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ASSESSMENT REPORT

Assessment of the Mediterranean Sea: Fulfilling Step 3 of the Ecosystem Approach Process

UNEP/MAP
Athens, 2010

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A Note from the Secretariat

The draft integrated assessment has been prepared by the Secretariat with the assistance of Ms Tundi Agardy as UNEP/MAP consultant. The report is based on the subregional reports prepared by the respective MAP components MED POL, SPA/RAC, and Blue Plan (Mangos *et al.*, 2010), as well as additional information from REMPEC and published sources.

Many portions or the text originate from subregional reports and the overall biodiversity report prepared by UNEP/MAP-SPA/RAC. Additional material was derived from the UNEP/MAP-BP/RAC report, as well as national reports.

This consolidated report 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 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.

Acknowledgments

To be completed later.

Executive Summary

TO BE COMPLETED LATER ONCE COMMENTS ARE RECEIVED AND REPORT IS AMENDED

I. Introduction

A. The Ecosystem Approach and Mediterranean Assessment Under the Ecosystem Approach Process

1. At their 15th Meeting held January 2008 in Almeria Spain, the Contracting Parties agreed to begin 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" (Decision IG 17/6).

2. To further ecosystem approach, the Contracting Parties 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.

3. A roadmap to achieve these strategic goals was discussed and adopted; 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.

4. This assessment takes four subregional assessments and looks for commonalities, as well as issues of relevance to particular subregions. This methodology follows a decision made by the Government-designated Experts meeting held in July 2008 to subdivide on provisional basis 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** (comprised of coasts and Mediterranean waters of Algeria, France, Italy (Ligurian and Tyrrhenian Seas), Monaco, Morocco, and Spain

- Subregion #2: **Ionian Sea and Central Mediterranean** (comprised of coasts and waters of Greece (Ionian Sea), Italy (Ionian Sea), Libya, Malta, and Tunisia)

- Subregion #3: **Adriatic** (comprised of coasts and waters of Albania, Bosnia & Herzegovina, Croatia, Italy (Adriatic Sea) Montenegro, and Slovenia)

- Subregion #4: **Eastern Mediterranean** (comprised of coasts and Mediterranean waters of Cyprus, Egypt, Greece (Aegean and Cretan Seas), Israel, Lebanon, Syria, and Turkey

5. The subregional reports that formed the basis of sections II-V 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.

6. 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 available across all four regions, and how to aggregate analyses in order to achieve a truly effective ecosystem approach.

7. Assessment for the purpose of furthering an Ecosystem Approach is not a one-step process, but an iterative one. Future assessments could utilize methodologies that determine changes in the status of ecosystems (what is known as environmental or ecological status, and what is specifically referred to in the EU as ‘GES or Good Environmental Status’); impacts on the condition of ecosystems resulting from direct and indirect human uses; present value of ecosystem services; trends in delivery of ecosystem services; and management effectiveness. In other words, in order to know whether EA is being achieved, it is 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.

B. <u>The Mediterranean Marine Environment</u>

8. The 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 1.1 below). 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.

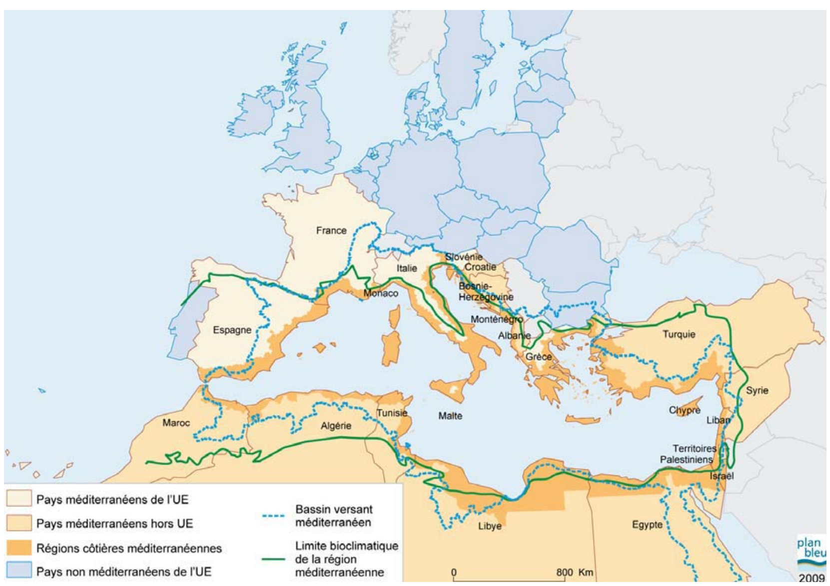


Figure 1.1. Countries bordering the Mediterranean Sea, showing coastal zones (shaded dark beige) and major watershed (in blue dotted lines) (UNEP/MAP-BP/RAC, 2009)

9. 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.

10. 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 Gibraltar Strait. The formation and subsequent spreading of the intermediate water, together with the inflow of the Atlantic Water through the Gibraltar strait, 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. Figure1.2 shows the major currents while Figure 1.3 highlights permanent fronts associated with this regional thermohaline circulation.

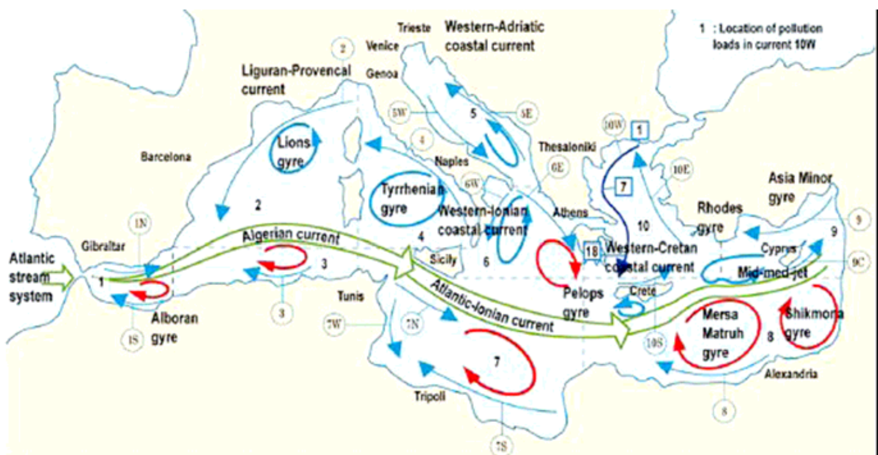


Figure 1.2. Major areas of the Mediterranean Sea and the 18 coastal currents (Reprinted from Stamou and Kamizoulis, 2009)

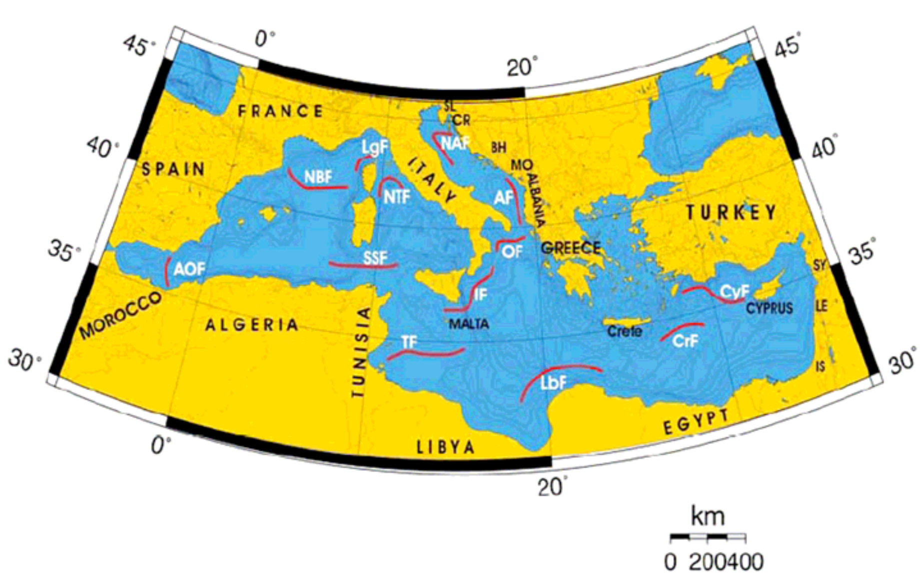


Figure 1.3: Fronts in the Mediterranean Sea (source: Belkin *et al*., 2008, in Sea Around Us, 2009). AF=Albanian Front, AOF=Almeria-Oran Front, CrF=Crete Front, CyF=Cyprus Front, LbF=Libyan Front, LgF=Ligurian Front, NAF=North Adriatic Front, NBF=North Balearic Front, NTF=North Tyrrhenian Front, OF=Otranto Front,SSF=Sardinia-Sicily Front, TF=Tunisian Front. Countries: BH=Bosnia-Herzegovina,
CR=Croatia, IS=Israel, LE=Lebanon, MO=Montenegro, SL=Slovenia, SY=Syria

Region-wide Biodiversity

11. 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- RAC/SPA, 2003; Boudouresque, 2004; Bianchi, 2007; Briand & Giuliano, 2007; Boero, 2007; UNEP/MAP-Blue Plan, 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 recognised on a planetary scale (Meyers *et al*., 2000) (Fig. 3). 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.

12. 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.

13. 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-Blue Plan, 2009).

14. 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.

15. 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) (Fig. 6). Mediterranean marine macrofauna includes over 600 fishes (including 81 chondrichthyans and 532 osteichthyans), three reptile species, about 33 nesting bird species, and 22 marine mammal species.

Coastal Habitat Diversity*: *Sand Dunes

16. 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

17. 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).

18. Mediterranean estuaries and coastal lagoons offer a diversity of habitats for many species. 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.

19. 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.

20. 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.

21. 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.

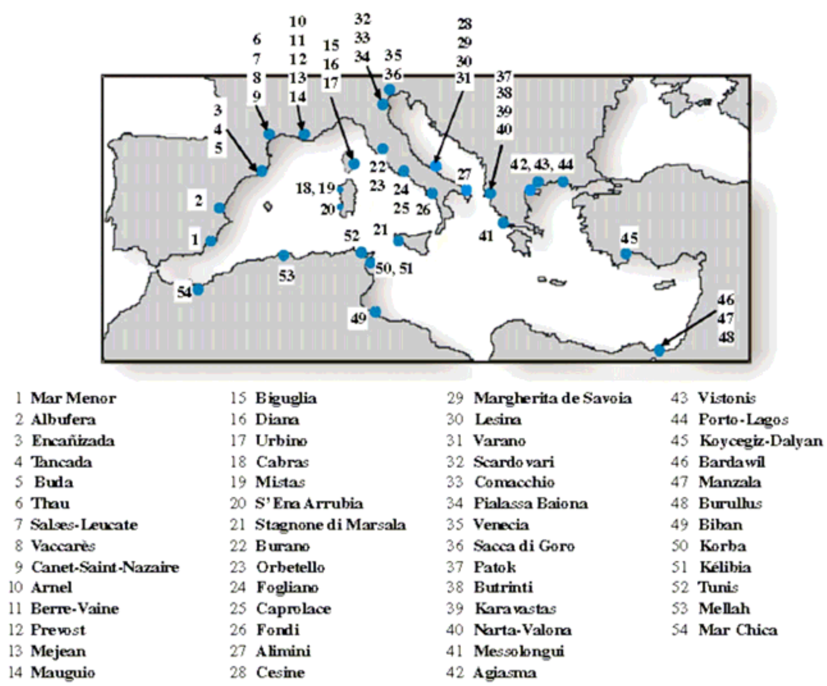


Figure 1.4: Main coastal lagoons in the Mediterranean basin related to the availability of hydrological, geomorphological and ecological data in the scientific literature (Pérère-Ruzafa *et al.*, 2010b)

Nearshore or Neretic Marine Areas

22. 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).

23. 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.

24. 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 (RAC/SPA), a reference list of 27 major types of benthic habitat was made, to help the Mediterranean countries in drawing up inventories of natural sites of conservation interest (UNEP/MAP-RAC/SPA, 2002). The SAP BIO 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.

25. 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

26. 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).

27. 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).

28. 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).

29. 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

30. 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-RAC/SPA, 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

31. 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

32. *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).

33. 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).

34. 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

35. 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:

36. 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

37. 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 at this level (George *et al*., 1991).

38. 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.

39. 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.

40. 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.

High Seas Pelagic Systems

41. 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 is known in the Mediterranean: the Pelagos Sanctuary for Mediterranean marine mammals (UNEP/MAP-RAC/SPA, 2009a).

42. 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 are the chondrichthyan fishes, the cetaceans and the marine turtles.

43. Pelagic systems of the Mediterranean include distinct features such as upwellings, gyres and fronts (see Fig. 2). 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.

44. 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.

45. Deepsea 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).

46. 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.

47. 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).

C. Ecosystem Values

Value of benefits provided by coastal and marine ecosystems

48. 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.

49. 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.

50. Coastal and marine ecosystems present a complex web of goods and services, perhaps more so than any other major ecosystem type. Clearly individuals and communities value the coast, as burgeoning population growth and resource use in coastal areas attest. But there is not a clear understanding of the extent to which intact ecosystem services, particularly when taken individually, support human well-being and economies. Too often the value of services is only realized in the wake of calamities, once the ecosystems providing them have been degraded or destroyed.

51. Dependence on coastal zones is increasing around the world, even as costs of rehabilitation and restoration of degraded coastal ecosystems are on the rise. In part, this is because population growth is coupled to increased in-migration to the coasts, in part due to degradation of terrestrial areas (fallow agricultural lands, reduced availability of fresh water, desertification, and armed conflict all contributing to decreased suitability of inland areas for human use). Resident populations of humans in coastal areas are rising, but so are immigrant and tourist populations.

52. Mediterranean ecosystems support 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 shrimp and 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 (Blue Plan, 2010).

53. 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).

54. 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 Blue Plan report 2010).

55. Mediterranean marine ecosystems also sequester carbon and play a large role in climate regulation. Blue Plan 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 Blue Plan 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).

56. 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. Thus Mediterranean coastal and marine ecosystems are valuable for both the goods (resources) and the services (hydrological balance, carbon sequestration, buffering land from storms, providing recreational opportunities, providing space for shipping, processing/ assimilating wastes) and currently undervalued but critically important processes such as keeping introduced species in check and preventing them from becoming invasive.

UNEP/MAP-BP/RAC study

57. The recent economic study completed under the auspices of UNEP/MAP-BP/RAC is entitled "The Economic Value of Sustainable Benefits from 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 Blue Plan website http://www.planbleu.org/themes/intro_marinUk.html).

58. 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 assessment 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.

59. The methodological framework for this assessment (chapter 1) 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.

60. 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:

Categories of ecosystem services :	**Ecosystem services:**	**Benefits assessed:**
Provisioning services	Production of food resources	Resource rent relating to the production of food resources of marine origin
Cultural services	Amenities	Resource rent relating to the provision of amenities and recreational supports
	Support for recreational activities	
Regulating services	Climate regulation	Value of man-made CO_2 sequestration
	Mitigation of natural hazards	Value of protection against coastal erosion
	Waste processing	Value of waste treatment

61. 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.

62. Each type of benefit was individually assessed (chapter 2). 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.

63. Aggregation of these results provides an estimation of the overall value of the benefits resulting from the Mediterranean marine ecosystems (chapter 3). At regional level, the benefits are estimated 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.

64. 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.

65. 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.

D. Threats to Mediterranean Ecosystems

66. Human pressures on the Mediterranean environment are many and growing. In 2000, the combined Mediterranean coastal population was greater than 150 million, with the coastal population in the North expected to remain relatively stable, and the coastal population in the South projected to increase. In fact, the southern rim of the Mediterranean now contains more than 50 percent of the total population and this percentage is expected to grow to 75 percent by 2025. These projected demographic changes in the region will have significant effects on the Mediterranean environment, as

demand for natural resources will dramatically increase in the south. Population densities are much greater in coastal than in non-coastal areas, especially in the southern parts of the Mediterranean. Visitor populations (tourists) are also growing.

67. In the 2006 UNEP/MAP-EEA report entitled "Priority Issues in the Mediterranean Environment", a dozen threats were highlighted as the most crucial issues in the region. These included: sewage pollution and urban run-off; solid waste disposal; discharge of industrial effluents; urbanization and with it the alteration of the physical environment; eutrophication; sand erosion from beaches; oil and PAH pollution from marine transport activities; invasive species spread; Harmful Algal Blooms (HABs); over-exploitation of marine resources and fisheries-related impacts on ecosystem processes; expansion of aquaculture with corollary pollution effects; and natural hazards and global change (including climate) (UNEP/MAP-EEA, 2006). These issues are still paramount 5 years later at the time of this assessment, however new issues are emerging which merit attention, such as the increase in desalination, with impacts that include the effects that brine discharge has on nearshore ecosystems.

Coastal Habitat Loss and Degradation

68. Coastal development and urbanization exerts great pressures on the marine 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.

69. Population pressures lead to increased use of resources and habitats, and indirect degradation as well. 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.

70. 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-RAC/SPA, 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).

Fisheries

<u>Synopsis of Mediterranean Fisheries</u>

71. The pressures of fishery activities stem from commercial fisheries, recreational fisheries, and aquaculture. Commercial fisheries include both artisanal (mainly trammel, traps, gillnets, loglines, 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.

72. 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.

73. 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).

74. 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).

75. 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.

<u>Over-exploitation</u>

76. High levels of fishery resource extraction in Mediterranean fisheries have led to over-exploitation, or, in the best cases, optimum exploitation (UNEP/MAP-RAC/SPA 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.

77. 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.

78. 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 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).

79. 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.).

80. 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).

81. In the high seas, species targeted by 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-MAP RAC/SPA, 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.

82. 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.).

83. 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).

84. A number of studies have established that intensive fishing strongly impacts all levels of biological organization of marine life (UNEP/MAP-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.

By-Catch and Discards

85. 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.

86. 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).

87. 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.

88. 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.

Benthic Disturbances

89. The effects related to 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. 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 - RAC/SPA 2003). Trawling is also responsible for changing grain size distribution and sediment texture and for destroying bedforms.

90. Coralligenous and maerl communities are mainly endangered by trawling, responsible for the disappearance of maerl in large Mediterranean areas (UNEP-MAP-RAC/SPA, 2008a).

Illegal Fishing and Fishing in Areas Beyond National Jurisdiction

91. 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.

92. 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).

93. 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.

94. 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.

95. Driftnet fisheries have long been the object of discussion in several Mediterranean countries because it is 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.

<u>Aquaculture/mariculture</u>

96. 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 molluscs, 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).

97. 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-RAC/SPA 2003).

98. Fisheries and aquaculture 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 prey are "released" from predation when predators are removed.

Introduced and Invasive Species

99. 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.1.5). These species are represented by 13 branches dominated by molluscs (216 species), followed by fishes (127 species), benthic plants (124 species) and crustaceans (106 species).

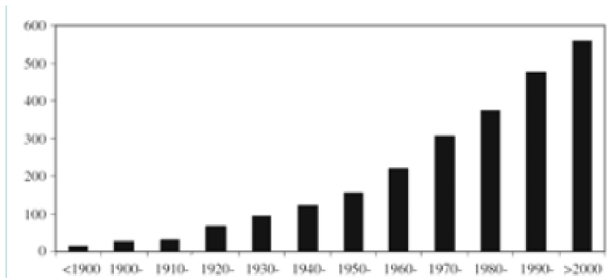


Figure 1.5. Number of species introduced to the Medityerranean Sea in the 20th Century.

100. 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.

101. 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. 10). 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 1.6).

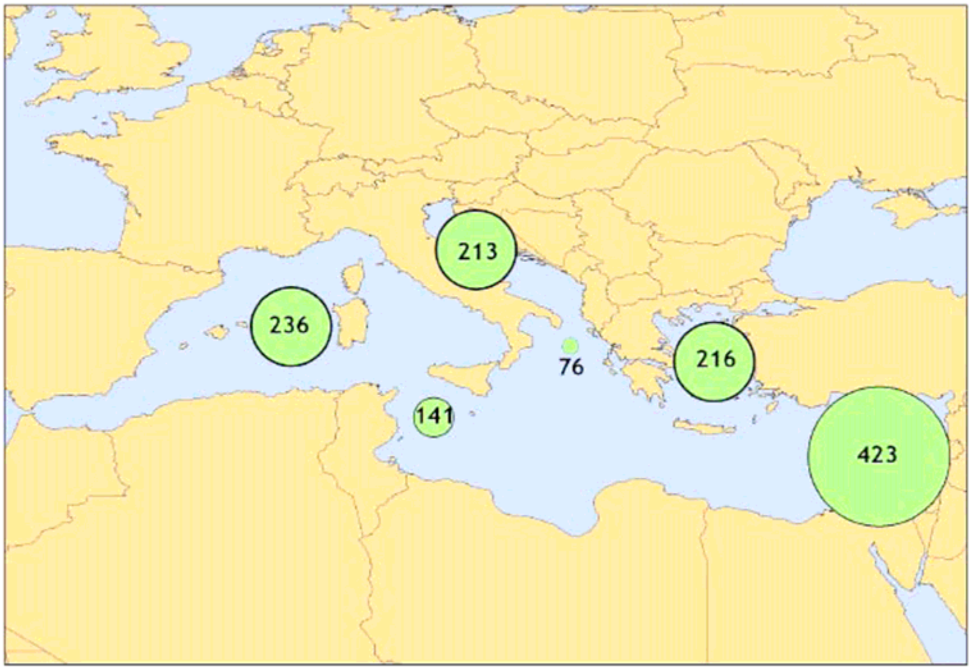


Figure 1.6 Distribution of exotic species in the Mediterranean basins (source: Zenetos & Streftaris 2008)

102. 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 (UNEP/MAP-EEA, 2006). Yet it is important to recognize that: not all the non - indigenous species are also invasive (i.e. in the Aegean Greek 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.

103. 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.

104. 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.

105. 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).

106. 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.

107. 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.

108. 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.

109. 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).

110. 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 (UNEP/MAP-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)**

111. 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 (Southern Turkey) 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.

112. Several examples of invasive species impacts able to determine economic losses have been described in coastal water, where are concentrated the main part of human activities and the pressures, cumulating, trigger the trend towards the degradation of the ecosystems. As examples, the macroalgae *Womersleyella setacea* and *Acrothamnion preissii* clog up fishing nets in France and Italy, where these invasive species are known as 'pelo' due to its impact on the fishing gear (Verlaque, 1989; Cinelli *et al.,* 1984); another example is given by the jellyfish *Rhopilema nomadica* today distributed along the eastern Mediterranean coast and as far north as the southeastern coast of Turkey where impact on 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.

113. 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*) (UNEP/MAP-EEA, 2006). Forty-three percent of the halieutic resources of Turkey come from alien species.

114. 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.

Pollution

115. 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 1.7.

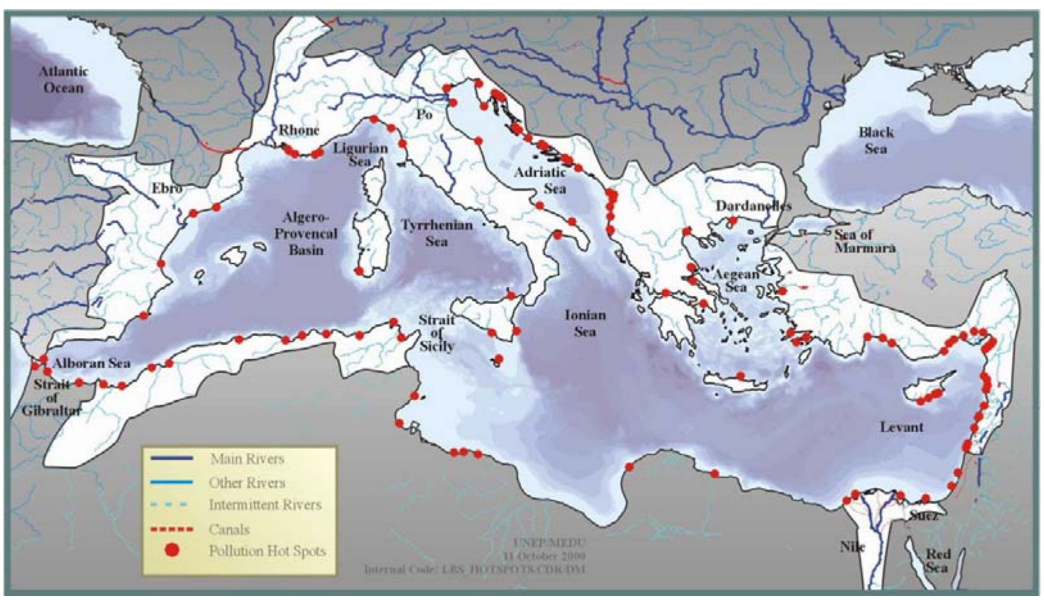


Figure 1.7 Pollution hotspots as identified by UNEP/MAP-MED POL

116. 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.

Toxins

117. 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 (UNEP/MAP-EEA, 2006). The input deriving from the nuclear industry is considered very small compared to other sources. According to the UNEP/MAP-EEA (2006) the overall total inventory of radionuclides in the Mediterranean Sea is declining.

118. UNEP/MAP (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.

119. 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).

120. Shipping also 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.

121. 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/MAP Chemicals, 2002). Illicit vessel discharges can be detected through the interpretation of ERS SAR (Synthetic Aperture Radar) satellite images (figure 26 and 27).

122. 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.

123. 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, Figure 1.8). Finally incidents at oil terminals and routine discharges from land-based installations have been estimated at 120,000 tonnes/year (UNEP/MAP-EEA, 2006).

Figure 1.8. Location of Major tanker oil spills (> 700 tonnes) 1990–2005 (reprinted from UNEP/MAP-EEA 2006)

124. REMPEC (2008) recently reviewed the maritime traffic in the Mediterranean region. 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.

Marine Litter and Debris

125. Associated in part with the high degree of shipping in the 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 1.9).

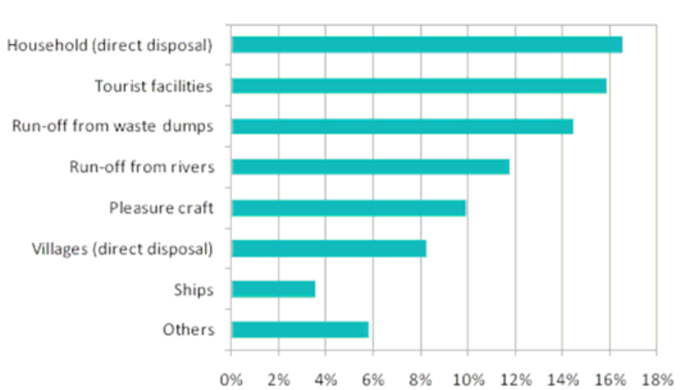


Figure 1.9. Sources of marine litter (Blue Plan, 2009)

126. 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.

127. 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.

<u>Eutrophication and Blooms of Algae and Jellyfish</u>

128. 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.

129. The level of nutrients entering the Mediterranean has been rising over the last decades, as illustrated in the bar graph below (Figure 1.10).

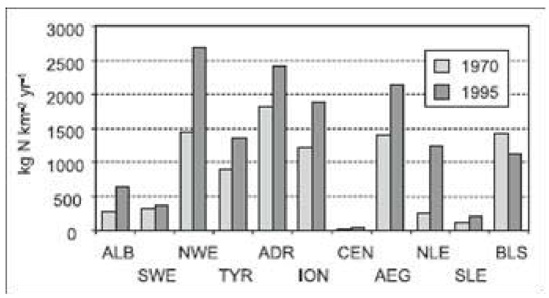


Figure 1.10. Fertilizer use in drainage basins of the Mediterranean and Black Seas in 1975 and 1995. (Source: Ludwig et al 2009)

130. An UNEP/MAP-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.

131. 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%).

132. 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.

133. 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.

134. 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.

135. 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 Medterranean (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).

Spread of 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-RAC/SPA 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 (UNEP/MAP-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.

Climate Change

147. 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. However, because the purpose of this assessment is to pinpoint priority threats that can be addressed through revised management under an ecosystem approach, climate change threats will not be detailed in this report.

II. Subregion #1 Western Mediterranean

A. Physical and chemical characteristics

Bathymetry

148. The Western Mediterranean Sea can be divided into four main morphological units (Rehault et al, 1984). 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.

149. 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 influx carried out 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.

150. 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. 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°.

151. Around the Mediterranean Basin, numerous submarine canyons cut the continental slope, and some deep incisions reach the pre-Pliocene sedimentary layers and, sometimes, the ante-Mesozoic basement. They are derived from the messinian crisis leading to lower sea levels, 5 to 6 millions years ago (Bache *et al.*, 2009; Garcia-Castellanos *et al.*, 2009).

152. *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 threemorphological 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.

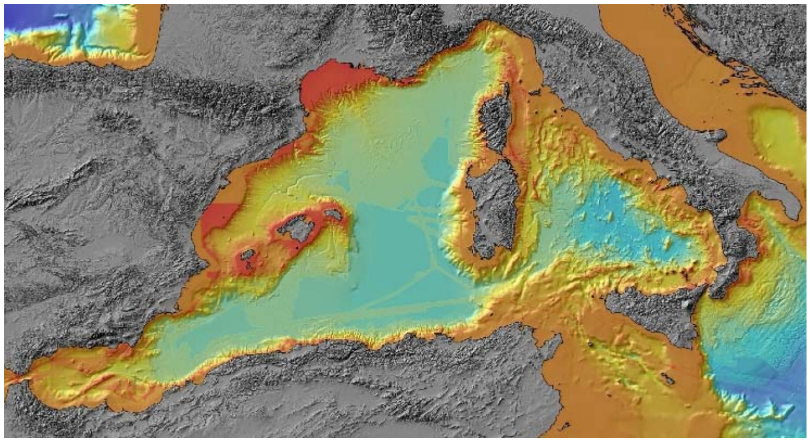


Figure 2.1 : Bathymetry of the western basin of the Mediterranean sea (from Geosciences Azur, IFREMER, CIESM, 2008) and sea beam data from surrounding countries)

153. 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.).

Sediments

154. Sedimentation is of dual origins, biogenic from planktonic or benthic organisms and terrigenous from river sediments (fine, coarse). The latter is most important. 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 facies: 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 facies 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). The distinction between these two sources is difficult.

155. Inputs linked to tectonics are important in volcanic areas and around geothermal sources such as the southern Tyrrhenean. 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).

156. 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.

157. On the south shores, atmospheric particles from the Sahara-Sahel Corridor (Western Sahara, Algeria, Chad and Niger) are natural sources of aluminium 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).

158. 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).

Ocean Circulation

159. The Western Mediterranean sea has a negative water budget: the loss in the atmosphere by evaporation is larger than the gains by precipitation, runoffs 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.

160. 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 Gibraltar Strait. The formation and subsequent spreading of the intermediate water, together with the inflow of the Atlantic Water through the Gibraltar strait, 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.

161. 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. Favorable hydrographic conditions cause bottom and intermediate water formation, which in Mediterranean occurs where strong winds and cyclonic structures are recurrently observed. 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 Gibraltar strait, 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 strait.

162. 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. Atlantic water inflow in the Alboran Sea and the Northern Current in the Ligurian Sea both 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.

163. 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 upwellings and downwellings 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.

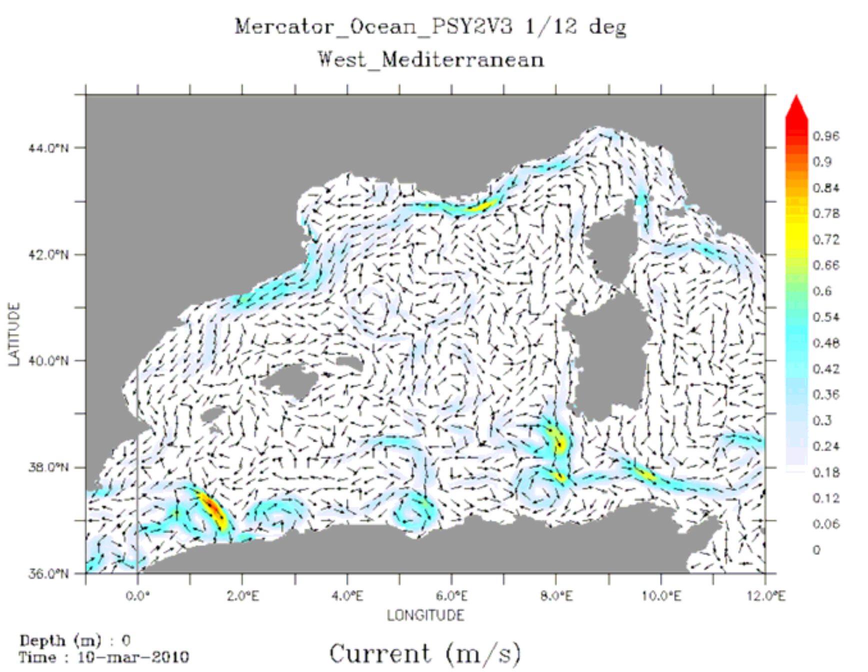


Figure 2.2: Large scale General circulation in the occidental Mediterranean basin on March 10th (Mercator, http://www.mercator-ocean.fr/) and March 21st (http://www.cnr.it/sitocnr/home.html)

164. 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. 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).

165. 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.

166. 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.

167. 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 °C 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.

168. 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%.

169. 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.

170. 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.

171. 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).

172. 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

173. 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.

Salinity and temperature

174. 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 upon which local orographic effects are superimposed. Lowest average temperatures of <5°C are found in the higher parts of the Alps, whereas temperatures of >20 °C 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.

175. 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.

176. 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°C 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.

177. 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.

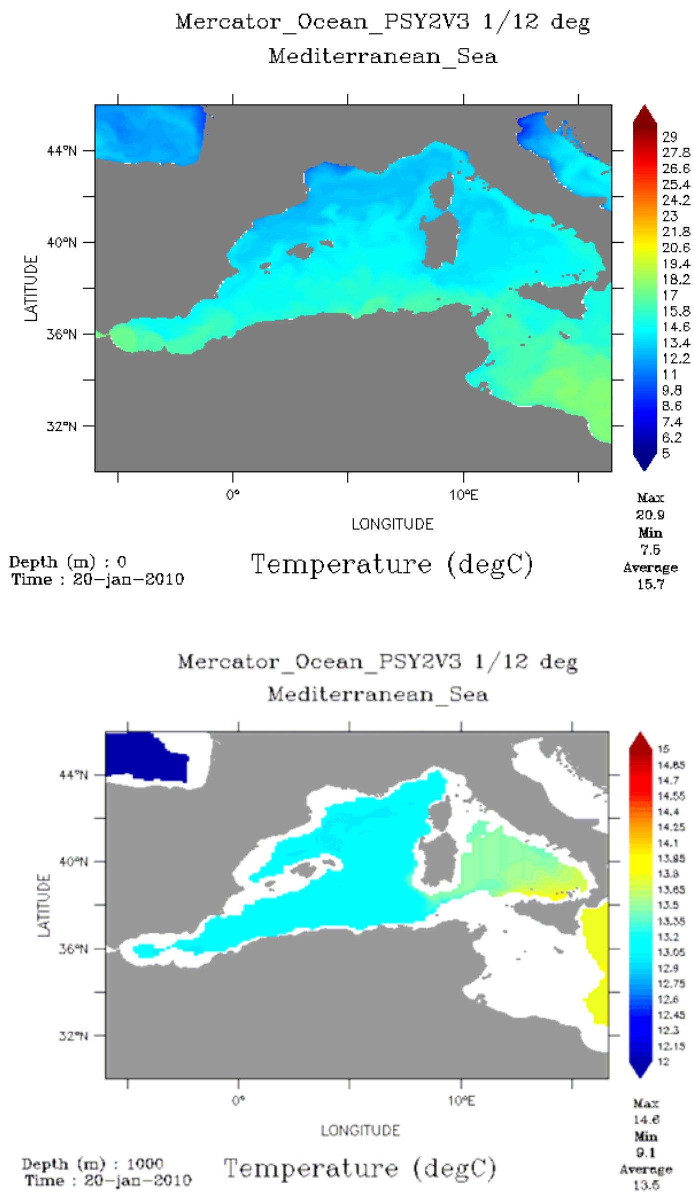


Figure 2.3: Examples of temperature measurements at the occidental basin scale (http://bulletin.mercator-ocean.fr/)

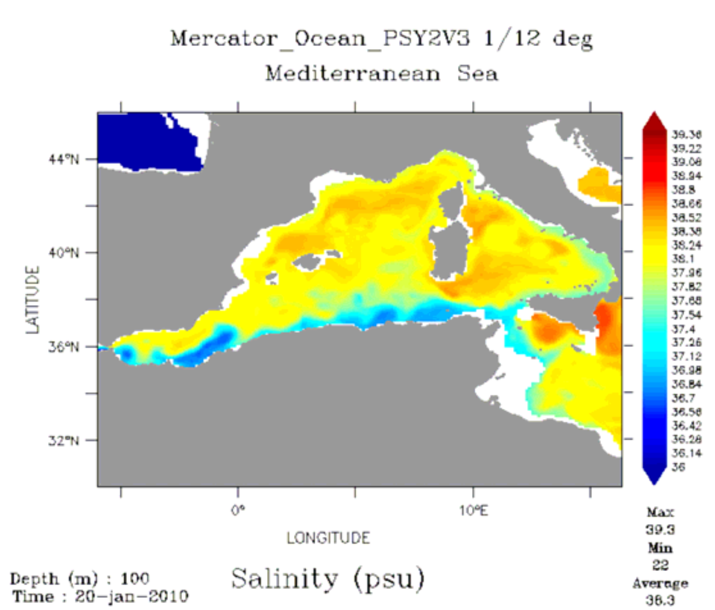


Figure 2.4: Surface Salinity of the occidental basin scale (20/01/2010) and salinity profile along a Sete – Tunis transect (mean values for the period from 28/07 - 04/08/2009, http://bulletin.mercator-ocean.fr/)

B. Biological Characterization

178. The Mediterranean basin 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.

179. The Western 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 (beta level) 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.

180. The Pelagos Sanctuary for the Protection of Mediterranean marine mammals is a particularly 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).

181. The Pelagos Sanctuary contains 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).

182. 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.

183. The area also supports significant numbers of loggerhead turtles (G. Lauriano, pers. comm.).

184. The Alboran Sea, Balearic Islands, and Gulf of Lion are also relatively well-studied, with high habitat and species diversity, and high productivity supporting commercial and recreational fisheries, as well as tourism. These individual pressures, and the increasing conflicts around various uses in some areas (biodiversity conservation and shipping come to mind in the Alboran Sea, for instance), have already had impacts on marine biodiversity. The loss of Posidonia meadows throughout the region is one example.

185. Rocky areas and soft-bottom communities in this region are also productive and diverse. Yet these areas 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).

186. 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).

187. 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.

C. <u>Pressures and Impacts</u>

188. 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 (UNEP/MAP-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.

189. 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 behavior 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.

190. 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.

191. National sensitive areas (Orbetello) are also affected although mostly related to transitional waters. 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).

192. In the case of France (UNEP/MAP, NAP France, 2006), defined sources of pollution and "hots 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 immersed deep in the Cassidaigne canyon (metals) and to a lesser extent asbestosresidues dumped in the past in the western part of Cap Corsica (Galgani *et al.*, 2006) must also be considered. 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.

193. 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.

194. 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, 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 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. Then, the city of Tangier and its industrial activities should be considered as 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).

195. 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.

196. 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.

197. 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 behavior may be very different as Pb and Cu remains in the sediments while Zn is advected. 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 (Almaden in Spain, 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).

198. 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.

199. 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.

200. 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.

201. 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).

202. 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).

203. Data of contaminants in water and sediments are not widespread in northwestern Mediterranean. Analysis of UNEP/MAP-MED POL 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 (> 10 mg / kg) in the site El Portus (Spain), in the Bay of Naples and the south west coast of France.

204. 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. 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).

205. The site El Portus, near the hot spot Cartagena (UNEP/MAP, 2003), is under the influence of a naval base, an industrial complex and former Portman Mining. Three sites are affected by metals on the coast of Spain in addition to the area of Cartagena. The mouth of the Llobregat, responsible for massive inputs of lead in the Barcelona area, the Bay of Algeciras with high concentrations of cadmium and the bay of Valencia affected by Nickel also confirms previous data (Palanques et al, 2008; Benedicto et al, 2005).

206. 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).

207. 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).

208. 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.

209. 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.

210. 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.

211. 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 (eg 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.

212. 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.

213. 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. Persistent organic pollutants (POPs) are a problem in the vicinity of industrial and urban sites, as in major Mediterranean rivers mouths. Harbors 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).

214. 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.

215. 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 etal., 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.

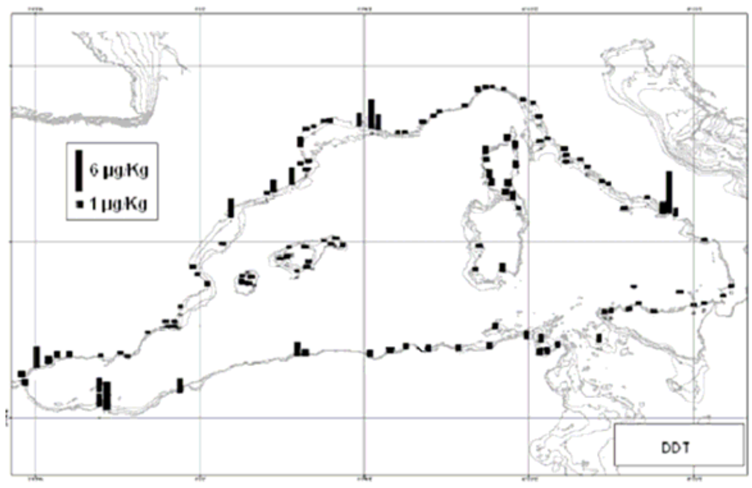


Figure 2.5: Levels of DDTs in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Scarpato *et al.*, 2010)

216. An analysis of dioxins in mussels *Mytilus galloprovincialis* in 33 stations from the whole occidental basin (Andral *et al.*, submitted shows highest values were recorded in Marseille (2.66 ng/kg) with significant inputs. 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) when Corsica and Northern Africa were the areas with lower concentrations.

217. The west Mediterranean has been described as also affected by PAHs contaminations, 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).

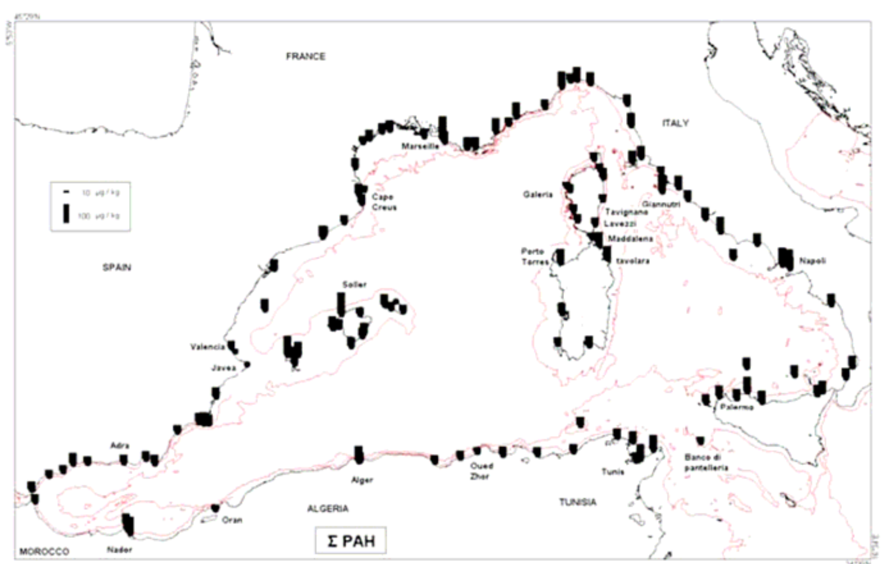


Figure 2.6: Levels of total PAHs in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Galgani *et al.*, 2010)

218. Studies on TBT in the occidental basin shows that contamination is however not limited to harbor areas, but extends along the coast, including protected areas where Ccontamination 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).

219. 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.

220. 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).

221. 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).

222. 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).

223. 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.

224. 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 2.7). 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.

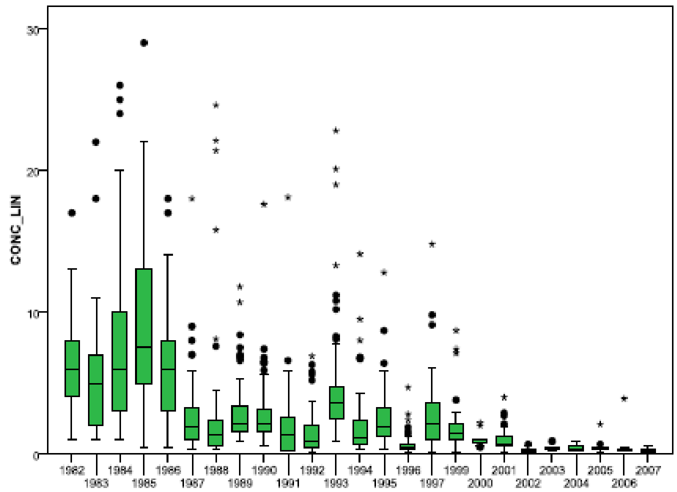


Figure 2.7 : Temporal trends of lindane (ng g-1 dw) in *Mytilus galloprovinciallis* from the Frenc h monitoring network in Mediterranean stations (www.ifremer.fr)

225. 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.

226. Shipping-related pollutions is also an key presuure 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.

Nutrients

227. The Mediterranean basin is characterized by low production of raw materials and a reduced biomass of phytoplankton. 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 rivers Rhone and Ebro. They have catchment's areas extending to 96,000 and 84,000 km2 respectively. 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.

228. 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.

229. 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.

230. 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).

231. 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.

232. 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 Gibraltar strait. Other eutrophicated areas were found close to Valencia and the Ebro delta, where dinoflagellates blooms were developed.

233. 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.

234. Eutrophication causing conditions arise to a large extent from the effects of effluent discharges from urban agglomerations and only in a few cases from inputs of rivers. Only episodic but serious eutrophication events occur in the western coast of Italy.

235. For the Ligurian Sea, two sites have been identified as eutrophic. Foce Torrente Lerone with urban wastewater discharges and organic inputs from industries and Genova harbor 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.

236. Using satellite imagery, the Gulf of Lion and Ebro area were confirmed to be the most affected area. The southern coastal waters of Italy are oligotrophic with a few exceptions as the Gulf of Naples due to sewage.

Dumping

237. 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.

238. 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.

239. 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).

240. 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.

Overfishing

241. 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, 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 and in the Gulf of Lions (GFCM, 2008).

III. Subregion #2 Central Mediterranean

242. The Central Mediterranean and Ionian subregion includes the parts of Greece and the parts of Italy within the Ioniana Sea, Malta, Libyan Arab Jamahiriya (henceforth referred to as Libya) and Tunisia (Figure3.1).

Figure 3.1: Subregion #2, showing major coastal cities, location of pollution hot spots (red circles) and locations of major environmental concerns (blue circles).

243. 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.

244. 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.

A. <u>Physical and Chemical Characteristics</u>

Bathymetric, hydrodynamic, and other features

245. 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 3.2 shows the bathymetry of the subregion.

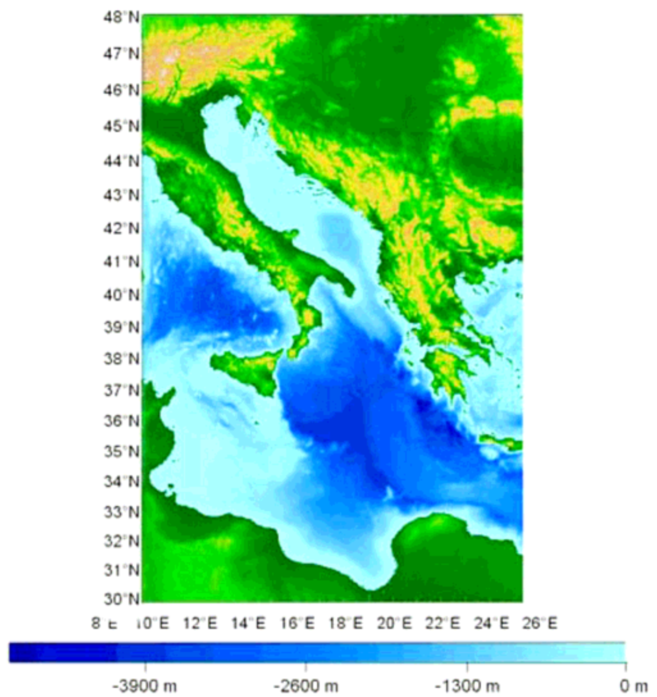


Figure 3.2. Marine bathymetry of the area under review

246. 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. 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).

247. 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.

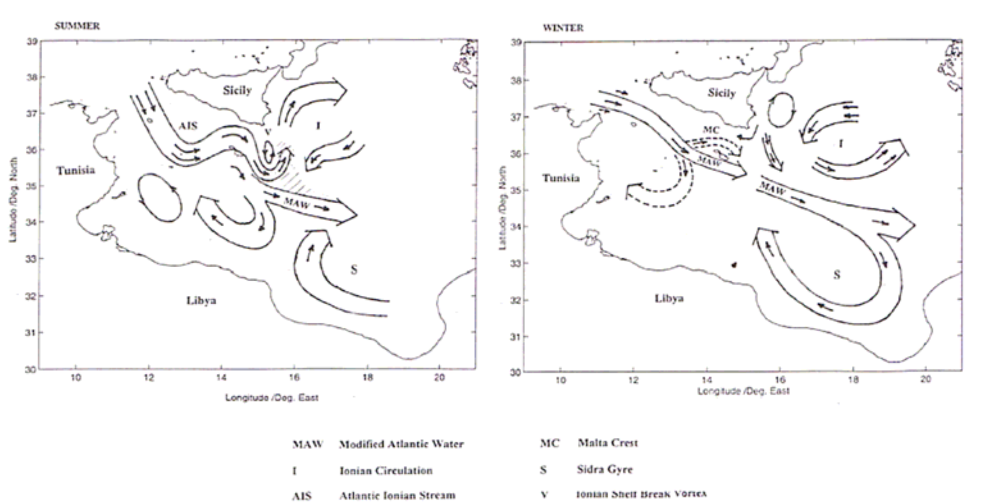


Figure 3.3: Surface currents in the Central Mediterranean *(From Drago and Sorgente, 1998)*

248. 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.

249. 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 northwestern sector (like the Mistral) the surface eastward transport in the Sicily Channel is enhanced. In contrast, for opposing wind conditions (blowing from the southeastern sector), the transport trough the Channel is significantly reduced.

250. 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 3.4).

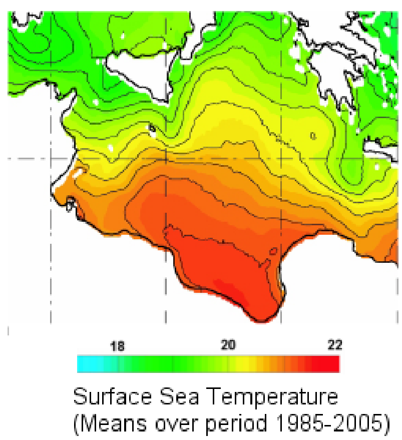


Figure 3.4: Sea surface temperatures for the area under review as estimated by Marullo *et al.*, 2006.

251. 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.

Nutrients and primary productivity

252. 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.

253. 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.

254. 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.

255. 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.

256. 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 threedimensional 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 Gibraltar Strait, 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.

257. 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 Ionion and Central Mediterranean, the values for Chl:C for ultra-plankton ranged from 0.01 to 0.04 (Figure 3.5), 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.

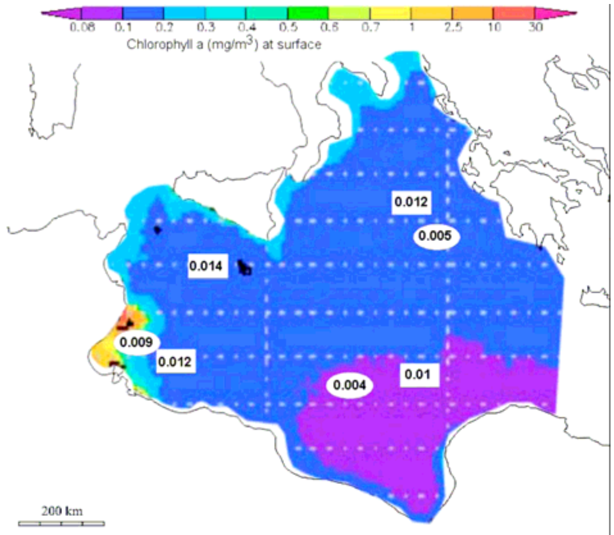


Figure 3.5. Chlorophyll a level means averaged between August 2002 and December 2008 (Cruzado 2009). The values inserted in rectangles show annual chlorophyll to carbon ratios relative to plankton, and those inserted in eclipses show the same ratios relative to net plankton (Pacciaroni and Crispi 2007)

258. In the south and central Ionian and in the far Eastern Mediterranean, values are generally well below 0.05 mg Chl m−3 (Figure 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).

259. 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

260. As regards the atmospheric nutrient deposition in the different Mediterranean areas, 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 within the Central Mediterranean.

261. These values are intermediate between those for the Western and Eastern basins. Figure 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.

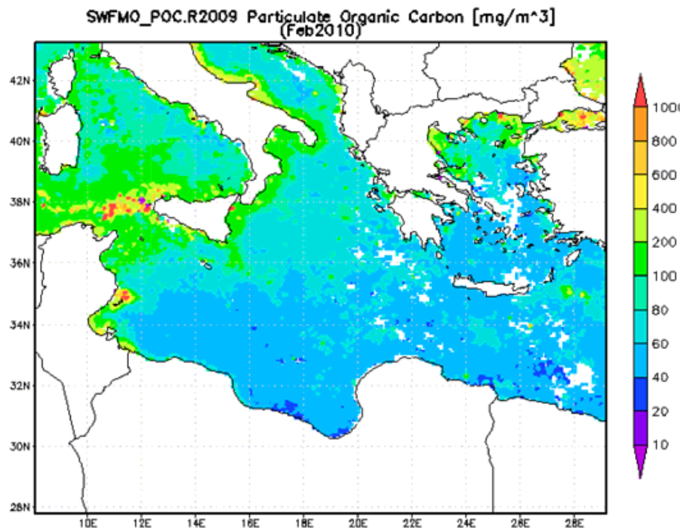


Figure 3.6: Particulate Organic Carbon as recorded in February 2010. *Analyses and visualization were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.*

Biological Characteristics

262. 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. Wetlands of unique beauty may also be found along the Greek coastline such as the Gialova lagoon at Pylos, Messinias.

263. 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 both high levels of endemism and critical levels of habitat loss, and it is thus on them that conservation efforts mainly focus.

264. 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-Blue Plan, 2009).

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

266. 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.

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

Anthropogenic Impacts

268. 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 3.7 shows the location of these urban centers, together with the relative levels of populations residing in such centers.

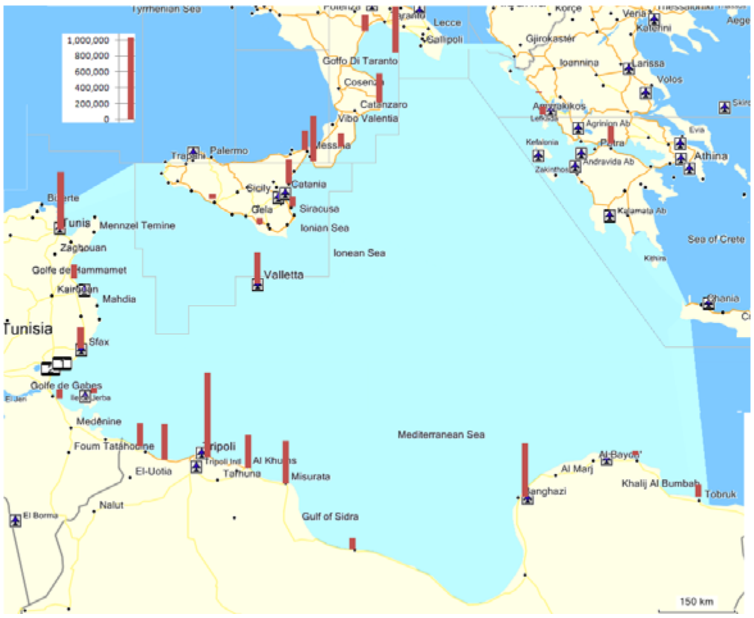


Figure 3.7: Location of major urban centres with relative population levels in the area under review.

269. 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 submitted to the Mediterranean Action Plan (MAP). 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 3.1.

270. 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 amount to 0.55 (CIESM, 2006).

271. 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.

272. 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.

273. 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.

274. 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.

Impacts

275. According to UNEP/MAP-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.

276. 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.

277. 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.

278. 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.

279. 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 3.8 shows such assessment graphically.

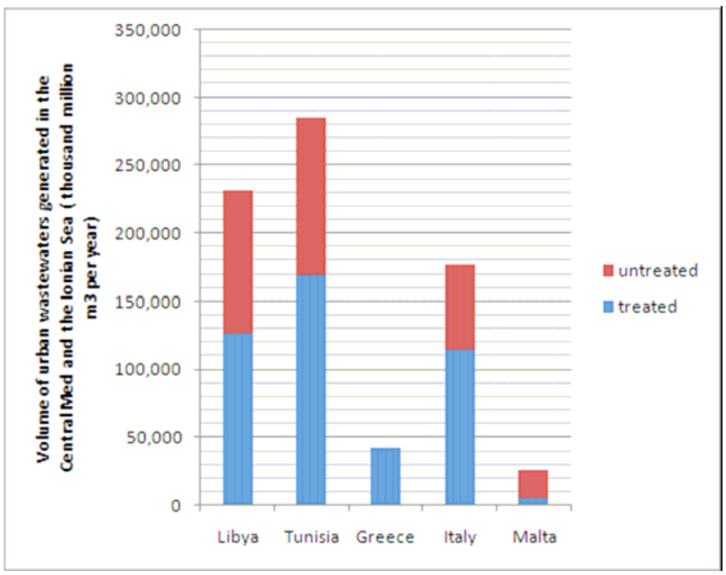


Figure 3.8: Volume of urban wastewaters (million *1000 m3 per year) by the various regions bordering the Ionian and Central Mediterranean.

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

281. 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.

282. 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 UNEP/MAP-BP/RAC 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 UNEP/MAP. 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 3.9 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.

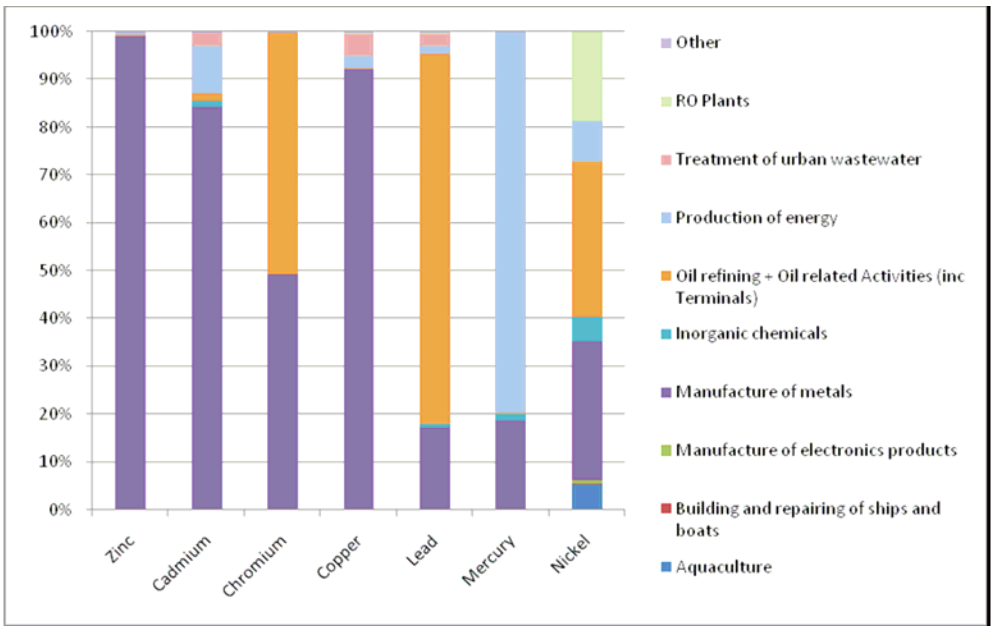


Figure 3.9: The relative importance of various sectors for the release in the marine environment of various trace metals (based on data from Italy-Ionian, Malta and Libya)

283. 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).

284. Figure 3.10 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.

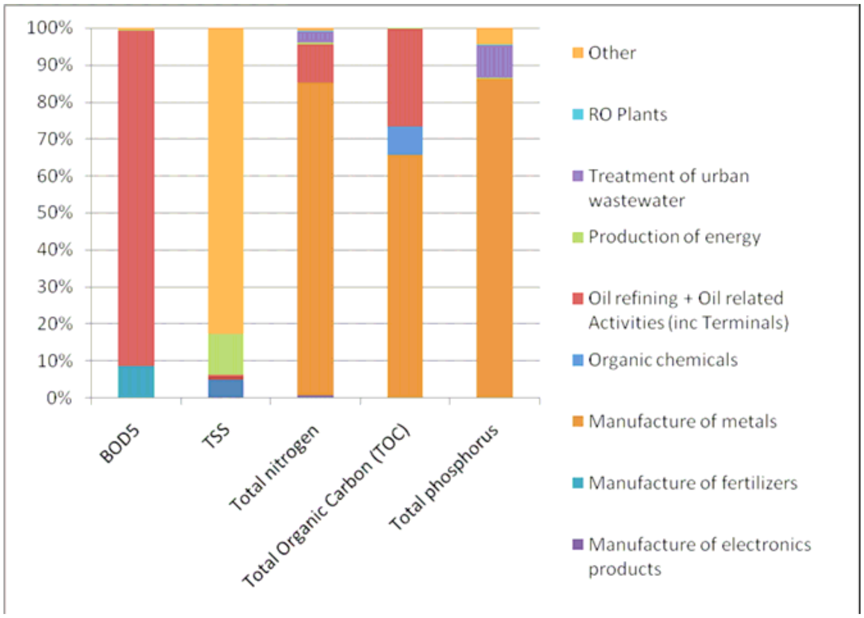


Figure 3.10: The relative importance of various sectors for the release in the marine environment of BOD5, TSS, TOC and total Nitrogen and Phosphorus (based on data from Italy-Ionian, Malta and Libya)

285. 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.

286. 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).

287. 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).

288. 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.

289. 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.

290. 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.

291. 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.

292. 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.

293. 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.

294. 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.

295. 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.

296. 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).

297. 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. It was found that in bulk seawater, TBT values ranged from below the detection limit of 5 ng Sn L-1 to 300 ng Sn L-1; in sediments deriving from the most polluted areas, TBT concentrations as high as 1500 ng Sn g-1 dw were measured as seen from Figure 3.2.

298. 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).

299. 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.

300. 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.

301. Few spatial and long-term temporal trend 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.

302. 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. 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). 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.

303. 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.

304. 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.

305. 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.

306. 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.

307. 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.

308. 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.

309. 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.

310. 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.

311. Small to medium size oil slicks and floating pelagic and coastal tar are unfortunately 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}.

312. 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).

313. 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.

314. 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.

315. 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.

316. 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. The results are presented in Figure 3.11 below.

317. 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).

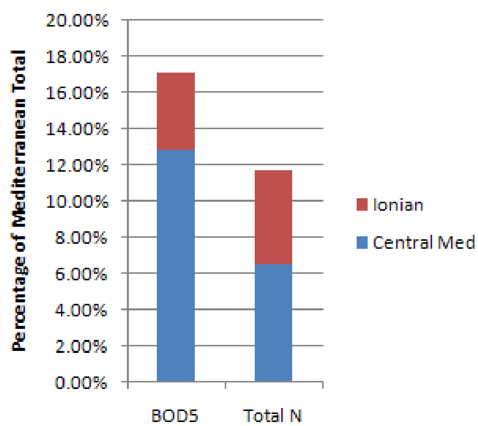


Figure 3.11: Percentage releases from industrial point sources, of BOD5 and of total nitrogen as reported by UNEP/MAP-BP/RAC, (2009) in the area under review as compared to releases in the whole Mediterranean.

318. 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.

319. For the Greek Ionian waters, eutrophic conditions have been reported in the semienclosed 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).

320. 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.

321. 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).

322. 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 runoffs) 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.

323. Figure 3.12 shows the distribution of recorded events of eutrophication and of harmful algal blooms.

Figure 3.12: Locations of reported cases of eutrophication (red circles) and of harmful algal bloom events (green circles) in the area under review. *(Sources: UNEP/MAP-EEA, 2006)*

324. 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.

325. 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.

326. 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.

327. 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.

328. 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.

329. 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.

330. 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.

331. 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.

332. Though not being classified along with hazardous substances, marine litter often pose 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.

333. 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.

334. UNEP/MAP, 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.

335. UNEP/MAP, 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.

336. 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.

337. 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.

338. 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.

339. 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.

340. 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 3.13 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.

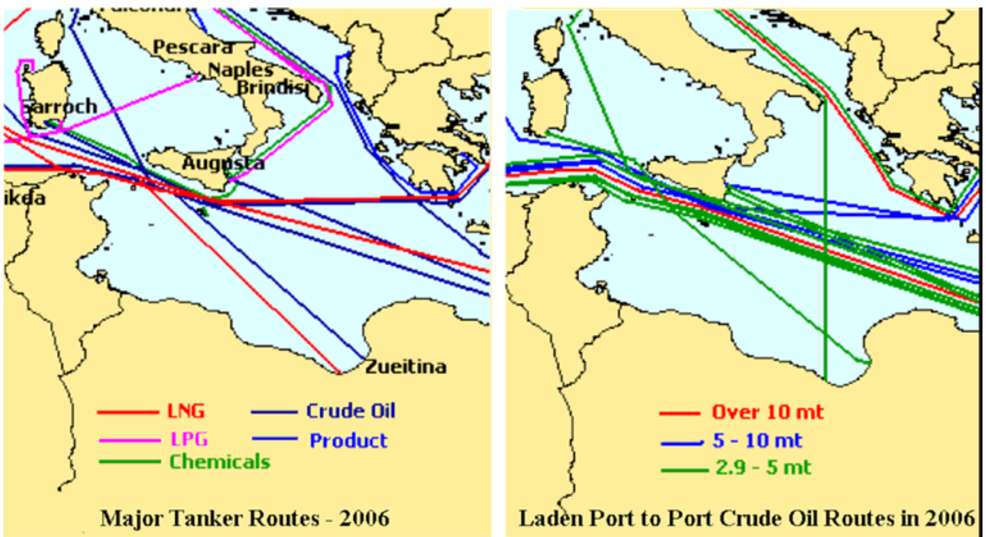


Figure 3.13: Main maritime routes in 2006 according to Lloyd's Marine Intelligence Unit, as reported by REMPEC (2008).

341. 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.

342. 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 casualty in the region.

343. 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.

344. 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.

345. The fisheries of the region are characterized by a high level of exploitation, often resulting in overfishing. 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*).

346. 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 is one of the causes of overfishing of protected species such as grouper.

347. The trophic level of exploited species is clearly decreasing. Due to the modernization of fleets for longer campaigns and navigation in rough seas, a tendency to increase the exploitation of species living in the open ocean and deep water is noticed.

IV. Subregion #3: Adriatic Sea

A. Physical Characteristics

1. Bottom topography and bathymetry

348. 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 4.1).

Figure. 4.1. The Adriatic Sea subregion

349. 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 Northern Adriatic clearly shows its relationship with boreal region, termophilous 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.

350. 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 High 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. Alongside the Rhone and the Ebro, the Po 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 is one of the threat for the Adriatic Sea due to excessive nutrient discharge.

351. The Adriatic Sea stretches in the NW-SE direction in the length of 783 km, with the surface area of 138,595 km² at the mean sea-level. Its salinity is relatively high - cca 38,3 ‰. North Adriatic is extremely shallow with depths varying from 25 to 50 m 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). Middle Adriatic is also rather shallow (average depth of 140 m) with the exception of Jabuka Pit that reaches depth of 275 m. South Adriatic depression goes down to 1330 m. The depths of up to 200 m (continental shelf) occupy as much as 73.9 % of the Adriatic. Water temperatures in Middle Adriatic vary from 12-13 ºC and in South Adriatic from 13-15 ºC. 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 300 m have also been registered.

352. 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 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).

353. 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).

354. 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).

355. The Croatian Adriatic mainland coast length is 1777 km coast. Entire coast is divided on Istria, Hrvatsko Primorje and Dalmatian area. The Dalmatian coastline area is the longest, extending from Premuda near Zadar to the Kobili promontory 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).

356. 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).

357. 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. Adriatic Sea catchment part in Slovenia is 3 842,25 km2 large. This represents 19% of the country area. 81% of Slovene hydrogeographical network drains in the Black Sea (Danube catchment). Two hundred eighty thousand inhabitants live in the Slovene part of Adriatic catchment area, representing 12% of entire population (NDA Slovenia, 2003).

358. 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 4.2). 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.

359. 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).

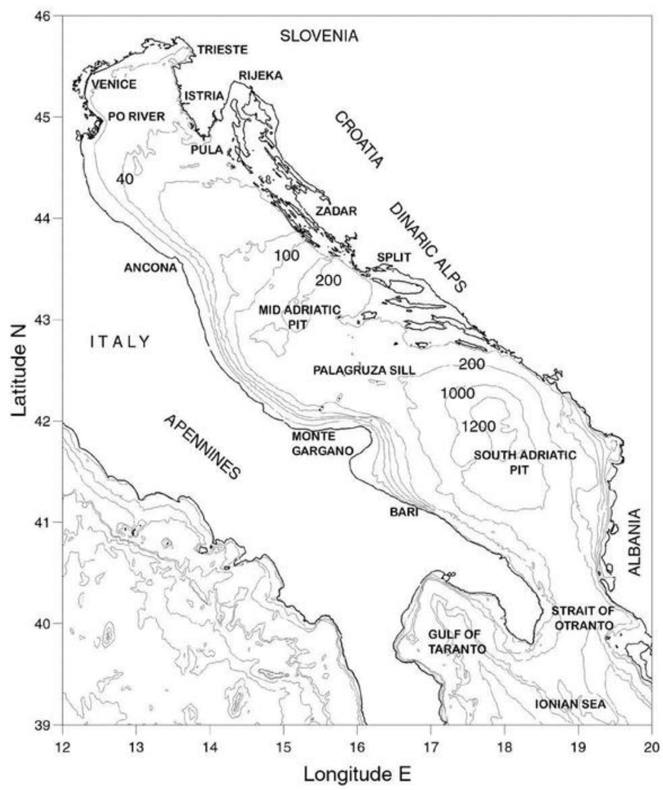


Figure 4.2. Adriatic Sea coastline and topography. (from Cushman-Roisin et tal., 2001)
The eastern coast is generally high and rocky, whereas the western coast is low and mostly sandy.

2. Salinity, temperature and hydrodynamics

360. 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).

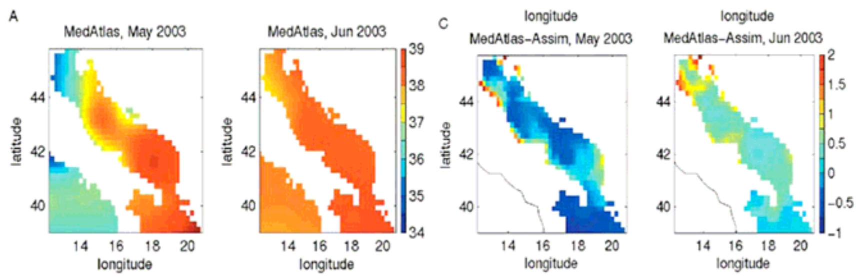


Fig. 4.3 Monthly mean salinity at 5 m depth (in psu) for May and June: A: MedAtlas climatological months for May and June, B: salinity AF for May and June 2003 (Grezio and Pinardi, 2006)

361. The annual surface temperature range is 18°C in the South and 25°C in the North. The extremes of the surface temperature range from 3°C to 29°C respectively. Adriatic is a temperate warm sea, since even temperatures of the deepest layers are mostly warmer than 10°C. 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).

362. 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°C 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 4.4).

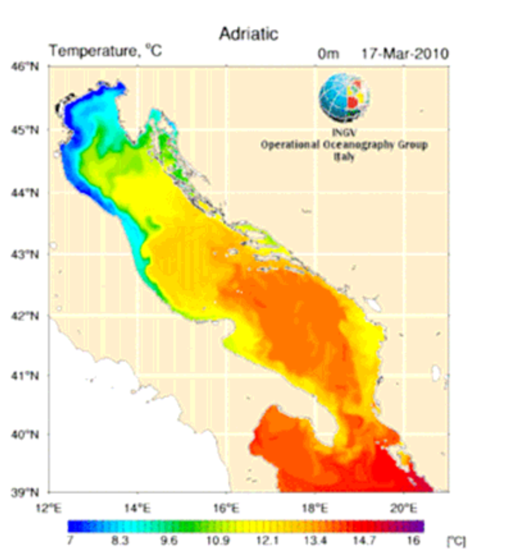


Figure 4.4. SST in March 2010 (From: http://gnoo.bo.ingv.it/afs/external/domani_T.gif)

363. 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, °C), salinity (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).

364. 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.

365. 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.

366. 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 flows 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°C. 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.

367. 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).

368. 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 4.5). 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).

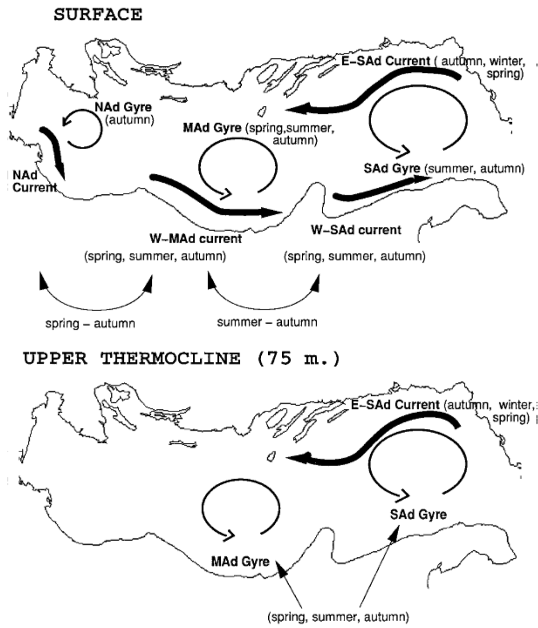


Figure 4.5. Schematics of the Adriatic Sea baroclinic circulation (Artegiani et al, 1997b)

369. 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.

370. 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).

371. 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).

372. 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).

373. 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.

374. 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).

375. 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.

376. 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).

377. The Albanian coast is a narrow shelf area, north of the Strait of Otranto, with smooth bathymetry and with circulation features determined by waters from Ionian Sea. The total discharge of Albanian rivers reaches 1000 m3/s. The influence of freshwater inflow is felt also far downstream the Croatian coast. 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).

378. 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).

379. 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.

380. 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.

381. 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).

382. 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).

3. <u>Nutrients</u>

383. In the northern Adriatic, the most extensive nutrient comes 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 was 43-49% (Rhine), 28-58% (Elbe), and 47-57 % (Po) for N and 13-21% (Rhine), 11-16% (Elbe), and 22-25 % (Po) for P. The reduction of the fertilizer consumption and the increase of crop yields resulted in a slight (Rhine and Po basins) and a drastic (Elbe basin) 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.

384. 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).

385. 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 and 1840. The association of existing vegetation started to change and decreased substantially. Since 1900 the trend of nutrification started to increase and became strongly eutrophied until 1930's. Faunal changes from 1960's are related to seasonal anoxia episodes (Barmawidjaja, 1995).

386. 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 4.6).

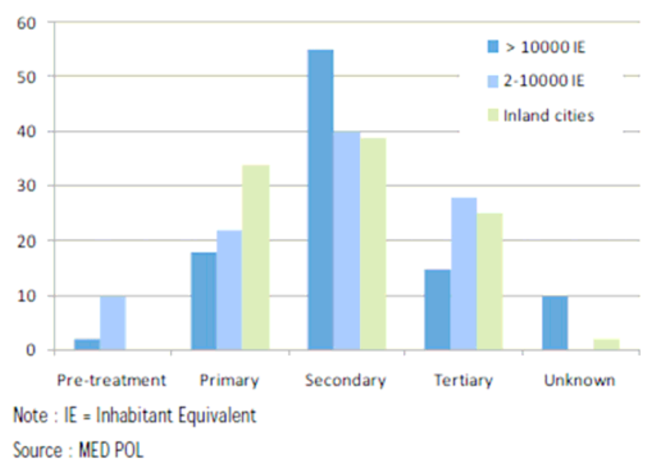


Figure 4.6: Degree of treatment process of waste water treatment plants in coastal and inland cities, 2004 (%) (From UNEP/MAP-BP/RAC, 2009)

387. 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.

Biological Characteristics

388. 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.

389. For instance, the phytoplankton population dynamics in many parts of this subregion are strongly influenced by hydrology of adjacent watersheds. The Gulf of Trieste has only recently been involved in long-term phytoplankton studies, but it is well recognised that phytoplankton dynamics in the Gulf are mostly driven by freshwater runoff.

390. The most important fraction of phytoplankton 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 coccolithophorides are of minor numerical importance in the phytoplankton community of the Gulf of Trieste.

391. Among microzooplankton oligotrich ciliates are representing the dominant group through the whole year, while copepod nauplii are important mostly in the warmer period of the year. Tintinnids are present more or less in modest abundances only occasionally they may become very metazooplankton) it should be mentioned the role of a marine cladoceran *Penilia avirostris*, which is usually a dominant metazooplankton element in the summer period.

392. 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*.

393. The hard bottom communities are less studied than soft-bottom communities and only few reports are published in that regard. Certain taxonomic groups such as mollusks deserved better attention than others. There are 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 fragmentated 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.

394. One marine turtle species is regularly occurring in the Adriatic: the loggerhead turtle (Caretta caretta). It can be found in the Solenian area mainly from May through October (Ţiţa 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.

395. 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*).

396. The Slovenian part of the Gulf of Trieste is inhabitated regularly only by one 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).

397. Baleen whales are only rarely reported. 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 humbpack 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.

Pressures and Impacts

398. In Albania, mercury contamination inland of the former chlor-alkali plant 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.

399. 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, 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.

400. 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).

401. 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.

402. 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).

403. 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).

404. 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 (UNEP/MAP-EEA, 2006).

405. 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 the same impact (UNEP/MAP-EEA, 2006).

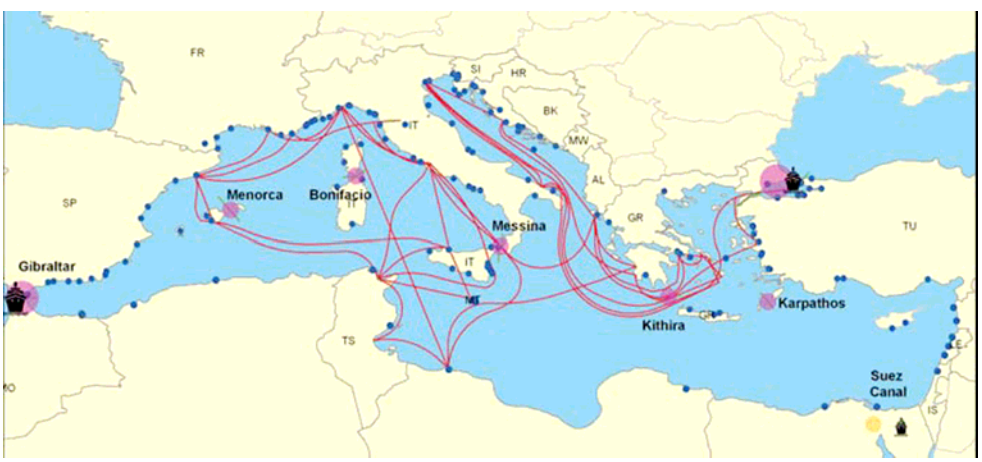


Figure 4.7. Major ports and shipping lanes, including those in the Adriatic subregion.

406. 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 estimated at between 0.3 and 1 000 tonnes annually (UNEP/MAP Chemicals, 2002).

407. 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 4.8). 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 (UNEP/MAP-EEA, 2006).

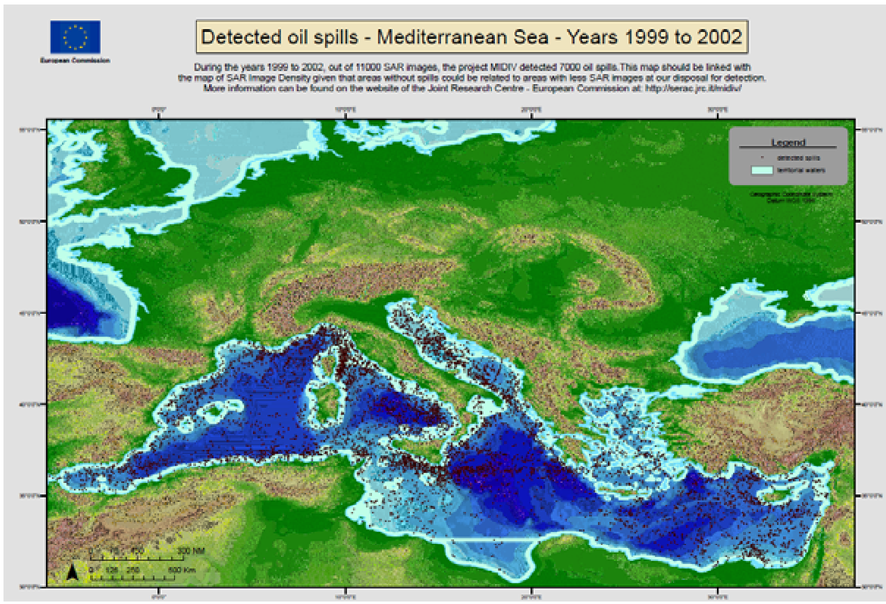


Figure 4.8. Oil spill locations 1999-2002 (Source UNEP/MAP-EEA)

Levels of hazardous substances in the marine environment: Trace metals

408. 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 stations with high levels of Hg, Pb and Zn in Croatia. 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).

409. 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).

410. 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).

411. 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).

412. 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.

413. Data for concentrations of DDT levels in sediments were published for river Po delta. Concentrations were in the range of between 0.3 – 1406 DDTs (ng/g dw), while background values 0.08 – 5 were determined for Mediterranean (Gómez- Gutiérrez *et al.* 2007).

414. 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).

415. 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.

416. 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.

417. 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.

418. 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.

419. 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-l (as Sn) in summer (Nermanic *et al.*, 2002).

420. 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 persistance 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).

421. Concerning 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).

422. 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.

423. The UNEP/MAP-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 (UNEP/MAP-EEA, 2010).

424. Temporal trends of pollution based on Eionet data 1998-2005 prepared by UNEP/MAP-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 (Figure 17) (EEA CSI 40, 2010).

425. 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 (Figure 20). 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.

426. 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.

4. <u>Dumping</u>

427. There are several large ports in the northern Adriatic as well as in the southern part (Figure 4.9). 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.

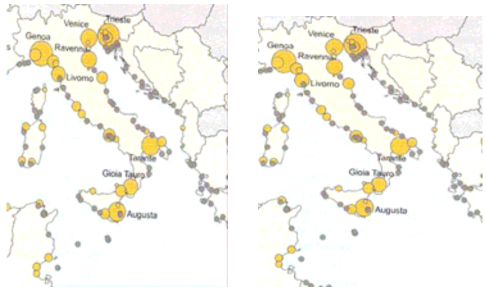


Figure 4.9. Major ports showing number relative number of exits in thousands of tones per port (left) and relative number of entries in thousands of tones per port (Source Blue Plan, 2009)

428. 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).

429. 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).

430. 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).

431. 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:

- 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

(review from Simonini *et al.*, 2005a and references therein).

432. One of the transboundary impacts of waste released in the 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 in 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 (Figure 33) 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.

433. 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-BP/RAC, 2009).

5. Nutrient Enrichment

434. 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).

435. According to the UNEP/MAP-MED POL reports (Legovic et al, 1990; UNEP/MAP-MED POL 2009), eutrophication of the northern Adriatic Sea was investigated since 1911 until 1982 using data on dissolved oxygen (DO). It was concluded that 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.

436. 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.

6. Biological Disturbance

437. 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).

438. 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.

439. 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).

440. Scientists are still not sure how human activities affect mucilage occurrence. New approaches to the research of mucilage are being conducted with hypothesis that occurrences are a consequence of the carbon cycle disruption (Gogek, 2008).

441. 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.

Most Threatened Areas in the Subregion

442. 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.

443. 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.

444. Kastela Bay in the central Adriatic is another threatened area. 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.

445. 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, seem to trigger explosive development of certain populations mainly

those with organisms (dinoflagellates) showing competitive advantages over other organisms thus developing monospecific blooms. When these blooms collapse, oxygen consumption takes place resulting in anoxic or quasi-anoxic states.

446. 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).

447. 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.

448. 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).

Nutrient Enrichment

449. 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).

450. 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.

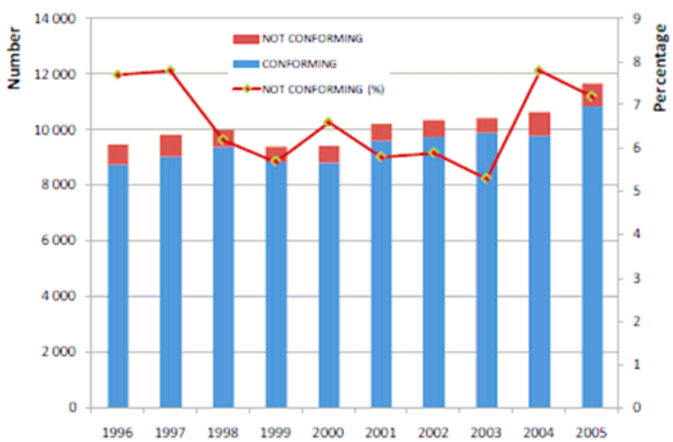
451. Time trend analyses of data from Italy shows that oxidized nitrogen concentrations are increasing at 4% of the stations, decreasing at 1% of the stations, and no statistically significant trend can be detected at the remaining 95% of stations.

452. 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.

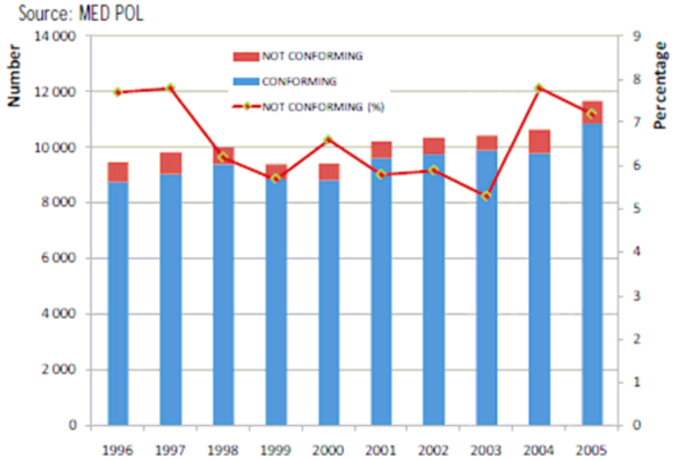
453. In both coastal and freshwaters the point sources of pollution that cause most health concern are those due to domestic sewage discharges. Diffuse outputs and catchments aggregates of such pollution sources are more difficult to predict. Risks to human health are related to recreational waters quality and to shellfish associated infections.

454. 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. 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.

455. 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.



Source: MED POL



Source: MED POL

Figure 4.10: Number and percentage of bathing water areas complying and non-complying with the national legislation per year, 1996–2005 (UNEP/MAP-BP/RAC, 2009).

Fishing and Other Impacts

456. Insufficient fisheries management is one of the problems in the Adriatic Sea.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* and *Arnaglosus laterna.*Recently a total 28 shark species were confirmed from the Adriatic Sea and the Adriatic was supposed to be nursery and spawning areas for many large shark species, such as *Carcharhinus plumbeus*, *Alopias vulpinus*, *Prionace glauca*, *Oxynotus centrina* and *Lamna nasus* (Soldo, 2006).

457. 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.

458. 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).

459. 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*).

460. ADRIAMED project is one example of regional cooperation. This project named "Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea" is an FAO Regional Project since 2007. The project aims to promote scientific cooperation among the Adriatic countries (Albania, Croatia, Italy, Montenegro and Slovenia), in line with the Code of Conduct for Responsible Fisheries (UN-FAO). Expected results are to establish a scientific information network pertinent to the shared fisheries resources of the Adriatic Sea and their management. In addition, the continuation of a process of cooperation and coordination in the various key areas (data collection; dissemination of information; biological, statistics, economic and social research and analysis; institutional networking and strategic planning). Results of the Project will help fisheries management in the Adriatic Sea.

V. Subregion #4 Eastern Mediterranean

461. 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.

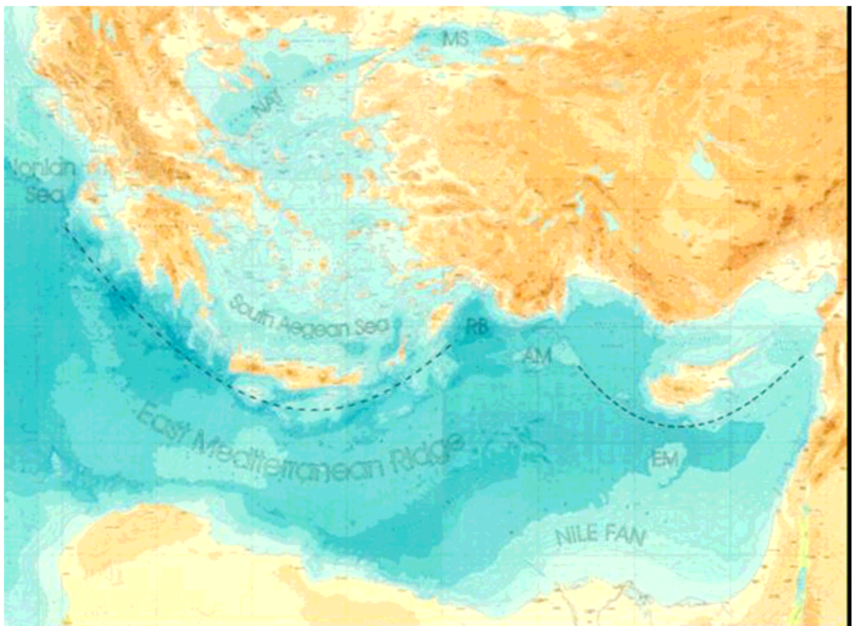


Figure 5.2. Morphology of the Aegean –Levantine Basin

A. Physical Characteristics

1. Bottom topography and bathymetry

462. 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.

463. 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 Peloponese. 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.

464. 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.

465. 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.

466. 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).

2. <u>Salinity, Temperature, Circulation, Currents</u>

467. 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 Dardanelles. 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).

468. 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. 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).

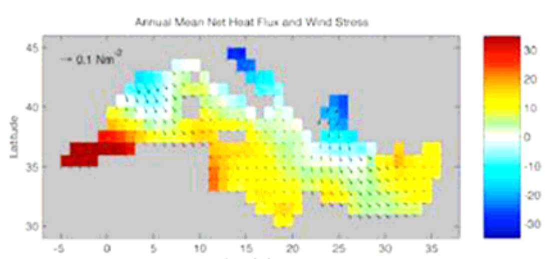


Figure 5.2: Climatological annual mean fields based on the SOC climatology for the net heat flux and the wind stress. Climatological annual mean net heat flux (colours Wm- 2) and wind stress (arrows) (Josey *et al.*, 1999)

469. The physical characteristics (T and S) of the waters in eastern Mediterranean are summarized in Table x1. Satellite derived maps describing the mean spatial T and S variability are shown in figure 37 whereas figure 5 provides satellite snapshots of T across the basin in May 2010 (top) and December 2009 (bottom).

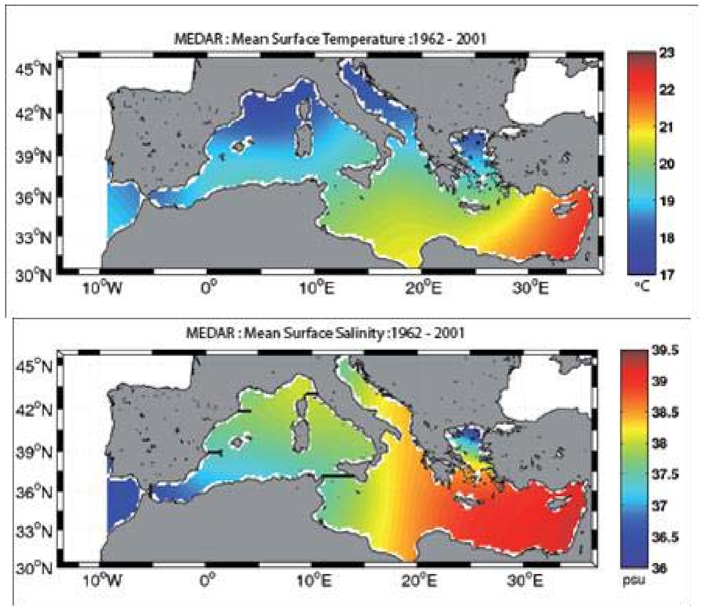


Figure 5.3: MEDAR Mean surface Temperature (top) and salinity (bottom) 1962 -2001.
Source: Reprinted from Vidal-Vijande (2008)

470. 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 dynamic of currents (UNEP/MAP-EEA, 1999).

471. 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 38) :
• 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°C and salinity of 38.4-39.1 psu;
• the Mediterranean Deep Water formed in both the western and eastern basins; the Western Mediterranean Deep Water (WMDW) is characterized by a temperature of 12.7°C and a salinity of 38.4 psu while the Eastern Mediterranean Deep Water (EMDW) is characterized by a temperature of 13.6°C and a salinity of 38.7 psu.

472. 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). the North and South Aegean Sea, is also an important source which under the synergy of extreme meteorological and favorable hydrological conditions become more effective and may considerably influence the thermohaline circulation in medium or longer term. 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).

473. 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.

474. 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 (Figure 38).

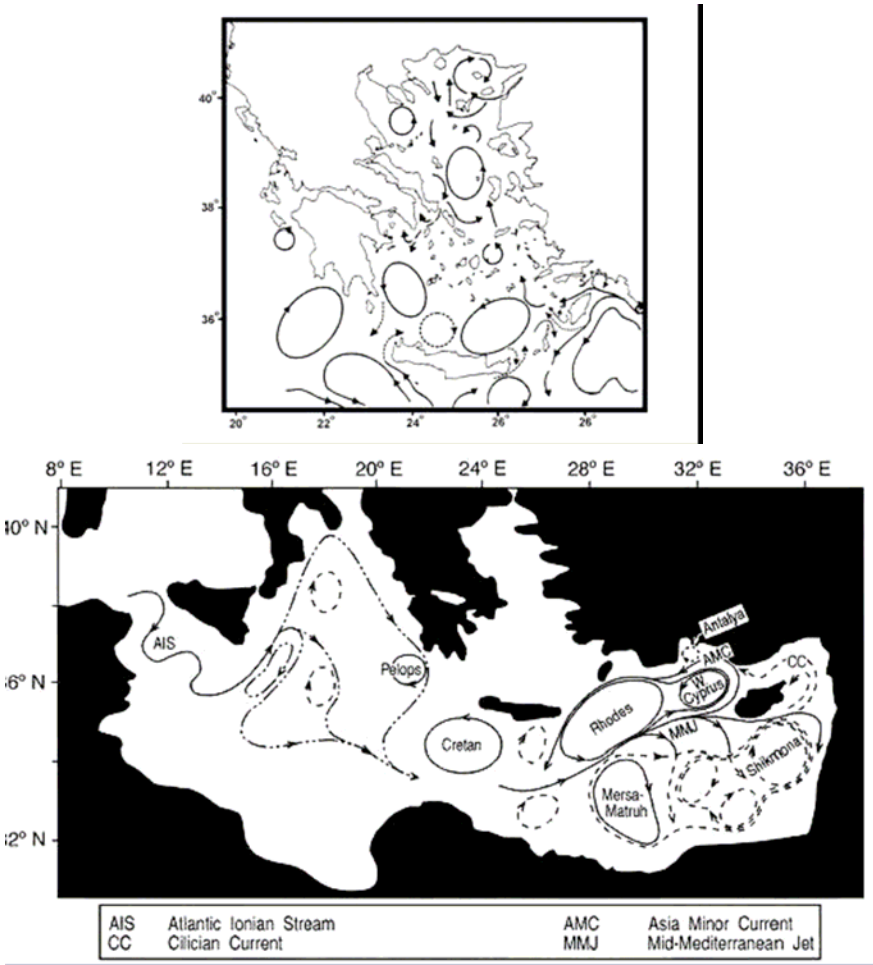


Figure 5.4: Schematic upper general circulation in Eastern Mediterranean(Lykousis *et al.*, 2002 (top) and Malanotte-Rizzoli et al, 1997 (bottom))

475. 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).

476. 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).

477. 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 the1999, that altered the thermohaline circulation of the eastern Mediterranean (Figure 6a,b) (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).

478. 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).

479. 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). Estimates of total riverine freshwater flux into the Mediterranean and Black Sea have been established in a recent work (Ludwig et al 2009) Table 2. 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.

480. 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.

481. The application of an appropriate model to the entire drainage basin allowed a realistic valuation of the impact of climate forcing on the river freshwater fluxes to the sea (Ludwig *et al.*, 209). The work suggested that climate change alone could have provoked 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 reduction 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).

482. 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. Our 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.

3. <u>Nutrients</u>

483. 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) Table 4, whose 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) (table 5, figures 10,11,12).

484. 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 (Figures 10,11, 12). However no long time series exist of field data to acquire a trend of nutrient enrichment and eutrophication.

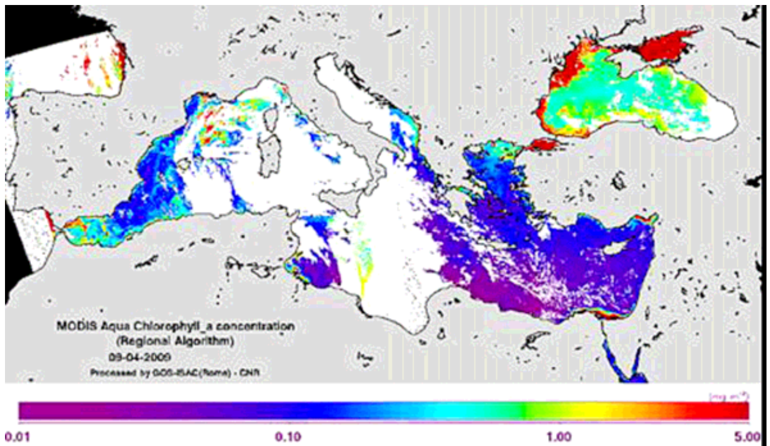


Figure 5.5: MODIS Aqua chlorophyll-a concentration (regional algorithm), 9/4/2009
Source: HCMR Poseidon System

485. 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 the satellite image analysis in figures 12 and 13. 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.

486. In recent assessments of Chlorophyll and nutrients in transitional, coastal and marine waters along EU 27 countries (UNEP/MAP-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 (Figure 14). 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 (Figure 15); however as not long enough time series exist to detect any statistically significant trend.

487. 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.

488. 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 (figure 16 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.

489. 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). With regard to the situation in 1960 (Table 6), Mediterranean and Black Sea rivers are nowadays 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).

490. 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.

491. 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.

492. 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.

493. The Aegean Sea, which shows very complicated seafloor morphology, is chosen as a case study area, to present the main sedimentological characteristics with emphasis on coastal areas based on Karageorgis et al, 2005 and Sakellariou et al 2005.

494. 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%.

495. In the south Aegean, sediments collected from the southern part of the Kyklades 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 characterised 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.

B. Biological Characteristics

496. 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.

497. Several flagship species of great conservation interest are present in this part of the Mediterranean Sea.

498. The most important one 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.

499. 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.

500. Phytoplankton diversity is also 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. Dowidar (1971) singled out *Ceratium egyptiacum*, among several such species of dinoflagellates, which in his view is a fairly recent alien originating from the Red Sea. This species is now recorded not only from the Suez Canal but also from the Nile Delta and from the Bardawil lagoon in northern Sinai (Kimor, 1975). Among the diatoms, the presence of *Chaetoceros coarctacus*, generally considered a circumtropical species, was recorded in the Bay of Haifa (Zismann *et al.*, 1975). In the pre-Aswan Dam period, the diatoms formed up to 99 % of the total algal biomass during late summer, when the Nile‘s nutrient-laden water reached the sea (Halim, 1960). These algal blooms were stimulated by the nutrients, mainly silicates and phosphates. These diatom blooms, consisting of several centric species, were carried by the prevailing anticlockwise coastal current to the Israeli coast. Post- Aswan Dam, these blooms are less apparent and predictable, largely due to the fairly constant salinity and low nutrient load. In general, it may be said that the dinoflagellates consist of tropical-subtropical species, together with eurythermal species. Tropical shade forms are amply represented in the dinoflagellate flora of the Levant Basin. These forms are generally stenothermal and stenohaline. Their distribution pattern is similar to that of of several groups of microzooplankton which inhabit the upper water layers during the winter and sink to deeper layers during the summer. The eurybathy of *Ceratium carriense* var. *volans*, found in surface

waters and in the very deep strata of the euphotic zone in summer, is worth mentioning, Viable specimens of this species had been recorded throughout the water column down to depths of thousands of meters during the Pillsbury Expedition in the summer of 1965 (Kimor and Wood, 1975).

501. The Pillsbury cruise to the eastern Mediterranean in 1965 resulted in remarkable data on the bathymetric distribution of some of the Microzooplankton species: as in the case of the Ceratiaceae and Dinophysiaceae, many of the winter epipelagic species of Acantharia and Spumellaria migrate to deeper levels during the summer months (Kimor and Wood, 1975). Among the Acantharia recorded at great depths was *Lychnaspis giltschi* (at 2000-3000 m) (Kimor, 1971). Some of the deep water Acantharia displayed potentially functional zooxanthellae, suggesting that as in the case of the free living *Ceratium carriense* var. *volans* and *Halosphaera viridis* (Kimor and Wood, 1975), the existence in the eastern Mediterranean of viable, though rare, populations of potential primary producers well below the photic zone. The tintinnid fauna of the Levant is remarkably similar to that of the Red Sea (Komarovsky, 1959, 1962).

502. Several taxonomic groups of zooplankton had been studied both from regular collections along the coast of Israel and from collections carried out within the framework of projects supported by various agencies, notably the Smithsonian Institution in Washington D.C. The latter supported a 5-year (1967 to 1972) project entitled —Biota of the Eastern Mediterranean and the Red Sea. It would far surpass the scope of this report to refer to all the results of these investigations. Therefore, only a few examples are given, resulting from the work of several local and foreign scientists that could best emphasize the peculiarities of the zooplankton assemblages of the Levant Basin.

503. 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. It was assumed that the Bitter lakes of the Suez Canal formed an insurmountable obstacle in the dispersal of these species, but as their salinity has decreased it may opportune to re-examine the biota. A similar picture of dissimilar taxa in the two adjacent marine environments, connected as they are by the Suez Canal, is provided by the appendicularian fauna: *Oikopleura longicauda* and *O. dioica* prevailing in the Levant and *O. rufescens, Megalocercus huxleyi* and *M. abyssorum* in the Red Sea (Fenaux, 1960). The thaliacean fauna of the Levant, though essentially Mediterranean in character, with the exception of *Salpa cylindrica*, an Erythrean alien (Godeaux, 1960). The Cladocera, consisting of few neritic, thermophilic and euryhaline species, provide additional examples of the region's biogeographical aflinities: the prevailing species of the genus *Evadne, E. tergestina* and *E. spinifera*, are common in both inshore and offshore waters of the Levant Basin, and Podon polyphemoides used to thrive in the coastal waters of Israel at the time of the Nile floods (Komorovsky, 1953). However, the species *Penilia avirostris*, so common in other parts of the Mediterranean, is conspicuous by its absence. This has been established for both the inshore and offshore waters of the Levant Basin (Pasteur et al., 1976) and confirmed by Lakkis (1981) from Lebanese coastal waters.

504. The neritic element in the copepod fauna include *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).

505. 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.

506. 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.

507. 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.

508. Fish species diversity in 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 strait 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.

509. The subregion contains large numbers of both loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles. Up to the mid 20th century hundreds of loggerhead turtles 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 (Sella 1982). However, the number declined rapidly thereafter. Along some 55 km of coastline, which include the area surveyed by Sella's, between 10 and 16 nests were annually found between 1984 and 1989. The decline is attributed to overfishing - nearly 2000 green turtles were hunted each year during the third decade of the 19th century (Hornell, 1935), and to beach sand extraction. To date, both *Chelonia mydas* and *C. caretta* nest in small numbers on the Mediterranean coast of Israel.

510. Pond farming along the northern and central coastal plain of Israel expanded during the 1970's, and attracted many species of water birds, especially during migration. Eleven marine and coastal threatened and endangered species (Annex II, SPA Protocol)(*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.

511. 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.

512. The rare beachings of sperm whales (*Phvseter macrocephalus*) and fin whales (*Balaenoptera phvsalus*) 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.

Pressures and impacts

1. Contaminants

Trace metals

513. 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.

514. 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).

515. 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 5.5 and 5.6.

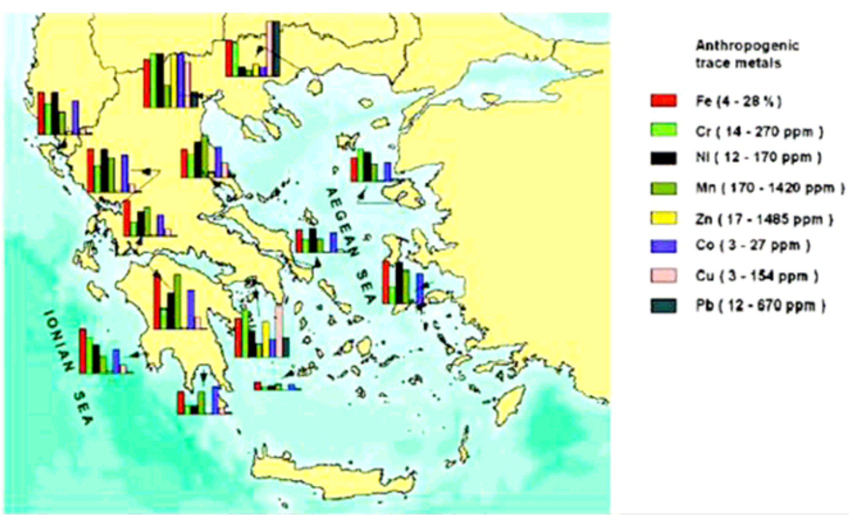


Figure 5.5: Heavy metals distribution as estimated from measurements of the anthropogenic component (mean values over the year). Source: Reprinted from SoHelMe, 2005

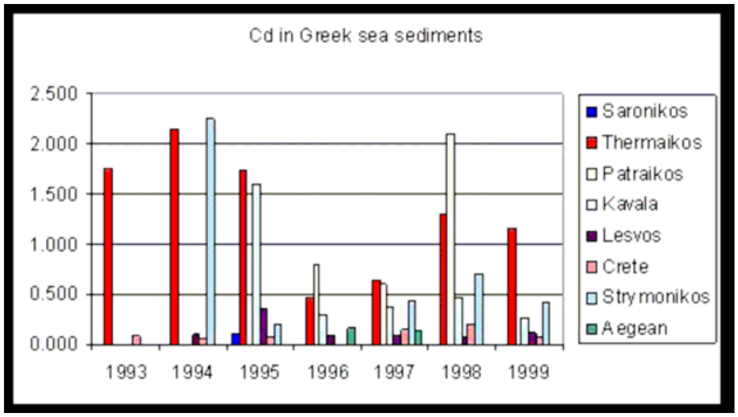


Figure 5.6: Trends of Heavy metals (Cd µg/g) in sea sediments across the Greek seas. (HCMR data base – UNEP/MAP-MED POL data, courtesy of Kaberi, E.)

Trace metals - biota

516. 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 (MED POL, 2009a).

517. 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.

518. 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).

519. 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 5.7. Identified 'hot spots' for the concentrations of PCBs, DDTs and HCB 4 in the Mediterranean sediments Source: Reprinted from Gomez-Gutierrez et al (2007)

Chlorinated pesticides in biota

520. Chlorinated pesticides have been extensively analyzed in Mediterranean biota since the inception of UNEP/MAP-MED POL (UNEP/MAP, 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 Mediterraenan 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).

PCBs in biota

521. 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).

522. 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 5.8.

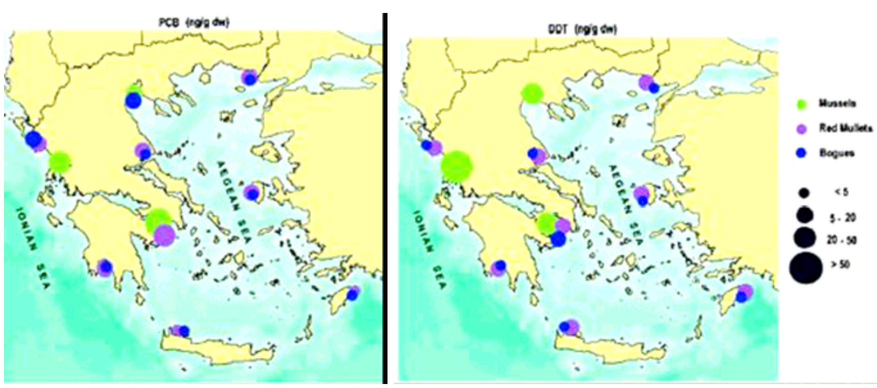


Figure 5.8. PCBs (left) and DDTs (right) concentrations in mussels and fishes (ng/g ww) in Greek seas.(Reprinted from SoHelME)

523. 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).

524. 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
a) Trace metals

525. 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 (figure 39). 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).

526. 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).

527. 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).

528. 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.

529. 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

530. 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 common bottlenose dolphins,

collected along the Israeli Mediterranean coast during 2004–2006, were highest in the blubber, with a wide concentration range.

531. 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).

532. 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.

533. 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). 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).

534. Significant differences in concentrations and pollutant patterns were found between populations. Thus, 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).

535. 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.

536. 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.

537. 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).

2. <u>Dumping</u>

538. 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).

539. 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.

3. <u>Nutrient enrichment and eutrophication</u>

540. 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.

541. Hot spots of nutrients and organic matter releases has been identified by UNEP/MAP at the NW Aegean (Thermaikos Gulf - rivers and the sewage from the city of Thessaloniki), at rivers' 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 32).

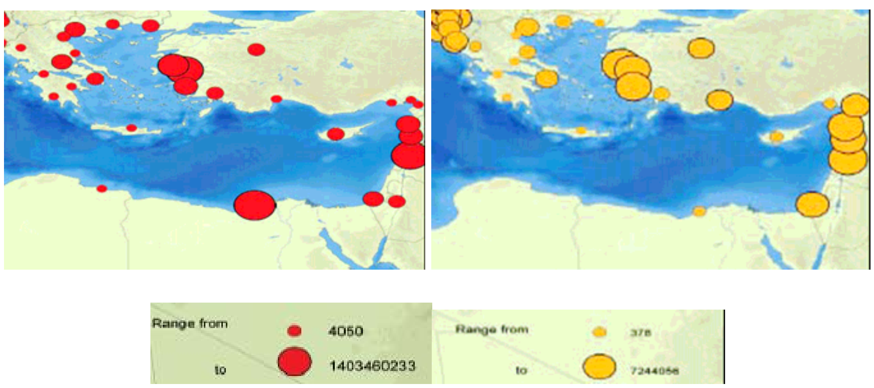


Figure 5.9. Industrial Total Nitrogen (left) and BOD (right) releases from point sources. Source: UNEP/MAP-MED POL NBB, reprinted from UNEP/MAP-BP/RAC, 2009

542. The Aegean-Levanine Seas experience a decreasing trend in riverine fluxes. A decreasing trend has been established for the Aegean (AEG) and the Southenn Levantine (SLE) wheras 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.

543. 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.

544. 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.

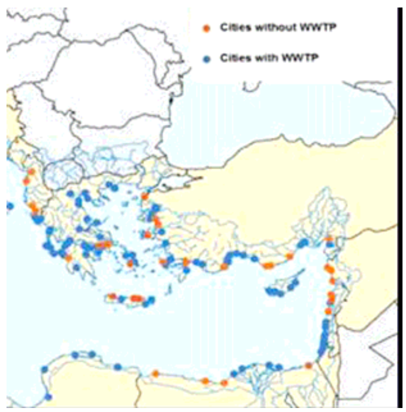


Figure 5.10: Localisation of waste water treatment plants on the coast of Aegean –Levantine (Source: UNEP/MAP-BP/RAC, 2009)

545. Stamou and Kamizoulis (2009), using UNEP/MAP-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 (see Figure 5.11).

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 5.11 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)

546. 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).

547. 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).

548. 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.

549. 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.

550. 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).

551. 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).

552. 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.

553. 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. In Turkey the Sea of Marmara and Bosphorus Straits are presenting serious eutrophication phenomena, and some coastal areas in NE Aegean (Izmir bay).

554. 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.

4. Fishing impacts

555. 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.

556. 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).

557. Other geological features which 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).

558. The following sites are considered critical areas in the subregion, especially with regards to fishing impacts in Mediterranean open seas, including demersal and pelagic ecosystems:

- 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.

5. Biological Disturbance

559. 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.

560. 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.

561. 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.

562. Tropicalization, i.e. the establishment of tropical species that were previously absent from the basin, is eveident 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.

563. 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. <u>Physical Disturbance, Coastal Development, and Litter</u>

564. 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.

565. 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.

566. The country reports provide some more details about specific situations, but, overall, the general picture denotes high human pressures on the coast and the marine environment, ensuing environmental degradation that is perceived in a qualitative way, and that should be quantified in a more stringent way.

567. 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.

568. The studies of marine debris in the Mediterranean so far 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.

569. 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). Table 22 presents the main findings of the studies conducted in the eastern Mediterranean with emphasis in Greek waters.

570. The conclusion drawn by UNEP/MAP (2005) on the incomparability of the studies becomes evident however general remarks can be drawn 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.

571. 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) Sea attributed to the proximity of study sites with metropolitan areas.

572. 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).

VI. Commonalities and Priorities

A. Commonalities in Ecosystem Condition, Threats, and Drivers

573. 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; over-fertilization 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.

574. Perhaps the greatest commonality in the overall region, and the biggest challenge facing the Mediterranean countries, is the lack of information on both 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.

575. The attempt to standardize assessment in each of the four subregions has resulted in a number of other important findings:

- Common threats, similar trends in all subregions
- Differing priorities regarding key threats/pressures in each subregion
- Habitats/ systems of high ecological and ecosystem services value
- Emerging new developments in environmental quality and issues since the UNEP/MAP - EEA report of 2006
- Identification of data incompatibilities and insufficiencies
- Furthering of knowledge on how much good information already exists on Mediterranean environmental quality and ecology
- An emphasis on the need to map information and use GIS as a tool

576. Each of these subjects is summarized separately below; subsequent sections speak to the implication of these findings for completing the remaining steps of the ecosystem approach process and for finding opportunities to guide the Mediterranean region towards the ecosystem approach.

Common Threats, Similar Trends

577. The pressures and impacts that are common to all four subregions include:

- habitat loss and indirect effects (e.g. pollutant loading) caused by **urbanization**;
- **overfishing**, and in particular the effect that overfishing has on community structure, ecological processes, and delivery of ecosystem services;
- **destructive fishing,** including bottom trawling and fishing methods resulting in significant by-catch;
- **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 shipping**, energy exploration and recovery (operational as well as disaster-related);
- **invasive species** and microbial pathogen spread, in many cases mediated by climate changes;
- loss or **degradation of transitional or estuarine areas**, which serve as critical nursery areas for commercial fisheries and also support unique assemblages of species.

578. Desalination and mariculture-related degradation are emerging issues which will need monitoring. Lack of information on some pressures and/or their ecological impacts, and short-sighted and sectoral management that was the norm for many years are drivers behind much of the degradation.

Different Priorities in Key Issues /Pressures

579. A common approach to assessment has also highlighted 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.

580. A detailed discussion of key issues in each subregion is provided in the assessment chapters, but can be summarized as follows. In the Western Mediterranean subregion, urbanization and with it the loss of habitat and increases in pollutant loading; shipping and port-related disturbances and pollution (including direct impacts on species as well as noise and chemical pollution); and over-fishing and fishing-related habitat disturbance emerge as the top threats to marine ecosystems. Similarly, in the Ionian and Central Mediterranean subregion, over-fishing, fisheries-related conflicts, and maritime activities (shipping, etc.) pose the greatest threats.

581. In the Adriatic subregion, the high levels of nutrients (both naturally occurring and anthropogenic) have led to eutrophication and harmful algal bloom outbreaks. Pollutants in sediments and biota are also causes for concern in some localized areas. In the Eastern Mediterranean, urbanization and with it changes to hydrological regimes and loss of habitat, as well as pollution (especially untreated human sewage) is an issue in portions of the subregion, while over-fishing is a major threat throughout.

582. However, it should be noted that this overly simplistic highlighting of key threats 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.

583. These differences raise the question of whether sub-dividing the assessment into four regions facilitates the process of assessment for the purpose of moving towards an Ecosystem Approach.

High Value Habitats

584. The 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.

585. The UNEP/MAP-BP/RAC economic valuation exercise has provided some important data to support 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.

New Developments and Emerging Issues

586. Since the 2006 UNEP/MAP-EEA report "Priority Issues in the Mediterranean", 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.

587. 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, 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.

588. 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.

Data and Knowledge Gaps

589. 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 UNEP/MAP Protocol species and habitats that are of conservation interest in the Mediterranean is sometimes limited. Regional priorities to address these data gaps are suggested in Annex I.

590. This exhaustive list in Annex I 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 management can be designed so that it derives needed data and 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.

Information Inventory

591. 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.

592. There is also a different 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.

593. Key meta-databases already exist, having been compiled by UNEP/MAP and other institutions. UNEP/MAP is presently conducting an inventory of metadatabases and will establish a system for quick links into public databases, in order to support the ecosystem approach process specifically and management activities in general.

The Need for Mapping

594. A 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. This information already exists but should now be mapped. The detailed information provided by national reporting on the distribution of seagrass meadows, coralligenous communities, and other critical marine and coastal habitats could be mapped and added

to other maps (such as the distribution of coastal lagoons shown in Section I Figure 1. 4) to support GIS analysis.

595. Areas under multiple threats (hotspots for multiple pressures) can also be mapped.

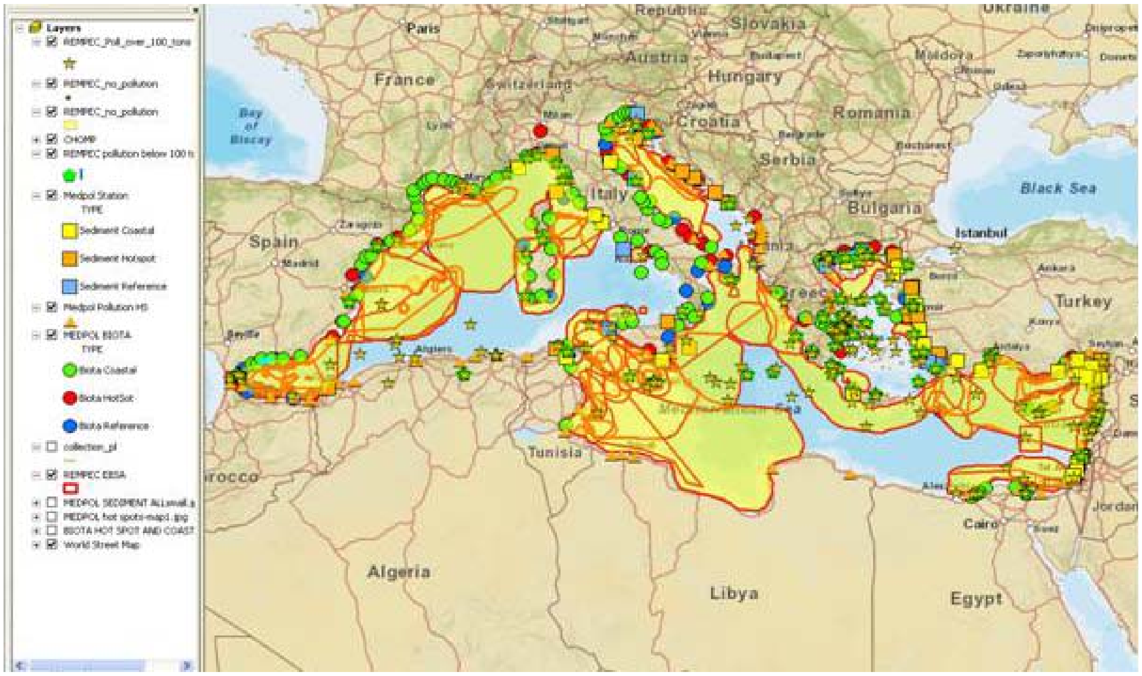


Figure 6.1. Snapshot of some of the information currently being mapped by UNEP/MAP

596. 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.

B. Implications of the Findings for the Ecosystem Approach Planning Process

597. Many of the preliminary assessment reports coming from the four sub-regions of the Mediterranean call for significant new research or expansion of research into new geographic areas. However, the roadmap has a set timeline, and delaying the setting of operational objectives and management measures needed to achieve them will not serve the marine and coastal ecosystems well. UNEP/MAP and other regional institutions will need to draw upon relevant, geo-referenced information coming from existing monitoring and research undertaken through the legal instruments and monitoring programs of UNEP/MAP. More importantly, some consensus will need to be reached on which ecosystem areas, components or services constitute priorities – whether because of their inherent value, vulnerability, or degree of threat they face.

Increasing Feasibility of Ecosystem Approach by Prioritizing

598. In order to move towards an Ecosystem Approach, basic understanding of the target ecosystems needs to be furthered, focusing on key ecosystem functions, resilience, and delivery of ecosystem services (values capitalized by humans). This is not to say that everything must be known with certainty. Indeed, formally incorporating uncertainty and risk in an assessment will enhance its overall utility. Given limited time and resources to "get it right" – a special challenge in a marine area as large, diverse, and complex as the Mediterranean –the next steps in the ecosystem approach process must focus on priorities. These priorities can emerge by focusing on known threats, the most valuable ecosystem services, or special areas (habitats identified under the Habitats Directive and Natura 2000, SPAMI sites, Ecologically or Biologically Significant Areas.

599. Other geographical priorities that focus on threats exist in the region. The Transboundary Diagnostic Analysis (TDA) undertaken in 2005 lists the geographical priorities of 12 Mediterranean

countries participating in the evaluation of transboundary threats, and these could serve as a useful foundation for further prioritization under the ecosystem approach process. Climate change hotspots identified in Italian waters provide another example at the national level.

600. Targeted metadata analyses are also useful. UNEP/MAP recently pioneered the identification of areas of conservation interest in pelagic environments (some in areas beyond national jurisdictions). Using available data as well as expert opinion, priority areas for conservation were highlighted. These areas could also serve as one possible “filter” for determining ecosystem approach priorities.

601. Another example is provided by a recently undertaken exercise called CHOMP (Critical Habitats of Mediterranean Predators). The focus of this effort was on marine top predator 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.

602. Figure 6.2 shows some of this data on major mega-vertebrates, showing areas of high overlap.

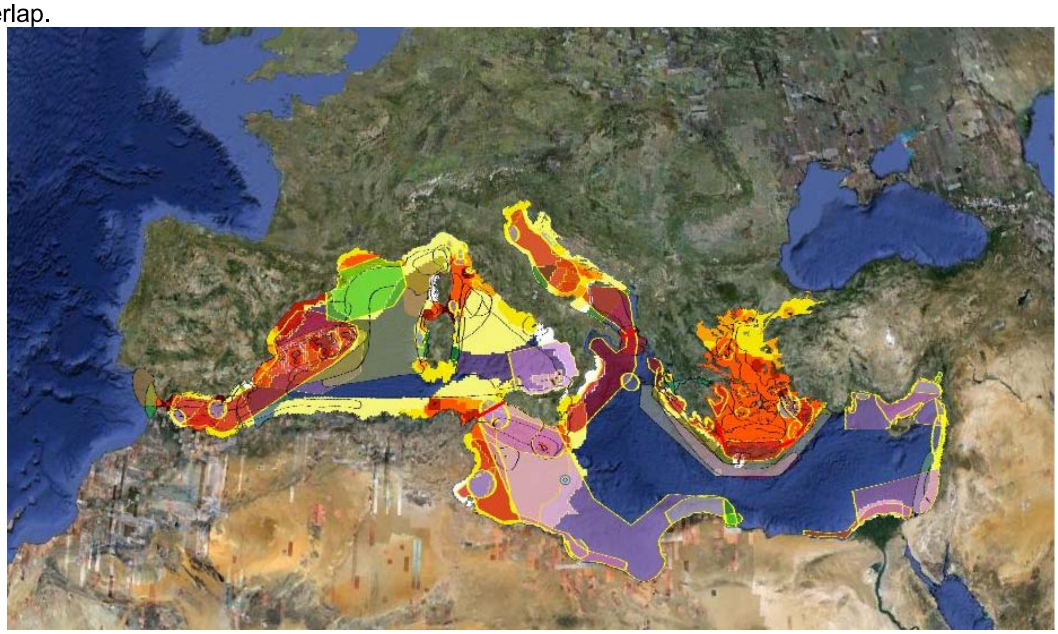


Figure 6.2. Main areas of ecological importance for select Mediterranean megavertebrates, as provided by the CHOMP exercise.

603. In addition, a variety of tools capable of regional-scale assessment using satellite and aircraft remote sensing have been developed and the resulting maps are relevant to the assessment of isolated and expansive environments that are difficult to audit using traditional field-techniques. The maps also deliver base-data for predictive models of habitat health, the designation of protected areas, and investigations of ecosystem function, including genetic and larval connectivity.

Tools for Completing the Next Steps of the Ecosystem Approach Process

604. 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.

605. A good example concerns eutrophication tracking. Remote sensing from airplanes and satellites offers the opportunity to detect large scale changes in the biological properties of the Mediterranean (e.g. use of color data), to detect changes in coastal areas and to detect and monitor accidental pollution (UNEP/MAP-EEA, 1999). The long-term record of ocean color data provided by the SeaWiFS mission is an important asset for monitoring and research activities conducted on primary production and to study the major characteristics of temporal variability associated with optical properties across the Mediterranean Sea (Vandeprotte *et al.* 2010).

606. Decision Support Tools (DSTs) for marine conservation and management decision-making are now a fundamental and widely used component of the Ecosystem Approach. DSTs can often enable useful management and defensible resource allocation decisions to be made in data poor environments, through the use of a variety of easily available surrogate measures or descriptors. In addition, there is an increasing interest in the use of risk assessment in conservation and management priority setting, largely due to increase in human impact and the emerging impact of climate change on many marine ecosystems. Both cost and ecology must be considered in the solution and these complex trade-offs can best be made with the assistance of well-formulated decision support tools.

Rationale for an Optimal Mediterranean Monitoring System

607. To successfully move towards an ecosystem approach, periodic monitoring should be structured to generate information needed to:

- Determine trends in environmental status;
- Help predict changes in ecosystem services delivery and values;
- Develop scenarios that describe various management outcomes;
- Allow decision-makers to evaluate trade-offs;
- Highlight key management issues;
- Help determine the form of management, including choice of management tools and scale of management (Mediterranean-wide measure, national policy, marine protected area management, fisheries area management, mitigation measure in a specific location, etc.)

Once ecological objectives and baselines have been established, mechanisms should be put into place that can easily derive 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.

608. Cause and effect should 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.

609. Availability of trend data is another feature of environmental monitoring of the Mediterranean that the subregional assessments have highlighted. Trends can be discerned for some classes of pollutants (nitrogen and phosphorus, as well as trace metals and pesticides in places where monitoring programmes have been in place for some time). Trend information can also be derived for commercial fisheries, although illegal, unregulated and underreported fishing remains a problem within

national waters, and even more so in Areas Beyond National Jurisdiction. The fact that systems are not yet in place to monitor impacts of human activity on Areas Beyond National Jurisdiction, which comprise the vast majority of the Mediterranean's biosphere, raises the issue of what mechanisms can be put in place by UNEP/MAP to better understand threats to the offshore systems, as well as opportunities for their effective conservation.

610. At a minimum, UNEP/MAP should continue its efforts (or develop new efforts, where such monitoring is lacking) to track and map outbreaks of Harmful Algal Blooms (HABs), track non-indigenous species, especially known invasive species; estimate mortality of threatened species; determine location and scope of toxic pollutant hot-spots; and monitor water quality in bathing areas and areas where commercial fisheries or aquaculture industries operate. To the extent practicable, early warning systems should be put in place that allow researchers/managers to determine trends over time and in space, and where thresholds are known, indicate when these threats are causing ecosystems to approach tipping-points.

611. 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. An optimized monitoring strategy should inform understanding of these synergistic effects.

612. In the context of streamlining, a parallel but related process occurring in the Mediterranean Basin merits mention. European countries, under the Marine Strategy Framework Directive (MSFD), 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 the 11 descriptors (in essence these are ecological objectives) 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.

613. 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). 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.

614. 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, determining ecological and operational objectives, and prioritizing these so that small, feasible steps towards an ecosystem approach can be taken.

Key Tasks to Support the Next Steps

1. Complete inventory of metadatabases and create database management system that allows easy access and updating

2. Map information, and begin GIS analyses to help determine priorities.

3. Launch a rational process for determining priorities, in order to focus down the setting of objectives (Steps 4 and 5 in ecosystem approach) to a realistic and tangible subset.

4. Develop one or more pilots to test the feasibility of setting ecological objectives and related operational objectives, and to test the choices of targets and indicators.

Literature Cited

NEED TO ADD ALL REFERENCES FROM TECH COMP REPORTS

Badalamenti F., *et al.*, 2008. National overview (except the Adriatic coast) on vulnerability and impacts of climate change on marine and coastal biodiversity. Contract RAC/SPA, N° 13/RAC/SPA_2008. 36 pp.

ANNEX I

- 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.

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.

These gaps, issue by issue, can be summarized as follows (more details are given in the supporting document provided by RAC SPA):

- 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 must be emphasized too…
- 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.

Annex

LIST OF MARINE AND COASTAL SITES CONSIDERED TO BE ESPECIALLY AT RISK (OR ENDANGERED) IN THE SHORT-TERM BY THE EFFECTS OF CLIMATE CHANGE IN ITALY (ADRIATIC EXCLUDED).

Liguria

Coralligenous assemblages and/or “encourbellement" of Lithophyllum lichenoides within the Marine Protected Areas of:

1. Isola di Gallinara
2. Isola Bergeggi
3. Portofino
4. Cinque Terre

Tuscany

Areas at risk from rises in sea level:

5. Verisilia Riviera

Coralligenous assemblages and/or “encourbellement" of Lithophyllum lichenoides within the Marine Protected Areas of:

6. Arcipelago Toscano
7. Secche della Meloria

Latium

Areas at risk from rises in sea level:

8. Fondi and Pontina plains

Coralligenous assemblages and/or “encourbellement" of Lithophyllum lichenoides within the Marine Protected Areas of:

9. Secche di Tor Paterno
10. Isole Pontine di Ponza, Palmarola and Zannone
11. Isole di Ventotene e Santo Stefano

Campania

Areas at risk from rises in sea level:

12. delta of Volturno in the Gulf of Gaeta
13. delta of Sele in the Gulf of Salerno

Coralligenous assemblages and/or “encourbellement" of Lithophyllum lichenoides within the Marine Protected Areas of:

14. Regno di Nettuno (Isole di Ischia, Vivara and Procida)
15. Isola di Capri
16. Punta Campanella
17. Santa Maria di Castellabate
18. Costa degli Infreschi

Sardinia

Areas at risk from rises in sea level:

19. Pilo lagoon
20. Tortolì lagoon
21. Gulf of Orosei (beach and lagoon)
22. Murtas Beach
23. Porto Pino and Palmas (Sardinia)
24. Gulf of Cagliari
25. Gulf of Oristano

Coralligenous assemblages and/or “encourbellement" of Lithophyllum lichenoides within the Marine Protected Areas of:

26. Asinara
27. Capo Testa - Punta Falcone
28. Arcipelago della Maddalena
29. Tavolara - Punta Coda Cavallo
30. Golfo di Orosei - Capo Monte Sannu
31. Capo Carbonara
32. Penisola del Sinis - Isola di Mal di Ventre

33. Capo Caccia – Isola Piana

Sicily

Areas at risk from rises in sea level:

34. Stagnone di Marsala
35. Trapani and Paceco saltmarshes
36. Noto and the Vendicari lagoon
37. Pantani Cuba and Longarini

Vermetid platform within the Marine Protected Areas of:

38. Egadi and
39. Capo Gallo - Isola delle Femmine

Coralligenous assemblages and/or “encourbellement" of Lithophyllum lichenoides within the Marine Protected Areas of :

40. Isole Egadi
41. Capo Gallo e Isola delle Femmine
42. Isola di Ustica
43. Isole Eolie
44. Isole Ciclopi
45. Plemmirio
46. Isole Pelagie
47. Isola di Pantelleria

Posidonia recife barriere

48. Capo Feto SCI (Site of Community Interest)

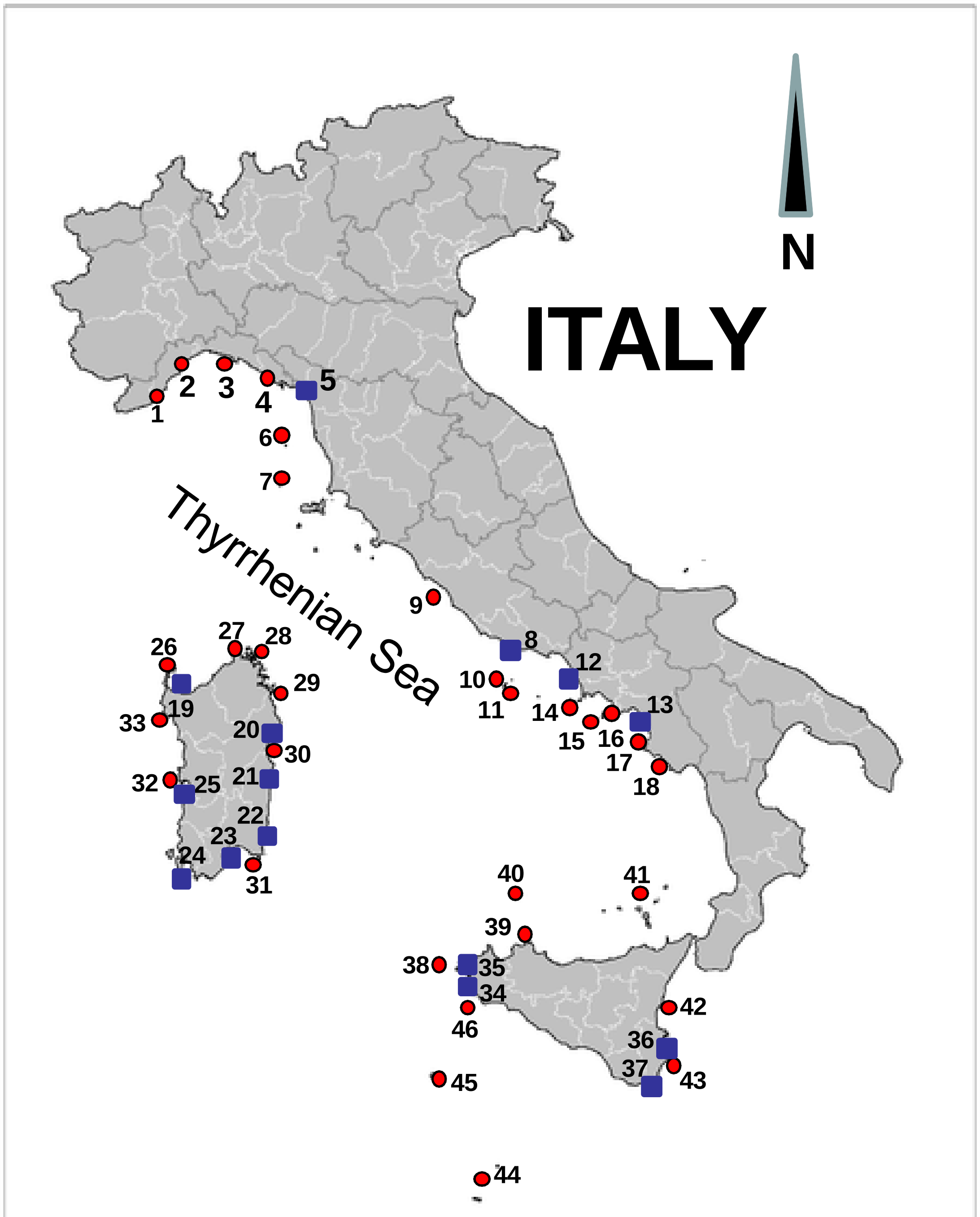


Figure 1. List of marine and coastal sites considered to be especially at risk (or endangered) in the short.term by the effects of climate change in Italy (Adriatic excluded). Squares refer to Areas at risk from rises in sea level and circles refer to areas at risk of impact on biodiversity. More details are in Annex 1.