relict populations with affinity for cold waters (e.g. the molluscs *Buccinum humphreysianum*, *Colus gracilis*, *Natica catena* and the fish *Pomatoschistus pictus*, *P. microps*, *P. minutus*), which in the Atlantic are generally not found south of the Gulf of Biscay, as well as numerous endemics.

3.3.5 Fish populations including abundance, spatial distribution

307. The Mediterranean fish community is dominated by small pelagics, where sardine and anchovy prevailed in terms of fish biomasses and catches (Coll *et al.* 2006). Detritivores are also important components, particularly in the demersal region. Pelagic landings have been declining since 1994 coupled with a decrease of pelagic biomass (Coll *et al.* 2006). Analyses for the causes of variation in landings in the waters surrounding the Ebro River continental shelf (north-western Mediterranean) provided evidence for a strong effect of riverine inputs and wind mixing on the productivity of small pelagic fish, dominated by anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*)(Lloret *et al.* 2004). Moreover, there has been a significant decline in the mean trophic level of Mediterranean landings (by ~0.15 Trophic Levels over 26 years, Pinnegar *et al.* 2003). However, this decline is suggested to be almost entirely a result of increased landings of bivalve molluscs from mariculture and not due to changes in landings from capture fisheries, which has not changed significantly since 1973 (Pinnegar *et al.* 2003).

308. Since 1981, cage culture of high trophic level species such as sea bass (*Dicentrarchus labrax*) and seabream (*Sparus aurata*) has become increasingly important.

309. In the western Mediterranean basin (1950–2003), a significant positive relationship was found between round sardinella landings and temperature anomalies (Sabatés *et al.* 2006). The abundance of round sardinella in the two warmest and southernmost areas was positively and significantly correlated with sea surface temperature registered during the start of gonad maturation the previous year (Sabatés *et al.* 2006). There has been a marked increase in larval abundance during the last decades and the present appearance of larvae in the northernmost study areas, where they did not occur 20 years ago. This indicates the successful reproduction of round sardinella in the northern part of the Mediterranean, where the species has expanded, confirming its establishment in the area with seawater warming (Sabatés *et al.* 2006)

310. The red shrimp (*Aristeus antennatus*) is one of the most important resources of bottom trawling in the Spanish Mediterranean. It is captured on the slope between depths of 400 to 800 m and despite a relatively small catch, it contributes importantly, up to 30%, to the total earnings of the fishery. The catches increased greatly from 1948 to 1997, but the catches have been declining in the last five years along with a decline in mean size (Carbonell *et al.* 1999), providing evidence of overexploitation of this fish species.

311. Overexploitation is not only a consequence of pressure from commercial fishing, but also from the growing pressure from - poorly regulated - recreational fisheries. A study in the Island of Majorca showed that 5.14% of the population are engaged in recreational fishing, with a sizeable impact on the coastal fauna (Morales-Nin *et al.* 2005). Annual catches by recreational fisheries represent 31% of production at trophic level 4, which raises concern about sustainable exploitation in the recreational fishery (Morales-Nin *et al.* 2005).

3.4 Habitat classification and known distribution of habitats

312. *Posidonia oceanica* meadows rank amongst the most threatened ecosystems on Earth (Duarte et al 2008), and this information on the distribution and status of these habitats is more readily available than for any other habitat type. Since the 1980s, 102 of a total of 176 meadows reported in the Mediterranean basin have suffered a decline in area and/or abundance of shoots, exceeding 50 % in 17 % of the meadows (Marbà 2009). Annual monitoring of shoot density in permanent plots distributed across 40 Spanish Mediterranean *P. oceanica* meadows revealed that during the current decade 67% of the meadows have suffered net losses of shoot density. Overall studied meadows, the recent net rate of change in shoot density was -5 % year $^{-1}$, revealing a general trend towards decline (Marbà et al 2005, Marbà 2009). These losses were observed in seagrass meadows situated not only in coastal areas experiencing strong anthropogenic pressure, but also in protected areas like the Cabrera Archipelago National Park (Balearic Islands), where measures to conserve the marine and terrestrial ecosystems have been in force since 1991 (Marbà 2009). The major threats to *P. oceanica* meadows are eutrophication, mechanical damage, burial and erosion and global warming.

313. These seagrass meadows are key habitats in the Mediterranean as they provide important services to coastal areas, such are carbon sequestration, support of biodiversity and fisheries productivity, maintenance of water transparency, stabilisation of sediments and prevention of coastal erosion. Their extent along the western Mediterranean has declined for several decades, and shoot density is currently thinning in places such as the Spanish coast, where areal extent has been tracked (see Figure 3.7). The major threats to seagrass meadows include eutrophication, coastal construction and dredging, but biological invasions, in particular those by *Caulerpa racemosa* and *Lophocladia lallemandii*, are emerging threats.

314. Information about distribution and conservation status of other vulnerable marine ecosystems, habitats and species in the western Mediterranean is scarce, as noted by Marba and Duarte, 2010, among others. In European states, efforts to fill this gap of knowledge are being conducted within the Natura 2000 Network. However, the Natura 2000 Network does not extend to all vulnerable marine habitats and species.

315. The Regional Activity Center for Specially Protected Areas (UNEP/MAP – SPA/RAC) has drawn up a reference list of major types of benthic habitat, the bulk of which is represented, to some degree in the western subregion. This list is shown in Table 3.5 below. In addition, SAP BIO is committed to making a complete inventory of Mediterranean habitats (benthic and other). However, at the time of this initial assessment, no comprehensive mapping of known benthic, or pelagic, habitats had been completed.

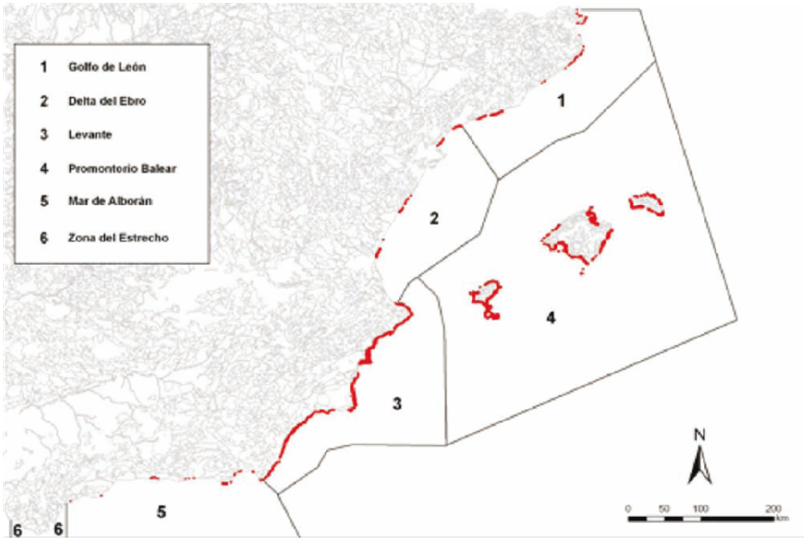


Figure 3.7 Distribution of Posidonia meadows along the coast of Spain (Marba and Duarte, 2010)

Table 3.5 The benthic habitats types, including deep sea habitats,being considered in the SAP BIO (Cebrian 2009)

I. SUPRALITTORAL
I. 1. MUDS
I. 1. 1. Biocenosis of beaches with slowly-drying wracks under glassworts
I. 2. SANDS
I. 2. 1. Biocenosis of supralittoral sands
I. 3. STONES AND PEBBLES
I. 3. 1. Biocenosis of slowly drying wracks
I. 4. HARD BEDS AND ROCKS
I. 4. 1. Biocenosis of supralittoral rock
II. MEDIOLITTORAL
II. 1. MUDS, SANDY MUDS AND SANDS
II. 1. 1. Biocenosis of muddy sands and muds
II. 2. SANDS
II. 2. 1. Biocenosis of mediolittoral sands
II. 3. STONES AND PEBBLES
II. 3. 1. Biocenosis of mediolittoral coarse detritic bottoms
II. 4. HARD BEDS AND ROCKS
II. 4. 1. Biocenosis of the upper mediolittoral rock
II. 4. 2. Biocenosis of the lower mediolittoral rock
II. 4. 3. Mediolittoral caves
II. 4. 3. 1. Association with *Phymatolithon lenormandii* and *Hildenbrandia rubra*
III. INFRALITTORAL
III. 1. SANDY MUDS, SANDS, GRAVELS AND ROCKS IN EURYHALINE AND EURYTHERMAL ENVIRONMENT
III. 1. 1. Euryhaline and eurythermal biocenosis
III. 2. FINE SANDS WITH MORE OR LESS MUD

III. 2. 1. Biocenosis of fine sands in very shallow waters
III. 2. 2. Biocenosis of well sorted fine sands
III. 2. 3. Biocenosis of superficial muddy sands in sheltered waters
III. 3. COARSE SANDS WITH MORE OR LESS MUD
III. 3. 1. Biocenosis of coarse sands and fine gravels mixed by the waves
III. 3. 2. Biocenosis of coarse sands and fine gravels under the influence of bottom currents
III. 4. STONES AND PEBBLES
III. 4. 1. Biocenosis of infralittoral pebbles
III. 5. POSIDONIA OCEANICA MEADOWS
III. 5. 1. Posidonia oceanica meadows (= Association with Posidonia oceanica)
III. 6. HARD BEDS AND ROCKS
III. 6. 1. Biocenosis of infralittoral algae
IV. CIRCALITTORAL
IV. 1. MUDS
IV. 1. 1. Biocenosis of coastal terrigenous muds
IV. 2. SANDS
IV. 2. 1. Biocenosis of the muddy detritic bottom
IV. 2. 2 Biocenosis the coastal detritic bottom
IV. 2. 3. Biocenosis of shelf-edge detritic bottom
IV. 2. 4. Biocenosis of coarse sands and fine gravels under the influence of bottom currents
IV. 3. HARD BEDS AND ROCKS
IV. 3. 1. Coralligenous biocenosis
IV.3. 2. Semi-dark caves (also in enclave in upper stages)
IV. 3. 2. 1. Facies with Parazoanthus axinellae
IV. 3. 2. 2. Facies with Corallium rubrum
IV. 3. 2. 3. Facies with Leptosammia pruvoti
IV. 3. 3. Biocenosis of shelf-edge rock
V. BATHYAL
V. 1. MUDS
V. 1. 1. Biocenosis of bathyal muds
V. 1. 1. 1. Facies of sandy muds with Thenea muricata
V. 1. 1. 2. Facies of fluid muds with Brissopsis lyrifera
V. 1. 1. 3. Facies soft muds with Funiculina quadrangularis and Apporhais seressianus
V. 1. 1. 4. Facies of compact muds with Isidella elongata
V. 1. 1. 5. Facies with Pheronema grayi
V. 2. SANDS
V. 2. 1. Biocenosis of bathyal detritic sands with Grypheus vitreus
V. 3. HARD BEDS AND ROCKS
V. 3. 1. Biocenosis of deep sea corals
V. 3. 2. Caves and ducts in total darkness (in enclave in the upper stages)
VI. ABYSSAL
VI. 1. MUDS
VI. 1. 1. Biocenosis of abyssal muds

316. This List, dating back to 2002, is not fully exhaustive with regard to the open seas and the deep seas domain. It is, however, the only one adopted so far for the Mediterranean region by the Parties to the SPA/BD Protocol.

3.5 Pressures and impacts

<u>3.5.1 Contamination by hazardous substances</u>

317. The northwestern basin of the Mediterranean is affected by intense human activities that can cause chemical contamination, degradation and risk of serious harm in the marine and coastal areas (EEA, 1999). The coast is particularly affected because of maritime traffic, absence of tides, the importance of the maritime routes and the oil related industries present all around the basin.

Urbanization has experienced significant growth particularly along the coastal strip, to serve the population for permanent and temporary, with related changes in the quality of the environment.

318. Highly developed industrial countries in the North are mainly affected with a striking contrast with non-urbanized areas of the south shores. In the future, coastal areas should be facing even greater pressure and a multi-disciplinary approach should be adopted in studies of distribution and flows of chemical contaminants, since the behaviour and fates of anthropogenic compounds are influenced by the dynamics of major biogeochemical cycles (Cossa *et al.* 2009). The evaluation of national plans and reports on "hot spots" and the identification of sources of pollution enable to understand the nature and levels of chemical contamination along the coasts of the western basin of the Mediterranean.

319. Although the contaminants are usually found at coastal waters, they also might be detected in certain areas of the continental shelf and adjacent canyons. This is particularly important in NW Mediterranean Sea where the continental shelf is very narrow and the number of coastal canyons important. However, this kind of pollution is not well studies yet. On a global scale and in the context of the management and protection of environmental quality from terrestrial inputs, it is necessary to take into account the different compartments of a continuum watershed-coastal strip, canyons and continental slope - abyssal plain and the characteristics of the deep-sea environment. Occasional discharges during floods may play an important role in transporting sediment to continental shelf and through the canyons to the deep sea plains (Bourrin et al., 2008). Furthermore, industrial solid wastes (such as red mud residues from aluminium manufacturing) are deposited on the continental shelf (Galgani et al., 2006; Dauvin, 2010) and may also be transported, together with other sedimementary deposits, to deeper marine areas carried by turbidity currents. Along deep river beds (Var, Rhône, Ebro), which sometimes cover long distances of several tens of kilometres (Mulder et al, 2003), hyperpycnal flows are transporting particulate matter to the deep-sea floor. These flows are characterized by sudden increase of current velocity and downward particle fluxes that can reach up to 600 g m^{-2} d^{-1} of particles and 3.1 g m^{-2} d^{-1} in terms of organic carbon. Canyons are active for material transport and supply of organic matter and probably contaminants to deep sea (Khripounoff et a., 2009). These violent turbidity currents are common in the western basin due to reduced adjacent shelves that facilitates the supply and transport of sediment. For example, significant increases in levels of trace metals were detected in sediment cores in the upper canyon of Blanes (Palanques et al., 2008). The metal enrichment occurred during the 20th century are correlated with periods of increased population and industrial activities in the adjacent region. Deeper in the canyon at 1370 m depth, no metal enrichment was detected, probably due to the dispersion of particles and dilution with uncontaminated sediment. However, studies in deep sea sediments show that in some areas of Mediterranean, contamination does not affect just the coastal and continental shelf, but also the side of the continental slope sediments, transported through submarine canyons. On the bathyal plain, the isotopic signatures of industrial discharges have shown transport of contaminants in the direction of the general circulation over distances of several hundred miles.

Localized Pollutants

320. For Italy (UNEP/MAP, NDA Italy, 2005), even with objectives of reduction of almost total input by 2025 and the closure of landfills, the most consistent sources remains linked to industries and urbanization in Genoa, La Spezia, Livorno-Rosignano, Piombino, Bagnoli-Napoli and Palermo. Sources are varied but still responsible for contributions of major pollutants (metals, hydrocarbons, PCBs and insecticides). In some areas, some pollutants are more specific such as metals in SW Sardinia, hydrocarbons and nutrients in Porto Torres, Chromium at Cogoleto Stopani (Genoa) or nitrogen oxides in Piombino. Similarly the Italian rivers of the western basin (Arno, Tevere, Salento rivers) are described as sources of organic matter but also pollutants. National sensitive areas (Orbetello) are also affected although mostly related to transitional waters.

321. Because the principality of Monaco has developed a rational management of waste, recovery of industrial and wastewater treatment including specific processes, it is not an area heavily affected by pollution (UNEP/MAP, NAP Monaco, 2005).

322. In the case of France (UNEP/MAP, NAP France, 2006), defined sources of pollution and "hot spots" are primarily located in the south-eastern coast of the French Mediterranean. They cover the cities of Marseilles-Fos (municipal waste, industrial inputs, and port activity), Toulon (military and

commercial harbor) and in a lesser extent, the area of Cannes-Nice (highly urbanized area, light industry, marinas). Sources of specific contaminants sources such as the industrial waste from Gardanne end up deep in the canyons as do, to a lesser extent, asbestos residues dumped in the past in the western part of Cap Corsica (Galgani *et al.*, 2006). The Rhone and smaller rivers such as Var and Argens (Frejus) have significant inputs of contaminants. Finally areas of high sensitivity are also concerning the transition waters such as many coastal lagoons, but also nurseries in the Gulf of Lions.

323. Spain has identified 7 key priority areas in terms of pollution and two sensitive spots in the western basin (UNEP/MAP, NAP Spain, 2005). These are the port of Barcelona and the Llobregat in Catalonia, Tarragona –Vila seca coastal zone, the region of Castellon, Carthagena-Valle Escombreras- Port man (port operations, mining), Carboneras-Villaricos (province of Almeria, desalinisation plant, industrial and urban effluents), the region of Motril (iron mining) and the bay of Algeciras (petrochemical industries). Sensitive areas are represented by the Mar Menor lagoon and Ebro estuary, the latter being the most consistent in terms of contributions to pollution of coastline.

324. In Morocco, with a reduced population, an average low rainfall (300 - 500 mm / year), 14 oueds with only 2 having impacted coastal areas of more than 1 000 km2, the sources of marine pollution are limited to urban (Tangier-Tetouan, Al Hoceima, Nador / Melilla) and industrial (Tangier-Tetouan, Nador, Oujda) areas. Chemical and paper pulps in the west and steel and food industry in the east are the main sources of heavy metals. Discharges of sewage are the main sources of water pollution, also through the coastal oueds (oueds Moghogha, Martil, Lihoudi) enriched in Nickel, Arsenic, Chromium and Mercury. Cities have only basic infrastructure and reduced treatment (Nador, Al Hoceima) and wastewaters and stormwaters are discharged directly into the marine environment. There is no landfill and leaching often transport pollutants to the (Al Hoceima). The development of intensive agriculture and disinfection involve the consumption of significant quantities of pesticides. Old Pesticide stocks are limited to a few tonnes in the west. In recent years, Moroccan beaches have been subjected to tourism. Because of the proximity of the Straits of Gibraltar and nearby waterways, maritime transport can have significant impacts on the coast and its resources including risks related transportation of hazardous materials or oil spills. The city of Tangier and its industrial activities is a major source of pollutants that may affect the western basin. The elimination of old stocks of pesticides, improved control pollution levels, the rationalized program for effluents treatment and the recent collection of used oils are the main actual actions to improve the quality of coastal waters (Lahbabi and Anouar, 2005).

325. The detailed information on from Morocco reflects an intensive monitoring programme, and should not be taken to suggest that pollution loading is greater in Morocco than in other countries of this subregion. The main findings from long term monitoring are that discharges into the Mediterranean are generally domestic in nature, presenting significant organic loads as opposed to contaminations by organochlorides or heavy metals. This appears to be the case throughout the southern reaches of the Western Mediterranean subregion.

326. In Algeria (UNEP/MAP, Algeria NDA, 2003), the most affected coastal areas by the water pollution and detritus, are those adjacent to major cities (Algiers, Oran, Annaba) or neighbouring large industrial harbours (Ghazaouet, Mostaganem, Arzew, Bejaia, Skikda). These areas are impacted by several sources of pollution including Discharges with organic pollution (Algiers, Annaba, Oran, Mostaganem, Skikda), oil terminals and refineries chemical near industrial harbours (metals, hydrocarbons, nitrogens compounds, cyanides, pesticides and detergents), discharges from power plants (Marsat, El Hadjadj, Algiers, Cape Djinet), agriculture run offs (Central plain and Annaba), Mostly untreated Wastewaters and solid wastes, industrial and domestic, a special problem in metropolitan coastal areas and in adjacent oueds.

327. With its urban inputs, industrial and petrochemical related activities and supported by an important river system (oueds Medjerda, Meliane, Elbey, Bézirk, El Abid), the Bay of Tunis is the most affected area in northern Tunisia (Baouendi, 2005) and undergoes a strong anthropogenic pressure (Sammari, 2010). This heterogeneous structure (lagoons, bays, estuaries) and to a lesser extent, the Bizerte lagoon, remain potential source of contaminants.

328. Atmospheric deposition is a main route of entry of anthropogenic inputs of trace metals accumulated in recent sediments from the sea, while the lateral advection, currents and sediment gravity flows is proposed to reflect pre-industrial concentrations of metals (Martin et al, 2009).

Similarly, the geochemical behaviour may be very different as Pb and Cu remains in the sediments while Zn is adverted. In coastal areas, atmospheric inputs are largely superseded by fluvial deposits when they are present (Roussiez *et al.*, 2006). Given the particular importance of atmospheric transport of air-water exchange and circulation, offshore waters are also a source of concern for chemical contamination, especially through the processes of trophic transfer and bioaccumulation. The knowledge of concentrations, inflow and exit behaviour in water and sediments and toxicological impacts on ecosystems are highly variable, depending on the contaminant groups studied. For many countries, no detailed information is available on quantities of hazardous substances from point sources (industry and urban centers). In general, there is a lack of adequate data and data interpretation also passes through an understanding of geochemical cycles. As an example, the overall balance of mercury in the Mediterranean has been assessed by Rajar *et al.* (2008) with input from the bottom of 120 kmol / year. This includes direct inputs of sediment from the tectonic movements and the natural leaching of mercury. The distinction between these two sources is difficult. The contributions related to tectonic sources are important in volcanic and geothermal sources near as southern Tyrrhenean Sea. These contributions explain natural important levels in some islands of the basin. The presence of mines located upstream of rivers or streams in the basin (Monte Amiata, Tuscany) can explain flows to the sea which can be evaluated over the entire Mediterranean at 610 kmol / year compared to 4 to and kmol / year for other sources (UNEP/MAP, 1996).

329. A significant amount of information exists on the distribution of chemicals, both from research projects and monitoring. However, often data are available from local studies, resulting to significant gaps in geographical coverage or/and in emerging contaminants such as dioxins, alkyl phenols. In addition, lack of standardized methods in these surveys makes it difficult to compare and use data from different sources in a regional assessment in order to draw conclusions about the spatial and temporal trends.

330. The deposition of trace metals is dominated by atmospheric inputs (Migon *et al.*, 2005), which are characterized by a signature of European origin, both natural and anthropogenic. In the Mediterranean, Saharan dust signatures are superimposed on this natural background signature. The spatial variability of atmospheric deposition, however, seems low, despite the variability of weather and climate (rainfall, wind speed, the efficiency of the aerosol scan). The influence of major rivers is higher in coastal regions and the primary source of metal particles on some continental shelves.

331. In the Northwest basin, important metal inputs could be related to floods and natural disasters (up to 80% of contributions in certain coastal areas). Little is known about the absorption of contaminants in the first trophic levels (plankton and benthos) and how they behave in cycles. Bacteria seem to play an important role in the bioaccumulation and the metal enrichment of the first trophic level, both pelagic and benthic. The seasonality of phytoplankton blooms is responsible for large variations in metal concentrations and therefore on vertical profiles of nutrients. In case of high metal concentrations, their assimilation by organisms may be limited by their solubility or toxicity.

332. The transfer of trace metals in the food chain to higher marine organisms has been demonstrated, including dolphins and whales. The concentrations of trace metals in the stomachs of whales suggest that the food source is responsible for a significant proportion of metal contamination. During the 1970s, several articles have highlighted the high levels of mercury in fish Mediterranean. More recent work has confirmed the accumulation of methyl mercury in the hake in the Gulf of Lion, related in part to bioaccumulation from the food chain, especially phytoplankton and bacterioplankton (Harmelin-Vivien *et al.* http://www.ifremer.fr/medicis/EN/projets/merlumed.html). Concentrations of 0.1 to 1.4 mg Hg kg-1 with maxima of 4 mg kg-1 were evaluated in sharks and tuna (UNEP/MAP, 1996; Storelli *et al.*, 2006).

333. On the whole, trophic transfer could account for an export of 1 - 2 million tonnes per year. Fertilizers production represents the main source of lead and mercury, while cement industry, energy and metal processing produce emissions of mercury. Chromium in water is mainly rejected by oil refineries, followed by the fertilizer industry and the tanning. Finally, air emissions of nickel are originating from power plants. In the case of ports, the analysis of sediment cores clearly demonstrates the recent origin of metals in sediments. (Di Leonardi *et al.* 2009).

334. Data of contaminants in water and sediments are not widespread in northwestern Mediterranean. Analysis of MEDPOl evaluations revealed significant concentrations of cadmium and

copper on the coast of Morocco (Nador) and mercury lead in the northern Ligurian Sea. Cadmium is found in significant amounts in the bays of Naples, Nice, and Marseilles.

335. Average levels remain high also in the islands (northern Sardinia and Sicily) but probably related to a tectonic related natural background. Lead is mainly located in Italy, especially in areas around Lazio and the Gulf of Genoa. The levels of copper are very important along the Italian coast of Sardinia and while Zinc is located in Naples, Palermo and to a lesser extent in the Gulf of Genoa. A significant difference was observed for mercury between the eastern part of the North West basin, along Italian coast, with low concentrations and those found in the western part along Spain (UNEP/MAP - MED POL , 2009). Two main sites in Sardinia and Portoscuso El Portús in Spain, close to major industrial and mining areas are characterized by high levels of lead, mercury and cadmium. Portoscuso, in Sardinia is also a risk area for the Environment (Mitis et al, 2005).

336. The site El Portus, near the hot spot Cartagena (UNEP, 2003), is under the influence of a naval base, an industrial complex and former Portman Mining. Three sites may be affected by metals on the coast of Spain in addition to the area of Cartagena, including the mouth of the Llobregat, responsible for inputs of lead in the Barcelona area, the Bay of Algeciras with concentrations of cadmium, and the bay of Valencia affected by nickel – however previous reports suggesting these levels were significant (Palanques et al, 2008) have been disputed.

337. Other authors have reported high levels of cadmium and mercury in the seagrass *Posidonia oceanica* (Sanchiz et al, 2000). In Tunisia, the Gulf of Tunis is the most affected by metals due to inflows of the city, trade with the lagoon, the river flows Medjerda and its atmospheric inputs. In Algeria, discharges are responsible for main inputs. The maximum levels of Hg and Ni are in Skikda, Annaba, Oran and Algiers and mercury was found in Algiers as described previously (Taleb *et al.*, 2007; Soualili, 2008). The distribution of mercury in transplanted mussels (*Mytilus galloprovincialis)* in coastal areas of the Western Mediterranean Sea is presented in Figure 3.8. (Andral *et al.*, 2008)

Figure 3.8. Levels of mercury in Mytilus galloprovincialis transplanted in occidental basin of the Mediterranean (after Andral *et al.*, 2008)

338. On the coast of Morocco, the importance of lead has been confirmed in Nador (Benaoui *et al.*, 2004). On the French coast, the Huveaune (Pb and Hg) is considered a major source of pollution in the Gulf of Marseilles (Sauzade *et al.*, 2007). Similarly, the former factory of asbestos located in the Western Cape Corsica is responsible for inputs of contaminants associated with metals such as chromium, cobalt or nickel (Galgani et al, 2006, Lafabrie *et al.* 2009).

339. Beside Portoscuso, Palermo, Genoa and Livorno-Cornigliano-Rosignano are the sites most affected the Italian coast of North West Basin by metals, including cadmium and nickel (Tranchina et

al, 2008; Lafabrie *et al.*, 2007). In addition to these sites, Zinola, Oristano (Cucco et al, 2006; Magni et al, 2006), Piombino (Bocchetti et al, 2008) showed significant concentrations of metals in various organisms.

340. Rivers and streams promote metal inputs. The Tevere, the Rhone, the Ebro River and smaller rivers as Gapeau (France) or the Zhor area are responsible of inputs of industrial (Andral *et al.* 2004) or natural origin (Bouzenoune and Remoum, 2008). Runoff in polluted urban areas may also have major impacts on the environmental geochemistry of some coastal areas like Portman or Porto Ferraio on the island of Elba (Marín-Guirao et al, 2005; Benedicto et al, 2008). In these areas, resuspension is possible during storms in addition to natural leaching of soils and other geochemical origin. In the case of Islands (Balearic, Palmarola, Aeolians), inputs naturally associated with geological substrates seem the most likely source of trace metals.

341. In general, comparisons of concentrations with sites outside the Mediterranean basin (Andral *et al.*, 2010) show levels of contamination of the same order of magnitude. The comparison of data with values under European legislation demonstrates levels of metals did not exceed existing limits, except for mercury in organisms from the Gulf of Portoscuso. Related to processes of bioaccumulation and biomagnification, these compounds can reach dangerous levels, particularly in top predators, including marine mammals.

342. Available data indicate that contaminants are not uniformly distributed throughout the subregion. For example, concentrations of total DDT in sediments range from <0.25 to 885 ng / g and PCBs from 1.3 to 7274 ng / g, higher levels corresponding to the "hot spots" areas near outfalls wastewater of major cities and at the mouths of large rivers (e.g. Rhône). Levels up to 400 mg / g fresh weight of DDT and 1400 mg / g wet weight of PCBs were found in the fat of marine mammals (dolphins), far greater than the equivalent data in the Atlantic. Some geographical areas are in situations of concern. These include estuaries (Rhône, Ebro), bays and gulfs (Fos Sea, Bay of Algiers and Tunis, Genoa, Naples, Algeciras) and areas affected by the landfill.

343. In general, the highest concentrations of chlorinated hydrocarbons are found in port areas, due to limited water exchanges and intense urban and industrial activities. Direct discharges, runoff (Tolosa *et al.* 1995) or deposition of dredging (Alzieu, 2000) are also very important locally. Consequently, the concentrations found in the catchment areas of towns and rivers are above levels found in continental shelves.

344. Persistent organic pollutants (POPs) are a problem in the vicinity of industrial and urban sites, as in major Mediterranean rivers mouths. Harbours of Imperia, Viareggio, Piombino, urban areas of Marseille, Toulon, Barcelona, Genoa and Nice and pro deltas under the influence of the Rhone and Ebro are affected by POPs pesticides and particularly the family DDTS with the associated risks (SIDIMAR, 2005; Giuterrez *et al.*, 2007). From the UNEP/MAP - MED POL database, it was shown concentrations of aldrin, dieldrin, endrin, hexachlorobenzene, lindane, as measured in wild *Mytilus galloprovincialis*, are low in the northwest Basin. Concentrations of DDT are higher, especially the degradation products as p, p'-DDE (see Figure 3.9).

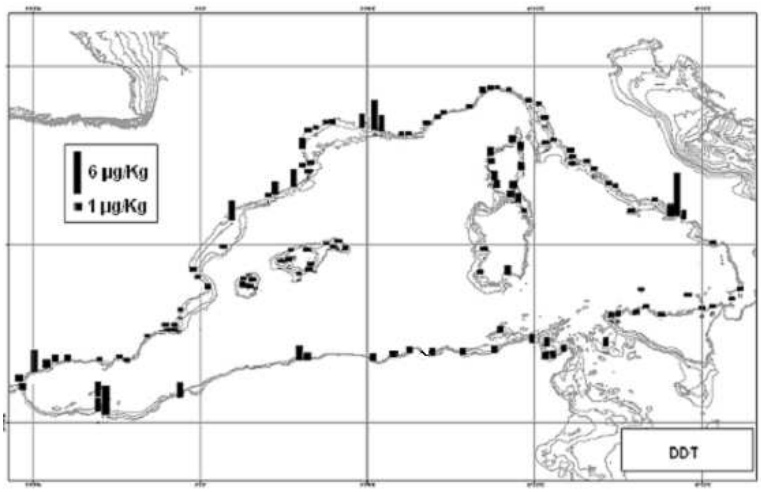


Figure 3.9. Levels of DDTs in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Scarpato *et al.*, 2010)

345. An analysis of dioxins in mussels *Mytilus galloprovincialis* in 33 stations from the whole occidental basin (Andral *et al.*, 2004) shows highest values were recorded in Marseille (2.66 ng/kg) with significant inputs (Figure 3.9). On the basin scale, the distribution of dioxins was similar to the one of PCBs, with highest values at Barcelona, la Maddalena (Sardinia), Algiers and Napoli but also in Toulon (Munschy et al, 2008, Andral et al 2008) when Corsica and Northern Africa were the areas with lower concentrations (Figure 3.10)

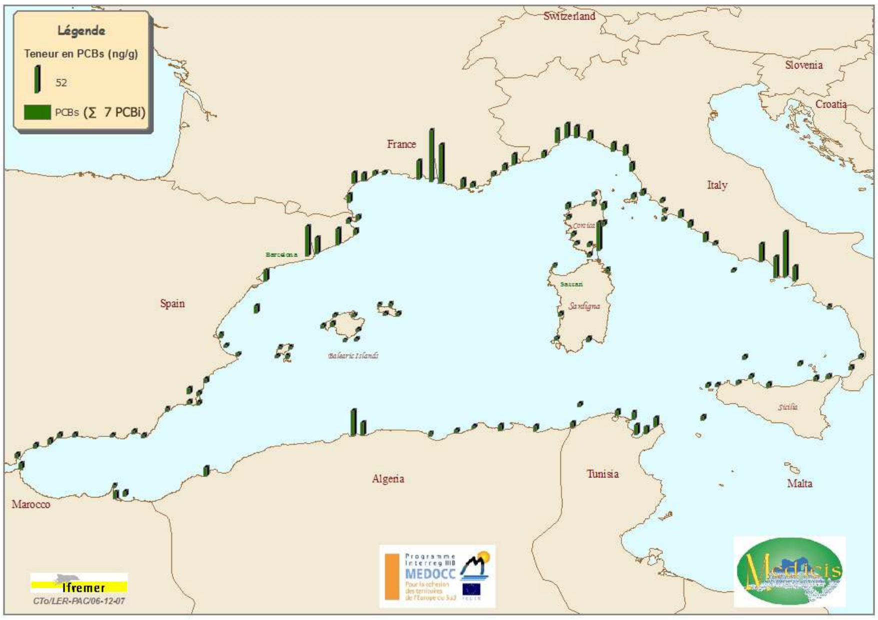


Figure 3.10: Levels of ∑ 7 PCB indicators (ng.g-1 d.w.) in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Andral *et al.*, 2008)

346. The western Mediterranean has been described as also affected by PAHs contamination, especially in sediments (Mille *et al.*, 2007; Martínez-Lladó *et al.*, 2007), water (Bouloubassi *et al.*,

2006), in marine organisms (Piccardo *et al.* 2001; Andral *et al.*, 2004, Galgani et al, 2010) and by measurement of biological effects (Burgeot et al .1996; Minier et al, 2006; Box et al, 2007, Martínez-Gómez *et al.*, 2008) (Figure 3.11).

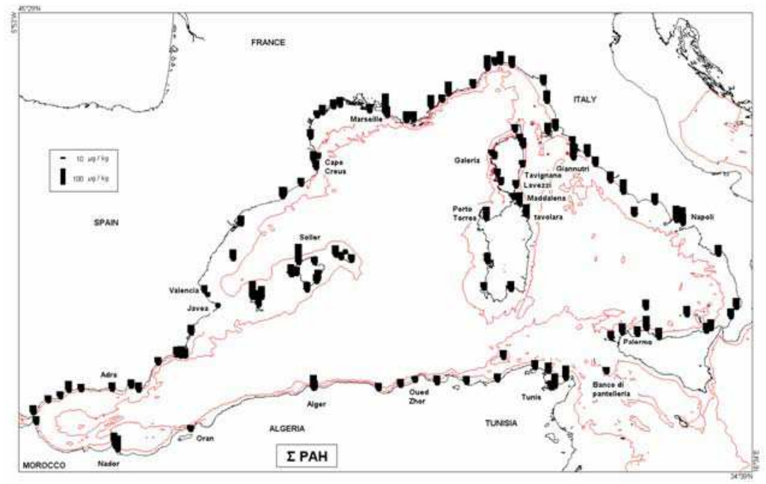


Figure 3.11. Levels of total PAHs in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Galgani *et al.*, 2010)

347. These contributions are related to increases in particulate matter associated with runoff, resuspension of sediments and the seasonality of use of agrochemicals. The analysis of the concentrations of total PCBs or from BC 153 to UNEP/MAP - MED POL data reveals a low number of data on marine organisms from the south shore. In the northern basin, the baseline levels are high and the sites most affected are the areas of Barcelona, Marseille (up to 1500 ng / g dry weight) and the Bay of Genoa.

348. The relevance of the sediment analyses for the evaluation of PAHs is important since they can persist for long time periods. As a counterpart, as fish are metabolizing PAHs, they are not adequate indicator of the impact of these pollutants and it is necessary to use benthic organisms to evaluate accumulation and effects.

349. The PCB congeners 31, 52, 156 and 180 are present at low concentrations and in industrial areas or urban. The PCB 153 and 138 show maximum levels of accumulation along the French coast, particularly at Marseilles and his emissary (respectively 42.3 mg / kg and 27.6 mg / kg) and to a lesser extent al mouth of the Rhone basin of the Mediterranean (after Scarpato *et al.*, 2010). Concentrations are also important along the Italian coast, in Napoli (28.0 mg / kg and 19.0 mg / kg) and Bagnoli (16.0 and 12.0 mg / kg), in Sardinia at La Maddalena (PCB 153: 26.0 mg / kg, PCB 138: 12.0 mg / kg), at the Llobregat mouth (18.1 and 14.4 mg / kg) and in Barcelona (11.0 and 8.2 mg / kg). In southern Mediterranean, significant values for PCB 153 and 138 (20.5 and 14.1 mg / kg) were demonstrated in Algiers.

350. Studies on TBT in the occidental basin shows that contamination is however not limited to harbour areas, but extends along the coast, including protected areas where Contamination as high as 7 ng TBT l-1 has been measured (Michel *et al.*, 2001) and deep sea waters as shown on a transect across the ligurian current (Michel and Averty, 1999).

351. Once released from antifouling paints, TBT is rapidly absorbed by bacteria and algae or adsorbed onto suspended particles in the water (Luan *et al.*, 2006) and incorporated into the tissues of filter-feeding zooplankton, grazing invertebrates, and, then in higher organisms where it accumulates (Borghi and Porte, 2002). TBT may under favourable conditions degrade within days to weeks through

successive dealkylation to produce dibutyltin (DBT), monobutyltin (MBT), and ultimately inorganic tin, becoming progressively less toxic in the process.

352. Concentrations of BTs in the recent sediments obtained from a large number of coastal stations in Spain demonstrated that Northern Mediterranean Sea marinas and harbours are more polluted than sampling sites of the Southern Mediterranean Sea (Diez *et al.*, 2002).

353. With the improvement and development of analytical techniques, identification and quantification of a large number of organic compounds not previously detected in the marine environment has increased dramatically in recent years. Molecules such as PBDEs, alkyl phenols, new pesticides or phenyl-ureas, veterinary medicines and pharmaceuticals, biocides bactericides and phthalates have been identified. These molecules could be of concern because of their persistence, toxicity and bioaccumulation properties. In the case of sea-surface microlayer concentrations up to 177 mg l-1 phthalates were demonstrated in the Tyrrhenian Sea (Cincinelli *et al.* 2009).

354. They are believed to be ubiquitous but data are lacking on their occurrence in the Mediterranean. Surfactants, used in industrial processes as well as household, have one of the biggest production rates. In Mediterranean cities, Linear Alkyl sulphonates are the main surfactant employed (Blasco *et al.*, 2010). Concentrations up to 50µg/l were found in water and 2mg/kg sediments in Spain. Other surfactants have been recorded in hotspots from the Spanish Mediterranean coasts, including nonylphenols (NP) and Nonylphenols ethoxylates (NPEOs).

355. Pharmaceuticals are also considered as emerging contaminants in the environment. Radionuclide (specifically 137Cs) activity in the Black Sea and North Aegean Sea were up to two orders of magnitude higher than those in the western Mediterranean Basin where activity ranged from 0.01 to 0.077 Bq kg_1 wet wt, Algeria being less affected than other countries. Data on trace metals for samples of *Mytilus galloprovinciallis* collected in 21 stations along the period 1979-2006 within the French monitoring system (RNO, http://www.ifremer.fr) clearly show a general decline of concentrations during this time span. Also, analysis of concentrations of metals in sediments from the Gulf of Tunis (Cd, Pb, Hg, Cu, Zn, Fe) performed in 1999, 2003 and 2010 demonstrated the metals remains in the same range for the last 12 years except Cadmium that was decreased more than 10 fold. Cadmium decrease was also found in *Mytilus galloprovincialis*, in Tunisian stations during the period 2001-2008.

356. The decrease in concentrations of banned or restricted persistent organohalogen contaminants such as PCBs and PCDD/Fs in environmental media such as biota or sediment has been observed both in Europe and on a global scale (Gomara *et al.*, 2005). (See, for example, lindane concentrations shown in Figure 3.12). This trend is related to the severe restriction or phasing out of these compounds and more efficient control of emissions. The data collected as part of national monitoring programs show a downward trend usually observed in the concentrations of chemicals which use has been banned for decades (DDT, PCBs, Lindane etc.), although in some cases the concentrations may remain relatively high.

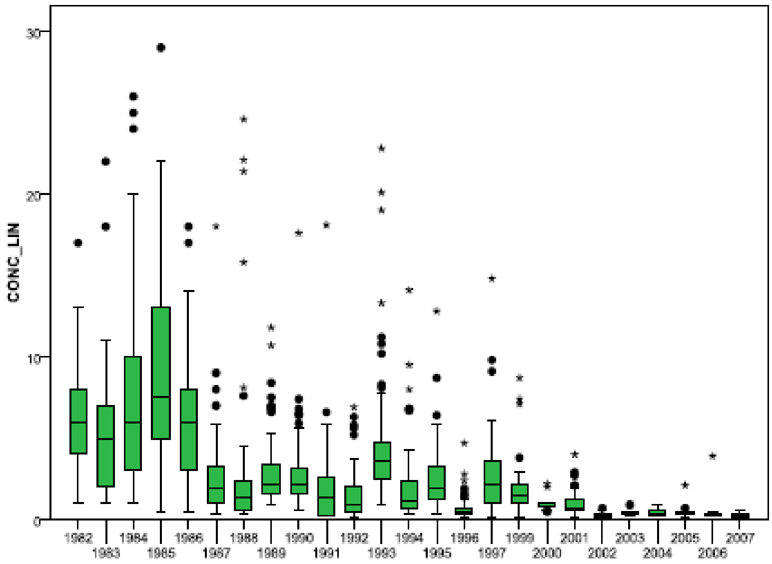


Figure 3.12. : Temporal trends of lindane (ng g-1 dw) in *Mytilus galloprovinciallis* from the French monitoring network in Mediterranean stations (www.ifremer.fr)

357. In the North of the basin, total DDT concentrations in mussels *Mytillus galloprovincialis*, decreased. More recently, an analysis of concentrations of DDT in the fatty parts of bottlenose dolphins conducted between 1978 and 2002 different points on the coast of western basin showed that concentrations were divided by 23.7 during this period (Borrell and Aguilar, 2007). Similar trends were also observed for PAH concentrations in mussels from French National Monitoring Program.

358. Shipping-related pollutions is also a key pressure in this subregion. Rates of chemical tanker and container vessel traffic are growing, and increases in transits are expected to be most pronounced in the product and crude tanker sector. The top 20 ports within the Mediterranean account for 37 per cent of all Mediterranean calls and 43 per cent of DWT capacity, and with a few exceptions most of the top ports are located in the western Mediterranean. However, crude oil ports that account for the bulk of ballast discharge-driven pressures (including polliton and release of non-indigenous species) occur primarily in the eastern and central Mediterranean.

359. Although the contaminants are usually found at coastal waters, they also might be detected in certain areas of the continental shelf and adjacent canyons. This is particularly important in the NW Mediterranean Sea where the continental shelf is very narrow and the number of coastal canyons important. However, this kind of pollution is not well studied yet.

360. On a global scale and in the context of the management and protection of environmental quality from terrestrial inputs, it is necessary to take into account the different compartments of a continuum watershed-coastal strip, canyons and continental slope - abyssal plain and the characteristics of the deep-sea environment. Occasional discharges during floods may play an important role in transporting sediment to continental shelf and through the canyons to the deep sea plains (Bourrin et al., 2008). Furthermore, industrial solid wastes (such as red mud residues from aluminium manufacturing) are deposited on the continental shelf (Galgani et al., 2006; Dauvin, 2010) and may also be transported, together with other sedimementary deposits, to deeper marine areas carried by turbidity currents.

361. Along deep river beds (Var, Rhône, Ebro), which sometimes cover long distances of several tens of kilometres (Mulder et al, 2003), hyperpycnal flows are transporting particulate matter to the deep-sea floor. These flows are characterized by sudden increase of current velocity and downward particle fluxes that can reach up to 600 g m−2 d−1 of particles and 3.1 g m−2 d−1 in terms of organic carbon. Canyons are active for material transport and supply of organic matter and probably contaminants to deep sea (Khripounoff et a., 2009). These violent turbidity currents are common in the

western basin due to reduced adjacent shelves that facilitates the supply and transport of sediment. For example, significant increases in levels of trace metals were detected in sediment cores in the upper canyon of Blanes (Palanques et al., 2008). The metal enrichment occurred during the 20th century are correlated with periods of increased population and industrial activities in the adjacent region. Deeper in the canyon at 1370 m depth, no metal enrichment was detected, probably due to the dispersion of particles and dilution with uncontaminated sediment. However, studies in deep sea sediments show that in some areas of Mediterranean, contamination does not affect just the coastal and continental shelf, but also the side of the continental slope sediments, transported through submarine canyons. On the bathyal plain, the isotopic signatures of industrial discharges have shown transport of contaminants in the direction of the general circulation over distances of several hundred miles.

Biological effects

362. A number of toxic effects in marine mammals, seabirds, fish and invertebrates have been associated with exposure to chemical pollutants. The observed abnormalities vary from molecular to ecosystem changes and from reversible to permanent alterations. Such effects have been thought to have contributed to population level impacts including reproductive failure and outbreaks of disease.

363. Biological effects of pollution are elements of major importance for the assessment of environmental quality. Estimated toxicities for different categories of sampling sites revealed harbours and Rivers as the main sources of POPs when Coastal lagoons and urban influenced areas are less effective (Gomez-Gutierrez et al., 2007).

364. The effects of pollution can be measured at different levels of biological organization, from the molecular to the community level. Biomarkers are cellular, biochemical, molecular, or physiological changes that are measured in cells, body fluids, tissues, or organs within an organism and are indicative of xenobiotic exposure and/or effect. Biomarkers response range from general to specific contamination and are most of the time used as early warning signals of environmental disturbance (Walker et al., 2006). They have been therefore incorporated into environmental monitoring programs including MED POL/ UNEP Mediterranean Biomonitoring Program (UNEP-MAP, 2006; Viarengo et al., 2007). More recntly, both EU water framework and Marine strategy directives pointed out the importance of biological monitoringIn the Mediterranean, because they are ubiquitous and easy to collect, Mussels (*Mytilus galloprovincialis*) and mullets (*Mullus barbatus*) are the most commonly used sentinel organisms in biomonitoring studies (Lionetto et al. 2003,Minier et al 2006; Viarengo et al., 2007; box et al, 2007; Bocchetti et al. 2008, Zorita et al., 2008) but some other species such as gobies (Corsi et al., 2003) are useful in very coastal waters. Beside non-specific biomarkers at cellular or molecular levels, most studies were dedicated to indicators such as Ethoxuresorufin deethylase (EROD), metallothionnein and Acetylcholinesterase respectively related to the presence of aromatic rings (e.g. PAHs, dioxins etc.), trace metals and organophosphorous or carbamates compounds. Few experiments were performed at the occidental basin scale (Burgeot et al., 1996) and data on coasts of north Africa are scarce (Banni et al., 2007 & 2009) but confirm biological effects of contaminants in the same pattern than for the northern part of the basin. Most of the results demonstrated effects of contaminants in fishes of mussels around industrials harbours and large towns but also showed, even with relevant data, the difficulties of using native fish as sentinels (Zorita et al., 2008). More recently, biomarkers of oxidative stress and multixenobiotic resistance related proteins were considered but large scale monitoring was recommended on regular basis only for lysozome stability and ACHE (Variengo et al., 2007, Martínez-Gómez et al., 2008, Fernández et al., 2010)

365. There is a clear need for an integration of chemical monitoring and monitoring which will permit an assessment of biological responses to contaminants. Such an integrated approach should be considered an important component of the overall assessment of the health status of the marine environment.

366. In the case of Spain for example, the chemical monitoring research activities were recently and progressively extended with limited biomarker measurements in mussels and fish (red mullet) as well as contaminant concentrations in superficial sediments and fish (Campillo et al., 2007). Regarding data, mussel populations of all sampling sites selected along the Iberian Mediterranean coast should be considered severely and moderately stressed.

367. MT content in mussels along the Spanish Mediterranean coast ranged from 97.9 to 271.0 µg/g tissue and were significantly correlated with Cd and Zn body burdens. In fish (*Mullus barbatus*) MT content ranged from 405.7 to 784.5 µg/g. with highest values in the Delta del Ebro as for genotoxic damage. Beside, mean values of EROD activity in red mullet specimens ranged from 81.90 to 272.9 pmol/min/mg prot, with the highest values found in Cartagena, related to the highest PAHs and organochlorinated concentrations in muscle tissues.

3.5.2 Dumping activities (introduction of substances and impact)

368. Dumping is controlled in most of the large harbours of the Western Mediterranean: Ecoports (www.ecoports.com) in Genoa, Livorno and Civitavecchia, management schemes (Valencia, Bejaia, Alger, Nador, Tunis, Napoli) including the reduction of treatment plants numbers to limit affected areas (Marseille), recolonisation experiments and monitoring of impacts. However, dumping (wastes, dredging, and industrial dumping) remains important, in the million tons range, around the Mediterranean harbours.

369. As examples of sites affected by dumping, controlled industrial inputs such as aluminium mineral residues (red muds) in the Cassidaigne canyon (France, 330 m, Galgani et al, 2005; Dauvin 2010) and ancient asbestos factory in Cape Corsica affected by leaching of metals enriched sediments (Galgani et al, 2006; Lafabrie *et al.*, 2009) enabled to evaluate biological effects of minerals dumping.

370. Littering is a growing problem in this subregion, which includes aesthetic degradation but also a number of potentially harmful implications including the transport of persistent organic pollutants, the release of toxic compounds (including medicines), the entanglement of larger marine organisms and the mortality of many marine species, including marine mammals, sea birds and turtles after ingestion of litter (Katsanevakis, 2008).

371. Among the most problematic marine litter is derelict or discarded fishing gear, which may continue to fish for years, a process that has been termed ‘ghost’ fishing. Entangled animals may get killed by drowning, suffocation, or strangulation.

3.5.3 Nutrient and organic matter enrichment

372. Throughout the Mediterranean, the main drivers related to eutrophication in the marine and coastal environment are urbanization in coastal areas, tourism, agriculture, industry and the influence of aquaculture and fisheries. Tourism could also be a strong pressure related to eutrophication. Beside nutrient inputs, the primary productivity at local scale is also controlled by additional factors such as the stratification of the water column, transparency, surface local currents.

373. The Ebro River and the Rhône River drain much of the Alps, causing the largest river discharge of water to the western Mediterranean basin. Yet the effect of nutrients discharged by these two rivers does not exceed the local upward nutrient fluxes caused by the largely unstable waters of the NW Mediterranean Sea. Winter production of deep water in this area also causes an important fertilization of the surface waters that remains for most of the year, particularly in fall, winter and spring. Smaller rivers (Aude, Herault, Têt, Tech) flow on the French side, within the Gulf of Lions and on the Spanish side (Muga, Fluvià, Ter, Tordera, Ter, Besòs, Llobregat) cause a very slight increase in Chlorophyll a values along the coasts, particularly of the Gulf of Lions. The city of Barcelona and the city and industrial complex of Tarragona also contribute to important discharges of nutrients from urban and industrial sources.

374. On the Algerian coast, the transfer of nutrients occurs from the terrestrial to the marine system trough the oueds runoff transferred directly to the sea and port areas (Djijell, Algiers and Annaba) or some adjacent bays (Arzew and the bay of Algiers). In these areas, the concentrations of nutrients in sediments are higher than those measured in the vicinity and correlated levels of organic pollutants.

375. In France, only two areas are really eutrophic but related to coastal lagoons (Palavas complex and Or lagoon). Enrichment and eutrophication events have been however found in other lagoons and coastal areas along the Gulf of Lion and some bays, which clearly demonstrate the important contribution of the Rhône and smaller adjacent rivers. Dinoflagellate blooms have been demonstrated regularly (UNEP/MAP, 2007).

376. In Morocco data used for eutrophication assessment were obtained through the National institute of Fisheries Research (INRH), the UNEP/MAP - MED POL programme coastal water monitoring and remote sensing authority. Only one important site, Oued Martil estuary, where urban and industrial wastes are discharged, was characterized as at risk to become eutrophic the maximum nitrate concentrations recorded ranged between 400-500 µg/l. The studies performed in the Nador lagoon showed also that certain areas present problems of eutrophication.

377. The Spanish coast is characterized both by natural enrichment due to upwelling and an induced eutrophication caused by human discharge. The high productivity of the Alboran Sea appears to be related to the upwelling generated by the anticyclonic circulation generated by the flow of Atlantic waters entering the Mediterranean through the Straits of Gibraltar. Other eutrophicated areas were found close to Valencia and the Ebro delta, where dinoflagellates blooms were developed.

378. In Italy, historical data for eutrophication assessment are available from 2001 to 2006 indicating that manifestations of eutrophication depends on the hydrology, hydrodynamics and morphology of the areas concerned. In the Ligurian Sea and the Tyrrhenian Sea, the phenomena are episodic and generally not widespread, with secondary effects (hypoxia/anoxia in the bottom waters) being of little significance.

379. In the Ligurian Sea, two sites have been identified as eutrophic: Foce Torrente Lerone with urban wastewater discharges and organic inputs from industries and Genova harbour and Marinella - Foce Magra with pollution from the harbour area of La Spezia, including discharges of domestic and industrial wastes and organic inputs from aquaculture activities. Discharges of domestic and industrial wastes from the highly polluted Sarno River as well as discharges from agriculture activities, nutrient, industrials and organic inputs from the harbour of Napoli are the main sources of eutrophication in the bay of Napoli. Nutrient (P and N) inputs from agriculture and urban wastewater discharges transported by Tevere River are responsible for eutrophication events at the Tevere estuary. Finally, nutrients transported by the Arno river, which are due to agricultural activities and urban wastewater discharges from Firenze and Pisa account for the eutrophication of the Arno estuary and adjacent areas.

380. Eutrophication causing conditions arise to a large extent from the effects of effluent discharges from urban areas and only in a few cases from inputs of rivers. Using satellite imagery, the Gulf of Lion and Ebro area were confirmed to be the most affected areas. The southern coastal waters of Italy are oligotrophic with a few exceptions such as the Gulf of Naples, which remains eutrophied due to sewage.

381. At the same time, many patterns (spatial and temporal) in primary productivity at the local scale are driven by climate forcing and other factors only marginally related to river inputs (e.g. water column stratification, localized surface currents).The extent to which these drivers will change nutrient availability, uptake, and primary production in light of climate changes needs to be considered in future monitoring and assessment.

3.5.4 Biological and physical disturbance

Overfishing and destructive fishing

382. Fishing effort is highest in this subregion (Micheli, in press), and over-exploitation and fisheries-related habitat and ecosystem impacts are extensive. According to the GFCM (2008), many species of commercial interest are currently being over-fished in this subregion. This is the case for hake (Merluccius merluccius), the mullet (Mullus barbatus) and the deep sea pink shrimp (Parapenaeus longirostris in the north of the Sea of Alboran, the Balearic Islands, northern Spain, the Gulf of Lions, and the Ligurian Sea), the sardine (Sardina pilchardus) and the anchovy (Engraulis

encrasicholus) in the north of the Sea of Alboran, in northern Spain and in the Gulf of Lions (GFCM, 2008).

383. The large pelagic species that inhabit the open seas, mainly bluefin tuna, swordfish, and albacore, but also pelagic sharks (short fin mako, blue shark and porbeagle) are of high conservation interest and are also overexploited by pelagic fishing gears. The main fishing gears for large pelagics are purse seines and pelagic longlines. Pelagic long lining fleets operate in Mediterranean waters, ranging from local coastal state fleets to large industrial foreign fleets; these are highly mobile, and cover almost the whole Mediterranean basin. Drift nets have been banned in the Mediterranean in 2005, although this activity is still practiced.

384. Important essential fish habitat (EFH) for large pelagic species are mostly determined by oceanographic features like upwelling areas or gyres, creating productive areas important for feeding and breeding; the main spawning areas for bluefin tuna have been located south of the Balearic Islands, Alboran Sea and Strait of Sicily; swordfish and albacore spawning areas overlap with the bluefin tuna spawning grounds.

385. Common dolphin and other marine mammal species are declining due to a variety of pressures originating in fisheries. In Spanish waters, this species is captured for interfering with fisheries. This species rank amongst the most affected by not selective fishing gear, and in the Alboran Sea there is accidental mortality due to ship collision. Pollution of coastal waters, probably, contributes to the observed decline of this species in the north western Mediterranean. Tissue concentrations of chemical pollutants in individuals inhabiting the Spanish coasts exceed by far healthy concentration values, and some of these pollutants impact reproduction and growth of marine mammals. The decline of this dolphin species may be enhanced by overfishing of marine stocks that also provided food to the marine mammal populations (Ministerio de Medio Ambiente, y Medio Rural y Marino, www.marm.es).

386. Deep-water coral ecosystems are prevalent along the Spanish Mediterranean coasts and in other parts of this subregion, but have been found to be severely impacted by deep-water trawling. Trawling is thought to have altered benthic communities throughout the region, as it has been shown to do in other portions of the globe (MEA, 2005).

387. Numerous scattered seamounts occur in the Alboran Sea and south Tyrrhenian; cold seeps, brine pools and hydrothermal vents are less common as these are concentrated in the East Mediterranean basin (south of Crete and Turkey, and near Egypt). The Western Mediterranean basin harbours numerous submarine canyons that provide essential fish habitat for red shrimp, like numerous canyons in the Gulf of Lions that sustain important fisheries of red shrimp, lobster, hake, monkfish, among other important commercial species; hake nursery areas are mainly located on wide extensions of continental shelves or banks, highlighting the south of Sicily, whereas hake spawning grounds seem to be located on the shelf break and slope canyons, being the Gulf of Lions the clearest example.

Alien species disturbances

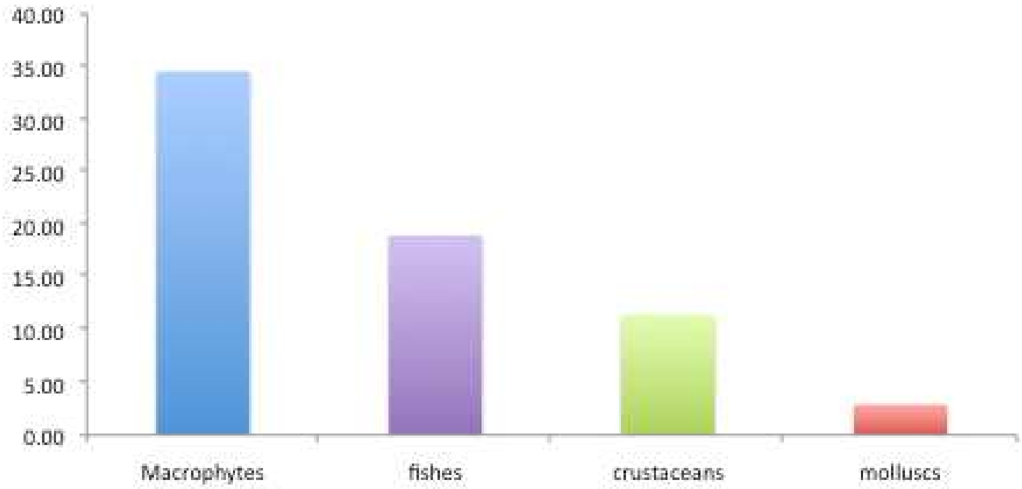


Figure 3.13 : Exotic taxons in the Spanish Mediterranean waters (from Marba and Duarte, 2010)

388. The Mediterranean is the European sea that hosts the largest number of exotic species (Streftaris et al 2005). Despite exotics are being introduced to the Mediterranean for centuries, the records of arrivals of new species in the Mediterranean Sea are accelerating since the second half of 20^{th} Century (Gollasch 2006). On average, the rate of species introduction between years 1999- 2004 was of one exotic species every 6 weeks (Streftaris et al 2005). At present, macroalgae is the marine group that is providing exotics at the fastest rates in the Mediterranean Sea when compared with those of other groups (Gollasch 2006).

389. There are currently 433 exotic taxons throughout the Mediterranean Sea, encompassing macrophytes (110 taxons), molluscs (137 taxons), crustaceans (70 taxons) and fishes (116 taxons) as well as exotic taxons of zooplankton and phytoplankton (CIESM, http://www.ciesm.org/online/atlas/intro.htm; Streftaris *et al.* 2005). In the Spanish Mediterranean, which can be emblematic of the western subregion, there are 38 exotic taxons of macroalgae, 22 of fishes, 8 of crustaceans and 4 of molluscs, indicating that this region contains 35 % of Mediterranean macrophyte exotics, 19 % of Mediterranean fish exotics, 11 % of Mediterranean crustacean exotics and 3 % of Mediterranean mollusc exotics (Marba and Duarte, 2010) (see Figure 3.13).

390. In the western Mediterranean there are 9 macroalgae species that have invasive behaviour: *Caulerpa taxifolia* (Pou *et al.* 1993), *Acrothamnion preissii*, *Asparagopsis taxiformis*, *Asparagopsis armata*, *Womersleyella setacea*, *Lophocladia lallemandii*, *Caulerpa racemosa var cylindracea*, *Codium fragile ssp tomentosoides* and *Colpomenia peregrina* (Ballesteros 2008).

391. In the Spanish Mediterranean, the invasive *Lophocladia lallemandii* is abundant between August and November in *Posidonia oceanica* meadows and infralittoral rocky shores of Formentera, Ibiza and south of Mallorca (Balearic Islands). This invasive grows epiphytically on seagrass leaves and rhizomes forming thick turfs that enhance *P. oceanica* mortality and decreases standing crop and shoot size underneath (Ballesteros et al 2007).

392. *Acrothamnion preissii* has invaded several *Posidonia oceanica* meadows of the Balearic Islands, particularly in Menorca. This invasive grows on *P. oceanica* rhizomes and outcompete with algae and invertebrates inhabiting the rhizomes. It is also found growing on marine rocks and caves with low light irradiance at 10-30 m water depth where it outcompetes with red algae (Ballesteros 2008).

393. *Asparagopsis armata* abounds in the region of Gibraltar Straight up to the coast of Granada down to 20 m depth and it is also present in Catalunya (Ballesteros 2008). When present, this species is the dominant one. *Asparagopsis taxiformis* it is present in Menorca (Balearic Islands) and Granada (Andalucia), but only occasionally exhibits an invasive behaviour (Ballesteros 2008).

394. *Caulepra racemosa var cylindracea* ranks amongst the most recent introductions in the Spanish Mediterranean. It arrived at the Balearic Islands late in the 90's and since then it has rapidly spread. It invades all kind of algal communities, dead *P. oceanica* rhizomes and the edges of P. oceanica meadows. On soft bottoms, proliferation of *C. racemosa*, as well as that of other Caulerpa species growing in the Mediterranean, enhances sulfate reduction rates and accumulation of hydrogen sulfide in the sediments (Holmer et al 2009), creating detrimental conditions for *P. oceanica* (Garcias-Bonet et al 2008).

395. *Caulerpa taxifolia* arrived in the Spanish Mediterranean in 1992 at Mallorca. It was present at three sites of Eastern Mallorca coast, but currently it only remains at one location and it is very sparse, growing on sand patches in between a *P. oceanica* meadow. It has not invaded other Spanish Mediterranean coastal area. The *C taxifolia* present in the Mallorca is much less invasive than that growing in France (Ballesteros 2008).

396. Little is known about the little invasive *Womerseleyella setacea*, which grows below 20-30 m water depth on rocky shores. It first arrived at the Balearic islands in the 80's and nowadays is also present in Catalan coasts. When present, it fully covers the substrate enhancing the mortality of many native macroalgae and suppressing growth of incrusting ones, which are key species of the habitat.

397. Ballast waters have been the vector of introduction of at least 17 red macroalgae species, 4 of which have invasive behaviour (*Asparagopsis armata*, *Asparagopsis taxiformis*, *Lophocladia lallemandii* y *Womersleyella setacea*, Ballesteros 2008). The oyster *Crassostrea gigas* has been introduced to the Spanish and other coasts through mariculture. Fish keeping is another vector of introduction of exotics and invasives such is the macroalgae *Caulerpa taxifolia* in the Mediterranean.

398. Some invasive species may cause major disturbance to native ecosystems, particularly when invasives affect habitat structuring native species. In the Mediterranean habitat structuring species are seagrasses, macroalgae, corals (including gorgonians), and sponges. In the Spanish Mediterranean the invasive species that cause marine habitat loss are macroalgae (Ballesteros 2008), and major losses are recorded in the infralittoral zone.

3.5.5 Effects of underwater noise and marine litter

399. The western Mediterranean region is one of the busiest in terms of maritime activities. At the same time, the shoreline is extensively developed, particularly in the countries that border the subregion to the north. All of these uses generate pollution, including noise pollution from ships, seismic exploration, and naval exercises, as well as marine debris. All ecosystems have the potential to be affected by these forms of pollution, but studies relating to quantifying these pressures or understanding their effects are nascent. Contracting Parties have been developing a strategy to address marine litter, however, and monitoring under the framework of ECAP promises to supply much information about the ecosystem impacts of noise and litter.

3.5.6 Emerging issues such as climatic change effects

400. The increasing anthropogenic emissions of greenhouse gases to the atmosphere have caused an increase of global atmospheric temperatures of 0.6 ºC in the last hundred years (IPCC 2007). The magnitude of atmospheric temperature rise in Spain during the 20th century has been larger than that recorded globally (de Castro *et al.* 2005). For instance, since 1976 the atmospheric temperature in the Balearic Islands has increased by 1.5 ºC (S. Alonso, personal communication), and

the maximum and minimum annual temperatures have tended to increase overall Spain (de Castro *et al.* 2005). The increase in atmospheric temperature is also warming the Mediterranean Sea. Seawater temperature time series available for the Spanish Mediterranean (e.g. Estartit) show a sustained increase of mean annual surface waters of 0.06 ºC yr^{-1} (Díaz-Almela et al 2007) and a warming rate of 0.025 ºC yr^{-1} of water at 80 m depth (Salat and Pascual 2002). Similarly, the number of years per decade when maximum seawater temperature exceeded the average maximum annual temperature over the last 40 years is increasing. Maximum annual seawater temperature at 5 m depth in L'Estartit revealed positive anomalies for 3 years during the 70s, 6 years during the 80s, 9 years during the 90s, and 3 years between 2000 and 2004. Sea level along the Spanish Mediterranean is stable or rising at an average rate of 2 ± 1 mm yr-1 during the last decades (Marbà and Duarte 1997), a trend similar to that reported for other North Mediterranean areas (Perez 2008). Sea level rise is mostly attributable to thermal expansion but in some areas also to local subsidence processes, as it occurs at the Ebro Delta (Cendero et al 2005).

401. Under the scenarios of greenhouse gas emissions A2 and B2 (CO2 global concentrations in 2100 850 ppm and 760 ppm, 120 % and about 50 % larger than that at present, respectively, IPCC 2007), global climate models forecast a relative uniform increase of temperature in Spain of, on average, 0.4 ºC $decade^{-1}$ in winter and 0.7 ºC $decade^{-1}$ in summer under the scenario A2, and of 0.4 ºC $decade^{-1}$ in winter and 0.6 ºC $decade^{-1}$ under scenario B2 (de Castro *et al.* 2005). Global greenhouse gas emissions and temperature, however, are increasing faster than that forecasted by the most unfavourable scenario. Since 1999, when future climate trends were projected, the observed global temperature during 4 out of 5 years exceeded those modelled. Despite discrepancies among the different global rainfall models available, all of them forecast a decrease of total annual rainfall, slightly larger under scenario A2 than B2 for 2100 (de Castro *et al.* 2005). The decline in precipitation is expected to be the largest during spring, and somewhat lower during summer. The frequency of extreme climatic events (heat waves, hurricanes, drought/floods) during 21st century is projected to increase. Sea level along the Spanish Mediterranean coast by the end of 21st century is expected to rise about 50 cm above present one, although a rise of 1m is less probable but still possible (Cendredo et al 2005). Changes in freshwater availability in watersheds caused by climate change also might have a significant impact to the coastal areas and transitional waters, as well as on the delivery of ecosystem services coming out of wetlands.

402. Fingerprints of climate change on marine and coastal biodiversity in parts of the western Mediterranean are already evident, reflected by an increased mortality of some species, changes in species reproductive biology during warm years, and an increase of exotic species arrivals (Marba and Duarte, 2010).

403. The critical impacts of climate change on lowland areas are related with increased frequency and/or intensity of storms, sea level rise and, to some extend, changes in river (sediment and water) flow.

404. Deltas rank amongst the most vulnerable coastal areas to sea level rise. Under a scenario of 50 cm sea level rise and no increase in sedimentary river transport, 50 % of the Ebro Delta and Llobregat Delta may disappear. Similarly, other coastal lowland areas along the Spanish Mediterranean might be impacted: about 20 km along the Manga del Mar Menor, coastal lagoons 5 km long at Cabo de Gata (Cendredo et al 2005). Some of these vulnerable low land areas are urbanised (e.g. Manga del Mar Menor, Llobregat Delta) and thus may be lost, but others that support agriculture or belong to protected areas may allow formation of new lowland areas as sea front progressed inland that might compensate for losses.

405. It must be mentioned that most of these coastal units are already deteriorated as a consequence of urbanisation and pollution from agriculture (e.g. Albufera de Valencia), industry or human population (e.g. Manga del Mar Menor, Cendredo et al 2005). Similarly, during the last 50 years, river sedimentary inputs to deltas (e.g. Ebro Delta) have largely decreased (by 90 %, Benoit and Comeau 2005) due to dam construction, regulation and watershed reforestation, enhancing the vulnerability of these coastal structures to climate change.

406. Sea level rise is the major climate change threat to beach habitats. Sea level rise would involve beach erosion, resulting into a decrease of beach surface or a progressive inland movement of the beach (Cendredo et al 2005). The rate of beach retreat would depend on beach characteristics.

Confined and cemented beaches would be the most vulnerable ones to sea level rise (Cendredo et al 2005). Beach surface loss would increase with decreasing beach slope. Beach losses due to sea level rise would be smaller if sedimentary inputs, from rivers and sand dune systems, to the beaches would increase. However, very few Mediterranean Spanish beaches preserve the associated dune systems intact, mostly because they have been destroyed and urbanised. In some areas (Almería), the sand from dune systems has been extracted. The loss of sand dunes, together with the construction of harbours and marinas along the coast, are the main cause of present instability, and erosion, of Mediterranean beaches, as the sedimentary dune-beach transport is broken or littoral drift modified (Cendredo 2005). An acceleration of beach erosion due to human pressure is evident along the entire Mediterranean coast of the Iberian Peninsula (Mazarrón,Murcia; Carboneras, Almería; Puçol and Massalfasar, Castellón; Albufera de Valencia, Valencia; Santa Pola, Alicante). The losses of *Posidonia oceanica* meadows along the Spanish Mediterranean mostly occurred during the last 3 decades as a consequence of anthropogenic impacts, contributed to accelerate coastal erosion. *P. oceanica* meadows act as marine forests, stabilising the sediments where they grow and preventing erosion. Moreover, *P. oceanica* meadows contribute to produce carbonate sand for adjacent beaches, since the calcareous organisms living on leaves and rhizomes, together with carbonate particles deposited on *P. oceanica* leaves, arrive to the beaches together with *P. oceanica* litter after storms.

407. The impacts of climate change on marine and coastal ecosystems will be different for up-welling ecosystems or stratified areas, as well as coastal and open ocean, and it will depend on the mobility of the species. The ecophysiological (photosynthetic capacity, growth rate) response of marine phytoplankton to increasing CO_2 concentration and warming of seawater is not yet fully known. The interactions between changes in the marine environment derived from climate change and other factors, as nutrient availability, may constrain the phytoplankton responses. The expected increase of the stratification period, together with changes in macroscale processes (upwelling, fronts, currents) might decrease marine productivity. The increase in CO_2 partial pressure could enhance productivity of benthic vegetation (seagrasses and macroalgae), as CO_2 limits productivity of these populations (Anadón et al 2005). Changes in marine primary production would change consumer production and then the rest of the marine food web.

408. Simultaneous impacts derived from climate change threaten marine and coastal species, populations and ecosystems. Coastal or shallow ecosystems are the most vulnerable ones to impacts of climate change. Sea level rise threatens seagrass ecosystems, which are rooted into sediments between 0.5 m and 45 m depth, as it enhances submarine erosion and then habitat loss (Anadón et al 2005). Similarly, wetlands are also highly vulnerable to increased coastal erosion and flooding derived from sea level rise. However, if impacted coastal ecosystems were able to colonise new habitat at similar rates as the sea progressed into land, sea level rise would also provide new habitat for coastal ecosystems to expand (Duarte 2002).

409. The increase of seawater temperature may compromise organism survival and change species life cycle. Mass mortality events of sessile (e.g. gorgonians, scleractinians, sponges) and benthic mobile (e.g. crustaceans) species have already been observed during anomalous warm and calm periods (Pérez 2008). Similarly, the mortality rate of the seagrass *Posidonia oceanica* along the Balearic Islands (Spain) significantly increased after summers 2003 and 2006, the warmest summers during the period 2000 and 2007 (Marbà and Duarte 2010). High summer temperatures also enhance sexual reproduction of *P. oceanica* (Díaz-Almela et al 2007). A massive, never before recorded, flowering event of *P. oceanica* meadows across the entire Western Mediterranean Basin occurred in fall 2003 (Díaz-Almela et al 2007), the time of the year when *P. oceanica* flowers. The large production of sexual recruits by *P. oceanica* after summer 2003, however, did not compensate for the plant losses due to plant mortality (Díaz Almela et al 2009). The massive flowering of *P. oceanica* has been interpreted as a plant response to thermal stress (Díaz-Almela et al 2007). There is also evidence that marine diseases triggering host mortality increase during warm events (Bally and Garrabou 2007, Perez 2008).

410. Many benthic and pelagic marine species are expected to modify their geographic distribution as a consequence of sea thermohaline changes. The increase in seawater temperature will result in displacements of biogeographic borders of many species. The distribution of most groups of organisms will be affected, expanding the distribution ranges of southern species and retreating those of northern ones. Changes in distribution ranges of marine species in the Northern Western

Mediterranean are already being observed (Laubier et al 2003). Moreover, interactions, not directly due to climate change, between new and old species are expected. The rate of changes in distribution ranges of marine populations driven by climate change may be faster or slower depending on the effect of atmosphere on marine currents and stratification.

411. Increasing seawater temperature may favour the settlement and spread of exotic and invasive species. Seawater warming also would enhance respiration of marine organisms and ecosystems, increasing O_2 consumption and CO_2 production. The lower O_2 solubility with increasing temperature would, in addition, decrease O_2 availability in the water column. Hence, seawater warming increases the risk of hypoxic events in coastal marine systems, particularly during calm periods.

412. The increase of CO_2 partial pressure in seawater resulting from increased atmospheric CO_2 is acidifying seawater (Anadón et al 2005). The decrease in pH of seawater might lower carbonate deposition in organisms with carbonate structures such are, for instance, bivalves or corals. The forecasted CO_2 concentrations for the end of XXI century (IPCC 2001) might be able to decrease enough seawater pH as to initiate carbonate dissolution in coastal waters triggering ocean CO_2 absorption (Anadón et al 2005).

413. Climatic variability directly affects fish recruitment, a key process for fisheries. Changes in marine currents, derived from atmospheric climatic variability, may modify transport and survival of larvae and juveniles. If climate change modifies primary and secondary production, food supply for fish larvae may be limited, constraining fish recruitment and thus fish population size. Changes in seawater temperature and salinity may also impact the physiology of diadromous species. Changes in the distribution ranges due to climate changes of diadromous species have been suggested. Fish migration routes may change due to changes in prey abundance and distribution, which are related with seawater temperature. Changes in seasonal isotherm distribution might constrain fish migratory routes, and then fisheries. Marine circulation shifts may change both pelagic and benthic populations even in deep water (Anadón et al 2005).

414. The impacts of climate change on mariculture are not clear. Cultures that require external food supply might not be much affected by a change in productivity in the area. However, these cultures would be highly impacted by climate change if ambient temperature exceeds, or pH or O_2 concentrations are below, the physiological limits for the species. In addition, climate change may impact extensive mariculture activities, such are bivalve farms at the Ebro Delta, relaying on local productivity. Mariculture may be particularly vulnerable during extreme climatic events. The increase of seawater temperature could also favour the arrival and spread of mariculture parasites (Anadón et al 2005).

415. Disease outbreaks have been reported in marine ecosystems wordwide, particularly since few decades ago in tropical regions. Global warming could trigger the recent increase in disease outbreaks (Harvell et al 2002). In the northwestern Mediterranean pathogenic bacteria could have been involved in the mass mortalities of the gorgonian *Paramuricea clavata* observed in late summers of 1999 and 2003, after seawater reached anomalous high temperatures (Bally and Garrabou 2007). Bally and Garrabou (2007) experimentally tested the pathogenic activity of *Vibrio coralliilyticus* strain isolated from damaged colonies of *P. clavata* during the 2003 mass mortality event in healthy *P. clavata*. The identification of *V. coralliilyticus* as an infectious agent for *P. clavata* and that it has been described as a thermodependent pathogen of tropical coral species reinforce its role in mass mortality events of *P. clavata* under seawater warming conditions (Marba and Duarte, 2010).

416. The most vulnerable ecosystems, therefore, are those where multiple impacts derived from climate change occur, as well as those supporting long-living and slow-growing organisms. Hence, wetlands and ecosystems dominated by sessile organisms (e.g. red coral, gorgonians, sponges, *Posidonia oceanica*) rank amongst the most vulnerable ones to climate change impacts. In turn, the loss of marine and coastal vegetation may contribute to accelerate global warming, since coastal vegetation is an important ocean carbon sink (Duarte et al 2005).

3.6 Conclusions and gap analysis of pressures and impacts

417. Coastal sprawl is a particularly acute issue in this subregion, especially in its northern reaches. Development has intensified over the past decade along the western Mediterranean coastline (especially in the European portion of this subregion) has lead to physical loss of sensitive coastal habitats in the coastline as well as alterations of sediment transport, leading to a widespread erosion of the sublittoral zone. Tourism development drives much of this habitat loss and degradation, and speculative development has left some areas dramatically altered and degraded, with little revenue generation resulting from the poorly planned developments. At the same time, the spread of recreational boating activities has lead to a number of additional pressures, including those derived from anchors, sewage and garbage emissions and sports and recreational fishing, as well as impacts derived from the construction and operation of recreational harbours. The pressures derived from recreational activities are considerable.

418. Overfishing, affecting most of the western Mediterranean coast, and resulting in a loss of biomass at all trophic levels, compromises the integrity of the pelagic and benthic food webs. Trawl fisheries also cause significant impacts to sensitive benthic habitats, including deep-water corals and seagrass meadows. Unsustainable commercial fisheries appear to be a major pressure in the western Mediterranean subregion.

419. Other fisheries-related impacts also occur. Aquaculture and fish farming at sea have been identified as a source of excess organic inputs in some regions, where the density of cages is high, resulting in damages to sensitive benthic ecosystems. Tuna aquaculture has been identified as particularly impacting as it causes acute impacts on benthic ecosystems and contributes strongly to the depletion of the already compromised tuna stock. Bivalve aquaculture produces few impacts on the benthic ecosystem and generates some benefits due to the filtration capacity of the organisms, increasing water clarity. However, conflicts may arise when limited ocean and coastal space is taken up by aquaculture operations that constrain access for other users.

420. Land-based sources of pollution are a major issue in the western Mediterranean subregion, given the large area of the catchments and the extensive development of coasts and river basins. Inputs of organic material, nutrients (nitrogen and phosphorus) and pollutants from land are causing loss of water quality, including blooms of toxic algae, loss of vulnerable benthic habitats, and - where coupled with limited water exchange - acute eutrophication and hypoxia in coastal bays.

421. On the other hand, data on trace metals for samples of *Mytilus galloprovinciallis* collected in 21 stations along the period 1979-2006 within the French monitoring system (RNO, http://www.ifremer.fr) clearly show a general decline of concentrations during this time span. Along the Mediterranean coast of Spain, although the collected data using mussels has not been globally studied yet, the comparison of the concentrations of PCBs and DDT and its metabolites, obtained between the years 1993 and 2001, showed a decreasing trends in the concentrations of these pollutants (Campillo et al, 2004). Similarly, analysis of concentrations of metals in sediments from the gulf of Tunis (Cd, Pb, Hg, Cu, Zn, Fe) performed in 1999, 2003 and 2010 demonstrated the metals remains in the same range for the last 12 years except Cadmium that was decreased more than 10 fold. Cadmium decrease was also found in Mytilus galloprovincialis, in Tunisian stations during the period 2001-2008.

422. The decrease in concentrations of banned or restricted persistent organohalogen contaminants such as PCBs and PCDD/Fs in environmental media such as biota or sediment has been observed both in Europe and on a global scale (Gomara et al., 2005). This trend is related to the severe restriction or phasing out of these compounds and more efficient control of emissions. The data collected as part of national monitoring programs show a downward trend usually observed in the concentrations of chemicals which use has been banned for decades (DDT, PCBs, Lindane etc.), although in some cases the concentrations may remain relatively high.

423. Warming of the Mediterranean Sea at rates much faster than global warming rates is already affecting vulnerable species, and favouring the spread of thermophyllic species. When invasive, these species can cause major changes to ecosystems and the delivery of some ecosystem services. Intensification of maritime transport, international trade of aquarium species, and climate change are all favouring the arrival to the Mediterranean of exotic species.

CHAPTER 4: IONIAN SEA AND CENTRAL MEDITERRANEAN SUBREGION

4.1 Introduction

424. The Central Mediterranean and Ionian subregion includes the parts of Greece and the parts of Italy within the Ionian Sea, Malta, Libyan Arab Jamahiriya (henceforth referred to as Libya) and Tunisia (Figure 4.1).

Figure 4.1: Subregion #2, showing major coastal cities, location of pollution hot spots (red circles) and locations of major environmental concerns (blue circles).

425. The Ionian Sea is bounded by southern Italy including Calabria, Sicily and the Salento peninsula to the west, and by southern tip of Albania, and a large number of the Greek Ionian islands, including Corfu, Zante, Kephalonia, Ithaka, and Lefkas to the east. The Central Mediterranean extends from the southern margin of the Ionian to the coastlines of Libya and Tunisia.

426. The approximate length of coastline involved has been estimated to amount to 5700 km which represents 12% of the total Mediterranean coastline. The total surface area of marine waters amounts to approximately 800,000 km2, which again represents 32% of the total surface of the Mediterranean Sea.

4.2 Physical and chemical characteristics

4.2.1 Topography, bathymetry and nature of seabed

Bathymetry

427. The bathymetry of the area under review is highly variable, with the western half being much shallower, generally up to 1000 m deep, than the eastern half, which can extend up to 3000m deep and more. This eastern half includes the deepest part of the Mediterranean (5267m) which is south-west of Pylos Greece, forming part of the Hellenic Trench. The western half forms the relatively shallow submarine ridge (sill) between Sicily and Tunisia, which divides the Mediterranean in two main basins. The eastern ridge has maximum depth of about 540m connecting the Sicilian Channel with the Ionian Basin. The western sill is divided in the large Adventure Bank and the Nameless Bank. These large sill systems are separated by the narrow shelf in the central part. The shape of slope is extremely irregular, incised by many canyons, trenches and steep slopes. The Maltese Archipelago is

located on the outermost limit of the Sicilian continental shelf. Figure 4.2 shows the bathymetry of the subregion.

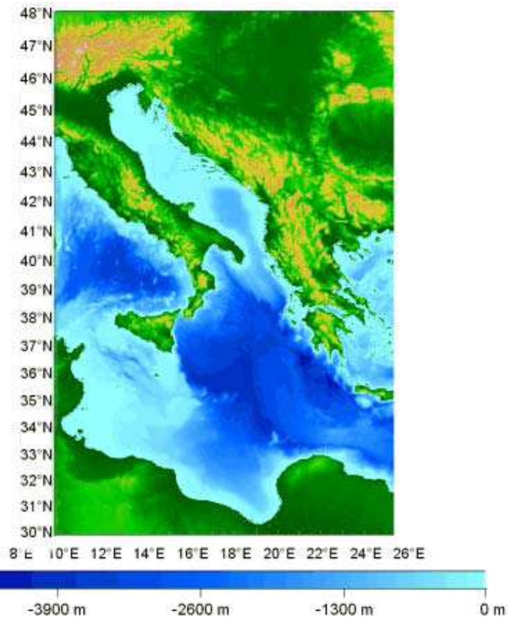


Figure 4.2. Marine bathymetry of the area under review

4.2.2 Salinity, temperature regime; currents; sediment transport

428. The hydrodynamics of the area (as in other Mediterranean areas) are determined by water exchanges through the various straits, by wind forcing and by buoyancy flux at surface due to evaporation, river inputs and heat fluxes. The slow Mediterranean thermohaline basin-scale circulation leads to the formation of a two water masses consisting of less saline Modified Atlantic Water flowing towards the East at surface and a deeper more saline Levantine Intermediate Water flowing in the opposite direction. This flow occurs at an average depth of 280m.

429. At surface the Atlantic-Ionian Stream (AIS) meanders its way towards the East for most of the year. As it reaches the deeper waters it moves northward forming the so-called Ionian Shelf Break Vortex (Drago and Sorgente, 1998, Robinson, *et al.*, 2001).

430. Modified Atlantic Water is carried along with the AIS across the area under review moving towards the South-East and re-circulating in part on the Tunisian and Libyan continental shelf areas. The Maltese Archipelago is located on the outermost limit of the Sicilian continental shelf.

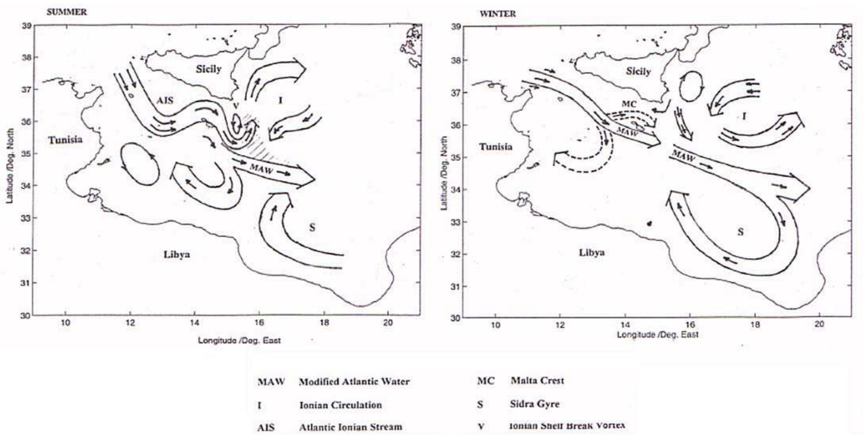


Figure 4.3. Surface currents in the Central Mediterranean (From Drago and Sorgente, 1998)

431. The surface currents in the Ionian Sea generally follow a counter-clockwise course, flowing towards the north parallel to the Greek coast and then turn west and south along the Italian coast. In general this current is not very strong though it can be stronger in straits or close to islands.

432. A recent review of surface circulation in the Central Mediterranean (Poulain and Zambianchi, 2007), based on data of satellite-tracked drifters for 1990-99, provides a broad quantitative description of the central Mediterranean surface circulation. The emergent view is that the dynamics of the channel at large, including the Tunisian shelf and the area south of Malta, sometimes exhibit unexpected characteristics of the surface velocity field, sometimes stagnant or even directed the opposite way with respect to the currents flowing further to the north. Furthermore the seasonal character of the surface circulation in the area as well as the effect of wind forcing was found to be well evident. It was found that when winds blow from the north-western sector (like the Mistral) the surface eastward transport in the Sicily Channel is enhanced. In contrast, for opposing wind conditions (blowing from the south-eastern sector), the transport trough the Channel is significantly reduced.

433. These hydrodynamic features are highly relevant to determine the fate of contaminants in the area. In general the tides in the area under review are weak, at about 10-50 cm. Surface sea temperatures and salinity patterns in the open waters are mainly influenced by seasonal circulation patterns and coastal upwelling. Upwelling events are often evident in the Straits of Otranto and off Sicily as well as off the Tunisian and Libyan coasts. Along the Sicilian coast upwelling is governed by the south-eastward winds and by the inertia of the isopycnal domes of the Atlantic Ionic Stream meanders and cyclonic vortices that can extend its influence far offshore due to the configuration of the circulation. Furthermore, relatively sharp transitions in SST along the east-west axis of the area under review are often evident especially during certain parts of the year, due to sub-basin hydrodynamic changes. In the coastal regions, SST exhibit wider diurnal and seasonal fluctuations due to the shallow water (Figure 4.4).

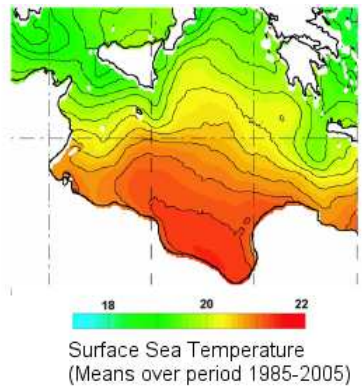


Figure 4.4. Sea surface temperatures for the area under review as estimated by Marullo et al., 2006.

434. The transitional nature of the area along the North-South Axis in terms of SST is clearly visible in this figure. According to the review by Ludwig *et al.*, (2009), the annual average rate of precipitation over the period 1960 to 2000 has been estimated to be 552 mm for the whole Mediterranean basin, 784 mm for the Ionian area and 79 mm for the southern Central Mediterranean. This clearly shows that the uneven availability of water in the area under review, with its European half having an average precipitation rate above the Mediterranean average, and its African half, being one of the driest areas of the whole basin. Furthermore trend analysis suggests that climate in the Mediterranean clearly evolved towards dryer conditions. The same authors indicate that the mean recorded air temperatures in the Mediterranean show an upward trend. The only exceptions are the drainage basins of the Ionian, Aegean and North-Levantine seas, where the trends are statistically not significant.

4.2.3 Spatial and temporal distribution of nutrients, dissolved oxygen and pH

Nutrients and primary productivity

435. Like in other oligotrophic marine areas, the Mediterranean, including the area under review is characterized by generally pronounced thermal stratification of the water column, which delimits (1) a warm surface mixed layer with high light intensity but depleted in nutrients and (2) a sub-superficial layer with low light levels and more nutrients. The depth where the dissolved nitrate concentration approaches zero (nitracline) is around 75 m in the Ionian Sea, during the stratified period. The same nitracline is found at about 10m depth at the Alboran Sea, and can reach more than 150 m in the Levantine basin of the Mediterranean Sea. This is one of the features of this area which well exhibits its transitional nature between the two basins.

436. As expected, these low nutrient conditions have a direct and great impact on the level of primary productivity in the area. In fact a decrease in integrated primary production, particulate carbon export and nutrient availability towards the eastern side of the Mediterranean Sea is observed, while integrated chlorophyll a remained constant.

437. Integrated primary production normally reach 300 mg C m-2 d-1 in the Ionian basin, which is again found to be intermediate between the value generally recorded for the western basin (approx. 500 mg C m-2 d-1) and that recorded in the Levantine basin, which is 150 mg C m-2 d-1 and which is considered as a limit for primary production rates under strong oligotrophic conditions (Moutin and Raimbault, 2002). The highest levels of productivity occur along the coasts, near major cities, and at river estuaries.

438. It is generally believed that in the Mediterranean, photosynthetic production is limited by phosphate availability. Dissolved inorganic phosphate concentrations in the upper photic zone are known to decrease from west to east reaching levels well below 1 nM (Moutin and Raimbault, 2002). Nonetheless in some places where nitrates or even silicates are low, they are also known to be major limiting factors for primary productivity.

439. Pacciaroni and Crispi (2007) evaluated the relative importance of nitrogen and phosphorus, as external loads, on Mediterranean biogeochemical cycles. Biomass concentrations were analysed considering the steady state response of the three-dimensional ECHYM model to three nitrogen and phosphorus atmospheric depositions, considered as continuous in time. The distributions of nutrients within the biochemical compartments were analysed, highlighting, inside the Mediterranean oligotrophic environment, the role played by ultraplankton, the smaller phytoplankton compartment. The authors review how the oligotrophy of the Mediterranean Sea is explainable as a response to the negative thermohaline circulation. The inverse estuarine circulation of the whole basin determines a negative budget for nutrients at the Straits of Gibraltar, since there, nutrient-poor surface water is imported from the Atlantic Ocean and relatively nutrient-rich intermediate water is exported. Thus the detailed three-dimensional hydrodynamics of the entire basin, coupled to the main biogeochemical dynamics, must be taken into account to resolve the Mediterranean ecosystem variability. Furthermore, phytoplankton growth depends on the abovementioned nutrient conditions. Chlorophyll concentrations remain high in the upper layer and coincide with nutrient depletion. The nutrient-depleted surface layer is separated from a layer of abundant nutrients, at some distance below the euphotic depth, by a nutricline, layer in which nutrient concentrations increase rapidly with depth. Therefore, depending on light intensity at the surface and the turbidity of the water, the displacements of nutricline and pycnocline determine abundance and productivity of phytoplankton.

440. The authors estimated through the application of models the yearly averaged Chl:C ratio for ultra- plankton in the whole Mediterranean basin. The western side of the Mediterranean Sea shows the greatest values, 0.018, in the Gulf of Lions and in the south of Sardinia. The lower Chl:C ratio is detected in the extreme eastern basin with about 0.008. They also estimated the Chl:C ratio for netplankton, giving values about halved than those for ultra-plankton. For the Ionian and Central Mediterranean, the values for Chl:C for ultra-plankton ranged from 0.01 to 0.04 (Figure 4.5), while for netplankton, the rations varied from 0.004 to 0.009. The higher values tended to be located in the western half of the area under review and in particular along the Tunisian coastline.

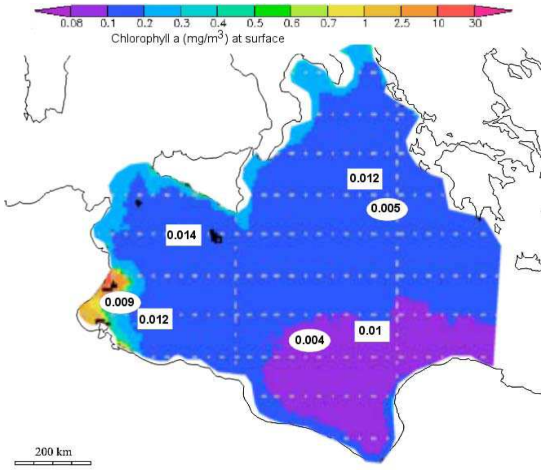


Figure 4.5. Chlorophyll a level means averaged between August 2002 and December 2008 (Cruzado 2009). The values inserted in rectangles show annual chlorophyll to carbon ratios relative to plankton, and those inserted in eclipses show the same ratios relative to net plankton (Pacciaroni and Crispi 2007)

441. In the south and central Ionian and in the far Eastern Mediterranean, chlorophyll values are generally well below 0.05 mg Chl m−3 (Figure 4.5). These models also show near-surface chlorophyll signals above background northwest and south of Sicily. Unfortunately such models did not cover many coastal zones of the southern Mediterranean (including Libya).

442. The same models were also used to estimate vertical profiles (up to 200m depths) of chlorophyll distribution along selected transects of the Mediterranean, one running from the Gulf of Gabes towards the East. The result suggest a deep chlorophyll maximum of 0.2 mg Chl m−3 at 100 to 40 m depths starting within the Gulf of Gabes, and extending along the Gulf of Sirte with values of 0.15 mg Chl m−3. The authors estimated values ranging from 9.9 to 10.4 x 10-8 umol N dm-3 s-1 for nitrates and 1 to 2.9 umol P dm-3 s-1 for phosphates in the Central Mediterranean.

443. These values are intermediate between those for the Western and Eastern basins. Figure 4.6 shows the distribution of particulate carbon in February 2010 as visualized and analyzed by the Giovanni online data system, developed and maintained by the NASA GES DISC. In spite of its limited temporal extent (representing the situation in a single month), this figure in general collaborates the features of bio-productivity in the area under review as have been identified in the above account.

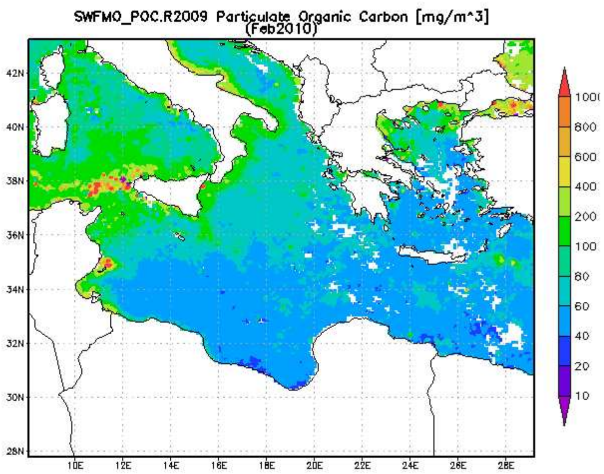


Figure 4.6: Particulate Organic Carbon as recorded in February 2010. Analyses and visualizations were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.

4.2.4 General description of the catchment area in relation to the analysis

444. The catchment basins for the Central Mediterranean subregion cover significantly less area than those of the western Mediterranean, yet degradation in the watersheds still has significant effect on the biodiversity, productivity, and delivery of coastal and marine ecosystem services. The drainage basins for this subregion are shown in Figure 4.7 below.

Figure 4.7 Catchment basins draining into the Ionian and Central Mediterranean (basin extent in orange, UNEP/MAP - BP/RAC, 2009)

445. The Central Mediterranean subregion comprises approximately 5700 km of coastline which represents 12.4% of the total Mediterranean coastline. The physical and topographic coastline features in the area vary greatly, from the relatively long sandy beaches of Libya to the undulating Ionian coastline of Greece. Unlike the rest of the Mediterranean basin, mountains are not particularly evident in this area, except for Mount Etna in Sicily. Relatively significant alluvial plains are found in Tunisia, being associated with the Medjerda River discharging in the Gulf of Utica and forming the crucially important wetlands associated with Ghar el Melh lagoon. Major wetlands are also found along the Greek coastline such as the Gialova lagoon at Pylos, Messinias.

4.3 Biological characteristics

4.3.1 Description of water column biological communities

446. Like the western subregion, the Central Mediterranean and Ionian subregion is characterized by high species and habitat diversity. Similar to the whole Mediterranean, biodiversity hotspots in the Ionian sea and the Central Mediterranean are characterized by relatively high levels of endemism. This high biological diversity is to be related to the specific geomorphological and hydrographical features of the Mediterranean basin, its geological history and its position as interface between temperate and tropical biomes that allow it to host both cold- and hot-affinity species (UNEP/MAP-BP/RAC, 2009).

447. The Central Mediterranean is currently experiencing a decline in the number of species and a deterioration of habitats, related to various human-origin activities, primarily uncontrolled urbanisation and coastal development, fish farming, pollution and fishing.

448. Broadly speaking in the Ionian Sea and the Central Mediterranean, the planktonic element (phytoplankton and zooplankton) remains little studied. In general, there is a low primary production, linked to low development of the higher levels of the trophic chain, including low production of fishes, are the main features that characterize the Mediterranean. The growth in oligotrophy from the west to the east is reflected in the abundance of the zooplanktonic biomass.

449. ‘Bloom’/proliferation of certain life forms in the subregion has become increasingly common over the past few years, especially in the Gulf of Gabes in the southern area of Tunisia.

450. Both the Ionian and the Aegean offshore waters are oligotrophic, while most coastal areas in the Greek portion of the Central Mediterranean subregion are mesotrophic (Gotsis-Skretas and Ignatiades, 2007; Siokou-Frangou *et al*., 2005). Mesozooplankton abundance and biomass and species composition in Greec e present the same trends of the rest of the Mediterranean; enclosed or semi-enclosed bays and gulfs are affected by anthropogenic inputs, such as the Amvrakikos (Ionian Sea) and Thermaikos as well as Elefsis Bay are the most productive whereas in offshore waters, the Ionian sea is characterized by a low mesozooplankton abundance values.

451. No comprehensive study has been done on the Libyan coast about plankton, but a survey done in the Libyan coast (Med-Sud-Med 2006) pointed out that the phytoplankton of the Libyan western coast is characterized by abundant diatoms and dinoflagellates, rare coccolithophores and very rare Silicotlagellates. A very high concentration of phytoplankton is located in Musrata area with diatoms are the most dominant phytoplankton, followed by coccolithophores and then Silicoflagellates. As for the Zooplankton, few studies have been undertaken. The Med-Sud-Med 2006 survey focused on the location areas of major concentration of Ichthyoplankton (eggs, and larvae of fish). The predominant species recorded were anchovy (Engraulis encrasicolus) representing 51% of the collected larvae, round sardine (Sardinella aurita) with 9.6% of the larvae and minor fraction of other species (Serranidae, Gobidae and Labridae).

452. Tunisian waters are better studied. The number of phytoplankton species identified in Tunisia is about 493 species distributed over 11 groups and mainly dominated by *dinoflagellates (259 species) and diatoms (198 species).* In the Gulf of Gabes, the summer season characterized by high temperatures and salinity, promotes stratification of the water column and induces the appearance of phytoplankton blooms with prominent presence of *dinoflagellates*, diatoms and cyanobacteria. Phytoplankton blooms have been recorded in the Gulf of Gabes, including an extreme event in summer of 1994. These episodes accompanied by a mortality and stranding large quantities of fish (eels, cuttlefish, etc.). The phenomenon continued for a week and microscopic observation revealed the proliferation of a monospecific population of *Gymnodinium* sp. very similar to *Gymnodinium nagasakiense.* The highest concentrations are recorded in the order of 4 to 6 ×. 10^{7} cells. $l^{-1.}$ In the offshore area of Kerkennah islands, an overgrowth of cyanobacteria (genus *Trichodesmium* (called "Muffa") commonly occurs. Generally in the Gulf of Gabes, the confined areas or tidal lagoons show signs of eutrophication, such as the case of the Sea Bougrara where level of chlorophyll a is moderate to fairly high.

453. The zooplankton community of the Tunisian coast is quite diverse, represented by 269 species distributed over 23 groups dominated by tintinnids and copepods. In the Gulf of Gabes, the zooplankton is distributed over 11 groups dominated by copepods, which represent 69-83% of the total zooplankton. Both species *Oithona nana* and *Acartia clausi* are particularly abundant along the coast and up to 50 m depth.

4.3.2 Information on invertebrate bottom fauna, macro-algae and angiosperms

Invertebrates

454. Some areas of Greece and Tunisia are well-studied in regards to benthic invertebrate fauna and flora. In Greece, 220 species of polychaetes are found in the Ionian Sea and 13 of them are exclusively reported from the Ionian Sea. Most of them inhabit sandy, biogenic and generally coarse substrate reflecting high dynamic littoral environment or angiosperm coverage. One hundred and five annelid species have been recorded in the eastern and southern regions of Tunisia. The sedentary polychaete annelids represent 64% of the total annelids against 35% of errant polychaetes and 1% of oligochaetes. Also in eastern and southern Tunisia, 83 bryozoans are identified. *Hornera lichenoides* is listed in Annex II of the SPA/BD protocol of the Barcelona Convention, while *Electra posidoniae, Pentapora fasciali*s and *Reteporella grimaldii* appear in the specific Tunisian list of species to be protected.

455. In contrast to the Aegean Sea, the anthozoan diversity of this region, and especially its deeper parts, is yet to be explored (Vafidis *et al.*, 2006; Salomidi *et al.*, 2010). Similarly, much knowledge on the Ionian sponge fauna comes from the Italian coasts, while the Hellenic (eastern) Ionian side remains poorly known, with only few and scattered relevant information (e.g. Tsoukatou *et al.*, 2003; Vacelet *et al.*, 2008). The study that has been done from Al-Gomas to Musrata regarding sponges in Libyan waters reported many species such as the economic species *Spongia afficinalis* and *Hippospngia communis* and other species like *Arcorina cerebum, Axinella* sp, *Petrosia sp* and *Calyx nicaensis* (Report 2009, MBRC). Sponges are represented in an uneven manner across the regions of Tunisia; the southern region is the richest at both generic and specific levels, with 115 species of sponges identified in the eastern and southern Tunisia. Among the Tunisia sponges, at least six species are considered as endangered or threatened species including *Aplysina sp., Axinella cannabina, Axinella polypoid, Geodia cydonium, Tethya Ircinia and foetida sp.* Ten species are designated as protected by the SPA/BD of the Barcelona Convention, namely *Aplysina aerophobia, Axinella polypoid, Geodia cynodium, Hyppospongia communis, Ircinia foetida, Spongia agaricina, S. officinalis, S. zimocca, T. citrina and Tethya auranium.*

456. In Eastern and Southern regions of Tunisia, studies revealed the presence of 52 species of echinoderms. Three species are mentioned in lists of the Barcelona Convention *(Asterina Panceri, Centrostephanus longispinus, Paracentrotus lividus).* One species *(Hacelia attenuata)* and the type *Holothuria* are on the specific Tunisian list of species to be protected. Only *Centrostephanus longispinus* is considered threatened in the Mediterranean (Annex 1 of the SPA/BD protocol).

457. In a recent assessment of the decapod fauna of Hellenic waters (Kitsos, *et al.,* 2006), a total of 250 species were recorded with the predominance of the true crabs (brachyurans) followed by caridean shrimps and anomurans (hermit crabs, squat lobsters). In the upper slope of the Ionian Sea, thirty species of megafaunal decapods have been reported from trawl catches. Most abundant are the shrimps *Parapenaeus longirostris* and *P. heterocarpus*. The main Hellenic fishing grounds of the Norway lobster N. norvegicus are located in Ionian Sea. In the 500-700 m zone, the giant red shrimp *A.foliacea* and the pandalid shrimp *P. martia* predominate in the experimental catches of the Ionian Sea. The former species and the blue and red shrimp *Aristeus antennatus* are the dominant decapods found in the 700-900 m zone. Thirty seven species of Crustaceans were recorded (6 Isopoda, 23 Decapoda, 7 Amphipoda and 1 Balanomorpha). A total of 167 species of crustaceans are identified in the Gulf of Gabes. Two species of amphipods and isopods, and ten inventoried in the Gulf, are exotic. *Penaeus kerathurus* is considered as a species to be protected by the Tunisian experts while *Maja squinado* is listed on Annex III of the SPA/BD protocol of the Barcelona Convention.

458. A total of 1160 mollusc species have been recorded so far in Hellenic seas with an increasing trend in bivalve species recorded in Hellenic waters is most apparent since 1980. Twenty one species of mollusca (other than cephalopoda) have a commercial interest particularly in fisheries and aquaculture since they are collected and/or cultivated for human consumption. Population assessment exist only for few species e.g., *Pinna nobilis, Lithophaga lithophaga, Donacilla cornea* in Hellenic seas, and these only at a local scale.

459. About 24 species of cephalopods were recorded in the Libyan coast (Ben Abdalha *et al.*, in press), belonging to 8 families and 3 orders. Although most of these species are commercial and have economic value in the Libyan market, no comprehensive study exists about these species till now. In the western part of the Libyan coast, 38 species of mollusca were found in the rocky zones, (27 Gastropoda, 10 Bivalva and 1 Polyplacophora).

460. In eastern and southern Tunisia, 328 species of mollusks have been recorded, distributed in 188 snails, 126 bivalves, 6 Polyplacophora, 4 scaphopods and 4 cephalopods. Seven species have heritage value and are subject to protection state, namely *Luria lurida, Tonna galea, Zonaria pyrum, Pinna nobilis, Pinna rudis, Haliotis tuberculata and Spondylus gaederopus.* Thirteen introduced species are reported in the Gabes Gulf, namely *Cellana radiata radiata, Crepidula fornicata, Cerithium scabridum, Erosaria Turdus, Bursatella leachii, Acteocina mucronata, Chromodoris quadricolor, Melibea viridis, Musculista senhousia, Crasostrea gigas, Pinctada radiata, Fulvia fragilis and Ruditapes philippinarum).* Among these shellfish, octopus, cuttlefish, squid, clams and snails are commonly used as a fishing product in this region.

461. Seventy seven species of ascidians are present in the Gulf of Gabes. Only four species are listed as Tunisia species that deserve protection: *Clavelina nana, Halocynthia papillosa, Microcosmus sabatieri* and *Microcosmus vulgaris.* Two exotic species are reported, namely *Cystodytes philippinensis* and *Microcosmus exasperates.*

Macroalgae

462. Case studies in the Hellenic part of the Ionian Sea estimated similar (163 taxa; Tsekos and Haritonidis 1977) or higher (265 taxa; Schnetter and Schnetter 1981) trends in seaweed diversity than in Aegean.

463. However, the macroalgae diversity in Libya is not rich. Fifteen genera (29 species) of Chlorophyta, 19 genera (34 species) of Phaeophyta, 76 genera (112 species) of Rhodophyta and 2 genera of Cyanophyta (3 species) were recorded according to Nizamaldeen (1979). Introduced species have been also recorded such as *Halophila stipulacea* in Ain-Al-Ghazala marine area, introduced from the Red sea through the Suez canal and *Halimeda sp*. On soft substrates of the Ionian the angiosperms *Posidonia oceanica* and *Cymodocea nodosa* are widespread, whereas the angiosperms *Zostera noltii* and *Halophila stipulacea* are restricted to specific areas.

4.3.3 Marine mammals, reptiles, and seabirds

Marine Mammals

464. The Ionian Sea hosts an important part of the total Mediterranean populations of the sperm whale (*Physeter macrocephalus*), the bottlenose dolphin (*Tursiops truncatus*) and the common dolphin (*Delphinus delphis*). Regarding the latter, the Inner Ionian Archipelagos - a Natura 2000 Site of Community Importance- used to be one of the last places in the central Mediterranean Sea where abundant common dolphins would be found (Politi *et al.* 1999). However Bearzi *et al.* (2008) showed recently a dramatic decline of the species' local population (from 150 to 15 recorded individuals in the last 13 years), urging for direct management measures for the conservation of this endangered species. Another exceptional and rare characteristic of the cetacean fauna of the Ionian Sea, is the permanent presence of mixed groups of striped dolphins with short-beaked common dolphins and even -occasionally- Risso's dolphins in the semi-enclosed Korinthiakos Gulf (Frantzis & Herzing, 2002). Despite a paucity of information on Libyan waters, it is known that 8 species of cetaceans are present in Libya, namely: Striped Dolphin (*Stenella coeruleoalba),* Sperm Whale (*Physeter macrocephalus),* Risso's Dolphin (*Grampus griseus),* Pilot Whale (*Globicephala melas),* Bottlenose dolphin (*Tursiops truncates*), Cuvier's beaked whale (*Ziphius cavirostris*), Common Dolphin (*Delphinus delphus*) and Fin Whale (*Balenoptera Physalus)*. Except for bottlenose and striped dolphins, all of the other species are mainly offshore and seldom found near the coast.

465. Mammals observed in the Tunisian waters of the subregion region are Minke whale *(Balaenoptera acutorostrata),* the fin whale *(Balaenoptera physalus),* the Risso's dolphin *(Grampus griseus),* the Humpback whale *(Megaptera novaeangliae),* the Striped dolphin *(Stenella coeruleoalba),* the bottlenose dolphin *(Tursiops truncatus);* these mammals are rather large pelagic, some may attend coastal waters for food. Apart from the common dolphin, the other species are rare to very rare.

466. In the Hellas portion of the Central Mediterranean, the population of the monk seal (*Monachus monachus*) is estimated to represent ca 90% of its total Mediterranean abundance (Notarbartolo di Sciara *et al.*, 2009). Although the Aegean Sea is known to be one of the most important areas for the species' conservation worldwide (Cebrian et al 1995), an approximate 15-20% of the Hellenic population lives and breeds in the Ionian Sea (Cebrian 1998a). The best studied seal concentrations until now are those found along the coasts of Zakynthos, Kefallonia, Ithaca and Lefkada islands (Panou *et al.* 1993, Cebrian 1998b).

467. Regarding the Monk Seal, there are only few documented sightings for this species in Libya and mostly in the areas of Tubruk and Bombah gulf (60 km east of Derna) (Norris1972; Sergeant *et al.*, 1978; UNEP 2003). In the Green Mountain, there are two areas that might still hold a potential habitat for the Monk Seal. The first one is between Derna and Rass Ateen and the second is between

Haboon and Al-Uglah. The shear costal cliffs of these areas hold caves that can be used by this species for breading and resting. There is a running project at the moment between EGA, IFAW and UNEP/MAP - SPA/RAC to fit camera traps in selected caves in order to monitor the population (Hamza *et al.*, 2003).

Sea Turtles

468. Three species of marine turtles, namely the loggerhead turtle *Caretta caretta*, the green turtle *Chelonia mydas*, and the leatherback turtle *Dermochelys coriacea* are encountered in the Hellenic seas. *For the* loggerhead populations (*Caretta caretta)* in the Mediterranean Hellas is among the major nesting sites (Margaritoulis, 2007). According to same source, one among the highest nest density, is Laganas Bay on the Ionian island of Zakynthos. Other nesting areas are found in Peloponessos (Bay of Kyparissia, Bay of Lakonikos). For the foraging species available data from Hellas indicate that juvenile green turtles (C. *mydas)* have been recently identified in Lakonikos Bay, southern Hellas (Margaritoulis, 2007).

469. Concerning sea turtles in Libyan waters, the Gulf of Sirt is considered as the most important area for sea turtle feeding, wintering and breeding on the national level. Thus, Environment General Authority (EGA) have started an initiative to protect three nesting beaches in west of Sirt (Libyan Seaturtle Program).

470. The sea turtles present in Tunisia are mainly present in the east and south of the country, including *Caretta caretta* (relatively common in Tunisia), *Chelonia mydas* (rare) and *Dermochelys coriacea*.

Seabirds

471. A regular survey of birds in Libya was started on 2005 aiming at the census of the wintering birds along the coast of Libya. This project is conducted by local and international team and sponsored by EGA, UNEP/MAP - SPA/RAC and AEWA. The objectives of these surveys (2005 – 2010) were to investigate whether a critical threatened species Slender – billed Curlew exists in Libyan habitat and accounting water birds wintering in Libya.

472. Tunisia is an important wintering site for Palearctic waterbirds and an important port of call for trans-Saharan-Palaearctic migration. However, studies on biodiversity of aquatic birds are limited.

4.3.4 Exotic, non-indigenous and invasive species

473. In a similar fashion as habitat destruction through pollution or anthropogenic effects, the introduction of species is considered as a nuisance and disruption to biodiversity. The number of introduced species in the Mediterranean has increased spectacularly since the start of the last century. Their distribution varies from country to country. They have been mainly introduced through two pathways: (i) by maritime transport and fish farming and (ii) through the Suez Canal.

474. In the Hellenic Ionian Sea, 60 alien species have been recorded, belonging mostly to zoobenthos (24 species) and phytobenthos (18 species). _Studies directly investigating the impact of alien species on the diversity of native biota as well as socio-economic impact of invasive alien species are missing.

475. Along the Libyan coast, 22 exotic fish species have been recorded. Most of the studies have focused on the Lessepsian fish species, Status, Biology, Ecology (Shakman, 2008). In the Libyan coast, the most abundant herbivorous fish were the Indo-Pacific fish species *S. rivulatus* and *S. luridus*, which are more numerous than the native fish species *S. cretense* and *S. salpa* (Shakman and Kinzelbach, 2007b). Two ectoparasite species *Anilocra physodes* (Linnaeus, 1758) and *Nerocila bivittata* (Risso 1816) belonging to the subfamily Anilocrinae are the first records of cymothoids from the Libyan fauna.

476. Introductions recorded in Tunisia come mainly through the Suez Canal and the Straits of Gibraltar (Indo-Pacific marine species and Eritrean origin or Atlantic). Besides the Suez Canal and the

Straits of Gibraltar, other routes of introduction include clinging or fouling on the hulls of ships, ballast water, leaks from aquaculture, accidental introductions, and unknown vectors. Introduced species in Tunisia are mainly observed in the Gulf of Gabès, which has suffered from the consequences of several disturbances and changes in habitats. Introduced species have increasingly recorded in recent decades, probably due to of maritime traffic, accidental introductions or ballast water.

4.3.5 Fish populations including abundance, spatial distribution and age/size structure

477. The Hellenic Seas are characterized by a thermophilic tropical and subtropical fish fauna originating from two different sources: i) relicts of the Tethys Sea and ii) immigrants of various origin arriving at different times from the Indian Ocean and the Red Sea (SoHelFi, 2007). According to the latest update of the IMAS-Fish database (IMAS-Fish, 2007), the total number of recorded fish species in Hellenic waters collected from experimental and onboard sampling by trawls, purseseines, nets and beachseines, since 1983 is 393 (S. Kavadas pers. commun.) of which 300 occur in the Ionian Sea (and 365 in the Aegean). Theminimum size allowed for fisheries and the closed fisheries period for selected species is regulated according to the Presidential Degree 227/03 and EU Regulation 1967/2006.

478. The highest fish species diversity in the Libyan coastal area is in the eastern region (45.65% corresponding to 42 fish species) while in the Gulf of Sirt and western regions the averages are are 23.91% and 30.43% respectively corresponding to 21 and 28 species. As for sharks in Libyan waters, surveys conducted by Ben Abdallha *et al.*, (in press) lists 55 species, with reports that fishing activity for these species were concentrated on the middle of the Libyan coast from Musrata in the west up to Benghazi in the East.

479. In the Central Mediterranean, marine fisheries are characterized by a large number of species caught per main fishing gear (i.e. multi-species fisheries) as well as by a variety of species that are exploited concurrently by different fishing gears (i.e. multi-gear fisheries).

480. Fish farming is a relatively ancient practice in the Mediterranean basin. It has expanded enormously since the 1990s, particularly marine fish farming. This involves farming the gilthead sea bream Sparus aurata, the sea bass Dicentrarchus labrax, the mussel *Mytilus galloprovincialis* and the flat oyster Crassostrea gigas. Greece is the first offshore marine fish farming producer country in the sub-region but also in the whole Mediterranean with over 120,000 tons per year of sea bass and gilthead sea bream. As for the raising of bivalve molluscs, mussels and flat oysters hold respectively first and second place.

481. Existing fishery assessments from research surveys of Greek waters indicate that most of the existing stocks are being overfished. This is causing growing concerns with regard to the sustainability of both commercial catches and the aquatic ecosystem from which they are extracted, as well as to safeguarding the livelihoods of fishermen. Fishing impact on the demersal resources of Hellenic waters could be considered strong for depths shallower than 500 m. The Libyan fisheries are not well known, but the fishery for sharks utilize a special gill net named KELLABEI in local, using seasonal landing sites.

482. Fishery production in Tunisia has reached 100,578 tons in 2008 against 90,039 in 1998 with a rise of 11%, primarily due to pelagic species. The eastern and southern areas provide 87,693 tons of catches, representing 87% of national production. The active fleet in this area consists of 10,214 active units (90% of the national fleet) and the maritime population of the area has 43,583 fishermen representing 84% of the national population. The Gulf of Gabes represents the most exploited area for fishing followed by the eastern portion of the country’s waters.

483. The latest estimates of pelagic resources in Tunisia, conducted by the Institut National des Sciences et Technologies de la Mer (INSTM), suggests fisheries are exploiting below maximum sustainable yields. Indeed, the exploitable biomass in this resource is greater than 80,000 tons while the domestic production does not exceed 45,000 tons. This situation of underexploitation is due to several factors, among them the exploitation of traditional fishing areas and the low efficiency of some fishing gears used.

4.4 Habitat classification and known distribution of habitats

484. The Mediterranean continental shelf possesses rich and important habitats. In the context of the tools developed by the Regional Activity Centre for Specially Protected Areas (UNEP/MAP - SPA/RAC), a reference list of 27 major types of benthic habitat was made, to help the Mediterranean states in drawing up inventories of natural sites of conservation interest (UNEP/MAP - SPA/RAC, 2002). The SAP BIO Programme (UNEP/MAP - SPA/RAC, 2003) had identified among its priority actions the making of a complete, integral inventory of its Mediterranean habitats, including mapping their spatial distribution and the cohort of species associated with each habitat.

485. *Posidonia oceanica* is endemic in the Mediterranean. Annex I of Directive 92/43/EEC describes meadows of *Posidonia oceanica* as a priority habitat type. Posidonia meadows do not appear in areas with low salinity and weak light penetration due to pollution. The ecological parameters that affect the distribution of the upper and lower limit of the meadows as well as their density are light and hydrodynamic conditions. According to the Barcelona Convention typology, in the habitat type "Posidonia meadows" (BC type III. 5. 1) two ecomorphosis are described: The ecomorphosis of striped meadows (III. 5. 1. 1.) and the ecomorphosis of barrier-reef meadows (III. 5. 1. 2.). A facies of dead “mattes” without much epiflora and an association with *Caulerpa prolifera* has also to be added.

486. Within this subregion, the seagrass meadows dominated by *Posidonia oceanica* are most extensive in the Gulf of Gabès (Tunisia). Posidonia meadows are also common in the Aegean as well as on the Ionian coasts. They are present in Libya (Bamabah Bay, Farwa, Ain Elghazala and El-Bardyya, Al Elghazalaha Bay); in the Italian waters; in Malta (Mifsud, 2006); and in Morocco near the Chafarin Islands (Bazairi, 2010). The meadows present in the Malta-Comino Channel are dense and show a high degree of shoot density, it has been recorded to host probably the highest shoot density in the Mediterranean (Micallef, S. (1996). The area also hosts the deepest records for Posidonia, in Malta, off the south coast of Comino.

487. The *Cymodocea nodosa* meadows are second in importance after *Posidonia*. These meadows are recorded in the Aegean and Ionian Seas, where it is widely found on loose substratum (Zenetos *et al*., 2010a and b); in Libya (Al Elghazalaha Bay) (Shakhman, 2010) in Tunisia (Romdhane, 2010) and in Malta.

488. The *Halophila stipulacea* meadows are restricted to specific areas; they have been sighted in Greece (Zenetos *et al*., 2010a and b); and in Tunisia in the Gulf of Gabès (Romdhane, 2010); as well as in central Italy in 2006.

489. Coralligenous communities constitute the second most important hotspot of specific biodiversity in the Mediterranean after seagrass meadows (Boudouresque, 2004). The coralligenous habitats and bioconcretions (pre-coralligenous populations, shelf coralligenous, associations with rhodoliths – maërl facies, association with rhodoliths – *pralines* facies, association with rhodoliths – *Lithothamnion minervae* facies, association with *Peyssonnelia rosa-marina* – free *Peyssonneliaceae* facies and big bryozoan facies of the coastal detrital bottoms) are being studied in the Ionian Sea. They have been also recorded in Tunisia (from El Haouaria to La Chebba) (Romdhane, 2010) and in Maltese waters where an extensive maerl bed covering 20km² of the seabed occurs at depths of between 40 and 80m off the north-eastern coast of Malta and Gozo (Borg *et al.*, 1998), whilst other studies have identified another extensive maerl bed off the eastern part of Malta (Dimech et. al., 2004). The main rhodolith forming algae in the Maltese maerl beds are *Lithothamnion corallioides, Lithothamnion minervae* and *Phymatholithon calcareum* (Lanfranco *et al.*, 1999).

490. *Cystoseira* forests can occupy large areas in the marine ecosystems, where they form highly productive communities with remarkable biodiversity. Species of the *Cystoseira* genus species are in a speciation process which has led to many varieties within a single species and these algae present significant morphological variability. *Cystoseir*a forests have been reported in Ionian Sea of Italy, in the in the Aegean and Ionian Seas; in many areas around the Maltese Islands.

491. *Neogoniolithon brassica-florida* concretations are known in the hypersaline lagoon of Bahiret-el-Bibane in the south of Tunisia, where they can form habitats as long as 31 km. This habitat has no parallel elsewhere in the Mediterranean Basin.

492. Beyond these specific habitat types, the available knowledge on other habitat types is extremely fragmentary and very variable in the Central Mediterranean and Ionian Sea (UNEP/MAP – BP/RAC, 2009). In the coastal strip, there are few ecosystems of world interest for the conservation of biodiversity, including coastal sand dunes and coastal wetlands, especially coastal lagoons. The lagoons are generally diversified, rich habitats that deserve more focused studies.

493. Finally, in the high seas, thermal fronts correspond to areas of contact between two masses of water of different temperatures. These regions are often the site of vertical mixtures likely to bring to the surface mineral salts that encourage plankton development and help install a food chain. Upwellings are considered as being among the most productive ecosystems in the marine environment.

4.5 Pressures and impacts

494. In the Central Mediterranean Subregion, an estimated 8.6 million inhabitants reside in a total of 27 coastal urban centers or areas. Of these, Tripoli is the biggest urban centre with 1.06 million inhabitants, with Tunis being the second largest with 0.72 million inhabitants, and Benghazi being the third largest with 0.67 million inhabitants. On the European side, the biggest coastal urban area is that of Taranto with 0.58 million and then Reggio Calabria with 0.57 million. This evidently shows that the urban concentrations with the highest populations are located on the African coastline in the subregion. On the Ionian Greek coastline, Patra is the biggest urban center with 0.22 million inhabitants. Figure 4.8 shows the location of these urban centers, together with the relative levels of populations residing in such centers.

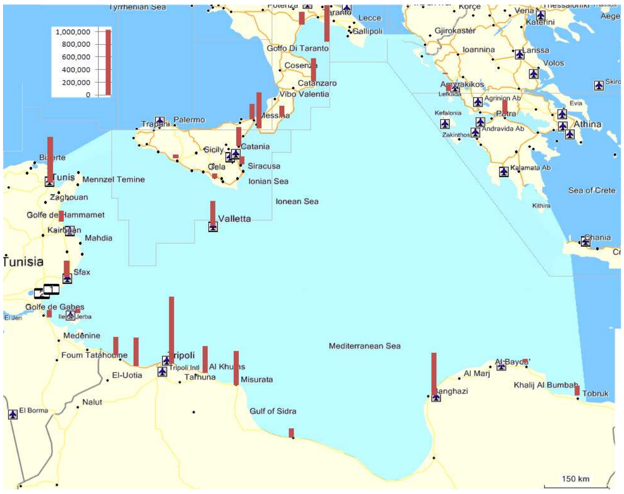


Figure 4.8. Location of major urban centres with relative population levels in the area under review.

4.5.1 Contamination by hazardous substances

495. The permanent population along the coastal areas of the Ionian and Central Mediterranean is in the order of 8.6 million inhabitants residing in about 27 coastal urban centers or conglomerations. The demographic features of the area have already been reviewed above. Furthermore, due to the intense tourism activities in the area, this population may be doubled during the summer peak months. Though no regionally based data of tourist's arrivals were available for the present report, a rough calculation from the available published data may indicate that the number of tourist arrivals may reach from 15 to 20 million visitors per year.

496. As part of the pollution reduction component of the Euro MED Initiative Horizon 2020, LDK-ECO S.A. Environmental Consultants (2006) reviewed the pressures arising from urban wastewaters in a range of South Mediterranean countries, including Libya and Tunisia. While past infrastructure projects have extensively taken place on urban wastewater sanitation in Libya, the report refers to defects in pumping stations and wastewater treatment plants, and improper connection with run-off ditches and open channels, resulting in lack of proper treatment of urban effluents. At least up to 2006, rehabilitation of the treatment plants was required for the largest two cities Tripoli and Benghazi, as well as Janzur, Dernah, Khums, Tobruk and Sabrata.

497. Maintenance of civil and mechanical works and connection of sewage pumping sanitation were needed for a number of wastewater treatment plants. The report also refers to large amounts of run-off water from urban areas find their way to the sea through special outlets, as in Tripoli, or through natural valleys and watercourses, as in Khums, Al Qarabulli, Tajura, and Sirt Cities. In the case of Tunisia, the LDK-ECO S.A. report (2006) states that wastewater services were very well developed. However up till 2006, some large cities required an extension of their sewage network (Ariana and Ben Arous in Tunis area, Mahdia, Sfax, Gabes and Djerba), where the connection rate is below 85%. Furthermore, because of the fast growth of the urban population, some treatment plants cannot cope with the rapidly increasing flow of effluents. For example, although the greater Tunis area operated a sewage treatment plant, the rapid population growth has resulted to a treatment capacity deficit of 60,000 m3 per day. It is quite likely that this state of affairs had improved since 2006.

498. As part of the present assessment, an attempt has been made to estimate the approximate volume of domestic wastewaters produced in the region, and of this how much receives treatment. Although available data are insufficient in some cases, nonetheless some estimates were possible on the basis of reported number of residents in these areas. Furthermore, according to various EU online databases, for the whole Italy it has been reported that than 60% of its urbane wastewaters, currently receiving some kind of treatment. Based on this information, as well as on the data provided by the NDA reports for the other countries, it was estimated that the approximate total volume of urban wastewaters generated in the area under review would be 765 million m3 per year. At least 40% of this remains untreated and a significant amount is bound to reach the marine environment. Figure 4.9 shows such assessment graphically.

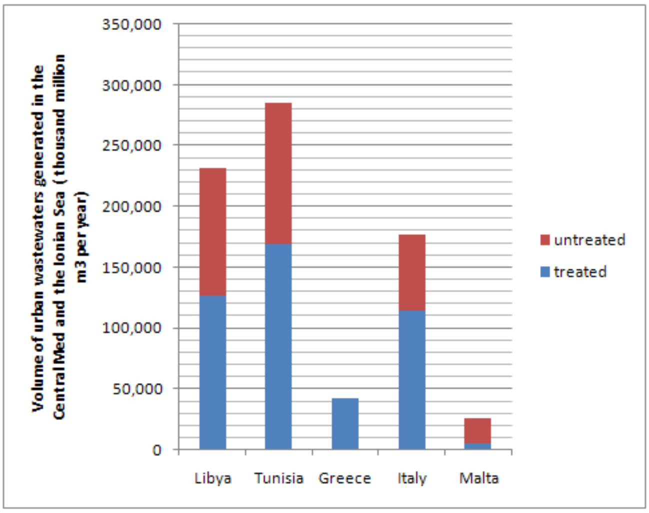


Figure 4.9. Volume of urban wastewater (million *1000 m3 per year) by the various regions bordering the Ionian and Central Mediterranean.

499. Industrial effluents also affect water quality, and in the case of phosphorus, industrial effluents far exceed urban effluents in importance.

500. UNEP/MAP (2008) had reported the total load of some selected pollutants as reported by all Mediterranean countries by sector. The data suggest that when compared to releases over the whole Mediterranean, the annual rates of release of a number of important pollutants in the subregion are

not significant. This particularly applies to mercury, phenols, lead, chromium and possibly nickel. On the other hand releases of polyaromatic hydrocarbons in this area are significantly higher than those that would be expected, probably related to the increased shipping traffic in the Central Mediterranean.

501. The most important sources of releases of marine contaminants in the Mediterranean, has been recently reviewed by UNEP/MAP (2008) and UNEP/MAP – BP/RAC (2009). As pointed out by the latter report, data transmission of NBB by the various states within the Mediterranean presents gaps. This is particularly so for the Central Mediterranean since the data on industrial releases from the southern Mediterranean states accounted to only 11% of the whole data set received by the UNEP/MAP unit.

502. Based on the emissions reported to UNEP/MAP - MED POL, in the Central Mediterranean area manufacture of metals and oil refining and oil/fuel related operations assume bigger importance as sources of pollution, than production of energy. As expected (due to the level of water scarcity), the industrial sector of desalination also features quite prominently. Also, aquaculture appears to be a sector of emerging importance. Figure 4.10 shows the relative importance of releases (% loads) of trace metals from the various identified industrial sectors in Italy (releases into the Ionian sea only), Libya and Malta.

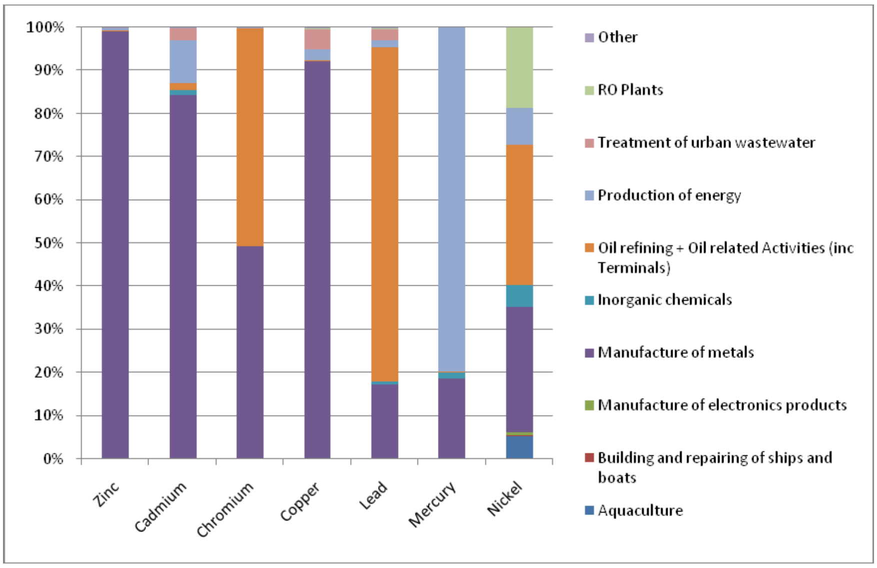


Figure 4.10. The relative importance of various sectors for the release in the marine environment of various trace metals (based on data from Italy-Ionian, Malta and Libya)

503. As would be expected, most of the metals released in the area arise mainly from the manufacture of metals as well as from oil refining and oil/fuel related activities. Mercury is mainly released from production of energy, unlike for the rest of the Mediterranean, where is mainly released from manufacture of fertilizers (UNEP/MAP, 2008).

504. Figure 4.11 shows the relative importance of releases (% loads) of various other main contaminants from the various identified industrial sectors in Italy (releases into the Ionian sea only), Libya and Malta.

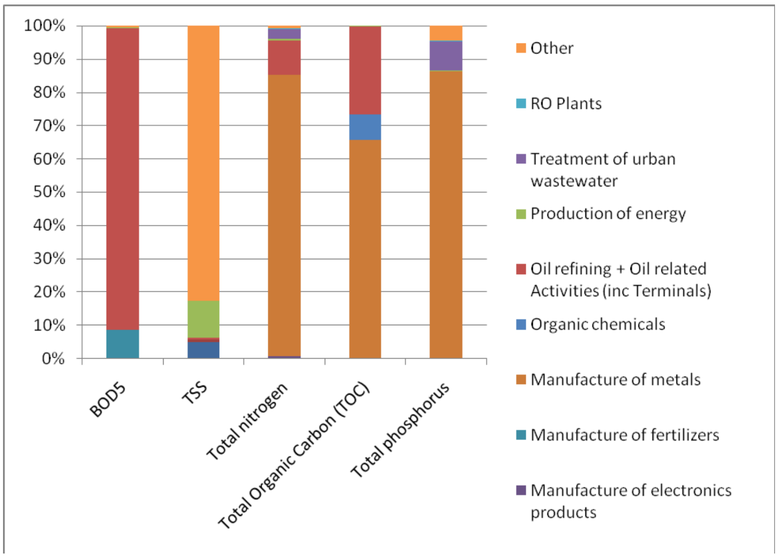


Figure 4.11. The relative importance of various sectors for the release in the marine environment of BOD5, TSS, TOC and total Nitrogen and Phosphorus (based on data from Italy-Ionian, Malta and Libya)

505. Manufacture of metals causes the release of a number of contaminants. This may not necessarily be representative for the whole subregion. Furthermore, UNEP/MAP (2008) shows this industrial sector to be only relatively important for the release of total nitrogen, for the Mediterranean as a whole.

506. The available data suggest that the oil sector is the main industrial sector responsible for BOD5 release. According to UNEP/MAP (2008), this is also a main feature found for the rest of the Mediterranean (along with food packaging, and farming of animals).

507. The following assessment of levels of contaminants in the marine waters, sediments and biota in the Ionian and Central Mediterranean is mainly based on UNEP/MAP (2008) and UNEP/MAP - MED POL (2009a). Both reports noted that the main problem to be taken into consideration was unequal geographical distribution of the available data.

508. Most of the data on trace metals are available on five metals, namely: cadmium, mercury, lead, zinc and copper. UNEP/MAP - MED POL (2009) produced synoptic figures of the distribution of mean concentrations of trace metals as found in coastal marine sediments and in marine bivalves, in the Mediterranean. As indicated by UNEP/MAP (2008), elevated levels of mercury in marine sediments are more often found in the immediate vicinity of industrialized or heavily urbanized coasts. For example, mercury levels in the Gulf of Taranto range from 40 to 410 ng g-1 dw in sediments near the coast and 70 ng g-1 dw in sediments offshore, in the centre of the gulf. An extensive study in the Strait of Sicily revealed that mercury levels ranged from 50 to 70 ng g-1 dw, with samples registering higher contents with maxima up to 202 ng g-1 dw . Similarly, sediments of the Strait of Otranto reached 78 ng g-1 dw.

509. Mercury levels in marine offshore sediments as recorded in the Ionian Sea were generally found to be comparable to those from other Mediterranean areas (around 50 ng g-1 dw). Di Leonardo *et al.*, (2006) have shown occasional high levels of mercury in the Strait of Sicily.

510. More recently some additional data is available for trace metals in sediments from Malta, Lampedusa and to a lesser extent from Linosa. The most elevated levels of such contaminants in sediments were associated with the main sewage outfall in Malta. This currently discharges 80% of the total liquid wastes (domestic and industrial wastes) generated in Malta, untreated in the marine environment. Of the trace metals assessed, zinc levels were generally higher, probably due to natural factors. For the case of mercury in marine sediments in Malta, Lampedusa and Linosa, levels were relatively low, except for some outlier maxima reported in the immediate vicinity of the main outfall in Malta.

511. Organotins have been used for a wide range of applications, generally related to their biocide effects. One of the best known is tributyltin (TBT) which has until recently been used as an antifouling agent for ships and boats (amongst other applications).

512. TBT is one of the most potent biocides which may reach the marine environment and as such warrants a more detailed look at the available data. UNEP/MAP (2008) reviewed much of the available data on organotins in general and more specifically on TBT. Such review has shown that much of the data available for the Mediterranean comes from the western basin (especially Spain) and Egypt. For the Central Mediterranean, Axiak *et al.*, (2000), reported that the two main sources of marine contamination by TBT in Malta were the ship-repairing dockyards and marinas.

513. At TBT levels found in local harbours, several biological responses were observed, including significant reduction in Mixed Function Oxidase enzyme system activities of fish; digestive cell atrophy in the oyster *Ostrea edulis*; and induction of imposex in the snail *Hexaplex trunculus*. The latter two responses are evident at TBT concentrations below the environmental quality standard (20 ng Sn L-1).

514. Imposex monitoring in Lampedusa and Linosa during 2006-2007 (Axiak, *et al.*, in press) have shown that recent TBT contamination in both islands which have to date been considered as relatively pristine areas, is significant. There is also evidence that the occurrence of such imposex has increased significantly since 1996 (as reported by Terlizzi *et al.*, 1998, and so has the impact on the populations of this species. The most likely source of pollution by TBT in both islands is the relatively high maritime activities during summer. Through imposex monitoring, it is evident that levels of TBT are or at least until very recently were widespread found in the Ionian, the Central Mediterranean and elsewhere.

515. According to UNEP/MAP-MED POL data, (UNEP/MAP - MED POL 2009a) the Central Mediterranean and Ionian Sea were relatively free of hotspots of chlorinated hydrocarbons in marine bivalves, at least according to the present availability of data. Lower median levels were also estimated for total DDTs, and for lindane in the bivalve *Mytilus*, when compared to median levels in other Mediterranean sub-regions.

516. Few spatial and long-term temporal trends monitoring of fish, mussels and seabird eggs have been carried out in the Northern Mediterranean. A general decline of DDTs has been reported for marine biota along the Mediterranean coast of France and Italy, and from the Adriatic Sea between 1970's and 1990's, which is consistent with the regulatory restrictions on production and use of this compound. PCBs, in general, do not exhibit such clear trend. No such conclusions could be reached for the area under review, due to limited availability of data.

517. UNEP/MAP (2008) reviewed the levels of various forms of halogenated hydrocarbons within the Mediterranean, including DDTs and other halogenated pesticides, chlorinated paraffins, perfluorinated compounds, brominated flame retardants, dioxins and furans, as well as polychlorobyphenyls. In this review, a number of case studies (often of an ad hoc nature, rather than resulting from long-term monitoring) are reviewed. Few case studies which fall within the area under review were identified.

518. Ranges of reported levels of PCB levels in the fish *Dicentratus labrax* and of *Thunnus thynnus* in the Strait of Messina, were in general comparable to those of other regions, though sometimes higher. The same applies to levels of DDT (though wide ranges in such levels have been often recorded).

519. Levels of dioxins and furans (polychlorinated dibenzo-p-dioxins, and dibenzonfurans) in the shrimp *Aristeus antennatus*, during 2001 as measured in the western and eastern Ionian Sea were generally lower or comparable to those measured along the Catalan and Balearic coastal waters. Recent results from 'mussel watch' experiments as well as chemical monitoring in sediments, in Lampedusa, Linosa and Malta (Scarpato *et al.*, in preparation) suggest that except in the immediate vicinity of the main sewage outfall in Malta, the levels of PCBs, chlorinated pesticides and other halogenated hydrocarbons are low and often below the detection limit.

520. Most of these halogenated hydrocarbons often reach the marine environment through river discharges, coastal runoff (especially from agricultural land for pesticides) as well as sewage outfalls (especially when industrial wastewaters are discharged into public sewers. The above account suggests that though levels of such contaminants may be high in the immediate vicinity of likely sources (as identified above), such as along heavily industrialized coastal areas along the Ionian and Sicilian Italian coast. However, the subregion as a whole is relatively free of contamination hot-spots.

521. A geographical trend in contamination was a found in studies of the striped dolphin in the Mediterranean basin: PCB and DDT levels decreased from the north-west (Ligurian Sea) to the south-east (Ionian Sea). Fossi *et al.*, 2004, investigated the bioaccumulation of a range of contaminants in specimens of striped dolphin collected from various regions within the Mediterranean.

522. Polyaromatic hydrocarbons (PAHs) are often related to crude oil, and petroleum fuels and products. Though there is a range of potential land-based sources of such marine contaminants, the most evident are maritime traffic and the chronic (from normal operations) and accidental releases of oils and other fuels, oil refineries and oil/fuel terminals, as well as atmospheric fallout from point and diffuse land-based sources. Industrial solvents and degreasers may also be considered as significant sources of such hydrocarbons.

523. PAHs are often associated with superficial marine sediments, especially in harbors and near coastal industrial complexes. UNEP/MAP (2008), while reviewing PAHs in marine sediments from several Mediterranean localities, indicated that such levels as measured in Sfax coastal region and in Bizerte lagoon, Tunisia, are in general comparable or lower than those from other regions. Furthermore, PAHs as measured in limpets collected from various Sicilian coastlines were again comparable or lower than PAHs as measured in a whole range of other biota, elsewhere. Levels of PAHs in superficial sediments from Lampedusa, Linosa and Malta were in general very low and often below detection limits, except in the immediate vicinity of Malta's major sewage outfall. However, the validity of such 'snapshot' to an assessment of a region-wide assessment of levels of pollution is limited.

524. Nonetheless there is evidence to suggest that levels of petroleum hydrocarbons in the vicinity of oil refineries and oil terminals located within the area under review are often significantly high. For example, Zrafi-Nouira *et al.*, (2008 a,b) reported on the concentrations, spatial distribution and chemical profiles of petrogenic PAHs in the coastal area of Jarzouna, Bizerte in Tunisia, which is one of the major oil refineries in the area. Total hydrocarbon levels ranged between 46 and 76 mg L-1 in seawater samples and between 28 and 102 mg L-1 in water extracts. The sites nearest to the oil refinery were found to be chronically contaminated by total petroleum hydrocarbons based on aliphatic biomarkers.

525. Zaghden *et al.*, (2005) also reported significantly high levels of non-aromatic hydrocarbons in superficial marine sediments from Sfax, Tunisia, with ranges from 310 to 1406 µg g-1 dw. The same authors suggest that such status is due to the marine discharge of untreated industrial effluents. Similar situations must be found in the vicinity of other refineries in Libya and Sicily. Cardellicchio, *et al.*, (2007) analyzed for a range of marine contaminants in surface sediments from various stations in the Mar Piccolo of Taranto. Total PAH concentrations ranged from 380 to 12,750 µg kg-1 d.w., these levels being considered as higher than those found in others marine coastal areas of the Mediterranean Sea. For PAHs, low molecular weight/high molecular weight, phenanthrene/anthracene and fluoranthene/pyrene ratio were used for discriminating between pyrolitic and petroleum origin. Results showed that PAHs were mainly of pyrolitic origin.

526. The research by Axiak (in preparation) indicates that levels in harbors may sometimes exceed 100 ug, especially near intense shipping activities and near a tanker reception facility. Bouloubassi *et al.*, (2006) showed that deep and open waters in the Mediterranean appear to act as a significant PAH sink. However, PAH temporal patterns showed noticeable seasonality.

527. Bianchi *et al.*, (2004), reviewed several data on persistent toxic contaminants in various environmental phases at Augusta-Priolo and Gela, Sicily (both sites of important oil refineries and petrochemical operations). These include a range of heavy metals, PCBs as well as PAHs. The group concluded that a high birth prevalence of hypospadias and other human congenital anomalies from the two areas are related to such levels of pollution.

528. Small to medium size oil slicks and floating pelagic and coastal tar are a common feature in surface waters of the subregion. Golik *et al.*, (1988) reported on a monitoring survey of 101 stations in the Mediterranean Sea in August– September, 1987, where floating tar samples were collected, using neuston nets. The authors concluded that the Gulf of Sirte, where the mean tar content was recorded at 6859 μg m−2 , had the highest level of oil slick pollution. The area with the next polluted levels was found to be in the far eastern basin with mean values being at least 75% less. The least polluted areas were the western Mediterranean, 236 μg m−2, and the northern Ionian Sea as far east as halfway between Crete and Cyprus, with mean tar concentration of 150 μg m−2.

529. At the four main Libyan oil terminals in the region (Tripoli, Misurata, Khoms and Zawia), no waste reception facilities are available, except for the one in Tripoli, which according to REMPEC lacks 'adequate and organized reception and treatment facilities for oily waste' (REMPEC, 2005).

530. According to the EC Joint Research Centre/IPSC (2006), the area between Sicily and Malta is a pollution hotspot regarding oil spills in the Mediterranean Sea. The same conclusion has been reached by a recent review by Heber, 2009. The author explains how since 2008, the European Maritime Safety Agency has been providing Member States with snapshots of their monitoring zone, allowing potential oil spills to be spotted. In 2007-2008, REMPEC collaborated with the European Space Agency under the MARCOAST project to report 454 potential cases of discharge.

531. Oil spill density maps derived from satellite imagery for the whole Mediterranean have been produced by various authors (e.g. Tarchi *et al.*, 2006; Ferraro *et al.*, 2007). In general, these reviews provide the following conclusions:

- Offshore areas, often beyond territorial waters are often exposed to high levels of oil spill incidents. This suggests that such spills arise from illegal and deliberate releases in high seas.
- For the subregional, most of the oil spills are often located along the major East-West maritime traffic lane along the Sicilian Channel, and especially between Malta and Sicily, as well as on the Ionian stretch between Sicily and the Peloponnese peninsula. Considerable oil spills are also present along the Ionian waters off western Greece and in the Straits of Otranto. These latter spills most likely arise from the considerable maritime traffic leading into and away from the Adriatic.
- The Gulf of Sirte and the Tunisian waters are often depicted as have relatively low levels of oil spills. This may be due to the relatively low number of images available for analysis from this area.

532. The main point source of radionuclides releases into the marine environment would be operational or active nuclear reactors used for energy generation and/or research. At present, the subregion is relatively free from such sources. However, no data on the levels of possible nucleotides in Italy were available. In the case of Greece, the NDA reported that the activities that could cause the pollution of waters with radioactive substances are limited and connected to research programmes of Institutes and thus, there is low probability of pollution. The NDA reports for Libya refer to the potential sources of radionuclides (these being research centres and hospitals) but do not provide any information on levels. The situation is the same for Tunisia.

533. UNEP/MAP - MED POL/WHO (2008) has carried out a basin-wide assessment of the state of microbial pollution in the Mediterranean Sea. The report gives a review of the potential sources of pathogens on coastal waters and sediments, as well as the various bacteriological standards for bathing waters in different EU and non-EU countries, and details will not be repeated here. The same report indicates that for Greece, by 2005, all of the 2006 sampling points were complying with the national standards. For Italy, by 2005, only 6.2% of the 4919 stations sampled failed to comply with the national (EU) standards. In the case of Malta, by 2005, all 87 stations sampled complied with EU standards.

534. In the case of Libya, it may be noted that the number of stations sampled was quite low (30) compared to the length of coastline. Of these 30 stations, 10% failed to comply with the national standards. For Tunisia, out of a total of 506 stations sampled in 2007, 10% failed to comply with the national standards. Considering that the Central Mediterranean is the main traffic-way between the East and West Mediterranean, and the Ionian Sea is the gateway to and from the Adriatic, it is not

surprising to conclude that the area under review is exposed to more than its fair share of such pressures as arising from such maritime activities.

535. With respect to the Ionian and Central Mediterranean, the main ports are Patras and Corinth in Greece, Gioia Tauro and Augusta in Italy, the Grand Harbour and Marsaxlokk in Malta, the Port of Tunis in Tunisia, and the ports of Tripoli, Misurata and Bardia in Libya. Since 1997, Gioia Tauro has been one of the focal points of development in the container trade in the region. Gioia Tauro and Augusta feature as two of the main Mediterranean ports which receive the largest vessels, while the Grand Harbour, Malta is one of the regional ports with the smallest size ranges of calling vessels. Figure 4.12 shows the main maritime traffic routes for the region in 2006. In addition, one major traffic route for container ships (in excess of 190 transits per year) passes along the Sicilian Channel. When compared to the location of oil spills throughout the Mediterranean, it becomes evident that the main cause of the reported spills in along these lanes are due to illegal releases of bilge oils and other 'operational losses', rather than due to any accidental releases from ships.

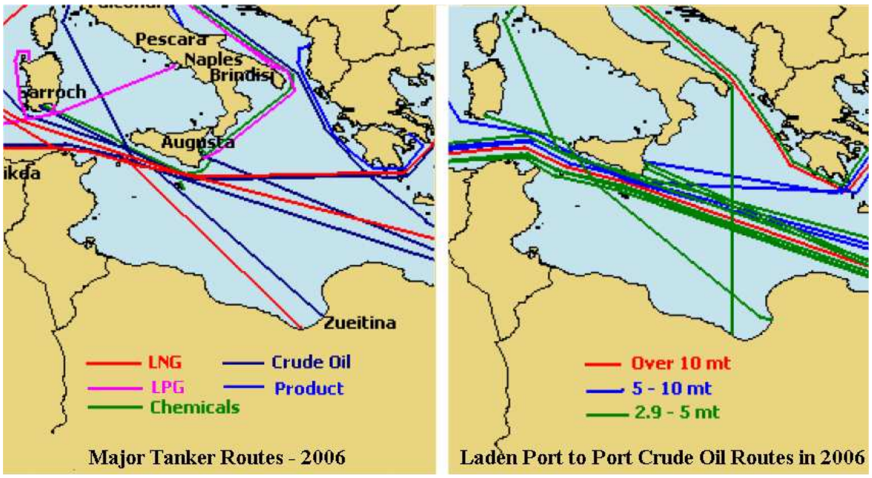


Figure 4.12: Main maritime routes in 2006 according to Lloyd's Marine Intelligence Unit, as reported by REMPEC (2008).

536. In 2006, crude oil loaded at Mediterranean ports amounted to 220 million tonnes. If we include the main oil loading port of Skikda, in Algeria, which is close to Tunisia, then the total weight of crude oil loaded in ports within the subregion amounts to 55.9 million tones, which is 25% of the Mediterranean total. In fact, crude oil and LNG trades are concentrated around a relatively small population of load and discharge ports and routes in the western and central Mediterranean. Crude oil shipments from Novorossiysk to Mediterranean destinations and from Sidi Kerir to both Mediterranean destinations and ports west of Gibraltar as well as exports from the Persian Gulf through the Mediterranean via Suez dominate the major traffic lines. In the LNG sector North African exports to other Mediterranean destinations predominate.

537. The average age of vessels calling at ports in the eastern Mediterranean is significantly higher than at western and central Mediterranean ports. For example, the average age of vessels calling Valletta, Malta is over 20 years compared to less than 14 years at the western Mediterranean ports. This point is highly relevant when assessing the risk of casualties (oil spills and accidental release of other contaminants) in the region.

4.5.2 Dumping activities (introduction of substances and impact)

538. UNEP/MAP - MED POL, 2005 had reviewed the main sources of dumping wastes reaching the Mediterranean Sea. Most of this dumped material originates from the direct disposal from household waste, with releases from touristic facilities and run-off from waste dumps being also significantly important. Dumping of mine tailings is particularly important due to the often hazardous nature of such wastes. Deliberate dumping of oily bilge wastes from ships also occurs.

539. Voluntary dumping or loss of fishing gear may also be considered of importance, especially in this area under review which is often exposed to intense fishing practices. This may often lead to ghost fishing whose ecological and economic impacts may be considerable.

540. The NAP for Greece states that the disposal of solid wastes and sludge to the aquatic environment is prohibited. However, the degree of compliance with such regulations is not assessed. In the case of Malta, Axiak *et al.*, (2002) reports that considerable amounts of excavation wastes and dredged spoils are dumped at sea off the Grand Harbour, Valletta. For 2001 alone, approximately 177,000 tonnes of material were deposited at this official spoil ground. This practice has been ongoing ever since.

541. The NAP for Libya refers to the fact that the disposal of solid waste often presents problems for 'all coastal towns'. Furthermore, 'rains may cause these wastes to be driven to the seashore and hence may go further back along the coast'. In Tunisia the discharge of industrial by-products such as phosphogypsum (10,000 -12,000 tonnes per day) into the Gulf of Gabes (e.g. near Sfax, Ghannouch) constitutes a threat to the coastal marine environment and the ecological impact of such releases is significant. Guillaumont *et al.*, (1995) had earlier on reported on a pollution impact study in the Gulf of Gabes in 1995, with particular reference to phosphogypsum discharge. The group indicated that 50 million tonnes of this material had been discharged near Gabes city since 1975. Analysis of remote sensing data indicated major ecological changes in the Gabes Gulf to the west of the Gneiss-Djerba sill. *Posidonia* meadows that covered most part of the Gulf were by then restricted to some areas upwards of 10m depth. Under hydrodynamic processes, bare sediments could be easily re-suspended. Light reaching the bottom was reduced, inducing a shift from bottom primary production to a planktonic one. As regards marine disposal of dredging from coastal engineering works, very little detailed information was available from the relevant countries' NDA reports.

542. Nonetheless, due to the intense urbanization as well as mass tourism developments along the most of the coastline of the area under review, it is likely that this type of impact is significant. The NDA report for Malta gives some details about such activities, especially related to development of marinas. The report states that over the period 1998-2002, the estimated coastline of mainland Malta had been increased by 5% as a result of such engineering works. The ecological impacts of such works were also briefly outlined and these included reduction in the transparency of the water column, regression of *Posidonia* meadows and other related benthic changes. It was calculated that over a period of 1996-2002, approximately 4870 tonnes of TSS had been released in the coastal waters arising from five major coastal engineering works and dredging. It is quite likely that the same phenomenon has been occurring along many coastal areas especially in Tunisia, Libya and the Ionian coast of Greece which have been exposed to intense tourism activities.

543. Badalamenti *et al.* (2006), report on impact studies of dredging works associated with a methane pipeline between Sicily and Tunisia (1981-93). This development involved considerable trenching at Capo Feto (Sicily) which resulted in significant impacts on *Posidonia oceanica* meadows. The mortality rate decreased with distance from the trench at all depth ranges, showing that the plants close to the excavation suffered a higher level of disturbance. Turnover and annual gross shoot recruitment rate were higher in the shallow portion of the meadow than in the deep range. Forecast of future meadow development close to the trench indicates that, if present conditions are maintained, shoot density will be reduced by 50% over the next 6 to 17 yrs.

544. Sea reclamation by disposal of solid waste in inshore waters has often been proposed as one management option for solid inert waste. Sandy beach reclamations and replenishment programmes are also known from Malta.

545. Though not being classified along with hazardous substances, marine litter often poses significant risks to marine life. Some of the most frequently documents risks are those related to marine turtles and cetaceans, as well as to the smothering effects of bottom sea litter on benthic communities. Furthermore, besides representing an aesthetic problem in several coastal areas, marine litter is known to lead to economic impacts due to damages to small water crafts. The NDA country reports for the area under review do not give sufficient details on this environmental issue, so only a brief outline of the potential problem within the area, may be included here.

546. Unpublished work from Malta (O'Neil, 2003) reported on the levels of beach stranded litter in four local sites in 2002. The same sites had been investigated in 1992. The study showed that the mean mass litter densities on the various beaches ranged from 622 to 40 g m-2, with plastic being the most abundant component. The reported beach litter densities of a decade before were of the same order of magnitude. This had been explained by assuming that the level of stranded marine litter at these sites has reached a dynamic maximum (dependent on a balance between rates of stranding and rate of release back into the water phase due to currents) which may not be exceeded. Compared to other beaches within the Mediterranean, the reported values of beach stranded marine litter were quite high.

547. UNEP, 2009, quotes studies undertaken by the University of Patras in collaboration with volunteer fishermen in four major gulfs along the western coast of Greece. A total of 3,318 items of marine litter were collected from an overall area of 20 km2 and reaching depths of 300 m. The results showed that the major sources of the collected litter were from land-based activities while the predominant items were composed of plastic (56 percent). The most impacted area was that of the Gulf of Patras with a recorded number of items ranging between 188 and 437 per km2.

548. UNEP, 2009, gives the most recent overview of this problem within the Mediterranean and elsewhere. During the period from February to April 2008, 14 reports were received from ships within the Mediterranean recording the incidence and densities of marine litter in surface waters. In total, observations of 1,947 km of Mediterranean Sea resulted in the recording of 500.8 kg of marine litter. Observations were carried out mainly in the eastern Mediterranean (Aegean Sea, Libyan Sea and Eastern Mediterranean Levantine Sea), in the Alboran Sea between Spain and Morocco and in the Adriatic Sea, with plastic items the most numerous.

549. Marine litter released from ships and water craft amount to only 5% of litter at sea. This was attributed to the fact that all vessels above 400 tons or carrying more than 15 persons are obliged to implement garbage management plans in accordance with international maritime law. It is also true that the situation concerning the availability of reception facilities in the major Mediterranean ports has also improved in recent years. The status of 'Special Area' of MARPOL Annex V for the Mediterranean has taken effect as from the 1 May 2009. Subsequently disposal of plastics, and other litter is now prohibited into the Mediterranean Sea. Furthermore, Italy, Greece, Malta and Tunisia have confirmed that they have adequate port reception facilities for garbage disposal in the area.

550. The same report states that 52% of marine litter in the Mediterranean originates from shoreline and recreational activities. This is mainly due to the inadequate solid waste management practices of several countries within the region. Marine litter from 'shoreline and recreational activities' is also highly related to the tourism industry. Given the importance of tourism industry in the area under review, there is little doubt that a substantial amount of marine litter originates from the tourism industry, even here. This will evidently be much dependent on the level of solid waste management at the localities mostly exposed to intense tourist influxes, especially in summer. In fact UNEP/MAP - BP/RAC, 2009, cited UNEP/MAP - MED POL sources indicating that tourist facilities may generate up to 16% of coastal marine litter.

4.5.3 Nutrient and organic matter enrichment

551. Agriculture has been reported to be the largest non-point contributor of pollutants to the Mediterranean (UNEP/MAP, 2001). One of the main drainage basins dominated by agricultural land is located in Sicily (online EU database: reports.eea.europa.eu). Indeed, agriculture is a main economic sector in the subregion. In fact it has been cited as the main consumer of fresh water resources within the Mediterranean (64% for the whole basin, UNEP/MAP - BP/RAC, 2009).

552. For Tunisia, Libya and Greece, irrigation for the agricultural sector accounted for approximately 80% for water demand over the period 2005-2007). Coastal agriculture is a common feature in the subregion, (especially for Tunisia and Libya), and in view of the need to increase produce with limited land availability, the application of natural and artificial fertilizers (apart from pesticides) must be quite intense in several localities. Rain runoff from the drainage basin containing such agricultural lands is most likely to bean additional source of nutrients and organic loadings in

coastal waters. This may be less important in countries like Libya where the rate of annual precipitation is quite limited, but may be much more important along the Ionian coastline.

553. Agriculture in Tunisia makes a considerable contribution to the country's GDP. The industry is faced with problems of water availability, desertification and soil erosion. Coastal agriculture in particular is characterized by fairly advanced technologies, including considerable use of inorganic fertilizers and increasingly generalized phytosanitary treatment. To a certain extent this contributes to the pollution of seawater (UNEP/MAP- BP/RAC, 2001). The development of intensive irrigated agriculture has led to the overexploitation of ground water; the response has been to design recharge programmes in order to maintain the agricultural activities necessary to the region.

554. Agriculture in Malta is not an important contributor to the country's GDP. Nonetheless it has an important role in landscape conservation. One of the main environmental pressures arising from current agricultural practices on the island is the release of excessive nutrients (particularly nitrates) in the fresh water aquifer resources. Several studies also indicate that specific coastal areas such as Marsascala, and Xlendi are particularly sensitive to increased nutrient loadings from agricultural run-off.

555. Eighty per cent of Libya's agriculture is located in coastal areas. A major environmental concern here is the depletion of groundwater as a result of overuse in agriculture, causing salinization due to sea-water penetration into the coastal aquifers.

556. Increased nutrient loads and localized enrichment by organic materials can lead to eutrophic conditions as well as possible to harmful algal blooms. A recent UNEP/MAP - MED POL draft assessment (UNEP/MAP – MED POL 2009b) commented that although in open water of the Central Mediterranean Sea there is no evidence of eutrophication, nonetheless a number of coastal and estuarine areas in the area are regularly exposed to such risks, due to localized enrichment by nutrients and organic material.

557. For the Greek Ionian waters, eutrophic conditions have been reported in the semi enclosed Amvrakikos Gulf, mainly due to agricultural runoff and effluents. Furthermore high levels of nutrients (e.g. nitrate maxima of >100 µg-at L-1) and phosphate levels in excess of background levels were often recorded in the Gulf of Patras. On the other hand, the Greek Ionian coastal waters are generally oligotrophic, except in the immediate vicinity of river discharges (which carry mainly agricultural runoff).

558. In Tunisia available data indicate eutrophic conditions of the coastal lagoon of the Lagoon of Tunis, where various cases of dystrophic events have been reported, including fish mortalities due to anoxic conditions and blooms of toxic algae. In the Northern Ionian Sea, including the Sicilian Channel only minor levels of increased nutrients have been recorded (as evidenced through chlorophyll levels). Libyan waters are mostly affected in the immediate vicinity of the large cities such as Tripoli and Benghasi. In the case of Tunisia, the levels of chlorophyll in the Gulf of Gabes were found to be relatively high, this being probably due to natural conditions. Incidence of mild eutrophic conditions in Maltese waters is restricted to harbour areas (such as the innermost part of Grand Harbour) and marinas (eg. Msida marina), as well as to creeks exposed to significant agricultural and other runoffs, such as Marsascala (Axiak, 2004). In Italy, only one area is reported a sensitive to eutrophication, in the southernmost regions, this being Castellamare del Golfo, in Sicily, which is not strictly within the subregion.

559. Satellite images of the subregion show the southern coastal waters of Calabria and Basilicata flanked by a large algal bloom with distinctive gyres. Image B, shows a massive long-shore algal bloom covering all of the southern coastline of Sicily. The eastern part of the bloom extends into large swirls which penetrate the Central Mediterranean and reaching to the East of Malta. Another algal bloom appears along the eastern coastal waters of Tunisia extending into the Gulf of Gabes, showing a very high anomaly (absolute values of chlorophyll equal or exceeding 10 mg m-3).

560. It is likely that these massive bloom phenomena are mostly due to natural hypertrophic events linked with local upwellings and other factors. Nonetheless, these images clearly show the geographical extent of such blooms, which may then be augmented through anthropogenic induced hyper-productivity especially in the vicinity of river estuaries (often carrying agricultural runoff), and

sewage or industrial discharges. Barale *et al.*, (2008) had used SeaWiFS data acquired over the period 1998 to 2003 to identify algal blooming patterns in the Mediterranean. In general the recurrent, increasing blooms at the various hotspots, appearing in the chlorophyll anomalies, have been described as localized phenomena, linked to either air–sea interactions in pelagic domain or increased nutrient availability and low water renewal in coastal areas. The latter kind of anomalous blooms are likely anthropogenic, or may be caused by the combination of specific geographical and meteorological conditions (e.g. enclosed bays during summer, when hydrodynamic forcing is low). This would suggest that noxious, or harmful, blooms — known to have occurred in the areas and periods considered — are predominantly local phenomena, with little or no connection to regional events.

561. Figure 4.13 shows the distribution of recorded events of eutrophication and of harmful algal blooms.

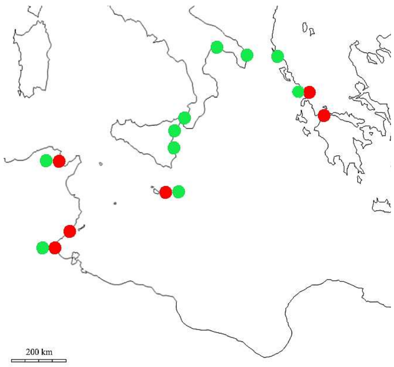


Figure 4.13. Locations of reported cases of eutrophication (red circles) and of harmful algal bloom events (green circles) in the area under review *(Sources: EEA, 2006)*

562. Apart from the coastal waters of Libya, it seems that the pressures possibly leading to such phenomena are evenly distributed throughout the coastline of the area, though in the case of harmful algal blooms, they seem to arise more frequently along the Italian coastline. Nonetheless, this may be an artifact of data availability. In fact no data is available about such phenomena from Libyan waters.

563. Terrestrial inputs including runoff and river discharges have a direct influence on the coastal and marine systems and therefore on the quality status. The degree of such an impact may be at least partly gauged by the ratio between the surface area of the terrestrial watershed to that of the marine basin into which such discharges are emptied. For the whole Mediterranean basin, this ratio is 0.55 (CIESM, 2006).

564. The various sub -basins within the Mediterranean have different ratios. For example the greatest value for such a ratio is that for the Central Mediterranean (1.87), while that for the Ionian Sea is the smallest (0.37). This implies that the Central Mediterranean and in particular, the shallow coastal waters along the African coastline would be expected to come under great influence of the terrestrial watershed (drainage basin), which is particularly large for Libya. On the other hand, since the rate of precipitation in the area is low, then the rates of discharges would be low. In fact, according to Ludwig *et al.*, (2003) the estimated rate of freshwater inputs in the Ionian Sea in 1995 was estimated to be 25 km3 per year, while that for the Central Mediterranean may be less than 5 km3 per year. Grenon and Batisse (1989) report the average annual runoff flows from different river basins within the Mediterranean from different sub-regions. While such runoff volumes would be expected to vary significantly from year to year depending on precipitation and other factors, it is evident that the area under review would be expected to receive approximately only 10% of the total annual runoff reaching the whole Mediterranean basin. Considering that this area is approximately 32% of the total surface of the Mediterranean, it may be expected that such area is not unduly directly influenced by such runoff when compared to other sub-regions within the Mediterranean. Furthermore, the greatest impact that may be expected from such runoff on coastal and marine water status would be in the Ionian part and along the coastlines of Italy and Greece, which would receive more than 95% of such runoff for the area.

565. Evidently, the manner and degree to which such land-based natural discharges effect the coastal and marine environment also depends on a large degree on the various anthropogenic pressures and activities on land. This includes forest cutting and grazing, leading to increased erosion, intensive agriculture as well as animal husbandry, damming and irrigation, as well as coastal urbanization.

566. In a recent report by Ludwig, *et al.,* 2009, river inputs of nutrients in the Mediterranean were reviewed. According to such estimates, the annual amounts of nitrogen, phosphorus and silica reaching the Ionian and Central Mediterranean from rivers in 1998, amounted to 63,000 tonnes N, 2,900 tonnes P and 59,000 tonnes Si, respectively. When compared to the same estimates for the whole Mediterranean, these inputs of N, P, and Si amount to 5 to 6% of the total amounts reaching the whole basin. The same report includes estimates of the amount of fertilizers (nitrogen) applied in the different drainage basins around the Mediterranean. For 1995 it was estimated that the amount of fertilizers (N) applied in the drainage basins for the Ionian and Central Mediterranean waters amounted to 1,900 kg N /km2/year. This amounted to 15% of the application rates for the whole Mediterranean basin.

567. Evidently, when viewed at the sub-region basin scale, river inputs may not be considered as a significant pressure on coastal and marine quality status for the subregion. The same may not be true to localized inshore areas in immediate vicinity of major river discharges.

568. Releases for nutrients, organic matter and total suspended solids within the Ionian and Central Mediterranean were assessed by UNEP/MAP - BP/RAC in 2009. The geographical distribution of point sources of BOD5 and Total N (industrial sources) was based on the individual countries' emission inventories (NBB). Using this information, an attempt was made to identify the percentage of releases of such contaminants in the subregion on the basis of the graphical information as reported by UNEP/MAP - BP/RAC, 2009. A synopsis is presented in Figure 4.14 below.

569. In spite of the inherent limitations of the available data, it appears that the releases of total nitrogen (from industrial point sources) as well as of organic matter (in terms of BOD5) from the area under review is lower than similar releases from other regions (taking into account that the area covers 32% of the total surface of the whole basin).

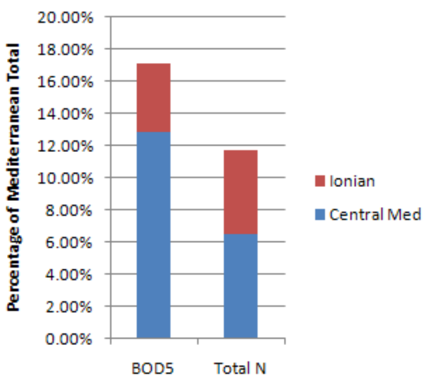


Figure 4.14.: Percentage releases from industrial point sources, of BOD5 and of total nitrogen as reported by UNEP/MAP - BP/RAC, (2009) in the area under review as compared to releases in the whole Mediterranean.

570. According to EEA (2006), all five countries within the subregion consider the marine discharge of urban wastewaters as a priority environmental issue. Such effluents often include excessive loads of nutrients and of organic matter which lead to a deterioration in the water and sediment quality status and therefore of the eutrophic status of inshore waters, as well as pathogens and a whole range of hazardous chemicals, which are potential risks to human health. These issues may seriously affect the

quality of life in the coastal areas, and therefore have economic implications to coastal development and tourism.

4.5.4 Biological and physical disturbance

571. In the Central Mediterranean, marine fisheries are characterized by a large number of species caught per main fishing gear (i.e. multi-species fisheries) as well as by a variety of species that are exploited concurrently by different fishing gears (i.e. multi-gear fisheries). Fish farming is a relatively ancient practice in the Mediterranean basin. It has expanded enormously since the 1990s, particularly marine fish farming. This involves farming the gilthead sea bream *Sparus aurata*, the sea bass *Dicentrarchus labrax,* the mussel *Mytilus galloprovincialis* and the flat oyster *Crassostrea gigas*. Greece is the first offshore marine fish farming producer country in the sub-region but also in the whole Mediterranean with over 120,000 tons per year of sea bass and gilthead sea bream, while in raising bivalve molluscs, mussels and flat oysters hold respectively first and second place. Recently, the maintaining and growing out of tuna *Thunnus thynnus* has expanded. Fisheries and aquaculture cause major impacts in the subregion.

572. The fisheries of the region are characterized by a high level of exploitation, often resulting in overfishing. Biological and physical disturbance can result. The target species are dominated by juveniles. The main species threatened by overfishing and illegal fishing are: *Anguilla anguilla*, *Epinephelus marginatus*, *Sciaena umbra, Thunnus thynnus, Xiph gladius, Mullus barbatus, Mullus surmuletus, Merluccius merluccius, Sarda sarda,* some species of cartilaginous fishes, crustaceans as *Homarus gammarus*, *Palinurus Elephas* and *Scyllarides latus*, bivalves such as *Lithophaga lithophaga*, sponges (*Hypospongia communis, Spongia spp*.) and red coral (*Corallium rubrum*).

573. The use of non-selective fishing methods often illegal contribute to the destruction of marine organisms in general and particularly juvenile fish, decreasing significantly the maintaining or recovery of the stocks. For instance, the use of dynamite or kyss (gear used in waters of southern Tunisia) is a significant example.

574. It is clear that intensive fishing has a significant impact at all levels of biological organization of Marine Life (EEA 2006). The impacts of some inappropriate practices on marine biodiversity are outlined in the reports prepared under the SAP BIO programme, but also in the present process leading to an observed decline of fish stocks and degradation of ecosystems. Advances in navigation and localization of resources contribute to the escalation of this situation.

575. The pressures of fishing activities can be classified as originating from commercial fishing, recreational fishing, and aquaculture or fish farming. In spite of stringent laws and efforts in order to ensure fleet reduction, these activities generate direct and indirect effects on resources and ecosystems.

576. The main direct effects of fishing on marine resources are over-fishing of large pelagic inducing a highly significant decrease in stocks for the following species: *Xiphias gladius, Thunnus thynnus* and *Thunnus alalunga.* Fishing gear such as drift nets and long lines may cause serious mortality to marine turtles and marine mammals.

577. The main species threatened by overfishing and illegal fishing are: *Anguilla anguilla*, *Epinephelus marginatus*, *Sciaena umbra, Thunnus thynnus, Xiph gladius, Mullus barbatus, Mullus surmuletus, Merluccius merluccius, Sarda sarda,* some species of cartilaginous fishes, crustaceans as *Homarus gammarus*, *Palinurus Elephas* and *Scyllarides latus*, bivalves such as *Lithophaga lithophaga*, sponges (*Hypospongia communis, Spongia* spp.) and red coral (*Corallium rubrum*).

578. The fisheries of the region are characterized by a high level of exploitation, often resulting in overfishing. The target species are dominated by juveniles. As a result, the trophic level of exploited species is clearly decreasing. Due to the modernization of fleets for longer campaigns and navigation in rough seas, increases in the exploitation of species living in the open ocean and deep water are expected.

579. The use of non-selective fishing methods often illegal contribute to the destruction of marine organisms in general and particularly juvenile fish, decreasing significantly the maintaining or recovery of the stocks. For instance, the use of dynamite or kyss (gear used in waters of southern Tunisia) is a significant example. Spear fishing, though selective, is one of the causes of overfishing of protected species such as grouper.

580. Several techniques of fishing and aquaculture techniques contribute directly or indirectly to the disruption of ecosystems, habitats and species. Among the most harmful fishing gears is include the "tonailles" (nets for tuna), long lines and drift nets, fine mesh nets and all trawling arts. Other fishing techniques, such as totally illegal use of poison or dynamite, significantly affect the entire natural environment. Finally, recent increases in grow out facilities for bluefin tuna *Thunnus thynnus* has contributed noticeably to the collapse of this species, as well as increased fishing pressures on fish used in the feeding of farmed fish.

581. The most egregious damage by fisheries is caused on benthic habitats and associated communities.

582. The indirect effects of fishing on biodiversity include the impact on non-commercial species (discards), habitat structure and ecosystem functioning, including the decline of populations (either commercial or not), due to by-catch fish, discarding, ghost fishing, etc.; the decrease of populations of non-commercial endangered and protected species such as cartilaginous fish, sea turtles, sea birds; the disturbance or destruction of habitats such as *Posidonia oceanica* meadows, coral and maêrl beds, due to trawlers often illegally operating in shallow waters, but also due to practices such as illegal collection of date shells *Lithophaga lithophaga*; the alteration of functioning and structure in other marine habitats such as sandy and muddy bottoms by trawling in particular because of sediment resuspension which causes extensive damage to non-target species.

583. Cascading effects on trophic structure of the marine ecosystem occur through the harvesting of top predators, either pelagic or demersal. Overfishing reduces the populations of more valuable large fish that are at higher trophic levels, such as piscivorous, significantly reducing the average level of catches. Jellyfish blooms are reported by certain authors as consequences of overfishing.

584. The introduction of alien species is also considered a major threat in the subregion, with corollary disruptions to biodiversity. The number of introduced species in the Mediterranean has increased spectacularly since the start of the last century. Their distribution varies from country to country. They have been mainly introduced through two pathways: (i) by maritime transport and fish farming and (ii) through the Suez Canal.

585. National reports on invasive and alien species have helped to highlight the magnitude of the establishment of exotics in coastal waters. However, these statistics remain more or less incomplete and need to be to updated and completed.

586. In the Greek Ionian Sea, there are 3 species of phytoplankton, 3 zooplankton species, 17 benthic plant, 24 species of invertebrates and 13 fish species. On the eastern and southern coasts of Tunisia, 21 plant species are listed, 51 invertebrates and 24 fish species. 22 exotic fish are cited in the Libyan national report. In the Maltese national report of SAPBIO, reference is made of 10 species of plants, 6 invertebrates and 1 fish. In Italian waters, 34 species of algae, 70 invertebrates and 19 fish were identified in the national report of SAP BIO.

587. These statistics do not definitely reflect the reality; the level of knowledge is very uneven from one country to another and from one group of species to another; the impacts of most of these species remain poorly studied and misunderstood.

588. Regarding the phytobenthos the presence of *Caulerpa taxifolia* is reported but its distribution and extension remains anecdotal. If considered as potentially invasive, it does not cause known effects due its sporadic character. The potential invasive *Caulerpa racemosa* is more important. The new signs are numerous in both Greece and Tunisia and the effects of this species are noticeable. The rapid growth of stolons resulting in almost total coverage of the substrate, mainly muddy sands at the expense of seagrass, algae but encrusting organisms. Its proliferation leads to difficulties in the fishing activity because large quantities contribute to clogging of the nets.

589. Cases of inter-specific competition are also well shown among the invertebrates such as the competition of *Percnon gibbesi* with native species (Malta and Italy) and also in fish populations. In Libya, rivalry between the two lesseptien species *Siganus luridus* and *Siganus rivulatus* and native species *Sarpa salpa* and *Sarpa cretans* is a prominent example.

590. Other phenomena due to the proliferation of invasive have direct effects on human health and economic activities. We mention in particular the increase in outbreaks of jellyfish blooms, including *Pelagia noctiluca* causing inconvenience to many holidaymakers. The proliferation of jellyfish significantly affects marine biodiversity, including commercial interest; these animals feeding on larvae and fish fry.

591. Economically, the case of the establishment *of Metapenaeus monoceros* in the Gulf of Gabès reveals sometimes the paradoxical economic impacts that invasive species could cause on economically and socially levels. This species has partially replaced the native prawn *Penaeus kerathurus*. In this region, catches of shrimp have not declined but are composed 50% of non-native species. The economic loss is due to the fact that the commercial price of the new species is seven times lower than that of native shrimp, in the benefit of the less affluent consumers.

592. The data on the impacts of invasive alien organisms are even more scarce in the deep and high seas, where changes are mainly due to the slow but perceptible spread of thermophyllic species in the Mediterranean in general, but also in the central Mediterranean. Some of these species out-compete.

593. Indigenous species, as occurs with the native species *Merluccius merluccius* and *Mullus barbatus* under pressure from exotic *Upeneus moluccensis* and *Saurida undosquamis* in the Hellenic Ionian waters.

4.5.5 Effects of underwater noise and marine litter

594. As in the rest of the Mediterranean Sea, the effects of maritime activity and marine litter and debris are speculated to cause changes in ecology and ecosystem services delivery, but their impacts have not been quantified.

4.5.6 Emerging issues: climatic change effects and deep sea modifications

595. The effects of climate change on the physical environment are already being detected, especially related with increase in surface sea temperature, hydrological and hydrodynamic changes, sea level rise and the expected repercussions on the integrity of the coastline, wetlands generally and more particularly lagoons, salty lakes (sebkhas), and estuaries, supra- and midiolittoral zones and the ecological and economic values thereof, – with particular emphasis on the threats to islands, and changes in the nutrient supply and dynamics of coastal and high-sea waters and increased frequency of extreme events –winds and storms.

596. In the medium term, more complex phenomena are expected, such as changes in the life cycle of marine species, distributional range shifts of species and habitats, local extirpation of vulnerable species and, ultimately, decrease in the resilience (i.e. resistance and reversibility to disturbance) as well as profound changes in the functioning of marine ecosystems, which at present are difficult to forecast with the adequate level of accuracy. There are rising risk of forest fires in coastal lands, impacts on coastal and marine natural resources, and the spread of thermophyllic non-native species, especially Lessepsian. Special emphasis has been put on the occurrence and spread of thermal species (both by colonisation of new species originating from the Atlantic through the Straits of Gibraltar and principally the Indo-Pacific through the Suez Canal. Other phenomena such as mucilage events, harmful algal blooms and mass occurrence of scyphomedusae are likely to be facilitated by climate change in synergy with other anthropogenic impacts (e.g. overfishing, nutrient load and other sources of pollution, etc.). Another ongoing phenomenon, increasingly frequent in coastal waters of the countries, is the occurrence of mass mortality of structural species (e.g. gorgonians, octocoral colonies, sponges, etc.).

597. Emerging issues also concern the deep sea. Here the deep seas are considered to be the marine environment that extends downwards from the continental shelf break, i.e. waters deeper than 200 m to its maximum depth. The Mediterranean deep sea comprises a high diversity of habitats, because of its geological history (Bianchi & Morri 2000). In particular, geomorphologic structures, such as submarine canyons, seamounts, mud volcanoes and deep trenches can harbor important biological communities. In general, deep sea Mediterranean biological communities are adapted to an oligotrophic environment; local areas of higher productivity and biodiversity hotspots are present.

598. In this subregion, the Mediterranean deep sea is physically split into two basins separated by the shallow Straits of Sicily (at about 400 m depth). Important differences between the eastern and the western basins, both in species composition and abundance have been observed (Sardà *et al.* 2004).

599. The Mediterranean deep sea is considered by some authors to be among the most heavily impacted deep-sea environments in the world, and at the same time among the least known areas in terms of biodiversity (UNEP/MAP - SPA/RAC, 2010): the risk is that a significant loss of biodiversity occurs before scientists have had time to document its existence (Briand 2003, Cartes *et a*l. 2004).

600. The main pressures affecting deep seas include the impacts of the bottom trawl fishery and other fishing practices; waste disposal (solid refuse); other marine pollutants; oil exploration and exploitation; deep pipeline installation; and the as yet not fully understood impacts of climate change.

601. Deep-sea fisheries currently only operate at depths of less than 1000 m in the Mediterranean, but that might exploit many SH, i.e. seamount fisheries could be exhausted in a period of time as short as three to four years (Johnston & Santillo 2004). The potential fishing interest of the currently unexploited bottoms below 1000 m depth (towed gears banned by GFCM, 2005) is very limited. This is so because the overall abundance of crustacean species is considerably lower, and fish communities are largely dominated by fish either of non-commercial interest (like the smooth head *Alepocephalus rostratus*) or of a small size (such as the Mediterranean grenadier *Coryphenoides guentheri*). If these species ever become of economic interest and trawlers could reach deeper areas, then the ecosystem could be rapidly deteriorated by fishing.

602. Pelagic fishing in the Mediterranean open seas, targeting large pelagic species (with few exceptions targeting small pelagic, e.g. anchovy and sardine, in the Adriatic Sea), is the only industrial fishing; it takes place mainly in international waters and even non-Mediterranean countries can be involved (Cacaud 2005).

603. Most information on the activity of the fishing fleets in the Mediterranean comes from the working group STECF and the GFCM Demersal Working Group, of the Subcommittee on Stock Assessment, and ICCAT for large pelagics, which relates the activity of the fleets from member countries. Therefore, there is a lack of reported information of fishing activity of EU non-member countries (e.g. North Africa) in STECF, although GFCM task 1, and the cooperation projects (Medfisis, COPEMED II, ADRIAMED and EASTMED) work on this direction.

604. The most important negative consequence of fishing activities is the degradation of marine ecosystems by the removal of target or non-target species and by physical disturbance inflicted by some fishing gears. Essential Fish Habitats (EFH) are those habitats necessary for feeding, refuge or reproduction of the species; and Sensitive Habitats (SH) consist on those areas with endemic species, high biodiversity or high productivity and vulnerable to fishing practices. The degradation of ecosystems by fishing indirectly affects the commercial species if the habitat is not longer adequate for these species. In this context, there is a necessity of regulating fishing activities to reduce the ecosystem degradation by the establishment of an Ecosystem Approach to Fisheries (EAF), which considers not only the protection of target species, but the ecosystem as a whole. Within the EAF framework the Precautionary Approach considers the most restrictive measures for fisheries management (including the establishment of areas closed to fishing, or Marine Protected Areas) against a general lack of knowledge on the functioning of many ecosystems that sustain fisheries resources.

605. Most Mediterranean waters constitute open seas. The Mediterranean open seas encompass a high diversity of habitats, both pelagic and demersal (deep seas). These habitats are poorly known in

relation to coastal and continental shelves ecosystems, which are more easily surveyed, while at the same time there is a good knowledge of their commercial species stocks status, by means of fisheries surveys and commercial captures. The protection of fauna at those areas is important for fisheries and ecosystem conservation because organisms can determine the healthiness of an ecosystem. Sessile benthic fauna play an important role as habitat structuring organisms providing refuge for many marine species (e.g. cold coral reefs, deep sea sponges, crinoidea beds).

606. Deep bottoms consist on wide extensions of soft sediments interrupted by geological features like submarine canyons, brine pools, seamounts, hydrothermal vents, cold seeps and mud volcanoes, that create a special habitat that harbour high diversity and endemism; many of these habitats have been only recently discovered and must be protected after the Precautionary Approach.

607. Demersal fisheries operating in Mediterranean high seas can be summarized as: bottom trawling, bottom long line, and gillnet. Deep-sea fisheries currently operate on continental shelves and some slopes, down to depths of less than 800m. Bottom trawling is a highly damaging practice that was banned in 2005 to Mediterranean bottoms deeper than 1000m, aiming to protect the vulnerable deep sea fauna.

608. Amongst benthic habitats at Mediterranean open seas, the components most vulnerable to fishing are coralligenous facies, the crinoidea *Leptometra phalangium,* and the cnidaria *Funiculina quadrangularis* and *Isidella elongata*, facies of sessile organisms that have been so far detected in continental shelves and the shelf break in the Western basin, although the location and extent of these habitats in the whole region is still poorly known.

609. At the deep seas there are several areas with considerable abundance of the highly vulnerable cold coral reefs, mostly detected in continental slopes, seamounts and on the walls of submarine canyons (e.g. off Cape Santa Maria di Leuca, in the Central basin, or at numerous submarine canyons and seamounts scattered along the Alboran Sea, in the West basin). Several abyssal plains, that harbour poorly known and vulnerable deep sea fauna, are located throughout the Mediterranean, with the deepest grounds found in the Central basin (e.g. Calypso depth in the Ionian Sea, SW of Greece). Other geological features might be vulnerable to fishing as they are hotspots of diversity and are habitat of vulnerable fauna like cold corals. The massive Eratosthenes seamount in the East basin (south of Cyprus) and numerous scattered seamounts in the Alboran Sea and south Tyrrhenian; cold seeps, brine pools and hydrothermal vents have been mostly located in the East Mediterranean basin (south of Crete and Turkey, and near Egypt). The Western Mediterranean basin harbours numerous submarine canyons that are EFH for red shrimp, like numerous canyons in the Gulf of Lions that sustains important fisheries of red shrimp, Norway lobster, hake, monkfish, among other important commercial species; hake nursery areas are mainly located on wide extensions of continental shelves or banks, highlighting the south of Sicily, central Adriatic in the Jabuka Pit, and Thracian sea, whereas hake spawning grounds seem to be located on the shelf break and slope canyons, being the Gulf of Lions the clearest example.

610. The large pelagic species that inhabit the open seas, mainly bluefin tuna, swordfish, and albacore, but also pelagic sharks (short fin mako, blue shark and porbeagle) are of high conservation interest and have long been overexploited by pelagic fishing gears. The main fishing gears for large pelagics are purse seines and pelagic longlines. Pelagic long lining fleets operate in Mediterranean waters, ranging from local coastal state fleets to large industrial foreign fleets; these are highly mobile, and cover almost the whole Mediterranean basin. Drift nets have been banned in the Mediterranean in 2005, although this activity is still practiced. The Mediterranean high sea is also the habitat of endangered cetaceans and turtles that are a common by-catch of pelagic fisheries and deserve special protection. Important EFH for large pelagic species are mostly determined by oceanographic features like upwelling areas or gyres, creating productive areas important for feeding and breeding; these areas that act as EFH must be identify to define protection measures for pelagic species. The main spawning areas for bluefin tuna have been located south of the Balearic Islands, Alboran Sea and Strait of Sicily; whereas swordfish spawns in almost all the Mediterranean area and albacore overlap with the bluefin tuna spawning grounds.

4.6 Conclusions and gap analysis on pressures and impacts

611. Fisheries impacts, though not fully understood, are a priority concern in the region. The following sites are considered critical areas in the subregion, regarding fishing impacts in Mediterranean open seas, including demersal and pelagic ecosystems. In demersal areas, the area south of Sicily, known as the Adventure and Malta banks are important as hake nursery areas where bottom fishing activities, specially trawling, should be restricted. Similarly, the cold coral reefs (*Lophelia pertusa*) off Cape Santa Maria di Leuca are highly vulnerable to any physical disturbance inflicted by bottom trawling, though this has already been adopted as FRA (Fishery Restricted Area) by GFCM.

612. Pelagic priority areas include the Strait of Sicily, as an important migratory route for tuna-like species, and the Mediterranean Bottoms beyond 1000m, which provide habitats for vulnerable fauna. Fishing using towed gears in this area has been prohibited by GFCM. Other important areas delivering ecosystem services include the wetlands of eastern Tunisia.

613. A list of pollution hotspots and locations of areas of major environmental concern for the various Mediterranean countries has been complied on the basis of national diagnostic analysis. Such list includes a total of 138 hotspots and 69 areas of major environmental concern. Fifteen (22) of such hotspots and 14% (10) of areas of major environmental concern are located within the subregion. The locations of such areas were shown in Figure 4.1.

CHAPTER 5: ADRIATIC SEA

5.1 *Introduction*

614. The Adriatic Sea is a semi-enclosed basin within the northernmost part of the Mediterranean Sea. It has a surface area of 138600 km2 and a volume of 35000 km3. It extends northwest from 40° to 45°45' N., with the length of about 800 km and width of about 200 km. The Strait of Otranto, which connects the southern part of the Adriatic Sea with the Ionian Sea, is 72 km wide and 780m deep, which allows for extensive water exchange between the two basins. The Adriatic Sea is characterized by an extended continental shelf in the Northern and Central part while the continental slope is mostly found in the Southern part where the maximum depth of 1223 m is reached. The sea basin is surrounded by Dinarides on the East, Alps on the North and Apennines on the West. The largest country in the Adriatic basin is Italy, followed by Albania, Croatia, Bosnia and Herzegovina, Montenegro and Slovenia (Figure 5.1).

Figure 5.1. The Adriatic Sea subregion

615. The Adriatic Sea represents a small but very specific and the most isolated part of the Mediterranean Sea. Due to its specificities it is considered as distinct biogeographical subunit of the Mediterranean Sea (Pérès and Gamulin-Brida, 1973). While the North Adriatic clearly shows its relationship with boreal region, thermophilous elements dominate in middle and southern basin. Due

to geomorphology of this area and its main abiotic characteristics, very high diversity of habitats and species has evolved in marine and coastal environment, including significant proportion of endemic elements.

616. The Adriatic is home to nearly half (49%) of the recorded Mediterranean marine species. Yet of all four subregions, the Adriatic may be the most unusual, due to its shallowness, restricted flows, and large degree of influence of rivers – all of which has colored that ecology and biological character of the subregion.

5.2 Physical and chemical characteristics

5.2.1 Topography, bathymetry and nature of seabed

617. The Adriatic Sea represents only 5 per cent of the Mediterranean Sea. Its northern part is the shallowest, with depths that do not exceed 50 m. The North Adriatic in particular represents only 0.4% of Mediterranean waters; however the specific environmental situation, with the presence of the Po basin, the Venice lagoon and its shallow waters, demands immediate action to manage and protect this particularly sensitive area. The Po River is one of the three most important Mediterranean rivers in terms of discharge. Roughly one-third of the Mediterranean continental water flows into the northern and central Adriatic Sea. Eutrophication resulting from excessive nutrient discharge is one of the most significant threats to the Adriatic Sea.

618. The Adriatic Sea stretches in the NW-SE direction in the length of 783km, with the surface area of 138,595 km² at the mean sea-level. Its salinity is relatively high - cca 38.3 ‰. The North Adriatic is extremely shallow with depths varying from 25 to 50m and also rather cold (6-12 ºC) because of the influence of cold winds and water coming from Alps. It makes this area unique in Mediterranean and famous for a number of boreal biota. The sea bottom here consists mostly of sand and sand-detritic sediments due to the inflow from the Po River. Although the Adriatic as the whole is oligotrophic sea, its northern part is one of the most productive parts of Mediterranean (Pérès and Gamulin-Brida, 1973). The middle Adriatic is also rather shallow (average depth of 140m) with the exception of Jabuka Pit that reaches depth of 275m, while the South Adriatic depression goes down to 1330m. The depths of up to 200 m (continental shelf) occupy as much as 73.9 % of the Adriatic while the area deeper than 1000m covers only 7,7% of Adriatic sea bed. The sea bottom along the eastern Adriatic coast is rocky while offshore it is mostly flat with sediments and corallogenic concretions along the islands. Large coral reefs beyond depths of 300m have also been registered.

619. The northern part of the Adriatic is very shallow, with depth increasing slowly southwards, reaching 270 m in the Middle Adriatic and Jabuka Pits (Pomo Depressions). The Palagruža pit (Pelagosa Sill) links Mid-Adriatic with much deeper south Adriatic Pi, reaching maximum depth slightly over 1200 m. Further south the bottom rises to 780 m in the Otranto Sill, which links Adriatic and Ionian Sea (Figure 5.2). The western coastline along the Adriatic is relatively smooth, without any islands and with a gentle shelf, while the eastern part is characterized by many islands and irregular bottom increasing steeply in the offshore direction. There are 1246 islands in the Adriatic Sea, of which only 69 are inhabited.

620. The difference between east and western part is attenuated by high mountain chain (the Dinaric Alps) in the east versus much smoother land surface in the Italian side, where the Apennine Mountains are more distant from the coast. The Dinaric Alps strongly influence the wind field and strengthen the land-sea temperature differences (Cushman-Roisin *et al.*, 2001).

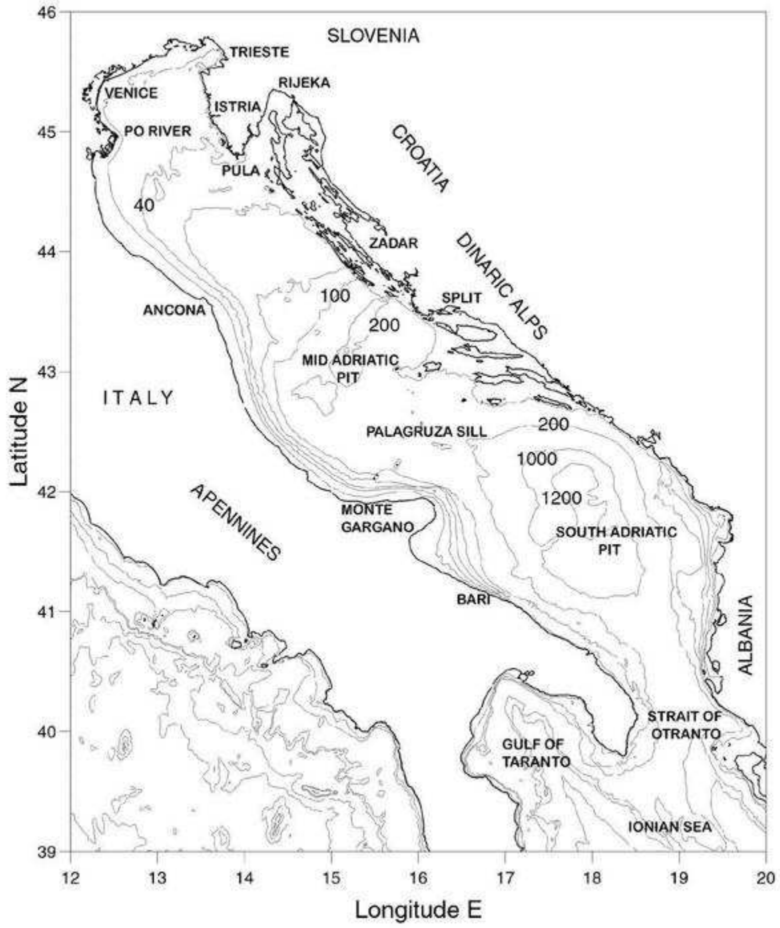


Figure 5.2. Adriatic Sea coastline and topography. (from Cushman-Roisin *et al.*, 2001) The eastern coast is generally high and rocky, whereas the western coast is low and mostly sandy.

5.2.2 Salinity, temperature regime; currents; sediment transport

Salinity

621. Inflow of fresh water by precipitation and river runoff exceeds evaporation in the Adriatic basin. Freshwater inflow decreases water salinity, while the influx of saline Mediterranean waters through the Strait of Otranto increases it. The open waters in the southern part of Adriatic basin have salinity between 38.4 – 38.9. Salinity is lower and more variable in the northern part and in coastal zones (average 37-38‰), while it can fall under 35‰ in the summer (Cushman – Roisin *et al.*, 2001). Long term measurements of salinity in the coastal and open waters in the middle and southern basins have shown historical increase of salinity, suggesting the reduction of freshwater supply caused due to Aswan Dam on the Nile River (Zore-Armanda *et al.*, 1991). Variability of other climatic factors, such as changes in precipitation and increase of evaporation may also contribute to fluctuations in salinity. (Grezio and Pinardi, 2006).

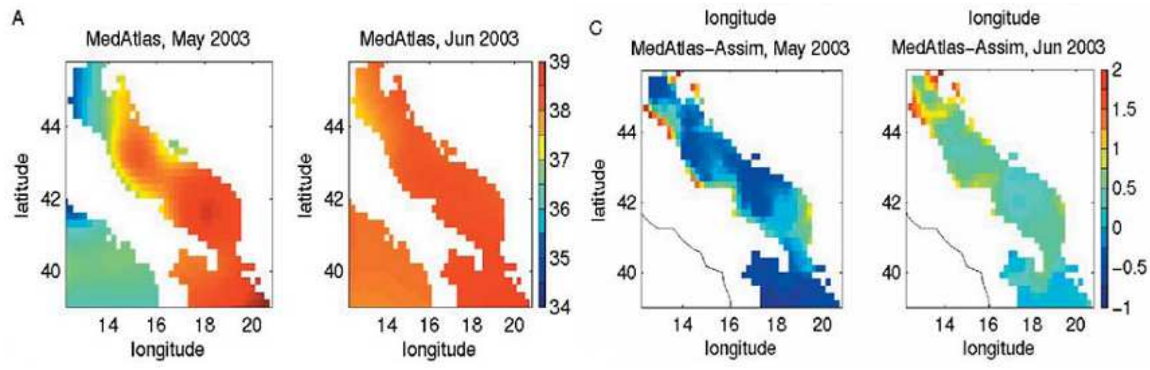


Figure 5.3 Monthly mean salinity at 5 m depth (in *psu*) for May and June: A: MedAtlas climatological months for May and June, B: salinity AF for May and June 2003 (Grezio and Pinardi, 2006)

Temperature

622. The mean annual surface temperature is 18℃ in the South and 25℃ in the North. The extremes of the surface temperature range from 3℃ to 29℃ respectively. The Adriatic is a temperate warm sea, since even temperatures of the deepest layers are mostly warmer than 10℃. The thermocline occurs at 10-30m during warmer seasons (Cushman *et al.*, 2001). The Northern Adriatic exhibits substantial fluctuations, possibly linked to the cycle of winter cooling and summer warming in the relatively shallow sub-basin. The northwestern section shows larger fluctuations than the northeastern one, with lower winter SST, probably due to the freshwater inflow from the Po River delta. The Southern Adriatic exhibits less variability, possibly influenced by the periodic water exchanges with the Ionian Sea. The South Eastern section shows somewhat larger fluctuations than the South Western one, with higher winter SST, probably due to the inflow of warmer waters from the south. The two Central sections reveal patterns similar to the ones of the whole basin. The observed temperature patterns appear to follow the classical Adriatic cyclonic circulation scheme (Barale *et al.*, 2004).

623. From a long-term time data (1981-1999), which were processed to estimate Sea Surface Temperature (SST) values, an apparent general warming trend of sea surface can be recognized in Adriatic basin. The linear fit to the seasonal cycles suggests an increase of about 2℃ in 20 years, essentially due to a steady rise of summer values. A general north-south temperature gradient can be found during winter, the northern sections being colder than the Southern ones. An east-west gradient also appears, the western sections being warmer than the eastern ones (Figure 5.4).

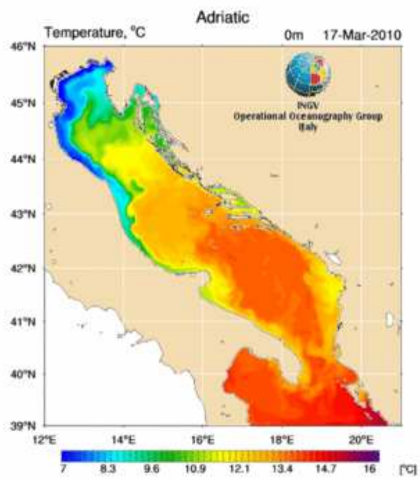


Figure 5.4. SST in March 2010 (From: http://gnoo.bo.ingv.it/afs/external/domani_T.gif)

Currents

624. The Adriatic Sea is composed of three regional basins (North, Central and South), differing in latitude, bathymetry, physiography and biogeochemical features. Three types of water masses were identified in Adriatic by Zore – Armanda (1963), distinguished according to temperature (T, ℃), salin ity (S) and density (σt in kg/m3). These three regions are:

- Northern Adriatic Dense Water (NadDW: T=11, S=38,5 and σt = 29,52 kg/m3);
- Mid-Adriatic Dense Waters (MadDW: T=12, S=38,2 and σt = 29,09 kg/m3);
- South-Adriatic Dense Waters, called also Deep Waters (ADW: T=13, S=3,6 and σt = 29,20 kg/m3).

625. Another distinct fourth water type is the Mediterranean Levantine Intermediate Water (LIW), formed in the Levantine Basin, which enters the Adriatic through the Strait of Otranto. The intensity of water exchange rate between the Adriatic and Ionian Sea is influenced by the variability of air pressure field, which varies considerably from year to year.

626. The variable impact of the Mediterranean water also influences primary and secondary production (Cushman-Roisin *et al.*, 2001). The Modified Levantine Intermediate Water, which enters the Adriatic Sea through the Otranto Strait recirculates within the central basin. However, part of the southern salty waters flow northward till the Gulf of Trieste, turning west and forming a cyclonic gyre in the Northern Adriatic. Northern Adriatic Dense Water is generated locally in winter, when water temperature drops below 12℃. These cold and saline waters sink and flow southward along the western Adriatic side close to the bottom until they reach the Ionian Sea through the Otranto Strait (Artegiani *et al.* 1997a; Russo *et al.* 2005). A main frontal system, mostly visible in winter, divides the coastal from the offshore waters, the latter containing the freshwater contributions of the Po and other minor rivers, showing a partial thermohaline stratification. The offshore waters in the eastern part of the basin are not influenced by continental inputs and are generally characterized by a lower degree of winter stratification.

627. The prevailing winds, ‘bora’ (NE) and ‘scirocco’ (SE), trigger modifications of hydrological properties by altering the stratification and the vertical stability regimes and by changing the physical features of the basin in general (Cushman *et al.*, 2001). This is reflected in the biogeochemical properties of the basin as well as biomass and the structure of the pelagic phytoplankton community (Mauri *et al.* 2007). The spatial and temporal extension of seasonal stratification, characterized by variable pycnoclines, also shows strong interannual variability in intensity and duration (Socal *et al.*, 2008).

628. Three regions of relatively homogeneous vertical water mass properties (climatological water masses) exist in the subregion: (i) the northern Adriatic Sea, from the 100 m isobath to the northernmost corner of the basin; (ii) the middle Adriatic containing the Pomo Depressions, more than 250 m deep; and (iii) the southern Adriatic starting approximately from the Pelagosa sill to the Otranto Channel. At the surface the winter general circulation is composed only of NAd and SAd current segments and the flow field is very different from all other seasons (Figure 5.5). The general circulation is dominated by temperature and salinity compensation effects, which give no resulting density signal. Barotropic, wind-induced transport and circulation are probably major components of the general circulation during winter (Artegiani *et al.*, 1997b).

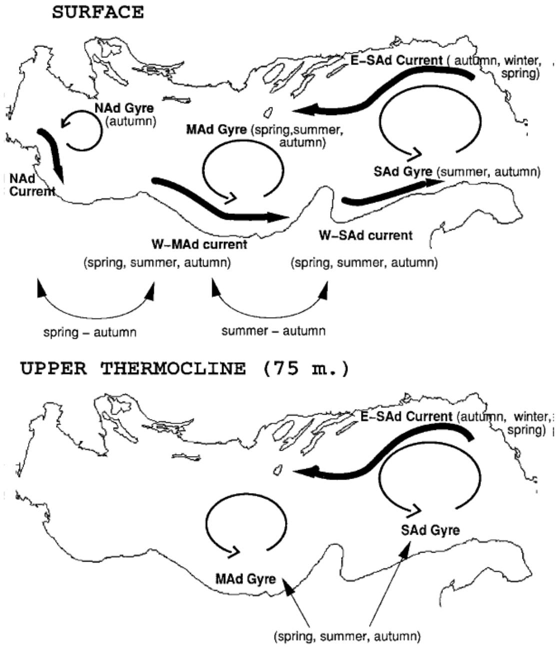


Figure 5.5. Schematics of the Adriatic Sea baroclinic circulation (Artegiani et al, 1997b)

629. The spring–summer surface flow field is characterized by the appearance of western current segments (W-MAd, W-SAd currents) and the two major cyclonic gyres of the Adriatic circulation. The seasonal vertical stratification in the basin triggers the appearance at the surface of gyres and boundary intensifications, more generally of eddies and jets, probably a result of baroclinic/barotrophic nonlinear instabilities in the basin. During summer the smallest spatial scales occur and the E-SAd current weakens. The autumn conditions are characterized by maximum spatial coherence in the general circulation structure. There are three cyclonic gyres, a continuous western Adriatic boundary current, connected between the three subbasins, and an intense SAd current. In autumn there is a maximum MLIW entrance and spreading from Otranto, causing maximum warming of the subsurface layers of the northern Adriatic. The aggregation of the general circulation into large-scale structures could be due both to the stabilization of the water column and to the structure of the external forcing of the circulation. The Otranto inflow of MLIW could be a substantial part of that external forcing. The wind driving during autumn also consists of a south-easterly wind, called ‘‘scirocco,’’ which in turn could reinforce the inflow of water at Otranto.

630. At the depth of the seasonal thermocline (75 m) the presence of the E-Sad current and the SAd gyre was identified. The MAd gyre is not evident at this depth during winter as is the case for the surface flow field. The spring–summer flow field is again characterized by smaller spatial scales than in the other two seasons (*Artegiani et al., 1997b)*.

631. The deep waters of the Adriatic can be separated into two categories: the first, clearly formed in the northern Adriatic region, cool and relatively fresh, found in the northern and middle Adriatic, and the second of much higher temperature and salinity, in the southern Adriatic. Vertical mixing between water masses is an extremely powerful dynamical process in the basin, especially as an explanation of the modification of NAdDW into MAdDW. (Artegiani *et al.*, 1997a)

632. The western side of the Adriatic basin is a site of intense current segments, which are disconnected in the three sub basins (northern, middle, and southern) in spring and summer. The autumn conditions show an overall cyclonic circulation with the intensification of three cyclonic gyres in the sub basins. The forcing of the general circulation has three major components, perhaps equally important for the overall Adriatic dynamical engine. The first component is river runoff, characterized by the low salinity waters derived mainly from the Po and Albanian Rivers. The Po forcing produces compensation of temperature and salinity gradients horizontally and is an important component of the buoyancy budget in the overall basin. The second component is the wind and heat forcing at the surface, which produce deep-water masses in the northern and southern Adriatic and forces the

circulation to be seasonal. The third component is the Otranto Channel forcing, which inputs heat and salt in the circulation as a restoring mechanism for the northern heat losses and water gains (Artegiani *et al.*, 1997b).

633. The Gulf of Trieste is limited in size (20kmx20 km) and occurs in the shallow (24 m) part of the northern Adriatic, but it plays an important role in the circulation of the entire northern Adriatic Sea. In general, circulation of the Gulf is driven by wind stress (particularly bora), buoyancy fluxes and general circulation of the Adriatic Sea, together with tides and seiches (Bogunović and Malačič, 2009). The Isonzo River is the largest freshwater inflow in the Gulf of Trieste (average of 204 m3/s according to Raichich, 1994). Dynamics of the Gulf is largely impacted by the Isonzo freshwater input, since its waters flow into the southern part of the Gulf. In all seasons there is a general inflow into the Gulf of Trieste at its lower, deeper part. This inflow makes a cyclonic turn cantered in the southern part during average winter conditions. This turn is enhanced during spring and closes in an elongated cyclonic gyre during average summer conditions. In spring and summer, the cyclonic gyre is coupled with an anticyclonic gyre near the closed eastern part of the gulf. A “dome”-like density profile across the gulf's axis in the inner part of the gulf above the bottom appears with this circulation during spring and summer. In climatic autumn there is a smaller anticyclonic gyre on its southern side. Near the sea surface there is an outflow during winter, which is driven by the dominant “bora” wind blowing along the gulf's axis.

634. This outflow, however, is detached from the southern coastline to the right, and crosses the gulf diagonally, merging with the belt of freshwater outflow along the northern coastline. This is shown to be a consequence of the balance between the pressure gradient force caused by elevation piled up in the direction out of the gulf, the Coriolis force, and vertical friction between layers near the sea surface. During the stratified season the surface of the gulf is occupied by an anticyclonic gyre due to the inertial plume of the Isonzo River (Malacic and Petelin, 2009).

635. Unlike the Western Adriatic, the eastern part is replete with islands and headlands, among which the water depths can reach 100 m. Due to complicated geographical features every bay and channel tends to have specific oceanographic characteristics. The wind is an important forcing mechanism and is modulated seasonally. Alongshore winds and offshore winds are stronger in winter than in the summer due to changing state of atmosphere above the Adriatic. The strongest winds in Adriatic are bora and sirocco, which are accompanied by different weather patterns. Bora winds come with high air pressure, low sea and air temperature, almost cloudless sky, low humidity and no precipitation, while sirocco winds are accompanied by low air pressure, high sea and air temperatures, large amounts of clouds, high humidity and heavy precipitation.

636. Freshwater discharges are smaller then along the Italian coast, amounting altogether to 900m3/s. 59% of freshwater input is due to rivers, 31% due to underground seepage, spring water (6%) and land runoff (4%). Upwelling events, associated to the prevailing NW winds, is frequent along the Croatian coast during summer months (Cushman-Roisin *et al.*, 2001).

637. The eastern coast generally has a narrow shelf area, with smooth bathymetry and with circulation features determined by waters from Ionian Sea. The influence of freshwater inflow is felt also far downstream, along the Croatian coast and the Albanian coast, where discharge from rivers reaches 1000 m^3. North-eastern wind generates also very intense coastal upwelling along the Albanian shoreline due to the sudden change of the coastline orientation. Bora winds induce an undercurrent at intermediate depths near the Albanian shelf break and weaken the Levantine Intermediate Water flow into the Adriatic Sea (Cushman-Roisin *et al.*, 2001).

638. In the Adriatic Sea, the sea level alteration due to storm surges is highly related to the tide’s amplitude, which is usually higher than in the rest of the Mediterranean, especially in the northern Adriatic. Astronomical forcing produces an almost complete “co-oscillation” with the Mediterranean, where the continuous driving from the southern inlet is much more important than the negligible local direct forcing from the moon and sun. Additionally, the southeast winds (Sirocco) raise the sea level, especially in the North Adriatic, where a long-lasting Sirocco and low air pressure can also raise the water level up to 1 m. Wind influence is less important in the South Adriatic, where the air pressure influence is dominant giving rise to sea level changes of up to 30 cm (Tsimplis *et al.*, 1995; Bondesan *et al.*, 1995; Leder, 1988).

639. Low-elevation coastal areas and their populations are at risk during and after the appearance of a storm surge event. The sea level rise due to storm surge events was examined for the period 2000–2004 and potential inundation zones were then identified using a 90-m horizontal resolution digital elevation model. Based on the combination of the risk level determination of an area and the calculation of sea level alteration the major 'risky' coastal regions were identified (1) (Krestenitis *et al.*, 2010). Venice Lagoon is the area of the highest risk is, due to the largest potential inundation area and highest population density.

Sediments

640. Geophysical investigations in western Adriatic indicate that the top of the limestone series, underlying the clayey and sandy deposits of the Pliocene and the Quaternary has a very uneven topography. Its greatest depths (4–6 km) are found a) between Ravenna and Rimini, b) between San Benedetto and Pescara, and c) below the Albanian shelf. Recent sands are mainly limited to the littoral zone; Pleistocene sand, originally supplied by rivers, covers the greater part of the deeper shelf. Between these zones a terrace-shaped pro-littoral mud belt is present, where the bulk of the recent terrigenous mud is deposited. The maximum rate of accumulation in this belt is probably about 4 1/2 mm per year.

641. The remaining part of the recent mud is transported in the sea water as floccules of such small size that they remain suspended over the deeper zones of the shelf. Most of it is deposited in the basins of the Central Adriatic (maximum accumulation rate for the Holocene on the average circa 1/2 mm per year) and in the bathyal basin in the southeast. The deepest area of the latter basin is formed by an almost horizontal plain (circa 1218 m deep). The longest core from this plain (240 cm of Holocene and 400 cm of late Pleistocene) is composed for roughly 61% of turbidity material, 5% of volcanic ash (coarser than fine silt), 0,2% of organic carbonate remains (coarser than silt) and 34% of normal terrigenous mud. The ash falls were limited to the central and south-eastern parts of the Adriatic (van Straaten, 1970).

642. The Po River, draining a catchment of about 75,000 km2, is the main sediment entry point in the region. The Apennine Rivers, draining smaller catchments characterized by very high sediment yield, act altogether as some sort of a linear source. The Adriatic pro-delta deposit is up to 30 m thick along a shore-parallel belt from the Po to the area south of the Gargano Promontory, and is characterized by subaqueous gradational geometry. Prograding sigmoids reflect fluctuations in sediment supply, climatic/anthropic impacts in catchment areas, and basinal energy regime. Fluctuations in sediment flux to the basin result in diagnostic geometries within the Adriatic pro-delta wedge and can be quantified by establishing chronological constraints from sediment cores (Vollenweider *et al.*, 1992; Boldrin, *et al.*, 2005).

5.2.3 Spatial and temporal distribution of nutrients, dissolved oxygen and pH

643. In the northern Adriatic, the most extensive nutrients come mostly from the extensive freshwater inflow of nutrient reach waters from Po River (de Wit, 2002). In the early 1990s the estimated average contribution of agriculture to the total nutrient load (phosphorus) was 22-25 % for the Po River. The reduction of the fertilizer consumption and the increase of crop yields resulted in a slight reduction of the agricultural surplus of N and (especially) P between 1985 and 1995. Nutrient concentrations have decreased in the last decade, as new sewage networks and freshwater treatment plants have been constructed, according to the UNEP/DEWA study of 2004 entitled "Freshwater in Europe".

5.2.4 Relation of catchment area to subregion

644. By far the Po River has the largest catchment area in this subregion, draining a catchment of about 75,000 km2. Smaller drainage basins occur in Slovenia, Croatia, Bosnia-Herzegovina, Montenegro, and Albania (see Figure 5.6).

Figure 5.6 Schematic showing catchment areas in orange for the Adriatic subregion (from Blue Plan)

645. The Adriatic Sea receives large amounts of fresh water from numerous rivers. The largest is the river Po, which contributes to 46, 5% of all the freshwater input. Most of the riverine input is in the north- west side (72%), while only 27% of fresh water comes from the Eastern side. The biggest river in the South-Eastern Adriatic area is the Drin, bringing 10% of annual freshwater input. Rivers provide important inputs of low-salinity waters and land-drained materials from the land (Cushman-Roisin *et al.*, 2001, Vollenweider *et al.*, 1992).

646. Albania's coast is about 429 km long, the northern part belonging to Adriatic basin, while the southern part belongs to Ionian coast. Albania has a population of 3.100.000 people, with approximately 58% of population living in the coastal zone. Its Adriatic coast, with a total length of about 259 km, is low-lying alluvial plain 4-50 km wide. The low coast is interrupted at a number of locations by hills at a right angle to the coast forming capes. These divide the coast into a number of closed physiographic units of varying sizes. Several small deltas and coastal lagoons, formed by nine rivers are in the Adriatic part of the coastline. Shoreline shows dynamic changes in the vicinity of the river mouths of the deltas, which are still kept in a natural state. In the case of the Darci River, however, the old delta is undergoing severe erosion at the river mouth as the sediment input to the coast has almost completely ceased (NDA Albania, 2003).

647. The coast of Bosnia and Herzegovina is 25 km long. Only 24% of the country's hydro-geographical network drains into the Adriatic Sea, while 76% drain into the Black Sea (Sava River) catchment area. The main rivers are Neretva, Trebišnjica and Cetina river catchment areas. Population density in the Mediterranean region of the country is 33 capita per square kilometre. The largest city in the coastal area is Neum, with population of 4 300 inhabitants (NDA Bosnia and Herzegovina, 2003).

648. The Croatian Adriatic mainland coast length is 1777 km, divided into Istria, Hrvatsko Primorje and Dalmatian areas. The Dalmatian coastline area is the longest, extending from Premuda near Zadar to the border to Montenegro south of Dubrovnik. Within this zone there are 4324.5 km of shoreline of which 74% are islands. Croatia has a permanent coastal population of 1 000 000 which increases considerably during the summer because of tourism. The larger coastal towns are Split, Rijeka, Zadar, Pula, Sibenik and Dubrovnik. Dalmatian area makes up two thirds of the total Adriatic coastline and island shoreline length. Within the main rivers outflows in Croatian coastline are Zrmanja, Krka, Cetina Rivers (NDA Croatia, 2003).

649. Italy's coastline stretches 7 500 km and the whole territory is located in drainage basins flowing into the Mediterranean Sea. Several rivers drain into the Adriatic Sea (Po, Piave, Adige and Reno). Some of the larger cities are Trieste, Venice, Ancona and Brindisi. The Po River, on the NW side of the Adriatic, together with other important rivers draining the southern divide of the Alps (Reno, Adige, Brenta, Piave, Isonzo, etc.) (NAP Italy 2005).

650. The Mediterranean coast of Montenegro has a population of approximately 150.000 and a total length of 293 km. The major towns are: Bar, Herceg Novi, Kotor, Ulcinj, Budva and Tivat. The summer population of these towns increases because of tourism. Slovenian coastline has the length of 46 km. It hosts approximately 80 000 people who mainly reside in the towns of Koper, Izola and Piran. Main rivers in Slovene coastal are Rizana, Badasevica and Dragonja.

5.3 Biological characteristics

5.3.1 Description of water column biological communities

Phytoplankton

651. The most important fraction of phytoplankton in the Adriatic is nanoflagellates, which on average constitute almost two thirds of the phytoplankton community at the annual scale. Diatoms, in contrast, constitute less than one third of phytoplankton abundance, and predominate only during blooms (up to 95% of the total phytoplankton). Dinoflagellates and coccolithophorids are of minor numerical importance in the phytoplankton community.

652. The phytoplankton population dynamics in many parts of this subregion are strongly influenced by hydrology of adjacent watersheds. For instance, the Gulf of Trieste has only recently been studied for phytoplankton, but it is well recognised that phytoplankton dynamics in the Gulf are mostly driven by freshwater runoff and being the reflection of rapidly modifying hydrological and nutrient conditions in the Gulf of Trieste. The chlorophyll biomass in the surface layer displays two annual peaks. A strong temporal variability is also characteristic for the phytoplankton community structure in the surface layer. The seasonality is similar to that of chlorophyll biomass.

653. The studies for the Albanian algae flora have started on a regular basis after the 1990, on the basis of the establishment of the respective research group on some Universities and the Sciences Academy institutions. Some decades before there had been very few and sporadic studies made by foreign experts, but regarding the coastal and marine studies the data were nearly absent.

654. More than 440 species or subspecies of diatoms (70 centricae and 370 pennatea) were described totally along the brackish coastal wetlands (Miho and Witkowski, 2003). More frequent are found the genus *Chaetoceros, Cyclotella*, *Actinocyclus*, *Navicula*, *Nitzschia*, *Amphora, Mastogloia*, etc., with about 111 species identified, of which there are 74 diatoms, 27 dinoflagellata and 10 species of other groups like coccolitophoridae, silicoplagellatae, eugenophytae, clorophytae.

655. The complete composition of phytoplankton in Eastern Adriatic is still not known. Diatomeae encompass more than 80% of species. While microphytoplankton (cells >20 µm) is better known, nanoplankton (cells <20 µm) in Croatian waters is very poorly researched. There were some investigations of pikoplankton in coastal and open waters of Middle Adriatic in period 1996-1998 (Nincevic-Gladan *et al.*, 2006). Results show that cyanobacteria *Synechococcus* makes even 96% of pikoplankton community. Pikoplankton is much more represented in phytoplankton biomass of open waters (31%) than of the coastal sea (9%).

656. The *Checklist of Phytoplankton in the Eastern Adriatic Sea* was published in 2002 (Vilicic *et al.*, 2002), based on a very comprehensive catalogue of phytoplankton of Northern and Middle Adriatic (Kerzan and Stirn, 1976) as well as more recent information from the period 1981-2000. According to recent insights, phytoplankton of the Eastern Adriatic Sea is composed of 888 determined species. The diatoms are represented with 518 species (330 pennates, 176 centric diatoms), dinoflagellates 254, prymnesiophyceae 101, chrysophyceae 2, raphidophyceae 1 and euglenophyceae 2 species. The checklist is accompanied by information on the general distribution of species in the north, central and south part of the Eastern Adriatic. After 2002, additional new taxa were registered. Today, the most research on phytoplankton is connected to sites important for monitoring of the state of marine environment like estuaries of rivers (Zrmanja, Krka, Neretva) as well as to sites containing some specific characteristics like the Otrant Straight and the Jabuka Pit. Generally, Northern Adriatic is

much better researched than the middle and southern part. A few specific sites are described in detail below.

657. The centric diatom *Cyclotella choctawhatcheeana* develops dense populations in the karstic estuary of the Zrmanja River, showing preference for oligotrophic and brackish conditions (Buric et al, 2007). A very rare dinoflagellate *Ceratoperidinium yeye* was found recently in Eastern Adriatic. This species has been registered only in few sites in the whole Mediterranean Sea (Nincevic-Gladan et al, 2006b).

658. One hundred forty six taxa of microphytoplankton have been registered in the Neretva Delta, most of them being diatoms. In the brackish lake Vlaska two new species have been found: *Oxyphysis oxytoxoides* and *Erythropsidinium agile agg* (Jasprica and Hafner, 2005).

659. A very interesting and specific site is a small, karstic marine Lake Rogoznica. In this naturally eutrophic, hypoxic and periodically anoxic lake with the brackish/seawater interface, Buric et al, (2009) found 40 taxa, mainly diatoms (62.5%) and dinoflagellates (29%) The research provided evidence of exceptionally dense populations and the seasonally-recurrent appearance of two rare dinoflagellates: *Prorocentrum arcuatum* Issel and heterotrophic species *Hermesinum adriaticum* Zacharias. Research of phytoplankton abundance and seasonality in the NE Adriatic Sea in the period 2002–2007 showed its direct relation to the annual regime of the Po River discharge (Vilicic et *al*, 2009). The dominant taxa are the diatoms *Cerataulina pelagica*, *Chaetoceros socialis*, *Chaetoceros vixvisibilis* and *Pseudo-nitzschia* spp., which appear at maximum abundances. Among other phytoplankton, the most common is the coccolithophorid *Emiliania huxleyi* and the dinoflagellate *Prorocentrum minimum.*

660. The Otrant Strait between the Adriatic and Ionian Seas is an oligotrophic area (Vilicic et al, 1995). Enrichment of the euphotic layer with the nutrients is mainly due to discharge of Albanian and Greek rivers, as well as mixing and upwelling in winter/early spring, resulting in periodical phytoplankton blooms. The eastern part of the strait is mostly influenced by the northerly inflowing current from the Ionian Sea, and the western part by the southerly outflowing current from the Adriatic Sea. Phytoplankton of the Jabuka Pit was investigated in 2003 during the winter mixing of waters as well as in spring period of stratification (Buric, 2007). Dominant species are: *Calyptrosphaera* sp., *Emiliania huxleyi*, *Cerataulina pelagica*, *Chaetoceros socialis* and *Pseudo-nitzschia* spp. Spatial distribution of phytoplankton is connected with the exchange of water masses.

Zooplankton

661. In the framework of preparation of the First National Report for the CBD, 767 marine zooplankton species have been registered for Croatia (Krsinic, 1997): 220 Protozoans, 117 Cnidarians, 10 Ctenophora, 15 Rotatoria, 18 Mollusca, 340 Arthropods - most of them being copepods (224), 11 Chatognatha and 36 Tunicata. Apart from Protozoans, the best researched group is copepods. On the basis of spatial variations in the abundance of the dominant species, three characteristic communities of copepods can be defined in Eastern Adriatiac (Hure and Krsinic, 1998). Biomass of copepods correlates with biomass of their predators Chaetognaths, the most abundant being *Sagitta inflata, S. lyra* and *S. minima* (Batistic, 1994). Chaetognats make significant proportion of zooplankton biomass at the end of summer and during the autumn, especially along the coast.

662. Planktonic ostracods abundance in deep Adriatic Sea (Brautovic et al, 2007) showed that between fifteen species found, the dominant ones were *Porroecia spinirostris* and *Archiconchoecia striata*. A marine cladoceran, *Penilia avirostris*, is usually a dominant metazooplankton element in the summer period, with abundances commonly higher than the abundance of copepods.

663. Research shows that abundance of copepods, especially of *Calanus helgolandicus,* is important in relation to the occurrence of basking sharks *Cetorhinus maximus* in the eastern Adriatic Sea (Soldo *et al.*, 2008).*Acartia italica* is the only strictly protected copepod in Croatia. It is the only planktonic copepod in the small marine Lake Rogoznica with characteristic periodical hypoxia and even total anoxia (Krsinic et al, 2000). After the period of total anoxia when massive mortality of all organisms occurs, *A. italica* recovers quickly as it is adapted to extreme conditions. This species has an important role in functioning of specific ecosystem of this small but very important site.

664. Regarding macrozooplankton, Batistic *et al.* (2007) reported, in the 0–1000 m water column at a deep-sea station in the northern part of South Adriatic Pit, out of 66 species identified, there were 19 hydromedusae, 14 calycophores, 3 ctenophores, 2 heteropods, 12 pteropods, 8 polychaetes and 8 chaetognaths. The calycophore *Muggiaea atlantica*, newly observed in the Adriatic, has replaced its formerly dominant congener *M. kochi*; the pteropod *Creseis virgula* has supplanted *C. acicula*, and the previously very rare *Pelagobia longicirrata* now is the dominant pelagic polychaete. Research on deep-sea gelatinous macrozooplankton in the Southern Adriatic (Onofri et al, 2009) by method of Blue Diving presented important data on ecology of several species like *Solmissus albescens*, *Nanomia bijuga* and *Forskalia formosa*.

665. One of the most important elements of macrozooplankton in the Adriatic is scyphomedusae because of their periodical swarms. Especially problematic are swarms of the mauve stinger *Pelagia noctiluca* because of its rather severe sting. High *Pelagia* densities have been observed with a periodicity of about 12 years in the western and central Mediterranean, while swarms in the Adriatic Sea have been less predictable. The moon jelly *Aurelia aurita* is usually present during the winter/spring in the Adriatic Sea. Since 2003, massive blooms of white jellyfish *Rhizostoma pulmo* have occurred during the autumn/winter period in the Northern Adriatic (Ramsak and Stopar, 2007).

666. An increasing dominance of two allochthonous macrozooplankton species was recorded recently: hydromedusa *Niobia dendrotentaculata* and thaliacea *Thalia orientalis* (Batistic et al, 2009). In August 2006 *N. dendrotentaculata* with 11.2 ind./m^3 made 44% of the total number of hydromedusae in the coastal area of the Southern Adriatic while previously predominant *Aglaura hemistoma* significantly decreased in abundance. Similar, *T. orientalis* has replaced its formerly dominant congener *Thalia democratica* in the coastal and open south Adriatic waters in January 2008. These faunal changes follow changes in zooplankton community structure recorded from 1995 in the Adriatic Sea, possibly due to large-scale hydroclimatic fluctuations, i.e. the North Atlantic Oscillation (NAO).

667. A new copepod *Speleophria mestrovi* was described from an anchihaline cave on Vis Island - the first report of a misophrioid copepod found in an Adriatic anchihaline cave (Krsinic, 2008). A new calanoid copepod genus and species *Speleohvarella gamulini* was described from the anchihaline cave Ziva Voda on Hvar Island (Krsinic, 2005a), while a new genus and species of calanoid copepod belonging to the family of *Ridgewayiidae* was described from an anchihaline cave on the small island of Badija (Krsinic, 2005b). Another new species of *Mesaiokeras* is described from the hyperbenthos of Veliko Jezero, a marine lake on the island of Mljet - the first species of the family *Mesaiokeratidae* reported from the Mediterranean (Krsinic, 2003). The most recent discovery is a new species of appendicularian, *Fritillaria ragusina*, that was described from specimens collected between the surface and 300 m depth at three stations in the open south Adriatic waters (Garic and Batistic, 2010).

5.3.2 Information on invertebrate bottom fauna, macro-algae and angiosperms

Benthic fauna

668. A limited number of invertebrate bottom fauna, macro-algae and angiosperms groups have been studied in the Adriatic Sea.

669. Data on marine macrozoobenthos of Albania are relatively limited. The most studied groups of macrozoobenthos are echinoderms, decapods crustaceans and molluscs. Data on sponges, cnidarians, bryozoans, annelids and ascidians are poor and collected just recently. Several benthic groups are almost or completely unstudied. Among the first studies on marine benthos in Albania is that on the echinoderms, by Gjiknuri (1980). In his doctorate he reported the distribution of about 46 echinoderms species along the Albanian coast. Vaso, during his doctorate theses has studied the Albanian decapods, reporting more than 100 species (Vaso and Gjiknuri, 1993).

670. A comparative taxonomic and ecological study of molluscs (Gastropods and Bivalve) of the Albanian coastal lagoons was carried out by Beqiraj (2004), where about 77 species were reported. Molluscs and annelids predominate in the species composition of the macrozoobenthos of the Albanian coastal lagoons and the highest abundance has been recorded for molluscs, crustaceans and chironomids (Beqiraj *et al.*, 2008). Regarding bottom fauna a number of 219 animal species

classified in the following taxonomic categories have been determined in Neum-Klek Bay: Porifera (19), Cnidaria (11), Annelida (20), Echiurida (1), Artropoda (312), Mollusca (91), Tentakulata (6), Echinodermata (29) and Tunicata (12). The most important are Mollusca among which 89 species from 35 families have been registered.

671. The benthos of the Adriatic Sea has been described very comprehensively in the book *Biological oceanography – Benthos – Benthos bionomy of Adriatic Sea* (Pérès and Gamulin-Brida, 1973). Generally, there are poor data on marine microphytobenthos in Croatia, composed of diatoms *(Bacillariophyceae)* and blue-green algae *(Cyanobacteria*). For the latter, Ercegovic (1932) studied lytophytic cyanobacteria and described several endemic genus like: *Dalmatella, Brachynema, Solentia, Hormathonema* etc. Out of 128 registered taxa of cyanobacteria in Croatia, even 53 (41%) are endemic for the Adriatic (Antolic, 1997).

672. In Croatia, 5,655 species of marine invertebrates have been recorded According to available data, only one species of sea squirt *Polycitor adriaticus* is stated as endemic to the Adriatic. Among 221 species of sponges recorded, the following species are strictly protected: *Geodia cydonium; Sarcotragus spinosulus; Tethya spp.; Axinella cannabina, Axinella polypoides ; Eunapius subterraneus molisparpanis; Eunapius subterraneus subterraneus; Asbestopluma hypogea; Aplysina cavernicola; Petrobiona massiliana* and *Oopsacas minuta. Sponigia officinalis* is still being exploited under Croatia's Marine Fishery Act.

673. Especially interesting are sponges *Oopsacas minuta* and carnivorous *Asbestopluma hypogea* that are usually typical for deep water of the bathyal zone but recently species has been found in several littoral caves in Croatia (Bakran-Petricioli et al, 2007). Because of morphology of these caves, the cold winter water stays there the all year long so these habitats represent the enclave of bathyal in infralittoral/circalittoral area.

674. Corals are very important habitat structuring elements. In 2008 the Red list of threatened corals in Croatia was completed (Kruzic, 2008). Sixty five species have been classified; critically endangered (CR) are: *Eunicella verrucosa*, *Sagartia luciae*, *Paramuricea macrospina, Pachycerianthus multiplicatus, Antipathes subpinnata, Gerardia savaglia, Dendrophyllia ramea* and *Coralium rubrum* that is still being exploited. Strictly protected species are: black corals *Antipathes dichotoma*, *A. mediterranea* and *A. subpinnata* as well as *Astroides calycularis* and *Gerardia savaglia*. Especially important habitat structuring species is *Cladocora caespitosa*, a colonial scleractinian coral. Due to the symbiotic zooxanthellae, sizeable bioherms of this species can be found. The *Cladocora caespitosa* bank in the Lake Veliko Jezero in the Mljet National Park is significant for its large size of 650m2. It spreads at depth from 4 to 18 meters and is one of the largest banks of this coral found in the Mediterranean Sea (Kruzic and Pozar-Domac, 2002).

675. The red gorgonian *Paramuricea clavata* and Yellow sea fan *Eunicella cavolini* also form rich coralligenous communities around Croatian islands. The latter is particularly significant for coralogenic biocenosis of the deep craggy seabed and in the biocenosis of semi-dark caves. Coral trees and branches are often overgrown by other organisms and also represent sites for depositing cephalopod and cartilaginous fish eggs.

676. The hard bottom communities in Slovenia support certain habitat structuring species known as bioconstructors and bioeroders. The main such species is the mussel date (*Lithophaga lithophaga*), which is boring burrows in the sandstone. Due to the exploitation of this species in the past, many huge rocks were fragmented into smaller pieces, which were subsequently less interesting for colonization of benthic organisms. Another habitat forming species in the Slovenian coastal area is the Mediterranean Stony coral (*Cladocora caespitosa*) which forms a unique facies with this species in the biocoenosis of photophilic algae (Lipej *et al.*, 2006) in the Natural Monument of Cape Madona.

677. The deep sea of the Adriatic is still poorly investigated so it is not sure if deep sea coral reefs are distributed in Eastern Adriatic. The elements of this biocenosis deeper than 300m (so called 'white corals' are known from the Jabuka Pit and area between Lastovo and Palagruza islands (Bakran-Petricioli, 2007). Characteristic species are *Lophelia pertusa* and *Madrepora oculata.* Bryozoans that are also important habitat structuring elements belong to the least known phyla in the Adriatic Sea. The list of Bryozoans with 184 species was published in 2001 (Novosel and Pozar-

Domac, 2001) but today there are 263 species registered. *Hornera lichenoides* is strictly protected species.

678. The Adriatic decapod fauna shows a high diversity. The checklist was recently supplemented (Kirincic and Stevcic, 2008). So far, 241 decapod species have been noted, including recently recorded new species for the Adriatic Sea as well as eight aliens from Asian and North American waters. Up to now, no Lessepsian migrants have been noticed. Several species are being exploited under the Marine Fishera Act like: *Maja squinado, Homarus gammarus* and *Palinurus elephas.*

679. Strictly protected benthic species from other groups of marine invertebrates are: *Asteroidea* - *Asterina panceri* and *Ophidiaster ophidianus* ; *Bivalvia* - *Pholas dactylus, Lithophaga lithophaga* and *Atrina pectinata (Atrina fragilis)*; *Gastropoda - Erosaria spurca, Luria lurida, Zonaria pyrum, Charonia lampas (Ch.rubicunda, Ch.nodiferum), Charonia tritonis (Ch.seguenziae), Ranella olearia, Tonna galea, Mitra zonata, Pinna nobilis* and *Pinna rudis*. New species of marine invertebrates are still being registered in Croatia, some of them being alien species.

Macroalgae

680. Despite relatively long tradition of macroalgal studies in the Slovenian part of the Gulf of Trieste, the number of species known to inhabit the area is still not ascertained. According to Matjašič *et al.* (1975) and Vukovič (1984) at least 277 algal species are known to inhabit Slovenian coastal sea.

681. For biocenosis of supralittoral and mediolittoral muds cyanobacteria represent main photosynthetic organisms. Epilitic cyanobacteria are important segment of biocenosis of supralittoral rocks, giving it characteristic dark brown-blackish colour. Endolitic cyanobacteria are characteristic for mediolittoral where they provide olive-brownish colour to the rocks of biocenosis of the upper mediolittoral (Bakran-Petricioli, 2007). In biocenosis of the lower mediolittoral rock endolitic cyanobacteria live at the base of the living part of the red coraligenous algae like *Lichophyllum lichenoides.* For biocenosis of mediolittoral caves in Croatia, cyanobacteria *Rivularia atra* is the characteristic organism (Bakran-Petricioli, 2007).

682. The most numerous Macroalgal taxa are red algae Rhodophyta with 350 registered species out of 816 Mediterranean, including 30 Adriatic endemics (Antolic, 1997). Brown algae *Phaeophyta* are represented with 179 species out of 255 Mediterranean, including 52 Adriatic endemics (Antolic, 1997), while green algae *Chlorophyta* are represented with 134 species out of 209 Mediterranean.

683. There are no endemic marine green algae in Croatia, but two species are strictly protected: *Caulerpa prolifera* and rare species *Penicillus capitatus.* Among brown algae, the most important is genus *Cystoseira.* Ercegovic (1932) has described a number of Adriatic endemic *Cystoseira* species like *C.spicata, C.adriatica, C.jabukae* (Pérès and Gamulin-Brida, 1973). Brown algae represent the main element of biocenosis of photophilic algae that are, along with sea grass meadows, the most diverse and ecologically the most important biocenosis (Bellan-Santini et al, 2002).

684. Important species is the Adriatic wrack *Fucus virsoides*, endemic brown algae for east part of Northern Adriatic, represented in biocenosis of lower mediolittoral rock. It is boreal element, considered to be a pre-Messinian relict and the only *Fucus* population in the Mediterranean.

685. The most of brown algae are photolytic, but some sciaphyle species are represented in biocenosis of infralittoral algae in deeper sites that form transition to coralligenous biocenosis, like *Flabellia petiolata* and different *Peyssonnelia* species.

686. Red algae are important habitat structuring organisms in the Adriatic. Although the most species are sciaphyllic, some form the important part of biocenosis of the upper mediolittoral rocks like *Catenella caespitosa*, *Bangia atropurpurea* and *Porphyra leucosticta*. Some species from *Corallinaceae* family, like *Lithophyllum papillosum*, create pink carbonate layers on surface of rocks. For biocenosis of the lower mediolittoral rocks on some sites of outer coasts of Middle and Southern Adriatic islands, important habitat is coraligenous rims created by red carbonate encrusting algae like *Lithophyllum lichenoides*, *Lithophyllum byssoides* and *Tenarea undulosa*. Biocenosis of mediolittoral caves has some characteristic red algae like *Catenella caespitose* and *Hildenbrandia rubra* as well as encrusting coralligenous algae *Phymatolithon lenormandii*. Coralligenous biocenosis of circalittoral

hard bottom is based on *Mesophyllum alternans*, *Lithophyllum cabiochae*, *L frondosum* as well as *Peyssonnelia rosa-marina* and *P. rubra*. Circalittoral coarse sands and fine gravels are inhabited with rhodolithes and maërl facies with *Phymatolithon calcareum* and *Lithothamnion corallioides* (Bakran-Petricioli, 2007).

Angiosperms

687. In the Adriatic there are meadows of four species of marine vascular plants, out of nine occurring throughout the Mediterranean. The most widespread is the eelgrass *Posidonia oceanica*, inhabiting the bottom covered by coarse sand and gravel up to 40 m of depth. On the sand and sometimes silt seabed the commonest among them are meadows of the lesser Neptune grass *Cymodocea nodosa*, more characteristic for Northern Adriatic. *Zostera marina* and *Zostera noltii* are represented on muddy sands of bays protected from the wind as well as in eurihaline and eurithermic bocenosis.

688. Posidonia meadows are considered as the most important ecosystem of the Mediterranean Sea and an ecological indicator of sea biodiversity because of their high primary production as well as of the health status of coastal ecosystems.

689. *Posidonia oceanica* was not recorded in the Bosnia & Herzegovina part of Adriatic Sea, perhaps due to insufficient dissolved salts present from the expressed attenuation of sea water from the Neretva River. *Cymodocea nodosa* beds can be found in Neum-Klek Bay but these beds are very limited in space. Precise data on endemisms, species of restricted distribution and species of known sharp reduction along last decades were not available since there is no monitoring in B&H which could provide it.

690. Five marine angiosperms are known to inhabit Slovenian coastal sea and Slovenian coastal wetlands: *Posidonia oceanica, Cymodocea nodosa, Nanozostera noltii, Zostera marina* and *Ruppia cirrhosa.* Among them only *C. nodosa* is widely distributed in the area, whereas others are restricted to particular habitat types. *Ruppia cirrhosa* inhabits various salt-marsh habitats such as basins and ponds, found in hyper-saline environment. *Zostera marina* is considered to be a rare species present only in the form of small ―islets , mainly in the mouths of rivers and streams. *Nanozostera noltii* is on the other hand quite common sea-grass occurring in different parts of the Slovenian coastal sea. The most endangered sea grass in the studied area is certainly *Posidonia oceanica*.

5.3.3 Marine mammals, reptiles and seabirds

Marine mammals

691. The marine mammal fauna of the Adriatic Sea is well-studied in certain areas. The Slovenian part of the Gulf of Trieste is inhabitated regularly only by one cetacean species, the bottlenosed dolphin (*Tursiops truncatus*), of which there are more than 100 specimens in Slovenia alone -- whereas other cetaceans are only sporadically or rarely observed in the area. Recently, striped dolphins colonized the area of Gulf of Trieste, as evidenced by the increasing number of records (see Francese *et al.*, 2007). Other dolphins known to be reported in the area are the striped dolphin (*Stenella coeruleoalba*), the Risso's dolphin (*Grampus griseus*) and the Common dolphin (*Delphinus delphis*). While the Common dolphin has been almost completely extirpated in the Gulf of Trieste area, there is an increasing trend of records of striped dolphins in the Gulf (Francese *et al*., 2007). Baleen whales are only rarely reported in Slovenian waters. The last record of the fin whale (*Balaenoptera physalus*) occurrence in the area is from 2009. This species has been previously recorded in several occasions (see Lipej *et al.*, 2004). A humpback whale (*Megaptera novaeangliae*) sighting was reported for almost two months in the Slovenian part of the Adriatic Sea (Genov *et al*., 2009); this was only the second record of this species in the Adriatic Sea.

692. Cetaceans have also been studied in Croatia, where all marine mammals are strictly protected. During last decade the research activities of marine mammals has significantly intensified and there are many new data.

693. The bottlenose dolphin *Tursiops truncatus* is the only resident species in the Croatian part of Adriatic Sea. Cres-Loinj Archipelago (Kvarneric area) represents the habitat of the resident bottlenose dolphin population that has been researched since 1987, mostly by Association *Blue World*. Based on this research this area is proclaimed as the part of National Ecological Network and potential NATURA 2000 site as well as proposed marine reserve.

694. In 2008 and 2009 extensive research of Vis and Lastovo archipelago (area of cca 5000 km^2) was performed by the Association *Blue World.* By method of photoidentification 287 individuals have been identified. The local community of bottlenosed dolphins of this area was estimated to 477 individuals. Data on animal behaviour indicate that the area is an important feeding as well as breeding site, as 12 newborn animals have been reported. The estimated population is relatively high compared to other researched areas in the Adriatic (100-130 ind. in Kvarneric, 2500km^2; 70 ind. in Trieste Bay and West Istrian coast, 1200 km^2) (Holcer *et al.*, 2010). Bottlenose dolphins are regularly registered in area of Kornati Archipelago near Zadar (Middle Adriatic) but there is no estimation of number of animals (Gomercic, 2008). It is hard to estimate the population for Croatia as the whole area was not systematically investigated.

695. During July and August 2010, the Institute for Environmental Protection and Research (ISPRA) from Italy, in cooperation with ACCOBAMS Partners, carried out an aerial survey of cetaceans in the entire Adriatic Sea. The preliminary data indicate that *Gramphus griseus* and especially *Stenella coeruleoalba* (cca 1000 individuals recorded in groups up to 100) are not rare species in Adriatic as they were previously considered. The study concluded that *Stenella coeruleoalba* can be considered regular species in the Adriatic (Blue World, 2010).

696. Analysis of stranded cetaceans during last decades confirms the presence in Croatia of *Delphinus delphis*, *Grampus griseus*, *Stenella coeruleoalba*, *Baleanoptera physalis, Ziphius cavirostris* (Gomercic *et al.*, 2008). The sperm-whale *Physeter catodon* is also a regular visitor in the Adriatic.

697. The Mediterranean monk seal *Monachus monachus* was considered extinct in Croatia until recently (Tvrtkovic, ed, 2006b). During the last decade the number of reports is increasing, especially in the Northern Adriatic (Eastern Istria and Kvarner Islands). In 2009, 30 sightings were recorded in the Middle Adriatic (Antolovic, 2010). In 2006-2009 altogether 79 sightings were reported (Antolovic *et al.*, 2010). According to the systematic research of suitable habitats (21 caves) of the open-sea islands and the Adriatic coast, it has been determined that a monk seal uses them. Simultaneous sightings in various areas as well as video records and photographs of individuals taken in caves or near them indicate possible breeding of the monk seal in the Adriatic (Antolovic *et al.*, 2010).

Marine turtles

698. The loggerhead turtle *Caretta caretta* is the only resident turtle of the Adriatic Sea. Animals from several Mediterranean colonies, mostly from Greek, Turkish and Cyprus ones, enter the Adriatic in early stage of life, grow there, forage and winter, leaving it only for breeding purposes. The Adriatic Sea with its extensive area of continental shelf, suitable water temperature and rich benthos biocenosis represents the largest and, along with Gabès Bay in Tunis, the most important critical neritic habitat of this species in Mediterranean (Lazar and Tvrtkovic, 2003).

699. About 2500 specimens are accidentally caught each year by the Eastern Adriatic trawl fisheries and more than 4000 by Italian fishing fleet. Based on this data and on recent satellite tracking of five animals, the analysis of critical habitats was performed in 2009 (Lazar, 2009). It included feeding areas (pelagic and neritic) and wintering areas in the whole area of the Adriatic under national jurisdiction of Croatia. The analysis shows different distribution of loggerhead turtles in summer and in winter period. Loggerheads feed on benthic organisms from shallow coastal waters of infralittoral down to circalittoral habitats.

700. Wintering areas are inside neritic feeding areas, restricted to depths <100 m and water temperatures of ≥ 11ºC. According to winter isotherms, this is southern of 45ºN. From the management point of view, the core area can be defined by Croatian fishery zones I and B (Regulation on boundaries of fishery zones, OG 144/05). This is one of the most important wintering areas for loggerhead turtles in the Mediterranean (Lazar, 2009).

701. Pelagic habitats for loggerheads exist in deep offshore waters in the Southern Adriatic and in oceanic province of the Middle Adriatic. Only the small part of it is in Croatian fishery area while the most of it is situated in territorial waters of Montenegro and Albania as well as in open international waters. Turtles are mostly threatened by by-catch in gill-nets and degradation of habitats through fishery activities (trawling) as well as by water pollution with solid and other organic and anorganic waste.

702. The loggerhead turtle (*Caretta caretta*) can be found in the Slovenian area mainly from May through October (Țița *et al.*, 2001). The majority of loggerhead turtle specimens are juveniles in the size range from 20 to 50 cm. There are also two known sightings of the leatherback turtle (*Dermochelys coriacea*), recently confirmed for the very first time in Slovenia (Lazar *et al*., 2009) in the waters of Izola.

703. The green turtle *Chelonia mydas* has been recorded in the Adriatic only occasionally. Several old records exist for Croatia and recently this species was registered in 2001 near Peljesac in the Southern Adriatic. Off-shore waters of the Southern Adriatic have certain importance as pelagic development area for a part of Mediterranean population of this species (Tvrtkovic, ed, 2006).

Marine and coastal birds

704. Small offshore islands are key habitats for several breeding seabird species from Annex I of the SPA/BD Protocol, while coastal habitats like wetlands Neretva Delta and Vrana Lake or mudflats/sandflats in Northern Dalmatia are important for migratory and overwintering birds (Radovic *et al.*, 2005).

705. The Mediterranean shearwater (*Puffinus yelkouan*) is occurring in the area only seasonally, from July to November. The data on this species are rather scarce since it is only rarely approaching the coast (Makovec, 1995). Much more data exists on terns and gulls. Regular monitoring of the breeding population of Yellow-legged Gull (*Larus cachinnans*) occurs in its unique breeding ground in Slovenia, the coastal wetland Sečovlje salina. Two other important breeding bird species are the common tern (*Sterna hirundo*) and the Little tern (*S. albifrons*). The breeding population of the first is more or less stable or showing a slightly increase in the very last years, whereas the trend of the later is growing increasingly (Iztok Škornik, *personal communication*).

706. Lastovo Arhipelago and Offshore Islands are parts of the National Ecological Network (NEN) and proposed NATURA 2000 sites (SPA's) with qualification species: *Calonectris diomedea, Puffinus yelkouan* and *Larus audionii*. *Falco eleonorae* is additionally important for the Offshore Islands and *Larus audionii* for the Mljet Island and Middle Dalmatian Islands. Proposed SPA's in northern part of the coast include as target features two SPA/BD Protocol species: *Phalacrocorax aristotelis desmarestii* and *Sterna albifrons. Phalacrocorax pxgmaeus* breeds on Vrana Lake (see the map 2). Additionally, important coastal species in Croatia is *Charadrius alexandrinus* that has been proposed for extension of SPA/BD Annex I list as well as *Gyps fulvus* that has the only breeding colonies in the whole Adriatic on Kvarner islands. The only SPA/BD Annex I bird species that does not occur in Croatia is *Sterna bengalens.*

5.3.4 Exotic, non-indigenous and invasive species

707. The introduction of species is considered as a nuisance has disrupted biodiversity in the Adriatic Sea.

708. The number of introduced species in the Mediterranean has increased spectacularly since the start of the last century. Their distribution in this subregion varies from country to country. They have been mainly introduced through three pathways: (i) by maritime transport (fouling and ballast water), (ii) through intentional introduction such as fish farming, and (iii) through the Suez Canal (Lessepsian migration).

709. A number of alien phyto- and zooplankton species have been introduced into the Adriatic most probably by ballast water during last several decades, such as siphonophora *Muggiaea atlantica* and several dinoflagellates like *Pseliodinium vaubanii* recorded from 1977 as well as recently recorded

Spatulodinium pseudonoctiluca, *Alexandrium minutum* and *Ceratoperidinium yeye* (Marasovic and Zuljevic, 2006).

710. Many new alien species indicate tropicalization of the Adriatic Sea. During 2008 a number of fishes that were previously rare or accidental for Adriatic, have been recorded to increase in numbers and spread northwards (Zuljevic *et al.*, 2008). The most numerous is reticulated leatherjacket *Balistes capriscus,* feeding on corals, sea urchins and shellfish. Others include predator species that influence significantly marine food chains like *Thalassoma pavo, Sphyraena viridensis* and especially *Pomatomus saltator* that feeds on commercial fish species. It seems to reproduce in the Adriatic and could possibly become commercially important species. Other fish species in progression are *Sparisoma cretense*, *Trachinotus ovatus* and *Lichia amia.*

711. The colonization of the Mediterranean Sea by Indo-Pacific and Red Sea species *via* the Suez Canal, known as Lessepsian migration, is an ongoing process that has considerably enriched the biodiversity in the Mediterranean Sea. The temperature is the most important abiotic factor determining the dispersal of Lessepsian fish (Golani, 2002). Changes in the Adriatic ichthyofauna have been recorded and among that some Lessepsian fish species were recently reported. The first records of new fish species for the Adriatic in 2008 are: *Caranx crysos* (Istria) as well as two Lessepsian migrants*: Fistularia commersonii* and *Terapon theraps* (being also the first record for Mediterranean) (Zuljevic *et al.*, 2008). Besides these two Lessepsian migrants, already nine of them have been recorded previously: *Pampus argenteus, Saurida undosquamis, Stephanolepis diaspros, Sphyraena chrysotaenia, Siganus rivulatus, Leiognathus klunzingeri, Epinephelus coioides, Hemiramphus far* and *Parexocoetus mento.* One species escaped from mariculture farm – *Pagrus major* that seems to have established natural population in the Adriatic.

712. Exotic species of decapods have also been registered in the Adriatic recently, like: *Marsupenaeus japonicus*, *Scyllarus caparti*, *Dyspanopeus sayi, Rhithropanopeus harrisii, Callinectes danae*, *Callinectes sapidus, Hemigrapsus sanguineus* and *Eriocheir sinensis* (Kirincic and Stevcic, 2008) and *Paromola cuvieri* (Zuljevic *et al.*, 2008).

713. There are no major data on introduced species in Albania. The most evident problems are related to the genus Caulerpa. A large distribution of the invasive algae (tropical seaweeds) Caulerpa racemosa var. cylindracea developed mainly on “dead mattes” from 2m to 21m depth (Kashta *et al.*, 2005; 2007). On the other hand, there are only a few observations of the more invasive species Caulerpa taxifolia that is displacing Posidonia meadows in some areas. The seaweed Halophila stipulace was introduced in the 1980’s from the Indian Ocean.

714. Since most invasive species are carried in ballast water, the fact that there is no seaport in Bosnia & Herzegovina makes it unlikely that these species are present in its marine area, even though there has been no specific research on this issue in the last 20 years.

715. In Croatia, the alien mollusc *Pinctada radiate* has been reported (Doğan and Nerlovic**,** 2008). *Ficopomatus enigmaticus* were recorded at two locations in the Krka river estuary and Neretva River delta (Cukrov *et al.*, 2010). The invasive tropical green algae *Caulerpa taxifolia* and *Caulerpa racemosa var. cylindracea* are spreading quickly in the Adriatic since 2000; up to 84 sites in 2008 have been registered in Croatia (Zuljevic *et al.*, 2008) in two geographic areas: Dalmatia and Northern Adriatic. *C. taxifolia* was probably transferred into the Adriatic by ship anchors and as ship fouling. It was recorded for the first time in 1994 in Starigrad Bay of the Hvar Island. In 2006 the new squid *Thysanoteuthis rhombus* was found (Marcic *et al.*, 2008). The marine polychaete *Ficopomatus enigmaticus* was discovered in the Krka estuary and Neretva Delta. This invasive species lives in brackish water and often becomes dominant, sometimes even building reefs. Reefs have not yet been found in Croatia but specific habitat type (Facies with *Ficopomatus enigmaticus)* with this species has been recognised (Bakran-Petricioli, 2007).

716. Invasion of alien species is a growing threat for Montenegro and needs to be investigated. One of the most successful lessepsian migrants in the Mediterranean, *Fistularia commersonii*, indicates that the spreading of this species has occurred in Montenegrin water (Jaskomovic *et al.*, 2008). Rapid population explosion at invaded areas and potential effects on the local fish fauna are emphasized. In addition, *Rapana venosa* entered Mediterranean Sea, and settled in the brackish parts of the upper Adriatic Sea. It was observed in the Adriatic coast of Montenegro in 2008. This species

may have some detrimental impact to the native oyster and mussel beds as it did in the Black Sea previously. Similarly, *Caulerpa racemosa*, a species of algae that has recently introduced itself to the Montenegrin coast also may have adverse impacts on the native biota.

717. Up-to-date information on alien species in Slovenia is still rather poor in comparison with other states. In August 2007, a specimen of *Terapon theraps* was captured by trawl in Slovenian coastal waters. There are also records of invasive epibionts being transported via ship's hulls, including *Ficopomatomus enigmaticus*, which inhabits the brackish habitats in Slovenian coastal wetlands.

718. There are also some species which were purposely or accidentally introduced in the area by mariculture. The former example of introduction is the Japanese Oyster (*Crassostrea gigas*), known to inhabit many shallow areas in the Slovenian coastal sea, while the example of the accidentally released species include algae such as *Falkenbergia ruflolanosa*. The mosquito fish *Gambusia hoolbroki* is an example of the introduction of non-indigenous species by means of biocontrol.

5.3.5 Fish populations including abundance, spatial distribution

719. The most recent census of Adriatic fishes listed 442 taxa (Jardas *et al.*, 2008) that represent about 65 % of Mediterranean ichthyofauna. The number of jawless species and subspecies is 3, of cartilaginous fishes 55 and ray-finned 384. From the biogeographical aspect, the most of Adriatic species belong to Atlantic- Mediterranean element (almost 67%). Others are mostly cosmopolitans (about 17%) and Mediterranean endemics (about 9%) while the rest of 17% belong to Mediterranean-Black Sea, Lessepsian and the Adriatic (endemic) elements (about 7%). The number of species is higher in the Southern Adriatic and it decreases towards the north.

720. According to Jardas *et al.* (2008), the Adriatic is inhabited by 6 endemic fish species (1.4 %) inhabiting the continental shelf area. These are anadromous Adriatic sturgeon *Acipenser naccarii*; the darkflank pipefish *Syngnathus taenionotus* known only from the western Adriatic coast; then four littoral and bottom-living goby species (the lagoon goby *Knipowitschia panizzae* from brackish lagoons and pertinent rivers of northern Italy, the brackish and freshwater Canestrini's goby, recently described cryptobentonic Grotto goby *Speleogobius trigloides* found in the Northern and Central Adriatic in 1975 and 2005 and the Kolombatovic's *goby Gobius kolombatovici* in the North Adriatic.

721. The Red List of Adriatic fishes (Jardas *et al.*, 2008) lists 123 species (28%). One species is considered to be regionally extinct (RE): cartilaginous species *Squatina oculata* and bony fishes *Accipenser sturio* and *Argyrosomus regius.* Another 24 species belong to categories of CR, EN and VU, even 16 of them being cartilaginous species. The main reason of threat is overfishing, while others include habitats degradation, sea pollution, biological factors (reproductive potential of the species, high fry mortality, slow growth), human disturbance, alien species, climate changes and others.

722. Recently total 28 shark species were confirmed from the Adriatic Sea and the Adriatic is hypothesized as a nursery and spawning area for many large shark species, such as *Carcharhinus plumbeus*, *Alopias vulpinus*, *Prionace glauca*, *Oxynotus centrina* and *Lamna nasus* (Soldo, 2006).

723. The ichthyofauna of Albania is well studied and about 313 species have been recorded. About 64 of these are freshwater species and other 249 fish species from marine waters of Albania. As mention before the marine bottoms vary from north to south on our seashore; while in the north the shelf is wide and generally with soft bottoms, reaching up to 200m isobars, in the south the sea is deeper and the bottoms are hard. The marine ichthyofauna consists of a number of species and subspecies, 100 of which are important for the fishing industry. However, the majority, which includes a small number of rare species, are not important for fishing.

5.4 Habitat classification and known distribution of habitats

724. The Adriatic Subregion encompasses 32 biocenoses. It also has unusual habitats, such as the submerged karst-like anchihaline caves, marine caves, descending caves with bathyal elements,

vruljas (submerged freshwater springs), karstic estuaries, marine lakes and deep circalittoral hard bottoms (naked karst. In the context of the tools developed by the Specially Protected Areas Regional Activity Centre (UNEP/MAP- SPA/RAC), a reference list of 27 major types of benthic habitat was made, to help the Mediterranean states in drawing up inventories of natural sites of conservation interest (UNEP/MAP- SPA/RAC, 2002). The SAP BIO Programme (UNEP/MAP - SPA/RAC, 2003) had identified among its priority actions the making of a complete, integral inventory of its Mediterranean habitats, including mapping their spatial distribution and the cohort of species associated with each habitat.

725. The marine and coastal areas of the Adriatic Subregion contain the most notable marine and coastal Mediterranean habitats that provide valuable ecosystem services. They include seagrass meadows, coralligenous communities, macroalgae forests, sea caves, and coastal lagoons and marshes, discussed below.

726. **Magnoliophyte meadows** are among the most productive coastal ecosystems in the marine environment. The available data on these habitats is very heterogeneous on a regional scale, and in certain countries like Bosnia and Herzegovina have not found. All national reports describe meadows in the Adriatic subregion.

727. The ***Posidonia oceanica*** **meadows** are considered to be the Mediterranean's most important ecosystems. *Posidonia oceanica* is endemic in the Mediterranean. It is present in Albania and Slovenia. Annex I of Directive 92/43/EEC describes meadows of *Posidonia oceanica* as a priority habitat type. Posidonia meadows do not appear in areas with low salinity and weak light penetration due to pollution. The ecological parameters that affect the distribution of the upper and lower limit of the meadows as well as their density are light and hydrodynamic conditions. According to the Barcelona Convention typology, in the habitat type "Posidonia meadows" (BC type III. 5. 1) two ecomorphosis are described: The ecomorphosis of striped meadows (III. 5. 1. 1.) and the ecomorphosis of barrier-reef meadows (III. 5. 1. 2.). A facies of dead "mattes" without much epiflora and an association with *Caulerpa prolifera* has also to be added.

728. The ***Cymodocea nodosa*** **meadows** are the second most ecologically important seagrasses after *Posidonia*._***Halophila stipulacea*** **meadows** are also notable but this is a Lessepsian species, restricted to specific areas, such as for example small populations in Saranda Bay and in Vlora Bay in Albania (Kashta et *al*, 2005). ***Zostera nana*** and ***Zostera noltii*** meadows are less well-represented in the region but are found in Bosnia and Herzegovina, as biocoenosis of mediolittoral detritic bottom. The association with *Zostera marina* was observed in Slovenia.

729. **Coralligenous communities** are biogenic constructions which constitute the second most important hotspot of specific biodiversity in the Mediterranean after the Posidonia meadows. The coralligenous habitats and bioconcretions (pre-coralligenous populations, shelf coralligenous, associations with rhodoliths – maërl facies, association with rhodoliths – *pralines* facies, association with rhodoliths – *Lithothamnion minervae* facies, association with *Peyssonnelia rosa-marina* – free Peyssonneliaceae facies and big bryozoan facies of the coastal detrital bottoms) are being studied in the Adriatic Sea. They have been also recorded in Ionian part of the Albania. In Slovenia, *Cladocora caespitosa,* biocoenosis of the coastal detritic bottom and biocoenosis of the muddy detritic bottom and coralligenous biocoenosis (=precoralligenous formations) have been reported.

730. ***Cystoseira*** **forests** can occupy large areas in the marine ecosystems, where they form highly productive communities with remarkable biodiversity. Species of the *Cystoseira* genus species are in a speciation process which has led to many varieties within a single species and these algae present significant morphological variability. *Cystoseira amentacea* sp. *spicata* and *Cystoseira crinita* have been reported in Albania (Kashta et *al*, 2005). In Slovenia, biocoenosis of infralittoral algae with *Cystoseira crinita* also reported. In Bosnia and Herzegovina, *Cystoseira barbata* and *C.crinata* reported in the biocenosis of infralittoral area.

731. **Sea caves** are peculiar habitats in the submerged karst characteristic for the Croatian side of the Adriatic Sea. There are anchihaline caves, sea caves, cold sea caves and pits with bathyal elements, vruljas, karst estuaries, submerged river canyons, submerged tuffa barriers, marine lakes, and bare karst in the sea.

732. **Coastal lagoons and marshes** are important transitional water systems at the mouths of major rivers of the subregion, including Italy's Po River, Albania's Drini and Mati Rivers, and others. In Albania these coastal lagoons exceed 15,000 hectares and have economic and ecological interest for Albania since they constitute important centers for fishing, as well as being important sites for birds.

5.5 Pressures and impacts

5.5.1 Contamination by hazardous substances

733. Hazardous substances occur throughout the Adriatic, but mostly confined to urban and industrial areas. The river Po in Italy is a very important pollution vector in the area transporting urban and industrial wastewater as well as agricultural run-off from its drain-age basin to the Adriatic Sea, draining the entire northern part of most industrialized part of Italy.

734. Specific sites are reviewed country-by-country, however it must be noted that information from Italy (the entire expanse of the western Adriatic Sea) is largely lacking.

735. In Albania, mercury contamination inland of the former chlor-alkali plant was detected in an area of 20 ha around the factory at a soil depth of 1.5 m is problematic in Vlora district (mercury concentrations 5 000–60 000 mg/kg soil) as well as mercury in groundwater and coastal sediments of Vlora Bay (up to 2.33 mg/kg). Chlorinated hydrocarbons and other dangerous pollutants are found in the soil (NDA Albania, 2003). After 1991, most large Albanian industries (e.g. mineral production and processing, pesticides, fertilizers, chemicals, plastics, paper, food and textiles) were closed down. This left stockpiles with obsolete hazardous substances as well as contaminated land.

736. In Bosnia and Herzegovina, the pollutants generated in the drainage basins of the major Bosnian rivers of Neretva (from the nearby towns of Konjic, Mostar, Caplinja, as well as the nearby Croatian towns of Ploce and Metcovic) and Trebisnjica (from the towns of Bileca and Neum) can be carried to the Adriatic Sea affecting its environment (NDA Bosnia and Herzegovina, 2003). The area of greatest concern is Mostar (population 130 000), where barrels of obsolete chemicals have been left on both riverbanks. During the war (1992–1995), bombing destroyed electric power transformers leading to oil leakage and contamination of soil and water with PCBs.

737. In Croatia, major pollution problems occur in Kastela Bay (Split), where metals and organohalogen compounds accumulated in the sediment due to the discharge of untreated urban and industrial wastewater (NDA Croatia, 2003).

738. The main areas of concern in Montenegro are in Bar, due to industrial wastewater coming from food industry; Herceg Novi, due to effluents from urban areas and industry (shipyard, harbor and food); Kotor: urban and industrial (metal, chemicals, petroleum storage and harbor); Ulcinj: urban and industrial impacts (salt and harbor); Budva: urban and harbor; Tivat: urban and industrial (shipyard and harbor) (NDA Montenegro, 2003).

739. In Slovenia, discharges of partly treated industrial wastewater (NDA Slovenia, 2003), which contain heavy metals (Ni, Cr and Zn), are emitted in Koper Bay. Tributyltin compounds are also still reaching high concentrations in sediments as well as in water column (national monitoring programme, 2008).

740. The main sources of oil pollution in the marine environment include land-based activities (either discharging directly or through riverine inputs), maritime transport, both through accidental and deliberate discharges, atmospheric deposition (from military activities and commercial jet flights), coastal refineries and offshore installations (GESAMP, 2005; GESAMP 2007; Redondo *et al.*, 2008). Marine transport is one of the main sources of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbon (PAH) pollution in the Mediterranean Sea (EEA, 2006).

741. Oil discharges and spills to marine areas can have a significant impact on marine ecosystems in this and other subregions of the Mediterranean. The consistency of oil can cause surface contamination and smothering of marine biota, and its chemical components can cause acute toxic

effects and long-term cumulative impacts. The damage of oil spills is not restricted to the environment but also has socio-economic component. Oil spills in fishing (catching, spawning and feeding) or aquaculture areas or coastal locations which rely upon tourisms can be severely impacted. Fisheries may close and tourism decline with the associated loss of income and livelihoods. Even if there is little or no actual environmental damage the perception that an oil spill has affected the coastline can still have the same impact (EEA, 2006). However, it should be noted that no oil spilles greater than 100t have been recorded from this subregion.

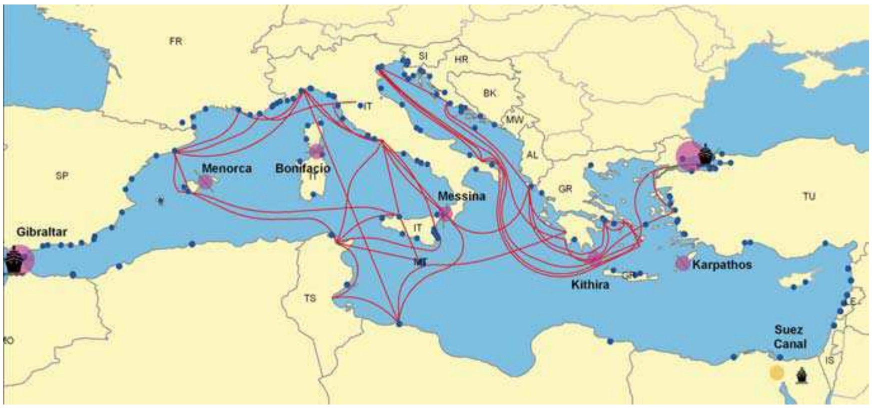


Figure 5.7. Major ports and shipping lanes, including those in the Adriatic subregion.

742. Throughout the Mediterranean, it is estimated that about 220 000 vessels of more than 100 tonnes each cross the Mediterranean each year discharging 250 000 tonnes of oil. This discharge is the result of shipping operations (such as deballasting, tank washing, dry-docking, fuel and discharge oil, etc.) and takes place in an area which since 1973 has been declared as a 'Special Sea Area' by the MARPOL 73/78 convention, i.e. where oily discharges are virtually prohibited. The PAH input varies according to the type of oil discharged, with a range is estimated at between 0.3 and 1 000 tonnes annually (UNEP Chemicals, 2002). Much of the discharging shipping activity takes place in the Adriatic Sea, although the subregional effects have not yet been quantified.

743. In assessing Mediterranean-wide frequency and impact of oil spills, several approaches to assessment of oil spills quantities are widely used. Illicit vessel discharges can be detected through the interpretation of ERS SAR (Synthetic Aperture Radar) satellite images. Analysis shows that during the years 1999 to 2002 about 7000 oil spills were detected (Figure 5.8). According to the Regional Marine Pollution Emergency Centre in the Mediterranean (REMPEC) statistics, 82 accidents involving oil spills were recorded during the period January 1990 to January 1999 and the quantity of spilt oil was 22 150 tonnes (REMPEC, 2001). Incidents at oil terminals and routine discharges from land-based installations (estimated at 120 000 tonnes/year (EEA, 2006).

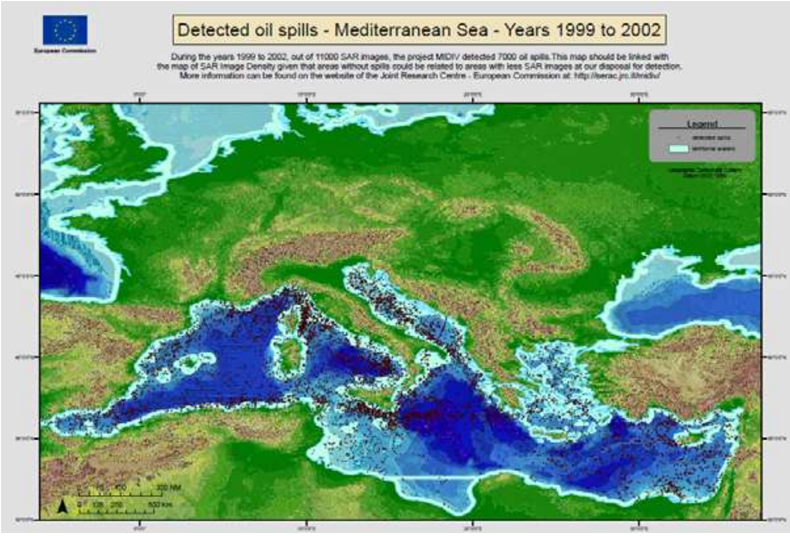


Figure 5.8. Oil spill locations 1999-2002 (Source EEA)

Levels of hazardous substances in the marine environment: Trace metals

744. Overall concentration ranges of Cd, total Hg, Pb, Zn and Cu in sediments and biota (*Mytilus galloprovincialis*) in the Adriatic are monitored by the Adriatic countries. Analysis reveals the occurrence of some discrete stations with high levels of Hg, Pb and Zn in Croatia, such as at Kastela Bay (NDA Croatia, 2003). Significantly higher concentrations of Cd and Zn as compared to the previous years are recorded in Martinska Bay (station MA) this year.

745. A mercury contamination problem also exists in the Northern Adriatic (Gulf of Trieste), according to information from the National Diagnostic Analysis of Slovenia in the framework of the Strategic Action Programme (SAP) (MED POL 2003). Mercury (Hg), as a critical contaminant in the Gulf of Trieste, has been studied more thoroughly (Covelli et al., 1999; Horvat et al., 1999; Hines et al., 2000). Data showed that even 10 years after the closure of the Idrija Hg mine, Mercury (Hg) concentrations in river sediments and waters were high and no decline of Mercury (Hg) concentration in the Gulf was observed (Horvat et al., 1999).

746. The accumulation in mussels follows a similar trend as what is seen in sediments, with Cd values higher than mercury, which in turn are higher than lead levels, and which in turn are higher than zinc levels (UNEP/MAP - MED POL, 2009). Results obtained for the mussels collected along the Croatian coast in the framework of trend and state monitoring program for year 2009 are comparable with already published values for low to moderately polluted areas of the Croatian and Mediterranean coast.

747. Comparison of mean metal concentrations obtained at 12 “hot spots” and means values obtained in mussels from unpolluted areas as are shellfish breeding farms, shows that those concentrations are similar for Cd and Zn, whereas for Pb, Cu, Cr and Hg average levels on “hot spots” are 2-3 times higher. The origin of this contamination is not clear, so it should be further investigated and measured in the future.

748. Kljakovic-Gaspic *et al.* (2007) monitored the Blue Mussel (*Mytilus galloprovincialis*) in the Mali Ston Bay, located on the eastern Adriatic coast, from 1998 to 2005. The content of trace metal concentrations in the edible tissue of mussels fell in the range of values usually found in low to moderately contaminated marine coastal areas, although according to EU and WHO legislation and guidelines, consumption of the edible tissue of the mussels was not harmful for humans. Analysis of temporal trends during the 7 years of monitoring showed that metal concentrations have not changed significantly over time (UNEP/MAP - MED POL, 2009).

749. Similarly, a monitoring survey carried out during the 2001-2005 period in the Croatian coast using the blue mussel as an indicator species, determined that Pb and Hg were significantly elevated in the urban and industrial areas, while Cd was more uniformly distributed across the monitored sites, being also high in mussels from rural areas located far away from anthropogenic sources of pollution. The majority of values were below the maximum thresholds for fresh seafood. Again, metal concentrations had not changed during the five year-period (Kljakovic-Gaspic *et al.*, 2007).

750. However, a review of data obtained by monitoring tissues of cetacean species shows that concentrations of mercury in liver found in species living in the Mediterranean are substantially higher than in species from the Pacific and Atlantic (Monaci *et al.*, 1998; Capelli *et al.* 2008).

751. Looking at 2009 data, the highest concentration values of chlorinated hydrocarbons in Croatia were recorded in densely populated and/or industrially developed areas with harbour activities such as Split (Kaštela bay: VR, IN) and Dubrovnik (RD). This finding can be related to the wastewater discharges into the investigated areas.

752. According to all these analyses, coastal waters of the Adriatic Sea belong to unpolluted to moderate polluted areas. Exceptions include a few very narrow areas, which are in direct contact with different sources of pollution. At these areas some indicators are showing the presence of determined type of pollution depending on the sources of pollution that are present in defined area.

753. Concentrations of aldrin, dieldrin, endrin, lindane and hexachlorobenzene in *Mytilus galloprovincialis* are in the low ng g-1 range, with the exception of some stations from Albania. Concentrations of DDTs were one order of magnitude higher, with p,p'-DDE being, in general, the predominant component, although recent inputs of DDT in some areas cannot be ruled out. Concentrations up to 9779 ng g-1 dw of total DDTs were found in mussels from the Albania coast, probably indicating the presence of stockpiles of DDT in the country, as well as of lindane. There has been no DDT production in Croatia, beginning with the ban in 1972. Data for concentrations of DDT levels in sediments were published for Po River delta showing concentrations ranging between 0.3 – 1406 DDTs (ng/g dw), in contrast to background values of 0.08 – 5 determined for Mediterranean (Gómez- Gutiérrez *et al.* 2007).

754. PCB content in sediments in Mediterranean according to overview (UNEP/MAP – MED POL, 2009) ranges between 1-15815 ng/g dw (Aloclor eq.), while PCB levels in *Merluccius merluccius* from the Adriatic Sea were shown to slightly decrease between 1993 and 2003 from 1,380 ng/g to 943 ng/g lipid weight (Storelli *et al.*, 2004). The remaining levels are still high and the declining trend was not statistically significant. Such values are in accordance to the PCB concentrations in other fish species from the same region (UNEP/MAP - MED POL, 2009).

755. In general, PAH pollution in the Mediterranean is widespread detected in coastal areas, clearly influenced by urban and industrial emissions to air and water. Atmospheric inputs are the main source of pollution in the open sea. In sediments, research has been focused on ports, coastal lagoons, river mouths and coastal enclosures close to urban centers. Higher levels are usually detected in harbors, especially Trieste. Maximum levels of PAHs in biota are usually lower than those reported in sediments. The highest levels (up to 46700 ng/g dw) have been detected for mussels and fish in the Egyptian coasts. According to referenced data, concentrations in the Adriatic do not exceed 1000 ng/g dw.

756. The widespread use of organotin compounds as stabilizers in the manufacture of polyvinylchloride, as biocides in agriculture, as a fungicidal component in wood preservation and as anti-fouling agents has provided several sources of entry for these compounds into aquatic and terrestrial environments, which are found in both estuarine and marine waters, sediments and biota. Much of the attention on the release of organotin compounds into the environment has focused on tributyltin (TBT), which has been widely used as a biocide in paints and coatings in marine antifouling applications.

757. Antifouling products play an important role in the shipping industry and are of significant economic importance. Research evidence of the damage caused by organotin compounds on the reproduction and growth of various marine organisms has prompted action by many countries to regulate or ban their use in antifouling products. TBT has been banned since the 1980s in antifouling

paints for ships smaller than 25 m in many countries, including many European countries. TBT-based antifouling paints, however, are still used in developing countries, for example most Asian countries, and their use have also continued worldwide for most vessels longer than 25 m (Horiguchi 2000, Stewart 1996). Despite such restrictions, TBT persists in many areas at levels considered to be chronically toxic to the most susceptible organisms (Berto, *et al.*, 2006). Recent uses of tributyltin beside as a biocide in anti-fouling paints are wood preservatives and a wide range of industrial applications including cooling water, pulp and paper mills, breweries, leather processing and textile mills.

758. TBT has been found to be a problem in the Adriatic, but show downwards trends (Nemanic *et al.* 2008). In the year 2000, organotin pollution was investigated in the Bay of Piran, Slovenia, at the northern extremity of the Adriatic Sea by speciation analysis of pentylated organotin compounds in water and mussels (*Mytilus galloprovincialis)*. The highest concentrations of tributyltin (TBT) in marine water ranged from 500 to 630 ng L-I (as Sn) in summer (Nermanic *et al.*, 2002).

759. Notwithstanding the increasing efforts to outlaw the TBT in antifouling paints, there is evidence of a persistent contamination in the aquatic environment. Measurements in the southern Venice lagoon there still show high TBT and DBT contamination in waters and sediments due to the increase of dockyards, shipping, and fishing activities. Significant contamination of TBT and DBT in the scavenger gastropod*, N. nitidus*, at dockyards, harbors, and marinas testifies to the continuous, even if not massive, input of BTs in the southern part of the lagoon. The higher content of DBT than TBT in gastropods is probably due to the greater mobility of DBT than TBT in the aquatic systems. The persistence of BTs in sediments and their diffusion, through resuspension by storms and by the enhanced anthropogenic activities, could facilitate the mobilization of these contaminants and their transfer to invertebrates and fish (Berto *et al.*, 2007).

760. Concerning contaminants in fish species, Bayarri *et al.* (2001) carried out a study regarding PCDD/Fs content in anchovy (Engraulidae), mackerel (Scombridae) and red mullet (*Mullus barbatus*) from the Adriatic Sea. In general, PCDD and PCDFs contamination levels were found to be low. PCDFs analytical contributions were higher than those of PCDD. Concentrations were greater for those species at higher levels in the trophic web (mackerel > red mullet > anchovy), although the higher fat content of these species should also be taken in account. PCDD/Fs in species from the northern area were in general greater than those from the central and southern areas. Thus, these species showed a trend towards higher contamination levels associated with areas showing increased anthropogenic impact (Bayarri *et al.*, 2001).

761. There are very few countries with more than five years of available data to fulfil the requirements of a temporal trend assessment. In general, the country median values do not exhibit clear trends for metals, with few exceptions. On the basis of recent UNEP/MAP-MED POL monitoring data, concentrations of Cd in Slovenia appear to be decreasing during the last decade. In the case of Italy, the decreasing trends are observed in NW Adriatic, while slight increase is observed in NE Adriatic part. Trends of Hg concentrations do not show tendencies, although concentrations seem to have increased in Albania (which is recognized to keep stockpiles of obsolete chlorinated pesticides) and the NW Adriatic (Italy) since 2000. The median values of DDT in mussels from Croatia exhibit clear decreasing trends.

762. The EEA indicator using the Mediterranean mussel (*Mytilus galloprovincialis*) as a monitoring organism reveals that in most cases low or moderate levels were found, in particular for HCB, cadmium, mercury, and, to a lesser degree, lead. However, high concentrations were found in PCBs and DDTs in 87% and 62% of the cases, respectively. Even though only 3% of the stations had high values for cadmium, there is a statistically general upward trend in this compound. The large number of high values and upward trends should be a strong warning sign that steps to safeguard the abatement process (EEA, 2010).

763. Temporal trends of pollution based on Eionet data 1998-2005 prepared by EEA show that concentrations of Hg in marine organisms are moderate in Northern, NE and NW part of the Adriatic Sea basin, while they are high in one area in Dalmatia. Generally the concentrations are lower in the southern part of the basin. Concentrations of Cd in marine organisms in Adriatic Sea show low concentrations and no significant trend in northern and eastern coast and decreasing trends along the western coast (EEA CSI 40, 2010). For hexachlorobenzene (HCB), temporal trends of pollution in

marine organisms based on Eionet data 1998-2005, show mostly low concentrations along the northern and eastern coast with two areas with moderate concentrations. PCB concentrations show the highest values of all substances reported in the CSI 40 (EEA). Concentrations are moderate along entire northern and western coast, with one area with high concentrations. Data on lindane are available for eastern part of this subregion (Croatia). Concentrations are low and a decreasing trend is shown in most of the area.

5.5.2 Dumping activities (introduction of substances and impact)

764. There are several large ports in the northern Adriatic as well as in the southern part (Figure 5.9). Intensive marine traffic and related port maintenance work are expected to have significant impacts on the marine environment, especially in the sensitive, shallow part of the Northern Adriatic.

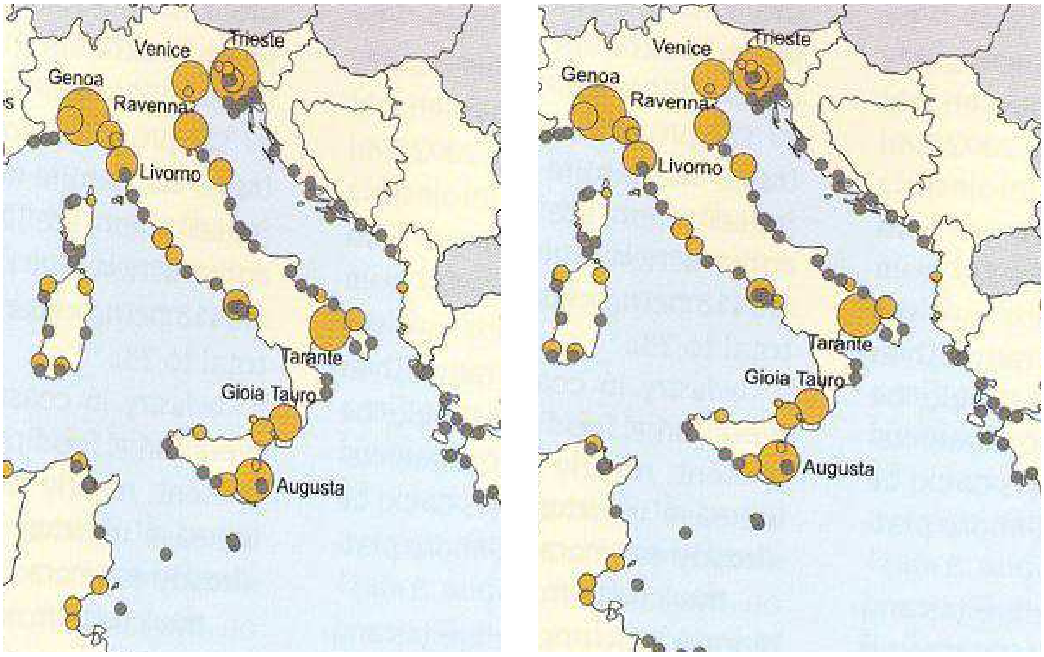


Figure 5.9. Major ports showing number relative number of exits in thousands of tones per port (left) and relative number of entries in thousands of tones per port (Source Blue Plan, 2009)

765. Accessibility of coastal ports, fishing harbors and navigable waterways is rarely naturally deep; therefore navigable depths must be maintained by repeated dredging. Every year, dredging operations result in hundreds of millions of cubic meters of sediment worldwide, which must be disposed of and managed in economically and environmentally sustainable ways (Van Dolah *et al.*, 1984; Harvey *et al.*, 1998). Dredging and disposal of dredged material is one of the most important problems of coastal zone management (Simonini *et al.*, 2005a).

766. This report does not include a review of dredge disposal or other dumping at sea specific to the Adriatic, however information does exist in MedPOl for countries that monitor dumping of dredge spoils under the Dumping Protocol to the Barcelona Convention, as well as in databases maintained by the London Dumping Convention Secretariat. The paragraphs that follow pertain to generalized dredge disposal impacts.

767. Depending on their chemical and physical characteristics and the concentration of contaminants, dredged sediments may be disposed of in several ways: i.e. clean sediments with appropriate grain size may be used for beach nourishment, while contaminated sediments must be isolated and contained on land. However, for economic reasons, most dredged material is currently disposed of in appropriate offshore disposal sites (Regoli *et al.*, 2002; Cruz-Motta and Collins, 2004). In Italy, the discharge of dredged material in appropriate off-shore disposal sites is permitted only if

there is no established technical or economical possibility for their reutilization or settlement in land dumps (ICRAM, 2002; Simonini *et al.*, 2005a).

768. Sediment disposal in open water may be more damaging to the benthic community than to any other part of the aquatic ecosystem because of the relative immobility of benthic organisms. Studies of dredge spoil dumping have demonstrated a range of impacts on soft-bottom benthos, ranging from large, long-term impacts to few or non-detectable effects (Harvey *et al.*, 1998; Newell *et al.*, 1998; Van Dolah *et al.*, 1984; Roberts and Forrest, 1999; Smith and Rule, 2001; Simonini *et al.*, 2005a). Where impacts were detected, these were primarily manifested by reductions in the diversity of communities at the receiving sites, compared to controls. Shifts in dominance patterns within the community may also occur, with a reduction in the abundance of some species and an increase in the abundance of opportunistic species (Harvey *et al.*, 1998; Simonini *et al.*, 2005a).

769. In some cases, studies have also demonstrated a shift in the trophic structure of the affected community. The type and severity of the impact of sediment disposal on benthic ecosystems varies, depending upon several factors (review from Simonini *et al.*, 2005a and references therein):

- chemical–physical characteristics and volume of sediment,
- water depth, surface, sedimentary and hydrological regime of the dumping site,
- time of the year and similarity of the sediment in dredged and disposal areas,
- contamination of dredged material,
- disposal method,
- adaptation of organisms to the local sedimentary regime and structure, and
- composition of benthic assemblages in the dumping site and nearby areas.

770. Other dumping beyond dredge spoils include disposal of fish waste, inert sediments, and man-made materials such as ships, decommissioned drilling rigs, etc. The extent to which these activities are occurring in the Adriatic has not been quantified in this report.

5.5.3 Nutrient and organic matter enrichment

771. The extent to which the Mediterranean is nitrogen-limited, as are other ocean bodies, is open to speculation. Research by Guerzoni *et al.* (1999) suggests that despite the early observations of P limitation, later work suggests that Mediterranean surface waters are nitrogen-limited. In fact, there is growing evidence that the Eastern MED is phosphorus-limited and that the Western MED is probably N-limited, or that limitation shifts from nitrogen to phosphorus and vice versa depending on the period of the year, or the area considered. The uniquely high levels of N/P ratios in the Mediterranean (20/27) compared with other open ocean averages (15) may reflect this situation, and are probably evidence of P limitation (Guerzoni *et al.*, 1999).

772. In Croatia, eutrophication parameters have been monitored since 1998 on some 20 sites along the coast. Data show that the largest part of coastal waters is oligotrophic, with exception of few sites that are mesotrophic due to antropogenic eutrophication (Kastela Bay near Split, Sibenik Bay near the Krka estuary and waters along the Istria under the influence of the Po River. Neretva Delta Phytoplankton biomass was estimated in the period 2003-2004 from satellite images. Results show that the trophic level of eastern Adriatic is significantly lower than the western part.

773. In the early 1990s the estimated average contribution of agriculture to the total nutrient loads 47-57 % for N and 22-25 % for P in the Po catchment area. The reduction of the fertilizer consumption and the increase of crop yields resulted in a slight reduction of the agricultural surplus of N and (especially) P between 1985 and 1995. However, this reduction has not (yet) resulted in a similar reduction of the agricultural inputs to the river network. Nutrient concentrations have decreased in the last decade also due to new sewage networks and wastewater treatment plants (UNEP/DEWA, 2004).

774. The average amount of municipal waste generated in EEA countries per capita per year exceeds 400 kg/capita. Comparison of the generation of municipal waste in EEA countries to average generation of waste in Croatia, Italy and Slovenia shows, that waste generation in Italy the average is similar to other EEA countries; the average quantities in Slovenia were relatively high, but are dropping in the period of 1995-2007; in Croatia the quantities were lower but growing in some areas,

with improvements in specific locations.In Vranjic Basin in the eastern portion of Kastela Bay (middle Adriatic), for instance, the trophic status changed from eutrophic to mesotrophic after offshore municipal outfalls stopped being used in 2004 (Silic et al., 2010)..

775. Recent monitoring from 2007 onwards shows that all monitored sites are oligotrophic and that water quality has improved. No “red tide” blooms of dinoflagellates have been registered. It must be mentioned that during previous decades the blooms of the “red tide” species *Prorocentrum minimum* was common in spring and summer period. The blooms of toxic phytoplankton genus *Dinophysis* became rare, mostly registered only locally in Northern Adriatic. In 2008 concentrations of chlorophyll *a* was inside reference values on all monitored sites near river estuaries and large cities (Zadar, Sibenik, Split, Ploce). In phytoplankton communities of these sites diatoms preferring the high concentrations of nutrients were prevailing, like *Pseudo-nitzschia* spp., *Leptocylindrus danicus*, *L. minimus* and *Skeletonema costatum*. The percentage of dinoflagellates decreased as the ratio of diatoms has grown.

776. According to the UNEP/MAP - MED POL reports (Legovic et al, 1990; UNEP/MAP - MED POL 2009), dissolved oxygen (DO) increased in the surface layer and decreased in the bottom layer in all seasons except during winter. DO changes were attributed to an increase of anthropogenic nutrient inflow starting from 1955-66. According to these observations, the North Adriatic ecosystem had changed towards a more eutrophic state leading to more frequent occurrence of significant episodes such as extensive phytoplankton blooms, extensive mucilage formations and mass mortality of benthic animals than before. The only remedy for decreasing the growth of primary production was to reduce the excessive rate of inflow of nutrients. Primary production, chlorophyll-a, dissolved oxygen near the bottom and measures of DO were parameters, measured regularly in affected areas while the benthic and demersal communities had been poorly investigated although massive mortalities of benthic organisms connected to oxygen depletion at the bottom have been reported.

777. In the shallow North Adriatic, the 1989 autumn offshore phytoplankton bloom was followed by a lack of oxygen in the bottom layers and a wide-scale mortality of sediment-living meio- and macrofauna (Zavodnik *et al.*, 1990). In meiofauna an initial mortality of 80-95% was established: nematode p populations were less affected than copepods and other taxa. The recovery "latent" period lasted about six months and, afterwards, a sharp increase in abundance occurred. From the macrofauna, some sponges, polychaetes, echinoderms and tunicates were almost totally exterminated but most of the actinians survived. The recovery of macrofaunal populations occurred stepwise but the process was faster in infauna than in sessile epifaunal assemblages. Some bivalve and nematode species took advantage of the "free space" phenomenon observed at all stations surveyed. After two years of recovery the monitoring showed that at the macro- and meiofaunal levels, the communities studied were not yet stabilized.

778. The results of this study suggest that the EU Nitrates Directive may not be stringent enough to substantially reduce the river N and P load in the nearby future (2015-2020). One solution for agriculturally-based nutrient pollution in Europe would be a large-scale change towards agricultural systems where the input (manure and fertilizers) is balanced with the requirements of the output in crops (de Wit *et al.*, 2002).

779. The research of Barmawidjaja (1995) shows the historical impacts of Po River on the Northern Adriatic Sea ecosystem. First substantial changes are related to variations in sedimentation rate due to changes in natural course of the Po River (canals, dikes) as well as deforestation started already between 1800 and1840. The association of existing vegetation started to change and decreased substantially. Since 1900 the trend of nutrient over-enrichment started to increase and became strongly eutrophied until 1930's. Faunal changes from 1960's are related to seasonal anoxia episodes (Barmawidjaja, 1995).

780. The average rate of urban population with access to a sanitation system in Adriatic basin is around 96%, although not all collected wastewater is appropriately treated. Across the Mediterranean, the rate of wastewater collected and treated by public sanitation ranges from 7% to 90%. On a regional scale, 40% of municipalities with over 2,000 inhabitants (673 cities out of 1699) are not served by wastewater treatment plants. The most common treatment level is secondary treatment, used in 55% of the coastal cities with over 10 000 inhabitants. Tertiary treatment is not extensively

used, albeit proportionally more in small cities: 28% and 25% for non coastal cities and 15% in large coastal cities (Figure 5.10).

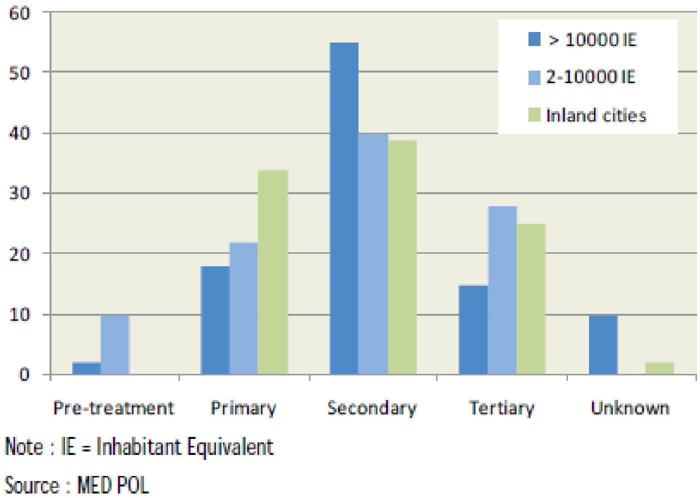


Figure 5.10. Degree of treatment process of waste water treatment plants in coastal and inland cities, 2004 (%) (From UNEP/MAP - Plane Bleu, 2009)

781. Comparison of quantities and degree of wastewater treatment in small and large coastal cities shows that smaller cities have no- or limited primary treatment, while larger coastal populations in big cities are connected to WWTP with primary or secondary treatment.

782. The Krka River salt wedge is another area of concern. In the Krka River estuary, the exchange of freshwater and marine water in the stratified estuary varies with flux (Zutic and Legovic, 1990). During winter, the estimated renewal time of freshwater was from 6 to 20 days while during summer it was found to be around 80 days. The exchange time of marine water is about five times longer. The temperature maximum is located on the lower edge of the halocline where the highest temperature in the Adriatic has been recorded (31 ºC). Strong northerly wind induces a tilt of the brackish water layer and hence sudden mortality of marine shellfish culture located close to the halocline. The halocline is an accumulation interface of living and non-living organic particles and pollutants; a site of physico-chemical transformation of organic matter under the influence of salinity gradient; a site of intensive, mainly marine, primary production with a peak of dissolved oxygen concentration; a site of intensive decomposition processes; a barrier for oxygen transport to the marine layer.

783. The main source of silica and nitrogen is the Krka River itself. The dominant source of phosphorus in the upper estuary sinks and decomposition of freshwater phytoplankton occurs, while in the lower estuary receives the anthropogenic inflow of the city and port of Šibenik. Benthic hypoxia and massive mortality of benthic macrofauna was observed in two consecutive years. The hypoxia persists until the river flow increases and the sea water on the bottom is renewed by compensatory flow with colder, oxygen richer water. A similar effect was found to happen in the lower Ebro River in Spain (Cruzado et al, 2002).

784. The effect of river discharge mediated eutrophication in the Gulf of Trieste is limited to the river mouths and to some inner part of the bays (*e.g.* Koper bay). Chlorophyll biomass, phytoplankton abundances and nutrient concentrations in these areas are higher compared to more distant stations, but the extent of observed biological response is not as high as expected. The same trends as stated above are true for the whole Northern Adriatic and are even more pronounced in the western part of the basin (Mozetič *et al.*, 2009).

5.5.4 Biological and physical disturbance

Physical and Biological Disturbance from Fishing Activities

785. In the Adriatic Sea, the fisheries sector is growing due to both fish farming and fishing, with some lagoons also exploited for fisheries purposes. Sea bream and sea bass are common farmed species. Oyster and mussel are also cultivated. There are not many industrial type fishing boats and most of them are artisanal type. Illegal, unreported and unregulated fisheries have become common practices.

786. Determining the influence of fisheries on pelagic fish in the Adriatic, especially on clupeids and scombrids as they are subject to seasonal and years-long fluctuations caused by different environmental factors, is difficult. Bluefin tuna is globally endangered species and quotas issued by the ICAAT for Croatia range from 800 -1,000 t/y. It is forbidden to fish tunas smaller than 30 kg but exception is made for the purposes of mariculture when fishes larger than 8 kg can be caught. During last decade tuna fattening has become very popular and economically important in Croatia as all production goes for Japan market.

787. Compared to pelagic fishing, the catch from demersal fisheries is relatively low, amounting to 6,000 tonnes per year (mostly including *Merlucius merlucius* and *Mullus barbatus*). The most common fishing tool is the trawl-net. As a consequence of unsustainable exploitation through many years, many fish populations in the Adriatic have heavily declined in number. This may be well illustrated by the open Adriatic area where cartilaginous bottom sea fishes (*Scyliorhinus canicula, Raja* spp*, Mustelus* spp.*, Squalus* spp.*,* etc) have almost disappeared as a consequence of intensive fishing (Jardas *et al.*, 2008).

788. The abundance of certain fishes of coastal fish communities in the catch through years shows that they are on the verge of disappearance, such as *Sciaena umbra, Labrus merula, Labrus mixtus, Labrus viridis* while the presence of some other species, such as *Scorpaena porcus, Symphodus tinca,* increased because they proved more resistant to exploitation.

789. Regarding other fishery species, it seems that *Nephrops norvegicus* is the most threatened. Its biomass index shows sharp negative trend for years now because of overfishing. *Spongia officinalis* and *Corallium rubrum* became rare but are still exploited. Collecting of 100 t of sponges and 450 kg of red coral per year was registered in 2003 and 2004. Permits for collecting sponges and corals are today connected only to traditional activities in some areas. 200 kg of red corals per one permit is allowed. In some areas, divers have almost completely eradicated lobster colonies *Homarus gammarus* and *Palinurus elephas*. Despite the longstanding legal protection of noble pen shell *Pinna nobilis* and the dateshell *Lithophaga lithophaga*, these species are still illegally collected.

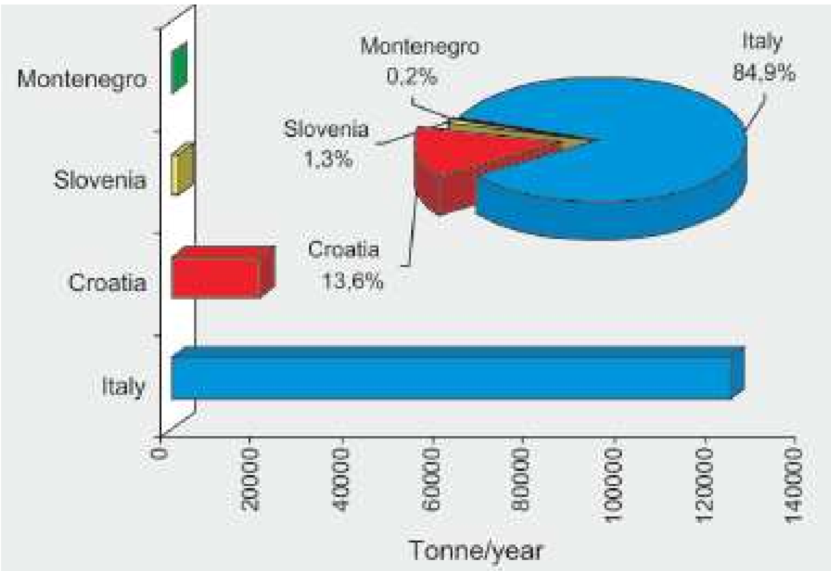


Figure 5.11 Annual catch of the countries of the Adriatic Sea between 1992-2004 (Jardas *et al.*, 2008)

790. By-catch appears to be a serious problem in Slovenia. There are data are available for incidental catch of the loggerhead turtle (*Caretta caretta*) and the bottlenose dolphin (*Tursiops truncatus*), though the problem may be even more crucial for shark and ray species in the area. Many rays are continuously discarded in the sea, with rather negligible possibilities for survival. Some of the species recorded as byctach are the basking shark (*Cetorhinus maximnus*), thresher shark (*Alopias vulpinus*), blue shark (*Prionace glauca*), bull rays (*Pteromylaeus bovinus*), eagle rays (*Myliobatis aquila*) and pelagic stingray (*Dasyatis violacea).*

791. Bycatch has been monitored in Croatia for several years (CEA, 2010). At least 2.500 loggerhead turtles are being caught by trawl-nets each year in East Adriatic. Other kinds of nets catch at least 658 loggerheads yearly (North Adriatic) and sometimes even *Chelonia mydas* and *Dermochelys coriacea.* As for cetaceans, mostly *Tursiops truncatus* is being registered, with average annual records of 15-20 animals.

792. Adriatic Sea fisheries production in the last 5 years, even though increasing, has not yet reached the level of the period before the year 1990 with 10.400 tons. The actual current production is equal to 74% of the production before '90 (MoEFWA, 2009). The bottom fishing has increased but there is a considerable decrease for the small pelagic fish. The fish stock data are, due to the lack of funding, are gathered mostly from the donors' projects but there is no continuity and scientific base monitoring, which lead to a difficulty in presenting accurate data on fish structure population and abundance. The official data available are those from the Mediterranean international trawl survey (MEDITS), a program aiming to support the fish management in the Mediterranean area (MoEFWA, 2009).

The table below presents the total distribution of fisherman by vessels type and length classes of their nets (MoEFWA, 2009).

Type of boats	Number of fishermen				**Total**	**Total**
	>12m	>12m %	<12m	<12m %	**number**	**%**
Purse Seiners	0	0	4	1	**4**	1
Seiners Other	2	2	31	5	**33**	5
Trawlers	9	8	502	86	**511**	72
Gill netter	83	70	45	8	**128**	18
Long liners	14	12	2	0	**16**	2
Multipurpose	9	8	3	1	**12**	2
Unknown	2	2		0	**2**	0
TOTAL	119	100%	587	100%	**706**	**100%**

793. The most common and commercial fish are *Sardina pilchardus sardina, Engraulis encrasicholus, Merluccius merluccius, Sparus auratus, Dicentrarchus labrax, Mullus barbatus, Mugil cephalus, Mugil labrosus*, *Anguilla anguilla*, *Lithognathus mormyrus, Solea* sp., *Aphanius fasciatus, Lichia amia, Pagrus pagrus, Arnaglosus laterna*, etc. Major fisheries are listed below:

- Sardine (*Sardina pilchardus sardina*) is one of the most important fish for the fishing industry, which is found along the Albanian coast and mainly in Vlora and Shengjin 30-80m deep. It is more frequently found from 50-70m deep.
- Anchovy (*Engraulis encrasicholus*) is another small pelagic of a special significance for fishing industry, occurring from 100-300m deep and more often 50-120m deep.

- The European codfish, *Merluccius merluccius* is also important for fishing. It occurs along the Albanian coast, particularly in Vlora, in Buna from 50-350m deep and more often occur from 70-150m deep.
- *Dicentrarchus labrax*, occurs along the coast up to 60m deep and mainly occurs 20m deep and in coastal lagoons.
- Sparidae species, such as *Sparus auratus*, *Diplodus* spp, (five species), *Pagellus* spp. (three species) *Dentex* spp. (three species etc occur mainly in the near coastal area.
- Red Mullets, *Mullus barbatus* and *Mullus surmuletus*, occur along the whole coast, mainly on the Adriatic from 20-150m deep and mostly in the rocky and muddy bottoms from 5-60m deep.

794. The shellfish (mostly sepia species) is also a very important part of the commercial fish species in the country but is not monitored or numbered in the existing documents.

795. Insufficient fisheries management is one of the major management issues in the Adriatic Sea.The most common and commercial fisheries species are *Sardina pilchardus sardina, Engraulis encrasicholus, Merluccius merluccius, Sparus auratus, Dicentrarchus labrax, Mullus barbatus, Mugil cephalus, Mugil labrosus*, *Anguilla anguilla*, *Lithognathus mormyrus, Solea* sp., *Aphanius fasciatus, Lichia amia, Pagrus pagrus* and *Arnaglosus laterna.* Fisheries influence not only populations of target species but also non-target bycatch species like marine turtles and mammals. These animals are usually slow-growing animals with very low reproductive rates, such that the impacts on their populations can be quite severe. There are also many species of all taxa bycaught with fisheries. They are not consumed by humans and discarded. Although the discarded animals may be consumed by opportunistic feedes in the water, most are wasted, considerably damaging ecosystems and the delivery of ecosystem services in the process. A synopsis of fisheries issues in each country of the subregion is given below.

796. Fishing in Albania is primarily marine, although lagoon and inland fishing does take place on a limited scale. During recent years aquaculture has been increasingly promoted with particular focus on carp fingerlings and fish for general consumption (including sea farms). Currently there are 58 Albanian fish farms: 9 fish farms, 3 carp fingerling hatcheries and 46 for trout culture. Albania's domestic fisheries production in 2006 was approximately 7 699 tonnes, of which 5 729 from capture and 1 970 from aquaculture. In addition, fishery imports in 2003-2007 totalled an average of about 13 559 tonnes, while fish exports stood at 4 382 tonnes. Fishery imports in 2006 totalled about 16 347 (1 000 USD) while exports was 23 914 (1 000 USD) with a net balance of 7 567 (1 000 USD). In 2003-2005, average per capita supply was 4.5 kg/year (FAO, 2008).

797. During the last ten years, there has been fishing along the coast within depths of 2-30m, which has led to the depletion of the breeding grounds of Sparidae, Soleidae, Mullidae, and other families. The breeding grounds of *Posidonia oceanica* have also been severely deteriorated because of changes in the structure of the fishing fleet. More than 50% of fishing boats have small power motors (100 HP) and hence are able to apply deep fishing techniques (trawling) in shallow areas since they are unable to fish in zones more than 50m deep. It is evident that the Albanian fishing fleet is characterized by a high presence of trawlers (62%) followed by gill-netter (28%). A good part of fishing fleet of Albania is concentrated in its fishing activity, illegally, in the shallow waters in front of communication channels of the lagoons with the seas, fishing in distance less than 6km from the seashore. Consequently, the natural regeneration and repopulation of the coastal lagoons is seriously damaged, and fishery resources have depleted in all the lagoons (MoEFWA, 2009). Artisanal fisheries are expanding along the coast and exploit the shallow area of the sea up to 4 km from the shore, particularly as the coasts become much more populated. There are about 250 small boats that are used for this kind of fishing (MoEFWA, 2009).

798. In Albania there is no tradition of fishing for molluscs, but they have been farmed in some particular areas. Albania is not allowed to export mollusc from the country due to EU rules and requests. On the other hand the development of bivalve culture farming has been cultivated since the beginning of the 1960s in the coastal lagoon of Butrint where fixed structures are being used for the production of Mediterranean mussel (*Mytilus galloprovincialis*). Due to the excellent environmental conditions in this lagoon, about 80 fixed concrete units were constructed here during the 1970s and the production has grown steadily, reaching a maximum of 5 000 tonnes/year by the end of the 1980s. In the last 5 years the gathering of the species *Litophaga litophaga* (which means "stone-eater") is increasing and extraction has caused destruction of the rocky shoreline habitat.

799. Not many data on fisheries in Bosnia & Herzegovina are available, but 176 fish species have been reported. Two fish farms for sea bass and gilthead sea bream rearing exist, together with several low scale mussel rearing sites (*Mytilus galloprovincialis)* in Neum-Klek Bay (there are also very close mussels and oysters (*Ostrea edulis*) farms in Mali Ston Bay in Croatia).

800. The fishing of small pelagic fish in Slovenia is performed by three types of fishing gears. Among the gears used, the drift nets are the most primitive. The target species for this gear with very good selectivity is *Sardina pilchardus (*Marčeta, 2002). The next types are purse seines, used for European pilchard, European anchovy, Atlantic mackerel, chub mackerel, and horse mackerels. Two pairs of midwater trawlers are used for fishing in international waters of North Adriatic Sea. They are working around the year following the target species - European pilchard. The bottom trawl fleet (23 trawlers in 2001) is fishing from September to February.The most important species in their multi-specific catches are musky octopus, common cuttlefish, and various demersal fish species. The number of small scale fishermen is approximately 80.

801. Fisheries in Croatia follow the trend for the Adriatic as a whole. Out of 442 registered fish taxa in the Adriatic Sea, about 200 species are affected by the fishing. Between them approximately 70 are targeted, 50 accidental and the rest are rare species and those recorded as by-catch. There is a problem of overfishing in the Adriatic Sea that has significant negative impact on fish communities (Jardas *et al.*, 2008).

802. Pelagic fishing is mostly based oneight species of small fish, with the pilchard *Sardina pilchardus* and the anchovy *Engraulis encrasicolus* being the most important and the most abundant. Several other species of large fish are important, the bluefin tuna *Thunnus thynnus* holding the most important place by the volume of catch and economic importance. Others include *Scomber japonicus, Scomber scombrus* and *Sarda sarda.* Commercially the most important demersal fish species are the hake *Merlucius merlucius* and the red mullet *Mullus barbatus*. Others include *Merlangius merlangius*, *Lophius* sp*, Pagellus erythrinus, Trachurus* sp*, Trisopterus m. capelanus, Zeus faber* and some cartaligenous species like *Raja clavata, Scyliorginus canicula* and *Mustelus mustelus.* Additionally, fish stocks in coastal waters include *Boops boops, Dentex* sp*, Diplodus vulgaris, Liza* sp, *Mullus surmuletus, Oblada melanura, Sarpa salpa, Scorpaena* sp*, Solea* sp*, Spicara maena* and *S. smaris* (CEA, 2010).

803. Besides fishes, economically important fishery species are crustaceans and molluscs. Between crustaceans the most important is Norwegian lobster *Nephrops norvegicus,* followed by *Homarus gamarus, Palinurus elephas, Maja squinado* and *Parapenaeus longirostris.* Important cephalopods are *Loligo vulgaris, Octopus vulgaris* and *Sepia officinalis* as well as *Eledone cirrhosa, E.moschata* and *Illex coindeti. S*hellfish include *Mytilus galloprovincialis, Ostrea edulis, Pecten jacobaeus, Arca noae, Ruditapes decussates* and *Venus spp.* Also, commercial species include sponge *Spongia officinalis* and red coral *Coralium rubrum* are still being collected in some areas as part of traditional fisheries.

Aquaculture

804. Aquaculture can also have significant impact on marine biodiversity, although mostly on the local level. In case of cage fish farming, the uneaten feed (some 10 per cent of the total volume) and metabolic products enter the sea, causing organic pollution and eutrophication and often even local hypoxia and anoxia. Almost all fish farms show degradation of benthic communities under the cage to a certain extent, the most often being valuable *Posidonia* meadows. The seafloor under the cage shows often compact white films of the bacteria *Beggiatoa* spp. (Jardas *et al.*, 2010). Aquaculture can also be a source of spreading alien organisms or even microbial pathogens into open sea. Because of mentioned influences, environmental impact assessment is obligatory before issuing permits for larger aquaculture farms in most countries.

805. Aquaculture data is limited, but figures are available from Croatia. Today Croatian aquaculture has the total annual production around 12,000 t and income goes to 10 million €. Bluefin tuna fattening dominates with production of cca 5,000t/y and income of about 80 million €. Breeding of white fish produces cca 4,000 t/y and includes mostly the sea bass *Dicentrarchus labrax* and sea bream *Sparus aurata* and additionally (less than 5% of total production) *Dentex dentex* and *Puntazzo puntazzo*. The total production of shellfish in 2006 was estimated to 3,500 t of mussels *Mytilus galloprovincialis* and a

million of oysters *Ostrea edulis*. During last several years there is a large increase in shellfish production, due to modern mechanized offshore breeding and opening new breeding sites. The trial production of new species of bivalves have been started: from species for which there is already developed technology for rearing (scallops), through the species that are in advanced phase of research (*Venus verrusoca* and *Pina nobilis*), to interesting species that have yet to be explored like dateshell *Lithophaga lithophaga* (Glamuzina *et al.*, 2009).

Physical and biological disturbance from alien species

806. Introduction of alien species occurs through the discharge of ballast waters at sea, Suez Canal, mariculture and fouling. Dulcic *et al*. (2010) reported at least 11 lessepsian migrant fish species were identified in the Adriatic Sea. Dulcic and Gerbec (2000) found that the change of the ichtyofauna in the Adriatic was associated with climatic and oceanographic changes.

807. The cubozoan, *Carybdea marsupialis,* was firstly recorded from the Adriatic in the mid-1980's and now an obnoxious stinger. Besides, *Pelagia noctulica* is increasing again. The global trend towards high abundance of jellyfish might also be correlated with overfishing. Jellyfish and fish interact both as predators and competitors of each other. The removal of large fish, due to overfishing, is opening an ecological niche for jellyfish (Boero *et al.*, 2008).

808. Bello *et al.* (2004) reported that the tropicalization of the Adriatic Sea is confirmed by the population expansion northward along its south-western coast of the some resident species (bony fishes *Thalassoma pavo* and *Sparisoma cretense*, a gastropod species *Stramonita haemastoma*, a cephalopod species *Octopus macropus*, and the short-term resident *Caulerpa racemosa*, a chlorophyte) and the settlement in the province of Bari of three tropical dinoflagellates (*Ostreopsis lenticularis, Coolia monotis* and *Prorocentrum mexicanum*).

Nutrient over-enrichment

809. During 1989-1992, phytoplankton blooms occurred several times in offshore and coastal north Adriatic areas. Mucous aggregates ("sea snow", "strings", "carpets") were assessed as a visual, i.e. secondary, effect of microphytic blooms. Mucous aggregations can be displaced by means of wind/waves and currents, and can be accumulated locally. Under special hydrographic and meteorological conditions, mucous aggregates can accumulate and deposit on the sea bottom, thus adversely affecting the benthic flora and fauna by smothering and/or provoking oxygen depletion in the bottom layer. In the area surveyed, bottom oxygen depletion was limited in space and time. Following the mass mortality of benthic organisms at one station in November 1989, biological anoxia was noted repeatedly in 1990 and 1991. These events affected the population and community recovery process (Zavodnik et al, 1994).

810. In the last two decades, a shift from red tides to mucilage phenomena was observed. This phenomenon is known to occur regularly for more than two centuries and was first recorded in 1729 (Vollenweider *et al.*, 1995). Almost every year mucilage phenomena appears as marine snow or as dense cobweb, clouds, blankets, creamy/gelatinous layer (Precali *et al.*, 2005). Mucus aggregates influence zooplankton temporal and spatial variability and can severely affect some species of fish which breed during the warm period of the year (Bochdansky and Herndl, 1995; Malej & Harris, 1993; Cabrini *et al.*, 1992; Cataletto *et al.*,1996; Fonda Umani *et al.*, 2005). When the mucilage sinks to the bottom, it physically covers the organisms living on the bottom or in the sediment and thus makes normal physiological processes impossible. Below the settled mucilage, total lack of oxygen occurs.

811. In the subregion, the most destructive anoxia was recorded in September 1983 and lasted for two weeks, covering one third of the Gulf of Trieste (Stachowitsch, 1984,1986; Faganeli *et al.*, 1985). In the affected area all the attached, partially attached and poorly mobile demersal animals died at that time. Recovery of the benthic system is not complete yet (Stachowitsch, 1991; Kollmann & Stachowitsch, 2001).

812. In anoxic events, the most sensitive macro-organisms to biological anoxia proved to be sponges, some polychaetes, echinoderms and tunicates, while actinians appeared to be the most resistant. Of the sediment living meiofaunal taxa, copepods were affected much more than nematodes

(Zavodnik et al, 1994). The recovery of soft bottom communities is a slow process which, because of the community instability, is very sensitive to interactions of biotic and abiotic environmental factors.

5.5.5 Effects of underwater noise and marine litter

813. No information exists that allows assessment of the magnitude of impacts caused by noise generated from maritime activities, however, the marine litter problem has been addressed in general terms as a Mediterranean-wide phenomena. This report does not provide information on this topic specific to this subregion.

814. One of the transboundary impacts of waste released in the Mediterranean environment related to waste dumping or inappropriate waste management is the phenomenon of marine litter. A recent bibliographical study conducted by UNEP/MAP - MED POL on the phenomenon throughout the Mediterranean concluded that, between 2002 and 2006, the situation had not improved significantly. Marine litter, found in the sea and on the coastline, originate mainly from coastal urban centers. These wastes are generated by direct disposal of domestic waste, tourism infrastructure waste, flows from landfills and rivers and waste from maritime traffic. UNEP/MAP - MED POL observes, in particular, that the management of solid waste in coastal areas is generally not covered by national environmental policies, but by health policies, and that there is generally no municipal policy of management of solid waste: municipal strategies being geared, above all, to meeting basic standards of public hygiene. For technical and economic reasons, it seems that the sea is still considered as the easiest waste disposal site and that, consequently, the disposal of solid waste into the sea is still common practice for small and medium size towns.

815. There are signs of that the litter issue is being addressed in specific regions, however. Croatia, for instance, has developed a waste monitoring plan and monitoring strategy that includes municipal waste management; this could be expanded to include marine litter monitoring.

816. National, regional and international NGOs are active in Mediterranean beach cleaning campaigns. The International Coastal Cleanup (ICC) observes that, in the Mediterranean, the heavy fraction (big household appliances) is on the decrease and that the average weight of waste found in the sea has dropped from 511 g to 258 g. As regards the light fraction, the number of plastic bags, caps and plastic bottles is also on the decrease; the share of plastic found in the sea dominates and composes 75% of collected items. The analysis of the data available indicates that coastal and recreation activities account for 52% of the waste found on beaches (UNEP/MAP-Blue Plan, 2009).

5.5.6 Emerging issues: climatic change effects and deep sea modifications

Climate Change Impacts

817. One of the significant indicators of climate change in the Mediterranean Sea is tropicalization. Bello *et al.* (2004) reported that the tropicalization of the Adriatic Sea is confirmed by the population expansion northward along its south-western coast of the some resident species (bony fishes *Thalassoma pavo* and *Sparisoma cretense*, a gastropod species *Stramonita haemastoma*, a cephalopod species *Octopus macropus*, and the short-term resident *Caulerpa racemosa*, a chlorophyte) and the settlement in the province of Bari of three tropical dinoflagellates (*Ostreopsis lenticularis, Coolia monotis* and *Prorocentrum mexicanum.* Corals like Gorgonians (*Paramuricea, Eunicella* and others*)* are threatened by the sea temperature rise (mass mortalities due to stress induced epidemics connected with changes in sea temperature in Mediterranean have been already recorded); the same threat is posed to the colonial scleractinian coral *Cladocora caespitosa* that builds sizeable bioherms in the Adriatic Sea due to the symbiotic zooxanthellae.

818. Several marine taxa are likely to be affected by future climate change. Loggerhead turtles *Caretta caretta* will likely be affected, as will marine mammals like the bottlenose dolphin *Tursiops truncatus* and the Mediterranean monk seal *Monachus monachus* are likely to be threatened by changes in their prey (plankton, fish and squid) distribution and abundance.

819. Marine birds could be affected by climate change through availability of breeding sites and food resources because of the sea-level rise and possible changes in fish populations. Regarding commercial species, changes of spawning and distribution patterns of economically the most important pelagic species sardine *Sardina pilchardus* and sprat *Sprattus sprattus* as well as Spanish sardine *Sardinella aurita* have already been registered in the Adriatic Sea. Important spawning areas and nurseries could be threatened like Velebit Canal, Neretva Delta, Jabuka Pit and others. The European eel *Anguilla anguilla* and other anadromous fishes entering rivers will also be threatened by changes of water regime.

820. It was concluded that impacts of new thermophyllic species appearing in the Adriatic could be twofold, depending on whether they are observed in economic or ecological sense. For example, migration of dusky groupers from southern to middle and northern Adriatic has a positive economic impact to fishery, as dusky groupers are rare and quite wanted fish. However, there is also negative impact due to a competition with some local species. Implications for the fishing sector could be: increase of species that tolerate warm water and lower oxygen levels, the recruitment of species that thrive in warm water should be significantly better while the opposite is likely to occur with species that thrive in cold water, such as prawn. Also, introduction of new organisms that transmit disease or exotic or undesired species is likely to occur due to increased sea temperatures.

821. Positive impact of climate change is possible within the area of aquaculture. Species, better adapted to higher sea temperatures like sea bream, due to the increase in winter, could have more favorable conditions to grow and develop. Global warming will probably have a positive impact on tuna breeding as well, as the most important economic product in fishery sector.

822. The hydrographic regime of the Northern Adriatic influences, during certain seasons, the hydrographic, chemical and biological characteristics of the rest of the Adriatic, because it is highly influenced by freshwater inputs from the entire catchment of the Northern drainage basin. Climate change-mediated changes to precipitation or to level of ice melt in that area could potentially alter the oceanographic condition over the entire Adriatic Sea. Changes in precipitation quantity over the catchment feeding rivers and the coastal aquifers would influence also the availability of fresh water resources and inputs of freshwater to the marine environment.

823. Increased air temperatures are expected to influence the process of stratification in enclosed areas, such as Kastela Bay for instance. In the case of water temperature changes it is expected that species currently found in warmer, more southern latitudes might shift northwards and by that influence the abundance of species and the composition of animal and plant communities (UNEP, 1992). More detailed information on potential climate change impacts on Adriatic coastal areas is available in a study on climate change in Kastela Bay and Cres/Losinj Islands (UNEP MAP 1996).

Open Ocean and Deep Sea Modifications

824. Pelagic fishing in the Adriatic is mainly concentrated in the northern half of the region and targets either large pelagic species or small pelagics, e.g. anchovy and sardine, in the Adriatic Sea. Cumulative impacts maps show that the central northern portion of the Adriatic Sea is a high pressure area for both demersal and pelagic fisheries, using both destructive and non-destructive fishing methods, and often resulting in by-catch.

825. The most important negative consequence of fishing activities is the degradation of marine ecosystems by the removal of target or non-target species and by physical disturbance inflicted by some fishing gears. Essential Fish Habitats (EFH) are those habitats necessary for feeding, refuge or reproduction of the species; and Sensitive Habitats (SH) consist on those areas with endemic species, high biodiversity or high productivity and vulnerable to fishing practices. The degradation of ecosystems by fishing indirectly affects the commercial species if the habitat is not longer adequate for these species. In this context, there is a necessity of regulating fishing activities to reduce the ecosystem degradation by the establishment of an Ecosystem Approach to Fisheries (EAF), which considers not only the protection of target species, but the ecosystem as a whole. Within the EAF framework the Precautionary Approach considers the most restrictive measures for fisheries management (including the establishment of areas closed to fishing, or Marine Protected Areas) against a general lack of knowledge on the functioning of many ecosystems that sustain fisheries resources.

5.6 Conclusions and gap analysis on pressures and impacts

826. Nutrient over-enrichment leading to eutrophication, mucilage events, and occurrences of harmful algal blooms are key pressure points in some areas within this subregion. Fisheries are increasing, and may exacerbate imbalances caused by nutrient over-enrichment. Eutrophication also impacts fisheries production, and may cause human health concerns and impacts on tourism revenues when bathing beaches are closed. Invasive species and climate change impacts are also main issues for the subregion.

827. The Gulf of Trieste is known to have frequent algal blooms and hypoxia events. The first bloom has been described in 1954 from a coastal area close to the Po delta and was due to algal organism typical for transitional waters (*Chromulina rosanofii* and *Oscillatoria tenuis*). Monitoring shows that such events are frequent in this area (Danovaro, 2003). The most affected areas are south of river Po and lagoons in the northern portion of the Adriatic (Giovanardi and Vollenweider, 2004). One of these lagoons is the Lagoon of Venice, which is a eutrophic lagoon system receiving urban, industrial and agricultural nutrient loads. This nutrient loading has drastically changed parts of the original ecosystem with enhancement of seaweed growth and proliferation of anoxic areas.

828. The northwestern Adriatic coastline is the most commonly and severely impacted area affected by periodic anoxia events and frequent algal blooms, jelly fish invasions and mucilages.

829. Kastela Bay in the central Adriatic is a previously threatened area which is showing signs of improvement in recent years. Studies were undertaken in order to gain better knowledge of the red tide phenomenon frequently recorded in the coastal waters of the Adriatic Sea (Marasovic, 1990). Long term observations in the most threatened areas were aimed at determining the circumstances preceding the red-tide phenomenon and which species caused it. Results showed a very high level of biological activity due to an increased eutrophication of Kastela Bay. In summer, due to poor vertical and horizontal circulation in parts of the water surface, stratification occurs with layers manifesting characteristics different from the rest of the bay. These phenomena seem to be responsible for the algal concentration, fostering the growth of monospecific blooms of those organisms showing certain competitive advantages in relation to the rest (*Gonyaulax poliedra*, *Olisthodiscus luteus*). In addition to a whole range of other competitive advantages, such as photoadaptation, resting cysts, temporary cysts and production of certain metabolites which enable them to exclude other organisms from the environment, these flagellated organisms are highly motile. Such intensive phytoplankton blooms eventually lead to their self-destruction. The resulting anoxia causes mass mortalities of other marine organisms.

830. A thorough consideration of these results leads to the conclusion that those regions constantly burdened with waste waters have sufficient quantities of micro and macro nutrients not to cause but, on the contrary, to enable and to support excessive phytoplankton blooms. In Kastela Bay, sea temperature in excess of 22 ºC, triggered explosive development of certain populations mainly those with organisms (dinoflagellates) showing competitive advantages over other organisms thus developing monospecific blooms. When these blooms collapsed, oxygen consumption takes place resulting in anoxic or quasi-anoxic states. However, conditions have improved in this and other Adriatic regions in recent years. A rapid decrease of phytoplankton biomass since 1998 has been recorded (Nincevic Gladan et al., 2009).

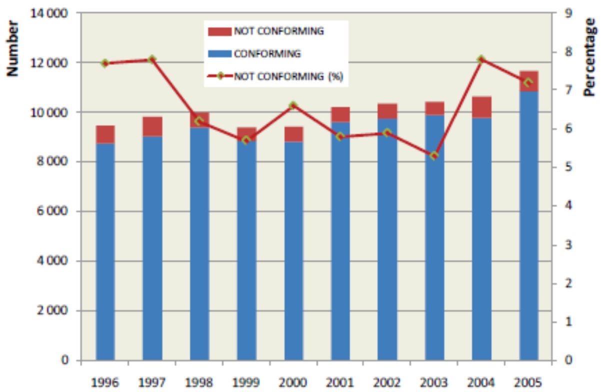
831. Some regions in the Central Adriatic have achieved such a high level of eutrophication that they can be described as hypertrophic. In order to rehabilitate such regions, it is essential to reduce the discharge of waste waters. However, since great quantities of micro- and macro-nutrients are deposited in the sediments, these areas will continue to exhibit a high level of eutrophication for a long time. The results obtained from these studies, combined with the results of physical, chemical and dynamic investigations should enable a more precise evaluation of the basin absorptive capacities i.e. to estimate the quantities of waste water that can be discharged without a significant disturbance of the ecological balance (Marasovic, 1990).

832. Assessment of nutrients concentrations and chlorophyll data, based on Eionet data (2005), show consistently, that largest problems with eutrophication are observed in the northwestern part of Adriatic Sea, related to river Po input of nutrients. Time trend analyses shows that summer chlorophyll a concentrations are increasing at 8% of the Italian stations, decreasing at 5% of the stations, and no statistically significant trend can be detected at the remaining 87% of stations. In 2005, the highest oxidized nitrogen concentrations were observed along the coast of Italy. In NW part of Adriatic the high concentrations can be attributed to inputs from the Po River. High concentrations were also observed at single stations in Croatia. Time trend analyses of data from Italy shows that oxidized nitrogen concentrations are increasing at 4% of the stations, decreasing at 1% of the stations, and no statistically significant trend can be detected at the remaining 95% of stations.

833. In 2005, the highest orthophosphate concentrations were observed along the coast of Italy. In the NW part of Adriatic the high concentrations can be attributed to inputs from the Po River. Time trend analysis shows that while orthophosphate concentrations are decreasing at 6% of the Italian stations, they are also increasing at 5 % of stations and no statistically significant trend can be detected at the remaining 89% of Italian stations.

834. In both coastal and freshwaters the point sources of pollution that cause most health concern are those due to domestic sewage discharges. Diffuse outputs and catchments aggregates of such pollution sources are more difficult to predict. Risks to human health are related to recreational waters quality and to shellfish associated infections.

835. During the period 1996-2005, there was a near stagnation in the percentage of bathing waters conforming to national standards (from 92.3% to 92.8%), with fluctuations during the period. Quality of those areas where monitoring takes place appears to have steadily increased until 2003 and then a slight worsening of quality are seen in 2004. A slight improvement is seen between 2004 and 2005 (see Figure 5.12). It should be noted that data only refer to waters that are officially monitored and that there may be a number of bathing areas which are used for recreation that are not monitored.



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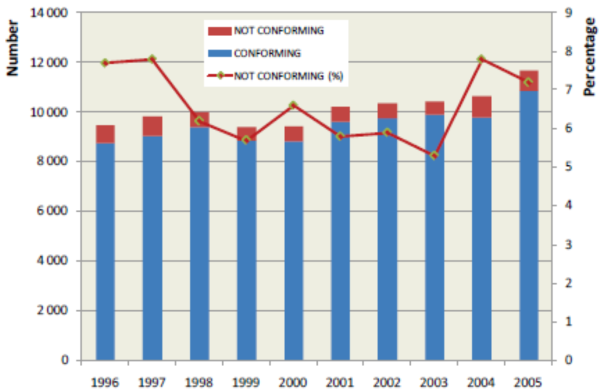


Source: MED POL

Figure 5.12. Number and percentage of bathing water areas complying and non-complying with the national legislation per year, 1996–2005 (UNEP/MAP- Blue Plan, 2009).

836. The positive trend for bathing water is also noticed in the number of sampling points, where samples were collected for analysis. In fact, following a minor decrease in 1999-2000, the number of sampling points was increased from 9,500 to 11,600 sampling points per year. The results confirm that every year more and more countries with an increasing number of sampling points implemented monitoring programmes.

CHAPTER 6: EASTERN MEDITERRANEAN SUBREGION

6.1 Introduction

837. The East Mediterranean Sea constitutes the last remnant of the Mesozoic-Cenozoic oceanic basin of Tethys, which is now almost totally consumed as a result of the long term plate convergence between Eurasia and Africa. The morphology of the East Mediterranean seafloor relates both to the early history of formation of the deep basins and the recent geodynamic interactions between interfering microplates.

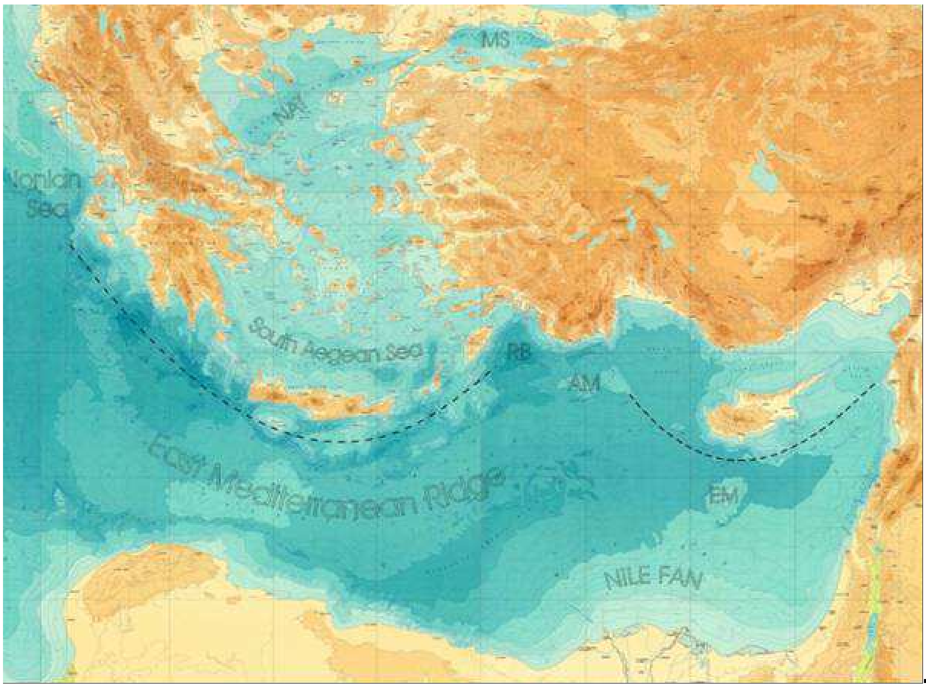


Figure 6.1.Morphology of the Aegean –Levantine Basin

838. The countries that border this subregion include Libya, Egypt, Israel, Lebanon, Syria, Cyprus, Turkey, and Greece.

6.2 Physical and chemical characteristics

6.2.1 Topography, bathymetry and nature of seabed

839. From southwest Peloponnesus to south of Crete and Rhodes, this subregion is characterized by a 1500 km long and 200–250 km wide, arc-shaped, sedimentary wedge / accretionary prism known as the East Mediterranean Ridge (Heezen and Ewing, 1963; Emery *et al.*, 1966). It results from the relatively rapid convergence between Eurasian and African continents, the subsequent subduction of the oceanic crust along the Hellenic Island Arc underneath the overriding Aegean microplate and the deformation of its sedimentary cover, which is responsible for the cobblestone relief of the ridge (Le Pichon *et al.*, 1995; Dewey and Sengoer, 1979; Kreemer and Chamot-Rooke, 2004; McClusky *et al.*, 2000; Reillinger *et al.*, 1997). Gas hydrates are also thought to occur.

840. The deep trenches north of the Mediterranean Ridge, known as Hellenic Arc and Trench System, represent the morphological expression of transpressional fault-zones, like the Herodotus and Matapan trenches to the west and the Strabo and Pliny trenches to the east. Maximum depth of

5100m has been observed in the Oinousses Deep, southwest of Peloponnese. Numerous canyons and deep valleys originate from the shelf off mainland Greece and the Ionian and South Aegean Islands. Of particular interest is the seafloor topography of the West and East Cretan Straits, which are characterized by complex morphology with narrow canyon running between steep sloped ridges. The Hellenic Arc terminates eastward at the Rhodes basin, a 4000- 4500m deep relatively young basin east of Rhodes island, characterized by thin sedimentary cover.

841. Adjacently to the eastern side of the deep Rhodes basin the Anaximander Mountains are rising to minimum depth of about 1500m. They represent a continental block, tectonically separated from Anatolia, composed of alpine rocks (Woodside and others 1997, 1998). The Anaximander Mountains are the only site in the Mediterranean Sea where gas hydrates have been sampled (Lykousis *et al.,* 2004). Their formation is related to the active mud volcanoes which occur on the shallow parts of the mountains.

842. A second arc-shaped feature, the Cyprus Arc, initiates at the Anaximander Mountains and comprises the Florence Rise, the Cyprus margin, Larnaka and West Taurus ridges, to finally stretch towards the Levantine coast off Syria. Eratosthenes Seamount, located south of the Cyprus Arc, is a striking positive morphological feature of the Levantine seafloor. It has been interpreted as a continental block of the African plate, which is underthrusting beneath the Cyprus Arc.

843. The Nile Fan, covering the Egyptian passive margin over more than 100000 km2, which corresponds to a fairly thick sedimentary wedge, resulting from successive terrigenous inputs delivered by the Nile River since at least 5 million years before present (Dolson, Boucher, & Shann, 2000; Salem, 1976). Extensive mass movements and widespread cold seeping phenomena (mud volcanoes, pockmarks etc) characterize particularly the deeper, western sector of the fan (Loncke *et al.*, 2004).

6.2.2 Salinity, temperature regime; currents; sediment transport

Temperature Regime

844. The Mediterranean Sea consists of two major interacting sub-basins, the western and eastern Mediterranean, connected by the Straits of Sicily with sill depth ~1000m. The Ionian, Levantine, Adriatic and Aegean are the sub basins in the eastern part, which communicates with the Black Sea through the Strait of Istanbul, the Strait of Çanakkale and the Sea of Marmara. On the largest scales of interest, i.e. interannual and basin-wide scales, the circulation of the Mediterranean is determined by its exchanges of water and heat with the atmosphere through the sea surface and the water and salt with the adjacent seas through the Straits. The thermohaline circulation of the Mediterranean, which reflects the largest scale motion, is forced by the buoyancy exchanges and is driven by its negative heat and freshwater budgets (Theoharis, 2008) and the wind stress forcing (Tsimplis et al 2006).

845. A general north-south gradient in the net heat flux is apparent, from a net heat loss in the northern half of the basin to a gain in the southern half (Figure 6.2). The gradient primarily reflects a reduction in the shortwave flux with increasing latitude and strong wind driven latent heat loss in the Aegean Sea. In winter, the heat loss is the major factor contributing to the deep water formation. Significant interannual variations in the winter heat loss are known to occur, the prime example being the severe winters of the early 1990s which have been linked to the Eastern Mediterranean Transient (Theocharis *et al.*, 1999; Josey, 2003).

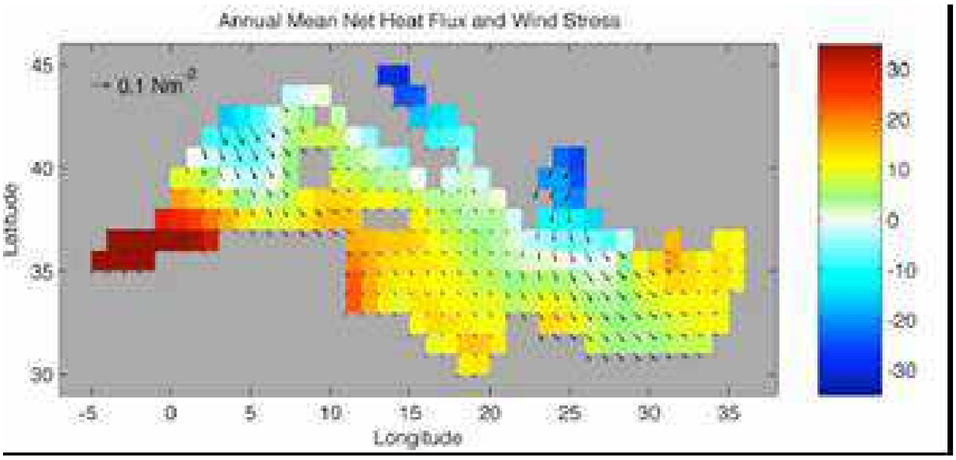


Figure 6.2 Climatological annual mean fields based on the SOC climatology for the net heat flux and the wind stress. Climatological annual mean net heat flux (colours Wm- 2) and wind stress (arrows) (Josey *et al.*, 1999)

846. Satellite derived maps describing the mean spatial temperature and salinity variability are shown in Figure 6.3 .

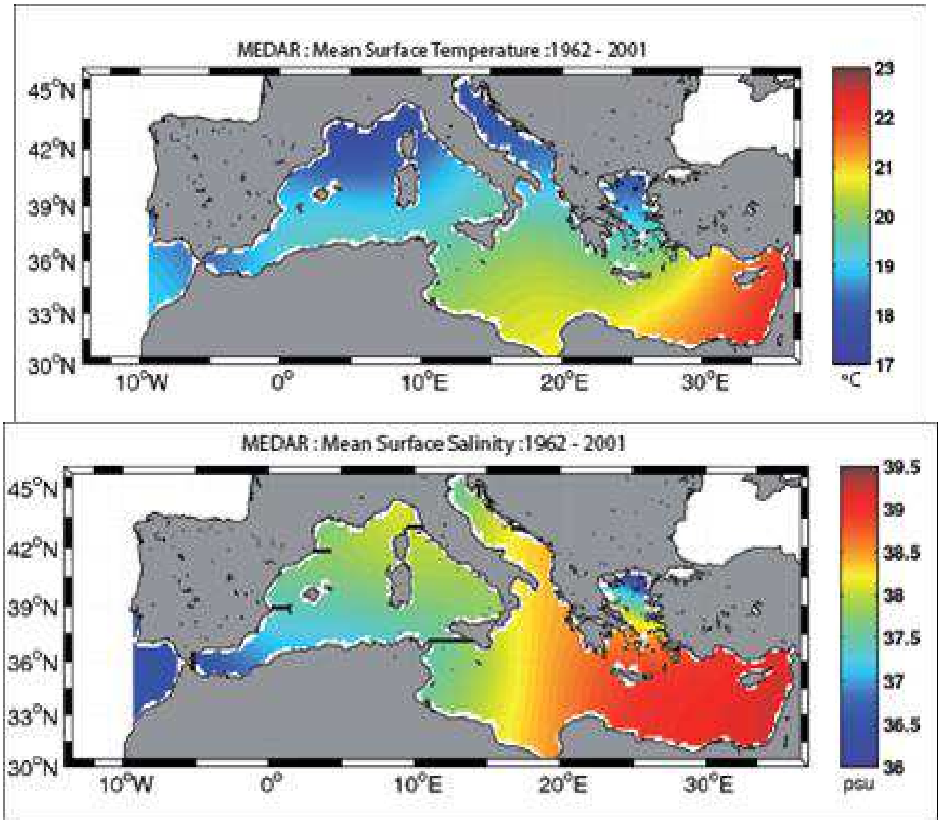


Figure 6.3. MEDAR Mean surface temperature (top) and salinity (bottom) 1962 -2001.
Source: Reprinted from Vidal-Vijande (2008)

847. The general circulation consists of a number of sub-basin-scale gyres and eddies interconnected and interleaved by current jets and filaments. There is variation in the shape, position and strength of permanent gyres; the meander pattern, bifurcation structure and strength of permanent currents; and the occurrence of transient and aperiodic eddies and jets (Robinson et al

1991). The inherent seasonal and interannual flow variability impinges on the coastal regions and strongly influences the local dynamics of currents (EEA, 1999).

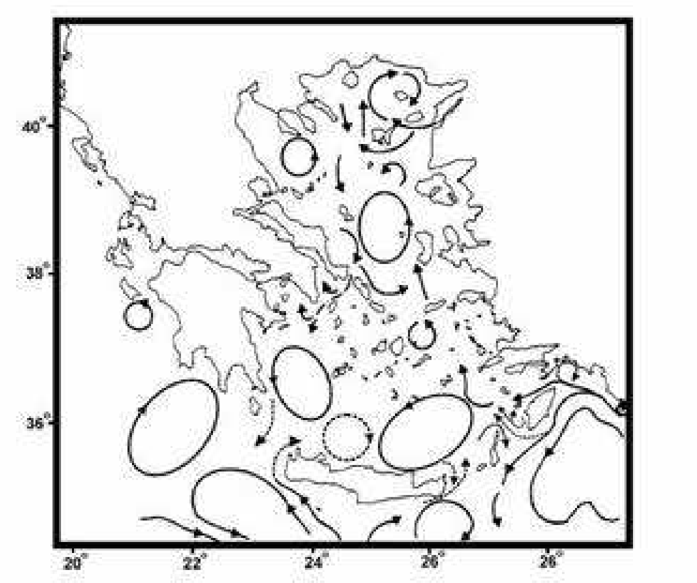
848. Schematically, the Mediterranean Sea can be considered as comprising three main water masses all of which of major importance in the eastern Mediterranean sub-basin (Figure 6.4) :

- the Atlantic Water, found in the surface layer, having a thickness of 150-200 m and characterized by a salinity of 36.2 psu near Gibraltar to 38.6 psu in the Levantine basin;
- the Levantine Intermediate Water (the main water body of the Mediterranean) formed in the Levantine basin, from the overlying Levantine Surface Water (LSW) lying in depth between 200-500 m, and characterized by temperatures of 13-15.5℃ and salinity of 38.4-39.1 psu;
- the Mediterranean Deep Water formed in both the western and eastern basins; the Eastern Mediterranean Deep Water (EMDW) is characterized by a temperature of 13.6℃ and a salinity of 38.7 psu.

849. The northwest Levantine Basin is the main source of the Levantine Intermediate Water (LIW), while the Adriatic Sea is basic site of Eastern Mediterranean Deep Water (EMDW). LIW is considered the most important component of the large scale circulation and dynamics because it spreads throughout most of the Basin and affects the background stratification at the other major deep water formation areas (Adriatic and Aegean). It is also the main constituent (80%) of the high-salinity Mediterranean Water that is exported to the Atlantic Ocean (Lascaratos *et al.*, 1999).

850. Another loop connects the Mediterranean with the Black Sea. In this case, the Aegean Sea acts as an intermediate machine that modifies the received LIW and exports it to the Black Sea via the Marmara Sea.

851. Sub-regional eddies and local current systems have also been identified: the mid-Mediterranean jet which is an intensification of the Atlantic-Ionian Stream in the Levantine basin; the Rhodes and Ierapetra gyres; and the Mersa-Matruh and Shikmona gyres (see Figure 6.4).



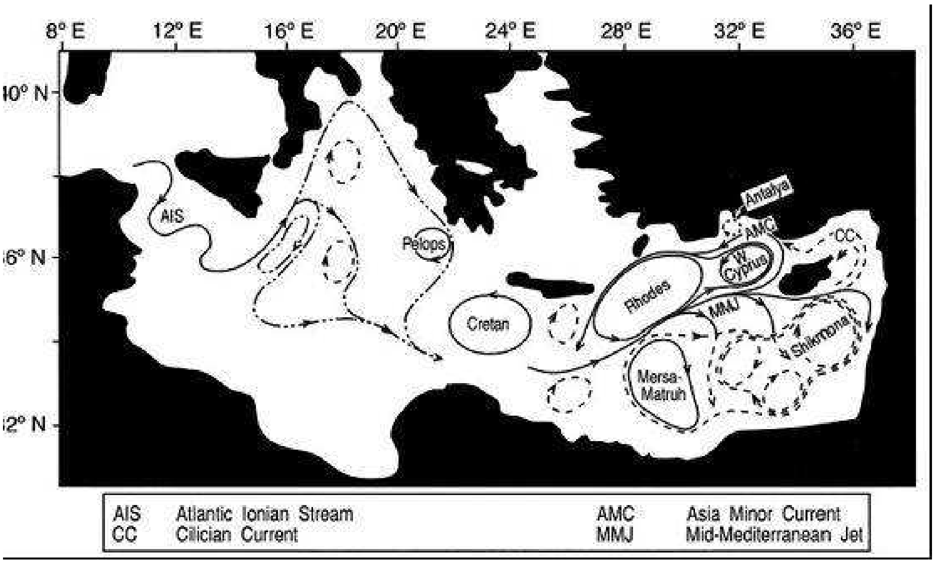


Figure 6.4. Schematic upper general circulation in Eastern Mediterranean(Lykousis *et al.*, 2002 (top) and Malanotte-Rizzoli et al, 1997 (bottom))

Salinity

852. Although the inflow of water from the Black Sea to the Mediterranean is about 2 orders of magnitude smaller than the inflow of Atlantic water, the large salinity difference between the Black Sea and Mediterranean of ~18 psu, makes the role of the Black Sea outflow significant at least for the Aegean Sea. This inflowing Black Sea water occupies the surface layers in the north Aegean Sea where it is thought to have a controlling function on the vertical stability and mixing (Zervakis et al, 2004).

853. Variations of the Black Sea water outflow may affect the thermohaline circulation in the North Aegean; reductions of ~100 km3/yr are quite plausible, which are equivalent to changes in evaporation of 0.2 m/yr over the Aegean Sea (Stanev and Peneva, 2002). By contrast, an increase of the transport of Black Sea water into the Mediterranean Sea could block or at least decrease the rates of any deep water formation taking place in the north Aegean Sea (Zervakis et al, 2004).

854. It is only recently that the role of the Aegean Sea as a deep water formation area has been conclusively demonstrated (Roether *et al.*, 1996). In late 80s-early 90s, abrupt significant consecutive changes, increase in salinity (1987-1992) and drop in temperature (1992-1994), caused continuous increase of density and massive deep water formation in 1999, altering the thermohaline circulation of the eastern Mediterranean (Robinson *et al.*, 2001; Roether *et al.*, 1996) with consequences also for the distribution of other environmental parameters (Klein *et al.*, 1999). This major event, unique in the oceanography of the Mediterranean since the beginning of the 20th century, evolved within the last 18 years and was called the “Eastern Mediterranean Transient” (EMT). The engine of the conveyor belt was up to 1987 the convective cell of the Southern Adriatic, while in early 90s the active convection region shifted to the Aegean. The Aegean became the new more effective source than the Adriatic, since it produced not only denser water, namely the Cretan Deep Water (CDW), but also in large volumes (Theocharis et al, 1999).

855. It is worth mentioning that palaeoceanographic information has certified the large sensitivity of the Aegean Sea to climatic variability. Additionally during the EMT period a new intermediate water was generated in the Cretan Sea, namely the Cretan Intermediate Water (CIW), that replaced the LIW within the western region of the Eastern Mediterranean (Ionian Sea). This salty water fed the Adriatic during the following years, supporting the reactivation of the previous long term dominance of the Adriatic (Theocharis, 2008). In conclusion, the Mediterranean is not in a steady state and is potentially very sensitive to changes in atmospheric forcing (Tsimplis *et al.*, 2006).

856. Rivers are important sources of freshwater and nutrients for the Mediterranean (Ludwig et al 2009). Freshwater inputs alone can influence the marine ecosystems functioning through their control on the general water circulation in the Mediterranean Sea (e.g. Skliris *et al.*, 2007). In the eastern Mediterranean a decreasing trend has been established for the Aegean (AEG) and the Southern Levantine (SLE); for the North Levantine Sea (NLS) no significant trends could be detected. Discharge reductions were frequent in the rivers of the eastern Mediterranean when the records extend to recent years rather than stopping in the eighties. This is in agreement with Skoulidikis and Gritzalis (1998) who reported that many Greek rivers reduced to up to half of their original discharge.

857. According to Ludwig *et al.* (2009), the patchiness of the discharge records makes it difficult to extrapolate the detected changes to larger spatial and temporal scales unless the records are compared to the general evolution of climate. Results of trend analyses on hydroclimatic parameters in the eastern Mediterranean revealed a precipitation decrease with reductions in the Aegean Sea (-13%), and the South- Levantine Sea (-10%) following the general Mediterranean precipitation trend. On the other hand the drainage basins of the Aegean and North-Levantine seas have experienced a decrease in temperature in contrast to the strongly increasing temperatures of the entire basin.

Sediments and Sediment Transport

858. The basin sediments of the eastern Mediterranean Sea are muddy with high carbonate contend due to the biogenic particles originated from the phytoplanktonic production of the system. Deep-water ventilation changes, on longer time scales, are witnessed in the sedimentary record of the eastern Mediterranean Sea, by the presence of sapropels. These dark organic-rich layers are found throughout the eastern Mediterranean Sea.

859. The precise mechanisms leading to this unusual past accumulation of organic matter in the Mediterranean Sea are still a matter of debate (Anagnostou pers. comm.). Their formation is related to a slow-down of deepwater ventilation attributed in most cases, to changes into much wetter climatic conditions. For the sapropel formation the stagnation/anoxia theory has been proposed, which suggests that, during times of excessive freshwater influx into the Mediterranean Sea, the water column became strongly stratified, preventing vertical mixing and oxygen supply to the bottom waters. This procedure contributed to the preservation of higher percentage of the total organic carbon (TOC) and to the sapropel formation with >2–5% total organic carbon. The sapropel formation seems to be also associated with increases in export productivity and increase in the flux of organic matter.

860. The Aegean Sea, which shows very complicated seafloor morphology, is described in detail, with emphasis on coastal areas based on Karageorgis et al, 2005 and Sakellariou et al 2005.

861. In the northern Aegean, sand and silt are the major constituents of the sediments, with a minor amount of clay and, therefore, these sediments are classified as sands, muddy sands, muds and silts. Sand is the predominant sediment fraction in the continental shelf and upper slope of the north Aegean Sea. The sediments of the north Aegean Sea are generally characterized by low carbonate content (<20%). In the continental shelf (water depth <130 m) and upper slope area (water depth 130-300 m) carbonate content is generally <20%, however, some elevated values appear around the islands of the area. In coastal areas and semi-enclosed gulfs, sediments are generally muddy sands and muds. The carbonate content varies from values <40% in values up to 70%.

862. In the south Aegean, sediments collected from the southern part of the Cyclades Islands, the northern part of the Cretan Sea and a part of the central offshore sector north of Kriti Island are mainly composed of sand and silt, and minor clay content. They are classified mainly as sandy muds and muddy sands. Sediments around the islands are characterized by high sand content (>80%), with the volcanoclastic component predominating around Milos and Santorini and the biogenic component in the rest of the area. Offshore sand decreases to smaller contents. The silt content is up to 70%, the higher values are observed mainly in the Cretan Sea. The clay content is also up to 60%. The carbonate content exhibits high values (60 to >80%) in the areas where the biogenic component predominates in the sand fraction.

6.2.3 Spatial and temporal distribution of nutrients, dissolved oxygen and pH

863. The Mediterranean Sea is oligotrophic and thus chlorophyll and nutrient concentrations are lower than in the other regional seas. The Eastern Mediterranean Sea is an extreme oligotrophic environment (Krom *et al.*, 2003; 2005). The ultra-oligotrophic status is reflected in the exceptional water clarity low concentrations of nutrients, extremely low values for all phytoplankton related variables, including chlorophyll a, primary production and cell abundance dominance of small-size phytoplankton and outstandingly low bacterial abundance and production (Psarra *et al.*, 2005 and references therein); this extreme ‘‘poverty’’ has also been verified by satellite imagery of sea-surface chlorophylls and derived primary production (Bosc *et al.*, 2004).

864. Primary productivity in the eastern Mediterranean (and particular in the Levantine basin) has been shown to be phosphorus limited (Krom *et al.*, 1991) or co-limited as recently verified (Krom et al 2005, Law *et al.*, 2005, Psarra et al 2005, Pitta et al 2005, Zohary et al, 2005). Satellite snapshots and maps of averages (seasonal and/or multi annual) are available that can be used to monitor algal blooms and primary production on a long term basis in order to detect modifications in the biogeochemical equilibrium and assist in monitoring the onset and impacts of eutrophication (Figure 6.5). However no long time series exist of field data to acquire a trend of nutrient enrichment and eutrophication.

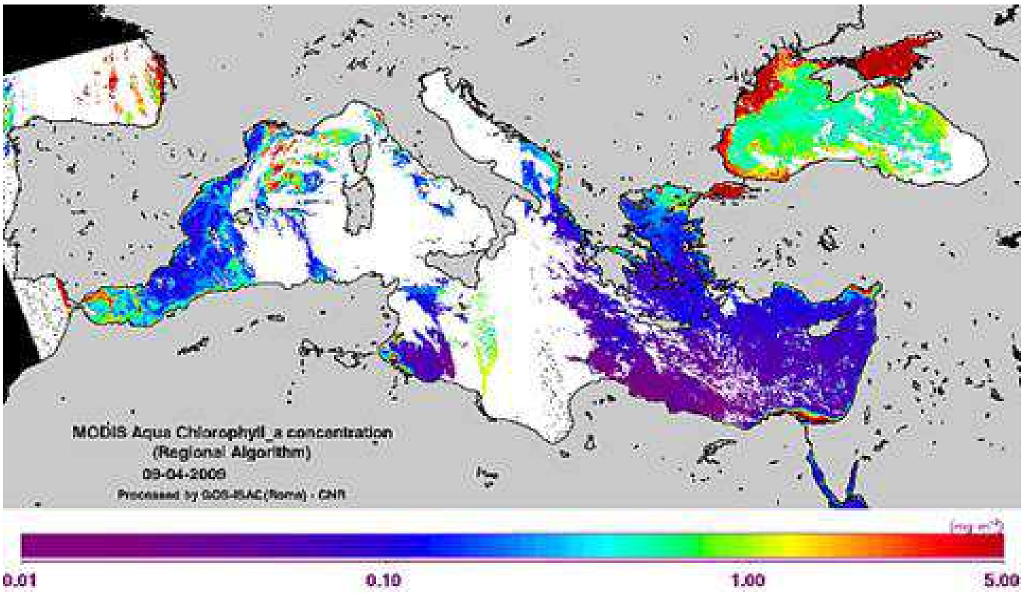


Figure 6.5. MODIS Aqua chlorophyll-a concentration (regional algorithm), 9/4/2009.Source: HCMR Poseidon System

865. The general spatial and temporal trends of algal blooms and primary production can be summarized by the main findings of Bosc et al (2004) when analyzing SeaWiFS data. All the subregions in this basin are characterized by low chl-a concentrations all around the year (e.g. 0.03 to 0.3 mg m_3 for spatial averages), the lowest concentrations being observed in the Levantine Basin (with the exception of waters at the boundary of the Nile plume). A marked seasonal cycle is observed in the various regions, with a decrease of the algal biomass by a factor up to 3–4 from winter to summer (e.g. for the Levantine Basin, from 0.12 to 0.03 mg m_3 on average, Bosc et al 2004), and large interannual variation (e.g in 200-2001 the largest decrease is observed for the Aegean Sea (-14%), and the North Levantine Basin (-11%) as depicted in satellite image analysis. Seasonal and interannual variations are also present in primary production where surface biomass in most provinces decreases significantly from winter to summer and as a result, primary production exhibits a weakly marked maximum over summer.

866. In recent assessments of Chlorophyll and nutrients in transitional, coastal and marine waters along EU 27 countries (EEA CSI 021and CSI 023 respectively, 2009) in 2005 high oxidized nitrogen

concentrations were observed at single stations in Cyprus and Greece in Eastern Mediterranean; Greece also exhibited high concentrations of orthophosphate. Only Greece has submitted long enough time series to perform a trend analysis which shows that oxidized nitrogen concentrations are increasing at 4% of the stations, decreasing at 1% of the stations, and no statistically significant trend can be detected at the remaining 95% of stations. No statistically significant trend could be detected for orthophosphate. As for chlorophyll (investigating eutrophication in European waters) high concentrations were observed at single stations in the Gulf of Orfani in Greece; however as not long enough time series exist to detect any statistically significant trend.

867. Chlorophyll variations in surface waters, in general revealed that the highest levels correspond to the areas close to river deltas or those off large urban agglomerations. The main spatial features, detected include the general gradient in algal biomass from north to south and from west to east of the Eastern Basin, the ‘‘ultra-oligotrophic cores’’ of the south Levantine Basin (corresponding to the Mersa-Matruh and Shikmona Gyres, the Nile plume, the north-south gradient in algal biomass in the Aegean Sea, attributed to the combined effects of river inputs, northerly winter and signal from the nutrient reach Black Sea waters. Hot spots can also be identified.

6.2.4 General description of the catchment area in relation to the analysis

868. Figure 6.6 shows the catchment basins for the eastern Mediterranean subregion in orange. The area extent of the catchment basin was determined for this initial assessment report.

Figure 6.6 Catchment basins in the eastern Mediterranean subregion

6.3 Biological characteristics

6.3.1 Description of water column biological communities

869. This subregion captures less than half of the known Mediterranean species diversity, with 43% of the listed species occurring in the eastern Mediterranean. However, it should be noted that this subregion is probably the least well-studied, particularly in offshore areas. The lower level of biodiversity, at least as far as species diversity is concerned, reflects a general trend of biodiversity reduction from the West to the East, given that the conditions of the Levantine Basin are not

conducive for the thriving of the Atlantic contingent, being so biased by a founder effect. Previously, the floods of the Nile deeply affected the biology of this part of the Mediterranean Sea, however after the construction of the Aswan Dam, in the 1970s, the bearing of the Nile on the Mediterranean was severely reduced.

870. Phytoplankton diversity is high. The mean high temperatures prevailing in the eastern Mediterranean, especially the Levantine basin, impart to this region a tropical character in regard to the planktonic biota: several species of dinoflagellates, such as *Pyrocystis noctiluca, Ceratium carriense, C. trichoceros* and *C. massiliense*, which are the most common and widespread species in the Indian Ocean, and similarly, in regard to the diatoms, the *Chaetoceros-Rhizosolenia* complex, dominates the Levant Basin (Kimor, 1972). Notwithstanding the low biological productivity, the diatom and dinoflagellate flora is characterized by a wealth of species, generally characteristic of tropical and subtropical seas: according to Halim (1965) about 50 % of the thecate dinoflagellate species of the world are represented in the plankton of the southeastern Mediterranean. Another feature is the presence of an increasing number of species of Indo-Pacific origin which have entered over the years through the Suez Canal and established populations in the Levant Basin.

871. One of the most striking characteristics of the zooplankton of the eastern Mediterranean is its chaetognath fauna. This was one of the first groups to be studied along the Mediterranean and Red Sea coasts of Israel (Furnestin, 1953, 1958). Only one of the five most abundant species in both seas, *Sagitta enflata*, is common to both. The principal neritic Levantine species, *Sagitta friderici*, is unknown from the Gulf of Elat.

872. The neritic element in the copepod fauna includes *Paracalanus parvus, Euterpina acutifrons, Acartia clausii* and *Centropages kroyeri*. Offshore, and occasionally recorded inshore as well, are *Temora stylifera*, *Clausocalanus furcatus, Acartia negligens* and *Centropages violaceus*, the latter species considered an indicator of Atlantic waters (Kimor, 1983). Some deep water species of the genera *Pleuromamma*, *Luciculia* and *Euaelidus* have been recorded in the surface waters in winter (Kimor and Berdugo, 1967; Pasternak *et al.*, 1976).

873. Of special interest for the changing biogeography of this region is the occurrence of copepod species of Indo-Pacific origin in the inshore waters of the Levant Basin, such as the calanoids *Acartia centrura, Calanopia media* and *C. elliptica* (Berdugo, 1966, 1968, 1974). The evidence currently at our disposal points to a pelagic flora and fauna with some affinities to the adjoining Red Sea. The causes are probably twofold: an invasion of species through the Suez Canal, enhanced by the decline of the former salt barrier and the disappearance of the freshwater barrier following the damming of the Nile; coupled with the hydrographic heterogeneity of the Mediterranean, with higher temperatures in the Levant.

6.3.2 Information on invertebrate bottom fauna, macro-algae and angiosperms

874. Meiofauna and other invertebrate in-fauna in the eastern stretched of the subregion are well-studied and diverse in species. Benthic fauna include hundreds of species in the Nematoda, Annelida, Arthropoda, Mollusca, Chaetognatha, Echinodermata, Tunicata, Cnidaria, Ctenaria and Porifera.

875. A series of biogeographic studies published recently, show that the Aegean is the second richest area in species numbers among the Mediterranean and Black Sea regional seas. It is also demonstrated that the biodiversity indices (as calculated from polychaetes) are higher than expected and that this extreme biodiversity richness can be partly attributed to the number and total surface of the Aegean islands. The pattern of both species' number and abundance is the same in the north and south Aegean (Cretan Sea). Recent studies showed a pronounced difference between the two seas. As exhibited with other biological parameters, benthic diversity in the north Aegean is always richer in comparison to that in the south Aegean. Recent investigations provide rich and detailed information about the main benthic taxa.

876. Of the 589 hitherto known Mediterranean Demosponges, 200 occur in the Aegean Sea. The percentage of the Aegean endemic sponges is rather low for the Mediterranean as a whole. The sponge fauna presents a clear distinction between the North and South Aegean basins, the former being much more species diverse. As for anthozoans, a review of the Hellenic Anthozoan fauna

yielded 90 species in the Aegean Sea, a number accounting for at least 57.5% of their total Mediterranean biodiversity. Most species are of Atlanto-Mediterranean origin (65.6%), followed by a high percentage of endemic (17.8%) and cosmopolitan (13.3%) species. This ranking is quite similar to the one estimated for the majority of the macrobenthic taxa in the wider Aegean Sea. Representatives of the class Anthozoa occur mostly on hard substrates, where quantitative studies are very limited in Greece. The endemic actinia *Paranemonia vouliagmenensis* is the only species so far to have been classified as vulnerable in Hellenic waters. Until today, no extensive *Lophelia-Madrepora* mounds have been discovered in the Aegean Sea, although the species' presence has been long verified by some broken but live colonies dredged off Thassos Island. Numerous findings of loose coral rubble and coral-bearing hardgrounds confirm the previous occurrence of cold-coral reefs in this region and suggest that live coral grounds may still persist in some hitherto unexplored areas.

877. A total of 132 sponge species are known from the Aegean and Mediterranean Seas of Turkey: 47 species have been recorded from Izmir Bay, including 18 new records for the Turkish fauna; 34 species were Gökçeada Island and production possibilities and recorded 34 sponge species in the area. In a monograph on sponge fisheries 73 species were recorded, whereas 13 sponge species were recorded from the north shore of Gökçeada Island. In Turkey 131 Anthozoa species occur, whereas 23 hydroid species are reported from the Aegean Sea. The Scyphozoans *Pelagia noctiluca, Chrysaora hysoscella, Aurelia aurita, Rhizostoma pulmo,* and *Cotylorhiza tuberculata* are native species in the Aegean and Levantine coasts. No gelatinous plankton bloom has been reported from the Turkish part of the Aegean and Mediterranean Seas. Sea fans, such as *Eunicella singularis* and *E. cavolinii,* are under threat due to mass diving tourism in some areas such as Ayvalık, Bodrum and Datça. Also in Turkish waters, 42 bryozoa species are reported from the Mediterranean and 112 species from the Aegean Seas, while 570 polychaeta species are recorded from the Aegean and Mediterranean part, including alien species.

878. A total of 1160 mollusc species have been recorded so far in the Hellenic seas, while a recent assessment of the decapod fauna in the Hellenic waters reported a total of 250 species. The most diverse in terms of species number are the true crabs (brachyurans) followed by caridean shrimps and anomurans (hermit crabs, squat lobsters), while Dendrobranchiate shrimps and macrurans (lobsters and relatives) contribute to a lesser extent to the decapod species diversity. In Turkey, the most complete study reported 220 decapod crustacean species, among which there are 75 natantia, 15 reptantia, 36 anomura and 94 brachyura from the Aegean and Mediterranean Sea. The mollusca fauna in Turkish Seas comprises over 800 species recorded along the Turkish coasts. Among these, 174 species are endemic to the Mediterranean and 55 species are Lessepsian migrants originating from the Indo-Pacific region.

879. One hundred and eight echinoderm species (70.1% of the known Mediterranean fauna) have been recorded in the Aegean Sea. The total number of echinoderm species in Turkey is 80. Syria's National Country Study For Biological Diversity (NCSBD) recorded 1027 faunal species, benthic fauna species comprised 34 Nematoda, 10 Annelida, 166 Arthropoda, 315 Mollusca, 7 Chaetognatha, 12 Echinodermata, 13 Tunicata, 40 Cnidaria, 1 Ctenaria and 15 Porifera. Most species are regarded as rare in the Syrian coast, and only 8 species of gastropods, 1 bivalve, 5 crustaceans, 1 echinoderm, 1 cnidarian and 2 ascidiacea were abundant.

880. In Lebanon, 662 species macrozoobenthic species were identified in Lebanese coastal waters: Polychetes (136 species), Mollusks (298 species), Crustacea (104 species), Echinoderms (16 species), Nematodes (2 species), Sipunculoidea (2 species), Ascidiacea (26 species), and Porifera (33 species). Comprehensive studies on the population dynamics and the biomass of benthic organisms are lacking.

881. Knowledge about the benthic ecosystem in Egyptian Mediterranean waters is almost restricted to the Alexandria region with but one exception, the site of El Dabaa 160 km west from Alexandria. Long term changes appear to have taken place in the structure and composition of the benthic communities in the last few decades.

Macroalgae

882. In general, 35% of marine algal species and 75% of spermatophytes are now regarded as threatened species in Syria (NCSBS, 2002), and this may be representative of other developed

portions of this subregion. Coastal activities and the associated sedimentation, beside other unfavourable conditions such as pollution and climate change will accelerate local extinctions.

883. About 300 macroalgal species have been recorded from the subregion within the Mediterranean coast of Israel – a number that falls far short of the more than 1,100 species known for the entire Mediterranean. This may be due to the small number of specialists and the meager number of studies conducted throughout the 20th century, but may reflect also lower biodiversity due to the extreme oligotrophic conditions, paucity of shallow rocky habitats, and recently, to the rapid degradation of the littoral.

884. The total macrophyte taxa inhabiting the Hellenic coasts are estimated to ca. 500 species, referred to different geographic elements, e.g. Mediterranean Endemic, Eastern Atlantic warm-temperate, Amphi-Atlantic tropical to (warm-) temperate and Indo-pacific tropical to (warm-) temperate. Species endemic to the Eastern Mediterranean are very scarce. Many records are problematic since morphological descriptions and voucher material is limited. The Aegean Sea is by far the better-investigated area of the Hellenic coasts. The *Cystoseira crinita* algal community was studied at different pristine Aegean Sea sites in order to describe the NATURA 2000 sites. In total 113 taxa (73 Rhodophyceae, 25 Phaeophyceae, 15 Chlorophyceae) were identified.

885. Recently, the endangered species *Tenarea tortuosa* (Esper) Lemoine has been observed in the Mediterranean around Kalkan, where it forms barriers. Various species have been observed forming Maerl on coralligenous and sandy substrates in deep or shallow water in the middle and south Aegean. Nine coralline macroalgal genera (*Corallina, Amphiroa, Lithophyllum, Titanoderma, Haliptilon, Jania, Hydrolithon, Pneophyllum, Neogoniolithon*) have been recorded on the Mediterranean coastline.

886. One hundred seventy three macro-algal species have been identified from various littoral terraces along Syrian coast: they are 79 from Rhodophyta, 34 Chlorophyta, 32 Fucophyta and 28 Cyanophyta. They are distributed as 109 species in the infralittoral zone, 50 species in the Mediolittoral zone, 3 in the supralittoal zone, 8 in both infralittoral & Mediolittoral zones and 3 in both the Mediolittoral & supralittoal zones. Invasive species such as *Galaxaura lapidescens* and *G. rugosa* flourish in some areas, where *Cystoseira amentacea*, a sensitive species to pollution, diminished.

887. In Lebanon, studies on benthic species are scant. About 243 species of macrophytes have been identified in Lebanese waters: Cyanophyta (25 species), Xanthophyta (1 species), Chlorophyta (58 species), Phaeophyta (29 species), Rodophyta (127 species) and Monocotyledones (3 species).

888. With regard to the Egyptian algal flora, several macroalgal species which were obviously common in surveys carried out in the 1940s appear to be absent at present. *Cystoseira compressa*, a previously common species is no more to be found. In the meantime, *Caulerpa racemosa* and *Tricleocarpa oblongata*, not recorded in the Fourties, are commonly found at present.

889. About 300 macroalgal species have been recorded from the Mediterranean coast of Israel – a number that falls far short of the more than 1,100 species known for the entire Mediterranean. This may be due to the small number of specialists and the meager number of studies conducted throughout the 20^{th} century, but may reflect also lower biodiversity due to the extreme oligotrophic conditions, paucity of shallow rocky habitats, and recently, to the rapid degradation of the littoral.

890. Though the macroalgae are recognized for their high rate of endemism in the Mediterranean, only a single species was recognized as endemic off the Israeli coast, *Cystoseira rayssiae* Ramon, 2000. The rapid physical modification of the coastline and pressures of land and sea-based pollution, destructive trawling, dredging in addition to the establishment of alien seaweeds mean that the makeup of the flora has been altered.

Angiosperms

891. On soft substrates of the Aegean Sea, the angiosperms *Posidonia oceanica* and *Cymodocea nodosa* are widespread, while angiosperms *Zostera noltii* and *Halophila stipulacea* are restricted to specific areas.

892. Three angiosperm species are present in the Syrian marine ecosystem, *Cymodocea nodosa***,** *Halophila stipulacea***,** *Zostera noltii***.** Studies have shown that *Posidonia oceanica,* which was present in Syrian waters in the seventies of the last century, is no longer present in any part of Syrian marine waters. The disappearance of *Posidonia* meadows may indicate habitat degradation at large scale and may lead to disappearance of many species associated with it.

893. According to literature there are three main species of angiosperms in the Lebanese coastal waters: *Zostera nana (=Zostera noltii)* which does not form dense meadows; *Halophila stipulacea* which is rare and has Indo-Pacific origin; and *Cymodocea nodosa* inhabits the Mediolittoral and Infralittoral zones and occupies a relatively low percentage cover. The scarcity of extensive areas of sandy seabed and the destruction of existing ones by anthropogenic activities and pollution may be the main factors limiting the distribution of angiosperms in Lebanese coastal waters. The phanerogame *Posidonia oceanica* also grows in patchy meadows in Egyptian waters, west of Alexandria.

6.3.3 Marine mammals, reptiles and seabirds

894. Several flagship species of great conservation interest are present in this part of the Mediterranean Sea. The most notable one, especially in this region, is the Mediterranean monk seal (*Monachus monachus*), is still present in Greece, Cyprus and Turkey. This part of the Mediterranean is also very important for the great availability of nesting sites for marine turtles, especially *Caretta caretta*, and for the presence of many species of cetaceans.

Marine mammals

895. Of the 14 cetacean species listed from the Mediterranean, ten are known from the Levantine Basin: five may be considered residents: *Tursiops truncatus, Stenella coeruleoalba, Grampus griseus, Delphinus delphis,* and *Ziphius cavirostris*, and five visitors, *Steno bredanensis, Pseudorca crassidense, Physeter macrocephalus, Balaenoptera acutorostrata* and *Balaenoptera physalus*. *T. truncatus* is by far the most common, associated with commercial trawlers and accounting for nearly all reported net entanglements.

896. Out of the 12 cetacean species reported from Greek seas, seven are represented by permanent and commonly observed populations. The most abundant one is the striped dolphin (*Stenella coeruleoalba*), followed by the bottlenose dolphin (*Tursiops truncatus*), the common dolphin (*Delphinus delphis*), the sperm whale (*Physeter macrocephalus*) and the Risso's dolphin (*Grampus griseus*)**.** The Aegean Sea is an area of particular importance for the harbour porpoise (*Phocoena phocoena*), which is strictly limited in the north and mainly in the shallow plateau of the Thracian Sea. This rare species is not to be found anywhere else in the Mediterranean but the Black Sea. Until today, no quantitative data regarding cetacean species abundance are available and no critical areas have been defined for their conservation.

897. In the Turkish Aegean Sea and Mediterranean Sea, nine cetacean species have been known to occur: *Delphinus delphis, Tursiops truncatus, Stenella coeruleoalba, Globicephala melas, Grampus griseus, Pseudorca crassidens, Physeter catodon, Ziphius cavirostris* and *Balaenoptera physalus.* In the northern Aegean Sea, *Phocoena phocoena* is known to occur but only occasionally. All these cetacean species are found in the Turkish waters and, as a result, all have been under legal protection since 1983. In January 2009, a rare beaked whale species, *Mesoplodon europaeus,* stranded alive in Fethiye Bay in southwestern Turkey. A national cetacean protection strategy was established in 1994. During 1990-1997, 23 stranded cetaceans were recorded. Whereas 20 strandings were reported during 2001-2003 in the Aegean Sea, including four strandings of the sperm whale.

898. Collection of field data on cetacean stranding along the Syrian coast during the period 2003-2009 reported 15 stranded dead individuals: *Tursiops truncatus* (6 cases), *Ziphius cavirostris* (5 cases), *Megaptera novaeangliae*, *Physter catodon*, *Balaenoptera physalus*, *Grampus griseus* were represented by one individual each. Records from Lebanon exist for *Delphinus delphis*, *Stenella coeruleoalba*, *Tursiops truncatus* and *Physeter macrocephalus.*A cetacean survey over the Israeli continental shelf was conducted during September 2005, yielding 14 cetacean sightings (53 individuals) on five out of the 15 survey days. They included the first sightings of off-shore *T. truncatus*

and a group of 25 *G. griseus* sighted already in June 2005, suggesting a long-term residence of the species in the area. In 2009 surveys along 1,608 km sighted 39 *T. truncatus* individuals. The population is estimated at 360 individuals. The low overall sighting rate (0.088 animals per nm) is in line with the extreme oligotrophy of the Levant.

899. The cetacean populations off the Israeli coast have hardly been studied systematically. Marchessaux (1980) recorded eight species of cetaceans from the existing literature, his own data, and from the national natural history collections at Tel Aviv University and the British Museum of Natural History. Current information is based on beached or entangled specimens and opportunistic sightings collected by IMMRAC since 1993 (Goffman *et al.* 2000, 2006). Of the 14 cetacean species listed from the Mediterranean, ten are known from the Levantine Basin: five may be considered residents, bottlenose dolphin (*Tursiops truncatus*) striped dolphin (*Stenella coeruleoalba*), Risso's dolphin (*Grampus griseus*), common dolphin (*Delphinus delphis*), and Cuvier's beaked whale (*Ziphius cavirostris*), and five visitors, roughtoothed dolphin (*Steno bredanensis*), false killer whale (*Pseudorca crassidense*), sperm whale (*Physeter macrocephalus*), minke whale (*Balaenoptera acutorostrata*) and fin whale (*Balaenoptera physalus*). *T. truncatus* is by far the most common, associated with commercial trawlers and accounting for nearly all reported net entanglements.

900. The rare beachings of sperm whales (*Physeter macrocephalus*) and fin whales (*Balaenoptera physalus*) may result from accidental straying or of drifting of floating carcasses. A carcass of the false killer whale (*Pseudorca crassidens*) was found on July 13 2004 and sighted twice in a group at sea. Two calves of minke whale (*Balaenoptera acutorostrata*) which drowned entangled in gill nets were reported in Akko in May 2000 and in Haifa on February 2004, and an adult was sighted near Haifa port in winter 2005. Frequent sightings at sea of *S. coeruleoalba*, *D. delphis* and *G. griseus* attest to an apparently year-round presence. The Mediterranean population of *D. delphis* has been designated 'endangered' on account of past and present negative size trends. Yet, off the Israeli coast, there has been a surge of sightings of large groups (20->70 animals) in recent years. Strandings and sightings of *S bredanensis,* including an unusual sighting of a large pod foraging inside Haifa Harbor, all occurring during February-April, suggest a seasonal presence. An uncertain identification raised the possibility of an introduction of a Red Sea species (*Sousa chinensis*) through the Suez Canal (Kerem *et al.*, 2001). A cetacean survey over the Israeli continental shelf was conducted during September 2005 to estimate the population abundance of cetaceans residing along the Israeli shoreline (www.ecoocean.com/en/scientists/research. They included the first sightings of off-shore *T. truncatus* (18.5 – 55.5 km from shore, at depths of 170 to >1200 m) and an apparent reencounter with a group of 25 *G. griseus* sighted in June 2005, suggesting a long-term residence of the species in the area. The low overall sighting rate (0.088 animals per nm) is in line with the extreme oligotrophy of the Levant.

901. The Greek populations of the monk seal (*Monachus monachus*) are estimated to represent ca 90% of the total Mediterranean abundance of the species. In particular, the Aegean Sea is known to host more than 78% of the species' total Hellenic population (about 200-250 individuals; Cebrian, 1998). The Northern Sporades, the Kimolos-Polyaigos and the Karpathos-Saria complexes as well as Gyaros island are prominent for resident and breeding populations in the Aegean Sea. So far, only the Northern Sporades Islands enjoy a legal protection framework, formally established in 1992 (PD 519/28-5-92) as the first Hellenic Marine Park to protect the population of the monk seal.

902. Turkey also has a monk seal population and has had the Mediterranean monk seal under legal protection since 1977. A national strategy has been prepared in order to coordinate all the efforts for the survival of this species and to develop a comprehensive policy. The Aegean Sea, with small, quiet and isolated islets and islands, calm beaches and underwater caves, is the most important monk seal habitat in Turkish waters. However, due to tourism and fishing pressure and over-urbanization, the monk seals are losing their habitats, this being the greatest cause of their decline. Other important threats are deliberate killing and entanglement in fishing gears and there have been several reports of seals killed by drowning in the nets. The Aegean Sea population is viable, as indicated by the presence of pups.

903. *Monachus monachus* occurred in Syria more than 38 years ago and is still present. Arwad, Tartous port, Lattakia port, Fanar Ibn Hani, Afamia, Borj Islam Oum Altiur, Ras AlBassit and Alhamam Islands are places the Monk seal is mostly encountered. The monk seal sightings during the period 2000-2010 are totaled to about 28. Due to the presence of suitable caves and beaches, monk seals

probably breed in the area. Monk seals (*Monachus monachus*) used to be observed along several beaches in Lebanon (latest record of 9 individuals at Amchit, Mount Lebanon in 1970), but there have not been any recent sighting of this species.

Marine turtles

904. Three species of sea turtles, *Caretta caretta*, *Chelonia mydas*, and *Dermochelys coriacea* are encountered in this subregion. The loggerhead turtle and the green turtle occur regularly in Hellenic territorial waters while *Dermochelys coriacea* is infrequently encountered. Only *C. caretta* is known to nest in Hellas, concentrating about 60% of the total documented nesting of this species in the Mediterranean. *Caretta caretta* is listed as Endangered and *D. coriacea* as Critically Endangered in the IUCN Red List of Threatened Species. The major threat to marine turtle populations originates from their interaction with fishing activities. Conservation efforts in a sea turtle nesting area can be undermined by the impact caused by fisheries by-catch on the same population in another area or country.

905. According to investigations made so far, 19 *Caretta caretta* and 5 C*helonia mydas* nesting sites have been identified in the Turkish part of the Aegean and Mediterranean Seas. The major nesting beaches identified for *C. caretta* are in Turkey and Greece, with smaller numbers recorded in Cyprus, Libya, Tunisia, Israel and Italy. The general reasons for decline and current threats are direct exploitation in the past, incidental capture, pollution and plastic wastes, tourism and related activities. Problems include sand extraction, photopollution from hotels, beach traffic, night access to the nesting beaches, predation of nests by foxes, dogs and jackals, sun beds and umbrellas on the nesting beaches, speed boats near the beaches and other fishery activities near the nesting grounds. Turkish law has several sections about conservation of natural and cultural heritage. The status ''Marine Turtle Nesting Beach'' provides no direct protection, but facilitates the declaration for formal protective status. Most of the marine turtle nesting beaches in Turkey are Natural SIT areas as they have scientific, ecological or aesthetically important areas on land or underwater.

906. The sea turtles present in the Syrian marine waters include *Caretta caretta*, *Chelonia mydas*, *Dermochelys coriacea*. Only the first two reproduce along the Syrian coast. Considerable numbers of turtle hatchlings were annually lost by the ghost crab *Ocypode cursor* predation. These crabs were numerous, probably due to the high levels of beach litter. Another identified threat of greatest concern was the deliberate killing or boat collision. Little has been done to estimate sea turtle populations in Syria. Estimates report 104 nests of green turtle in a 12 km sandy beach south of Lattakia. The loggerhead turtle nesting had previously been reported, making this site the most important green turtle nesting site in Syria. It is also of major regional importance as it ranks in the top 10 Mediterranean nesting beaches in terms of maximum number of nests recorded.

907. Three species of sea turtles are present in Lebanese waters: *Chelonia mydas* and *Caretta caretta* nest on Lebanese beaches, while *Dermochelys coriacea* is only a visitor. Assessment studies indicated that there are currently 19 beaches (12 south of Beirut and 7 north of Beirut) that represent potential nesting habitats. This was one the reasons for declaring two coastal nature reserves by law: “Tyre Coast Nature Reserve” (Decree 708, 12/11/1998) and the “Palm Islands Nature Reserve” (Decree 121, 12/03/1992). Annual nesting numbers remain speculative due to lack of standardized monitoring of the main nesting areas. Catching turtles, whales and seals is strictly prohibited throughout Lebanese territorial waters, but accidental catches in the nets of fishermen occur on a regular basis.

908. Up to the mid 20th century hundreds of *Caretta caretta* nested along the Mediterranean coast of Israel. In the 1950's, some 200 nests with a density of about 15 nests per km were recorded on 15 km of typical beach in northern Israel. However, the number declined rapidly thereafter. Both *Chelonia mydas and C. caretta* nest in small numbers on the Mediterranean coast of Israel. A national management program was prepared and implemented since 1993 by the NNPPA. The main threat to turtle nests is the intensive traffic of four wheel drive vehicles on the beaches. Other threats are predation by foxes, inundation by sea water during summer storms, growing urbanization along the coastal plain threaten nestlings with disorientation by anthropogenic light sources, traffic, as well as nighttime human activity, may disturb nesting female turtles. From data gathered from stranded carcasses of *C. mydas*, 60% of the injuries were fishing related (Levy, 2008).

909. Knowledge about marine turtles in Egyptian waters remained anecdotal and fragmentary until when all beaches between Alexandria and Sallum on the border with Libya were surveyed for the occurrence of marine turtle nests during the peak nesting season in June-July 1993. Of the 602 km surveyed, only 255 km consist of sandy beaches forming a potential nesting area for marine turtles, the remaining coast being rocky; all nests were from loggerhead turtles.

910. The Nile Soft-shelled turtle (Trionyx triunguis) is not a marine turtle species but its presence in coastal areas merits its discussion here. This species of fresh water turtle is listed by IUCN as "critically endangered" in the Red Data Books and the Mediterranean population has been classified in category "CR C2A" which means that the population suffers from a continuing decline in numbers of mature individuals and population structure, and that the (sub-) population does not contain more than 1000 mature individuals. This species is also included in Appendix II of the Bern Convention and Appendix III of CITES. It is often caught as by-catch in fisheries together with marine turtles, and even shares some nesting beaches with marine turtles such as the Dalaman and Dalyan beaches.

Seabirds

911. Greek waters are rich in seabirds, including inter alia, the Yelkouan Shearwater and other shearwater species, Mediterranean Shag, Pygmy Cormorant, European Storm-Petrel, Northern Gannet, Great Cormorant, Pomarine Skua, Arctic Skua, Long-tailed Skua, Great Skua, Audouin's Gull and many other gull species, 11 tern species, as well as numerous shorebird species belonging to the family Scolopacidae.

912. Algal blooms negatively affect some seabird species in this subregion. For instance, a bloom that began at the end of 2009 has had devastating effects particularly on the breeding performance of the Mediterranean Shag in the Northern Aegean, where the species largest colonies in Greece are located. The breeding success was literally decimated, as some colonies produced up to 50 times less juveniles then during previous years. The extent of algal bloom was much greater than initially expected reaching as far as Limnos, Northern Sporades and Skyros in the central Aegean Sea. Similarly, seabird surveys at sea indicate that areas affected by algal bloom are inhospitable to seabirds which avoid them (www.ornithologiki.gr).

913. Turkey is a natural corridor for many species of migratory birds and their protection has been developed in recent years. However, habitat loss due to drainage, water diversion, changes in annual water regime, eutrophication, reed cutting, and land fills, chemical pollution, and hunting are main threats for the sea birds in Turkey. Coastal wetlands and islands off the coast are important habitats for birds. Many of them host significant bird communities, some of which include threatened species. Among such species, pygmy cormorant, dalmatian pelican, marbled teal and Audouin’s gull are particularly important both regionally and nationally. *Larus audouinii* and *Falco eleono*rae are endangered species.

914. Lebanon is a main route for the migration of birds in the East Mediterranean making it rich in avifauna. The revised checklist of the birds of Lebanon lists 395 species that includes 144 coastal species belonging to 12 orders (marine or of marine affinity) of which five are threatened at the global level and 90 are classified of high significance according to the AEWA Convention. The most threatened coastal and marine avian species belong to the Pelecaniformes, Anseriformes, Accipitriformes, Gruiformes, and Charadriformes. Few of these species breed in the coastal belt of the country. The relative poverty in breeding birds can be attributed to disappearance of coastal wetlands, extensive urban development along the coastline, hunting and continuous anthropogenic disturbances.

915. In Israel, pond farming along the northern and central coastal plain expanded during the 1970’s, and attracted many species of water birds, especially during migration. Eleven marine and coastal threatened and endangered species (*Calonectris diomedea, Puffinus yelkouan, Hydrobates pelagicus, Pelecanus onocrotalus, Phoenicpterus rubber, Pandion haliaetus, Falco elenorae, Larus audouinii, Sterna bengalensis, S. sandwicensis, S. albifrons*) have been recorded along the Mediterranean coast of Israel, in addition to 73 native, migrant and visiting species (Shy, 2002). Marine birds nest on some islets off the Mediterranean coast of Israel, and about 2,000 *Phalancrocorax carbo* overwinter on islets off Rosh Hanikra. As Israel is on a major flyway for migratory birds, the aquaculture farms in Israel are susceptible to damage from piscivorous waterfowl

during migration stopovers. Some 75,000 *Pelecanus onocrotalus* migrate twice annually through Israel. In addition, tens of thousands of piscivorous waterbirds, like *Phalacrocorax carbo* and *Nycticorax nycticorax* over-winter in Israel. The NNPPA formulated guidelines for using netting over fishponds in Israel in order to reduce the mortality of piscivorous waterbirds and tries to reduce the damage caused to pond farmers by piscivorous birds, and to limit the use of guns and netting. . Other threats to coastal and marine birds stem from coastal urbanization, natural habitat despoliation and degradation, with much of the coastal streams reduced or badly polluted; direct anthropogenic interference with nesting, feeding, roosting and resting; increased predation by species attracted to litter (jackals , foxes, Egyptian mongoose, feral dogs, black rats, brown common rats, black kites and hooded crows) that impact also the birds' breeding success.

916. Ornithological knowledge about birds in Egypt on the coast between Alexandria and Sallum is very poor. The regular presence of the Greater Sand Plovers, *Charadrius leschenaultii* is noted. During the autumn and spring migration, however, the Mediterranean coast receives vast numbers of Palearctic migrants. The Nile Delta wetlands are of particular importance for a large number of migrant water bird species. According to several bird counts hundreds of thousands of wintering waterfowl visit these wetlands every year. The Egyptian wetlands therefore proved to be one of the most important areas for waterfowl in the Eastern Mediterranean region and the entire continent of Africa. The numbers of Whiskered Tern *Childonias hybridus* wintering in Lake Borullos is one of the largest concentrations of this species in the world. The largest bird count of water birds in any of the wetlands of Egypt was counted in Lake Manzala, with prominence of cormorants, waders, gulls and terns. Large numbers of water birds, notably herons, egrets, ducks, waders, gulls and terns pass through the Zaranik area at the eastern end of the lake. The breeding population of Little Tern, Sterna albifrons and the Kentish Plover *Charadrius alexandrinus* at L. Bardawil are among the largest in the Mediterranean. Populations of the Greater Flamingo *Phoenicopterus ruber* are among the largest in the country.

6.3.4 Exotic, non-indigenous and invasive species

917. Most information on non-indigenous species (NIS) regards is occurrence data, and it is seldom the case that some more information is reported, unless the species do have some commercial effect or are of some harm to human activities. Species numbers are underestimated, since only the obvious species are usually recorded whereas, due to lack of expertise on most of marine taxa, inconspicuous species are very probably passing unnoticed.

918. The routes of the access of alien species by ship transportation may be categorized such as transportation with ballast water, sessile (fouling) and vagile (clinging) form on ship hulls. International straits used for navigation in the Mediterranean and Black Sea are biological corridors at the same time from the biogeographical pont of view. For example, one of the intentionally introduced fish species, *Mugil souyi,* was first introduced to the Azov Sea and after the successful colonization there, entered to the Black Sea via the Kerch Strait. Later it entered the Strait of Istanbul, the Strait of Çanakkale and the Sea of Marmara and is presently found in Mediterranean Sea. There are some other examples such as *Rapana venosa* and *Mnemiopsis leidyi*. Their first record was in the Black Sea and after the successful migration through the Straits, they penetrated to the Aegean and Mediterranean Seas. The Straits of Gibraltar are also important for the Atlantic originated species distribution inthe Mediterranean and Aegean Sea. Through the Suez Canal, several marine species migrate to the Mediterranean Sea such as marine phanerograms, macrophytes, coelenterates, molluscs, crustaceans and echinoderms as well.

919. Alien fish species entered the Mediterranean Sea via four pathways: a) via the Straits of Gibraltar, b) via the Suez Canal, c) via the Çanakkale Strait and d) via human activities such as ship-meditated transportation, mariculture and others. Besides fish, molluscs and crustaceans, some other alien taxa are also found mostly in the eastern Mediterranean Sea, such as several jellyfishes, ctenophores, polychaetes, ascidians and echinoderms.

920. In Greece, 172 alien species have been recorded in the Aegean Sea, 145 of which occur in the South Aegean and 72 in the North Aegean. Of them, 101 species are well established and spreading. They are mostly zoobenthic species, followed by macroalgae and fish. Several Indo-Pacific species of fish were reported in the Dodecanese (SE Aegean) almost simultaneously as in the coasts

of Israel. Such are the cases of *Siganus rivulatus*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Pteragogus pelycus* and *Fistularia commersonii.* The trend in fish species introduction and establishment success is increasing; *Scomberomorus commerson* was recorded in 2007, *Lagocephalus sceleratus* spread rapidly in the Aegean; *Upeneus pori, Scomberomorus commerson* and *Torquigener flavimaculosus* are recorded more and more often. Their mode of introduction is mostly through the Suez Canal. With regard to the origin of species, 98 species (56%) are of Indo-Pacific origin, 27 species (16%) come from the Atlantic, and 10 species (6%) originate in the Pacific, while the rest are mostly warm water species having a subtropical, circumtropical or pantropical distribution.

921. In 2005 a list of alien species reported from the Turkish coasts yielded 263 species belonging to 11 systematic groups, of which Mollusca had the highest number of species (85 species), followed by Crustacea (51), fishes (43) and phytobenthos (39). The Black Sea hosts a total of 20 alien species, the Sea of Marmara 48 species, the Aegean Sea 98 species and the Levantine Sea 202 species.

922. In Turkish waters, Red Sea fish species accounted for a large proportion of the total demersal fish biomass: 62% in the Gulf of Iskenderun, 34% in Mersin Bay and 27% in the coastal strip between Incekum and Anamur. Out of the 227 fish species recorded from Syrian marine waters, 54 (23.7%) entered the area either from the Red Sea through Suez Canal (39 species, 17.1%) or from the western Mediterranean and the Atlantic through the Straits of Gibraltar (15 species, 6.6%).

923. Regarding the non-indigenous bottom fauna species, 30 species of Indo-pacific orign were recorded in Syria, among which some prominent examples are: *Cerithium scabridum, Strombus decorupersicuss, Gafrarium pectinatum*, *Brachidonta pharaonis, Spondyllus spinosus*, *Charybids helleri*, *Portunus pelagicus, Penaeus japonicus, Phallusia nigra*. Lessepsian Macro-algae include *Caulerpa racemosa var. lamourouxii, Stypopodium schimperi*, *Asparagopsis taxiformis*, *Neomeris annulata, Caulerpa scalpelliformis*, *Caulerpa mexicana* and *Galaxaura rugosa*. Other record of alien species for the Eastern Mediterranean include: *Acetabularia parvula, Cystoseira balearica, C. caespitosa, C. barbatula*.

6.3.5 Fisheries species abundances and spatial distributions

924. Fish species diversity in this subregion is high, both in chrondrichthys and osteichthys, with the major portion of bony fish species in the following families: Scombridae, Clupeidae, Carangidae, Sparidae, Labridae Serranidae, Mullidae, and Mugilidae. In this region, there is a mixing of classically “Mediterranean” species with species from the Red Sea and Indo-Pacific. For instance, out of the 227 fish species recorded from Syrian marine waters (Ibrahim *et al. 2010a;* Ammar *et al., 2009;* SAAD*, 2005,* Ibrahim *et al., 2002)*, 54 (23.7%) (see appendix 1-d) entered the area either from the Red Sea through Suez Canal (39 species, 17.1%) or from the western Mediterranean and the Atlantic through the Straits of Gibraltar (15 species, 6.6%). The Indo-Pacific originated invasive fish species are common in the Syrian marine ecosystem, especially in the recent years.

925. Hellenic Seas are characterized by a thermophilic tropical and subtropical fish fauna originating from two different sources: i) relicts of the Tethys Sea and ii) immigrants of various origin arriving at different times from the Indian Ocean and the Red Sea. Overall, the total number of marine fish species reaches 485. Among these, according to the latest update of the IMAS-Fish database, the total number of recorded Hellenic fish species collected from experimental and onboard sampling by trawls, purseseines, nets and beachseines, since 1983 is 393. Of these, 365 occur in the Aegean Sea. The following species are included in the Red list of threatened animals in Greece: Critically endangered: *Carcharias taurus, Isurus oxyrinchus, Lamna nasus, Oxynotus centrina & Dipturus batis*; Endangered: *Carcharodon carcharias, Carcharhinus plumbeus, Thunnus thynnus & Mobula mobular*; Vulnerable: *Heptranchias perlo, Cetorhinus maximus, Alopias vulpinus, Centrophorus granulosus & Alosa macedonica.*

926. Available data on the number of species and diversity patterns of soft bottom demersal fish assemblages in Hellenic waters are derived from experimental trawl surveys conducted on a seasonal basis. These studies have shown that the number of demersal fish of interest to fisheries is positively correlated with increasing latitude (increasing form south to north) and negatively related with increasing longitude (decreasing from west to east).

927. Hellenic marine fisheries are characterized by a large number of species caught per main fishing gear (i.e. multi-species fisheries) as well as by a variety of species that are exploited concurrently by different fishing gears (i.e. multi-gear fisheries). In the mean landings per fishery over the 1982-2003 period, more than 30% of the mean trawl landings was dominated by five species (*M. merluccius*, *M. barbatus*, *T. mediterraneus*, *S. smaris*, and *Micromesistius poutassou*). For purse-seiners, five species (*E. encrasicolus* and *S. pilchardus* and, to a lesser extent, *T. mediterraneus*, *B. boops* and *S. japonicus*) cumulatively contributed more than 84% of the mean total landings. For beach-seiners, more than 60% of the landings were comprised mainly by *S. smaris*, *S. pilchardus* and *B. boops*. Finally, only 30% of the mean ‘other coastal boats’ landings was comprised of five taxa (*S. pilchardus*, *B. boops*, Mugilidae, *S. smaris* and *E. encrasicolus*). Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) are the two most important small-sized pelagic species in the Mediterranean, making up 18-25% of the total Hellenic landings and 60% to 70% of the total purse seine landings.

928. Out of a total of 1160 molluscan species recorded so far in Hellenic seas, 21 (besides the Cephalopoda) have a commercial interest particularly in fisheries and aquaculture since they are collected and/or cultivated for human consumption. Additional species have been either traditionally harvested as food resources, collected for use as fish baits, or intentionally imported for culture during the last decades are still exploited in certain coastal areas of Hellas. Apart from a few species and only at a local scale (e.g., *Pinna nobilis, Lithophaga lithophaga, Donacilla cornea*), there is no population assessment in the Hellenic seas. Populations of *P. nobilis* have been greatly reduced over the past few decades, but important local populations still exist in Hellenic seas. Nowadays it has been declared an endangered species and its exploitation has been banned. *L. lithophaga* is endemic to the Mediterranean Sea. In the Aegean Sea, the species is found in the N Sporades Islands, the Dodecanese, Kriti, Lesvos Island, Maliakos and Argolikos gulfs, and the Chalkidiki penninsula. The population density of this species is high in the N. Evvoikos Gulf (36 inds/dm^3). In the past, *L. lithophaga* was extensively exploited in the Hellenic seas and it was found in seafood markets and fish restaurants at many locations. It is still exploited by divers (illegally), though this species is under strict protection.

929. Studies on demersal cephalopod assemblages are available only from the northernmost part of the Aegean Sea. *A. media*, *L. vulgaris*, *E. moschata*, *O. vulgaris* and *S. elegans* dominated catches on the upper shelf of both studied areas, with *S. officinalis* showing a very high abundance on the coastal shelf areas of the North Aegean Sea. It’s interesting that the Aegean Sea harbours 20 species, 62.50% of the known Mediterranean Teuthoidea (squid) fauna. Molluscan species of major commercial value in the Hellenic Seas (more than 90% of the total production) are the gastropod *Hexaplex trunculus* and the bivalves *Modiolus barbatus*, *Mytilus galloprovincialis* (both collected from natural banks and aquaculture units), *Arca noae*, *Cerastoderma glaucum*, *Donax trunculus*, *Chlamys glabra*, *Ostrea edulis*, *Callista chione*, *Ruditapes decussatus* and *Venus verrucosa*. The caramote prawn, *Penaeus (Melicertus) kerathurus*, lives in coastal marine or brackish waters on muddy sand or sand, usually at depths between 5 and 50 m. It prefers areas in the vicinity of estuaries where its nursery grounds are located. The shrimp is fished both by trawlers and the artisanal fleet. Trawl catches in the Thermaikos Gulf vary greatly inter and intra-annually, with maximum catches of up to 7.5 kg/h occurring at the beginning of the fishing season.

930. Of the 500 fish species recorded in the Turkish part of the Mediterranean coastal waters and 300 in the Aegean Sea, about 100 species of fish and invertebrates have potential commercial value. The contribution of the Aegean Sea and Mediterranean Sea to the fishery production of Turkey is 12 % and 10 %, respectively. The main fish species caught by artisanal fisheries in the Aegean and Mediterranean part of Turkey are red mullet *Mullus barbatus,* surmullet *Mullus surmuletus,* gilthead seabream *Sparus aurata,* seabasses *Dicentrarchus labrax* and Atlantic horse mackerel *Trachurus trachurus.* These fish were caught by set nets, trammel nets and long lining in the Turkish waters. On the other hand, commercial fisheries is a main sector of the Turkish economy, with fishing targetting highly migratory fish such as bluefin tuna, swordfish, albacore tuna and stocks of small pelagics like anchovy and sardine. Today, nearly 250 registered trawlers operate in the Aegean and the Turkish Mediterranean coast putting heavy fishing pressure on the fish stocks. This increase in industrial fishing power and the subsequent reduction in the total catch of main target species by small-scale coastal fishermen is well studied. The CPUE (catches per unit effort) has dropped 10 times during the last 15 years in the Mediterranean Sea. Furthermore, not only has the size of the individuals been

remarkably reduced in the last two decades, but also low-value "trash" fish has replaced large valuable commercial fish species. Today, there is a remarkable decline in the stocks of large sized species like sharks, groupers (Serranids) and in rare species such as sea horses (*Hippocampus* spp.). Use of detrimental fishing gears is increasing threat to diminishing fish stocks. Use of dynamite for fishing purposes is reported from some areas on the near shore rocky littoral zones, a favourable settlement and nursery ground.

931. Syria's trawling grounds on the shelf are ≈300 km^2; grounds are unsuitable for trawling, may be exploited by other means of fishing. The official figures of marine fish landing is totaled to 2500-3000 t/y, the amount which is believed to be underestimated since not all fish catch passes through the landing points and fisherman usually do not declare the actual amount of catch, to escape taxation. Overall the fish stocks in Syrian waters are overexploited; evident signs of this are: the decrease of catch per unit effort from year to year, the increase of smaller size classes, and the decrease of larger size classes of a given fish species.

932. Lebanese fisheries are artisanal or traditional in nature. The country's coastal sea comprise 1685 fauna species with more than 50 of which are fish of commercial importance. The main gear includes trammels, longlines, purse seine nets (lampara) and beach seines. Fishing usually occurs to a maximum depth of 200m while most activities take place at an average depth of 50 m. The Lebanese fishing fleet is made of 4800 fishing boats spread all over the coast, only 2700 are officially registered. Even-though it is prohibited by law, spear fishing using scuba diving gear is widely practiced. Furthermore, fishing nets with illegal mesh sizes are widely available on the black market increasing the by-catch of immature organisms and leading to negative impacts on recruitment rates.

933. The overall composition by species of the Mediterranean catch of Israel has remained more or less steady for most of the 1960s-1970s with two major exceptions: the sardine catches, which fluctuated around the 1,000 t level, dropped sharply in 1977 to 340 t, steadying at 400-500 t up to 1981. Since 1982, stocks seem to recuperate providing annual catches of 680 t in 1982, 870 t in 1983, 1,030 t in 1984. Surveys conducted by the Department of Fisheries indicated larger stocks that are left alone due to low market value. The Erythrean alien lizardfish, *Saurida macrolepis*, once constituting nearly 30% of the trawl catch, dropped in the 1980s to 6.5% of the total trawl catch. The main species of interest in 1984 (total catch 4,200 t) were *Sardinella aurita*, mullids, sparids, *Epinephelus, Trachurus* and *Siganus* spp.. In 1998 the total catch still stood at 4,136 t, but has since declined precipitously – in 2006 (the last year for which the Department of Fisheries published records) it was but 2,219 t. The main species of interest in 2006 were cephalopods (235 t), sparids (185 t), mugilids (183 t), mullids (182 t), elasmobranchii (179 t), penaeid shrimps (145 t), and *Saurida* still constitutes 7% of the total trawl catch.

934. The collapse of fisheries in 1966-1980 was caused by the combined effects of environmental changes and of the severe security regulations of the fishing activities following the 1967 war. The recovery and the improvement of the fisheries are the result of the synergy of several factors: the restoration of normal fishing activities, the increase of the fishing effort with the use of modern fishing techniques and the increase in the size of fishing fleet. A most effective factor in sustaining the shelf fisheries of Egypt is the increased agricultural drainage to the sea. The shelf fisheries are driven by runoff. The outstanding peaks in 1997-99 are associated with the release of larger volumes of Nile water necessitated by exceptionally high floods. On the other hand, the fleet is immensely more developed in size. It comprises 3196 motorized boats, including 1136 trawlers, of which 231are purse-seiners, 1734 hook and line and trammel net boats. Comparison with the size of the pre-High Dam fleet is compelling: 30 motorized boats in 1930, 482 in 1952 and 622 in 1961. As a consequence of over fishing, the yield per unit effort is falling (see under 3.1.2, this report). Fishing activities now extend beyond Egyptian waters.

935. Certain invertebrate species are over-exploited in the subregion overall. Red coral (*Corallium rubrum*) harvest, for instance, is regulated by countries. Greece divides the Hellenic territorial waters into five large geographical sectors, allowing only one of them to be harvested for a five year period, by up to ten licensed vessels. Although this system ensures a 20 year coral fisheries moratorium for each region, the absolute lack of scientific data on red coral distribution, abundance and population dynamics in the Hellenic seas renders any such management scheme rather uncritical. Moreover, all the available data show that the shallow water red coral stocks (up to 50-60 m) are almost depleted, and poaching continues.

936. Despite the small number of the hard substrate invertebrate organisms exploited in the Aegean Sea and the fact that their total production/year is rather small (3000 tonnes/year), their economic value is considerable (over 17 million EURO/year). In addition to Mollusca and Crustacea, exploited species in the Aegean Sea include different groups of invertebrates such as sponges, echinoderms, cnidaria, and ascidians. The mean annual production of these species is 7000 tonnes (less than 10% of the total fisheries production).

937. The availability of Mediterranean commercial bath sponges was dramatically decreased by the depletion of natural banks due to high fishing pressure and devastating epidemic events. A survey of the diversity and population density of sponges with manifest or potential economical interest was conducted in the area of Dodecanese in 2004-2005. Results showed that although bath sponges occurred at a restricted number of stations and in relatively low population densities, they revealed signs of recovery after the devastating epidemic events.

938. Nonetheless, finfish remain the most important taxonomic group for fisheries. A representative sample of catches is illustrative. Throughout the eastern Mediterranean, the top commercial species in 2007 were:

Trawl	
Cartilaginous fish	*sharks, rays*
Lizard fish	*Saurida undosquamis*
Sole	*Solea aegyptiaca*
Grey gurnard	*Eutrigla gurnardus*
Bivalves	*Paphia textile, Donax variabilis, D. variegatus*
Shrimps	*Marsupenaeus japonicus, Metapenaeus spp*
Cephalopoda	*Sepia officinalis*
Trawl/Trammel Net	
Gilt Head Sea Bream	*Sparus auratus*
Bogue	*Boops boops*
Red mullet	*Upenaeus moluccensis, U.barbatus, U. asymetricus, U. surmuletus*
Crab	*Portunus pelagicus*
Purse-Seine	
Silver sides	*Atherina sp*
Sardinella	*Sardinella aurita, S. maderensis*
Blue scads	*Trachurus mediterraneus*
Barracuda	*Sphyraena sphyraena, S.chrysotaenia*
Hook And Line	
King fish	*Scomberomoris commerson*
Cutlass fish	*Trichurus lepturus*
Hook / Trammel Net	
Grouper	*Epinephelus alexandrinus*
Sea bass	*Dicentrarchus labrax*
Hook / Trawl	
Sea bream	*Pagellus erythrinus*
Trammel	
Mullets	*Mugil spp, Liza sp*

939. In conclusion, knowledge on the size of stocks of commercially important fish is very limited. Some mullidae, penaeid shrimps, sardines, and to some extent, hake (*Merluccius merluccius*) have been subject of biological studies, but the size of these stocks and the maximal sustainable yields have not been defined. Analysis of statistical data seems to indicate that the common demersal commercial stocks are exploited near the maximum permissible level.

6.4 Habitat classification and known distribution of habitats

940. Habitat diversity is generally high, and there is a marked difference between the island- and rocky seafloor habitats of the northern portion and the soft-bottom habitats present in the alluvial stretches of the southern portion. However, there are large gaps in knowledge about the distribution of habitats. A strong priority is to be given to bioconstructors, from vermetid reefs to *Lythophyllum* rims, to *Posidonia* meadows, to coralligenous formations in general. Some of these bioconstructions are almost extinct in the easternmost part of the basin (e.g. *Posidonia* meadows) whereas others are still thriving, albeit being threatened by anthropogenic activities.

941. In Greece, some good examples of the habitat types described in the Annex I of the EU "Habitats" Directive (92/43/EEC) occur on Hellenic coasts. Although these types are described under geomorphological terms, there is a direct link between them and the biological communities included in the Barcelona Convention. The following paragraphs present the biological information under the codes of the EU "Habitats" Directive.

942. The Habitat type "*Posidonia oceanica* meadow" (code 1120) is the most common biological feature on the Aegean as well as on the Ionian coasts. Most of the meadows are found between 5 and 35m depth. Habitats of the type 1110 "Sandbanks which are slightly covered by sea water all the time" are common in many sites in the Ionian and Northern Aegean. They are usually not covered by vegetation or the vegetation is not permanent; when vegetation occurs two types of sea grass meadows are present: *Cymodocea nodosa* and *Halophila stipulacea,* a Lessepsian migrant that appears only in the eastern Mediterranean. The habitat type "Mudflats and sandflats not covered by seawater at low tide" (code 1140) occurs on shallow and flat bottom covered with mud. Typical examples occur in sites of the north Aegean coasts (Thessaloniki Gulf, Porto Lagos) and north Evvoikos coasts (Atalanti). The habitat type "Large shallow inlets and bays" (code 1160) occurs at semi closed bays where the depth does not exceed 10-15m. Good examples occur in many gulfs of the Aegean (Thessaloniki, Gera, Kalloni, and Elefsis). Meadows of the Angiosperm *Cymodocea nodosa* are the dominant vegetation elements, as well as the populations of some *Cystoseira* species, such as *Cystoseira barbata* and *Cystoseira schiffneri*, growing on small stones and shells in low hydrodynamic conditions. The habitat type "Reefs" (code 1170) describes isolated rocky substrata surrounded by deeper waters, near the coast or offshore. The alga *Cystoseira* is a prominent inhabitant of "Reefs". The habitat type "Marine caves submerged or semi-submerged" (code 8330) occur along many rocky calcareous coasts. Good examples of this habitat type 8330 in the Aegean occur in the marine park of Sporades archipelago and the Cyclades archipelago.

943. Based on the derived typology, analysis of pressures and ecological status classification, the Hellenic coastal waters were distinguished into 233 coastal water bodies and these were classified into 4 main units: 1. Water bodies in the Hellenic coasts of the Northern Aegean Sea and its embayments, 2. Water bodies in the Hellenic coasts of the Central Aegean Sea and its embayments, 3. Water bodies of the Hellenic coasts of Southern Aegean and its embayments, and 4. Water bodies in the outer Deinaro-Tauric arc.

944. Studies on habitat types in Turkey are sparse, there exists some research in the form of local inventories. These are mostly gray literature such as postgraduate thesis, unpublished project reports, and proceedings of national symposiums. UNEP/MAP - SPA/RAC's list of habitat types, associations and facies, has not been applied yet to the whole Turkish waters. The Turkish seas have not yet been evaluated according to this habitat classification system. The Turkish coast in question may be divided into four ecoregions; *i*) North of Lesvos Island in the Aegean that is under the Black Sea influence, *ii*) South of Lesvos down to Datca Peninsula in the Aegean, *iii*) East of Datca peninsula to Cape Anamur, *iv*) East of cape Anamur to Syrian border that is a part of the Lessepsian province.

945. Cyprus is in the middle of the Levantine Basin, and is characterized by a high percentage of alien species (Lessepsian immigrants). The Cyprus coastal and marine areas have a large number of habitats ranging from rocky cliffs with caves and sandy beaches and sand dunes on the coast to underwater reefs with submerged caves and extensive *Posidonia* meadows. The coastal strip is now fragmented, with precious coastal habitats, an expanding urban sprawl and an increasing number of coastal works (breakwaters, etc). Cyprus is one of the very few Mediterranean States that has an EEZ

(off its southern coast so far). There is very little or no information on the biota of these deeper waters so far.

946. The Larnaca Salt Lake Complex is one of the two main wetlands in Cyprus which are of international ecological significance. It consists of four main lakes, the main Salt Lake (Alyki), Orphani, Soros and the small Airport Lake. The lakes, though inter-related, vary significantly among them. Alyki, the main Salt Lake, has a very high salinity regime, hence its use in the past for salt collection. This salt collection stopped in 1986, due to the discovery that the salt was unsuitable for human consumption. The lakes are seasonal, drying up in summer. The alga that forms the basis of the food chain here is mainly *Dunaliella salina;* it is fed upon by *Artemia salina,* the Brine shrimp, and *Branchinella spinosa*, which lives mainly in the other Larnaca lakes, which generally have a lower salinity regime. The Larnaca Salt Lakes are mainly known for their waterfowl. Many birds overwinter here, such as the Flamingo and various species of duck and seagulls. Many other birds also stop-over in the area during their spring migration, while other species nest and reproduce there.

947. Following the disappearance of *Posidonia* meadows from the Syrian marine ecosystems, it is estimated that few areas are left without compromised resilience due to the increasing threats of overfishing, bioinvasion, pollution …etc. Many monk seal habitats present along the Syrian coast could be of interest as eventual resting and/or haul-out areas. The Levantine Vermetid Terraces (LVTs) distributed almost everywhere at 20-30cm above the sea level of the rocky coasts are found mostly along the northern parts of the Syrian coast, starting from Lattakia district northwards till the Turkish border. Such terraces have a rich biodiversity.

948. Some habitats from the coastal area are of particular importance due to their sensitivity or they serve as breading grounds for other species: Emerged sandy beaches: important as nesting sites for marine turtles, frequently visited by Green and loggerhead turtles ; marine caves present in the south of Ras AlBassit and in Oum Tiur should be conserved as good habitats of Monk seal ; platforms with *Dendropoma petraeum* in Ras El Bassit reef and in other similar places along the coast. In many places, such platforms are of small sizes due to habitat fragmentation; Facies with the calcareous algae Titanoderma bissoides which can be found at low densities in many zones along the Syrian coast. Such facies are rich in fauna and accommodates a variety of organogenic structures and associated calcareous algae and molluscs (such as *Tonna galea* and *Erosaria spurge*).

949. The Lebanese coastline is about 220 km long along a north-south axis in the eastern Mediterranean. Along the coastline there are 3 bays, 12 prominent headlands headlands and several river deltas. The continental shelf is widest in the north (12 km), narrows down in a north-south axis, and widens up again to 8 km in the south. The sea cliffs are normally associated with wave washed terraces that show typical erosion patterns with potholes, blowholes and narrow channels.

950. The existing seabed along the Lebanese coastline is a mixture of bare rock, boulders, gravel and sand. Several types of marine biotopes including rocky, sandy, sludgy, coastal, neritic and oceanic can be found in neritic and oceanic waters, where biocenoses develop according to the prevalent geological, physical and chemical conditions. The main habitat types in Lebanon include the following:

Sandy and pebble beaches, found only in a few areas protected from currents and wave action, and estimated at about 20% of the total Lebanese coast. Most of the sand and pebble beaches have been lost to quarrying activities with a reported loss of 462,022 m^3 of sand in eight coastal localities.

Zostera meadows - infralittoral zones with a soft sediment structure shows several types of unique habitats occupied by phanerogame species (*Zostera nolti*). In Lebanon, this type of habitat is threatened by sand dredging, water pollution and a wide range of anthropogenic activities.

Sand dunes are one of the unique habitats in Lebanon is coastal formed by natural processes. They are under the influence of a set of dynamic processes that cause shifting in their geography. The coastal sand dunes are of great ecological importance and provide a niche for several special plants that also stabilize them in addition to being the first line of defense against storms generated at sea. In Lebanon, unfortunately, this ecosystem is threatened due to land appropriation, coastal sand extraction for construction and erosion of beaches caused by both natural and anthropogenic factors.

Rocky shorelines show unique characteristics. They are well-developed platforms of a particular biological construction: facies with vermetids. An association of several species (*Vermetus triqueter* and *Dendropoma petraeum*) builds up these organogenous formations very slowly. This habitat constitutes a major element in the rocky coast landscape, and is considered as a biological marker for water level and a fine indicator for the shoreline. In Lebanon, similar fossil platforms can often be found, but are threatened by anthropogenic activities including pollution, sea filling, and artificialization of the coast. In addition, the entire reef system functions as an important wave barrier and protects the coast from erosion and breaching from waves generated by storms.

951. Similar conditions exist in Israel. The predominant habitat types along the Israeli coastline comprise:

Vermetid reefs composed of a series of offshore rounded platforms with raised rims, running parallel to the coast. The reef platforms (0-1m) are formed by the gregarious sessile vermetid gastropods *Dendropoma petraeum* and *Vermetus triqueter*, endemic to the Mediterranean. Other benthic habitats include sublittoral, well sorted sands ; coastal silty-sand bottom ; coastal detritic bottom ; coastal sandy-silt bottom ; coastal silty-clay bottom ; coralligenous formations ; bathyal muds. It is noteworthy that *Posidonia* meadows have never been reported from Israel.

952. Egypt is somewhat different. The five coastal wetlands ("lagoons" or "lakes") of the northern coast of Egypt owe their outstanding importance to their high biodiversity and productivity. Four of them belong to the Nile Delta system, Maryut, Edku, Burullos and Manzala. The fifth, L.Bardaweel, on the Sinai coast, is independent from the Delta. The four lakes or lagoons are shallow brackish depressions (1-1.5m depth) located at the northern rim of the cultivated lands. They depend almost entirely on agricultural wastewater delivered through several drain canals. Except for L.Maryut, which is land-locked, there is also a limited tidal mixing with sea water around the lake-sea connections. They act therefore as transition basins where active biotransformations take place between inland waters and the coastal Mediterranean Sea. The coastal lagoons provide the usual services typical of transitional waters. In the area off Alexandria *Posidonia* grows in scattered patches in shallow waters at 2-8m, the deeper water meadows covering more extensive areas. Meadows also grow west from Alexandria at depths down to 26m. The western beds are in continuity with the North African beds along Libya, Algeria, Tunisia. The Alexandria meadows represent the eastern-most extension of this phanerogam an along north Africa as it is absent from the Nile Delta, and the coast of Israel. Only the Alexandria beds and those of El-Dabaa have been studied. The western meadows are more healthy and more dense than the Alexandria meadows.

953. The west coastline includes several biodiversity hotspots, in particular the Mersa Garbub-Ishaila Rocks. (31^{o} 31;N,26^{o} 37^{o}) and the Gulg of Sallum (31^{o} 35.N,25^{o} 7;E to 25^{o}30'E). Ishaila Rocks are a series of numerous offshore rocky islands which have never been submitted to any studies. Being proximal to great depths, their ecosystem is most probably very different from that of the rocky coasts elsewhere along Alexandria and the east coast. They are also expected to be an important sea bird sanctuary. Sea grass meadows (*Posidonia oceanica*) with their associated fish and invertebrate fauna extend in the shallow waters. The sandy beaches along Mersa Garbub have been identified as a nesting area for marine turtles. The site of Mersa Garbub-Ishaila Rocks is recommended as a marine reserve to protect an important biodiversity hotspot and a breeding area for birds, fish, invertebrates and marine turtles. It lies 65 km west from Marsa-Matrouh. The Gulf of Sallum is characterized by several hundred meters high sea cliffs with several endemic plant species. The sea cliffs and caves could be a suitable habitat form Mediterranean Monk Seals, but this needs confirmation. The sandy beaches of the gulf are quite suitable for marine turtle nesting and tracks have actually been observed. *Posidonia oceanica* grows in lies 200km west from Marsa-Matrouh, remains untouched by tourism investors. Its protection therefore presents some urgency.

954. Most habitat descriptions refer to the sea bottom, and the water column is often considered as a simple medium for the organisms living in it. The water column, however, is far from being uniform. The features of the coast, in fact, often do interfere with the main current patterns, forming conditions that, albeit temporary, might be of great importance for many species. Gyres, eddies, upwellings, downwellings, sites of intense terrestrial runoffs, among others, set particular oceanographic conditions that determine peculiar features for at least some portions of biodiversity.

6.5 Pressures and impacts

6.5.1 Contamination by hazardous substances

Trace metals

955. Draft analysis of representative trace metals in the sediment and biota in the eastern part of Aegean – Levantine by UNEP/MAP - MED POL (2009a) despite lack of data in some of the countries (notably Syria and Lebanon in general and from Greece and Cyprus in the case of sediments) revealed patterns of anthropogenic source of these trace metals originating from point and diffuse land-based sources providing useful information on the identification of hotspots in the area although not fully comprehensive.

956. The analysis of representative trace metals in the sediment in the eastern part of Aegean – Levantine by UNEP/MAP - MED POL (2009a) revealed values in sediments that in general, are in the lower range than those reported in previous assessments (derived from UNEP/MAP - MED POL I and II).

957. In Greece monitoring of metals in sediment based on Greek UNEP/MAP - MED POL (HCMR) data, revealed a pollution gradient across the Greek coastal areas indicating different pollution fingerprints in different areas (SoHeLME, 2005). However the moderate coverage in temporal terms does not allow for the determination of apparent trends (Kaberi, pers. comm.). In Greece monitoring of metals in sediment based on Greek UNEP/MAP - MED POL (HCMR) data, revealed a pollution gradient across the Greek coastal areas indicating different pollution fingerprints in different areas (SoHeLME, 2005). However the moderate coverage in temporal terms does not allow for the determination of apparent trends (Kaberi, pers. comm.). The temporal and spatial coverage of trace metals in Greek Seas are presented in figures 6.7 and 6.8.

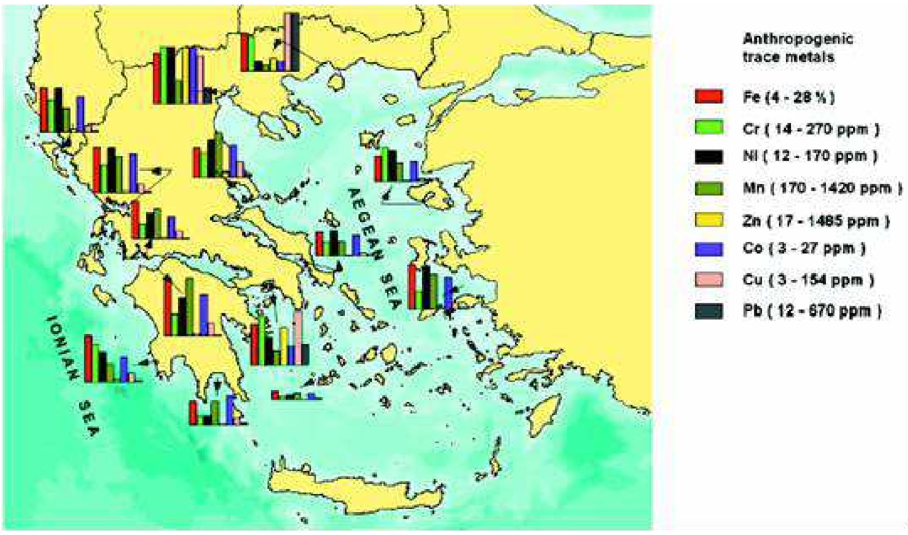


Figure 6.7. Heavy metals distribution as estimated from measurements of the anthropogenic component (mean values over the year). Source: Reprinted from SoHelMe, 2005

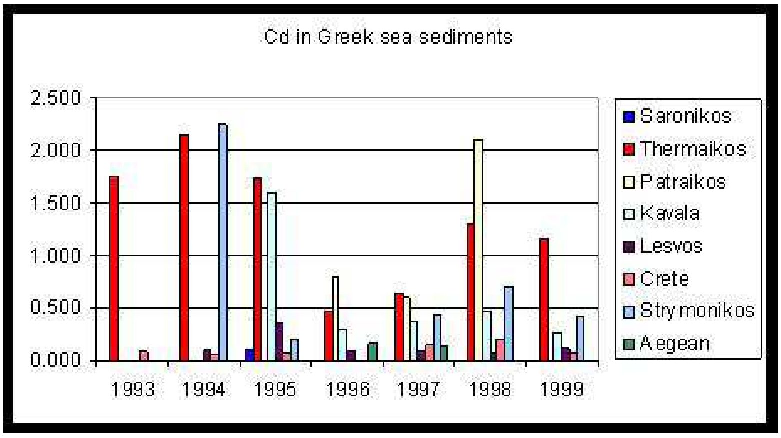


Figure 6.8. Trends of Heavy metals (Cd µg/g) in sea sediments across the Greek seas. (HCMR data base – UNEP/MAP - MED POL data, courtesy of Kaberi, E.)

Trace metals - biota

958. Trace metal analysis in biota is more comprehensive as it encompasses almost all countries in the area (except Lebanon and Syria) exhibited low values in general for the area in the case of *Mytilus galloprovinciallis*. Analysis in *Mullus barbatus* appeared uniform metal bioaccumulation through the area but certain stations from Greece and Turkey exhibited the higher levels of Cd and Cu. In general the accumulation was found higher in mussels than in fish with reported values, excluding the hotspots, of the same order of magnitude than those obtained during the UNEP/MAP - MED POL I and II (UNEP/MAP - MED POL, 2009a).

959. Organochlorines [PCBs (polychlorinated biphenyls), DDTs (dichloro-diphenyltrichlopo-ethane), HCHs (hexacholohexanes, of which γ- HCH Lindane is the most infamous representative) and HCB (hexachloro-benzene)] are highly toxic persistent and bioaccumulative compounds. The levels of selected persistent organic pollutants, namely polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroetane and its degradation products (DDTs) and hexachlorobenzene (HCB), in Mediterranean sediments (1971 to 2005) along with their main drivers and pressures has been by assessed by Gomez-Gutierrez et al (2007); gaps were also identified. This study only included Greece and Egypt from the Aegean-Levantine countries identifying a major gap in sediment analysis in the area. Large cities have been identified as critical sources of hazardous substances pollution, since most of the “hot spots” are located in their neighboring sediments (Alexandria and Port Said in Egypt and Athens and Thessaloniki in Greece). Also, high concentrations of hazardous substances are found in sediments located in river mouths and estuaries of major Mediterranean rivers (Nile) and lagoons (Lake Manzala, Egypt.

960. Maximum values for PCBs and DDTs throughout the Mediterranean were found in the Nile river mouth, ranging from 53 to 1500 ng g-1 for PCBs (Aroclor) and from 29 to 826 ng g-1 for DDTs (El-Dib and Badawy, 1985; Abd-Allah *et al.*, 1992). In the Aegean Sea, high concentrations of the target compounds were found in the Saronikos Gulf, close to Piraeus and in the Thermaikos Gulf, near to Thessalonica (Greece). The highest values available for the area of Piraeus correspond to the 1970s probably reflecting the state of contamination when these products were still in production and usage in the region (Dexter and Pavlou, 1973. However, a recent study showed also high concentrations for both PCBs and DDTs (Hatzianestis and Botsou, 2005). Furthermore, based on the DDT/DDE ratio, authors indicate that recent disposal of DDT is probably occurring in the area. In addition to this, concentrations recently reported in the commercial harbour of Piraeus also showed elevated levels (up to 76 ng g-1 of DDTs and 927 ng g-1 of Aroclor) (Galanopoulou *et al.*, 2005).

961. In the southeastern part of the Mediterranean basin, sediments off the city of Alexandria showed high levels of pollution. The coast of Alexandria and especially the semi-enclosed bays (Abu-Quir and El-Max bays) are subject to the discharge of untreated agricultural and industrial wastes from major urban centers as well as to the diffuse agricultural runoff. In fact, two main disposal outfalls discharge industrial, agricultural and domestic wastes directly into the Mediterranean Sea through

these two bays (Abd-Allah and Abbas, 1994). Based on recent data analysis, PCBs, DDTs and HCB are compounds of concern in the area (Barakat, 2004).

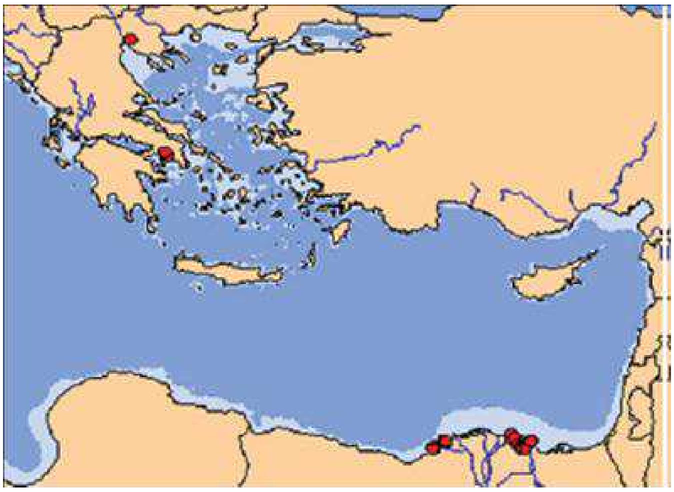


Figure 6.9**.** Identified 'hot spots' for the concentrations of PCBs, DDTs and HCB 4 in the Mediterranean sediments Source: Reprinted from Gomez-Gutierrez et al (2007)

962. Chlorinated pesticides have been extensively analyzed in Mediterranean biota since the inception of UNEP/MAP - MED POL (UNEP, 1990). However, it has been only since the last decade that they have been continually monitored, and data gathered in the UNEP/MAP - MED POL Database and in the case of Aegean-Levantine spatial analysis is limited to Cyprus (fish) and Turkey (mussels and fish) as shown in tables 13 and 14. In the latest assessment concentrations of aldrin, dieldrin, endrin, lindane and hexachlorobenzene in *Mytilus galloprovincialis across the Mediterranean* were in the low ng g-1 range with the exception of some stations from Turkey where concentrations of DDTs were one order of magnitude higher (UNEP/MAP - MED POL 2009a).

963. Data on *Mullus barbatus* and *Mytilus galloprovincialis* in the latest UNEP/MAP - MED POL analysis is limited to Cyprus and Turkey (table 14 and 15). The values can be considered in the low range, taking into account the higher accumulation capacity of fish with respect to mussels (UNEP/MAP - MED POL, 2009a).

964. Organochlorine concentrations accumulated in biota destined for human consumption, (based on monitoring programmes -- mainly Greek UNEP/MAP - MED POL) exist, allowing determination of the levels of pollutants in filter feeding organisms (mussels) and commercial fish species (red mullets and bogue)) are regarded low and below the standard human health limits (SoHelME, 2005). The spatial analysis of the organochlorine bioaccumulation in biota across the Greek coastal environment is presented in Figure 6.10.

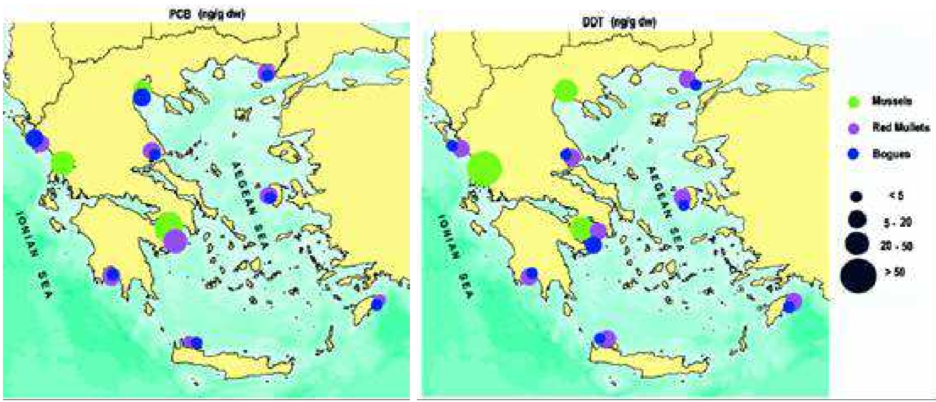


Figure 6.10. PCBs (left) and DDTs (right) concentrations in mussels and fishes (ng/g ww) in Greek seas. (reprinted from SoHelME)

965. The analysis provided evidence of a contamination gradient when mussels were used as an indicator. Two areas were identified as sources of heavy metals into biota: a PCB pollution area (Saronikos Gulf- industrial and urban effluents) and a DDT contaminated area (Amvrakikos Gulf – agricultural effluents). On the other hand spatial analysis of bioaccumulation in fish revealed a homogeneous pattern indicating no point sources of pollution (SoHelME, 2005).

966. Temporal trends are also available (mainly as a result of the Greek UNEP/MAP - MED POL programme) providing useful trends. These trends in mussels indicate no reduction of pollutant levels despite the ban indicating continuous inputs into the coastal environment; similarly temporal trend in fish revealed no pattern of reduction (SoHelME, 2005)

Hazardous substances in higher biota

967. Very little is known about heavy metal concentrations in tissues of cetaceans inhabiting the Eastern Mediterranean. A stranding of Risso's dolphin (*Grampus griseus*) on the Mediterranean coast of Israel revealed high concentrations of trace metals (Hg, Cd, Zn, Fe and Se) while Cu and Mn concentrations were naturally low. No connection was found between the high concentrations of trace metals in the internal organs and the cause of death and it was assumed that the high concentrations were a result of the high trophic level of this species, its diet and its advanced age. Anthropogenic influence could not be assessed due to the sparse database of trace metals for this species, in particular knowledge of the natural levels (Shoham-Fridera et al 2002).

968. Examination of heavy metal content in 61 bottlenose dolphins and 8 striped dolphins stranded in Israel from1993 - 2001, (the first large series ever reported with the scope of metals and tissues tested) allowed only qualitative comparisons with findings from other part in Mediterranean observations. It seemed that that mercury levels tend to be similar while cadmium levels (at least in muscle and liver) are lower in the western Mediterranean locations in the case of bottle nose dolphins while striped dolphin resemble the Tyrrhenian–Ligurian population in their mercury levels but could be distinct in having higher cadmium and zinc concentrations in muscle and skin (Roditi-Elasar et al 2003).

969. Concentrations of heavy metals (Hg, Cd and Pb) were determined in internal organs and nest contents of green turtles *Chelonia mydas* and loggerhead turtles *Caretta caretta* from northern Cyprus. Concentrations of mercury in liver tissue were higher in loggerhead turtles (median 2.41 μg g-1 dry weight) than in green turtles (0.55 μg g-1 dry weight). Data suggested cadmium concentrations to be highest in kidney tissue of loggerhead turtles (median 30.50 μg g-1 dry weight) but in liver tissue of green turtles (median 5.89 μg g-1 dry weight). Concentrations of lead in internal tissues were often below analytical detection limits in both species, but when measurable, tended to be higher in loggerhead turtle. These findings suggested that metal levels in both green and loggerhead turtles are not likely to be high enough to affect the health of these endangered species (the only exception to this might be relatively high lead concentrations in loggerhead turtle hatchlings, and perhaps also green turtle hatchling (Godley et al 1999).

970. These data from Cyprus are comparable with those encountered in specimens in other parts of the Mediterranean Sea e.g. Adriatic (Storelli et al 2009) and Murcia Spain (Jerez, 2010) confirming the homogeneity of the area comprising the southeastern basin of the Mediterranean Sea from an ecological point of view.

971. Concentrations of heavy metals have been measured in tissues of common bottlenose dolphins collected along the Israeli Mediterranean coast during 2004–2006. These concentrations were similar to those found in specimens collected during previous years in the region, suggesting stability over time in the HM levels of the basin's food-web ((Shoham-Frider et al 2009).

Chlorinated hydrocarbons

972. Cetaceans and seals, top predators in the marine environment, have a reduced capacity to metabolize hydrophobic persistent chemicals compared to birds and land mammals. They accumulate high levels of these compounds up the food web and are most exposed to their toxic effects and therefore, they were suggested as potential bioindicators for organochlorine contamination of the

marine environment. ΣDDT and PCBs concentrations in tissues of bottlenose dolphins, collected along the Israeli Mediterranean coast during 2004–2006, were highest in the blubber, with a wide concentration range.

973. Blubber PCBs values were an order of magnitude lower than in tissues of this and other delphinid species in the Western Mediterranean. A relatively high DDE/ΣDDT percentage (85–96%) was discovered, which fit the general trend of increase in the last 20 years in the Mediterranean Sea, indicating the progressive degradation of the remnant DDT and the absence of new inputs. These findings were in accordance to the ones reported from Greece for *Stenella coeruleoalba* from Georgakopoulou-Gregoriadou *et al.* (1995).

974. Concentrations of individual chlorobiphenyls (CBs) and organochlorine pesticides (OCPs) in marine turtle tissues collected from the Mediterranean (Cyprus, Greece) and European Atlantic waters (Scotland) between 1994 and 1996 are described. ΣCB concentrations were highest in adipose tissue and ranged from 775 to 893, 39 to 261 and 47 to 178 mg/kg wet wt in loggerhead (*Caretta carretta*), green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles, respectively.

975. The measured concentrations of contaminants in marine turtles from Mediterranean were similar to those determined in the same species elsewhere in the Atlantic, and were considerably lower than the concentrations shown to cause deleterious effects in freshwater turtles (Mckenzie et al, 1999).

976. Blubber from Mediterranean monk seals (*Monachus monachus*) from the Western Sahara coast (Atlantic), sampled during 1996– 1999, and from the Greek coast), sampled during 1995–1999, was analyzed for organochlorine pollutants (OCs). Significant differences in concentrations and pollutant patterns were found between populations. Mediterranean individuals presented significantly higher levels of HCB (hexachlorobenzene), tPCB, and DDTs concentrations andDDE/tDDTand tDDT/tPCB ratios than their counterparts from the Atlantic. Moreover, the relative proportion of different congeners in relation to the total PCB load (congener/tPCB) was also different between the two areas indicating a predominance of industrial inputs over those associated with agriculture in Atlantic as opposed to Mediterranean seal population, where a proportionally higher contribution of pollutants of agricultural origin was suggested (Borrell et al 2007).

6.5.2 Dumping activities (introduction of substances and impact)

977. Relatively little is known about the disturbance caused by the disposal of industrial solid wastes or dredging dumping on marine benthic communities. Studies in Greek waters demonstrated effects of tailings comparable to those of organic pollution. Dumping of coarse metalliferous wastes, at about 75m depth had mostly indirect effects on the benthic fauna, through changing the particle size composition of the sediment and increasing the instability of the environment (Nicolaidou et al 1989). Continuous monitoring of the area and long assessment over a period of over 10 years verified this classical model of variation of community parameters along a gradient of increasing stress as for organic pollution; the observed spatial and temporal variations of the macrozoobenthic communities under the pressure of solid waste discharge were mostly attributed to the physical effects of the discharge such as turbidity and the mechanical effects of sedimented and resuspended tailings. Direct effects on the community structure, as comparison with reference site showed, include decline in species diversity and species richness (Simboura et al, 2007).

978. Pollution in eastern Mediterranean (Aegean and Levantine) has been manifested mainly through the impacts of hazardous substances and eutrophication. Marine pollution from cities, the industry and tourist resorts, is large but localized. The presence of macro-waste on beaches and in the high seas has a considerable impact (UNEP/MAP – BP/RAC 2009), but has not been quantified.

6.5.3 Nutrient and organic matter enrichment

979. As described before, the main spatial features of chlorophyll-a and nutrient analysis, include the general gradient in algal biomass from north to south and from west to east of the Eastern Basin, the ‘‘ultra-oligotrophic cores’’ of the south Levantine Basin (corresponding to the Mersa-Matruh and

Shikmona Gyres, the Nile plume, the north-south gradient in algal biomass in the Aegean Sea, attributed to the combined effects of river inputs, northerly winter and signal from the nutrient reach Black Sea waters.

980. According to Ludwig et al (2009) although analysis results indicated that nitrogen pollution was not a major problem in Mediterranean rivers and was usually dominated by diffuse sources, in particular agriculture, which is characterized in southern Europe by less intensive cultivation practices depicts the evolution of N fertilizers and the load drained particularly in the Aegean Sea) and that no clear regional pattern could be neither observed for Phosphorus whose pollution is normally dominated by point sources, such as urban waste waters, the evolution of river fluxes of nutrients exhibits increasing nitrogen and phosphorus fluxes, enhanced via anthropogenic activities in the drainage basins.

981. However, the anthropogenic nutrients did not follow exactly the same trends. Efforts undertaken to mitigate point source pollutions in the 1980s and 1990s had an immediate impact on the phosphorus loads; after a dramatic increase in the 1960s and 1970s, phosphorus rapidly declined to early 1960s levels. The pattern is somehow different for nitrogen, mainly released via diffuse sources such as fertilizers. Nitrogen followed more or less a continuous increase over the study period, before starting to decrease only recently in the whole basin but not so in the eastern basin (Ludwig et al, 2009). Mediterranean and Black Sea rivers are currently characterized by a strong excess of nitrogen over phosphorus and silica. Interestingly gross primary production sustained by rivers (PPR) represents only less than 2% of the gross production (PP) in the Mediterranean; possible ecological impacts of the changing river inputs should therefore be visible only in productive coastal areas (Ludwig et al, 2009).

982. Finally, atmospheric deposition data tend to be regarded as not consistent to support reliable calculations for Eastern Mediterranean (UNEP/MAP 2007b). Some information exists for wet deposition fluxes of inorganic nutrients (PO4-, NO3-, NO2, NH4+) at sites along the Mediterranean coast of Israel, which were made as part of a long-term study (UNEP/MAP - MED POL Phase II and III monitoring activities, Herut *et al.*, 1999, Herut, 2005). Herut (2005) has reported on dry atmospheric deposition of N and P in SE Mediterranean focusing on the role of Sahara dust in enhancing primary production.

983. Information on hot spots of nutrients and organic matter releases has been identified by UNEP/MAP at the NW Aegean (Thermaikos Gulf – from rivers and the sewage from the city of Thessaloniki), at river mouths in the North Aegean, at the coastal area of Izmir in NE Aegean (Izmir bay), at Lebanon and Israel coast in the SE Mediterranean and in the coastal zone in front of Alexandria area and in the Nile delta system (UNEP/MAP – BP/RAC, 2009) (Figure 6.11).

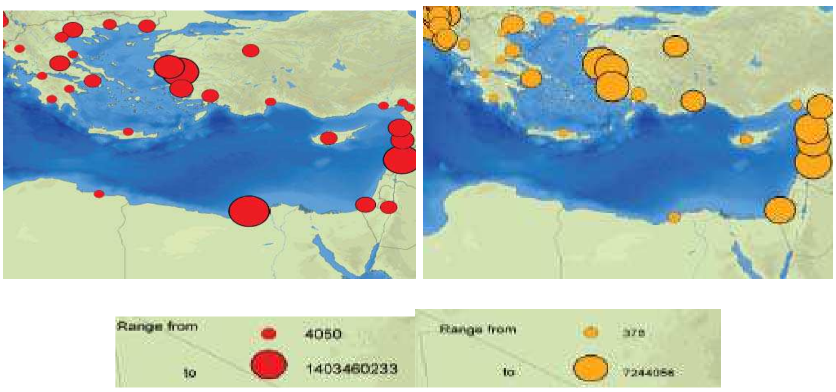


Figure 6.11. Industrial Total Nitrogen (left) and BOD (right) releases from point sources. Source: UNEP/MAP - MED POL NBB, reprinted from UNEP/MAP- BP/RAC 2009

984. The Aegean-Levantine Seas have experienced a decreasing trend in riverine fluxes. A decreasing trend has been established for the Aegean (AEG) and the Southern Levantine (SLE) whereas no trend could be detected for the North Levantine Sea (NLS). Trend and model analyses on hydroclimatic parameters revealed also a precipitation decrease with reductions in the Aegean Sea

(13%), and the South-Levantine Sea (-10%) following the general Mediterranean precipitation trend and increases of the dry spell length. On the other hand the drainage basins of the Aegean and North-Levantine seas have experienced a decrease in temperature in contrast to the strongly increasing temperatures of the entire basin.

985. The Eastern Mediterranean Sea is an extreme oligotrophic environment with phosphorus-limited primary productivity. All the sub-regions in this basin are characterized by low Chl-a concentrations all around the year, the lowest concentrations being observed in the Levantine Basin (with the exception of waters at the boundary of the Nile plume). No temporal trends could be detected A marked seasonal cycle is observed in the various regions, with a decrease of the algal biomass from winter to summer along with large inter-annual variations. Seasonal and interannual variations are also present in primary production. Spatial chlorophyll variations in surface waters, in general revealed that the highest levels correspond to the areas close to river deltas or those off large urban agglomerations. The main spatial features, detected include a general gradient in algal biomass from north to south and from west to east of the Eastern Basin, the ''ultra-oligotrophic cores'' of the south Levantine Basin (corresponding to the Mersa-Matruh and Shikmona Gyres, the Nile plume, the north-south gradient in algal biomass in the Aegean Sea, attributed to the combined effects of river inputs, northerly winter and signal from the nutrient reach Black Sea waters.

986. River fluxes have resulted in increasing trends of nutrient fluxes in to the marine environment enhanced via anthropogenic activities in the drainage basins (despite the decrease of riverine flow) of nutrients into the sea for both N and P. However there is a marked difference: nitrogen has been on a steady increase, whereas Phosphorus has recently started a decreasing trend.

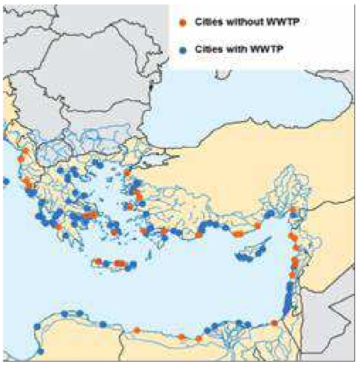


Figure 6.12. Location of waste water treatment plants on the coast of Aegean –Levantine
(Source: UNEP/MAP – BP/RAC, 2009)

987. Stamou and Kamizoulis (2009), using UNEP/WHO, 1999 and UNEP/MAP, 2000 and 2004 data, estimated the BOD5, TN and TP loads for the present conditions discharged to the 18 typical Surface Coastal Currents (SCCs) of the Mediterranean. The Levantine, Asia Minor, and Aegean appear to be enriched in BOD5, Total N and total P in the sub-region, though less than the Adriatic subregion.

SCC	Area-Sea	BOD_5 maximum	BOD_5 average	TN maximum	TN average	TP maximum	TP average
1N	1-Alboran	6	4	7	5	3	2
1S	1-Alboran	10	4	9	2	4	1
2	2-Balearic	99	37	157	86	24	14
3	3-Algerian	43	17	24	10	10	4
4	4-Tyrrhenian	51	14	38	15	11	5
5W	5-Adriatic	630	106	235	93	26	11
5E	5-Adriatic	53	22	31	21	37	22
6W	6-Ionian	19	6	14	4	6	2
6E	6-Ionian	12	4	12	7	2	1
7N	7-Libyan	6	4	3	2	1	1
7W	7-Libyan	17	6	27	17	11	7
7S	7-Libyan	15	3	22	8	9	3
8	8-Levantine	142	25	75	35	30	14
9	9-Asia Minor	183	50	67	34	12	8
9C	9-Asia Minor	2	1	1	0	0	0
10W	10-Aegean	65	15	108	49	42	14
10E	10-Aegean	38	8	37	15	12	5
10S	10-Aegean	5	3	7	4	3	2

Figure 6.13. Calculated average and maximum concentration values (mg/l) in the 18 Surface Coastal Currents (SCCs) for the existing conditions (Reprinted from Stamou and Kamizoulis, 2009)

988. Cyprus is the only country were all wastewater produced is treated and is reused, thus there is no disposal of sewage into the sea for cities >10000 inhabitants (permanent population 330,300). For the 106,958 inhabitants (populating twenty-four coastal cities with population between 2,000 and 10,000), eight cities are served by a main sewage treatment plant or individual treatment systems (UNEP/MAP - MED POL/WHO, 2004 and 2008).

989. Of the 5,161,000 inhabitants (in cities > 10000 inhabitants) in 2003), 50% were served by wastewater treatment plant. However, Alexandria seems to produce large quantities of primary treated wastewater (74% of the population is served by wastewater treatment plant) and the remaining cities are subjected to secondary treatment). There was no direct discharge of treated sewage into the sea. Regarding the untreated sewage there was no adequate information on either quantities or way of discharge (UNEP/MAP - MED POL/WHO, 2004). In the 12 coastal cities (population between 2,000 and 10,000) with a resident population of 65,458 inhabitants, only two operated wastewater treatment plants. Treated wastewater discharge was led into the sea by canals. Regarding the untreated sewage is disposed in the soil, possibly in desert (UNEP/MAP - MED POL/WHO, 2008).

990. According to the 2003 information, 7.2 million people inhabited 63 areas each with population greater than 10,000 that are located close to the coastline. More than 60% of the population is located to the greatest Athens area (capital of Greece) and Thessaloniki. Only 10% of the wastewater produced is untreated and the treated wastewater in most cases this is disposed after secondary treatment trough submarine outfalls or in some cases trough rivers or streams to the sea (UNEP/MAP - MED POL/WHO, 2004). According to UNEP/MAP - MED POL/WHO, 2008, 764,580 peopled resided in hundred and seventy eight areas with population between 2,000 and 10,000 inhabitants that are located close to the coastline and approximately 31% of the total number of the cities were served by a WWTP, 42% did not have treatment facilities while a significant percentage of 23% will be served by a treatment system (plants under construction/projected). Treated wastewater, 61,322 m3/ day, was discharged mainly to the aquatic environment (through a submarine outfall - 36% of the cases - or directly into the sea – 55% of the cases). Untreated sewage was reported not to be directly discharged to the marine environment since in all cases raw sewage from households is collected to septic tanks.

991. In Israel, all 3,640,000 habitants in the nine cities with population more than 10000 were served by respective wastewater treatment plants, (seven operate secondary treatment and two operate primary treatment (UNEP/MAP - MED POL/WHO, 2004). All the 8 coastal cities (population between 2000-10000) with a resident population of 44,982 inhabitants were served by respective wastewater treatment plants, which in all of the cases provided secondary treatment, while only one coastal city out of eight was served at about 50% by a plant and uses septic tanks for the rest 50% (UNEP/MAP - MED POL/WHO, 2008). In both categories there was no discharge of untreated wastewater while treated wastewater was mainly reused.

992. Available information for Lebanon refers to only cities (locations) which gather a population over 10,000 residents. Wastewater facilities served 32% of the population of 2,256,000 persons in large coastal cities (only one of the seven cities, Beirut, was served by a primary wastewater treatment plan), while sewage system network serves the remaining 68%. The total wastewater produced was in the order of 300,000 m3/d 70% of which was untreated and discharged raw in the marine environment (UNEP/MAP - MED POL/WHO, 2004). In the 2008 report data involved thirteen coastal localities with a total population of 5,675,000 inhabitants, in three of which the population was served by a treatment plant. The degree of wastewater treatment was primary for 15% of the total number of cases and secondary for the rest 85% (UNEP/MAP - MED POL/WHO, 2008).

993. All the population in the seven Syrian coastal cities larger than 1000 inhabitants (607,635 people) was served by network and probably by individual autonomous wastewater services such as septic tanks or other similar devices. The total amount of untreated wastewater discharged mainly to the sea through small submarine outfalls, was to the order of 60,000 m3/d (UNEP/MAP - MED POL/WHO, 2004). Fifty-three smaller coastal cities with a total resident population of 205,776 inhabitants exist and none was served by WWTPs. The total amount of untreated wastewater discharge reached the 30,656 m3/ day totally into the marine environment (UNEP/MAP - MED POL/WHO, 2008).

994. In Turkey, a total of 41 large coastal cities were reported and 62% of the population was having wastewater treatment facilities (19 wastewater treatment plants serve about 3 million inhabitants). The reported quantity of treated wastewater (about 721,000 m3/day) was directly discharged to the marine environment since in all cases raw sewage from households is collected to septic tanks.

995. Regarding nutrient and organic matter enrichment, subregional hot spots can be identified. Eutrophication from nutritional substances has been increasing for 20 years; however it is limited to local areas. In Greece, the NW Aegean with Thermaikos Gulf (rivers and the sewage from the city of Thessaloniki), as well as rivers' mouths in the North Aegean, and Saronikos bay off the city of Athens, consist the most seriously eutrophied areas. The Strait of Istanbul, the Strait of Çanakkale and the Sea of Marmara are presenting serious eutrophication phenomena, and some coastal areas in NE Aegean (Izmir bay).

996. In the SE Mediterranean a few cases of eutrophication are recorded in Lebanon port areas, Israel, coasts. Finally in Egypt, ports in Alexandria area and in the Nile delta system are frequently encountering eutrophication phenomena.

6.5.4 Biological and physical disturbances

Fishing Impacts

997. Most information on the activity of the fishing fleets in the Mediterranean comes from the working group STECF and the GFCM Demersal Working Group, of the Subcommittee on Stock Assessment, and ICCAT for large pelagics, which relates the activity of the fleets from member countries. Therefore, there is a lack of reported information of fishing activity of EU non-member countries (e.g. North Africa) in STECF, although GFCM cooperation projects (Medfisis, COPEMED II, ADRIAMED and EASTMED) are attempting to rectify this.

998. Demersal fisheries operating in eastern Mediterranean high seas can be summarized as: bottom trawling, bottom long line, and gillnet. Deep-sea fisheries currently operate on continental shelves and some slopes, down to depths of less than 800m. Bottom trawling is a highly damaging practice that was banned in 2005 to Mediterranean bottoms deeper than 1000m, aiming to protect the vulnerable deep sea fauna. Several abyssal plains, that harbor poorly known and vulnerable deep sea fauna, are located throughout the Mediterranean, with the deepest grounds found in the Central basin (e.g. Calypso depth in the Ionian Sea, SW of Greece).

999. The following sites are considered noteworthy areas in the subregion, especially with regards to fishing impacts in Mediterranean open seas, including on demersal and pelagic ecosystems:

- Thracian sea. Demersal ecosystem at Strymonikos gulf and Samothraki plateau as important spawning grounds for hake where bottom fishing activities, mainly trawling should be restricted.
- Eratosthenes Seamount. Important SH vulnerable to bottom fishing activities. Already adopted as FRA (Fishery Restricted Area) by GFCM.
- Nile Hydrocarbon cold seeps. SH being a unique environment in the Eastern Mediterranean basin that needs to be protected from damaging bottom fishing activities. Already adopted as FRA (Fishery Restricted Area) by GFCM.

1000. Other geological features may be vulnerable to fishing, as they are hotspots of diversity and are habitat of vulnerable fauna like cold corals, include features like the massive Eratosthenes seamount in the East basin (south of Cyprus) and the cold seeps, brine pools and hydrothermal vents located in the East Mediterranean basin (south of Crete and Turkey, and near Egypt).

Invasive species

1001. Biological transformations have also taken place in the eastern Mediterranean subregion. Invasive species, largely originating from the Red Sea and Arabian Seas, have caused large transformations in the biotic communities of the subregion.

1002. All national reports describe a dramatically changed situation in the composition of the local biota, when known, in respect to some decade ago. The changes are invariably linked to the prevalence of alien species that are more or less rapidly replacing native ones. The spread goes in both directions, starting from the Suez Canal and proceeding both northwards (Israel, Lebanon, Syria, Turkey, Greece) and westwards (in this case Egypt, but the phenomenon is going on also in Tunisia and Algeria, whereas little is known about Libya). Some of these species are a nuisance and even a danger for humans (see the problem of jellyfish below), but others are a resource for local populations that are very happy to harvest them, and some are even cultured after their establishment. A parallel phenomenon, denounced at least by some reports, is the regression of the native species.

1003. The arrival of species from the Red Sea has been considered in different fashions by the scientific community and even by different countries. Some authors consider the arrival of “aliens” as a terrible event, whereas some other authors salute the new contingent as an enrichment of Mediterranean biodiversity. The Egyptian report, for instance, speaks to the beneficial effects of the arrival of Non Indigenous Species (NIS), with the proposal of compiling a list of the 100 most beneficial aliens, to oppose to the available list of the 100 worst aliens (Streftaris and Zenetos, 2006). NIS, furthermore, arrived and still arrive to the Mediterranean also by other means, and not only through the Suez Canal (CIESM, 2002). Most authors (e.g. Galil 2000) consider the spread and settlement of alien species as a menace to the integrity of biodiversity and, in many reports, alien species are seen as one of the worst threats to the environment, if not the worst.

1004. Other transformations are taking place as well. Previous observations made on platform habitats of the Mediterranean coast of Israel, for instance, have demonstrated that changes in the receiving habitat (e.g. the reduction of the external rim of the vermetid *D. petraeum* platforms) may have increased the fitness of *B. pharaonis*, causing a dramatic reduction in the indigenous mussel *Mytilaster minimus* (Rilov *et al*., 2004). Moreover, the displacement of this native mussel by the larger Eritrean alien appears to have changed predation patterns so that the native whelk *Stramonita haemastoma* preferentially preys on *Brachidontes* (Rilov *et al*., 2002). Since then *B. pharaonis* has dramatically changed the community structures on many platforms along the Israeli Mediterranean coast. Considering its current rate of spread and growth, it may soon reach massive populations and likely also have a significant impact on Italian vermetid platforms (Badalmenti *et al.*, 2008).

6.5.5 Effects of underwater noise and marine litter

1005. No systematic information is available on the effects of maritime activities, especially the generation of noise, in this subregion. Conversely, the impacts of marine litter are relatively better-studied.

1006. The studies of marine debris in the Mediterranean to date have focused on beaches, floating debris and the seabed of the continental shelf or the deep sea. In most of the studies that investigated marine debris on the seabed, debris was collected by trawls (Katsanevakis and Katsarou 2004). Similarly in the eastern Mediterranean studies have been performed by means of trawling and only one has focused on the distribution of underwater marine debris in coastal areas (shallow (<25 m) by diving.

1007. Most studies of benthic litter describe its composition and origin (i.e. plastic, metal, fishing gear), calculate its concentrations for each type, estimate its density on the seabed, and identify their sources (broadly categorized into land and marine origin (vessel and fishing based). Katsanevakis and Katsarou (2004) concluded that in shallow coastal Greek areas marine debris density is much greater than debris concentration estimated by other studies in the Mediterranean continental shelves or on the deep seafloor, with the exception of some accumulation zones in the open sea (described in detail in Galgani *et al.*, 2000). Furthermore greater abundance of marine debris was found in bays than in open areas. Results from Koutsodendris et al 2008 support the argument and suggested that a large volume of the litter that enters the marine system is concentrated to shallow coastal areas and only a small percentage reaches deeper waters.

1008. Comparing the findings from the deeper parts, Stefatos et al (1999) concluded that the debris concentration on the seafloor of the western Greek gulfs is comparable with the debris concentration found on the seafloor in the eastern Mediterranean (as described by Galil et al 1995); the comparison of the Greek gulfs to the sites in western Mediterranean by Koutsodendris et al (2008) revealed that three of them show moderate litter pollution (<150 Item/km2), which is comparable to most sites around the world, whereas Patras Gulf shows significant litter pollution (150-500 Item/km2), which is comparable to the Adriatic Sea, East Corsica, Bay of Biscay, and Gulf of Lions (as described by Galgani *et al.*, 2000), attributed to the proximity of study sites with metropolitan areas.

1009. Plastics dominated the composition of seafloor debris in all case with the exception of the eastern Mediterranean transect (table 24). The percentage of plastic items from the Greek sites is close to the 60± 80% of plastic components reported to constitute the litter on beaches of 13 Mediterranean beaches (in Spain, Italy, Turkey, Cyprus and Israel) (Gabrielides *et al.*, 1991) with almost all worldwide other studies. Both Koutsodendris et al (2008) and Stefatos et al (1999) remarked that land-based debris provided the majority of the total litter items followed by vessel-based and fishery-based sources (69%, 26% and 5% respectively in the four gulfs investigated by Koutsodendris et al (2008) despite the fact that some of the site were fishing areas. These findings are in accordance with the Gabrielides *et al.* (1991) report of low percentage (2.8%) of fishing gear on the Mediterranean beaches. UNEP/MAP – BP/RAC (2009) has quantified the origin of marine litter in the Mediterranean attributing it to coastal urban centers (generated by direct disposal of domestic waste, tourism infrastructure waste, flows from landfills and rivers).

6.5.6 Emerging issues including climatic change effects

1010. Like the other subregions of the Mediterranean, the eastern subregion is already experiencing climate change-induced alterations to its marine ecosystems. Tropicalization, i.e. the establishment of tropical species that were previously absent from the basin, is evident in the subregion. Some species start their colonization in the easternmost part of the Mediterranean, i.e. the warmest one and, also, the one in direct contact with the Suez Canal, the main conveyor of tropical species to the Mediterranean Sea. Meridionalization and tropicalization occur because the climate is warming and this response is an adaptation of the Mediterranean biota, both with its internal resources (Meridionalization) and with the acquisition of other contingents (Tropicalization). On the other hand, the cold water species are regressing (Boero and Bonsdorff, 2007; CIESM 2008b) so leaving an ecological vacuum that is being filled by the new tropical contingent. In a way, it is to be expected that, if climate becomes warmer, species of warm water affinity tend to become dominant, whereas those of cold water affinity tend to regress.

1011. Sea level rise is expected to affect coastal areas, human habitation, and industries situated in low-lying areas. Inundation by seawater will affect infrastructure, but also may impact fisheries productivity due to loss of nursery areas, and may result in the release of contaminants currently locked up in coastal (terrestrial soils).

6.6 Conclusions and gap analysis on pressures and impacts

1012. Large cities have been identified as critical sources of hazardous substances pollution, since most of the “hot spots” are located in their neighboring sediments (Alexandria and Port Said in Egypt and Athens and Thessaloniki in Greece). Also, high concentrations of hazardous substances were found in sediments located in river mouths and estuaries of major Mediterranean rivers (Nile) and lagoons (lake Manzala, Egypt). Pollution from heavy metals appears to be somewhat decreasing, as their content in sea water remains low and even the situation seems to be improving.

1013. Similarly, concentrations of chemicals (DDT, PCBs) are also decreasing, but in some cases concentrations still remain relatively elevated. Hazardous substances trend revealed decreases more evident in the case of DDTs probably due to a more efficient regulation of this chemical. PAHs are studied to a limited extend both spatially and temporally; and the same can be concluded for anthropogenic radionuclide concentrations. However, these limited studies on the latter revealed a 137Cs concentrations decreasing from the surface to bottom in Greek waters and from east to west as well as through time reaching levels similar to those of the pre-Chernobyl period highlighting the effect of Black Sea water in the radioactivity of the area.

1014. Investigation of a small number of studies of the bioaccumulation of hazardous substances on the high trophic level (cetaceans, and turtles) suggested that levels were similar to those in other parts of the Mediterranean and not high enough to have likely affected the health of these endangered species. In contrast seals presented significantly higher levels of organochlorines than their counterparts from the Atlantic indicating a predominance of pollutants of agricultural origin in eastern Mediterranean. Although most big cities in the eastern Mediterranean operate wastewater treatment plants for a part of their population, there is still an important part of the population of this area, which is not connected to a wastewater treatment facility (UNEP/MAP – BP/RAC 2009).

1015. Perhaps more importantly, human intervention in this subregion, coupled with sea level rise, is greatly altering coastal habitats. The traditional reaction to sea level rise is to build coastal defences, often to protect settlements that have been placed very near to the coast line. Coastal development, often leads to cases where coastal lagoons are radically altered or even destroyed for the management of mosquito presence, once linked with malaria. The development of tourism is heavily affecting the coastline, with increasing settlements right on the shore, and road constructions running parallel to the sea. Furthermore, sandy habitats are often intensively exploited to mine the sand, for the construction of buildings. This combines with other impacts: for instance, the construction of dams which results in fewer sediments reaching the sea.

1016. The rapid increase in population density along the coastal plains in some parts of this subregion, and consequent urbanization, has generated land reclamation schemes. Sand mining in the past and the existing marine structures along the coast have depleted sand reserves and increased coastal erosion. Effluents, such as sewage, agricultural run-off or industrial wastes increase nutrient loading locally, most notably in bays and in some lower reaches of the coastal streams. In such nutrient-enhanced sites, appropriate ambient physical conditions may cause the development of toxic algal blooms. Yet, overall, levels of toxic contaminants are relatively low, except for areas having concentrations of heavy industries.

1017. The large number of rivers and streams in the wetter parts of the subregion, combined with the sandy structure of soil (on the shoreline and in the lower coastal plain) make the land susceptible to various levels of erosions, especially where the coastal mountains steeply project towards the sea. Sediment pollution in the nearshore waters is one consequence. Conversely, one of the major problems facing arid coasts is a deficiency in sediment loading leading to erosion of sandy beaches. Since the construction of the Aswan High dam in Upper Egypt in 1964, erosion in Lebanon, for instance, has increased greatly in the Nile Delta as sediments are trapped in Nasser Lake. Yet, since no monitoring of coastline retreat has been carried out in Lebanon including its causes, it is difficult to ascertain the extent to which beach erosion along the Levant coast can be attributed to the Aswan dam. Apart from this possible sediment loss, three kinds of extracting activities cause or exacerbate coastal erosion: sediment dredging offshore, sand extraction on beaches and gravel quarrying in river beds. Exacerbating an already bad situation, sea-filling activities for coastal land expansion is affecting the direction and speed of currents as well as the intensity of waves leading to erosion of soft shorelines.

1018. Coastal development also lowers water quality. During the period 1996-2005, there has been a near stagnation at a high level in the percentage of bathing waters conforming to national standards (from 92.3% to 92.8%), with fluctuations during the period. A slight improvement is seen between 2004 and 2005. It should be noted that data only refers to waters that are officially monitored and there may be a number of bathing areas which are used for recreation that are not monitored.(UNEP MAP – BP/RAC, 2009). The report concluded that although there is no real trend evident during the sampling period it can be seen that, 50% of the countries submitting data for 2005 achieved over 90% compliance with national standards for bathing water quality, and that Cyprus, Greece, and Turkey all achieved 100% compliance with their national standards by 2005. All Eastern Mediterranean countries have legislation and microbiological quality criteria and standards for bathing waters. EU countries are bound by the relevant EU Directives, while the Mediterranean non-EU countries by their common Guidelines.

1019. Water quality has had myriad impacts on biodiversity. In just one example from Turkey, a comparison of the algae collected in Izmir Bay over the space of a year with records from the 1970s, it was shown that pollution-indicating groups had increased, and that species such as *Cystoseira* which are indicative of clean coasts, had either migrated to cleaner waters, or had disappeared altogether. Invasive species spread, such as that of *Caulerpa taxofolia* and *Caulerpa racemosa* (Forsskal) adds to pressures on marine systems.

1020. At the same time, marine litter remains a key aspect of transboundary issues in the subregion, which has densely populated and highly industrialized areas, along with intense coastal and shipping activities. A recent bibliographical study conducted by UNEP/MAP - MED POL on the phenomenon in the Mediterranean concluded that, between 2002 and 2006, the situation had hardly changed.

1021. Seagrass and *Cystoseira* communities, *Laminaria rodriguezii*, and coralligenous biotopes and maerl Beds are at the point of disappearance because of anthropogenic impacts on some coasts. Some species of seaweeds are disappearing from where they were previously recorded, others are migrating. Some populations are re-declining in particular the sea grass *P. oceanica*, which has been seriously affected by pollution from urbanization and tourism development along the coasts, coastal modifications and fishing. At the same time, highly diverse coralligenous biocenoses are at risk from the unreported or illegal trawl fishing. *Posidonia* beds are negatively affected by such activities as fish farming, coastal mass tourism and the coastal development associated with it, marina construction, yachting and anchoring. Fish farming installations are widespread in the region, and unregulated or uncontrolled feeding leads to eutrophication and the retreat of sea grass beds.

CHAPTER 7: COMMONALITIES AND IMPLICATIONS FOR THE ECOSYSTEM APPROACH PROCESS

7.1 Cumulative and Concurrent Impacts

1022. The Mediterranean Sea, like many other regional seas around the world, is undergoing change from the direct and indirect effects of human activities, in the ocean, on the coast, and across upland areas. Based on the information currently available, both similarities and differences exist between the status of ecosystems within the four subregions which were delineated by the Contracting Parties for the purposes of initial assessment. The differences between subregions can be thought of as differences in degree, not in kind, however – because pressures occur throughout the basin and the responses of the ecosystems to multiple and cumulative impacts are similar if not identical across the whole of this heavily used and highly valued sea.

1023. Although not as discretely delineated as the semi-enclosed Mediterranean Sea itself, the four subregions of the Mediterranean present a conglomerate of linked coastal and marine ecosystems, with many shared resources, species,and common approaches to both environmental monitoring and management. Each of the major pressures or classes of threat identified by national monitoring, the research undertaken by scientific institutions, and the analysis of multilateral agencies and programs such as MAP, occur across all four subregions – but the priority issues are different in each. This is part based on the underlying physical and biological characteristics of each subregion, and the degree to which various impacts are being felt by the marine ecosystems within them.

1024. The Western Mediterranean subregion is characterized by exchange with the North Atlantic through the stratit of Gilbralter, and complex physic-biological dynamics. There is a high level of industrialization and coastal development-related habitat loss and alteration in this region – especially on the north coasts. Tourism drives much of the coastal development and pressure on resources, and tourism is behind much of the degradation of coasts and nearshore waters. In addition to the physical alteration of the environment and the degradation caused by pollution and loss of key habitats, growth in tourism and urbanization drive increasing pressure on resources, including freshwater (limiting availability in wetlands and estuaries and increasing the need for desalination, with its attendant pollution impacts) and fisheries. In the southern portion of this subregion, population growth along the coast has led to degradation from sewage inputs and run-off. Maritime industries, including shipping, energy development, and aquaculture also degrade the environment and impact biodiversity, causing localized pollution as well as broader impacts on the delivery of ecosystem services due to trade-offs.

1025. The Western Mediterranean is also notable for the degree to which coastal and marine environments have been systematically studied, particularly in the northern reaches of the subregion. Much of the information on environmental status and on pressures and drivers behind that status for the whole of the Mediterranean Sea comes from long-term monitoring in the northern countries, and there is a high degree of scientific research targeting marine species distribution and abundance, habitat distribution, ecological response to particular impacts, and cumulative impacts assessments.

1026. This initial assessment does not attempt to define priority areas for management. However, the subregional reports do point to some areas within each subregion which appear ecologically important or vulnerable. In the Western Mediterranean, these include the Gulf of Lions slope, the Alboran Seamount and Alboran Sea,the area south of the Balearic Islands, and the Strait of Gilbralter. Seagrass meadows have been mapped in much of the subregion, and are a critical area for many species.

1027. The Central Mediterranean and Ionian subregion experiences some of the same pressures and drivers, though the major impacts are somewhat different from the western Mediterranean, in part because of the differing physical characteristics of this subregion. There is no exchange with waters of the Atlantic, and in contrast to the wide open basin of the western subregion, the central subregion has complex bottom topography and numerous straits through which water masses and species pass.

Coastlines are generally not as highly developed as in the Mediterranean, though urbanization is a factor in some localized areas. Fishing is a primary pressure on species and ecosystems, both due to over-exploitation and incidental catch or by-catch, and due to the use of destructive fishing methods, including dynamite fishing, bottom trawling, and destructive removal of deep corals. Shipping pressures are concentrated in the straits between the African continent and the southern Sicilian coast, and nutrient over-enrichment from sewage and run-off puts the southeastern portion of this subregion at risk of hypoxia.

1028. Particularly important and / or vulnerable areas which emerge from the initial assessment and warrant further analysis include the region south of Sicily, especially the Adventure and Malta banks, and the . cold coral reefs off Cape Santa Maria di Leuca. The extensive wetlands areas in eastern Tunisia also merit further study and assessment of ecosystem services values and trends.

1029. The Adriatic Sea is a semi-enclosed sea within a semi-enclosed sea; given its limited flushing, agricultural inputs and urbanization along its western flank, and its relative shallowness, eutrophication is a major issue. Although point source pollution by toxic contaminants has been largely controlled and toxic pollution is confined to a few localized industrial areas, run off and inadequately treated sewage continues to upset the nutrient balances of the narrow sea, leading to algal blooms, mucilages, and spreading hypoxia. Climate changes may be exacerbating the impacts of these pressures, as well as compounding the effects of invasive species in the subregion. Fisheries over-exploitation is also identified as a pressure, especially in the northern reaches of the central Adriatic.

1030. Despite the pressures, the Adriatic Sea is remarkably diverse and productive, with a variety of ecosystems providing valuable ecosystem services. Tourism is important to the region, as are fisheries. The Northern Adriatic is a major spawning ground for anchovy and pilchard, while the Fosa di Pomo/Jabuka Pit area is important nursery area for hake and has biologically diverse cold seeps. The Adriatic is also noteworthy in that several of the countries within this subregion have been exploring ways to coordinate research and management, setting the stage for a facilitated movement towards an ecosystem approach.

1031. The Eastern Mediterranean subregion is perhaps the least known of the four subregions delineated for the initial assessment of the ECAP. This subregion is also very diverse in beta-level or large scale biodiversity: extensive archipelagos exist in the north, while a wide shelf with alluvial sediments is found around the Nile Delta to the south. The coastline and bottom topography is highly varied, as are the human uses of coasts and seas. While all the pressures that exist throughout the Mediterranean are found within this subregion as well, invasive species and climate change are the top issues of concern. Spreading hypoxia and lowered water quality result from untreated sewage inputs, desalination effluents, and urban run-off.

1032. The trends in water quality, invasive species spread, and tropicalization from climate change have not yet devalued this subregion. The northern portion remains one of the primary coastal tourist destinations in the world, and coastal communities throughout the region continue to depend on marine resources. Maritime industries are expanding, increasing the perceived value of the marine areas (but also causing alarm over possible increased degradation as well as conflict). Noteworthy areas from a ecological standpoint include the Thracian Sea and the Eratosthenes Seamount, as well as the Nile Hydrocarbon Cold Seeps.

1033. To the extent this information synthesis provides a common approach to assessment, it has begun to highlight how different threats or pressures have differing levels of importance in each region. These differences have to do with inherent characteristics of each subregion, including physical characteristics that influence vulnerability, as well as differing degrees of pressure in different subregions. Thus pressure-state-response all varies.

1034. It should be noted that this overly simplistic highlighting of key issues within each subregion masks some interesting variation *within* subregions. For instance, over-fishing and tourism-related coastal development appear to be main threats in the northern reaches of the eastern Mediterranean subregion, while in the southern and eastern portions of this subregion, pollution caused by urbanization and river discharge continue to be the key pressures.

1035. An overview of all four subregions, taken together with a review of literature on Mediterranean ecology overall, suggests that commonalities may be more pervasive than are differences between subregions. The pressures and impacts that are common to all four subregions include:

- **coastal development and sprawl,** driven by urbanization and tourism development, leading to habitat loss and degradation, and erosion/ shoreline destabilization
- **overfishing**, and incidental or by-catch, affecting community structure, ecological processes, and delivery of ecosystem services
- **destructive fishing**, including bottom trawling and fishing methods resulting in benthic disturbance **contamination** of sediments and biota caused by pollution, primarily from urbanization and industry, but also from anti-foulants and atmospheric inputs of hazardous compounds
- **nutrient over-enrichment**, sometimes but not always leading to eutrophication and hypoxia, more regularly leading to ecological imbalances (reduced water quality and growth of algae, mucilages, etc.)
- **disturbance and pollution caused by maritime industries**, including shipping, energy, aquaculture, and desalination (operational as well as disaster-related)
- **invasive species** spread, in many cases mediated by climate changes
- **degradation of transitional or estuarine areas**, which serve as critical nursery areas for commercial fisheries and also support unique assemblages of species

1036. Additionally, the initial assessment provides some information on ecologically important, biologically diverse, or vulnerable areas, and the potential biodiversity loss (inferred but not yet quantified) emerges as a priority issue across the whole of the Basin.

1037. Since the 2006 UNEP/EEA report on the State of the Mediterranean Environment, some changes in condition are apparent. Improvements in water quality are discernable in many places, thanks to strategic efforts to reduce pollutant loading. Quantities of hazardous substances such as DDT and heavy metals are declining in most areas.

1038. New issues, however, are emerging which warrant attention. Desalination and its effects, particularly with respect to brine release, should be better investigated. The increasing use of coastal and ocean space for aquaculture, including the grow out operations for bluefin tuna, brings with it the threat of increased pollution, eutrophication, invasive species and pathogen releases, and increased conflicts over reduced access and availability of space for other uses.

1039. Increasing and multiple uses of ocean space mean that any threats that work synergistically to cause even greater impact than if acting alone should be monitored. One example is how the combined effect of nutrient over-enrichment, over-fishing of certain functional groups like grazing fishes, and climate change can act together to cause imbalances in nearshore ecosystems, and loss of ecosystem services.

1040. Modelling supports the notion that it is important to understand the impacts of multiple threats acting simultaneously. The NCEAS-supported comprehensive spatial analysis and mapping of human pressures to Mediterranean marine ecosystems provides one example. It builds on a previous global analysis of cumulative human impacts (Halpern et al. 2008) that involved combining global spatial data on 17 types of pressures (from fishing, climate change, and pollution), the distribution of 20 marine ecosystem types, and scores representing the potential impact of each pressure on each ecosystem type derived through an expert judgment survey approach.

1041. In the Mediterranean analysis the same approach was used, but Micheli replaced some of the datalayers and included additional data to better reflect the specific pressures and ecosystems of the Mediterranean basin. A total of 22 spatial datasets of human activities and stressors and 19 ecosystem types were assembled and used in the analyses and maps (see http://globalmarine.nceas.ucsb.edu/mediterranean/).

1042. The analysis concluded that climate change, demersal fishing, ship traffic, and, in coastal areas, runoff from land and invasive species, exert the greatest impacts on Mediterranean marine ecosystems (Micheli, 2011).The lowest estimated impacts are associated with oil spills and oil rigs, due to a combination of the limited spatial extent of these pressures and their overlap with habitats with relatively low vulnerability to these potential threats. The analysis shows distinct spatial patterns in the distribution of cumultive human impacts (see Figure 7.1).

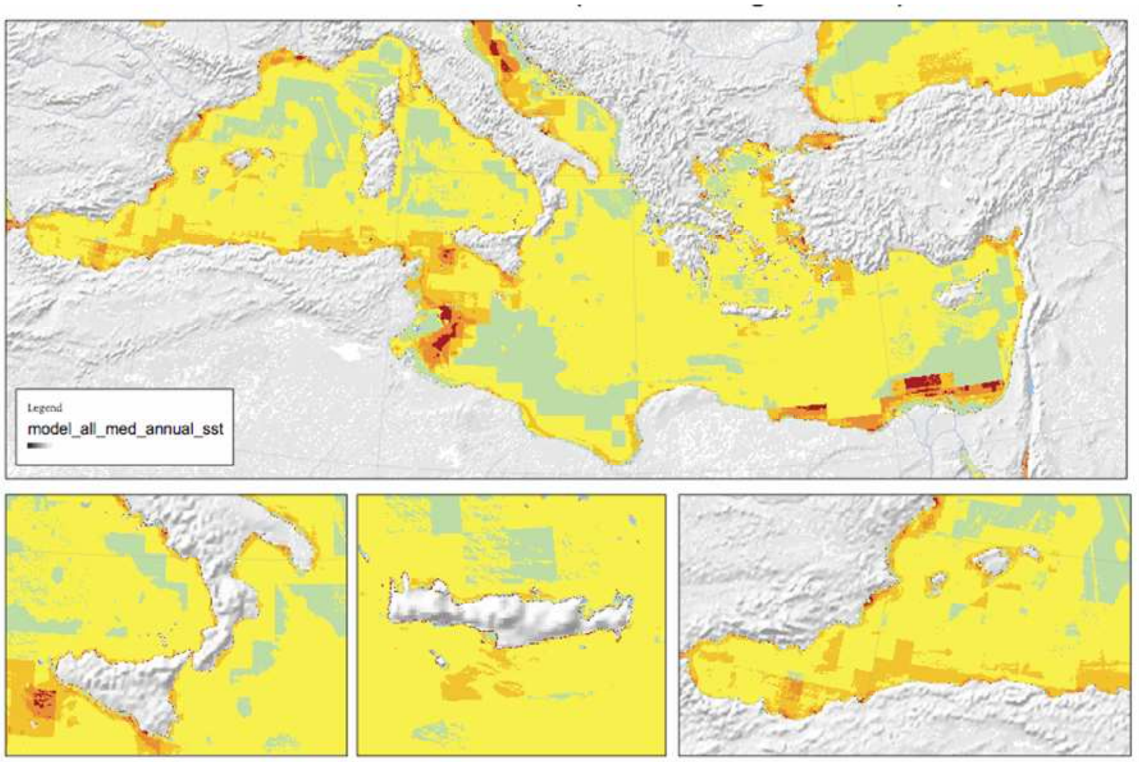


Fig. 7.1. Cumulative human impacts to the Mediterranean Sea, including the annual average increase of sea surface temperature (from http://globalmarine.nceas.ucsb.edu/mediterranean/).

1043. Supporting the findings of the initial assessment, the NCEAS modeling reveals the Adriatic and Alboran seas as the most impacted by multiple human pressures,while the Western Mediterranean and the Tunisian Plateau/Gulf of Sidra the least (see Figure 7.2). Coastal areas within the territorial waters of nations, particularly Spain, France, Italy, Tunisia, and Egypt suffer the greatest cumulative impact from multiple pressures, with estimated cumulative impact scores up to ten times greater than in the high seas.

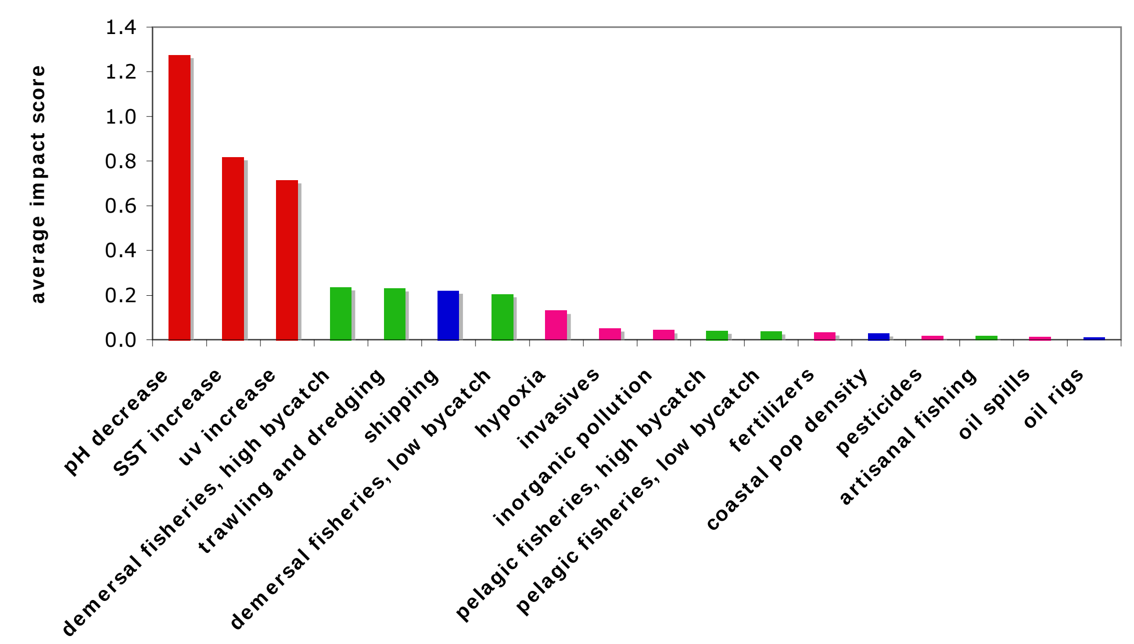


Figure 7.2 Average impact score of each activity or stressor to Mediterranean marine ecosystems. Climatic stressors: red; development and transport: blue; fishing: green; pollution: pink.

1044. It must be noted that the modeling of cumulative impacts only suggests areas for further study – ground-truthing is needed. In addition to establishing a systematic monitoring regime to derive needed information on condition and trends, future research will have to elucidate cause and effect relationships, not just correlations. The next steps of the ECAP, namely the setting of ecological objectives and operational objectives, together with indicators, will form the basis for such a rationalized approach to deriving information for all future assessments. Establishing targets, and analyzing trends information to know when targets are being approached, will provide the kind of robust scientific information needed to allow management priorities to be determined, and to guide effective ecosystem-based management.

7.2 Information Gaps and the potential for optimal monitoring under ECAP

1045. Unfortunately at this point in time, there is a general lack of information on some pressures, as well as consistently collected data by which to establish trends. Where quanitifcation is possible, it still remains a challenge to determine ecological impacts caused by particular stressors or pressures. However, it is clear that monitoring taking place within countries in order to meet the obligations of the Barcelona Convention and its protocols has provided a starting point for developing a systematic monitoring regime that will be able to provide the needed information in the future.

1046. There is also a critical gap in the information available on the ecology and environmental status of offshore areas, especially areas beyond national jurisdiction (ABNJ). As these areas are significant and little to no monitoring and surveillance of activities currently takes place there, an expansion of study to include offshore pelagic environments and the deep sea is recommended. The Barcelona Convention provides a useful framework for cooperation in this regard – and inclusion of offshore considerations will ensure that future management is indeed more ecosystem-based.

1047. Overall, the rich marine biodiversity of the Mediterranean Sea remains relatively little known despite the increasingly considerable efforts made by the international scientific community to grasp it. Knowledge of marine and coastal biodiversity is not homogeneous throughout the Mediterranean and has many gaps. Even information on the MAP Protocol species and habitats that are of conservation interest in the Mediterranean is sometimes limited. Regional priorities to address these data gaps are provided below, as identified by UNEP/MAP- SPA/RAC.

- Lack of clear national strategy to systematically inventory marine and coastal biodiversity in many countries. Marine and coastal biodiversity -linked aspects do not have priority in political decisions, as is the case for social aspects - The national inventories of marine and coastal species and habitats are not homogeneous. For most countries they are incomplete; the effort made is more focused on the north-western Mediterranean

- Many Mediterranean sectors and/or ecosystems remain little studied, even within country limits. Prospecting is usually done in areas that are easily accessed. The inventories drawn up in some countries (bibliography, site prospecting, updating etc.) are usually made in sectors concerned by programmes or action plans. Knowledge of the presence, distribution, abundance, and conservation status of Mediterranean coastal and marine species is uneven for taxa and regions.

- Deep sea and high seas reference habitats have commonly been little explored.

- Lack of national taxonomic skills for many groups of marine flora and fauna, leading to sometimes questionable identification of species. Experts in taxonomy of most groups are strongly concentrated in a few countries, mostly lying in the northern part of the Mediterranean

- Little sharing of recent knowledge within scientific circles in the various countries of the northern and southern Mediterranean

- Absence of programmes for monitoring non-native species in many countries, particularly the countries of the southern Mediterranean

- Patchy mapping of marine and coastal species and biocenosis, particularly those of conservation interest for the Mediterranean. Research done on marine and coastal biodiversity is compartmentalized, restricted to very narrow aspects, and lacks interdisciplinarity

- Absence of coordinated and cross-border scientific research, probably related to financial and administrative constraints.

1048. There are also gaps in understanding of the impacts of human activity on marine and coastal biodiversity. This can be observed at several levels: scientific knowledge; legal tools availability; enforcement of existing laws; public awareness; concrete actions and operative plan implementation.

1049. These gaps, issue by issue, can be summarized as follows (more details are given in the supporting document provided by UNEP/MAP- SPA/RAC):

- Invasive species: (i) a lack of a mechanism for collecting, compiling and circulating information on invasive non-indigenous species still exists, (ii) a lack of knowledge still exists, in particular about impact on structures and functioning of the ecosystems and (iii) a lack of long term monitoring programs on invasive species.

- Impact of fishery on target and non-target species: (i) An important lack regarding the limitation of the ecosystem approach application in fishery management, (ii) discards composition and quantification needs particular attention, (iii) Recreational fishery gaps regard both control of composition, abundance and size of catch and scientific data about landings, (iv) Gaps about the knowledge of possible interactions between eutrophication and fish cultivation practices in coastal lagoons and other marine sites, (v) Lack of enforcement of control and surveillance of fishery regulations (vi) Lack in monitoring, control and surveillance is particularly evident for high seas.

- Microbial pathogens: The main gaps to bridge in order to enhance knowledge of microbial pathogens have to be distinguished among classical and new ones as follows: (a) "Classical" pathogens: (i) low level of monitoring plans is generally found, (ii) a lack of basic knowledge of classical pathogens in sediments and beaches, (iii) an important gap is constituted by the lack of law enforcement to prevent or reduce the pathogens concentration in the sea water, (iv) a lack of knowledge on the consequences and impacts of pathogens on ecosystems and habitats…; (b) "New" pathogens: (i) lack of basic knowledge on new pathogens, (ii) the lack of legislation enforcement in controlling the vectors of introduction into the Mediterranean of non indigenous species and invasive marine species (i.e. mariculture) constitutes a significant issue, (iii) a lack of public awareness on health and safety issues for hazard species, gaps on knowledge regard consequences and impacts on ecosystems and habitats, (iv) a lack of effective scientific monitoring for Harmful Algal Blooms (HABs), especially for Southern Mediterranean waters…

- Climate change: the magnitude of Mediterranean marine biodiversity in response to climate change remain largely unknown due to (i) the lack of consistent long-term monitoring of Mediterranean marine biota and ecosystem processes; and (ii) the scarce information available on climate change impacts on marine organism physiology, population demography, reproduction, species distribution and ecosystem function, (iii) lack of monitoring, targeted research, institutional scientific capacities, technical expertise, national polices and priorities, critical area identification and studies and funding opportunities at national level, (iv) lack of studies on the socio-economical consequences of the impact of climate change on marine and coastal biodiversity, (v) lack of knowledge on the consequence of climate change on biodiversity due to the changes in the chemistry and biogeochemical cycling of carbon and carbonate (ocean acidification)…

- Deep sea: (i) The main gaps about deep sea deals with the very limited knowledge of this environment, particularly poor are data and scientific researches below 1000 m depth, (ii) especially for several areas of Eastern Mediterranean and in Southern waters, nothing is known about deep-sea biology, (iii) gaps exist also about the effects of anthropogenic pressures on deep sea species and habitats, where few data are available for fishery and no data are available about the effects and consequences on deep biodiversity of waste accumulation, (iv) an important gap, not specific for the Mediterranean sea, but in any case relevant also to the Mediterranean region, regards the lack of emergency technology and plans to deal with petrol spillage in deep water.

1050. This exhaustive list of needed information on biodiversity might suggest that an ecosystem approach to management is not possible at this point in time. However, this is not the case: improved management is possible guided by the information at hand, and future monitoring under an ecosystem approach can be designed so that it derives needed data and further improves understanding (this is the essence of adaptive management). Furthermore, targeted phased research that aims to fill the most pressing knowledge gaps could quickly enhance the body of knowledge about Mediterranean marine ecology.

1051. A final category of information important to developing an ecosystem approach but currently insufficient in the Mediterranean region is the mapping of available data. Mediterranean-wide inventory of critical habitats such as seagrass beds, intact rocky shorelines, persistent frontal systems, estuaries, deepwater coral assemblages, and (primarily in areas outside national jurisdiction) sea mounts could provide very basic information on areas with a high delivery of ecosystem services. Much of this information already exists but has not been systematically mapped. The detailed information provided by national reporting on the distribution of seagrass meadows, coralligenous communities, and other critical marine and coastal habitats should be mapped in the next phase of ECAP and added to other map layers (such as the distribution of coastal lagoons) to support GIS analysis.

1052. Areas under multiple threats (hotspots for multiple pressures) can also be mapped, using existing information as opposed to the cumulative impacts maps inferred from modeling (see discussion of Micheli 2011 above). Figure 7.3 demonstrates how information on areas of conservation interest could be overlaid with information on threats, through an exemplary (but very preliminary) demonstration map produced by Info RAC.

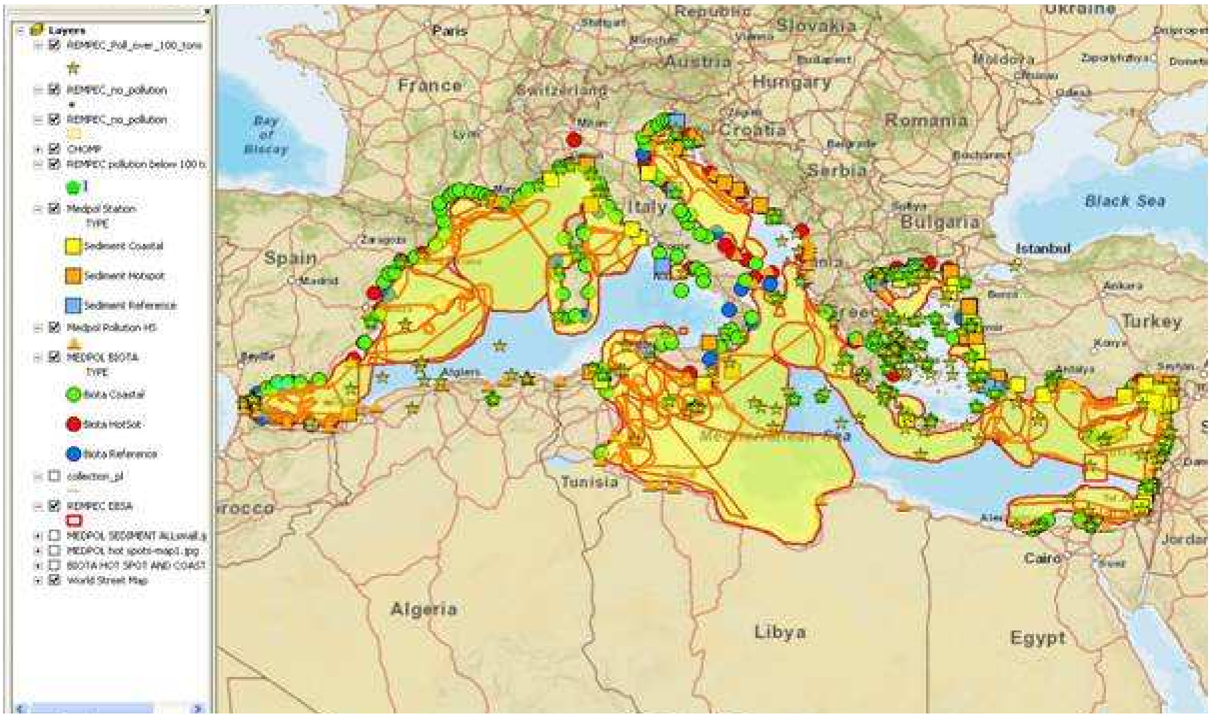


Figure 7.3. Snapshot of some of the ecological and human activity information mapped by InfoRAC.

1053. The purpose of providing this illustration is not to define areas, but to show that geographic priorities can be highlighted using mapping of both expert opinion and information derived from database analyses. Areas of overlap do not suggest maximum ecological impact, but they may influence where monitoring, once a systematic regime is established, should be implemented.

7.3 Conclusions of the Initial Assessment

1054. The Mediterranean remains a rich and valuable, but ever-threatened, marine system. The pervasive threats caused by human activity: primarily coastal development and urbanization causing loss of ecologically important habitats; pollution, especially hazardous substances such as heavy metals, halogenated and petroleum hydrocarbons, antifoulants, and radionuclides; nutrient over-enrichment caused by run-off and river inputs of nitrogen and phosphorus, and corollary eutrophication and hypoxia effects; over-fishing and fishing-related habitat disturbance; biological disturbance caused by invasive species, harmful algal blooms, and new forms of microbial pathogens; and dumping of dredge spoils and other waste, as well as discards of litter, all continue to take their toll on marine life throughout the region. Some of the most diverse and most ecologically important habitats (also some of the most valuable, from an ecosystem services sense) are the most impacted: for instance, seagrass meadows continue to be lost and degraded in all subregions, and the condition of coastal lagoons continues to decline.

1055. Perhaps the greatest commonality in the overall region, and the biggest challenge facing the Mediterranean countries committed to an Ecosystem Approach, is the lack of information on trends in pressures and environmental status, cumulative effects, and synergistic effects. As an Ecosystem Approach is by its nature integrative, a new emphasis on cumulative and compounding impacts will be imperative. Much-needed information includes the interaction of pollution with climate change effects, for instance, or the interaction of fishing-related changes in the food web with diversity and delivery of ecosystem services. Thin, too, is understanding of the extent to which activities on land: freshwater diversion, concretization and urban and ex-urban sprawl, habitat destruction – have measurable impacts on marine ecology, and if so, can be addressed in some sort of Ecosystem Approach framework.

1056. The attempt to standardize assessment in each of the four subregions has resulted in a number of important findings concerningcommon threats, similar trends in all subregions, differing priorities regarding key threats/pressures in each subregion, and new developments in environmental quality and issues since the UNEP/EEA report of 2006.

1057. At the same time, the identification of data incompatibilities and insufficiencies, despite the good information that already exists from monitoring undertaken by Contracting Parties, gives clear direction on how to improve systematic monitoring the future so that it can catalyze effective management under an ecosystem approach. At present, monitoring is not leading to derivations of trends, nor can the information coming from monitoring programs be used for scenario development and trade-off analysis.

1058. In general, pollution monitoring is systematic throughout the region and will continue to yield good information about environmental quality. However, other impacts are generally either not systematically monitored, or cannot be assessed in a regionally consistent way. For instance, the current system for monitoring fisheries in the Mediterranean under the GFCM utilizes many reporting areas, which neither correspond to the subregions in the ecosystem approach process nor to national boundaries. Furthermore, while the focus of the regional fisheries body is to derive information for fisheries management using effort restrictions, ecosystem impacts and the management of fisheries so as to preserve other provisioning, regulating, supporting, and cultural services is not its central mandate.

1059. There is also a difference between data and information (and knowledge) that merits mention. Future monitoring could increase the extent to which data are collected and managed in a way useful for assessing the condition of the Mediterranean in the future and for guiding management so it is optimally effective. The selection of operational objectives, indicators and targets that are meaningful and feasible (or, in the language of SMART: strategic, measurable, achievable, realistic and timebound) can guide that optimization.

1060. The four subregional assessments and the Mediterranean-wide compilation provide the initial information gathering step in a continual process of a science-based ecosystem approach to management. In essence, this information step is the entrée into a cyclic process of ecosystem-based management, as shown in the introduction in Figure 1.1. Rather than being a risk analysis or state assessment, this report represents the information gathering that launches the EBM process. Once priorities are determined and objectives are set, monitoring can be designed that will allow proper state assessments to take place, at regional, national, and even local levels.

1061. The initial assessment has identified, or further supported the previous identification of, key or critical habitats supporting Mediterranean ecosystems. These include seagrass meadows (not restricted to but including Posidonia beds); coralligenous communities; coastal lagoons and coastal soft-bottom communities; sea mounts and unique benthic features; frontal systems and other features of the pelagic (water column) environment.

1062. At the same time, the Blue Plan economic valuation exercise has provided some important data to support the ecosystem approach process, by investigating the extent to which five marine and coastal habitats contribute to the delivery of economically valuable ecosystem services. A mapping of these high value areas across the region is feasible and is recommended.

1063. As mentioned previously, primary information needed for an ecosystem approach includes accurate large-scale habitat maps of a given region. Such maps lend themselves well to integration within web-based and conventional geographic information systems (GIS). Through the medium of GIS, these spatial data facilitate simple and rapid analysis of marine ecosystems across space and time. This would include data extracted from time-separated satellite scenes, or through comparison to archive maps created from aerial photography. Additional data, such as existing in-country scientific and management projects, fisheries data, and other marine use and impact zones, can easily be melded into such a geospatial framework. The map product facilitates rapid viewing of the resources of the region within their true spatial context. Such knowledge can prove invaluable in defining the objectives, physical boundaries, and ongoing procedures of resource management. While a vital part of the conservation process, accurate mapping should not be regarded as an end-goal in and of itself. Such maps pave the way towards more in-depth scientific studies of both local and landscape processes. In turn, these can be fed back into knowledge-based management.

7.4 Next Steps

1064. The findings of this inital assessment help catalyze forward movement of Mediterranean countries towards the Ecosystem Approach in two ways: by identifying (preliminarily) priority issues that are common to all subregions and can serve as the basis for developing an initial list of ecological and operational objectives; and by highlighting gaps in understanding created by lack of monitoring or inconsistent monitoring (preventing comparisons across time or geographies).

1065. Once ecological objectives and baselines have been established, mechanisms can be put into place that can easily derive useful trend information. Thought should also be given to "early warning systems" which could alert governments and institutions to the rapid approach towards critical thresholds, where such thresholds have been determined.

1066. Cause and effect must be considered in order to determine what human activities are leading to the environmental outcomes documented. For instance, if *Chlorophyll a* production is increased in an area, it will be necessary to determine if this results from increased nutrient loading from land-based sources, or from hydrological / oceanographic changes at sea. Knowing the drivers behind impacts is necessary in order to craft a management response that will adequately address the pressure and improve the ecological status. In much of the subregional drafts, some indication of driver is given, but it will be important to ascertain the certainty with which such cause and effect statements can be made, and have citations to published research or datasets to substantiate statements.

1067. One further consideration is that a systematic and optimized monitoring program should not only look at environmental quality or ecological status but also management effectiveness. In other words, information should also be obtained on what sort of management exists, whether regulations are being enforced, and the level to which there is compliance with regulations (or, put another way, whether there are illegal or unreported activities going on despite the existence of management / regulations). This type of analysis was absent from the integrated assessment described herein, and the gap in this sort of information hinders development of effective management responses. In effect, monitoring would optimally provide the data needed in the future to do environmental assessment (i.e. whether ecological objectives are being met) and management effectiveness assessment (whether management objectives are being met). Thought should be given to optimizing data compatibility coming from the environmental monitoring stream with data and information coming from the management evaluation stream. Both information streams should feed the ecosystem approach process.

1068. However, one challenge which will be paramount in the implementation of the ecosystem approach will be monitoring that is streamlined and does not add unnecessary burden to countries, but which can derive meaningful information on the interaction between threats. For instance, although pollution monitoring is already providing very useful information about pollutant loading around designated sampling stations, and fisheries data provide some indication of level of effort, catch, and stock of target species, there are currently no mechanisms in place to determine how the environmental quality is changing in response to the cumulative and combined effects of pollution and fishing. This may be particularly important in areas where the threat of eutrophication is not paramount, but where the combined effect of overfishing and increased nutrient loading may be causing ecological imbalances. An optimized monitoring strategy should inform understanding of these synergistic effects.

1069. In the context of streamlining, the Mediterranean countries are harmonizing their ECAP efforts with the related process occurring under the Marine Strategy Framework Directive (MSFD). European Union countries have embarked on a process to evaluate good environmental status, determine targets and indicators, and design coordinated monitoring programmes for future assessment. Their work to assess 11 descriptors of Good Environmental Status using standardized indicators could be assisted by the successful formulation of the next steps of the ecosystem approach process, particularly if small, feasible pilot projects demonstrate how objectives can be assessed in the Mediterranean context.

1070. Adopting an Ecosystem Approach in the Mediterranean, with its enormous scale, variety of management challenges, non-uniform capacity for management, and limited resources, will be complicated and will take time. This and future assessments will lead to better understanding of environmental and ecological status, and will present options for further monitoring and evaluation, which will then provide the necessary information for determining trends, and prioritizing issues requiring management action so that the management response is effective and efficient in safeguarding the valuable ecosystems of the Mediterranean.

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