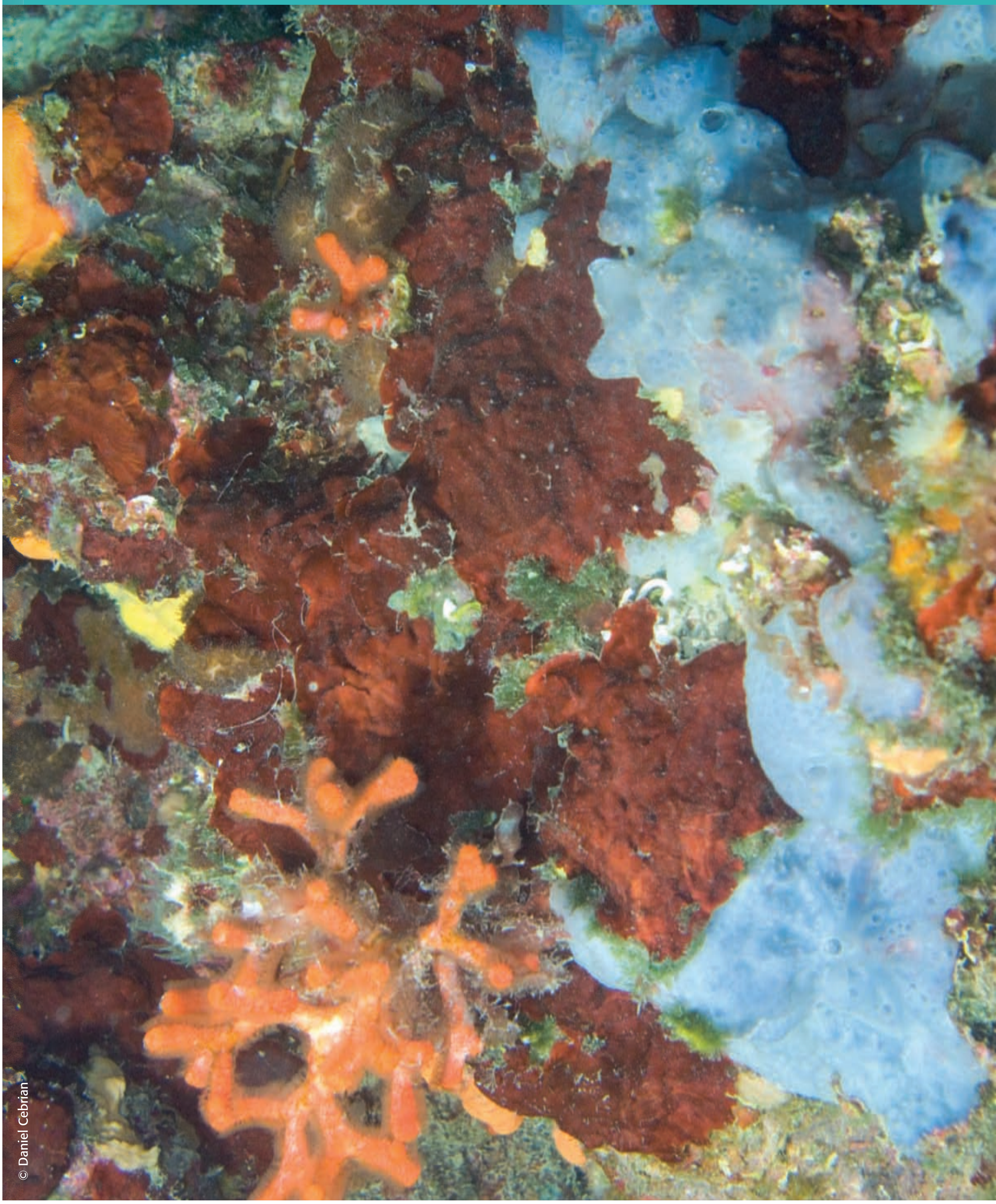
United Nations Environment Programme
Mediterranean Action Plan
Regional Activity Centre for Specially Protected Areas

The Mediterranean Sea Biodiversity: state of the ecosystems, pressures, impacts and future priorities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The Mediterranean Sea Biodiversity: state of the ecosystems, pressures, impacts and future priorities

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Mediterranean Action Plan
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INTRODUCTORY NOTE

This document is aimed to approach an assessment of the state of the ecology and identification of lacunae concerning the major properties of the ecosystems and associated pressures in the Mediterranean. It comprises in its first part a summary of the state of the ecosystems in the Mediterranean, particularly the biological features and types of habitat that exist there. A second part deals with the pressures and impacts on these ecosystems, essentially as regards biological disturbance and emerging problems such as the effects of climate change and modifications of the deep sea ecosystems, given the interest they are arousing worldwide. The document further deals with the gaps in the region and finally discusses priority needs and future urgent actions

For the purpose to identifying the important properties and assessing the state of the Mediterranean ecosystems and the pressure exerted on them, the Mediterranean Sea was subdivided into four regions. Such operational subdivision was the result of a consensus based on biogeographical and oceanographic considerations (2nd Meeting of Government-designated Experts on the Application of the Ecosystem Approach, Athens, 9-10 July 2008). The four regions identified (Fig. 1 below) are (i) Region 1: Western Mediterranean; (ii) Region 2: Adriatic Sea; (iii) Region 3: Ionian Sea and Central Mediterranean; and (iv) Region 4: Aegean Sea-Levantine Sea.

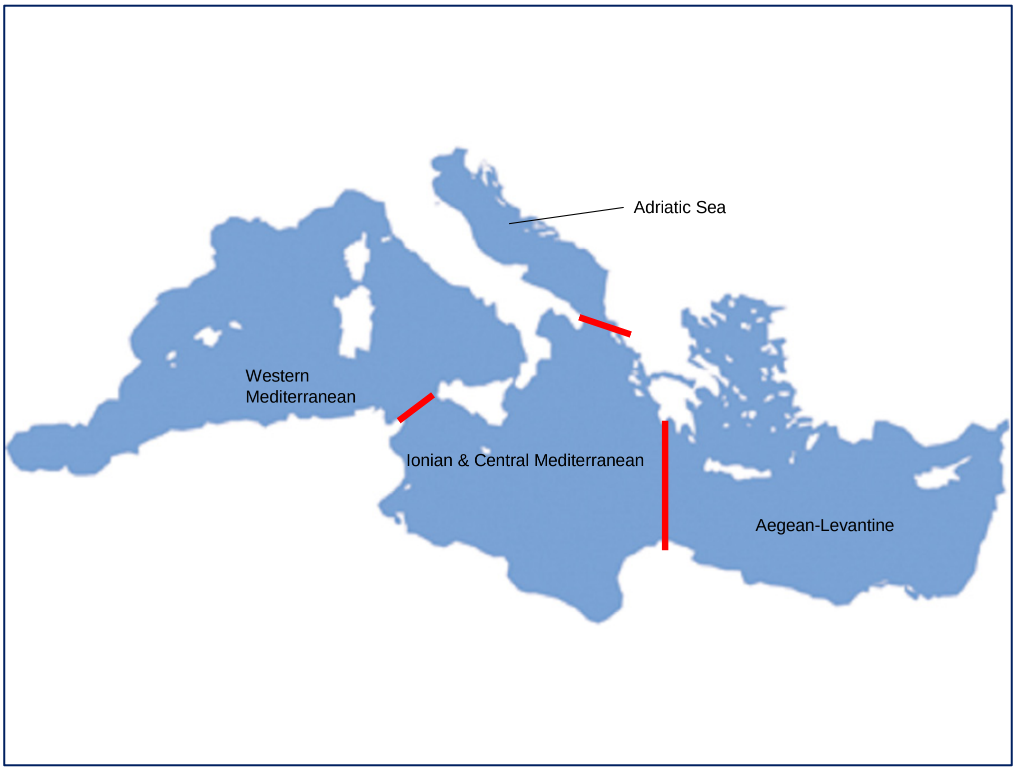

Figure 1: The Mediterranean divided into four regions

A wide array of the most recent and pertinent documents and conclusions at Mediterranean national and regional levels, related to the state of the ecology and biodiversity in the marine and coastal areas of the Mediterranean, were consulted and used as reference works when preparing this regional document. They had international, regional, sub-regional and national pertinence.

Particular attention was paid to:

- National Action Plans and Reports prepared as part of the Strategic Action Plan for the Conservation of Marine and Coastal Biodiversity in the Mediterranean Region (SAP BIO)
- RAC/SPA's 2009 Reports on vulnerability and the impacts of climate change on marine and coastal biodiversity in the Mediterranean
- The UNEP/MAP-Plan Bleu's 2009 Report on the state of the environment and of development in the Mediterranean
- The Report of the European Agency for the Environment dealing with priority problems for the Mediterranean Environment
- Reports defining and explaining the ecosystem approach – how it works and is implemented
- Information on the state of Mediterranean ecosystems, habitats and biodiversity on the coast and out at sea, as well as the inventories of pressures and impacts. This information derived from:
- documents from the SAP BIO process: Reports and National Action Plans and consolidated regional document
- documents produced under the aegis of RAC/SPA 2009, 2010, dealing with the state of the ecosystems in the Mediterranean, vulnerability and the impacts of climate change and other stressors on marine and coastal biodiversity: national contributions, sub-regional documents and regional synthesis.They were built up on the basis of a rich bibliography: almost a thousand references

The documentary base used is rich, especially that on biodiversity and those on pressures and impacts, but disparities and lacunae still exist at both national and regional level in the Mediterranean:

- Variable availability of information at geographical level
- the information needed for the riparian countries sometimes appears in documents that are difficult to access
- Variable availability of information at subject level
- The number of subject-based or sector-based bibliographic sources varies considerably from country to country and subject to subject. This variability results from the disparity of national capacities generally and the relative availability of specialists for certain subjects. Some subjects are sometimes not well documented because they are expensive to handle or require equipment that is not available to certain countries or regions
- For some countries, priority issues are linked to natural resources of commercial interest, and most of the means are devoted to such aspects
- The inventories and data are fragmentary and often do not concern the totality of the marine and coastal places
- The data availability is greater for the major systemic (animal and plant) groups (fishes, crustaceans, phanerogams, macrophyte algae, echinoderms, molluscs)

- Often the ‘official’ data are sourced from old books
- Prey-predator and inter-specific approaches are rare
- Dynamic approaches are rare and focus on a small group of exploited species
- There is a crying need for cartography and GIS and this lack is more marked for certain countries.
- Data and cartography is very poor concerning issues related to high seas and deep seas (status, pressures and impacts)

This report was drafted by the Regional Activity Centre for Specially Protected Areas (RAC/SPA). It was elaborated with contributions by the international consultants Hocein Bazairi (Hassan II Aïn Chock University, Casablanca, Morocco), Sami Ben Haj (Cabinet Thétis, Bizerta, Tunisia), Ferdinando Boero (Universita' del Salento, Lecce, Italy), Silvia de Juan (ICM-CSIC, Barcelona, Spain), Jordi Lleonart, (ICM-CSIC, Barcelona, Spain), Giovanni Torchia (Golder Associates,Turin, Italy), Chedly Raïs (Okeanos, Tunis, Tunisia) and UNEP/MAP RAC/SPA officers Atef Limam and Daniel Cebrian

LIST OF ACRONYMS AND ABBREVIATIONS

CBD: Convention on Biological Diversity
CHM: Clearing House Mechanisms
CIESM: International Commission for the Scientific Exploration of the Mediterranean Sea
CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora
EC: European Commission
ECAP: Ecosystem approach
EEA: European Environment Agency
EGA: Environment General Authority
EMT: Eastern Mediterranean Transient
EU: European Union
EUROHAB: European initiative on Harmful Algal Blooms
FAO: Food and Agriculture Organization
FEDEP: Environment and Depollution Funds
FNAT- DD: Territory Management and sustainable Development Fund
FNDPA: Fisheries and Aquaculture development National Fund
FNPZC: Littoral and Coastal Areas Protection National Fund
FNRST: Scientific Research and Technology National Fund
GFCM: General Fisheries Commission for the Mediterranean
GIS: Geographic (al) Information System
HABs: Harmful Algal Blooms
ICCAT: International Commission for the Conservation of Atlantic Tunas
ICES: International Council for the Exploration of the Sea
ICME: International Council for Maritime Exploration
IMO: International Maritime Organization
IUCN: International Union for Conservation of Nature
MADR: Ministry of Agriculture and Rural Development
MAP: Mediterranean Action Plan
MATET: the Ministry of Territory Management, Environment and Tourism
MCBD: Marine and Coastal Biodiversity
MEDITS: International Bottom Trawl Survey in the Mediterranean
MESRS: Ministry of Higher Education and Scientific Research
MPA: Marine Protected Area
MPRH: Ministry of Fisheries and Halieutic Resources
MSFD: Marine Strategy Framework Directive
MSSD: Mediterranean Strategy for Sustainable Development
My: Million years
NASR: National Authority for Scientific Research
NGO: Non-Governmental Organization
PCB: Policlorobifenil
Ppm: Parts per million
RAC/SPA: Regional Activity Centre for Specially Protected Areas
REMPEC: Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
ROVs: Remotely Operated Vehicles
SAP BIO: Strategic Action Programme for the Conservation of Biological Diversity in the Mediterranean Region
SPA: Specially Protected Area
SPAMI: Specially Protected Area of Mediterranean Importance
TPT: Triphenyltin
UNCED: United Nations Conference on Environment and Development
UNEP: United Nations Environment Programme
WFD: Water Frame Directive
WHO: World Health Organization
WWF: World Wide Fund for Nature.

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1. CONTEXT

The Mediterranean, an ecoregion that is remarkable for its climate and the common sea that links three continents, for the richness of its biodiversity, for its classical heritage and the diversity of its landscapes and its cultural places, for the feeling of belonging of the populations of the three shores, remains one of the parts of the world where the question of sustainable development is particularly acute, especially since climate change proves to be particularly sensitive there (UNEP/MAP-Plan Bleu, 2009).

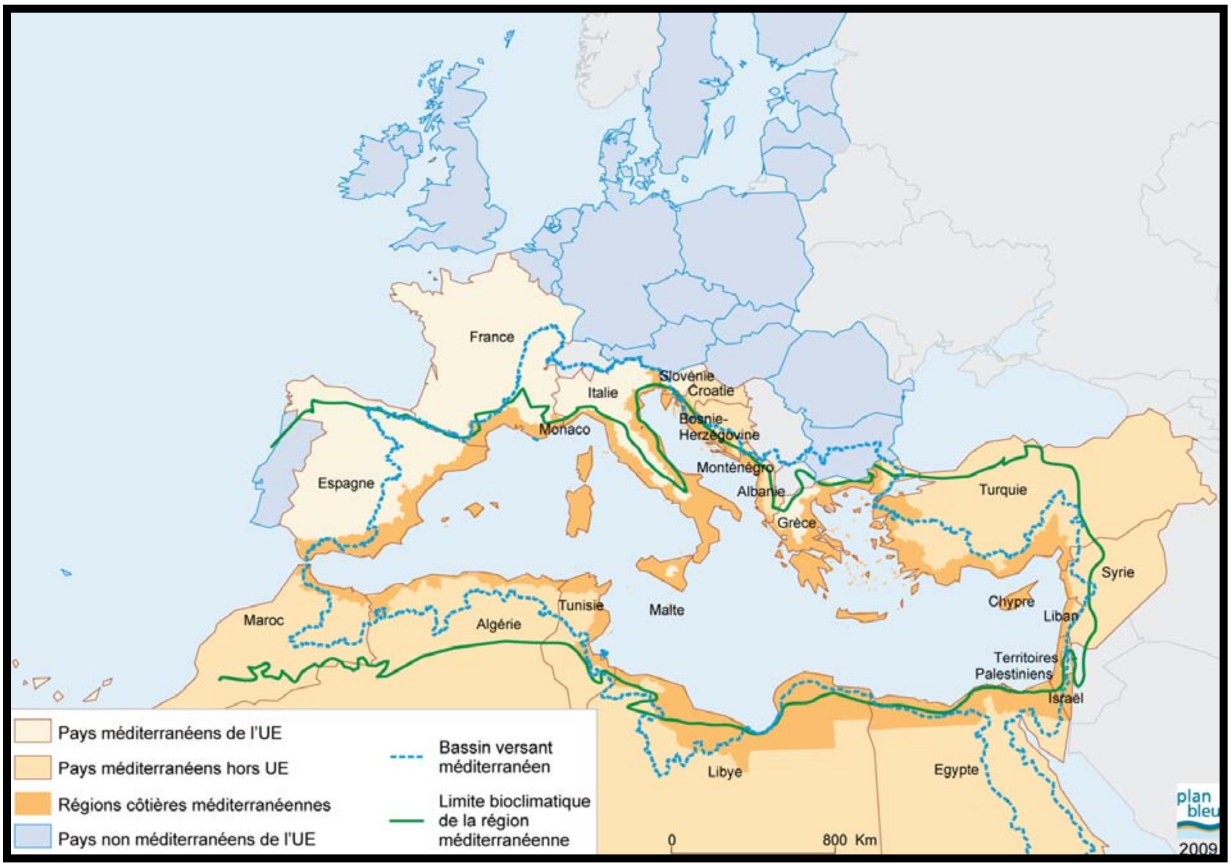


Figure 2: A multi-dimensional Mediterranean region (Source: Plan Bleu, 2009).

The 22 countries and territories that border on the Mediterranean represented (UNEP/MAP-Plan Bleu, 2009) host:

- 5.7% of the planet's land mass, including a large number of desert and mountain areas,
- 10% of known higher plant spe
- cies,
- 7% of marine species in less than 0.8% of its total ocean area
- 7% of the world's population with 460 million inhabitants (stable),
- 31% of international tourism, with 275 million visitors,
- 12% of world GDP (decreasing),
- 60% of the population of the world's "water-poor" countries,
- 8% of CO_2 emissions (increasing).
- every year, 30% of international maritime freight traffic

- 20 to 25% of maritime oil transport transits the Mediterranean sea.

That shows the importance of the sustainability of use of goods and services in the Mediterranean, and the potential interest in applying an ecosystem approach and conservation- and management-related measures not only to the areas under state jurisdiction but also to the habitats and ecosystems that lie in waters outside national jurisdiction.

2. STATUS OF COASTAL AND MARINE ECOSYSTEMS

2.1. BIOLOGICAL CHARACTERISTICS

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; UNEP-MAP-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 (Bianchi & 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. 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.

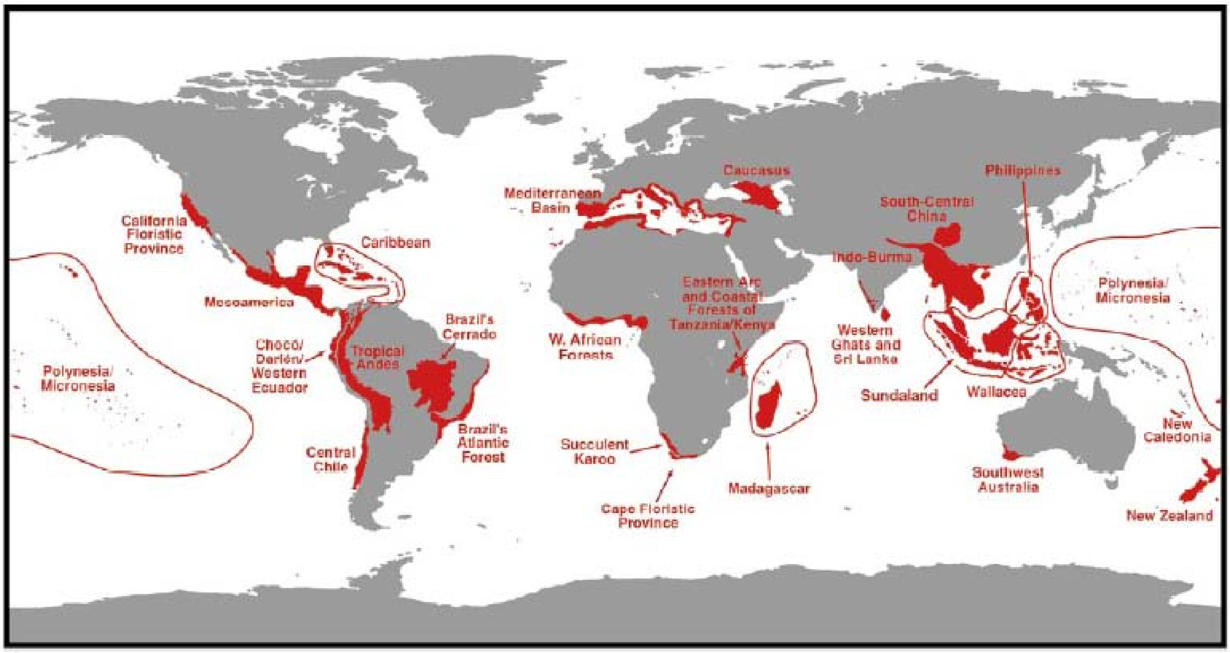


Figure 3**:** 'Biodiversity 'hotspots' around the world (from Meyers *et al*., 2000)

Endemism, i.e. numerous species living exclusively in the Mediterranean, is another marked feature of marine biodiversity in the Mediterranean. It is greater in the Mediterranean than in the Atlantic (Bianchi & Morri, 2000). At biogeographical 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 (Tab. 1). 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 *Posidonia oceanica* (Magnoliophyta, Viridiplantae, Plantae).

Table 1: Rate of endemism (number and percentage) for some taxonomic groups in the Mediterranean (cf. Boudouresque, 2004 for sources)

Phylum	Number of species in the Mediterranean	Number of endemic species	% of endemic species
Echinodermata	134	32	24
Priapulida	1	0	0
Polychaeta Errantia	371	88	24
Echiuria	6	1	17
Sipuncula	20	4	20
Brachiopoda	15	2	13
Mollusca	401	65	16
Crustacea Decapoda	286	52	18
Pogonophora	1	1	100
Phoronida	4	0	0
Hemichordata	5	2	40
Pisces	638	117	18
Total	**1 882**	**364**	**19**

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).

Longitudinal variation of biodiversity in the Mediterranean

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.

Box 1: The Mediterranean Sea: a crossroads of marine biodiversity

The Mediterranean Sea is what remains of an ancient ocean called Thetys, a mass of equatorial water open to the east that divided the two mega-continents (Laurasia and Gondwanaland) that had emerged when Pangaea broke up. In the Cretaceous era, after the Atlantic Ocean opened up, Thetys linked this newly formed ocean with the old Indo-Pacific Ocean. At that time, Thetys possessed a highly diversified tropical fauna and flora. At the start of the Miocene (10 M years) the Suez isthmus formed, thus cutting the Mediterranean off from the Indo-Pacific. Near the end of the Miocene, the communication with the Atlantic was also shut and the Mediterranean thus became a quasi-isolated sea. These 'Messinian' crises succeeded one another for 0.5 to 1 M years, each time almost drying up the Mediterranean. Indo-Pacific-origin biota almost died out. Only a few forms survived in refuges. When communication with the Atlantic was re-established after the Gibraltar Strait opened, the Atlantic water invaded the entire – now almost empty – Mediterranean basin, and a new Mediterranean biota, ancestor of the present-day biota, was founded. Alternating ice ages and hot periods between ice ages during the whole of the Quaternary led to migratory waves of respectively boreal or subtropical forms of life. However, the easternmost parts of the Mediterranean remained under-colonized by Atlantic-origin species, not because these could not reach these regions but probably because they did not find favourable conditions there for settling in these relative warmer areas. The opening of the Suez Canal re-established communication between the Mediterranean and the Indo-Pacific Ocean. Tropical species entered the Mediterranean, exploiting the tropical conditions that are a feature of the eastern Mediterranean.

From another angle, the alternation of hot and cold seasons, linked to the hydrological features of the Mediterranean basin, explain the prevalence of two essentially surface biotas: tropical-affinity species in summer and boreal-affinity species in winter. The northern Adriatic Sea possesses a boreal biota that is endemic to this part of the Mediterranean (e.g. *Fucus virsoides*).

As a result, the Mediterranean is a true crossroads of marine biodiversity. Its marine fauna and flora are made up of species belonging to several biogeographical categories: over 50% have their origins in the Atlantic Ocean, 4% are 'relic' species (witnesses from very old periods when the Mediterranean was subjected to a tropical climate) and 17% come from the Red Sea. In this last category we find both very old species, dating from the time when the Red Sea and the Mediterranean formed a single entity, and species that recently entered the Mediterranean when the Suez Canal was dug and that are deemed to be introduced species. It is also the history of the Mediterranean that is the reason for the high proportion of endemic species met there.

Marine biodiversity in the Mediterranean has constantly evolved over the different geological eras. Today, man has become a forcing factor by introducing, intentionally or unintentionally, directly or indirectly, new species and thus contributing to the decline of other species.

Bathymetric variation of biodiversity in the Mediterranean

- **Continental coastal strip**

Coastal forests

As the FAO puts it, forests are territories where the big tree cover is greater than 10% (UNEP-MAP-Plan Bleu, 2009). These ecosystems have become more developed on the northern shore than the southern, related to the regression of great over-exploitation that they undergo in the northern Mediterranean. In the eastern basin, the situation is intermediate.

Dunes

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 wetlands

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. The smallness of the tides associated with low-speed currents have encouraged the establishing of lagoon or endoreic systems (Britton & Crivelli, 1993; Ibanez *et al*., 2000; De Stefano, 2004).

Mediterranean 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, not including Sardinia.

Mediterranean coastal lagoons are the site of many kinds of anthropogenic disturbance, which affect the structure and dynamics of their biological communities (Castel *et al*., 1996). These highly dynamic environments do show great temporal and spatial variability in their physical, chemical and thus biological features. 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 organisation of communities, specific richness, phytoplanktonic v 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).

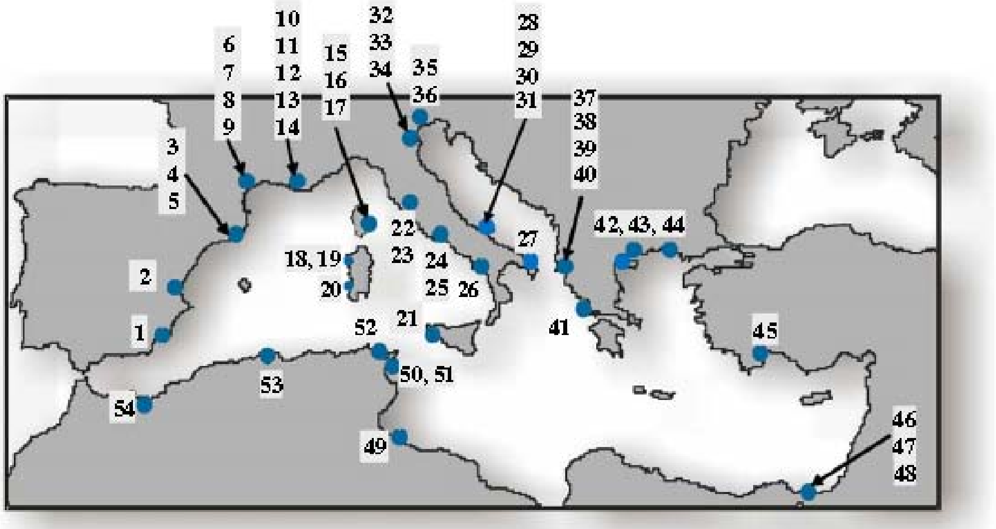


Figure 4: Main coastal lagoons in the Mediterranean basin related to the availability of hydrological, geomorphological and ecological data in the scientific literature (source: Pérère-Ruzafa *et al.*, 2010b)

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 are dominated by eurythermal-euryhaline lagoon communities with specific richness and low densities (shallow lagoons <3 m) or by benthic communities of the silty sand in calm conditions with great specific richness and densities (deeper lagoons >3 m). Very few fishes are sedentary in Mediterranean lagoons, i.e. pass the whole of their life cycle there. These are mainly migratory species that enter the lagoons for essentially trophic reasons. 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 sedentary species. Macroalgal biomass in a lagoon environment is closely linked to entry from hillside lakes and is dominated by species that develop quickly. The marine phanerogams found in the lagoons are *Cymodocea nodosa* (marine affinity), *Zostera noltii* and *Z. marina*, *Ruppia spp*. and *Potamogeton pectinatus* (near natural effluent). Also, a rich and varied avifauna uses these ecosystems as stopover or wintering sites since they find favourable ecological conditions there. Many coastal lagoons are now listed on the Ramsar Convention List as sites of world interest for birds.

- **Coastal area (phytal system)**

The distribution of Mediterranean fauna and flora in the coastal waters differs greatly according to distance from the coast, longitude and depth. The marine biodiversity is basically concentrated within the shore area (between 0 and 50 metres down), 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). The fauna is present right down to the bottom of the deepest cracks but becomes quickly poor with depth.

The level of knowledge about marine and coastal biodiversity by country is very heterogeneous. Few countries have managed to make an inventory of the fauna and flora of the coastal water of their Mediterranean coasts. The MCBD national inventories are far from being completed in many countries around the Mediterranean. Knowledge remains sector-based in most cases, and does not encompass the whole of the countries' Mediterranean coasts.

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 growth in oligotrophy from the west to the east of the Mediterranean basin is reflected in the abundance of the zooplanktonic biomass.

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.

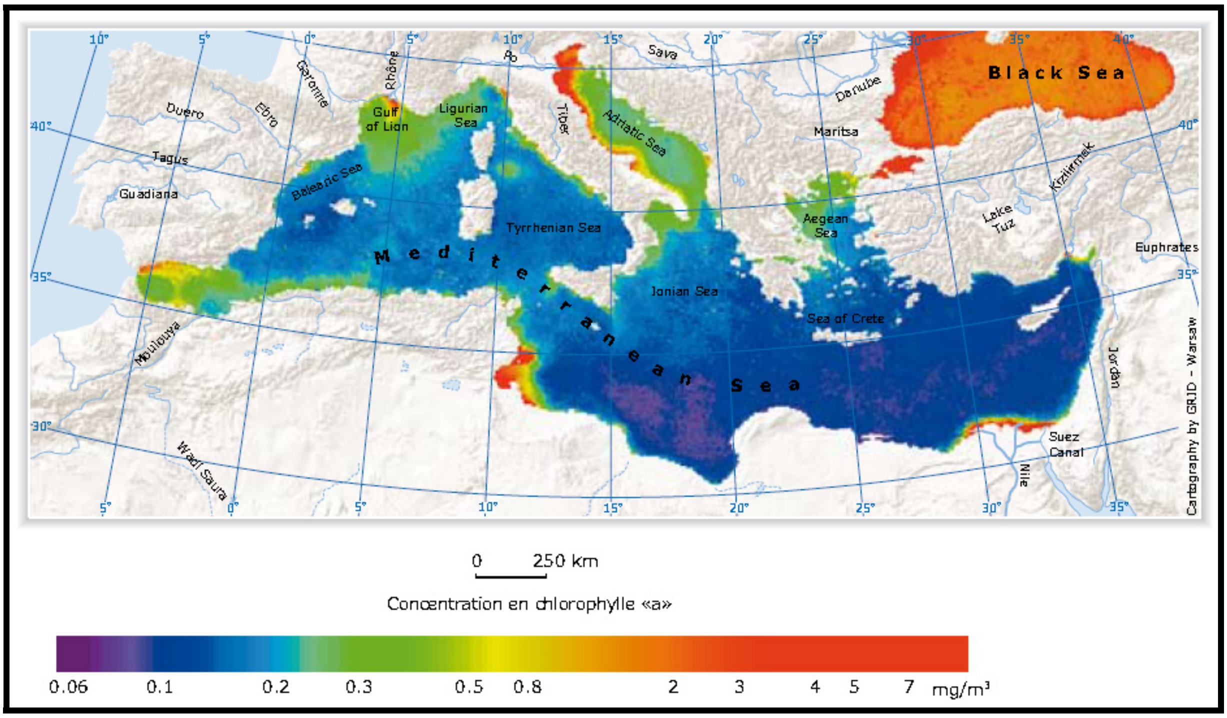


Figure 5**:** Average surface concentrations of chlorophyll ‘a’ in the autumn of 1998 (source: NASA SeaWiFS Project and Orbimage Inc. in AEE, 2009)

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). Their different distribution around the Mediterranean basin reveals a gradient that drops from the west to the east (Zenetos *et al*., 2003) (Fig. 6).

Mediterranean marine macrofauna is basically made up of over 600 fishes (including 81 chondrichthyans and 532 osteichthyans), three reptile species, about 33 nesting birds and 22 mammal species. Of these mammals, ten species are occasionally seen in the Mediterranean basin.

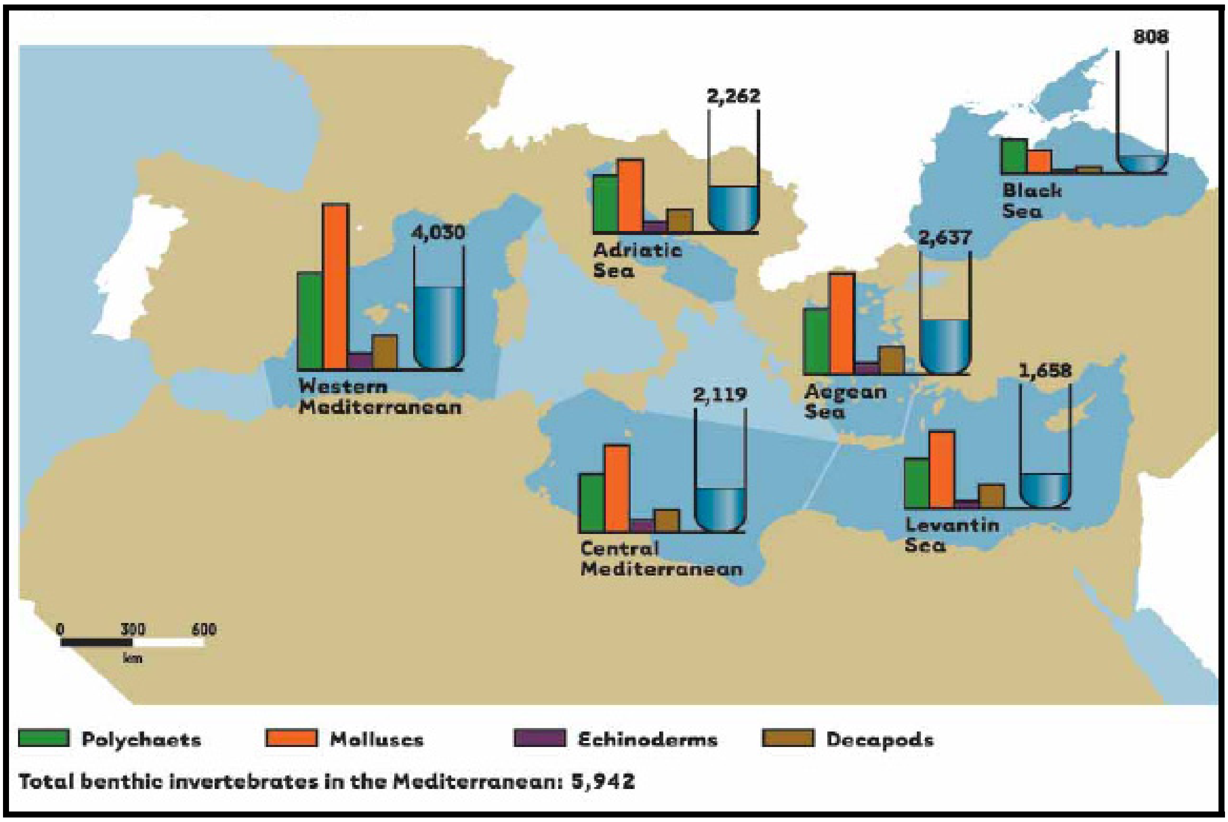


Figure 6: Biodiversity of benthic invertebrates in the Mediterranean (source: Zenetos *et al*., 2003)

- **Deep sea**

The deep sea usually means the marine depths from which photosynthetic organisms are absent. According to some authors and organisations, it 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).

Deep waters remain largely unexplored. The data available for the Mediterranean is fairly weak, but certain 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. 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 crustaceans, mysidaceae, echinoderms and gastropods) 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.

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.

- **Open seas (essentially pelagic ecosystems)**

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 square kilometres. 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).

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.

2.2. HABITATS

- **Coastal strip**

In the Mediterranean, the coastal strip contains ecosystems of world interest for the conservation of biodiversity. These are basically coastal sand dunes and coastal wetlands, especially coastal lagoons. The lagoons present diversified and rich habitats that deserve more specific study.

- **Coastal area**

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

The most typical Mediterranean habitats lie in the coastal strip. These 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 stage, and the coralligenous in the circa-littoral stage (Zenetos *et al*., 2002; Boudouresque, 2004). Added to these habitats are the Vermetid platforms and the *Neogoniolithon brassica-florida* concretion (Boudouresque, 2004).

- **Magnoliophyte meadows:** These are among the most productive ecosystems in the marine environment. Their economic value is estimated at over 15.000 euros per hectare, i.e. 100 times greater than that of their terrestrial equivalents (UNEP/MAP-Plan Bleu, 2009). Five species of marine phanerogam have been listed in the Mediterranean (*Cymodocea nodosa*, *Halophila stipulacea*, *Posidonia oceanica*, *Zostera marina* and *Zostera noltii*). These form vast underwater meadows at between zero and 50 m down in the open sea and in lagoons. Magnoliophyte meadows have been the subject of a regional summary whose aim was to establish the state of current knowledge on the geographical distribution of these sensitive habitats on a Mediterranean scale and map them (UNEP-MAP RAC/SPA, 2009b). Generally speaking, the available data on these habitats is very heterogeneous on a regional scale, and in certain countries even do not exist. The efforts made to map these habitats have mostly been in the north-western basin.

    - <u>The *Posidonia oceanica* meadows</u> are considered to be the Mediterranean'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). As part of the national reports drawn up in the UNEP /MAP ECAP process, *Posidonia* was sighted 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 and b); 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).

- The *Cymodocea nodosa* meadows are second 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 ECAP 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).
- The *Zostera marina* meadows. This is a species that is widespread throughout the northern hemisphere but rare, only growing very locally (area boundary) in the Mediterranean (mainly the north-western Mediterranean, the Adriatic, and the Aegean Sea). It was mentioned in the ECAP context in Algeria (Bou Ismail (Grimes, 2010); Morocco, in the Nador lagoon (Bazairi, 2010) and in Bosnia-Herzegovina (Vučijak, 2010);
- The *Zostera noltii* meadows. This species is widespread throughout the North Atlantic (from Sweden to Mauritania) but rarer and more locally growing in the Mediterranean (western Mediterranean, the Adriatic, Greece and Egypt). In the context of the ECAP process, it 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).
- The *Halophila stipulacea* meadows. This is a Lessepsian species, restricted to specific areas. It has been sighted in Greece (Zenetos *et al*., 2010a and b); in Syria (Ibrahim, 2010); and in Tunisia in the Gulf of Gabès (Romdhane, 2010). It was also spotted in Palinuro port (Salerno, Tyrrhenian Sea, central Italy) in 2006.

- **Coralligenous communities**: These are biogenic constructions. After the Posidonia meadows these habitats are the second most important hotspot of specific 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. Besides, even though it is relatively widely represented in the Mediterranean, data on the coralligenous 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 Chafarinas Islands) (Bazairi, 2010).

Figure 7: Coralligenous formation

- **Cystoseira forests**: The various forms of the *Cystoseira* genus 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 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 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*). the presence of these habitats is also confirmed 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 byssoides* (ex *L. lichenoides* and *L. tortuosum*) rim**: This habitat is 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 in some places they are over 2 m wide (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 also mentioned 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).

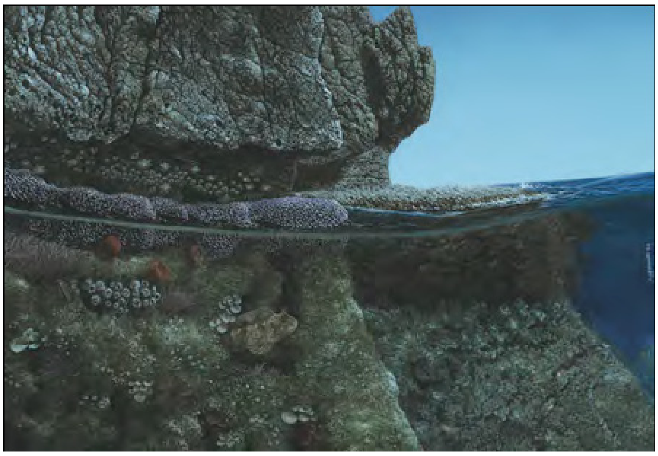


Figure 8 : *Lithophyllum* rim

- **Vermetid platforms**: These 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). These habitats were also 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).

- **Concretion with *Neogoniolithon brassica-florida***: The habitat known in the hypersaline lagoon of Bahiret-el-Bibane in the south of Tunisia (where it can be as long as 31 km) has no parallel in the entire Mediterranean. Other more localized reefs, less spectacular than the Tunisian one, are mentioned in the eastern Mediterranean, e.g. in Greece, Turkey and Albania (from Karaburun to Porto Palermo (Dedej, 2010).

Outside these habitats, the available knowledge is extremely fragmentary and very variable in the Mediterranean basin (UNEP/MAP-Plan Bleu, 2009)., the countries national reports, allow information to be gained on some habitats as well as the above-mentioned ones. In the supra-littoral area, the washed-up phanerogam biocenoses (Code RAC/SPA I.2.1.5.), 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* (Code RAC/SPA II.4.2.5.) 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* (Code RAC/SPA II.4.2.7.), an emblem 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 ECAP context, this habitat was reported in Slovenia (Lipej & Mavrič, 2010). Maërl bottoms (Code RAC/SPA III.3.2.1.) are responsible for much of the biogenic sediment of the coastal area. They have been sighted 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* (Code RAC/SPA IV.3.2.2.) 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**

Deep sea habitats, including hydrothermal vents, the seamounts and the deep sea coral reefs (IUCN-WWF, 2004; IUCN, 2010) present particular interest for the marine environment in the Mediterranean:

- Underwater canyons: these habitats 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*). Also they represent a remarkable reservoir of endemism in the Mediterranean (jellyfish, polychaetes)
- Chemosynthetic communities: these are communities of the hydrothermal springs characterized by symbiosis between invertebrates and chemotrophic bacteria which, using the energy freed by the chemical transformation of certain compounds of the hydrothermal fluid, in particular hydrogen sulphide, can synthesize the first organic molecules from carbonic gas and nutritive salts. Their interest lies in their originality and rarity in the Mediterranean. These habitats are found in southern Crete, southern Turkey (Anaximander Seamounts) and off Egypt and Gaza (ICSEMS, 2004).
- Cold water corals: these are habitats of great ecological value but that are threatened by deep sea trawling and by the effects of global warming (CIEMS, 2004).
- Seamounts: these 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 fish and cetacean. In the Mediterranean, 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.

- Deep Hypersaline habitats: known as brine pools are deep-sea habitats of high biodiversity importance, particularly to extremophilic bacteria and metazoan meiofaunal assemblages (IUCN-WWF, 2004). Little data exists on these habitats but they are considered to be important environments because of their specific Mediterranean feature (CIEMS, 2004).

- **Open seas**

Here we find basically upwellings, gyres and fronts (Fig. 9). 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.

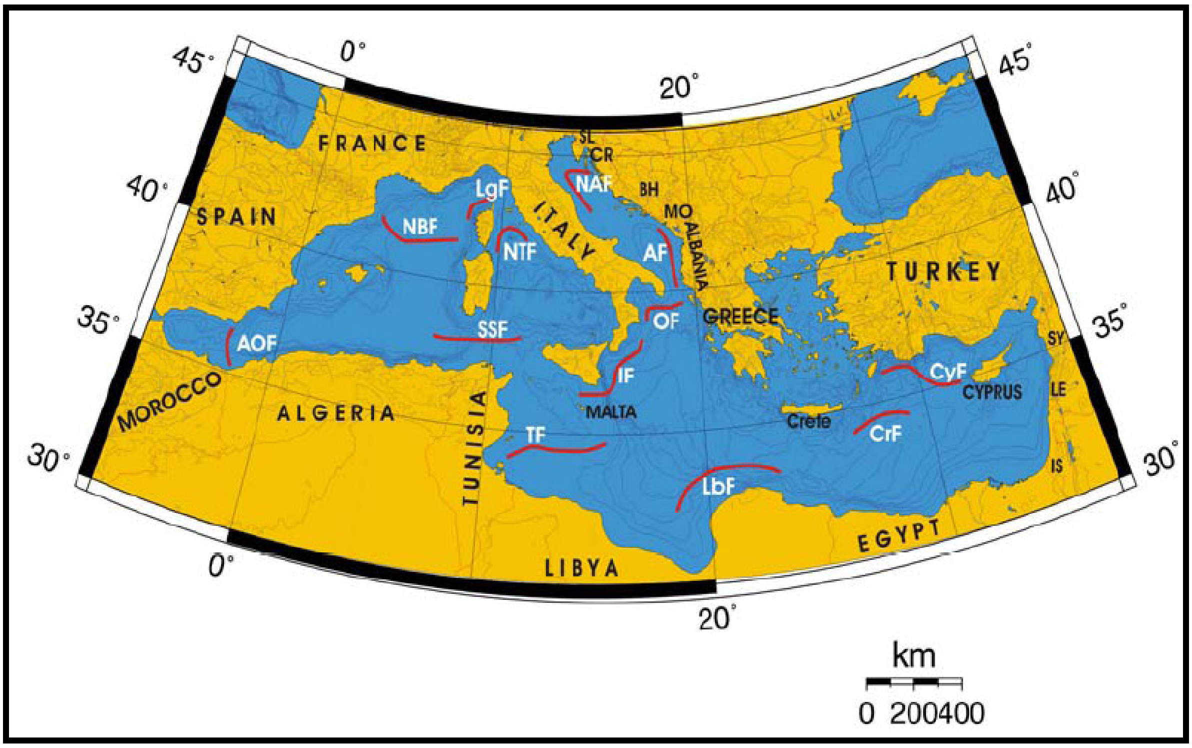


Figure 9: Fronts in the Mediterranean Sea (source: Belkin *et al.*, 2008, in Sea Around Us, 2009). AF=Albanian Front, AOF=Almeria-Oran Front, CrF=Crete Front, CyF=Cyprus Front, LbF=Libyan Front, LgF=Ligurian Front, NAF=North Adriatic Front, NBF=North Balearic Front, NTF=North Tyrrhenian Front, OF=Otranto Front, SSF=Sardinia-Sicily Front, TF=Tunisian Front. Countries: BH=Bosnia-Herzegovina, CR=Croatia, IS=Israel, LE=Lebanon, MO=Montenegro, SL=Slovenia, SY=Syria

2.3. EXPLOITATION OF NATURAL RESOURCES

- **Coastal lagoons**

In the Mediterranean coastal lagoons, fishing is the most extensive form of biological 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.

Fish farming in Mediterranean lagoons concerns 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).

- **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 favourite 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-Plan Bleu, 2009).

The main species of fish exploited 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.).

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.

- **Deep seas**

Mediterranean deep sea fisheries 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).

- **High seas**

Species targeted by fisheries in the open seas are usually those whose stocks straddle the high seas and the coastal areas. These are bony fishes, elasmobranches, crustaceans, cephalopods and big migratory pelagic fish like tuna and swordfish in particular (PNUE-MAP RAC/SPA, 2003)

- **Current trends:**

Fishing in the Mediterranean has over the past ten years grown by about 12%, with great 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.). Fish farming, however, continues to advance and represents a growing part of the halieutic production in the Mediterranean (Fig. 10).

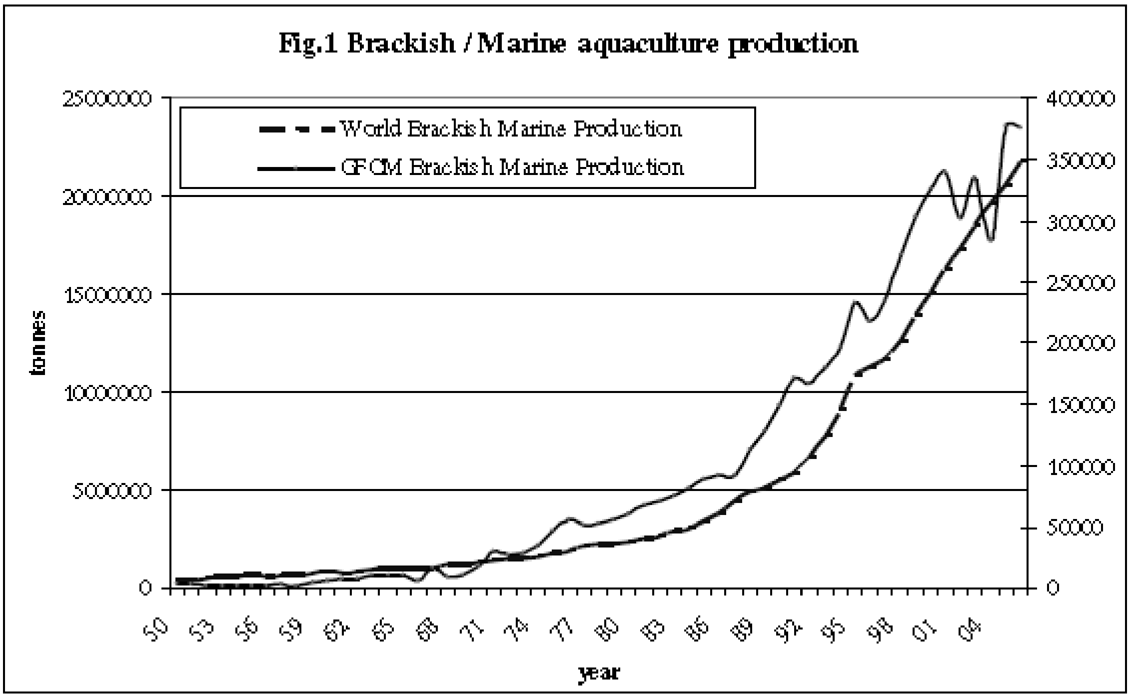


Figure 10 **:** Aquaculture production from fish farming in brackish and marine water on the scale of the marine water for the GFCM region, tons/year (source: GFCM, 2008)**.**

According to the GFCM (2008), 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) (Fig. 11).

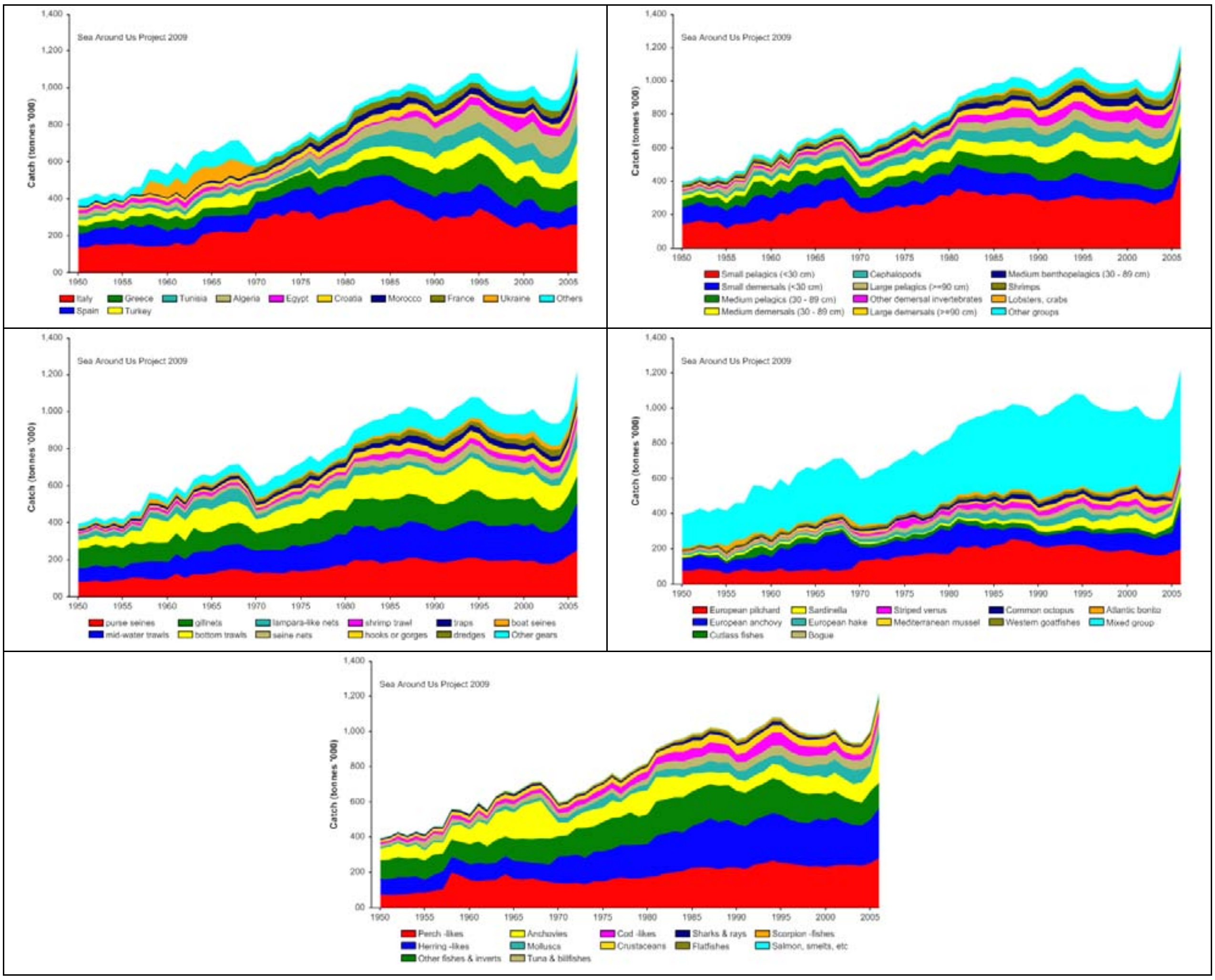


Figure 11: Temporal assessment of fishery catches (tons x 1,000) in the Mediterranean (source: Sea Around Us, 2009)

This is so also in the deep sea, 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).

In the high seas, populations of big sharks (e.g. *Mustelus mustelus, Scylliorhinus stellaris* and *Squalus blainvillei*) are dwindling badly 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.

2.4. NON NATIVE AND INVASIVE SPECIES

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. 12).

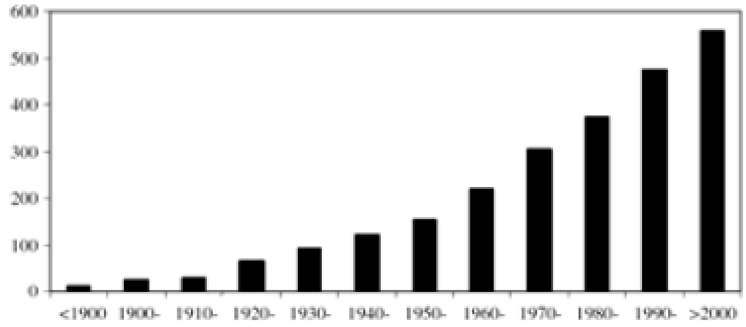


Figure 12: Temporal evolution in the number of introduced species in the Mediterranean.

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) (Fig. 13).

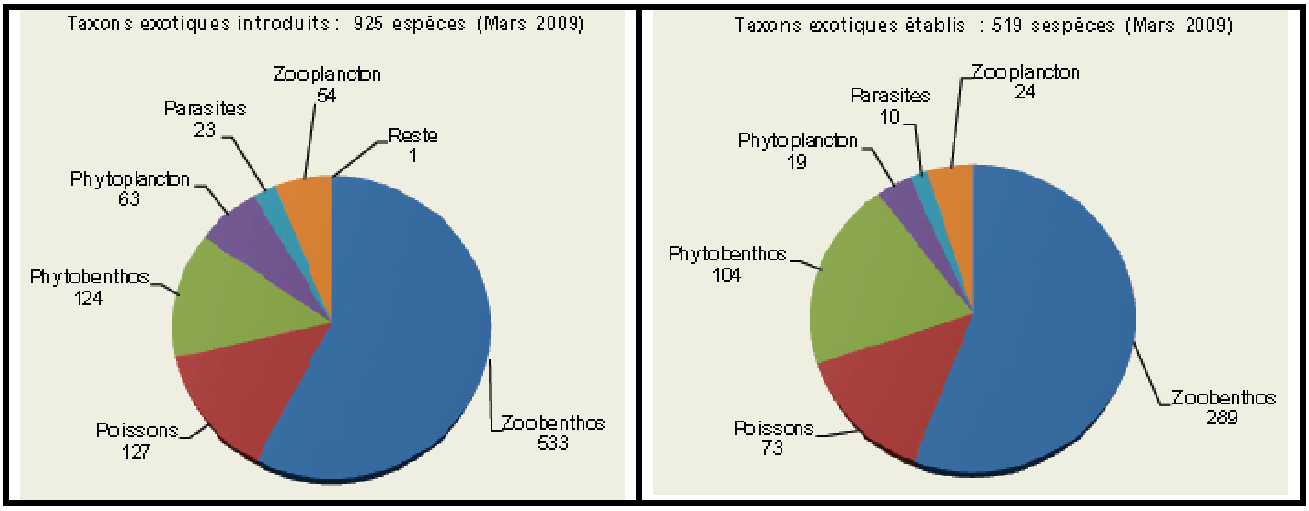


Figure 13: Distribution of exotic species in the Mediterranean (source: Hellenic Marine Research Centre in UNEP/MAP-Plan Bleu, 2009).

Among these exotic species, over 500 are well established in the Mediterranean (UNEP/MAP-Plan Bleu, 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.
The distribution of non-native species varies from country to country (Tab. 2). They are more preponderant in the eastern basin that the western (Fig. 14). Also, the origins of the introduction differ for the two basins. Non-native species in the western basin are mostly species that have been introduced by maritime transport and fish farming, whereas the species in the eastern basin are Lessepsian species that have entered the Mediterranean through the Suez Canal.

Table 2**:** Number of non-native marine species in the Mediterranean countries (source: Zenetos & Polychronidis, 2010).

Country	Number of non native species
Albania	9
Morocco	10
Algeria	11
Slovenia	11
Croatia	18
Malta	23
Lybia	31
Spain	39
Syria	45
Tunisia	50
Cyprus	75
France	83
Greece	88
Lebanon	113
Italy	120
Egypt	141
Turkey	182
Israel	261

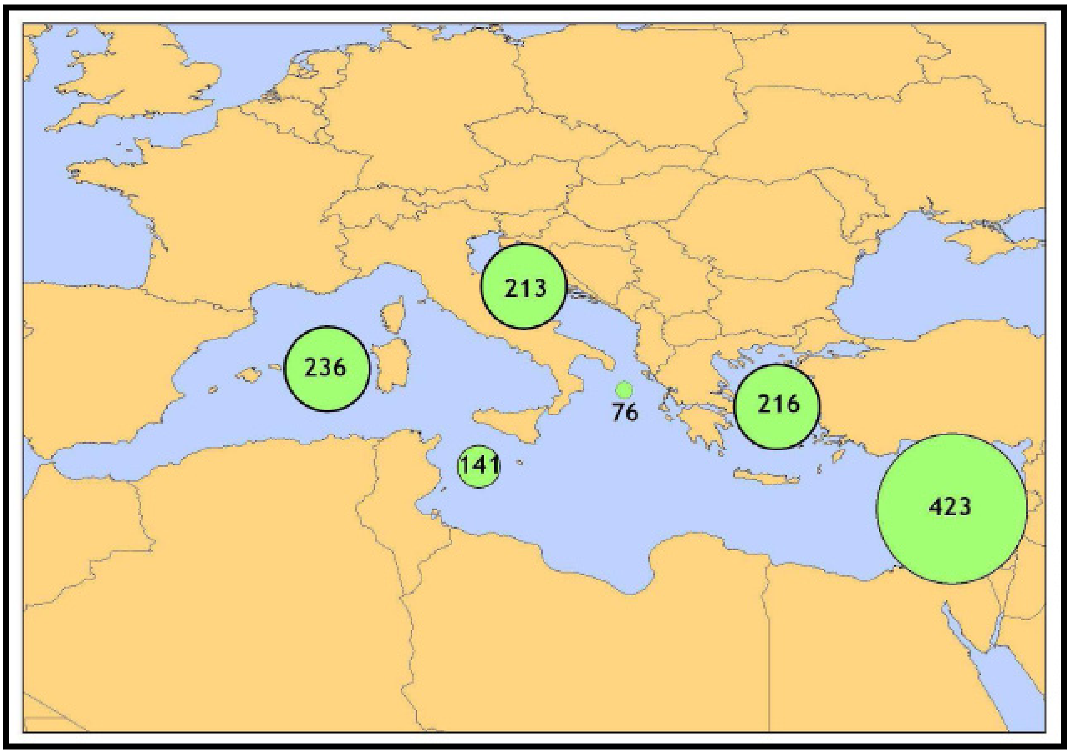


Figure 14**:** Distribution of exotic species in the Mediterranean basins (source: Zenetos & Streftaris, 2008)

- **Predictions (Heip *et al.,* 2009)**

Endemic native species with boreal affinity (cold water), common in the northern part of the Mediterranean, will dwindle, even disappear. A drop in their distribution has already been reported. It is also possible that certain species will become adapted to these new conditions after periods of stress. The alga *Fucus virsoides*, an endemic species of the northern Adriatic (the coldest part of the Mediterranean) has shown signs of stress recently, although it is at present particularly abundant, i.e. in the Venice lagoon. Generally speaking, the current warming has probably facilitated the establishing and distribution of non-native tropical species introduced through the Suez Canal or by maritime transport. Thus, although the current rate of warming is being maintained in the Mediterranean, in all the sub-regions, the biological characteristics could rapidly disappear and be replaced by homogeneous tropical ecosystems.

2.5. TEMPORAL APPEARANCES

'Bloom'/proliferation of certain life forms in the Mediterranean has become increasingly common over the past few years. These include:

- Phytoplankton 'blooms': these have been reported in many coastal regions of the Mediterranean. Also, periods of some species of mollusc poisoning have been observed in Spain, France, Italy, Morocco, Algeria and Turkey

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

- The arrival of the non-native ctenophore *Mnemiopsis* in the Black Sea through ballast water has caused a series of events, the worst being the collapse of fisheries in this basin. As well as obstructing fishing nets, this ctenophore eats fish eggs, larvae and also the crustacean zooplankton that fish juveniles and larvae feed on.

2.6. STATE OF CONSERVATION

The 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.

- **Erosion of biodiversity**

In principle one may classify species, in addition to extinct (disappeared) and no longer appearing in the wild (only surviving in zoos, botanic gardens, etc.), as normal situation species and threatened species. For the latter, there are (according to the IUCN criteria) endangered species (which have disappeared from much of their original area, with numbers reduced to a critical level), vulnerable species (whose numbers have dropped greatly) and rare species (whose numbers are naturally low or whose natural stations are very localized and which can rapidly move into the category of endangered species).

Over the past few years no species seems to have completely disappeared from the Mediterranean (Zenetos *et al*., 2002; Boudouresque, 2004). However, certain species have already disappeared from disturbed areas and are threatened with extinction in the near future.

Many species are currently considered to be threatened in the Mediterranean (UNEP-MAP RAC/SPA, 2003) and are listed in the annexes to the SPA/BD Protocol as threatened species or species whose exploitation must be regulated. The Mediterranean monk seal *Monachus monachus* is one example of an endangered species, as is the ferreous limpet *Patella ferruginea*. Many other species are currently vulnerable, like for example *Cystoseira amentacea* (alga), *Pinna nobilis* (mollusc), *Epinephelus marginatus* (fish) and *Caretta caretta* (marine turtle).

- **Destruction of habitats**

In the context of the MAP, many habitats have been identified as being of conservation interest in the Mediterranean. The most threatened habitats in the Mediterranean are the rims with *Lithophyllum byssoides*, the concretion with *Neogoniolithon brassica-florida*, the Posidonia meadows and the coralligenous (Boudouresque, 2004).

The *Posidonia* meadows are declining in many parts of the Mediterranean because of pollution, coastal development, the practice of unauthorized mooring with an anchor (pleasure boating), fishing activities and the invasion of the tropical macroalga *Caulerpa taxifolia*. These meadows have completely disappeared from Toulon (France) and the Gulf of Gabes (Tunisia), and the degree of their deterioration is 90%, 52% and 20% respectively in Marseilles (France), Alicante (Spain) and the Ligurian Sea (UNEP-RAC/SPA, 1997).

This is also so for other habitats like the coralligenous and the Cystoseira forests.

- **Marine Protected Areas (MPAs)**

Marine Protected Areas are without any doubt precious tools for the management and governance of biodiversity in the Mediterranean (IUCN, 2010). An example of a complete appraisal of all the Mediterranean MPAs (Fig. 15) (number, surface area, species and habitats contained by the management, etc.), carried out in the context of collaboration between RAC/SPA, the MedPAN Network, WWF-France and the IUCN (Abdulla *et al*., 2008) showed the following results:

1. The aim of the CBD to protect 10% of the world ecoregions is not at present being met in the Mediterranean: the surface area covered by coastal MPAs (not counting the Pelagos Sanctuary, i.e. 87,500 sq. km) is only 9,910 sq. km, which represents 0.4% of the total surface area of the Mediterranean Sea

2. Existing MPAs are not representative of all the Mediterranean habitats: the present situation of Mediterranean MPAs is neither representative nor consistent. All the MPAs lie in coastal water under national jurisdiction, with the exception of the Pelagos Sanctuary. Moreover, the MPAs are not homogeneously distributed around the Mediterranean basin: the western Mediterranean and the Aegean Sea together make up 76% of the Mediterranean's protected surface. Mediterranean habitats and important areas are only suitably represented in the western Mediterranean. The disparity in the distribution of the MPAs means that major Mediterranean marine biomes and habitats are not taken into account, and that the space between protected sites is perhaps too big to be sure that the larvae of most of the marine organisms in the protected area network can be exchanged.

3. Mediterranean MPAs are affected by many human-origin threats coming from adjacent or nearby land and sea places, which can influence their effectiveness. These pressures can be of local, regional and/or world origin.

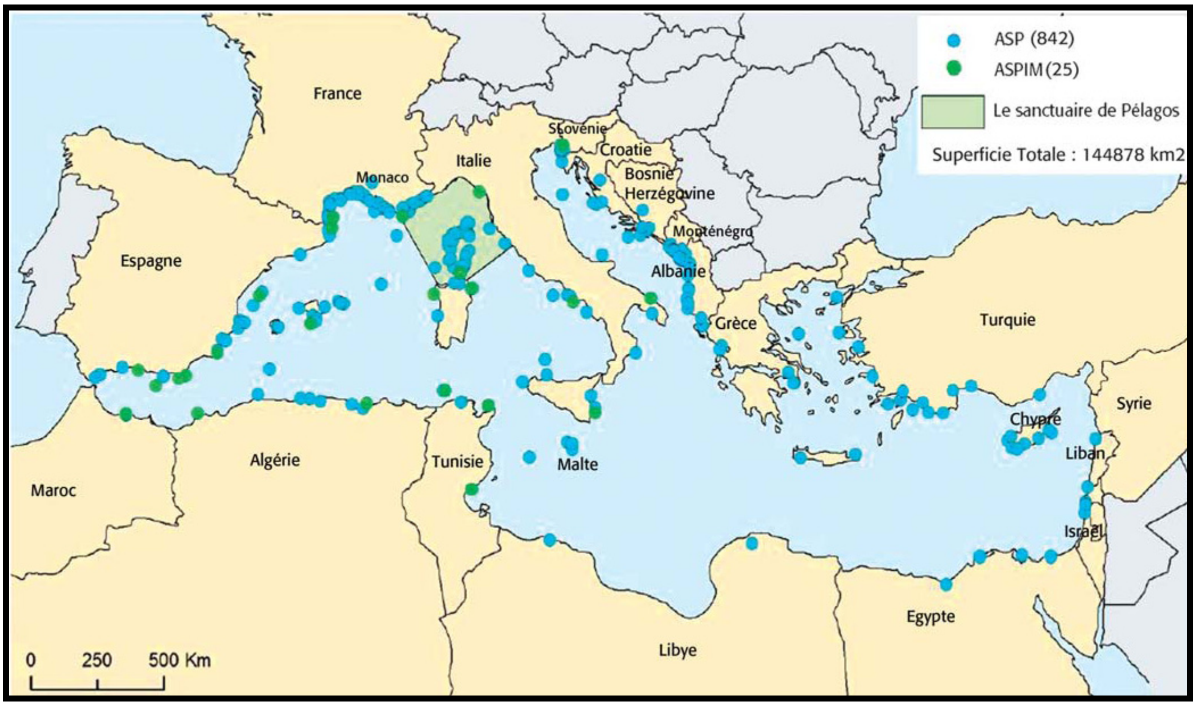
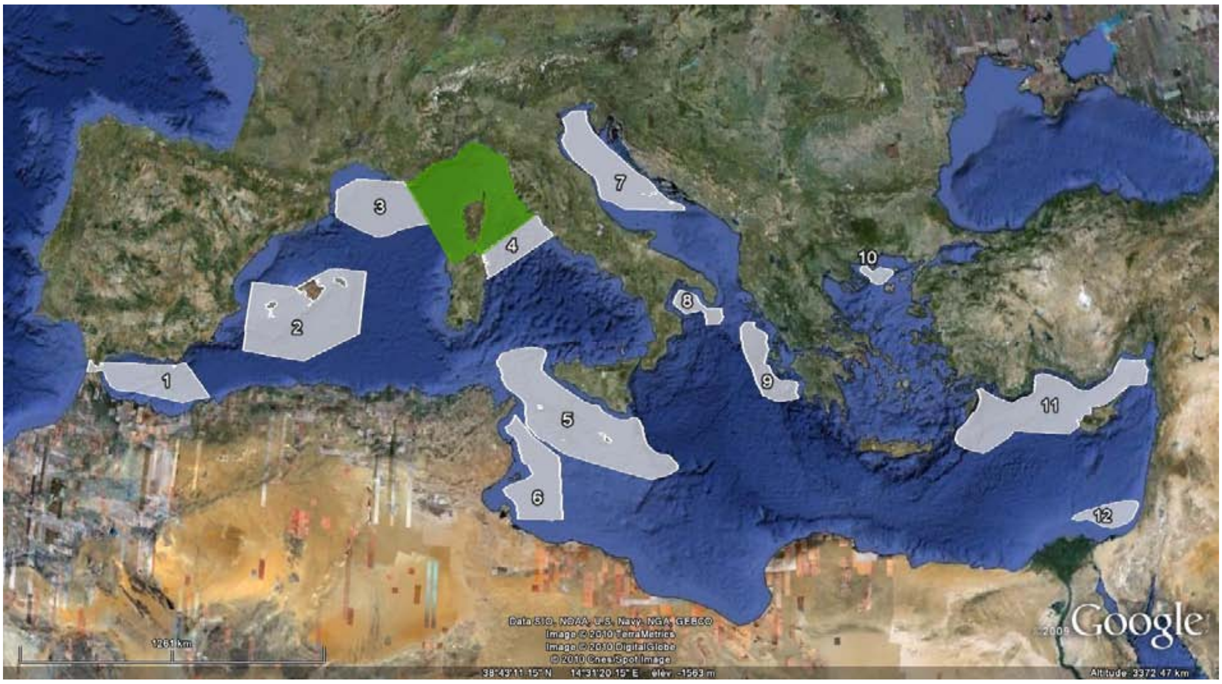


Figure 15: List and geographical situation of Marine Protected Areas in the Mediterranean (source: RAC/SPA, 2007)

Faced by such a situation, and as part of the ecosystem approach, protecting marine biodiversity basically involves taking into account a number of parameters that have no link with the boundaries of national jurisdiction. Collaboration between states, institutions and competent organisations is thus fundamental. The importance of an ecosystem approach takes on its full meaning (Abdulla *et al*., 2008). Therefore, new Marine Protected Areas must be created to protect the habitats that are not represented in the present network, particularly in the high seas and deep seas. In the coastal area, which is currently the main object of protection, the countries of the southern and eastern Mediterranean should in the future be better represented.

The situation is more alarming as regards Mediterranean high sea habitats, which lie outside national jurisdiction. To this end, on the basis of various appraisals (mammals, birds, turtles, fish nurseries, cold sea corals, key deep sea habitats, etc.), 12 areas were selected as areas of conservation interest in the open seas, including the deep seas (SPAMIs) (UNEP-MAP RAC/SPA, 2009a) (Fig. 16). These are: *1: Alborán Seamounts; 2: Southern Balearic; 3: Gulf of Lions shelf and slope; 4: Central Tyrrhenian; 5: Northern Strait of Sicily (including Adventure and nearby banks); 6: Southern Strait of Sicily; 7: Northern and Central Adriatic; 8: Santa Maria di Leuca; 9: Northeastern Ionian; 10: Thracian Sea; 11: Northeastern Levantine Sea and Rhodes Gyre; 12: Nile Delta Region (Green area: Pelagos Sanctuary declared as SPAMI in 2001)*.

Figure 16: Representation of Mediterranean priority conservation areas and the Pelagos Sanctuary (the latter in green colour).



3. PRESSURES AND IMPACTS

The loss of marine and coastal biodiversity is often due to concomitant causes and several pressures. The growing presence of non indigenous and invasive species, climate changes, development of microbial pathogens and other environmental disturbance can act in synergy; cumulative effects on native species and habitats can be dramatic: biological invasions of non indigenous species are often linked to climate change and other environmental disturbances, including fishing pressure; several microbial pathogens are introduced by invasive species and, in numerous cases, their success can be due to climate change also.

A cumulative and synergistic effect of pressures and impacts on marine and coastal Mediterranean biodiversity is a fact sometimes demonstrated by evidence but often difficult to be interpreted and especially predicted. Ecosystem approach can be a useful methodological tool to undertake and understand better on the one hand the relations and cumulative effect between pressures and impacts, on the other hand the direct/indirect ecosystem consequences and the cascade effects. These last in the first instance can be due to direct pressures, in second instance to the decline of native species and habitats.

3.1. BIOLOGICAL DISTURBANCE

The biological disturbance described below focuses on the three following items: non-indigenous and invasive species; impact of fisheries on target and non-target species; microbial pathogens.

3.1.1. Non indigenous and invasive species

Exotic invasive species are considered by several authors one of the biggest cause of loss of biodiversity.
There is no doubt that they represent a growing problem mainly due to the unexpected and harmful impacts that these species can have on the ecosystems and consequently on the economy and human health (EEA, 2006).
In any case, about alien species, 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.

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. Though no extinction of native species is known, rapid decline in abundance, till local extirpations, concurrent with proliferation of invasive non indigenous species, have been recorded.

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.

The **main pressures and impacts** of invasive alien species responsible for the loss of biodiversity can be summarised as follows:

Table 3**:** main pressures and impacts of invasive alien species

Pressures	Impacts
Competition for space and/or food	Reduction and niche contraction of native species; replacement of native species; other indirect ecosystem effects including negative impact on structures and functioning of the ecosystems
Predation (or grazing)	Reduction of prey (or vegetation) mainly because native prey species may not have evolved defenses against the novel predators; other indirect ecosystem effects including negative impact on structures and functioning of the ecosystems
Hybridizing with native species	The invaders genes "flood" the native species, such that no individuals contain the entire genotype of the native species, thus effectively driving the indigenous species to extinction
Introduction of pathogens	Reduction of indigenous species devoid of defenses against new pathogens; other indirect ecosystem effects

Invasive species can often change the **structures and functioning** of the environment; 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).
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.

In the literatures are reported several examples of invasive species able to cause, in addition to the impact on the ecosystem, also direct impact on human activities and human health.

Some example about non indigenous invasive species pressure and impacts are quoted in the sections below, distinguishing between coastal (including wetland), shallow water and high seas.

3.1.1.1. Coasts and wetlands

There are some known evidences in terrestrial coastal ecosystems of the presence of non indigenous and invasive species.

Lists of exotic species are available for some taxa and often regard a limited geographic extension. A national management plan was proposed by Israel within the SAP BIO for the invasion of *Acacia saligna*, a widespread planting characterized by a rapid growth in soil with low levels of nutrients.

The presence of the vegetal species Kaffir fig (*Carpobrotus edulis*) in parts of the Spanish and Maltese coasts must be noted. On the Mediterranean coast, *Carpobrotus* has spread out rapidly and now parts of the coastline are completely covered by this invasive species. It has been shown that another invasive species, the mammalian black rat (*Rattus rattus*), enhances the spreading of the plant through its faeces. As the plant represents a food resource for the rat, the invasive species benefit from each other (invasive mutualism).

A different example of undermining native species is the Common fresia (*Fresia refracta*), an ornamental vegetal species that is naturalized in coastal maquis and woodland undergrowth in areas such as *Buskett*, but has also become naturalized in various habitats, ranging from Valletta-Floriana area, the cliffs of Comino and the coastal garrigue communities of *Wied Harq Hammiem* (Malta).

Regarding **wetlands**, in particular lagoon or estuarine habitats, especially some species introduced by mariculture have caused problems for indigenous species.
Health problems to 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.

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* developed fronds longer than 4 m, that formed a sort of carpet on the lagoon surface and limited the navigation in the area.

3.1.1.2. Coastal water

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*.

C. 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. *C.taxifolia* 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.

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).

Still in coastal water, niche contraction and rapid decrease of indigenous species have been described as a result of competition with non indigenous invasive species. For example in Israel where the populations of the starfish *Asterina gibbosa*, the prawn *Melicertus kerathurus* and the jelly fish *Rhizostoma pulmo* decreased, whereas the non indigenous invasive species *Asterina burtoni* (starfish), *Marsupenaeus japonicus* (prawn), and *Rhopilema pulmo* (jelly fish) have increased their population (EEA, 2006).

For some coastal invasive species, together with the impact on coastal ecosystems, a direct impact on human health has been demonstrated. This is the case of the silverstripe blaasop *Lagocephalus sceleratus*, a toxic fish that lives in the shallow water 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.

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 is not decreased and is composed by the 50% of 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.

The same *Caulerpa taxifolia* spread (above quoted), is described by some authors for the negative impact on fishing and tourism (e.g. on recreational activities such as scuba diving).

However the economical impact of the non indigenous species is not always negative. A significant number of exotic species have become valuable fishery resources in the Levantine area for coastal fishery. Some of the most notable are: the conch *Strombus persicus;* the prawns *Marsupenaeus japonicus, Metapenaeus monoceros* and *M. stebbingi*; the crab *Portunus pelagicus* and a few fish species, such as the mullids (*Upeneus moluccensis* and *U. pori*), the lizard-fish *Saurida undosquamis,* the Red Sea obtuse barracuda (*Sphyranea chrysotaenia*), clupeids (*Dussummieria acuta, Herklotsichthys punctatus*) and rabbitfish (*Siganus rivulatus*) (EEA, 2006). 43 % of the halieutic resources of Turkey come from alien species.

3.1.1.3. High seas

Only little information is available about the impact of non indigenous invasive species in open sea. Probably this lack of data is mainly due to a poorer accessibility and knowledge of pelagic zone compared to coastal areas. Some of the cases quoted in the previous paragraph on coastal water can partially interest High seas too (i.e. Red Sea obtuse barracuda, the alien clupeids and the main part of non indigenous planktonic species). In some situation 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).

3.1.2. Microbial pathogens

In the last 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 check Koch's[1] premise and to decide with certainty on the infectious agent responsible (UNEP-MAP-RAC/SPA 2008).

[1] That method consists in isolating the sick organism, extracting the germ from the body, reproducing it in a pure culture, maintainable over several microbial generations, and isolating the phatogen of the newly affected organisms.

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.

Both climate and human activities may have accelerated global transport of species, bringing together pathogens and previously unexposed host populations (Harvell et *al*, 1999).

3.1.2.1. “Classical” pathogens

The quality of marine environments is influenced by a wide number of natural and antrophogenic hazards, which may cause impacts on human health, living resources, biodiversity and ecosystems.

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

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.

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).

The WHO recommends to use faecal coliforms (i.e. *Escherichia coli*) and faecal streptococci/enterococci bacteria (i.e. *Enterococcus faecalis*) as indicator for human pathogens in marine waters.

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).

3.1.2.2. “New” pathogens

While classical 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, the **invasion of alien or invasive species** and the **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)

The introduction of alien or invasive species into local ecosystems continues to be of serious concern and has been highlighted as significant threat by the International Union for the Conservation of Nature and Natural Resources. Absence of natural enemies, be it competitors, predators, pathogens, or parasites, is one of the explanations given for the success of the alien biota (Wolfe 2002, Torchin et *al.*, 2003).

Whether intentional or non-intentional, alien species represent 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. As a matter of fact, the modification and loss of biodiversity have been connected also with the involvement of parasites. 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. Antimicrobial defences of marine organisms are largely uncharacterized, although from a small number of studies it appears that chemical defences may improve host resistance.

A recent study in 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).

In parallel, it is very important to point out the attention also on microscopic algae (phytoplankton) that are components occurring normally in all aquatic environment. While most of these species of phytoplankton and cyanobacteria are harmless, sometimes they create population explosions called algal bloom.

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.

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.

Another issue regards the climate change. Although many discussions are carried out to understand whether the temperature rise will affect the biodiversity, such 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.*

It has been also demonstrated that the bearded fireworm *Hermodice caruncolata* is a source and vector of pathogenous agents (Sussman et *al.*, 2003) and again, Bally and Garrabou (2007) demonstrated that a tropical scleractinian pathogen could affect an Octocorallia of the temperate water and fishes, crustaceans and mollusc larva. The authors advance the hypothesis that this thermo-dependant phatogen has been encouraged by the Mediterranean warming.

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.

3.1.3. Fisheries on target and non-target species

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

Based on the results of the MEDITS (International Bottom Trawl Survey in the Mediterranean)[2], over-exploitation has led to a serious decline in many fish stocks. but a major impact of fishing on the marine ecosystem probably arises from the fact that fishing practices lead to discards (Bertrand *et al*. 2002).

[2] The MEDITS survey programme, started in 1993, intends to produce 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.

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.
The pressures of fishery activities can be distinguished between impacts from:

- professional fisheries,
- recreational fisheries,
- aquaculture.

Professional fisheries include both artisanal (mainly trammel, traps, gillnets, loglines, etc) and industrial fisheries (mainly trawlers and purse seine, large loglines, driftnet). Generally small-scale fishing is socioeconomically more important 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.

Fishing activity impacts both benthic and pelagic species (and habitats). The impact can stem from:

- direct over-exploitation of commercial species;
- indirect ecosystem effects.

The impact of fisheries on biodiversity depends on several factors such as fishing technique[3], water depth, sea bottom characteristics, 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 of net). These activities impact dramatically on habitats and ecosystem functioning.

The large variety of small-scale fishing gears in use and of species landed, as well as the importance of small-scale fisheries in general, make the management of Mediterranean fisheries extremely complex, the development of an **ecosystem-based management approach** that is specifically tailored to the region being fundamental (RAC/SPA, 2003). The basic concept of this approach is that it is not enough to protect the fish populations but also the environment that supports them.

The need for an ecosystem approach for Mediterranean fisheries is emphasized in several reports and documents. The formal origin of an ecosystem approach to fisheries can be found in Chapter 17 of Agenda 21 of the 1992 UNCED. The FAO Code of Conduct for Responsible Fisheries was developed and adopted by FAO Members States after UNCED and, while it does not explicitly refer to an ecosystem management approach, the major features and requirements of this approach can be found within the code (Cochrane and Young, 2005).

[3] More than 45 fishing techniques are used within the Mediterranean fisheries.

Pressures and impacts of fisheries on marine biodiversity is a fundamental issue of fishery management. Therefore it stands to reason that pressures and impacts must be studied, monitored and analysed through the ecosystem approach tool.

While a number of reports and guidelines have been produced to assist managers and stakeholders in interpreting and implementing the ecosystem approach in fisheries, its true application in fishery management is limited. Fisheries mainly have conventional target-species fishery management. This approach must not be replaced by the ecosystem approach but supplemented by it (Cochrane and Young, 2005).

3.1.3.1. Direct effects of over-fishing on the target species

A feature of Mediterranean fisheries is their high level of exploitation, which often places the resources in a state of over-exploitation, and 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*), four-spotted 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*).

Regarding **commercial fisheries,** around 63% of fishing vessels are owned by countries of the Western and Central Basins and 53 % by EU countries (Spain, France and Italy).

Recreational fishing activities are mainly associated to gears such as angling, handline, spearing, longline, rod-and-reel. The impacts of recreational fishing activities are badly estimated because of a lack of catch control. Using the available information the following facts can be synthesized:

- angling and handline fishing threaten juveniles of most littoral, demersal fishes, because they are practiced on nursery areas such as shallow rocky bottoms, seagrass beds;
- spear fishing 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).

Regarding **aquaculture,** the direct effects of over-fishing on the target species are not pertinent, excluding the effects of harvesting wild populations of bluefin tuna (*Thunnus thynnus*) to be fattened in cage-farming facilities. This practice, mainly developed in the last 10-15 years in the Mediterranean region, 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).

3.1.3.2. Indirect effects of fishing

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 are responsible for physical damage to the seabed and the degradation of associated communities.

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 are listed below:

- decrease in populations (either commercial or not), due to by-catching, discarding, ghost fishing, etc;
- decrease 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 oceanica* meadows, coralligenous and maërl beds; this impact is especially due to trawlers, often used 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 synthesised by Pranovi *et al*. (2000), ‘trawls and dredges scrape or plough the seabed, resuspend sediment, change grain size and sediment texture, destroy bedforms, and remove or scatter non-target species’.
- cascading effects on the trophic structure of the marine ecosystem by the harvesting of top predators, either pelagic or demersal species. This is generally indicative of a negative impact on the whole ecosystem caused by fishing and has been 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 catches declined by about one trophic level during the last 50 years (Pauly *et al.,* 1998).

Box 2: Some examples of indirect effect of bottom gear on soft bottom ecosystems

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 sulphide 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 fish, 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.
- “rapido” trawls are responsible for negative effects on the structure of the macrobenthic communities. The first effect to be seen (a few days after the impact), is the increase in the abundance and biomass of a few opportunistic scavenger species as a consequence of increased food availability (injured or dead bodies of invertebrates). 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 *(RAC/SPA 2003).*
- Trawling is also responsible for changing grain size distribution and sediment texture and for destroying bedforms.

Jellyfish blooms are indicated by some authors as consequences of overfishing. The impoverishment of fish populations is considered as one of the causes of the increase in jellyfish presences worldwide (Boero et al. 2008). The ecological vacuum ensuing from the removal of large carnivores from marine biota is being filled, in fact, by jellyfish which, in their turn, exacerbate the predatory pressure on fish, preying on fish eggs and larvae, and competing with their larvae for the use of planktonic resources, especially crustaceans. It is also true, however, that one of the worst invaders in this part of the Mediterranean, the alien scyphozoan Rhopilema nomadica, forms huge populations that, since almost a decade, strongly affect coastal economies in terms of nuisance both to tourism (swimmers are stung) and to fisheries (for the above mentioned reasons). Rhopilema is a warm water animal, and, so far, it did not spread to the rest of the Mediterranean due to the presence of lower temperatures there than in the Levant basin. In this case, thus, global warming might be the first cause for the success of this species, followed by overfishing. Also in this case, thus, the presence of multiple stressors might determine a given situation.

Figure 17: Blue fin tuna preying on a bank of anchovies

In the regional reports, the problem of jellyfish has received different treatment. If a specialist is present in the country (e.g. Israel and Turkey) the presence of jellyfish is evidenced and is considered as an important issue, in other countries it was not even mentioned in the first draft, to be then introduced when the rapporteur was asked directly if there was no jellyfish problem in his or her country. Besides the tropical jellyfish, like *Rhopilema nomadica* and *Cassiopea andromeda*, last year another gelatinous plankter reached the easternmost coasts of the Mediterranean: the ctenophore *Mnemiopsis leidyi* (Galil et al. 2009). *Mnemiopsis* reached the Black Sea in the early Eighties, presumably through the ballast waters of US oil tankers, since the invader is from the Eastern coast of the American continent. For decades *Mnemiopsis* remained confined to the Black Sea, to be sparingly recorded right outside it, along the Turkish and Greek coasts, but with no large populations. The reason invoked for this lack of spread to the Mediterranean was that the conditions of the Mediterranean presumably did not meet its physiological and ecological requirements.

Figure 18: *Rhopilema nomadica*

The establishment of this species in Israel (the Israel report states that *Mnemiopsis* is thriving also in 2010) means that it became acclimated to the warmer conditions of the Mediterranean Sea and, as a matter of fact, in 2009 it also reached the Western Mediterranean coasts, having been recorded from Italy, France and Spain, so having spread throughout the basin.

Figure 19: *Cassiopea andromeda*

The sooner this jellyfish problem will be properly perceived, the better it will be.

Figure 20: *Mnemiopsis leidyi*

Fishermen, tourists, coastal managers are perfectly aware of this situation, whereas the least prepared to tackle it are both the scientific community (lack of specialists) and the funding agencies (lack of funds).

When, in the Eighties, the swarms of *Pelagia noctiluca* became a constant in a series of summers, UNEP made money available to study the phenomenon. But when a whole task force had been assembled to tackle the problem of jellyfish, the jellyfish disappeared and remained rare for many years, to have some local bursts that were not as important as the swarms of the early Eighties. Now jellyfish are back, and not with a single, indigenous species. And they come both from warm places, like the newly recorded *Phyllorhiza punctata* (Galil et al. 2009), and from temperate ones, like *Mnemiopsis*. As stated by Boero et al (2008) the problem of jellyfish is affecting the whole world, and chances are good that it will not fade away as it happened in the early Eighties.

Figure 21: *Phyllorhiza punctata*

Particularly harmful to biodiversity is the **impact of fishing on the seabed,** which concerns mostly the use of bottom trawling gears, (otter trawls, beam trawls and dredges), together with some aggressive practices affecting rocky bottoms such as fishing coral and date mussels.

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 the single-species level, where the population dynamics of a species is altered, and the ecosystem level, where profound changes occur because of the disruption to food webs, favouring scavengers, etc.

Box 3: Discards in Mediterranean bottom trawl fisheries

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.

Commercial fisheries and recreational fisheries especially, as in the examples reported above, have the strongest indirect effect on biodiversity.

Regarding **aquaculture,** the indirect impact on biodiversity depends on several factors such as species reared, culture method, stocking density, food type and hydrology of the site.

In general, fish farming can induce pollution. The most widely known effect of fish farming is the increase in organic content of the sediment under the cages. The mortality of large benthic fauna, the deterioration of seagrass meadows and the changes in the trophic status of large water bodies represent the main potential effects of aquaculture on ecosystem biodiversity. In any case, these impacts, documented in some places, are generally limited to the area below or near the cages.

3.1.3.3. Coasts and wetlands

Wetlands provide food, and biomass for the populations living around them (UNEP/MAP/RAC-SPA, 2003). The importance of lagoons for fisheries is well known; Mediterranean coastal lagoons are shallow high productive interface ecosystems between marine and watershed water bodies (Kjerfve, 1994).

Several coastal lagoons are used for aquaculture purposes (i.e.Thau Lagoon in France, Nestos Delta lagoons in Greece). Moreover coastal lagoons are also nursery areas for several species and are known for their ecological and naturalistic value.
Three main types of pressure, due to fishery activities, can be identified in lagoons: overfishing; juveniles capture for aquaculture and eutrophication.

In some cases overexploitation of the lagoon resources leads to their collapse. Often fishing in coastal lakes and lagoons, through the use of nets and other methods, leads to dramatic decrease in catches, alteration of ecosystem functioning and loss of biodiversity.

In several Mediterranean lagoons the captures of juveniles of commercial species like sea bass, eel, white sea bream, used in aquaculture, can impact the target species and the lagoon ecosystem (i.e. the capture of eels in the Lac Burrulus in Egypte).

Moreover Aquaculture can contribute, along with other numerous human pressures, to causing high nutrient concentrations in the water and in the sediment of lagoons. The consequence is macroalgal blooms of opportunistic species, such as *Ulva* spp. and *Gracilaria* spp., then further increases in nutrients, oxygen variability in the lagoon and anoxia. The final consequence of the eutrophication is the loss of biodiversity.

3.1.3.4. Coastal waters

Except for some offshore fisheries targeting large pelagic fishes or deep crustaceans, most Mediterranean fleets conduct coastal fishing (Caddy 1996).

In coastal waters one of the most important negative effects of fishing on biodiversity is due to illegal trawling on seagrass beds, impacting on seagrass by both 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).

Experimental trawling hauls, carried out in disturbed and undisturbed areas, show that a medium-size typical trawler would uproot an estimated 99,200 and 363,300 *Posidonia* shoots per hour respectively (RAC/SPA, 2003).
The effects of trawling on Posidonia include changes in the structure of demersal fishery 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.

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).

Coralligenous and maerl communities are mainly endangered by trawling, responsible for the disappearance of maerl in large Mediterranean areas (UNEP-MAP-RAC/SPA, 2008a). Standard otter-trawling can also harm rocky bottoms (thanks to special rolling devices that prevent the gear from being damaged) with dramatic consequences for fragile benthic organisms and ecosystem functioning in general.

Another threat is constituted 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 is been banned in EU waters in 1994 (Council Regulation No 1626/94).

Finally, trammel nets and anchoring can also have important impacts on several erect species of coralligenous assemblages.

3.1.3.5. High seas

Fishing on high seas (carried out outside a country's territorial waters) 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.

In a worldwide context the deep seas are considered (among other definitions) to be the marine environment that extends downwards from the continental shelf break, i.e. waters deeper than 200 m to its maximum depth. Deep-sea fisheries currently only operate at depths of less than 1000 m in the Mediterranean, but that might exploit many SH, i.e. seamount fisheries could be exhausted in a period of time as short as three to four years (Johnston & Santillo 2004). The potential fishing interest of the currently unexploited bottoms below 1000 m depth (towed gears banned by GFCM, 2005) is very limited. This is so because the overall abundance of crustacean species is considerably lower, and fish communities are largely dominated by fish either of non-commercial interest (like the smooth head *Alepocephalus rostratus*) or of a small size (such as the Mediterranean grenadier *Coryphenoides guentheri*). If these species ever become of economic interest and trawlers could reach deeper areas, then the ecosystem could be rapidly deteriorated by fishing.

Several deep sea demersal species are particularly sensitive because of their low fecundity and low metabolic rates.

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

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

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

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 elasmobranches, marine turtles and seabirds taken as by-catch.

Drifnet fishery has 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. In the Mediterranean, during the last two decades some governments have reduced the number of fleets fishing with driftnet and this practices was prohibited by ICCAT and GFCM in 2003. However this practice (often under different names) is far for being eradicated in the Mediterranean.

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

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

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

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

The little information available about the effects of deep sea trawling on **demersal resources** underline the great 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. The above mentioned *Isidella elongata* facies distributed in bathyal muddy assemblages, constitute an example of deep habitats greatly affected by fishing.

At the deep seas there are several areas with considerable abundance of the highly vulnerable cold coral reefs, mostly detected in continental slopes, seamounts and on the walls of submarine canyons (e.g. off Cape Santa Maria di Leuca, in the Central basin, or at numerous submarine canyons and seamounts scattered along the Alboran Sea, in the West basin). Several abyssal plains, that harbour poorly known and vulnerable deep sea fauna, are located throughout the Mediterranean, with the deepest grounds found in the Central basin (e.g. Calypso depth in the Ionian Sea, SW of Greece). Other geological features might be vulnerable to fishing as they are hotspots of diversity and are habitat of vulnerable fauna like cold corals. The massive Eratosthenes seamount in the East basin (south of Cyprus) and numerous scattered seamounts in the Alboran Sea and south Tyrrhenian; cold seeps, brine pools and hydrothermal vents have been mostly located in the East Mediterranean basin (south of Crete and Turkey, and near Egypt).

The Western Mediterranean basin harbours numerous submarine canyons that are EFH for red shrimp, like numerous canyons in the Gulf of Lions that sustains important fisheries of red shrimp, Norway lobster, hake, monkfish, among other important commercial species; hake nursery areas are mainly located on wide extensions of continental shelves or banks, highlighting the south of Sicily, central Adriatic in the Jabuka Pit, and Thracian sea, whereas hake spawning grounds seem to be located on the shelf break and slope canyons, being the Gulf of Lions the clearest example.

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

The Mediterranean high sea is also the habitat of endangered cetaceans and turtles that are common by-catch of pelagic fisheries and deserve special protection. Important EFH for large pelagic species are mostly determined by oceanographic features like upwelling areas or gyres, creating productive areas important for feeding and breeding; these areas that act as EFH must be identify to define protection measures for pelagic species. The main spawning areas for bluefin tuna have been located south of the Balearic Islands, Alboran Sea and Strait of Sicily, whereas swordfish spawns in almost all the Mediterranean area and albacore overlap with the bluefin tuna spawning grounds.

3.2. EMERGING ISSUES

Climate change and deep sea ecosystems modifications are two relevant emerging issues of the last decades. These two themes interact. In particular deep-sea ecosystems, traditionally considered to be stable unchanging environments, seem to respond quickly to climate change. Danovaro *et al*. (2001), report that in recent years, climate change has modified the physical-chemical characteristics of deep waters in the eastern Mediterranean. Using a miniature ocean model, the authors showed that climate change has caused an almost immediate accumulation of organic matter in certain areas of the deep-sea floor, altered the carbon and nitrogen cycles and had negative effects on deep-sea bacteria and benthic fauna.

3.2.1. Climate changes effects

Climate change is an underway process that may act at several biological levels and may heavily threaten marine biodiversity. The real extent of possible effects on marine ecosystems is currently unclear (Lejeusne *et al*., 2010).

The Mediterranean Sea, which is the result of a complex geological and biological history, is widely recognized as an area among the most sensitive to climate change. Data recorded in the Mediterranean Sea show that sea temperature is increasing and extreme climatic events are becoming more and more frequent.

Climate change prediction models suggest by 2100 an increase of 0.7-4.6 °C in sea surface temperature, a 2-28%reduction of precipitation levels , and an increase of extreme weather events. In particular, temperature rise caused by human activities, acts synergistically with many other source of disturbance (other human pressures, changes in water physical and chemical features, etc.) and strongly affects Mediterranean marine biodiversity.

From the hydrological point of view, the Mediterranean Sea is divided in two deep basins: the western and the eastern basin. Each sub-basin has distinct water masses and is characterised by a homogeneous deep-water layer that, below 250 m depth, not get colder than 12-13 °C. In the recent years, this general pattern has been disrupted probably due to climate change and a general rise in temperature has been recorded.

These phenomena may strongly influence some biotic and abiotic patterns (planktonic and larval dispersal, nutrient cycles, etc) affecting ecosystems at several ecological levels.

Some unexpected effects of thermohaline circulation (termed Eastern Mediterranean Transient, EMT) have been documented to drastically change the hydrology of deep eastern Mediterranean, influencing temperature, salinity, stratification and circulation of water masses. EMT also affected the carbon and nitrogen cycle, negatively impacting on deep sea biota. There is recent evidence that EMT signals propagated also to the western basin, disrupting thermohaline circulation patterns.

The increase of water temperature may affect the organisms, causing several stresses and frequently bringing some physiological adaptations. In some cases, stress which exceed tolerance threshold, may determine alteration in life cycle or in the distribution pattern of the species. Currently, in Mediterranean Sea, “a direct consequence of warming trend is a simultaneous increase in the abundance of thermotolerant species and the disappearance or rarefaction of ‘cold’ stenothermal species” (Lejeusne *et al*., 2010).

Mediterranean marine biota has traditionally been divided into three main biogeographic provinces: the western basin, the eastern basins and the Adriatic Sea. Distribution of species was generally determined by latitude. Species of tropical origin dominated the southern part of Mediterranean Sea while temperate species were more abundant in the northern part.

The actual warming trend may enhance the spread of several top predators such as barracudas (*Sphyraena* spp.) and dolphinfish (*Coryphaena hippurus*). Temperature rise may influence the behaviour of large pelagic fishes, such as the bluefin tuna (*Thunnus thynnus*) and the greater amberjack (*Seriola dumerilii*). These migratory species currently seem to remains for longer periods in the western basin, with not negligible consequence on their stocks (possible overfished) and on the trophic food web.

Figure 22: Examples of southern species that expanded their distribution northwards (Meridionalization): *Sparisoma cretense, Colubraria reticulata, Aplysia parvula*

At the moment it seems not possible to foresee the extent of exuberance of warm-water species and the possible consequences to the functioning of marine ecosystems. Such a scenario has already been suggested, with some authors proposing that the Mediterranean Sea ongoing towards two main biotic events. One is **Meridionalization** (Bianchi, 2007), i.e. the northward widening of the distribution of species of warm water affinity that usually thrive in the southern, and warmer, part of the basin (i.e. meridional species). Of course this means that the conditions that are met in the Eastern sector of the Mediterranean are widening northwards and, with the establishing of new physical conditions, also the preadapted species follow. These southern species are thus favoured by the new conditions that are met in the northern part of the basin.

Recently, many species indicators of warm water widely expanded their range of distribution and are becoming more abundant in the north-western portion of the basin. One of the first evidence of this pattern is about the ornate wrasse (*Thalassoma pavo*). Until the 1980s, this species was considered very frequent in the south and eastern Mediterranean and rare in the northwestern part of the basin. Adults of *T. pavo* were recorded for the first time in Scandola in 1988, while juveniles were found in 1991. Currently there are evidences that the range of distribution of *T. pavo has* increased of about 1,000 km (Perez, 2008). The occurrence of the orange coral *Astroides calycularis,* a quite thermophilous species fairly common in the eastern Mediterranean, in NWM seems to be related to sea temperature rise. There are also evidences that new sightings in Adriatic Sea coincided with the hottest periods (Perez, 2008).

The other reaction to global warming is **Tropicalization**, i.e. the establishment of tropical species that were previously absent from the basin. Of course, these species usually 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 (about 67%).

Furthermore, climate change may also enhance invasive species originating from Atlantic Ocean, as in the case of the subtropical crab *Percnon gibbesi*. This species, which larvae probably entered in the Mediterranean with the Atlantic currents, was firstly recorded in Mediterranean waters in 1999. Currently the distribution of *P. gibbesi* range from northern limit in central Tyrrhenian Island (Ponza and Ischia) and southern limit along Libyan coastline (Elkrwe *et al*., 2008) and Aegean and Ionian Seas (Katsanevakis et al., 2010). A clear example of the westward spreading of lesseptian species is that of the rabbitfish *Siganus luridus* that recently reached the Gulf of Lions (Perez, 2008).

Sea warming trend seems to enhance not only lessepsian migration and Atlantic influx, but also human introductions (Occhipinti-Ambrogi, 2007).

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).

As a result of warming trend, a homogenisation of the Mediterranean biota, disrupting present biogeographical entities, could be expected. In a way, it is to be expected that, if climate becomes warmer, species of warm water affinity tend to become dominant. The cold water species are regressing (Boero and Bonsdorff, 2007; CIESM 2008) so leaving an ecological vacuum that is being filled by the new tropical contingent. Cold-water species, confined to the northern portions of the basin, will probably rarefy or will be lost from the Mediterranean if sea-warming trend will remain stable. Bianchi (2007) predicted that while the southern portions of the Mediterranean will be more and more occupied by tropical exotic species, the northern portions will be invaded by warm-water native species. On the basis of a moderate climate change scenario, Perez (2008) hypothesized an extinction of 15-37% of the species occupying north-western Mediterranean area by 2050.

The easternmost part of the Mediterranean is at the same time the "source" of meridionalization processes and, also, is the "crossroad" where the tropical species first converge, to be eventually "distributed" throughout the basin.

If the Mediterranean Sea is a miniaturized ocean, where we can find in advance what will happen in the future to the oceans of the world (Lejeusne et al. 2010), the Eastern Mediterranean is the portion of the basin where these changes will become more apparent, and deserves, thus, the greatest attention by the scientific community, so to give proper management inputs to the rest of the basin. The first settlement of tropical NIS, in fact, occurs here, and the resident species are the most probable colonizers of the northern part of the basin (as suggested by Galil (2010).

3.2.1.1. Coasts and wetlands

Main expected impacts of climate change on coasts and wetlands are related to warming trend, decrease in precipitation patterns, increase in frequency of extreme events and sea level rise.

These main factors may act in synergy with several anthropogenic pressures and may severely threaten coastal ecosystems.

Sea level rise may directly cause loss of lowlands and beaches in coastal ecosystems and thus may determine both coastal erosion and loss of habitat for several species, most of which are endemic or endangered. Sea level rise would thus be critical for some Mediterranean coastal habitat (such as wetlands, lagoons, deltas and estuaries, etc.).

In particular this phenomenon may severely threaten many key coastal ecosystems such as the Nile delta and may determine the loss of important habitats such as the loggerhead (*Caretta caretta*) nesting beaches (Perez, 2008; UNEP-MAP RAC/SPA, 2009d).

The combined effect of sea level rise, mean temperature rise and reduced precipitation patterns may threaten karst areas (most of which are influenced by freshwater fluxes), and may cause droughts and even desertification and wildfires in coastal ecosystems (UNEP-MAP RAC/SPA, 2009a).

With regard to wetlands, reduced annual precipitation may cause hydrological deficit and may act in combination with sea level rise inducing increase of salinity with heavy consequence on Mediterranean transitional waters' biota. Furthermore, sea temperature rise may increase the occurrence of dystrophic events in coastal lagoons and may determine severe erosion in biodiversity.

3.2.1.2. Coastal waters

The warming trend and the increase in frequency of exceptional events are main sources of stress due to climate change on coastal waters, which are already the most impacted by human pressures.

Littoral and infralittoral biota has been undergoing a rapid and deep change which may affect the Mediterranean marine biodiversity.

In the last decades many benthic termophilous species, such as the sea urchins *Arbacia lixula* and *Centrostephanus longispinus*, became very abundant and frequent in Northwestern Mediterranean (Perez, 2008).

The expansion of marine species also regards some toxic dinobionts characterized by tropical and subtropical distribution. These species may even have tremendous consequences on human health such as the *Gambierdiscus toxicus* (the main agent of ciguatera poisoning) and *Ostreopsis ovata*, which may cause irritation, cough, fever and respiratory problems (further details are available on the chapter on "microbial pathogens").

Generally, species respond to environmental stress by physiological, biochemical and molecular adaptations. Acute stress exceeding the tolerance threshold of the organisms may lead to disease and even to mass mortality events which may lead to species replacement and range shifts. The frequency of disease outbreaks and mass mortality events clearly increased during the last two decades. Among all marine organisms, sponges and corals (many of which are endemic stenothermal Mediterranean species) seem to be the most sensitive taxa. A well-documented case of multispecies (more than 38) mass mortality, probably related to exceptional temperature patterns, was recorded in the summers 1999 and 2003 over a wide area between the Tyrrhenian Sea and the Gulf of Lion (Cerrano *et al*., 2000; Perez, 2008). A dominant strain of warm-water *Vibrio* pathogen species was identified affecting the Mediterranean gorgonian *Paramuricea clavata* in Tyrrhenian Sea and the starfish *Astropecten jonstoni* along Sardinian coast (Lejeusne *et al*., 2010). Furthermore, biological invasion and the advance of exotic species, encouraged by the warming trend, may also be a supplementary stress factor for species already weakened by climate fluctuation.

As consequence of climate change on coastal ecosystems, a possible scenario foresee that Nortwestern Mediterranean warm sensitive species would be confined in deeper (cooler) water, as occur in South-eastern basin, or would disappear.

Climate change may also influence planktonic communities' composition and their distribution patterns. Plankton plays an important role in the flows of matter and energy in pelagic ecosystems and strongly influences recruitment of fishes. Planktonic species are the main trophic source for little pelagic fishe (anchovies, sardines, etc.) whose stocks have also been modified in the past decades.

There is a well documented case of change in the dynamics of relations between copepods and gelatinous plankton. Climatic changes seem to enhance blooms of jellyfish with a following increased predation on copepods (the main planktonic group) that strongly affects the whole pelagic trophic food web (Perez, 2008). Variation in patterns of plankton abundance and distribution due to climate change may thus determine negative effects on the ecosystem functioning. Furthermore, variations in water masses' circulation, which drive larval transport, in synergy with other anthropogenic pressures (i.e. overfishing), may give rise to severe consequences for population dynamics of several fish species.

Another important issue related to climatic changes in coastal ecosystems is the increase in atmospheric CO_2 concentration, whose partial pressure is expected to increase up to 700 ppm or more by the end of the century. Anthropogenic CO_2 is absorbed by the oceans leading to decreases in pH (Ocean Acidification) and $CaCO_3$ saturation state in seawater. Although the process is well known, potential effects of ocean acidification on Mediterranean marine ecosystems are currently not well assessed. Important consequences of ocean acidification include negative effects on the life cycles of coccolithophores (responsible for approximately half of the global $CaCO_3$) and on several other organisms with calcareous shell. Furthermore, water acidification may influence many important benthic ecosystems such as Coralligenous assemblages, vermetid reefs and the typical Mediterranean seagrass *Posidonia oceanica*. In the case of *P. oceanica*, the CO2 increase may lead to higher densities of the plant but, in the same time, to a reduction in the epiphyte coverage. As a consequence, plants living at low pH are more vulnerable to grazers because their lack of calcareous epiphytes (Yilmaz *et al*., 2008).

3.2.1.3. Climate change and the problem of multiple stressors

The problem of **multiple stressors** is very important to understand the interlinks among different phenomena and cause-effect relations. While the impact of global warming on coastal ecology is linked, of course, to increased temperatures it is also connected to the rising of the sea level and, hence, of coastal erosion.

For instance, *Posidonia oceanica* is almost extinct in the easternmost countries. The complete disappearance of the species from Syrian waters has occurred, Lebanon experienced its great regression, Israel does not even record its presence. In Egypt, *Posidonia* meadows start at Alexandria, to expand then westwards.

The **absence of *Posidonia*** from the easternmost corner of the Mediterranean is often ascribed to global warming, but chances are good that this is not the case. Just due to global warming, in fact, *Posidonia* meadows are blooming in the northern part of the basin, where flowers, seeds and seedling were unrecorded prior the global warming period that is currently affecting the basin. *Posidonia*, thus, might be even favoured by the warming of the waters. All these countries, however, denounce a great development of coastal settlements, with increases in coastal erosion.

It is true that **coastal erosion** might ensue from the **rising of the sea level**, but it is also true that the impairing of the dynamics of coastlines by **irrational coastal development** might be a major cause of coastal erosion. Erosion, furthermore, increases the turbidity of coastal waters and, also, sedimentation rates, so affecting the viability of *Posidonia* meadows.

It is very probable that the regression of *Posidonia* meadows is due more to coastal development than to global warming.

Figure 23: *Posidonia oceanica* meadows constitute habitat for hundreds of species

The problem of multiple stressors is very important, since a strong correlation might be found between one event (e.g. *Posidonia* regression) and a putative cause for it (e.g. global warming) but the comparison with other situations might lead to the individuation of other causes (i.e. coastal development) that are co-occurring with the one individuated in the first place.

It is important, thus, to carry out experimental studies to ascribe with some certainty a detected event to its putative causes. Comparisons among different areas of the Mediterranean might also lead to single out the real processes leading to the observed patterns.
Multiple stressors (e.g. coastal development and global warming) might even act in **synergy**, leading to tangled situations that should be completely understood before any proposal of mitigation measures since, if the identified cause is not the right one, all management actions might prove ineffective.

3.2.1.4. High seas and climate change

In the high seas, and regarding deep sea, only a few studies examined the potential effects of climate change because of the lack of adequate funding. Deep Mediterranean seawater, however, provided the first evidence of temperature rise: a three-decades historical series of data demonstrated a general warming trend of about 0.12 °C as a possible result of human-induced global warming (Lejeusne *et al*., 2010).

Deep sea ecosystems are generally more stable than coastal environments and have a very narrow range of temperature and salinity which remains nearly invariable over the time.

In the past decades a modification in physico-chemical features of the water has been recorded in the Eastern Mediterranean (Danovaro *et al*., 2001). An accumulation of organic matter on the seafloor and an alteration of both carbon and nitrogen cycles were recorded. These phenomena had negative effects in particular on deep-sea bacteria and benthic fauna. Danovaro *et al*. (2004) also highlighted that deep-sea nematode diversity can be strongly and rapidly be affected by temperature shifts (Danovaro *et al*., 2004).

As in the case of coastal waters, climate change could directly affects water masses movement and general patterns of abundance and distribution of planktonic communities and then may influence the whole ecosystem functioning. Only few data about this phenomenon are currently available.

3.2.2. Deep seas ecosystem modifications

The **upper limit** of deep sea is not clearly defined. Some authors and organizations consider deep sea to be the area beyond the continental shelf slope(deeper than 200 m); others consider it to be deeper than 400 m (or 500 m). In this document the discussion is focused mainly on areas deeper than 400 m (in agreement with the ICES definition).

Deep sea ecology is **only partially known**. Our knowledge is mainly limited to the bathymetric range over which commercial fishing operates (up to 800 m depth). Only extremely limited systematic oceanographic sampling campaigns have been carried out in deep sea. Below 1000 m only fragmented data are available. Briand (2003) underlines that "*there are basins in the Eastern Mediterranean and in southern waters where effectively nothing is known about deep-sea biology*".

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

The Mediterranean deep sea comprises a high diversity of habitats, because of its geological history (Bianchi & Morri 2000). In particular, geomorphologic structures, such as submarine canyons, seamounts, mud volcanoes and deep trenches can harbor important biological communities.

In general, deep sea Mediterranean biological communities are adapted to an oligotrophic environment; local areas of higher productivity and biodiversity hotspots are present.

Particularly interesting from the biological point of view are: **cold seeps**[4], discovered in the southeastern Mediterranean Sea, south of Crete and Turkey, north of Egypt near the Nile; **brine pools**[5] which were discovered in the Mediterranean on bottoms below 3300 m depth; **seamounts**, important for fishes and invertebrates, including corals (*Caryophyllia calveri*, *Desmophyllum cristagalli*); **Cold-water coral reefs**, which are formed by live colonies of the scleractinians (*Lophelia pertusa* and *Madrepora oculata*). This last assemblage in the deep Mediterranean is dispersed elsewhere. Recently, an important Lophelia-Madrepora deep-sea coral mound has been discovered in the Ionian Sea from 425 to 1110 m depth. These reefs, being a natural deterrent to trawling, are thought to produce a positive spill-over effect on the deep-water demersal resources intensively fished on the neighboring muddy bottoms (Tursi *et al.* 2004).

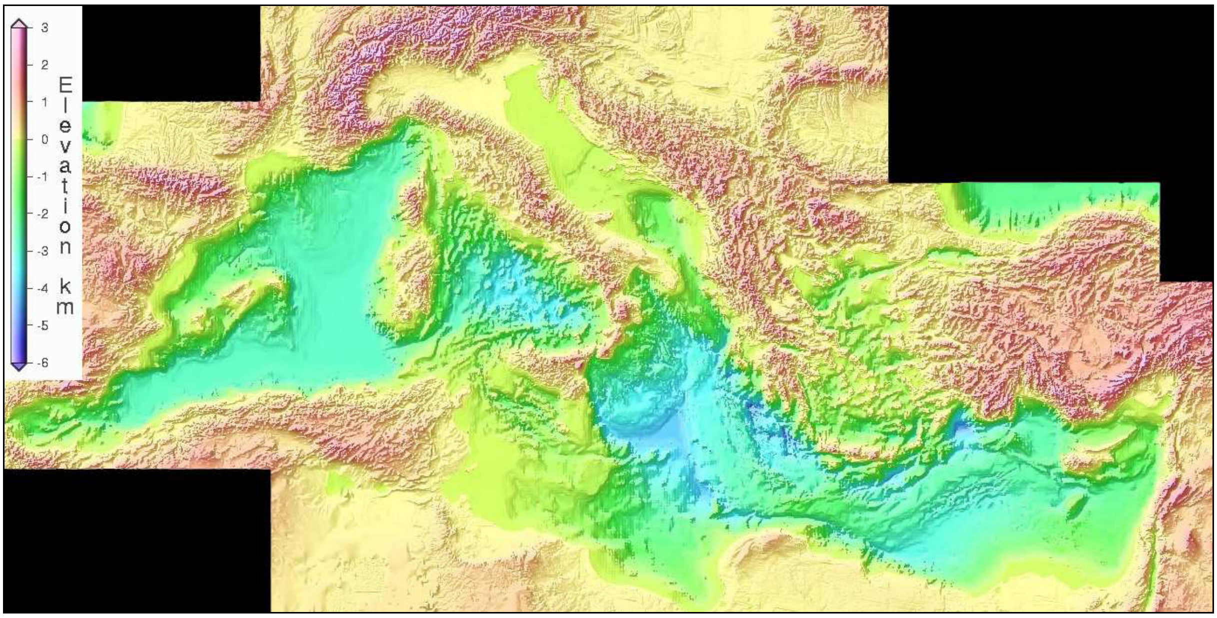


Figure 24: Topography of the Mediterranean Sea (*From* Smith and Sandwell, 1997)

[4] Cold-seeps harbour unique assemblages not based on photosynthetic production but on the oxidation of methane as the primary carbon. These assemblages are normally mainly dominated by bacterial mats and communities of bivalves and tubeworms.

[5] These zones, called also "Deep Hyperhaline Anoxic Basins", host a unique faunal assemblage, especially adapted to withstand high salinity levels, oxygen depletion and high concentrations of methane and sulphide.

In general the **sensitivity** of the deep sea to human pressures is mainly due to the following conditions:

- the uniqueness of the Mediterranean deep-sea communities, consequence of the presence of two, eastern and western basins, and of their relative isolation from Atlantic deep sea communities;
- the highly conservative ecological strategy followed by several deep sea species, which are characterized by low fecundity and low metabolic rates (Koslow *et al.* 2000);
- the high rate of endemism at the abyssal assemblages (deeper than about 2000 m);
- the more constant environmental conditions compared to the coastal environment, which makes deep sea, in general, more vulnerable to anthropogenic disturbance (Briand 2003);
- and, finally, the lack of knowledge about this environment which, applying the precautionary approach, makes these ecosystems highly vulnerable to exploitation (Briand 2003, Roberts *et al*. 2003).

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).

The **main pressures** affecting deep sea can be graded as below:

- trawl bottom fishery
- other fishing practices
- waste disposal (solid refuse)
- other marine pollutants
- oil exploration and exploitation
- deep pipeline laying
- climate change

Deep-sea trawl fishing is a relatively recent practice which has become important since the 1940-50's, mainly because of the high commercial value of red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*). This practice affects depths of up to 800-1000 m. The deep-sea bottoms below 1000 m remain relatively unimpacted by trawl fishing, but in any case are indirectly affected by fishing activities, for example from marine debris originating from fishing or through sediment resuspension[6]. The most impacted fishing grounds in high seas are located in the Western Mediterranean.

The impacts of bottom trawl on biocenosis have already been generally described in the previous section on “fisheries on target and non-target species”. More broadly regarding deep sea habitat, the following impacts from trawl fishing can be listed.

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[6] Palanques *et al.* (2001) showed evidence of how sediment re-suspension from trawlers working at 600-800 m depth reached a depth of 1200 m.

- Direct impact on target and non target species. Particularly important is by-catch biomass, which can be commercialised or returned to the sea as discard. For example, the vulnerable deep fauna of cartilaginous fishes is strongly affected by trawls.
- Removal of top predators with consequences for ecosystem functioning.
- Removal from soft bottoms of gorgonian communities such as *Isidella elongata* and other sessile organisms; consequent changes in the community structure with negative repercussions for species of commercial interest and in general for biodiversity.
- Accumulation of organic matter from discards and consequent alteration of the ecosystem balance.
- Homogenization, that is loss of complexity and heterogeneity, of the sea bottom through the elimination of burrows and other sediment structures, which play an important role as habitat microstructures (Thrush *et al*. 2001).
- Increase in turbidity which can have negative impacts on filter feeders (e.g. *Leptometra phalangium*).

Other fishing practices used in deep sea are in particular **long lining and gillnet**. The impact of these practices are mainly on target species (e.g. hake) and bycatch. These practices are particularly impacting because large-sized breeders are caught.

Deep sea bottoms are sites of accumulation of **solid waste**. 70% of the 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 the Mediterranean, this regulation is routinely ignored.

The consequences on deep ecosystems and biodiversity of this waste accumulation is not clearly analyzed in the scientific literature, but the physical impact (mainly covering) on sessile benthic communities and the risk from toxic substances in the environment suggest a negative effect on marine habitats.
Other marine pollutants impacting deep species are mainly chemical and microbiological. As a result of dredge spoil dumping at canyon heads, high concentrations of heavy metals and organic matter accumulate in deeper waters. Marine trophic food webs may be affected by human activities on land. 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.

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).

The dumping of harbour mud and other dangerous materials in high sea (or at canyon heads) represents another risk for deep sea ecosystems. A monitoring study of the disposal of coal fly ash in the Eastern Mediterranean sea (at 1400 m depth) carried out in 1993 by Kress *et al.,* reported an important impoverishment of the benthos in the impacted area compared to a control area.

Shipwrecks loaded with dangerous waste and scuttled in deep zones of the Mediterranean Sea constitute another important risk for both deep sea ecosystems and human health. Public authorities of several Mediterranean countries are investigating these crimes.

Petrol exploration and exploitation can constitute a serious danger for the deep environment both for survey seismic activities and for the direct physical impact on the sea bottom. Petrol incidents constitute another important potential pressure on ecosystems. The recent dramatic event in the Gulf of Mexico at 1550 m depth has emphasized the lack of emergency technology and plans to deal with petrol spillage in deep water. Of course the impact of these incidents is not limited to deep sea but involves the whole marine and coastal, environment.

Pipeline laying can partially impact deep ecosystems. However, while in coastal areas, near the shore terminal, the pipeline should be buried in a trench, in deep water, pipelines are simply set on the sea floor. Therefore, the impact can be mainly physical, affecting sessile species and limited to the areas covered by the pipe.

Finally, **climate change**, as observed by Danovaro *et al.* (2001), can be responsible for an accumulation of organic matter on the deep-sea floor, the alteration of carbon and nitrogen cycles and negative effects on deep-sea benthic fauna.

3.2.3. Critical areas vulnerable to pressure of open seas fishing on marine and coastal biodiversity

Those critical areas considered as EFH and SH that receives fishing impacts in the Mediterranean open seas, could represent an essential tool for managing fisheries in Mediterranean open seas within an EAF and Precautionary Approach; however, these areas might imply effective restriction of fishing activities, needing an adequate surveillance system and a long-term monitoring.

The following sites are considered critical areas in the Mediterranean region, regarding fishing impacts in open seas, including demersal and pelagic ecosystems:

Demersal priority areas:

- Alboran Sea Seamounts. This SH (this area encompasses cold coral reefs and submarine canyons) highly vulnerable to bottom fishing could be protected.

- Gulf of Lions slope. Demersal ecosystem to protect several commercial species (including hake, shrimps, monkfish) spawning areas from demersal fishing activities. Already adopted as FRA (Fishery Restricted Area) by GFCM.
- South of Sicily, Adventure and Malta banks. Demersal ecosystem important as hake nursery areas where bottom fishing activities, specially trawling, should be restricted.
- Cold coral reefs (Lophelia pertusa) off Cape Santa Maria di Leuca. SH highly vulnerable to any physical disturbance inflicted by bottom trawling. Already adopted as FRA (Fishery Restricted Area) by GFCM.
- The Central Adriatic. Fosa di Pomo/Jabuka Pit. This important nursery area for hake in the central Adriatic should be protected from demersal fishing activities, mainly trawling. Besides that, Pomo/Jabuca Trench has cold seeps.
- 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.
- Eratosthenes Seamount. Important SH vulnerable to bottom fishing activities. Already adopted as FRA (Fishery Restricted Area) by GFCM.
- 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.

Pelagic priority areas:

- Strait of Gibraltar and Alboran Sea. Important migratory route for bluefin tuna and cetaceans;
- South of Balearic Islands. Important spawning area for bluefin tuna in the Mediterranean, as well as an important area for cetaceans and sharks; therefore this area could be protected from pelagic fishing activities.
- Strait of Sicily. It is an important migratory route for tuna-like species
- The Northern Adriatic. Spawning grounds for anchovies and pilchards.
- The Northern & Central Adriatic. Important areas for pelagic sharks
- North of Levantine Sea. Important bluefin tuna spawning area in the Eastern Mediterranean

Pelagic and demersal priority areas:

- Mediterranean Bottoms beyond 1000m. Habitat of poorly known and vulnerable fauna that encompasses the whole region. Fishing using towed gears in this area has been prohibited by GFCM.

4. EVALUATION OF GAPS

4.1. CONCERNING STATUS OF COASTAL AND MARINE ECOSYSTEMS

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 MCBD is not homogeneous throughout the Mediterranean and has many lacunae. Data is patchy and does not allow us to pronounce on the many marine species, habitats and communities on a regional scale, in particular the MAP Protocol species and habitats that are of conservation interest in the Mediterranean. The availability of reliable information varies from country to country and the available information on MCBD in the Mediterranean cannot be considered to be satisfactory, for it is neither complete nor systematic and lacunae are obvious at both population/individual level (genetic diversity) and at that of species and habitats/communities.

The national reports crafted within the context of the SAP BIO programme and the ECAP process identified many gaps related to knowledge of MCBD that must be filled to facilitate the implementing of the ecosystem approach in the Mediterranean basin.

The main lacunae identified at regional level are:

- Lack of clear national strategy to systematically inventory marine and coastal biodiversity in many countries. MCBD-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 per country. 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
- Many marine and coastal biocenoses are still under-sampled on an overall Mediterranean basin scale. 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. This inevitably results in dubious 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
- In many countries, the data is old and needs to be updated
- Limited knowledge about all levels of biological organisation. Most publications describe biodiversity at species level, whereas work targeting the entire ecosystem is rare. Little data on the ecosystems. Furthermore, there is not much data on trophic interactions and energy flows in the ecosystem. MCBD

is usually dealt with on a specific scale, and less on a scale of ecosystem functioning (functional biodiversity)

- 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 biocenoses, particularly those of conservation interest for the Mediterranean
- Research done on MCBD is compartmentalized, restricted to very narrow aspects, and lacks interdisciplinarity
- Inventories of MCBD at regional level are very limited
- Absence of coordinated and cross-border scientific research, probably related to financial and administrative constraints.

4.2. CONCERNING IMPACTS ON COASTAL AND MARINE ECOSYSTEMS

Gaps about "impacts and effects on marine and coastal biodiversity" can be observed at several levels: scientific knowledge; legal tools availability; enforcement of existing laws; public awareness; concrete actions and operative plan implementations.

In particular, the following general gaps are especially relevant:

1) scientific data and institutional organization for the application of the ecosystem approach;
2) interpretation and prediction of cumulative and synergistic effect of pressures and impacts on marine and coastal biodiversity.

More in detail the main gaps, issue by issue, can be listed as below.

<u>Invasive species</u>

- In spite of the considerable improvement in communication of the last years (i.e. **coordination and data circulation)** the lack of a mechanism for collecting, compiling and circulating information on invasive non-indigenous species still exists.
- Several studies and research programmes have been carried out during the last decades and knowledge about non indigenous invasive species has improved. However a **lack of knowledge** still exists, in particular about impact on structures and functioning of the ecosystems.
- The lack of **long term monitoring programs** on invasive species must be emphasized too.

<u>Impact of fishery on target and non-target species</u>

- An important lack is constituted by the limitation of the **ecosystem approach application** in fishery management. Nevertheless, numerous reports and guidelines have been produced to assist managers and stakeholders in applying the ecosystem approach to fisheries. The lack of stakeholders real involvement and consultation in fishery management (participatory decision-making) makes extremely difficult the effective implementation of the ecosystem approach to fishery.
- Considering the importance of the impact of **discards** on ecosystems, discards composition and quantification needs particular attention. Some data and information on discards are available, in particular about discards from trawl, thanks to national and international monitoring programs on demersal resources. In any case, in view of the importance of this issue for ecosystem

conservation, a lack of scientific data about discards still exists, especially for several southern Mediterranean areas.
- **Recreational fishery** gaps regard both control of composition, abundance and size of catch and scientific data about landings.
- Considering the technical and economical difficulties to carry out studies and researches in deep sea, only very little information is available on the effects of **deep sea fishery** (and other anthropic pressures) on deep sea species and ecosystems.
- Gaps exist about the knowledge of possible **interactions between eutrophication and fish cultivation practices** in coastal lagoons and other marine sites.
- Lack of **enforcement of control and surveillance** of fishery regulations exists that vary greatly through the Mediterranean basin.
- Lack in **monitoring, control and surveillance** is particularly evident for high seas. This lack is mostly important in the Mediterranean where only few countries have claimed an economic exclusive zone or a fishing zone extending beyond these waters and, as a result, the area of high seas lies much closer to the coast than in other seas.

<u>Microbial pathogens</u>
The main gaps to bridge in order to enhance knowledge of microbial pathogens have to be distinguished among classical and new ones as follows.

“Classical” pathogens
- While several monitoring plans have been pursued for years, especially in the Mediterranean EU waters, a significant lack exists for the Mediterranean Southern countries where a low level of **monitoring plans** is generally found.
- Although the high level of knowledge of classical pathogens in the water column**,** there is a lack of basic knowledge of classical pathogens in **sediments and beaches**. Monitoring of beach sediments for microbiological contamination is not mandatory, and disease transmission from sediments has not yet been demonstrated, but beach sediments may act as a reservoir of potential pathogens, including fungi (Salvo and Fabiano, 2007).
- An important gap is constituted by the lack of **law enforcement** to prevent or reduce the pathogens concentration in the sea water. The deficiency of adequate legal instruments, supporting framework tools and technical skills, make the practical implementation of law extremely difficult**.** Sewage effluent, agricultural runoff, ship waste discharges and industrial processes are the main sources identified by WHO (2003). Massive but unseen amounts of feces from humans and from their pets and domesticated animals are discharged, dumped, or carried in runoff, bringing encysted zoonotic protozoan parasites (*Giardia*, *Cryptosporidium* and *Toxoplasma*) (Fayer et *al.*, 2004) to estuaries and coastal waters.
- because the ecosystem approach has received very little attention so far, there is a lack of knowledge on the consequences and impacts of pathogens on **ecosystems and habitats**. At present, investigations have been mainly directed to single species affected by pathogens or to consequences on human health (i.e. faecal coliforms as *Escherichia coli*).

“New” pathogens
- The most important gap is the **lack of basic knowledge** on new pathogens. While classical pathogens in the water column are already known, the concern for

the new ones is rapidly increasing. For example, although the negative effects of Harmful Algal Blooms (HABs) are obvious (mass fish mortalities, public health problems, ecosystem changes), the causes are subtle and difficult to be discerned (EEA, 2006). Besides, as highlighted for classical pathogens, the lack of basic knowledge refers also to the presence of new pathogens species in sediments and beaches.

- The introduction of new pathogens into local ecosystems continues to be a serious concern. A **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.
- Considering the low knowledge on new pathogens, an important gap regards the **lack of public awareness** on health and safety issues for hazard species.
- As for classical pathogens, also for the new ones, gaps on knowledge regard consequences and impacts **on ecosystems and habitats.** At present, investigation have been directed to single species affected by pathogens (i.e. coral bleaching diseases by *Vibrio shiloi*) while ecosystem approach and "cascade" effects have received very little attention.
- Although several initiatives have been initiated to investigate the increase of HABs under the EUROHAB (BIOHAB, HABES, STRATEGY, ALIENS, FATE), a **lack of effective scientific monitoring for Harmful Algal Blooms (HABs)** exists, especially for Southern Mediterranean waters.

Climate change

In general the information regarding impacts of CC on biodiversity in marine and coastal areas is very limited, especially compared to data and information on climate change in general, on its impacts on terrestrial habitats and on issues related to Green-house Gasses . The main gaps about climate change and marine and coastal biology were well identified through the RAC/SPA action addressed at updating the SAP/BIO on climate change issues[7] (UNEP-MAP-RAC/SPA, 2009a).

The principal gaps can be summarized as below:

- Even if climate change impacts on biodiversity are relatively evident, the **magnitude of Mediterranean marine biodiversity response to climate change** remain largely unknown; this 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.
- **At national level** several Mediterranean countries have emphasized the lack of monitoring, targeted research, institutional scientific capacities, technical expertise, national polices and priorities, critical area identification and studies and funding opportunities.
- Lack of studies on the **socio-economical consequences** of the impact of climate change on marine and coastal biodiversity is often emphasized.
- Lack of **models**, especially at local scale, and lack of knowledge on the consequence of climate change on biodiversity due to the changes in the

[7] This process, started March 2008 and concluded February 2009, included: (i) National Overviews prepared as part of the action; (ii) Sub-regional (Cluster) Synthesis Reports; and (iii) Working meetings organized at Clusters and regional level

chemistry and biogeochemical cycling of carbon and carbonate (**ocean acidification**) are underlined by several authors and reports.

Deep sea

- 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. Especially for several areas of Eastern Mediterranean and in Southern waters, nothing is known about deep-sea biology.
- Gaps exist also about the **effects of anthropogenic pressures on deep sea species and habitats**: few data are available for fishery; no data are available about the effects and consequences on deep biodiversity of waste accumulation; the influence on recruitment success and the effects of the incorporation of certain materials in the trophic fod webs is only partially known.
- 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 oil spillage in deep water**.

5. PRIORITY NEEDS AND URGENT ACTIONS

5.1. NEEDS

5.1.1. Linked to properties of Mediterranean marine and coastal ecosystems

To fill in the gaps on current knowledge of MCBD and the state of the marine and coastal ecosystems in the Mediterranean, the main needs formulated by the various countries can be grouped as follows:

- Need to improve and update current knowledge on MCBD on various scales of integration (species, habitats, ecosystems, trophic networks, functioning, etc.)
- Need for annotated and updated national and regional syntheses of inventories of MCBD
- Need to enhance technical and scientific capacities as regards MCBD, particularly in taxonomy
- Need to enhance clear national strategies and priorities as regards MCBD
- Need to enhance international cooperation, the exchange of knowledge on MCBD on a regional scale, and integration within regional, even sub-regional, networks.

5.1.2. Linked to critical impacts and effects on marine and coastal biodiversity

The principal needs can be identified from scientific literature, reports, documents, RAC/SPA Action Plans (e.g. Action plans on invasive species; action plans on marine vegetation, etc.) and deduced from the description and gap analysis on impact and pressures, developed in previous chapters of this document.

The main needs regard **research**, in particular:
- on structures and functioning of the ecosystems;
- on cumulative and synergistic effects of pressures and impacts on marine and coastal biodiversity;
- on fishery discards;
- on deep species and ecosystems (especially regarding deep sea in general in Southern and Eastern Mediterranean, and below 1000 m depth overall the Mediterranean sea);
- on the interactions between eutrophication and aquaculture;
- on impacts of pathogens on ecosystems and habitats;
- on climate change impacts on marine organism physiology, population demography, reproduction, species distribution and ecosystem function;
- on non-linear responses of littoral ecosystems to climate change, and population to ecosystem links (functional approach);
- on socio-economical consequences of the impact of climate change on marine ecosystems;
- on models for marine environment functioning;
- on anthropogenic pressures on deep sea.

Other needs deals with **monitoring**, in particular:

- long term monitoring programs on marine biota and ecosystem processes in general and on invasive species and especially on climate change;
- monitoring of recreational fishery landing;
- monitoring of pathogens in sediments and beaches;
- monitoring programs of Harmful Algal Blooms, and other “new” pathogens, especially in Southern and Eastern sectors;
- monitoring of the efficiency of sewage discharges.

Needs have emerged also about **tools, instruments and means** like:

- funding sources;
- methodologies and tools for national research and monitoring;
- mechanism of coordination and data circulation on invasive species;
- predictive modeling tools for climate change effects;
- general tools and means for the environmental protection and enforcement of control and surveillance of fishery (wherever but in particular in high sea) and of sewage discharges;
- means and tools for deep sea researche (in particular below 1000 m depth);
- training and capacity building and assistance to a number of countries.

Some needs regard **political and stakeholders’ goodwill** like:

- upgrading level of climate change and marine and coastal biodiversity issue in national policies;
- stakeholders further involvement and consultation in fishery management;
- ratifying the IMO Convention for the Control and Management of Ships’ Ballast Water and Sediments;
- public awareness on health and safety issues for hazard invasive pathogens species;
- legislation and control enforcement;
- strengthened international co-operation and coordination.

Finally some needs regard **concrete actions to limit the impacts and pressure on biodiversity**:

- limitation of trawling and introduction of technical measures to improve selectivity (e.g. seasonal rotation of fishing grounds through establishing temporal closures, banning of bottom trawling in large marine protected areas, increase mesh size; trawl ban below 1000 m depth as adopted by the GFCM);
- establishment of new MPAs;
- establishment of SPAMIs embracing Mediterranean areas beyond national jurisdiction;
- in general, for coastal ecosystems, limitation of anthropogenic pressures, in order to reduce their vulnerability to new stress like climate change and non indigenous invasive species.

5.2. URGENT ACTIONS

5.2.1. Linked to properties of Mediterranean marine and coastal ecosystems

From the available knowledge on marine and coastal ecosystems as regards biodiversity, the pertinent priority requirements for implementing an ecosystem approach can be resumed as follows:

1. Improve current knowledge:

- Update or deepen the current inventories in MCBD terms
- Regularly and systematically monitor MCBD
- Data collection that is more detailed in relation to the standards elaborated within the MAP framework
- Enhance countries' capacities in taxonomic skills by target training and regional exchange
- Encourage integrated studies targeting the entire ecosystem, including syn-ecological aspects, trophic networks and how the ecosystems function
- Detailed mapping of marine and coastal species, habitats and biocenoses, especially species and habitats that are of conservation interest for the Mediterranean, using protocols that have been crafted by RAC/SPA
- Systematic spatio-temporal monitoring of introduced species as regards number of species, their abundance and their expansion into national or even regional waters. Cooperation and exchange of knowledge on the scale of the entire Mediterranean basin is highly desirable
- Deepen knowledge on deep sea and high seas ecosystems for which knowledge remains rudimentary
- Do long-term monitoring of MCBD, at least in those sites identified as having priority for conservation on a national scale
- Take more steps to facilitate exchange, cooperation and coordination between national experts, laboratories and organisations
- Identify national, regional and cross-border priority sites for the conservation of MCBD.

2. Enhance technical and scientific capacities as regards taxonomy with the help of specialist training and international exchange. Guides to flora and fauna at the level of many Mediterranean countries are highly desirable.

3. International cooperation

- Craft more integrated monitoring programmes at regional level on MCBD
- Implement cross-border projects in areas at risk regarding MCBD

4. National priorities and policies

- Set up national committees (or work groups of experts) responsible for regularly updating and revising the national inventories on MCBD
- Enhance cooperation between all research and conservation institutions
- Develop marine stations in countries where there are none

7. At financial level, on a national scale help researchers and scientists to get the necessary funds to enhance national research on MCBD, especially in the countries of the southern Mediterranean.

Remarks

Priority needs and actions to fill the gaps regarding MCBD as identified in the context of the ECAP process differ from one country to the next as a function of the special features of each of the countries of the Mediterranean basin (present knowledge, technical and scientific capacities, national priorities, etc.). In most of the Mediterranean countries, particularly those of the southern shore and the eastern basin, the level of knowledge about MCBD is weak, even very weak. However, present knowledge in the western basin is relatively satisfactory, even if many areas have still been little prospected in certain countries.

It is clear that the requirements as regards scientific data that integrates the various levels of biodiversity (species, habitats and ecosystems) have priority. Such data and information are basic to good management. They act to back up all the phases of ecosystem management, such as forming policy, creating management plans, assessing progress made and updating management policies and plans to improve them permanently.

5.2.2. Linked to critical impacts and effects on marine and coastal biodiversity

In this section are presented priority actions for mitigating the impacts of non-indigenous invasive species, microbial pathogens, fisheries and climate change on marine and coastal biodiversity are presented. In addition actions for promoting the conservation of deep sea ecosystems are also identified.

Among a large set of useful actions, those most relevant, issue by issue, are as follows.

<u>Invasive species</u>
During the last decade invasive alien species has become a high-profile policy topic for the international community. The main national and regional actions for mitigating the impacts of alien species have been already identified and are reported in the “Action Plan concerning species introductions and invasive species in the Mediterranean Sea”. The implementation of the Action Plan is ongoing, in consultation and collaboration with other initiatives undertaken in the field of invasive species by other international organisations (e.g. EU, IMO, CIESM, REMPEC …). Therefore, during the last years, RAC/SPA and other relevant organizations have carried out several activities, in particular within the framework of the preparation of a regional strategy on ballast water management, capacity-building, training and raising awareness.

Two next important steps to be undertaken are:

- The setting-up of a States backed regional mechanism for collecting, compiling and circulating information on invasive non-indigenous species. (it might be benefited from synergy with CIESM current efforts). A Feasibility Study on this issue has been elaborated in May 2009 and the main next activity is the preparation of a preliminary web version of the system.
- The ratification of the “IMO Convention for the Control and Management of Ships’ Ballast Water and Sediments” by Mediterranean countries that have not signed it yet.

Other actions, as reported in the Regional Action Plan (UNEP/MAP-RAC/SPA, 2005), regard:

- Identifying and inventorying public and private actors whose activity could introduce marine non-indigenous species;
- Launching the procedures for enacting or strengthening national legislation governing the control of non-indigenous species introduction;
- Developing programs for data collection and monitoring;
- Strengthening, and where necessary setting up, systems to control the intentional import and export of non-indigenous marine species;
- Developing and implementing risk-assessment techniques (a guideline on this issue has been elaborated yet);
- Elaborating the National Plans[8].

Microbial pathogens

The actions that arise to fill the gaps in knowledge and limiting the impact of microbial pathogens can be identified as follows.

- Monitoring the release of sewage waters into the marine environment especially in Mediterranean Southern countries. The monitoring should include the location of the sewage release, the identification of sewage plants and the assessment of their functionality.
- Carrying out studies on both “classical” and “new” pathogens in beaches and sediments.
- The complex threats to human health and to ecosystems should be analyzed through the identification of the “new” pathogens’ biology, ecology and population dynamics. Pathogens should be distinguished between species that are harmful/not harmful to human health and to ecosystem and information on such a classification should be provided. Epidemiological studies should be made to determine the factors that trigger and spread pathogenic agents. Moreover the relative sensitivities of the various Mediterranean marine communities must be assessed.
- Operational programs for Harmful Algal Blooms (HABs) have to be developed/improved to determine the physiological and biochemical mechanisms responsible for toxin production and accumulation, and to evaluate the effect of phycotoxins on living organisms. In parallel, monitoring programs for HABs should be planned to prevent/reduce environmental, public health and economic impacts. The above initiatives have to be improved in Northern countries and developed in the Southern and Eastern Mediterranean sectors.

[8] “… The National Plan shall be based on the available scientific data and will include programmes for (i) the collection and regular updating of data, (ii) training and refresher courses for specialists, (iii) awareness-raising and education for the general public, actors and decision-makers and (iv) coordination and collaboration with other states …” (UNEP/MAP-RAC/SPA, 2005).

Fisheries on target and non-target species

Fisheries is matter of several specific international organizations (e.g. FAO, ICCAT), national and international bodies and institutions (e.g. CGPM, national research institutes).

Thanks to the work of these organizations, several national/sub-regional/regional actions, plans and programs, in order to improve fishery management (and reduce the pressures and impact on ecosystems), have been carried out and are ongoing.

Although numerous progresses have been made, in particular regarding legislations, researches, species biology and stakeholders involvement, several and weighty actions are still to be undertaken. The major next steps are summarized below, in particular these dealing with mitigating the impact of fisheries on marine biodiversity.

- Improving fishery statistics, in particular on fleet capacity, distribution and landings. A special action must be addressed to improving statistics of recreational fishery data (fleets, composition, abundance and size of catch).
- Enhancing researches on by-catch, discard, ghost-fishing and technology; regarding this last point in particular researches on gear modifications in order to reduce the undesired retention of small sized individuals or non-commercial species should be carried out. Developing gear technologies is also necessary to limit significantly the risks of catching endangered species or reduce their immediate or delayed mortality rates (e.g. deterrent devices).
- A special action should be addressed to the reduction of by-catches and discards by trawl. Trawling gear could be made more selective by using higher mesh sizes or incorporating special excluding devices, such as those based on rigid grids. The increase in mesh size (today is 40 mm) could reduce the impact of fishing on environment limiting the amount of discards.
- Further enforcing regulations for the banning of harmful fishing illegal practices like trawl within 50 m depth (or 3 miles offshore), driftnets, dynamite fishing, poison fishing, date extraction and Andrew Cross fishermen's. The enforcement of laws, in addition to the improvement of controls, can be helped by the identification of problems associated with the eradication of these practices and the launching of awareness/educational programs for fishermen.
- Improving guidelines, tools, monitoring key indicators on ecosystem approach fishery management. Moreover involving stakeholders in order to proceed with the applying of the ecosystem approach as supplement to the target species fishery-management. The quantitative and qualitative cost-benefits analysis of such management measures could be useful for promoting the involvement of fishermen.
- Adding to the current forbidden trawling below 1000 m depth by the GFCM, banning of bottom trawling in large marine areas; and creating a network of marine reserves totally closed to bottom trawling, or, at least, organizing seasonal rotation of fishing grounds through the establishment of temporal closures.
- In particular for some overfished species, an assessment of the suitability of a complete ban on their exploitation should be made, such as the assessment

and eventually implementing of the inclusion of new overfished species in the annexes of the SPA Protocol and in the appropriate CITES lists.

Climate change effects

About climate change, as premises to the actions, a general principle needs to be underlined "*Controlling climate variability is an impossible task. However, eliminating other sources of disturbance could reduce the vulnerability of species and ecosystems. By acting on introductions, we can try to check the arrival of competitors for space and the resource, new pathogens or parasites. By acting on emissions of pollutants, we avoid synergy with heat stress. By limiting the fragmentation of habitats, we are facilitating dispersion while maintaining connectivity between populations*" (UNEP-MAP-RAC/SPA, 2008b)

Thanks to the recent RAC/SPA process addressed to the updating of the SAP/BIO on climate change issues (UNEP-MAP-RAC/SPA, 2009a) several actions, useful to understand and to limit the consequences of climate changes on biodiversity, have been defined. The main are listed below:

- Upgrading the priority level of climate change and marine biodiversity issues in national policy agendas. This action could be helped by inducing political response through promoting awareness of general public and fostering fluent tailored information.
- Setting up a comprehensive and user friendly information exchange system (CHM), comprising international scientific literature, capable for periodic updating and with a free public access, in order to prevent or minimize risks of redundancy, overlapping, and implementation of inappropriate or unsustainable actions and to promote the exchange of information and harmonization across the region.
- Formulation and implementation of long-term monitoring programs. Within this framework some actions are necessary to strengthen institutional and human capacities for such monitoring, and for related training and capacity building. The ongoing biodiversity monitoring initiatives at sub-national, national and transboundary levels might facilitate starting initiatives for broader monitoring schemes at spatial and temporal levels, focused on climate change and biodiversity.
- Several actions concern researches and in particular: studies on thermohaline circulation and other oceanographic aspects influenced by climate change; functioning of marine ecosystems; sea level rise effects; climate change influence on planktonic communities composition and distribution patterns; changes in the chemistry and biogeochemical cycling of carbon and carbonate; trophic chain disruption; cumulative and combined stresses of environmental factors and predictive models for climate change and biodiversity under climate change scenarios.
- Carrying out detailed studies on vulnerability and impacts for highly critical areas already identified and reported in national documents and regional synthesis produced within the updating of the Strategic Action Programme for the Conservation of Biological Diversity in the Mediterranean Region (SAPBIO) on climate change issues. Improving /updating/ranking the list of national critical endangered areas.

- Studying and divulgating the economic implications at regional and local scales of the detriment resulting from climate change impacts on biodiversity.

Deep sea

Main actions identified within deep sea conservation can be summarized as follows.

- As already recommended by GFCM, and previously quoted in the fishery section of this document, an action based on the precautionary approach, concerns the prohibition of deep-sea fishery below 1000 m depth.
- Establishing new SPAMIs embracing areas beyond national jurisdiction in order to protect the main identified deep sea hot spots of biodiversity and sensitive areas. Within this framework an important action is ongoing by UNEP/MAP RAC/SPA
- Carrying out studies and research programs, in particular on distribution of deep sea ecosystems, biology of species, ecosystem functioning and effect of anthropic pressures on deep sea ecosystems.
- Investigation by side scan sonar, deep current meters, ROVs and submarines is currently carried out for the identification of the best route for pipeline and submarine cable deployment through deep sea areas. Thanks to these oceanographic campaigns a relevant number of data and information on deep sea have been collected (and other will be collected in the near future) but these data are, often, not available for scientific uses. In order to improve the knowledge about deep sea ecosystems a possible action could regard the development of cooperation research programs between biologists/ecologists and private or public energy companies.

6. CONCLUSIONS

6.1. LINKED TO PROPERTIES OF MEDITERRANEAN MARINE AND COASTAL ECOSYSTEMS

The Mediterranean is an oligotrophic sea. It is rich in oxygen and poor in nutriments. This oligotrophy declines from west to east. However, its great biodiversity makes it a world hotspot, with a remarkable rate of endemism. A declining gradient exists from west to east. The western basin is richer in terms of species and endemism than the eastern basin. The current trend, related to global change, reveals a considerable change in the MCBD in the Mediterranean. This is shown both in the marked erosion of biodiversity so that many species that appear in many international treaties aiming at protection are currently threatened, and in the fact that marine habitats are undergoing alarming pressure, which is expressed in the alteration and destruction of these habitats. Fishing has considerably reduced stocks of almost all the exploited species; today these are in a situation of overexploitation. The introduction of Atlantic and/or Lessepsian species is increasingly frequent, more in the eastern basin than in the western. The Mediterranean is today increasingly undergoing the phenomena of the meridionalization and/or tropicalization of its biodiversity. Lastly, the rich Mediterranean biodiversity has not been sufficiently studied, at least in many countries. Inventories are rare, and scientific research, in this field, is very limited and uncoordinated, probably due to financial and administrative constraints.

Marine Protected Areas undoubtedly constitute precious tools for the management and governance of biodiversity in the Mediterranean. But the present situation shows that the CBD's aim to protect 10% of the world's eco-regions is not being met today in the Mediterranean, that the existing MPAs are not representative of all the Mediterranean habitats, and that the current system of Mediterranean MPAs is neither representative nor consistent on a Mediterranean basin scale. Faced by such a situation, the setting up of cross-border MPAs on the grounds of marine biodiversity-linked risks seems to be the best alternative. Special attention is now being paid to the high seas SPAMIs for the conservation of high seas ecosystems, including those of the deep sea. These have been very little explored and mostly lie outside the territorial jurisdiction of the Mediterranean countries.

Furthermore, the national financial capacities are insufficient and do not permit ambitious research programmes to be undertaken. The current progress in terms of MCBD has been made possible mostly thanks to international funding, which operates on a unilateral or bilateral scale or via sub-regional or regional projects. The limited capacity of national institutions and experts to apply for international funding sources is a feature of many Mediterranean countries, particularly those of the southern Mediterranean.

Finally, all these factors combined are one of the challenges to overcome to conserve the region's biodiversity.

In most Mediterranean countries, particularly those of the southern shore and the eastern basin, the level of knowledge on MCBD is low or very low. Current knowledge is limited in most countries to specific biodiversity, particularly in the coastal waters; the deep sea and high seas ecosystems have been little prospected and information on these remains insufficient in most Mediterranean countries. Such pertinent information is necessary to give a solid basis for applying an ecosystem approach in the Mediterranean basin (integrated ecosystem approaches).

6.2. LINKED TO CRITICAL IMPACTS AND EFFECTS ON MARINE AND COASTAL BIODIVERSITY

The **loss of marine and coastal biodiversity** is due to concomitant causes and several pressures which act in synergy: the biological invasions of non indigenous species are often linked to climate change and other environmental disturbances, including fishing pressure; several microbial pathogens are introduced by invasive species and, in numerous cases, their development is due to climate change also.

The **ecosystem approach** must be implemented in order to improve the knowledge of the marine and coastal ecosystems and to better understand and evaluate the effects of pressures and impacts on biodiversity. In particular, indirect ecosystem consequences and cascade effects can be interoperated only through an ecosystem approach. Ecosystem approach to fishery management is accepted as the necessary framework to secure sustainable use of marine ecosystems.

The presence of **non-indigenous and invasive species** represents a growing problem mainly due to the unexpected impacts that these species can have on ecosystems and consequently on the economy and human health. The presence of invasive species can lead to the biotic homogenization of biodiversity, mainly through the reduction of genetic diversity, the loss of functions, processes, and habitat structure, and the increasing of the risk of decline and species extinction. Several authors consider invasive species one of the biggest causes of losing of biodiversity. However, up today, even if rapid decline in abundance, till local extirpations of native species are been documented, no extinction of native species is known.

It is likely that the recent high mortality rate of many marine species in the Mediterranean has been caused by **pathogenic agents**. While many pathogens are known, as well as their impacts on human health, the invasion of non-indigenous and invasive species in conjunction with climatic changes are increasing the number of new pathogens. To enhance the knowledge on new pathogens and to apply an integrated ecosystem approach further investigation is needed.

Fisheries, in particular inappropriate fishery practices, strongly impact marine biodiversity. Over-exploitation is responsible for the decline of many fish stocks. Particularly harmful to biodiversity is the direct impact of fishing on the seabed (mainly by trawl) and the fact that fishing practices lead to discards.

Climate change is an ongoing process that may act at several biological levels and may strongly impact marine and coastal biodiversity. The real extent of possible effects of climate change on marine ecosystems is currently unclear. In general, a homogenisation of Mediterranean biota and disrupting of present biogeographical entities could be expected. Some authors hypothesize extinction up to 15-37% of the species occupying north-western Mediterranean area by 2050. Much more information is necessary in order to assess the real resilience of the marine populations affected by climate change events.

The Mediterranean **deep sea** hosts some important ecosystems, habitats and assemblages (cold seeps, brine pools, seamounts, cold-water coral reefs). Deep sea species and habitats are, in general, particularly sensitive. Several pressures threaten this environment, in particular fishing practices (especially trawl bottom), pollutants, oil exploration and exploitation and climate change. Some authors consider the Mediterranean deep sea among the most heavily impacted deep seas in the world, and, at the same time, among the least known areas.

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