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State and pressures of the marine and coastal Mediterranean environment

UNEP

European Environment Agency

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Foreword

When tackling the pressing issue of sustainable development in the Mediterranean Region - among which the challenging issues of rapid urbanisation rates; increasing tourism and coastal zone development and degradation; water scarcity; and trade – the need to establish a knowledge base and help come to grips with the problems is widely recognised, as is the current lack of timely and targeted information for action. To fulfil this need means also to contribute substantially to improving access to environmental data and information at the regional and national levels, both for governmental bodies and other institutions, as well as for the general public throughout the Mediterranean region.

Significant progress in building monitoring capacities (e.g. MEDPOL / MAP, environment / development observatories) and in framing, shaping and collecting data for commonly identified indicators (cf. the recent activities of the Mediterranean Commission for Sustainable Development) has been made. This is remarkable, but is it enough? We do not believe so. Is the best available information put to work for the right challenges, i.e. more stringent environmental political commitments and targets to improve in general environmental quality and the rational use of significant natural assets of the Mediterranean and, finally, to progress towards sustainable development? We must, indeed, consider the unique opportunity that a new generation of shared information could represent for an effective support to the national and regional decision-making processes and for stimulating the expected public participation.

What does this mean? For instance, the costs of environmental actions are often emphasised, but there are clearly also cost-effective opportunities for countries to develop eco-efficient economies, eg. increasing the share of renewable energies is realistic for many Mediterranean communities. Another example is given by the externalities of the tourism industry which, in many areas, offset the incomes and benefits it provides. If the right choices are to be made then new kinds of partnerships between all stakeholders are necessary as well as a new type of information that is relevant to the choices of development paths available.

This said, it is fair to state that expectations in the development of harmonised environmental data in the Mediterranean region through a joint information provision exercise have been often raised. To fulfil this objective the various actors ask the European Environment Agency (EEA) to contribute directly by bridging the European partners with the other Mediterranean actors. We have therefore initiated a partnership between EEA and UNEP / MAP. One of EEA's tasks, through the work of the Topic Centre on Marine and Coastal Environment, is to establish an Inter-Regional Forum to facilitate the exchange and integration of existing data and information among regional and international conventions and organisations active in marine and coastal environmental monitoring. Major regional and international organisations / conventions such as MAP, OSPAR, HELCOM have joined the Forum. From the first discussions between EEA and UNEP / MAP Secretariat, the need for an updated report on the state and trends for the Mediterranean Sea was emphasised.

The result of the cooperation on compiling and publishing such a report is presented here. It gives the best available information on the marine environment in the Mediterranean Sea and its coastal zone. It documents and describes the various interactions between human activities and the environment. It confirms and updates the major problems of the coastal zones. One of the major objectives of the report also includes the identification of possible gaps in current knowledge, especially in the field of marine environmental monitoring, following two decades of coordinated activities in the region under MEDPOL and complementary programmes. The final aim of the report is to identify objectives and recommend actions to improve the information, which can be achieved by encouraging better use of the scientific capacity in the region in order to focus more accurately on the existing problems and to propose suitable priorities and action.

It is worth stressing that the EEA and UNEP / MAP see this report both as a contribution to and a milestone towards an overall assessment of the environmental situation of the whole Mediterranean basin. It is necessary, however, to go beyond, in support of the activities and political agenda dealing with environment / development issues. A status report on the current situation and prospects of the whole basin, including state of action, would address the specific needs of the European Union, UNEP, countries and international financial organisations to have an objective basis for decision-making. We should not wait too long before deciding about the making of this assessment report. In fact, such a report, which we might call 'The Mediterranean Basin. Situation and Prospects for the Next 20 Years' should be available for the Rio+10 Conference in 2002 in order to mark the place and ambitions of the Mediterranean within the world community.

In the meantime, we must dare to convey some strong messages, as demonstrated by the present report. Allow us to give you our perception of the issues:

- The Mediterranean sea and region is traditionally very rich in environmental data and specific, targeted information and scientific knowledge but extremely poor in consistent and integrated assessments. This difficulty to produce regular integrated assessments, linked to the political agenda, is a major handicap that has to be overcome;

- The Mediterranean is a fantastic asset: it is a strong and healthy sea that we submit, in spite of the reduction of some pollution, to excessive pressures; hot-spots identified by MAP are still numerous. Notwithstanding this, its natural conditions remain unique: its biodiversity, oligothrophic conditions, regular water renewal, rich coastal biotopes and landscapes, significant average depth (1.500 m), mild climatic conditions, etc. Properly used, the Mediterranean provides the basis for diversified economies in the basin while keeping a unique Mediterranean entity;

- We keep transforming all this potential and opportunities into threats for the future. If the sea, the water body, is still in favourable condition, **we are doing much to degrade the landscapes by urbanising the coast beyond carrying capacities; we are also degrading** the transition zone, the biotopes, the sealing of soils. In a way we are building a barrier of concrete that extends already over more than 25 000 km of the 47 000 total km of Mediterranean coast, behind which the Mediterranean identity and its resources are gradually disappearing .

- We also discharge too much untreated waste water and toxic substances; and biodiversity is threatened by bringing invading fauna and flora species and scraping the sea beds.

The Mediterranean basin will only be what we make of the coasts. In line with the recommendations of the Mediterranean Commission for Sustainable development, the time has come to implement common policies for action aimed to improve the current situation and stop the degradation observed in this report. Otherwise, there is little hope of honouring our responsibility to take care of what is still a treasure; the Mediterranean Sea.

EEA and MAP will continue to develop their cooperation to provide more in-depth assessments; these should form the basis for the global action to reverse the present trends. It is not too late: it is a matter of understanding our collective interest as well as the rights of future generations.

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Executive summary

Introduction

Intense human activities in regions surrounding enclosed and semi-enclosed seas such as the Mediterranean Sea always produce, in the long term, a strong environmental impact in the form of coastal and marine degradation and a heightened risk of more serious damage.

In view of the above and in addition to the specific measures taken by individual countries, several regional and international organisations have, during the last decade in particular, shown great interest in the Mediterranean basin and have launched and implemented a number of environmental programmes. In particular, the United Nations Environment Programme (UNEP) has coordinated the Mediterranean Action Plan (MAP) since 1975 and implemented several programmes covering scientific, socio-economic, cultural and legal aspects of the protection of the Mediterranean environment.

Scope of the report

The report, prepared by the European Environment Agency (EEA) and its European Topic Centre on the Marine and Coastal Environment (ETC/MCE) in cooperation with the Mediterranean Action Plan (MAP), presents an overview of the Mediterranean marine and coastal environment. The report adopts the DPSIR assessment framework (Driving Forces/pressures/State/Impacts/Response) developed by EEA, and describes the various interactions between human activities and environment.

The report makes an attempt to give a picture of the region and reflect important and characteristic features of the Mediterranean marine environment and the impacts of human activities, based on the best available information in 1997-98.

In presenting and assessing the state and pressures of the marine and coastal environment based on the best available data, the report identifies possible gaps in current knowledge, especially in the field of marine environmental monitoring. The report does not attempt to describe in detail the activities undertaken in the region by the various bodies. The report presents objectives and recommends actions to improve the quality and availability of information from the area.

It describes the Mediterranean Sea and its coastal zone by reviewing:

- its natural characteristics including morphology, seismicity, climate and hydrographic conditions;
- the human activities (or driving forces), including urbanisation, tourism, loads and discharges through rivers and from coastal population, agriculture, maritime traffic, industry, oil industry and the influence of fisheries and aquaculture, which exert pressures (in the marine and coastal Mediterranean environment);
- its environmental state and the main threats, including the state of eutrophication, microbial pollution and chemical and radioactive contamination in the Mediterranean marine ecosystems;
- the ecosystem sensitivity and impacts from climate change, changes in biodiversity and a discussion of environmental-quality related health risks in the area; and
- the responses at the regional level, giving information about the international programmes that have been launched in the Mediterranean Sea.

Data mainly from MEDPOL (Mediterranean Pollution Programme) and Blue Plan databases were used for assessment. Scientific literature, data and technical reports from other international organisations (e.g. FAO) and at national level have also been taken into consideration. The assessment has focused, where appropriate and available to the authors, on reliable and quality-assured data.

Driving forces and pressures

Concentration of populations (resident and non-resident) and human activities around the Mediterranean basin present considerable threats to coastal ecosystems and resources in four major areas:

- on the structure and function of natural ecosystems as a result of the construction and operation of facilities for human activities and the associated urbanisation and activities development;
- on the quality and quantity of natural resources (forests, soils, water, fisheries, beaches, etc.) as a result of increasing concentrations of people and activities adding to the demand for their use and exploitation and subsequent disposal of wastes;
- the coastal zones as a consequence of the development of different human activities and associated facilities as well as on the competition among conflicting users;
- the natural and man-made landscape as a result of the changes of activities, and of size and scale of related facilities and associated development.

In the future, coastal areas are likely to face increasing pressures, particularly on habitats, natural resources (land, fresh / marine waters and energy) and growth of demand for infrastructures (ports / marinas, transport, wastewater treatment facilities, etc). Urbanisation, tourism, agriculture, fishing, transport and industry are the major forces of change.

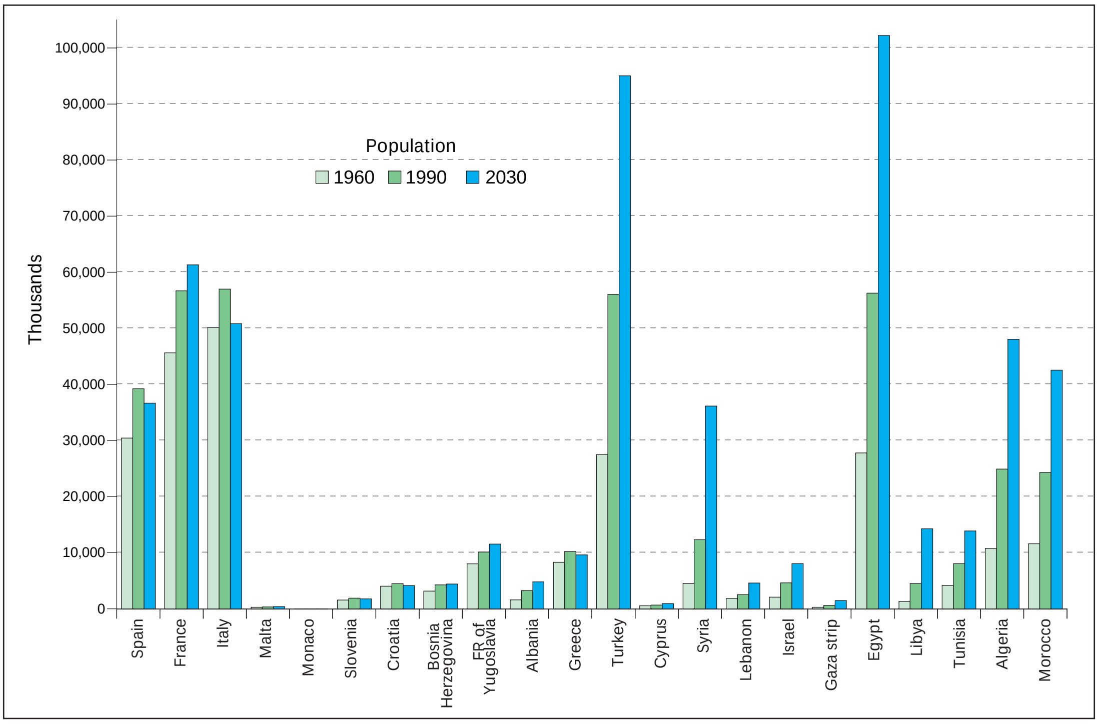
Urbanisation

The resident population of the riparian states of the Mediterranean was 246 million in 1960, 380 million in 1990 and is currently 450 million. 'Blue Plan' estimates that depending on the development scenarios applied, this figure will rise to 520-570 million in the year 2030, is expected to reach approximately 600 million in the year 2050 and possibly as much as 700 million at the end of the 21st century. Population density is greater in coastal regions, especially near the big cities.

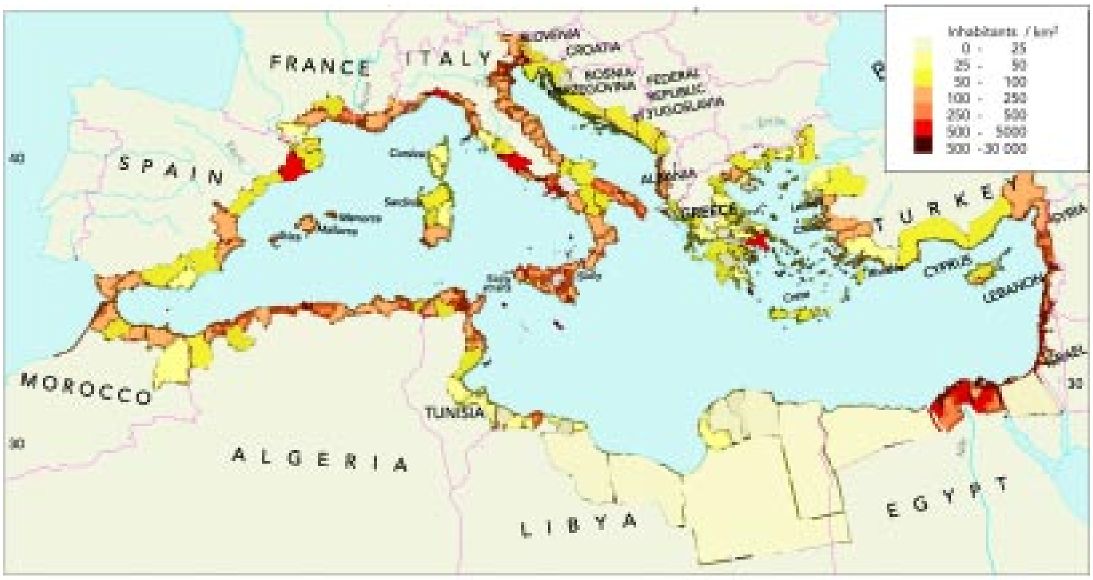
The distribution of population between the northern and southern countries has changed dramatically: in 1950, countries of the northern Mediterranean represented two thirds of the total population, while today it is only 50 % and may be one third in the year 2025, and one fourth in 2050.

In general, the mass migration towards the major urban centres in the basin has overstrained the labour and housing markets and the associated public services (water supply, roads, sanitation and transport).

Population increase in the different Mediterranean countries



Source: Blue Plan databases, United Nations, World Population Prospect, The 1994 Revision



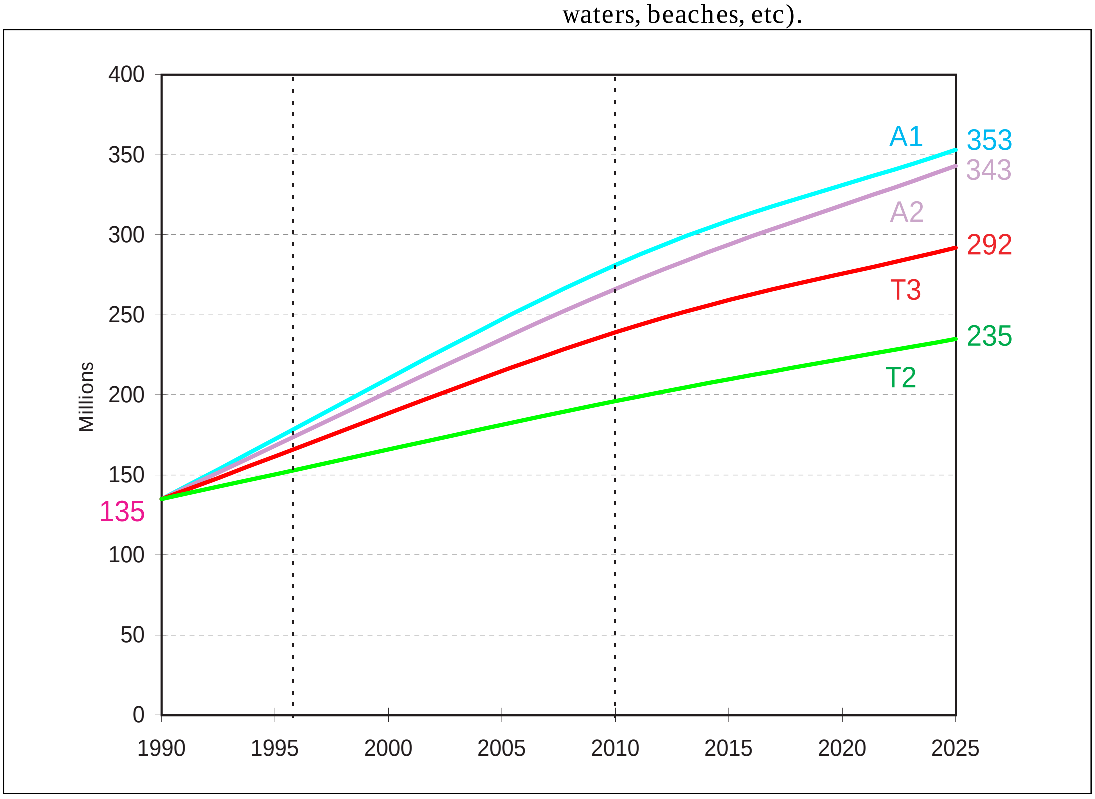
Population density in coastal regions

Source: Blue Plan databases

Tourism

The Mediterranean is the world's leading tourist destination, accounting for 30% of international tourism and one third of international tourism. Coastal tourism is strongly seasonal and increases annually. Pressures on the coastal zone are likely to continue to increase in the future, with an estimated doubling of tourism fluxes over the next twenty years from 135 million arrivals in 1990 to 235-350 million in 2025. Tourism is currently the first foreign currency source in the Mediterranean region and its contribution to GNP (Gross National Product) can average up to 22 %, as is the case for Cyprus, or 24 % for Malta.

The interactions between tourism and the environment in the Mediterranean region are seen in the following issues: land use; consumption of water resources; pollution and waste and physical and socio-cultural pressures. Coastal tourism causes reduction of natural sites and open spaces, substantial alteration of coastal landscapes and conflicts on the use of land, water and other resources. Pressures on the coastal zone are likely to increase in the future, with an estimation of a doubling of tourism related development in the Mediterranean in the next twenty years. However, in recent years, tourism itself has produced a strong incentive for the protection of the landscape and the improvement of the quality of the environment (e.g. bathing waters, beaches, etc).



Alternative estimates of the distribution of the tourist frequency during the peak period (May-September) in the Mediterranean region (according to diffrent Blue Plan scenarios)

Source: Blue Plan databases

Agriculture

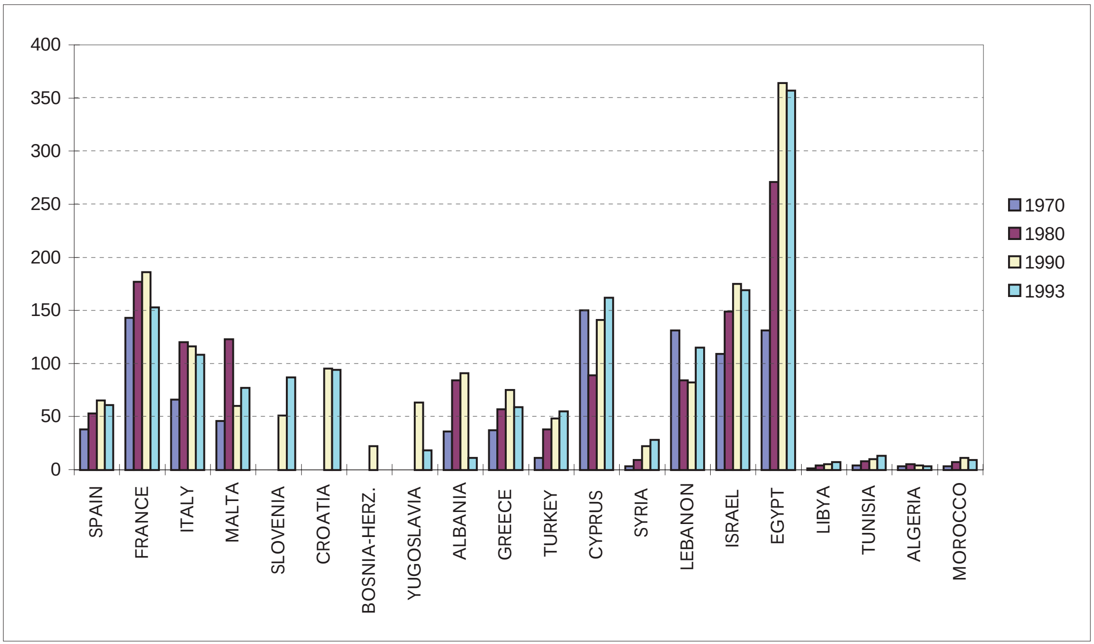
Due to the specific morphology of the Mediterranean basin, intense agricultural activity is carried out in the limited coastal plains, often as a result of reclamation of wetlands.

The role of agriculture in changing coastal environments of the Mediterranean basin is more indirect than direct and primarily affects the dynamics of wider areas. In most countries, all types of agricultural practices and land use lead to diffuse pollution of water and, hence, are difficult to quantify.

Agricultural land is one of the resources on which the pressures of development are the strongest, particularly on the narrow coastal strip bordered by desert regions on the southern coast.

The main pressures from agriculture are soil erosion and nutrient surplus when excessive fertilisers are applied. Large river basins like the Rhône and the Po Basins are subjected to agricultural pressures. The first six drainage regions, following a tentative ranking of the risk of soil erosion and nutrient losses, are found in peninsular Italy, Sicily, Sardinia, Greece, Turkey and Spain.

Fertiliser consumption in the Mediterranean countries from 1970 to 1993 (kg/ha)



Data source : The World Bank, Social Indicator of Development, 1996

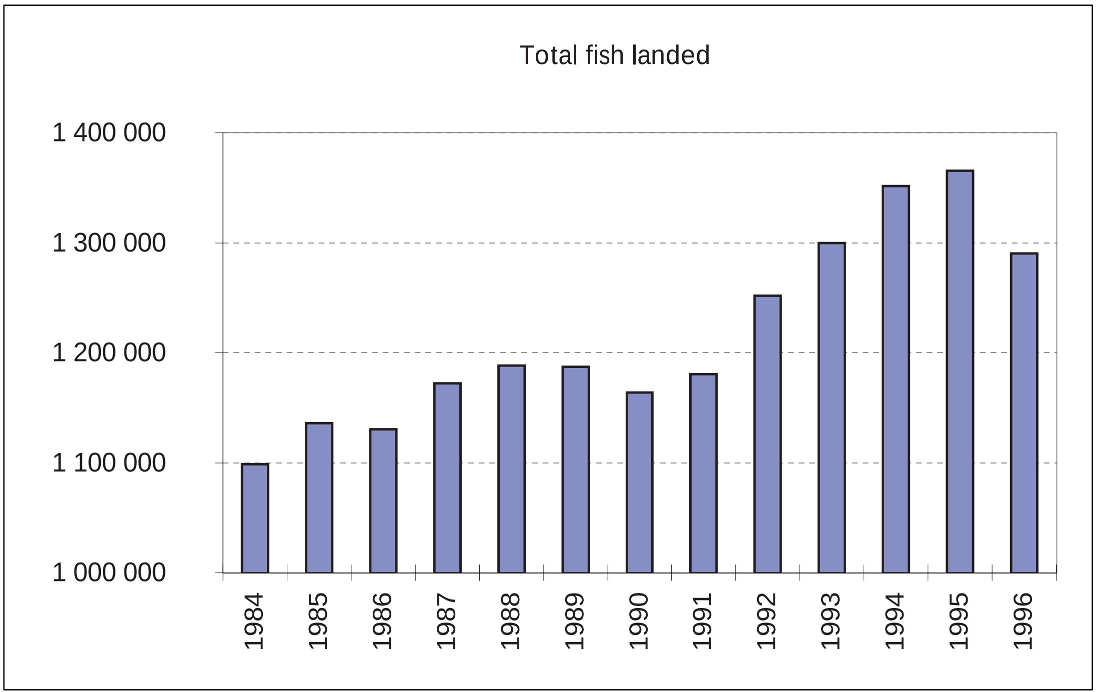
Fisheries

Mediterranean fisheries exert pressure on the environment as well as on the fish stocks. The overall value of the landings is still high in comparison to the relatively modest tonnage (approximately 1.3 million tonnes) landed. There have been relatively small changes in fishing techniques in the Mediterranean area during recent years. The number of fishing vessels increased from 1980 to 1992 by 19.8 %. Fleet technology in the industrialised EU countries is very high and there has been a shift from labour-intensive to more capital-intensive vessels, such as larger trawlers and multi-purpose vessels. The amount of 'passive' fishing by lost fishing nets has generally increased but the number of trawlers has remained steady since 1982.

Aquaculture

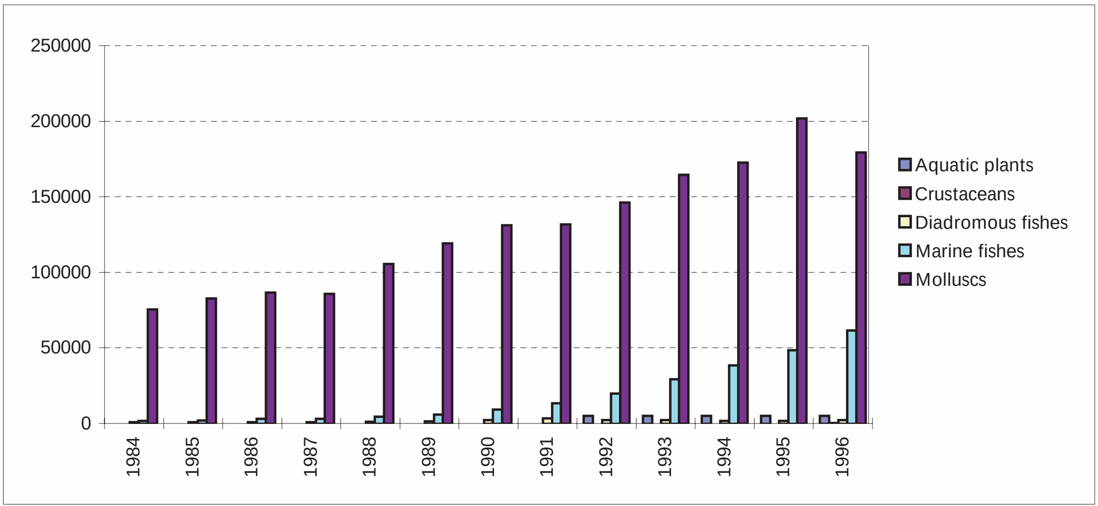
Marine aquaculture has shown a large expansion in production in a number of Mediterranean countries over recent decades and increased from 78 000 tonnes in 1984 to 248 500 tonnes in 1996 (freshwater aquaculture not considered). Its future development will have to be considered in relation to all other existing and planned activities. The careful selection of sites where aquaculture could be done, with precise definition of their environmental carrying capacity, will contribute to minimisation of nutrient loads on the ecosystem and to reduction of the effects of negative feedback which may eventually affect the production potential of fish-farming activities.

Since marine intensive aquaculture is a relatively new sector in the Mediterranean and concerns mainly shellfish and some fish species (mainly sea-bream and sea-bass), the impact of its relatively small productions (in comparison with Asia or South America) is still rather limited and very localised.



Total fish (tonnes) landed per year by Mediterranean countries

Source: FAO GFCM-PC release 1997 and FAO Fishstat-PC, release 1998



Aquaculture production (in tonnes) by major group in Mediterranean Sea from 1984 to 1996

Source: FAO Aquacult-PC, release 1998.

Industry

There is a large range of different industrial activities (from mining to manufactured products) scattered all around the Mediterranean basin, and a number of hot-spots are concentrated mainly in the north-west, generated by heavy industry complexes and big commercial harbours. Discharges and emissions of contaminants from this industry pose an environmental threat especially in the area of the hot-spots. Pressures from industry in the basin include mainly the chemical / petrochemical and metallurgy sectors. Other main industrial sectors in the coastal region are: treatment of wastes and solvent regeneration, surface treatment of metals, production of paper, paints and plastics, dyeing and printing and tanneries.

The export specialisation in each country provides a fairly precise image of the industrial activity which is most important in that country and could primarily cause environmental threats. Three groups of countries can be distinguished:

1. Countries highly specialised in exporting only few products, the rest being imported. This is typical of oil producing countries such as Algeria, Syria, Egypt and Libya;

2. a less specialised group, exporting goods even in a situation of comparative disadvantage with other countries, are Tunisia, Morocco, Turkey, FR Yugoslavia, Cyprus and Malta, exporting goods such as clothes, textiles, and leather. Each one also has more specific productions

(chemistry, oils and lubricants in Tunisia; chemistry and fertilisers in Morocco; textile fibres, wool, cotton, paper and cement in Turkey and FR Yugoslavia).

3. a strongly diversified and thus much less specialised group comprises the European Union Member states which account also for the biggest part of the petrochemical industry in the Mediterranean basin.

The impacts of industry on coastal areas can be direct or indirect. Direct impacts deriving from effluents from industry, involve pollution problems at the site level (large commercial harbours, heavy industry complexes) that contribute to the creation of hot spots. Indirect impacts are related to the location of industries, ultimately leading to concentration of activities and urban development on the coast. Industry is also a major contributor to air pollution. However there is a lack of information on the impacts of industry on the coastal environment.

Maritime transport

There are three major passage ways to and from the Mediterranean Sea: the Strait of Çanakkale / Sea of Marmara / Istanbul Straits, the Strait of Gibraltar and the Suez Canal.

The major axis (90 % of the total oil traffic) is from east to west (Egypt-Gibraltar), passing between Sicily and Malta and following closely the coasts of Tunisia, Algeria and Morocco.

On average, there are about 60 maritime accidents in the Mediterranean annually, of which about 15 involve ships causing oil and chemical spills. The most accident-prone areas, because of the intense maritime traffic, are: the Strait of Gibraltar and Messina, the Sicilian Channel and the approaches to the Straits of Çanakkale, as well as several ports and their approaches, particularly Genoa, Livorno, Civitavecchia, Venice, Trieste, Piraeus, Limassol / Larnaka, Beirut and Alexandria. The geographical distribution of pollution ‘hot spots’ is related also to the density of shipping traffic on the various Medterranean routes.

Activities of the oil industry in the Mediterranean Sea

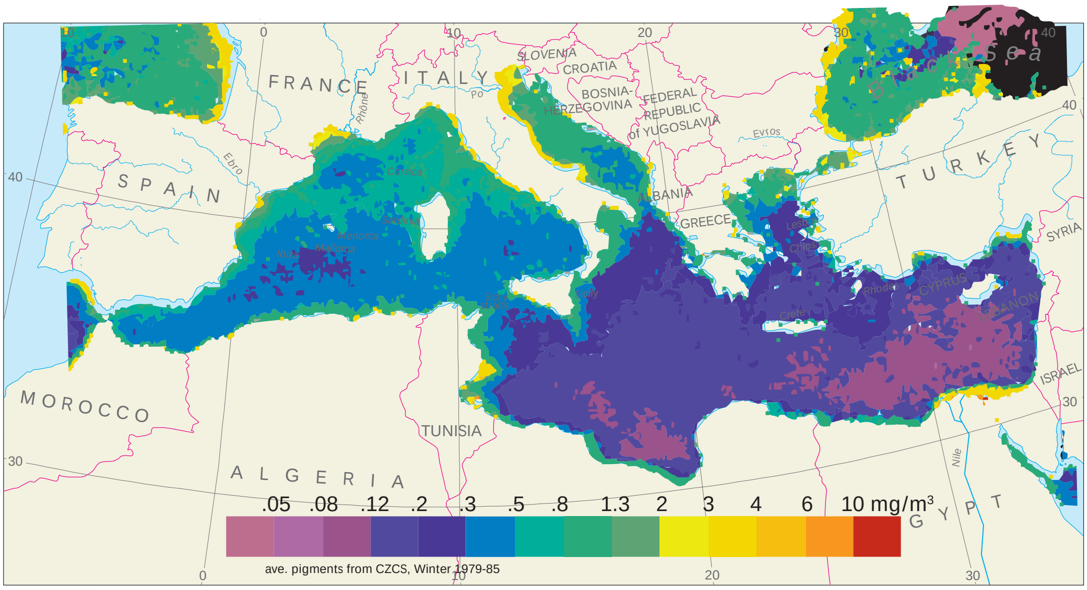
Source: RAC/REMPEC

State and impact

Eutrophication

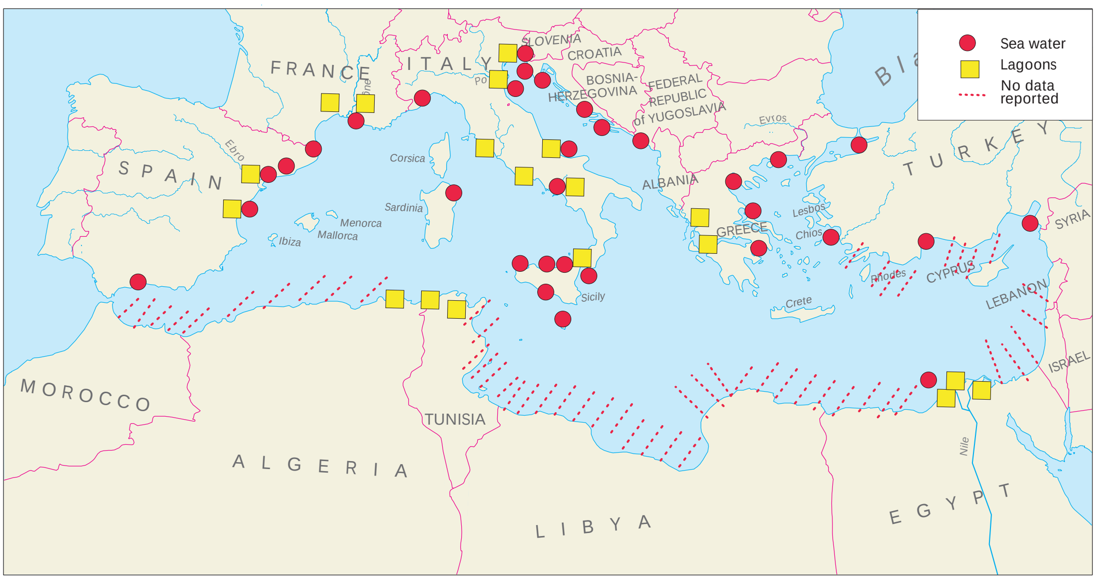
Eutrophication results from high nutrient loads from rivers and / or urban and industrial effluents. In the Mediterranean it appears to be limited mainly to specific coastal and adjacent offshore areas. Several, sometimes severe, cases of eutrophication are evident, especially in enclosed coastal bays which receive elevated nutrient loads from rivers, together with direct discharges of untreated domestic and industrial waste. Mediterranean surface waters in the open sea are classified among the poorest in nutrients (oligothrophic) of the world’s oceans. The absence of significant up-welling keeps nutrients like nitrogen and phosphorus out of the biological recycling process.

Algal blooms, diversity reduction of marine species and depletion of oxygen as well as potential human health risks related to the ingestion of seafood contaminated by pathogens or toxic algal blooms are some of the problems associated with eutrophication. Side effects (e.g. hypoxia / anoxia, algal blooms) have been reported in several places in the Mediterranean Sea but they are confined to limited areas rather than widespread phenomena . The Adriatic, the Gulf of the Lion and the northern Aegean are areas with relatively higher mean nutrient concentrations, higher primary and secondary production and, sometimes, local algal blooms related sporadically to hypoxic or anoxic conditions and rarely to toxic algal blooms.



Winter average pigments distribution in the Mediterranean Sea

Source: JRC, Ispra



Mediterranean areas where eutrophication phenomena were reported

Source: UNEP/FAO/WHO, 1996 (Modified)

Microbial contamination and human health risks

Microbial pollution is related to urban wastewaters. The most important eutrophication hot spots in the Mediterranean often coincide with coliform bacterial hot spots. Pathogenic and other microorganisms enter the marine environment mainly through municipal waste water discharges. As is the case in other regions, microbiological pollution of the Mediterranean Sea is principally the direct result of the discharge of untreated or partially treated sewage into the immediate coastal zone. Microbial pollution and its effects have been mitigated along the EU Mediterranean coast since the installation of urban wastewater treatment plants in most of the European urban areas. However, the problem elsewhere remains as severe as before.

Rivers also add a considerable amount of microbiological pollution, mainly from upstream waste water discharges, but their relative contribution to the pollution of the Mediterranean by micro-organisms (pathogenic and otherwise) has not been assessed in this report.

One current area of concern is that of viruses. Those so far isolated in the various matrices of the Mediterranean marine environment are listed in the table. The geographical imbalance in the occurrence of viruses is caused by the difficulty in isolation and quantification.

Viruses isolated in the Mediterranean marine environment

Virus	Location
Enteroviruses	
Poliovirus	Greece, Italy
Echovirus	France, Greece, Italy
Coxsackie virus A	France, Italy
Coxsackie virus B	France, Greece
Hepatitis A virus	France, Greece, Spain
Unspecified, non-polio	France
Other viruses	
Adenovirus	France, Greece, Italy
Rotavirus	Spain

Source: WHO, 1991

The favourable climatic conditions which lure to the Mediterranean coast one third of the global tourism also provide conditions for relatively long and frequent bathing exposure and beach overcrowding, and thus the area is potentially more conducive to disease transmission and contraction than would be expected in more temperate regions, such as northern Europe.

The main risks to human health arise from: intake of pathogenic micro-organisms from infected sea water; direct contact with polluted sea water and beach sand and consumption of seafood contaminated by pathogens; and, in a minor way, heavy metals and chemicals, especially in bioaccumulating organisms such as filter feeders and carnivorous fish.

The extent of damage to health on a Mediterranean-wide basis still has to be determined, and the same applies to pathogen incidence. Available records have a chronological span of one and a half decades, making it difficult to arrive at an accurate assessment of the overall situation. Furthermore, there are still large stretches of the Mediterranean coastal zone, mainly in the southern and eastern parts, from which records are sparse.

Land use and coastal erosion

Information, at basin scale, about the coastal zones and their use does not exist for the Mediterranean area. Aside from urban population concentrations, competing land use along the coast comes from tourism, agriculture, fisheries and aquaculture, transport, energy and industry infrastructure, causing acceleration of the modification of the morphology of the coastal system.

Coastal erosion is an environmental threat, related to a combination of human activities such as damming and coastal development, the abandonment of agriculture, and global climate change. Habitat erosion has also occurred mainly due to the competitive use of the coastal zone. Erosion data showed that the 1500 km of artificial coasts can be found

Evolutionary trends of some coasts of the European part of the Mediterranean Sea for both rocky coasts and beaches as % of coasts

Maritime regions in the Mediterranean Sea	No information	Stability	Erosion	Sedimentation	Not applicable	Total (km)
Balearic Islands	0.5	68.8	19.6	2.4	8.7	2861
Gulf of Lion	4.1	46.0	14.4	7.8	27.8	1366
Sardinia	16.0	57.0	18.4	3.6	5.0	5521
Adriatic Sea	3.9	51.7	25.6	7.6	11.1	970
Ionian Sea	19.7	52.3	22.5	1.2	4.3	3890
Aegean Sea	37.5	49.5	7.4	2.9	2.6	3408

Source: EC, 1998

in the EU marine area (Balearic Islands, Gulf of the Lion, Sardinia, Adriatic, Ionian and Aegean) with harbours and ports contributing the major part (1250 km) (EC, 1998). Based on the CORINE coastal erosion data, about 25 % of the Italian Adriatic coast and 7.4 % of the Aegean Sea show evolutionary trends of erosion while about 50 % of the total coastline of the Euro-Mediterrsanean area considered to be stable.

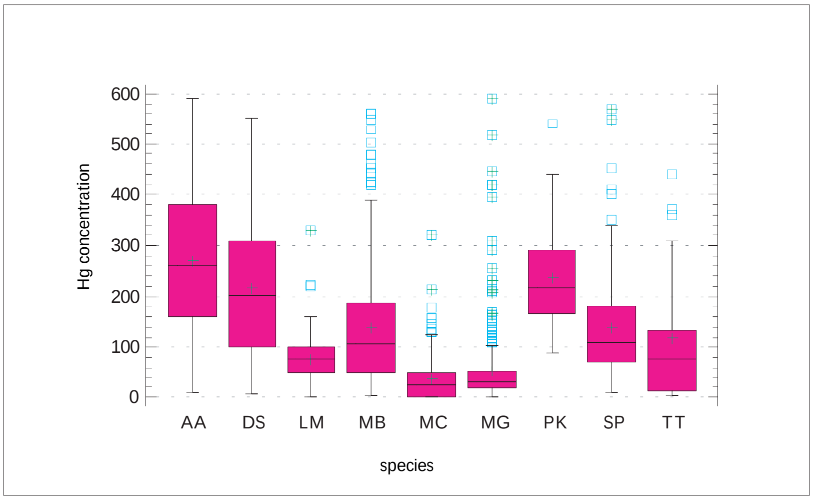
Heavy metals and organochlorine compounds

In the Mediterranean Sea, heavy metals are considered to arise mainly from natural processes , while anthropogenic sources, such as discharges from chemical industries, sewage and agriculture, are deemed to have a limited and spatially restricted effect. The relative importance of the various sources is, however, difficult to estimate due to the limited data available.

Total mercury values in Mediterranean species were generally higher than those found in the Atlantic. With the exception of mercury in biota and sediments, heavy metal concentrations are generally low. The higher mercury levels are deemed to be the result of the region being in the Mediterranean - Himalayan mercuriferous belt (Bryan, 1976; Bernhard, 1988). In the early 1970s, very high mercury concentrations were observed in some coastal areas, in 'hot spots', near harbours and industrial areas. As a result of dramatic reductions, starting in the late 1970s, in mercury releases from chlor-alkali plants there have been quick recoveries (2-5 years for half-life of mercury) in biota and indications of slower (6-33 years) reductions of concentrations in sediments (Heirut et al., 1996).

Chlorinated hydrocarbons are released entirely from anthropogenic sources, since no natural chlorinated hydrocarbons exist. Generally DDT concentrations are low in open sea sediments but high values were reported from the Rhône delta. These were considered extremely high and are comparable to values obtained in heavily polluted locations. Maximum values reported for DDT and PCB concentrations are generally much lower than the permissible limits for seafood consumption (WHO / UNEP, 1995). Most of these chemicals are no longer used in Mediterranean countries.

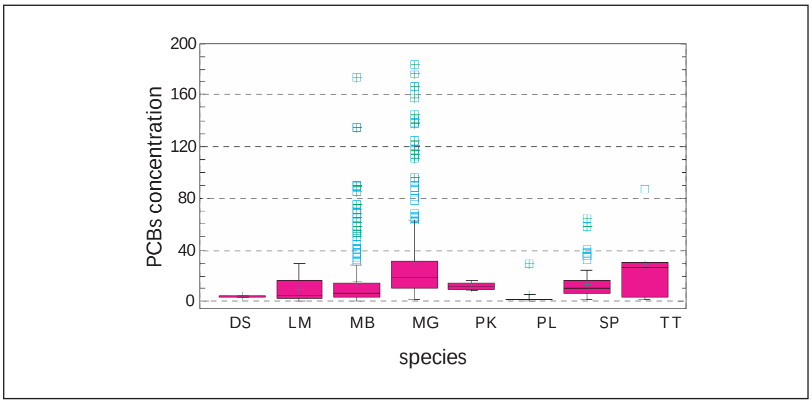
Box-and-Whisker plots showing the distribution of data for concentrations (in ng/g fresh weight) of mercury (Hg) in selected species from the Mediterranean Sea



(AA=Aristeus antennatus, DS=Diplodus sargus, LM=Lithognathus mormyrus, MB=Mullus barbatus, MC=Mactra corallina, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

Box-and-Whiskers plots showing the distribution of data for concentrations (in ng/g fresh weight) of PCBs in selected species from the Mediterranean Sea



(DS=Diplodus sargus, LM=Lithognathus mormyrus, MB=Mullus barbatus, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, PL=Parapenaeus longirostris, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

Oil pollution

Oil spills float and drift. Up to now, accidental oil spills have caused localised damage to the Mediterranean marine and coastal environment. Out of 268 accidents listed by REMPEC for the 1977-1995 period, more than three-quarters involved oil. The number of accidents is increasing in the Mediterranean Sea, with 81 events in recent five years (1991-1995) compared to 99 events in the previous ten years (1981-1990) (MAP / REMPEC, 1996). It should be stressed that a major oil spill could occur at any time in any part of the Mediterranean, particularly along the major sea routes and in or around the more important oil loading and unloading terminals, particularly as several ageing tankers are operating in the Mediterranean waters.

Between 1987 and the end of 1996 an estimated 22 223 tonnes of oil entered the Mediterranean Sea as the result of shipping incidents. The figures for individual years vary between 12 tonnes reported in 1995 and approximately 13 000 tonnes in 1991. Taking into consideration that an estimated amount of more than 360 million tonnes of oil are transported annually in the Mediterranean (in transboundary trade), the quantities spilled as a result of accidents appear to be low.

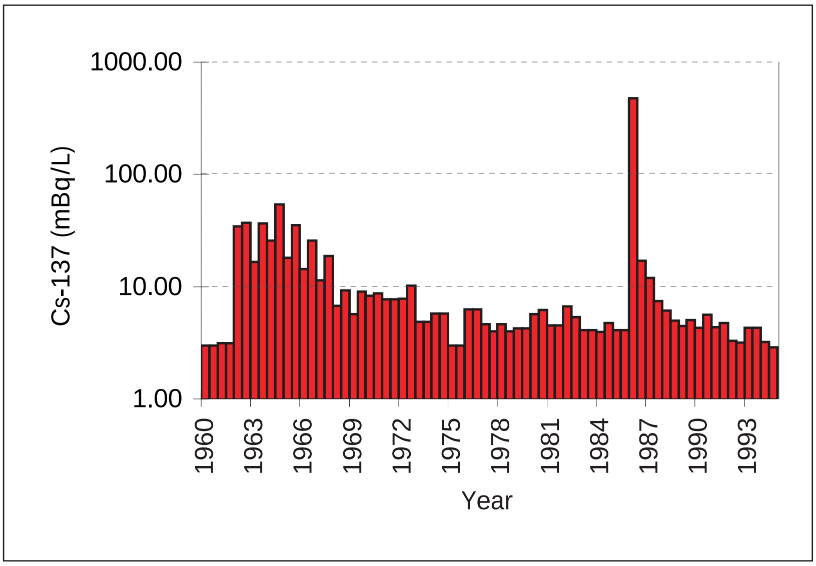
Generally, marine life at basin scale has not been affected by oil pollution. Of course localised incidents have sometimes had adverse effects on the benthic communities. In addition clean-up procedures such as the use of chemical dispersants can also damage the marine environment. In the open sea, the response of the authorities to an oil spill has to be very rapid to prevent the oil from reaching the coastline. It is practically impossible to avoid oil pollution of the coast. The time taken for oil-damaged populations of marine life to recover is highly variable and the extent to which the biological recovery of a habitat can be accelerated is severely limited.

Locations of 268 reported alerts and oil pollution accidents in the Mediterranean region between 1977 and 1995

Source: RAC/REMPEC, 1996

Radioactive contamination

^{137}Cs concentration in surface sea water of the Tyrrhenian Sea (1960-1995)



Data Sources: Giorcelli & Cigna, 1975; ENEA, 1975-1992; ANPA, 1992-1995; ENEA, 1978-95

Radioactive contamination appears not to be a problem in the Mediterranean Sea. The major source of anthropogenic radionuclides is fallout from past nuclear weapon testing and from the Chernobyl accident.

Overall, the total inventory of radionuclides in the Mediterranean Sea is declining. In surface waters the levels of ^{137}Cs (Caesium) and ^{239,240}Pu (Plutonium) show decreasing trends. In marine organisms used for human consumption, ^{137}Cs concentration is very low (less than 1 Bq / kg), far below the limit (600 Bq / kg) fixed by the EU as the maximum permitted level in food

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Nuclear facilities in the Mediterranean basin are mainly located along rivers and their effluents are subjected to riverine geochemical processes that delay, to a considerable extent, output to the sea. The contribution from these installations into the sea is low and limited to confined areas which are regularly monitored by national authorities.

Climate change

Assessment of potential impacts of climate changes in the Mediterranean region, based on several case studies were carried out by UNEP / MAP and include drought, floods, changed soil erosion and desertification processes, storms, coastal erosion, seawater temperature and salinity currents together with sealevel rise and biodiversity reduction.

Recent paleoclimatic data collected in geologically stable areas, combined with archaeological or historical evidence, indicate that sea level increase for the next century (2100) could be limited within 30 cm, taking into account the pace of anthopogenic enhancement of sealevel rise. This scenario is compatible with the lower limits range indicated by IPCC.

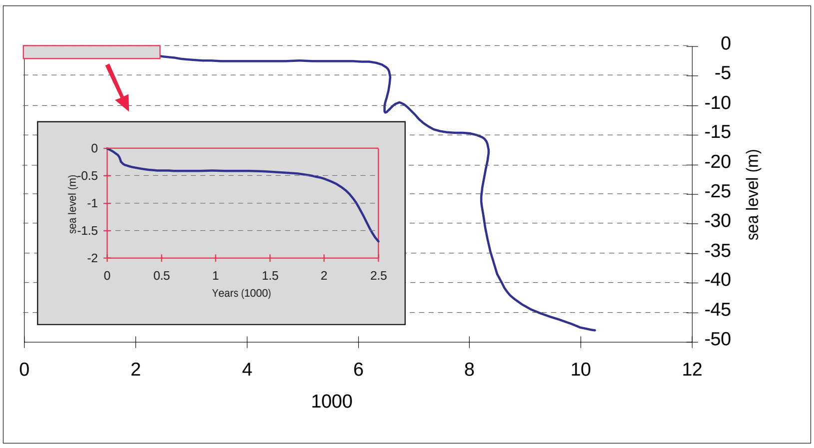
Major potential impacts identified in the UNEP/ MAP studies

Delta of Ebro, Spain	increased coastal erosion; reshaping of coastline; loss and flooding of wetlands; reduced fisheries yield
Delta of Rhône, France	erosion of unstable or threatened parts of coastline; reduction of wetlands and agricultural land; increased impact of waves; increased salinisation of coastal lakes; destabilisation of dunes; intensified tourism
Delta of Po, Italy	increased flooding and high-water events; increased coastal erosion; retreat of dunes; damage to coastal infrastructure; salinisation of soils; alteration to seasonal water discharge regimes; reduced near-shore water mixing and primary production; increased bottom water anoxia
Delta of Nile, Egypt	increased coastal erosion; overtopping of coastal defences and increased flooding; damage to port and city infrastructure; retreat of barrier dunes; decreased soil moisture; increased soil and lagoon water salinity; decreased fisheries production
Ichkeul-Bizerte, Tunisia	increased evapotranspiration leading to decreased soil moisture, reduced lake fertility and enhanced salinity; increased salinity of the lakes and shift to marine fish fauna; reduced extent of wetlands and loss of waterfowl habitat
Thermaikos Gulf, Greece	inundation of coastal lowlands; saline water penetration in rivers; drowning of marshland; increased sea water stratification and bottom anoxia; decreased river run-off; salinization of ground water; decreased soil fertility; damage to coastal protective structures; extension of tourist season
Island of Rhodes, Greece	increased coastal erosion; salinisation of aquifers; increased soil erosion
Maltese Islands, Malta	salinisation of aquifers; increased soil erosion; loss of fresh-water habitats; increased risk for human health, livestock and crops from pathogens and pests
Kaštela Bay, Croatia	inundation of Pantana spring and Zrnovica estuary; increased salinization of estuaries and groundwater; negative impact on coastal services and infrastructure; accelerated deterioration of historic buildings; increase in domestic, industrial and agricultural water requirements
Syrian coast	increased soil erosion; modification of vegetation cover due to increased aridity; increased salinisation of aquifers; erosion of beaches and damage to coastal structures and human settlements due to exceptional storm surges
Cres-Lolinj, Croatia	increased salinisation of lake Vrana; extension of tourist season; increased risk from forest fires
Albanian coast, Albania	salinisation of coastal aquifers and shortage of adequate quality of drinking water; soil erosion (physical); extension of summer drought; extension of tourist season
Fuka-Matrouh, Egypt	increased evapotranspiration and decreased rainfall; extension of summer aridity; increased coastal erosion; flooding in eastern part; decreased soil fertility
Sfax coastal area, Tunisia	salinisation of ground water; increased rainfall; possible flooding

Source: UNEP/MAP

Although the physical impact of climate changes can be better predicted, with the constant improvement of the accuracy of models, data obtained on the Mediterranean spatial scale are still somewhat unreliable for the assessment and solution of practical problems. It is also more difficult to estimate the impact of such physical changes on the future socio-economic framework of the threatened areas and countries, especially if considered in conjunction with other threats posed by human activity.

Sea-level rise in the Mediterranean region over the past 10 000 years



Source of data: *Pirazzoli, 1991, Antonioli* et al., *in press*

Biodiversity and ecosystem changes

Mediterranean marine fauna and flora provide a rich diversity of species which represent 8-9 % of world seas species richness (4-18 % according to the group of species considered e.g. mollusc, echinoderms, crustaceans etc).

The Mediterranean marine ecosystem is a high-diversity ecosystem. As such, it is highly vulnerable to environmental perturbation and the impact of pressures is expected to be more significant. Such perturbations in marine and coastal environment include pollution, over-exploitation of marine living resources, habitat erosion, climatic changes (e.g. through the greenhouse effect), introduction of non-indigenous species and other human activities leading to environmental degradation.

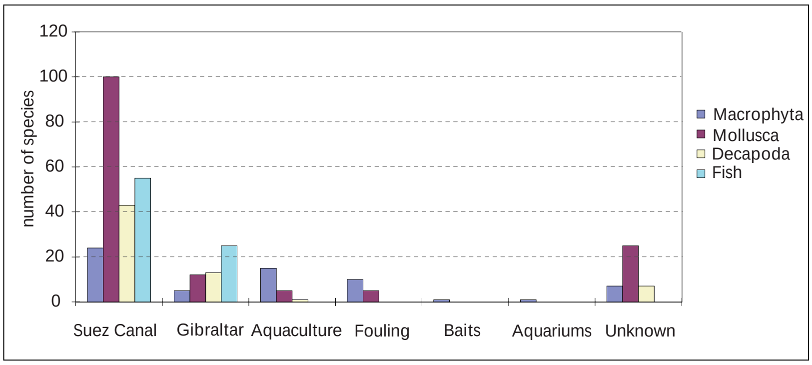
Mediterranean fisheries resources are in a state of over-exploitation driven by rising prices and demand in the past decades. Over-fishing and fishing practices largely account for the impact on natural stocks and habitats:

- demersal fish stocks (close to the sea bottom) are usually fully exploited, if not over-exploited, with a general trend towards smaller individual sizes;
- small pelagic fish stocks are highly variable in abundance (depending on environmental conditions) and probably not fully exploited except perhaps, for the anchovy resources;
- large pelagic fish stocks (tuna and swordfish) are overexploited also by international industrial fleets, especially the red tuna for which the Mediterranean is an important spawning area;
- habitats of high biological significance, such as the *Posidonia oceanica* meadows, are frequently destroyed by trawl-nets operating close to the shore.

Introduction of non-indigenous species is not a recent phenomenon in the Mediterranean Sea. A massive introduction of tropical species to the Red Sea was observed after the construction of the Suez Canal in 1869 (Lessepsian migration called after the famous Canal engineer Ferdinand de Lesseps). Other species are also being imported through transportation or intentionally through aquaculture practice.

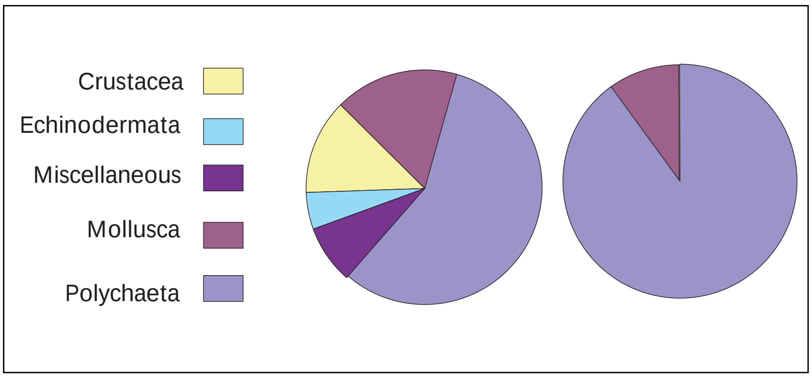
Reduction of habitats caused by anthropogenic pressures, coastal land development and coastal eutrophication, impacting directly on productivity but also on nursery grounds, leads to a reduction in biodiversity and ecosystem changes. No general effects of species disappearance have been ascertained for the Mediterranean Sea. Nevertheless, changes in species composition and richness have been detected for some seas in the Mediterranean Sea. Habitat loss or reduction that potentially could lead to extinction has been reported for species which are considered endangered such as Monk seal and other marine mammals, red coral, sea turtles and colonial water birds.

Example of introduction routes for non-indigenous species in the Mediterranean Sea



Data Sources: ETC/MCE compilation based on: Ribera & Boudouresque, 1995; National Centre for Marine Research, Greece data; CIESM 1999a; CIESM 1999b

Composition of Benthic communities in an undisturbed (left pie) and in a polluted area (right pie).



Source: ETC/MCE compilation, data from NCMR

List of endangered or threatened marine and freshwater species in the Mediterranean. (Annex II of the Protocol concerning Specially Protected areas and Biological Diversity in the Mediterranean Sea adopted in the Barcelona Convention in 1996; revised in the Bern Convention, 1998)

Magnollophyta
Posidonia oceanica
Zostera marina
Zostera noltii

Chlorophyta
Caulerpa ollivieri

Phaeophyta
Cystoseira amentacea
Cystoseira mediterranea
Cystoseira sedoides
Cystoseira spinosa
Cystoseira zosteroides
Laminaria rodriguezii

Rhodophyta
Goniolithon byssoides
Lithophyllum lichenoides
Ptilophora mediterranea
Schimmelmannia schoubsboei

Porifera
Asbestopluma hypogea
Aplysina cavernicola
Axinella cannabina
Axinella polypoides
Geodia cydonium
Ircinia foetida
Ircinia pipetta
Petrobiona massiliana
Tethya sp. plur.

Cnidaria
Astroides calycularis
Errina aspera
Gerardia savaglia

Echinodermata
Asterina pancerii
Centrostephanus longispinus
Ophidiaster ophidianus

Bryozoa
Hornera lichenoides

Crustacea
Ocypode cursor
Pachylasma giganteum

Mollusca
Charonia lampas lampas
Charonia tritonis variegata
Dendropoma petraeum
Erosaria spurca
Gibbula nivosa
Lithophaga lithophaga
Luria lurida
Mitra zonata
Patella ferruginea
Patella nigra
Pholas dactylus
Pinna nobilis
Pinna rudis
Ranella olearia
Schilderia achatidea
Tonna galea
Zonaria pyrum

Pisces
Acipenser naccarii
Acipenser sturio
Aphanius fasciatus
Aphanius iberus
Carcharodon carcharias
Cetorhinus maximus
Hippocampus hippocampus
Hippocampus ramulosus
Huso huso
Lethenteron zanandreai
Mobula mobula
Pomatoschistus canestrinii
Pomatoschistus tortonesei
Valencia hispanica
Valencia letourneuxi

Reptiles
Caretta caretta
Chelonia mydas
Dermochelys coriacea
Eretmochelys imbricata
Lepidochelys kempii
Trionyx triunguis

Mammalia
Balaenoptera acutorostrata
Balaenoptera borealis
Balaenoptera physalus
Delphinus delphis
Eubalaena glacialis
Globicephala melas
Grampus griseus
Kogia simus
Megaptera novaeangliae
Mesoplodon densirostris
Monachus monachus
Orcinus orca
Phocoena phocoena
Physeter macrocephalus
Pseudorca crassidens
Stenella coeruleoalba
Steno bredanensis
Tursiops truncatus
Ziphius cavirostris

Responses

The Mediterranean Action Plan

In 1975, the Mediterranean countries and the EEC adopted the Mediterranean Action Plan (MAP) and in 1976 the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention). The Convention envisages the preparation of technical protocols.

The main objectives of MAP were to assist the Mediterranean governments to assess and control marine pollution, to formulate their national environment policies, to improve the ability of governments to identify better options for alternative patterns of development and to make better rational choices for allocation of resources. The MED POL programme, major component of MAP, played a leading role in upgrading the technical capabilities of most Mediterranean countries (1975-1981). In its second phase it developed and maintained national monitoring programmes in the region.

A large number of concrete actions were taken by several countries in conformity with the requirements and provisions of MAP, thus influencing the environmental policies and practices of the Mediterranean countries.

In 1995 a new phase of MAP was approved, and was renamed 'Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean'. This second phase was designed taking into account the achievements and shortcomings of MAP's first twenty years of existence, as well as the results of recent developments such as the United Nations Conference on Environment and Development (Rio de Janeiro, 1992).

In the meantime, MED POL has entered its third phase shifting emphasis from pollution assessment to pollution control by means of action plans, programmes and measures for the prevention and control of pollution, for the mitigation of impacts and for the restoration of systems already damaged by pollution.

EU programmes

There are several EU and international programmes and projects which deal with one or more aspects of the environment in the Mediterranean. Furthermore, a good share of other EU programmes which cannot be classified strictly as environmental programmes, falling under 'regional development' trans-national co-operation; telecommunication, etc, also have some important environmental component. These arise also from the incorporation of environmental concerns in sectoral policies and planning as requested by the consolidated EU treaty (The Amsterdam Treaty). However, information on environmental programmes, funding and projects within the EU is fragmented, the environment being a transversal issue which is dealt with by several Commission Directorates General (DGs).

The following list of the EU programmes is not complete but it is worth mentioning some of the projects that have an impact on the information, knowledge and actions of the Mediterranean marine and coastal environment:

1. The **MEDA** programme is part of the creation of a Euro-Mediterranean free-trade zone and has stressed the need for continuing cooperation in the sectors of energy policy, environment, water policy, maritime transport, agriculture, reducing food dependency, developing regional infrastructure, and the transfer of technology.
2. The Short and Medium-term Priority Environmental Action Programme **(SMAP)** is a framework programme of action for the protection of the Mediterranean environment, within the context of the Euro-Mediterranean Partnership.
3. **LIFE Third Countries**, includes 15 Mediterranean countries and provides, inter alia, funds for technical assistance in the establishment of environmental administrative structures.
4. DG Marine Science and Technology **(MAST)** Programme, especially under the two Mediterranean Targeted Projects (MTP 1 and MTP 2-MATER) and **MEDATLAS**. MTP 1 and 2 represent a major effort in the understanding of the Mediterranean Sea today (both western and eastern basins).
5. Environment and Climate Programmes with major focus on European Land-Ocean Interaction Studies **(ELOISE)**.
6. The **AVICENNE** programme, covering areas of action such as organic and inorganic pollutants and their effects on the environment (cooperation with the Maghreb and the countries of the Mediterranean basin).
7. The **FAIR** programme had the aims of promoting and harmonising research in the major European primary food and non-food sectors including agriculture, forestry, fisheries and aquaculture.
8. **RECITE** and **ECOS OUVERTURE** programmes, stimulating inter-regional cooperation among EU member states and third countries in the Mediterranean basin on topics which are relevant at regional level.
9. **INTERREG** funds actions and studies for transnational strategies, identification of environmentally sensitive areas, actions to improve the territorial management of the marine areas at the periphery of the European Union, based on both economic development and environmental protection and improvement (e.g. integrated coastal development, prevention and control of sea pollution, and environmental protection).
10. **TERRA** programme within the framework of Article 10 of the European Regional Development Fund (ERDF) Regulation.
11. A concurrent growing quest at local level for management tools capable of jointly tackling local environmental problems and social and economic growth, has spurred the launch by the EU Commission of a specific Demonstration Programme for Integrated Coastal Zone Management (**ICZM Demonstration Programme**) with the close co-operation of three Directorates: DG Environment, DG Fisheries and DG Regional policies, and with the participation of DG Research, the JRC (Joint Research Centre) and EEA.

Many regional programmes have also been launched in co-operation with other multilateral organisations or international NGOs which are active in the region.

In November 1997 a meeting of environmental ministers held in Helsinki identified desertification and integrated coastal zone management as environmental priorities in the Mediterranean, together with the conservation and sustainable use of biodiversity as a 'horizontal' environmental issue.

Barcelona Convention and its Protocols

	Title	Adopted	Entered	Amended	New Title
	Barcelona Convention				
	Convention for the Protection of the Mediterranean Sea Against Pollution	Barcelona, Spain, 16.2.1976	12.2.1978	Barcelona, Spain, 9-10.6.1995	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean
1	Dumping Protocol				
	Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	Barcelona, Spain, 16.2.1976	12.2.1978	Barcelona, Spain, 9-10.6.1995	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea
2	Emergency Protocol				
	Protocol Concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency	Barcelona, Spain, 16.2.1976	12.2.1978		
3	Land-Based Sources (LBS) Protocol				
	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources	Athens, Greece, 17.5.1980	17.6.1983	Syracusa, Italy, 6-7.3.1996	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources and Activities
4	Protocol Concerning Specially Protected Areas				
	Protocol Concerning Mediterranean Specially Protected Areas	Geneva, Switzerland 3.4.1982	23.3.1986	Barcelona, Spain, 9 - 10.6.1995 The new Protocol includes Annexes which were adopted in Monaco, on 24.11.1996	Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean
5	Offshore Protocol				
	Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil	Madrid, Spain, 14.10.1994	in process of ratification		
6	Hazardous Wastes Protocol				
	Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal	Izmir, Turkey, 1.10.1996	in process of ratification		

Source UNEP/MAP

Conclusions and recommendations

State of the Mediterranean Sea

The state of the open waters in the Mediterranean Sea, based on the available information presented and assessed in this report, is considered to be generally good. In coastal areas, the presence of pollution hot spots, located generally in semi-enclosed gulfs and bays near important harbours, big cities and industrial areas, is probably the major problem of the Mediterranean Sea. Waters in the open sea are classified among the poorest in nutrients of the world ocean; marine ecosystems still seem to function well and the Mediterranean Sea is characterised by a high diversity of marine species. Nevertheless, in several cases, natural peculiarities (e.g. seawater movement and circulation patterns) determine the state of the Mediterranean Sea and, together with pressures deriving from coastal anthropogenic activities, create hot spots which pose adverse local environmental impacts and could be persistent.

In contrast to relatively favourable conditions of the Mediterranean Sea itself, only a small percentage of its coastal zone is still in pristine condition, of which an even smaller proportion is protected. This report shows that the current threats (e.g. localised eutrophication, heavy metals, organic and microbial pollution, oil spills, introduction of non-indigenous species) are mainly the results of pressures from anthropogenic activities and hence more attention to their management and control is needed.

Land-based activities (urbanisation, industry and agriculture) represent the main source of pollution into the Mediterranean Sea, although many uncertainties remain regarding their respective contribution, the different fluxes (rivers, atmosphere, non-point sources, etc.) and the fate of the contaminants they generate. In the case of urban and industrial pollution, the main problem is the rapid population growth along the southern coasts of the Mediterranean, where there are fewer legal instruments and lesser environmental infrastructure investments.

The pressure from tourism, especially in the northern Mediterranean countries, is one of the problems that have to be managed effectively to avoid any further degradation of the marine and coastal environment.

Recommended measures

The report also identifies several major issues, which need to be addressed to ensure higher environmental quality and better integrated information from the region:

1. **Climate change:** Multi-disciplinary research is still needed to assess the major environmental and socio-economic problems that may follow from accelerated sea level rise, erosion and desertification, floods and other threats that originate from climate change, and to distinguish natural fluctuations from the effects of anthropogenic activities.

2. **Biodiversity:** The creation of marine parks and protected areas for conservation purposes is often not sufficient as an impact-control measure, since many of the impacts derive from pressures that are not locally originated. Mediterranean wilderness and important habitats need to be protected as the Mediterranean Sea is recognised as one of the richest biotopes in the world with about 6% of the global total of higher species. Protection of the wilderness and habitats of the Mediterranean Sea requires integrated environmental management. As the coasts are heavily populated and co-ordinated action plans for environmental management are still lacking in most places, there is a threat that the number of important habitats will decline and impacts on biodiversity will become more evident.

   The following actions should be considered in order to further protect the ecosystem balance:

   · Develop national and Mediterranean-wide co-ordinated plans for environmental management and infrastructure development, with specific attention to the coastal zones;

   · introduce effective measures for environmental protection from threats arising from sea transport, coastal works and sea exploitation activities;

   · promote the implementation of the provisions of the (CBD) Convention for Conservation of Biological Diversity and of the Mediterranean protocol on specially protected areas and biodiversity at national level in the Mediterranean, including the development of national strategies for the conservation of biodiversity, adopting the biogeographic regional approach suggested by technical bodies of the CBD;

   · promote the implementation of the existing action plans for the protection of the threatened species in the Mediterranean;

   · increase protection of the remnants of pristine areas.

3. **Sewage discharges:** Sewage treatment plants are still missing from urban areas along the coasts and about 60 % of urban waste disposed in the Mediterranean Sea is still untreated. Based on the existing information, sewage should be discharged after advanced treatment in adequately designed treatment plants. The technology is available and reasonably cheap. As analysed convincingly by several studies, the health costs and other economic losses, especially in tourist areas due to contamination of coastal waters, is much higher than the investment necessary for achieving an acceptable sewage effluent quality.

4. **Agriculture practices:** In most Mediterranean countries, all types of agricultural practices and land use are treated as non-point sources of water pollution. It is very difficult to estimate the input from these diffused sources into the Mediterranean Sea quantitatively. Countries should adopt a holistic

approach to waterresource management, based on the integrated assessment of water quality and ecosystem health, from the coastal waters to the entire catchment area.

5. **Fisheries**: Control of fishing effort is an urgent priority identified by the General Fisheries Council for the Mediterranean (GFCM); although one must not forget that coastal fisheries by small scale boats play an important social and economic role along the Mediterranean coast.

6. **Marine aquaculture:** Careful selection of sites, with precise definition of their carrying capacity, needs to be regulated and enforced. Open sea practices should be further developed to avoid adverse coastal impacts.

7. **Oil pollution:** Oil reception facilities should be recommended for all big ports along the basin. The areas around straits and ports already appear to be top priorities for planning and protection.

8. **Coastal zones:** An integrated approach to coastal zone management and physical planning are still missing. Decisions and management of the coastal zones should be made at regional, national and local level, taking into account the driving forces and pressures of the human activities including tourism in order to integrate environmental protection into economic development. Integrated coastal zone management can be a success story only if the experience and expertise are maximised and the allocation of budgets to projects which take into account the holistic environmental dimension is enhanced. Organisational and legal instruments - including market-based instruments - should be developed to control and manage coastal development, land reclamation and groundwater exploitation.

Improvement of data availability

One of the major concerns identified in the report which emerges from the different issues dealt with in individual chapters is the scarcity or unavailability of comparable and, in some cases, reliable data for the Mediterranean basin as a whole. For the assessment of the state and pressures of the marine and coastal Mediterranean environment, the following missing elements in information have been identified:

1. **Coastal erosion:** Information - and access to existing information for its compilation at the regional level - is not available throughout the basin. Dispersal of the data among different administrative bodies, lack of knowledge of the existing inventories, data contained in reports considered confidential (or accessible only through long and hard administrative procedures) make the problem worse. Uncertainties about the evolution of numerous coastal segments still exist in cartographic atlases. The coastal evolution trends are thus often considered on the basis of expert judgements in the absence of studies or preliminary measurements.

2. **Contaminants:** Although a large effort has been made through the MED POL programme, there is still a scarcity of data from some regions. The monitoring capabilities of some Mediterranean countries have to be improved.

3. **Oil pollution:** Attention should be given at the planning stage to identifying areas that need protection, their order of priority and the techniques to be used.

4. **Microbial pollution:** The problems of the effects of microbial pollution in the Mediterranean coastal zone persist and are mainly related to urban waste water. Further research and data on virus contamination is required on a basin scale. The geographical imbalance of data is more acute. Intake of pathogenic micro-organisms causing damage to health on a Mediterranean-wide basis still has to be determined. Furthermore, there are still large stretches of the Mediterranean coastal zone, mainly in the southern and eastern parts, for which records are very sparse.

5. **Sewage discharges:** There is a need for further data and information on water quality and the operation of sewage treatment plants to be available.

6. **Radionuclides:** Information on radionuclide distribution is missing from some areas of the Mediterranean Sea, particularly from the eastern and southern basins; background data should be established in these areas.

7. **Fisheries:** Knowledge of Mediterranean fisheries needs to be improved. This will to a large extent depend on the quality of

statistics, which is still one of the main weaknesses in dealing with real amounts of catches for the different species, as well as the structure and capacity of the different types of fishing fleets.

8. **Biodiversity**: A specific inter-Mediterranean approach to the monitoring of marine biodiversity - and the identification of important risks threatening the present state - is still missing. In order to avoid biodiversity reduction special attention is essential in species introductions and habitat loss. Research on processes related to ecosystem changes and rehabilitation of degraded coastal ecosystems is also required.

The information collected by the countries around the Mediterranean Sea is not easily accessible as it is scattered in various departments and institutions and in many cases it is not available in electronic form. It is vital that this information is centrally gathered in electronic form in a national database, as for example the exercise with the National Oceanographic Data Centres (NODC), so that it can be utilised easily by decision makers in the administration and by other partners.

EEA, ETC/MCE and MAP could help establish the databases by giving guidance at the relevant technical level in the Mediterranean countries following the standard procedures that were adopted at basin level under the MEDPOL programme and making use of the experience and involvement in this field of the European Information and Observation Network (EIONET), co-ordinated by EEA.

Mediterranean monitoring

Development of an effective, common Mediterranean monitoring system of measurements of contaminants and their effects is still missing, although monitoring in the Mediterranean has been in place for a long time (for example, the MED POL programme initiated monitoring activities in 1975). Unfortunately, this monitoring has not been very effective and data is often unavailable. However, the plan of data gathering from Mediterranean Countries has not been consistent and large data gaps can be identified both temporally and geographically. Effective monitoring would include the following elements:

- Information useful for the protection of human health, e.g. levels of contaminants in seafood, microbial quality of bathing and shellfish growing waters, and algal toxins;
- information useful for the assessment of the effectiveness of pollution control and abatement measures taken (trends);
- support for implementation of the protocol of the Barcelona Convention in order to contribute to the reduction of pollution from land-based sources, especially the hot-spots;
- information useful for coastal zone management;
- an early warning system (bio-markers). Research would probably be needed in order to identify sources of pollution (e.g. non-point sources in agriculture) and biological effects of long-range pollutants.

Quality assurance and control procedures should be further developed and implemented to ensure data quality and reliability. Allocated resources should increase to enable a continuous flow of high quality data. An assistance component should be developed which could include training and establishment of contacts with more advanced laboratories (sister approach). The latter could be further developed through training and inter-calibration exercises between laboratories.

Future action could include the facilitation and coordination of responses to transboundary issues and problems. International cooperation between EU and non-EU countries, European Community bodies (CEC, EEA) and Mediterranean Institutions (MAP, CIESM, GFCM) should be further strengthened. Full implementation of the Barcelona Convention and its six protocols should be promoted at national level. Existing agreements, programmes and other cooperative efforts should be further developed to achieve maximum results and avoid duplication, while moves towards sustainable development should be reinforced at regional level. Action is needed at all policy levels; international cooperation, which should involve European Community bodies, should therefore play a fundamental role in the field of policy, research and information gathering through adequate resources directed to activities in the region.

1. Introduction

Intense human activity in regions surrounding enclosed and semi-enclosed seas, such as the Mediterranean Sea, always produce, in the long term, a strong environmental impact in the form of coastal and marine degradation and a heightened risk of more serious damage. The Mediterranean region is a clear example of a sea at risk as a result of its very long civilisation, its present permanent coastal population of approximately 130 million and the very intensive seasonal flow of tourism. Urbanisation, disposal of industrial and domestic wastes, intensive agriculture and animal husbandry, soil degradation, desertification and forest fires are in fact only a few of the many factors which have exerted pressure on the Mediterranean environment that now put its integrity at stake.

In view of the above, during the last decade in particular, and in addition to the specific measures taken by individual countries, several regional and international organisations have shown great interest in the Mediterranean basin and have launched and implemented a number of environmental programmes. In 1975 the United Nations Environment Programme (UNEP) launched the Mediterranean Action Plan (MAP) and has since then implemented several programmes covering scientific, socio-economic and legal aspects of the protection of the Mediterranean environment. In 1976, under the auspices of UNEP, the Mediterranean countries signed and ratified the Barcelona Convention for the Protection of the Mediterranean Sea and asked UNEP to act as Secretariat to the Convention through its Coordinating Unit for MAP.

As a result of the work of UNEP / MAP in the region, a large number of technical, scientific and management documents and reports have been prepared in consultation with the governments of the region (e.g. MAP Technical Reports Series). Some of them have attempted to give a more general and comprehensive picture of the state of the Mediterranean. For example, the one produced in 1989 by Blue Plan / Regional Activity Centre (RAC) on the Futures of the

The Mediterranean basin Figure 1

Source: IFREMER

Mediterranean basin and the one on the State of the Marine and Coastal Environment in the Mediterranean Region, published in 1996 in the MAP Technical Reports Series.

The European Community has also been active in scientific and policy cooperation in the region. Its most constructive role is probably the coordination of activities relating to environmental protection, socio-economics, agriculture, fisheries, etc. During the last five years, research activities of the Marine Science and Technology (MAST) Programme, part of the Fourth Framework Programme for Research and Technological Development in the European Commission, have set priorities for further oceanographic research of the Mediterranean Sea. Within MAST, the Mediterranean Targeted Project (MTP), a multi-disciplinary, large-scale project, involving approximately 200 scientists from eleven European countries, Morocco and Tunisia, has yielded important scientific results for the area. The European Union, through other programmes and initiatives such as FAIR, LIFE, TERRA, RECITE, ECOS OUVERTURE, INTERREG, etc., also includes in its priorities research, protection and management of the marine and coastal environment in the Mediterranean. Finally the MEDA programme, as part of the creation of a Euro-Mediterranean free-trade zone, will have accompanying studies and measures in the fields of energy policy, environment, water policy, maritime transport, agriculture, reducing food dependency, developing regional infrastructure and the transfer of technology.

This report, which is prepared by the European Environment Agency (EEA) and its European Topic Centre on the Marine and Coastal Environment (ETC/MCE) in cooperation with the Mediterranean Action Plan (MAP), gives an overview of the marine environment in the Mediterranean Sea and its coastal zone. The report adopts the DPSIR framework (Driving Forces/Pressures/State/Impacts/Response) that has been developed by the EEA for environmental assessment, and describes the various interactions between human activities and the environment. One of the major objectives of the report includes the identifation of possible gaps in current knowledge, especially in the field of marine environmental monitoring, by reviewing the available information on the state of the marine and coastal environment. The report does not attempt to describe in detail the activities undertaken in the region by the various bodies. The final aim is, therefore, to identify objectives and recommend actions to improve the information from the area. This can be achieved by encouraging a scheme for better use of the scientific capacity in the region, in order to produce reliable and good quality data for the understanding of the marine and coastal environment. Such a scheme will also enable regional organisations and national decision-makers to focus more accurately on the existing problems and to propose suitable priorities and action.

The report describes the Mediterranean Sea and its coastal zone by reviewing:

- its natural characteristics including morphology, seismicity, climate and hydrographic conditions in the Mediterranean Sea;
- the human activities (or driving forces), including urbanisation, tourism, loads and discharges through rivers and from coastal population, agriculture, maritime traffic, industry, oil industry and the influence of fisheries and aquaculture, which exert pressure in the marine and coastal Mediterranean environment;
- its environmental state and the main threats, including the state of eutrophication, microbial pollution and chemical and radioactive contamination in the Mediterranean marine ecosystems;
- the ecosystem sensitivity and impacts from climate change, changes in biodiversity and a discussion of environmental quality related health risks in the area; and
- the responses at the regional level, giving information about the international programmes that have been launched in the Mediterranean Sea.

The data used for the assessment are mainly taken from UNEP/MAP databases and, in particular from the MED POL (Mediterranean Pollution Assessment and Control Programme) and the Blue Plan Regional Activity Centre. Data sets from other international organisations (e.g. FAO) were also used. Scientific literature data and technical reports at national level have also been taken into consideration. The assessment has focused, where appropriate, on reliable and quality-assured data. The problem of availability of data sets has been almost a constant throughout the report with a general trend of lesser availability of data from the countries on the southern and Middle Eastern shores of the basin. Nevertheless the report - which is intended as a scientific-based document, yet not as a research-aimed publication – tries to strike a balance between sometimes contrasting perspectives presenting the dominating views in order to provide the necessary information and recommendations for management options.

Sometimes more readily available information from the northern and western countries of the Mediterranean can produce a somewhat distorted perception that environmental problems are concentrated in those areas, while this is often the result of the inevitably incomplete picture.

Finally, it should be stated that the report attempts to give an overall picture of the region based on the best available information to 1997. It is expected to provide a basic understanding of the important and characteristic features of the Mediterranean marine environment and the impacts of human activity despite the fact that in some cases recent information was missing from certain areas.

2. Natural characteristics

This chapter describes the Mediterranean Sea and its coastal zone by reviewing its natural characteristics and provides the broader frame into which information from the subsequent sections falls.

The Mediterranean Sea is an enclosed basin connected to the Atlantic Ocean by the narrow sill of the Strait of Gibraltar. Other geographical, climatic, hydrographical and morphological features described in this chapter, such as the water flow balance, are directly connected with the ecosystem and biological features.

The main features cover the morphology, seismicity and volcanic activity, climate, and physical chemical and biological oceanography. Although the coverage is quite extensive, lesser detail is given in some specific areas, such as for example in deep water oceanography or marine mammals, where the data sets on which the report was built are not homogeneously available for the whole basin.

Although any of the topics covered could fill thousands of pages on its own, this section is relatively brief, providing an introduction to the main DPSIR Assessment Framework (Driving forces / Pressures / State / Impacts / Responses).

2.1. Morphology

The Mediterranean Sea occupies an area of about 2.5 million km^2, is about 3,800 km wide from east to west, and has a maximum north-south distance of around 900 km between France and Algeria.

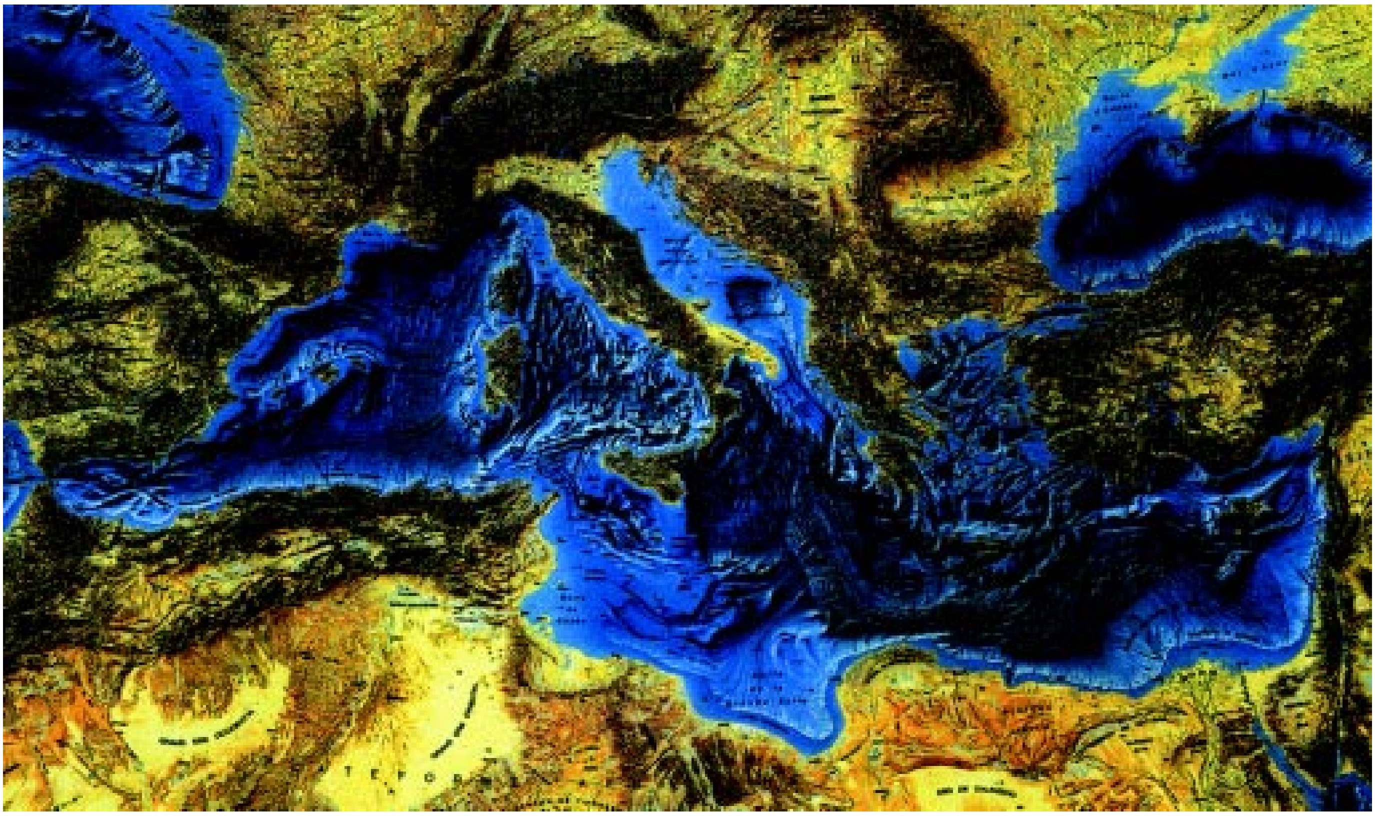
The Mediterranean Sea is the remnant of an older ocean, tens to hundreds of millions of years old and several times wider, named 'Tethys'. According to 'plate tectonics' theory, the Tethys ocean began to be consumed by the converging Euroasiatic and African continental plates some 50-70 million years ago, synchronously with the opening of the Atlantic Ocean. This process is still active, especially in the eastern part along the Hellenic Trench, where the eastern Mediterranean crust is submerging beneath the Aegean microplate, while it has only recently ceased along the Tyrrhenian Arc. Thus, the eastern part of the Mediterranean Sea is more active in terms of plate tectonics and is characterised by more complex morphology than is the western part.

The Mediterranean Sea is an enclosed sea connected to the Atlantic Ocean by the Strait of Gibraltar, a 15 km wide and 290 m deep sill, and to the Black Sea by the Strait of Çanakkale (Dardanelles), having a maximum width of only 7 km and an average depth of 55 m. The connection to the Red Sea occurs through the Suez Canal. The Mediterranean is divided into two main basins, the western and the eastern, separated by the Sicilian Channel which is about 150 km wide, reaching a maximum depth of 400 m. In contrast to the flat, 2 700 m deep basin of the western Mediterranean (west of Sardinia-Corsica), the Tyrrhenian, Ionian, Levantine and the Aegean seas are characterised by alternating deep depressions and morphological highs, submarine valleys and steep slopes. The greatest depth of the entire Mediterranean Sea, 4 982 m, is found in a narrow basin located off the shores of southwest Greece within the Hellenic Trench, along which several other small basins exceed 4 000 m in depth. The most shallow part of the Mediterranean Sea is the northern Adriatic, the depth of which does not exceed 200 m. The estimated, average depth is around 1 500 m. (**Figure 2.1**)

Morphologically, Corsica, Sardinia and the Balearic Islands are the most significant islands of the western Mediterranean basin. Sicily and Malta are located in the central part. Cyprus, Crete and Rhodes are the biggest islands in the eastern part of the Mediterranean Sea, where the 700 or more islands and islets of the Aegean archipelago form the most striking morphological feature.

Along the coastal areas, rocky shores - both hard and soft - predominate, with cliffs over 150 m high occurring in Spain and 'megacliffs' of over 1 000 m in Croatia. These are only occasionally interrupted by sandy beaches of limited length, associated with relatively narrow valleys cutting through the mountains or with small coastal plains surrounded landwards by mountainous areas

The morphology of the Mediterranean basin Figure 2.1



Source: IOC/UNESCO

(Table 2.1). Extended sandy beaches characterise the coastlines of coastal plains associated usually with significant rivers flowing into the Mediterranean Sea. Such plains are the Rhône delta area in southern France (Gulf of the Lion), the Po plain and the Taranto peninsula in northern and eastern Italy respectively, and the entire coastline of northern Africa, all along its length from Tunisia, and eastwards through Libya and Egypt to Israel.

Only a few big rivers flow into the Mediterranean Sea. The biggest in length is the Nile in Egypt, the catchment basin of which extends several thousands of kilometres into the north-eastern part of the African continent. The Nile river deposits, formed before the construction of the Aswan dam, a very impressive onshore delta plain on the coastal area of north-eastern Egypt and a huge submarine alluvial cone in front of its mouth in the Levantine Sea which, together with the submarine cone of the Rhône river, constitute some of the most striking morphological features of the Mediterranean basin. The Rhône itself rises in the central Alps in Switzerland and flows through Lake Geneva and south-eastern France to the Gulf of the Lion in the western Mediterranean Sea. The third most important river flowing out into the Mediterranean Sea is the river Po in northern Italy. The Po drains the southern flanks of the Alps and the northern part of the Apennine mountain range through the Po plain to the northern Adriatic Sea. The fourth most important river flowing into the Mediterranean Sea is the Ebro river in Spain. The large river catchments have delivered sediment to the coast as erosion of the moun-

Provisional first level coastal typology in the Mediterranean region Table 2.1.

Dominant landscape types	Components
a. Hard rock, cliffed coasts	
Karstic areas of the micro-tidal Mediterranean Sea	Sea cliffs, cliff islands, archipelagos, rias, rocky shores with caves, bay and pocket dunes, river mouths and small estuaries and embayments
b. Hard rock coastal plains	
Microtidal shores of the Mediterranean region	Karstic shores
c. Soft rock coasts	
Some parts of the coast	Tidal bedrock plains, other friable sea cliffs with e.g. shale and sandstone. Soft rock coastal bedrock plains
d. Wave-dominated sediment. Plains	
Microtidal zones	Lagoons, Black Sea limans, river deltas, dune coasts

Source: EUCC 1998

tains has taken place, thus creating new coastal habitats which include the large sedimentary coastal plains, which in micro-tidal areas in the Mediterranean region have grown to form large deltaic systems such as the Ebro Delta in Spain, the Po Delta in Italy or the coastal plain of Albania, to mention a few.

2.2. Seismic and volcanic activity in the Mediterranean region

The seismicity of the Mediterranean area began with the collision between European and African plates, which started in the Cretaceous era (70-100 million years ago) and lasted until the Miocene era (about 5-6 million years ago). From the Miocene up to the present the plates have continued to collide but the movement has been slower.

The entire Mediterranean region is characterised by the presence of microplates: the resulting geodynamic model is very complex since the microplates are moving one against another. Such plate tectonic processes are either still active (eastern Mediterranean area) or have ceased (western Mediterranean area). The seismicity of the Mediterranean area is presented in **Figure 2.3** The Azores in the Atlantic represent a triple junction between the North American, European and African plates. From these islands a system of strike-slip faults starts, crossing the Strait of Gibraltar and the southern part of Spain. The fault system develops between the Alborán Sea and western Sicily, even thrusting along a plain from east to west.

The Iberian peninsula is affected by very high seismicity both in the Pyrenean area and in Andalusia and Sierra Morena (**Figure 2.2 & Figure 2.3**). Strong earthquakes occur off the Lusitanian coasts (with damaging effects on the continent) and the Balearic Islands. Although earthquakes in the Rhône valley in south-eastern France are infrequent, those that do occur tend to be of great magnitude; it can be considered one of the areas of greatest risk in western Europe. Between Sicily and the Alps a seismic arc is present which has led to the creation of the Apennines.

The Italian peninsula is affected by great seismic activity with strong earthquakes recorded along the Apennines. These earthquakes are very damaging and affect western Sicily, the Sicilian Channel and the Apennines. In central Italy direct faults are mostly present along the Adriatic slope of the Apennines and along the Tyrrhenian coasts. In northern Italy the seismogenetic areas generate earthquakes of medium-to-high magnitude (**Figure 2.2**).

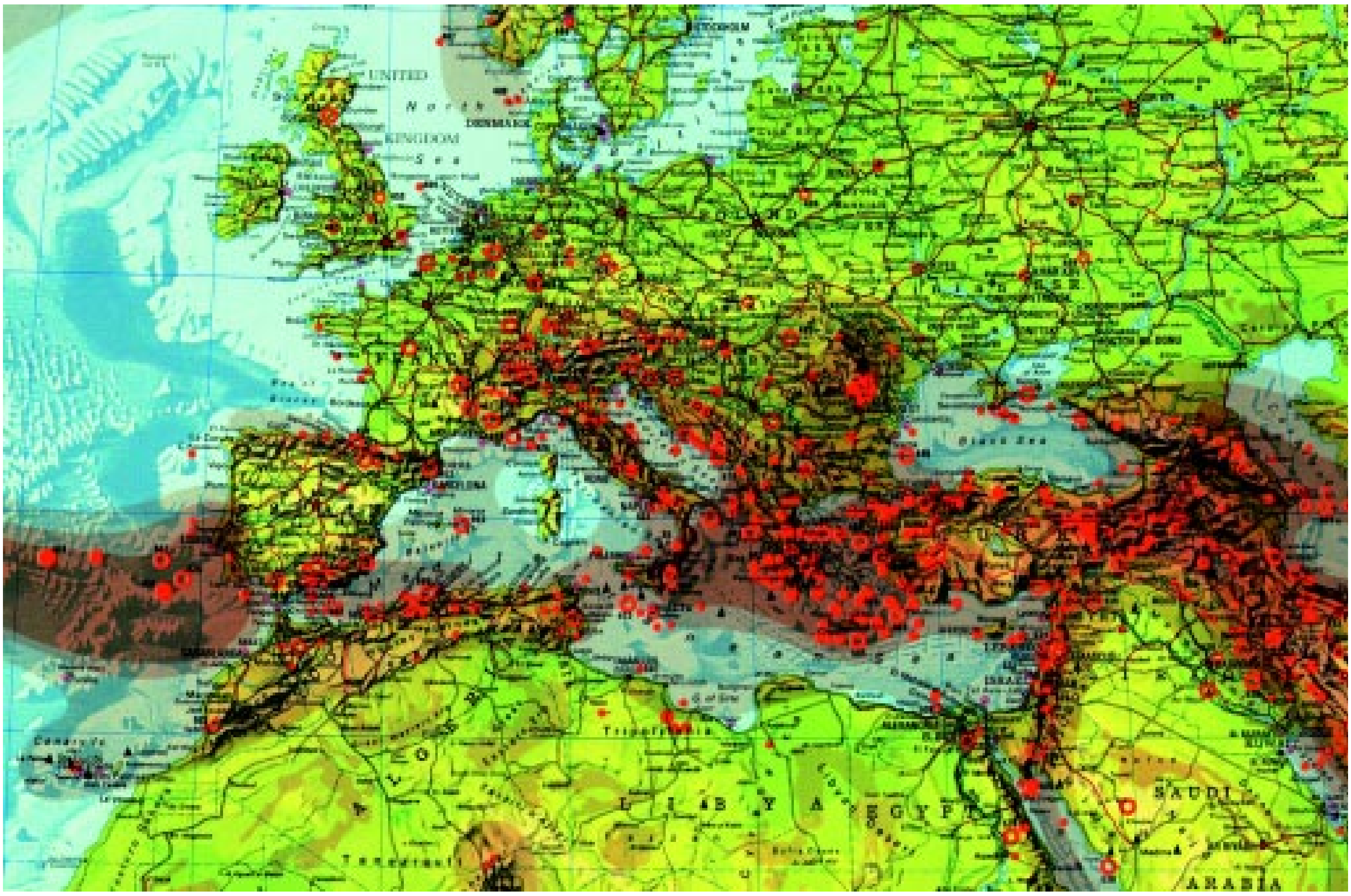
In the Alps the seismic activity is distributed along the Alpine Arc, following all the most important geological structures, from the Ligurian Pre-Alps to the Apennines, the Austrian Alps and, to a lesser extent, to the southern limestone Alps.

The Balkan Mountains have a geological structure similar to the Apennines. However, they are not subject to the stresses imposed on the Apennines. Seismic phenomena, mostly of great magnitude, spread across the zone comprising the Strait of Otranto and western Greece. Seismically, this is one of the most hazardous zones in the entire Mediterranean area and in the past it has witnessed disastrous earthquakes, especially due to the higher vulnerability of older buildings. In fact, within the last twenty years (1977-1997) earthquakes of great magnitude have afflicted extensive regions of Greece, including several large cities (**Figure 2.2**). The toll of these earthquakes included casualties, while some thousands of houses and other buildings suffered significant damage or had to be demolished. Various phenomena induced by earthquakes such as tsunamis, landslides, liquefaction, ground-sinking, etc., are responsible for a great part of the damage. The edge of the Aegean microplate, especially the Hellenic Arc and the islands of the Aegean archipelagos, is affected by seismic phenomena, generally of strong magnitude (**Figure 2.2**).

Along the Mediterranean coast of the Arabian peninsula, seismic phenomena of great magnitude are present. They are connected with the continuation of a northern branch of the rift valley system from which the Red Sea originated. They are located along the tectonic rift where the river Jordan flows. Often they strike the Mediterranean coast from the Gulf of Aqaba, in the eastern part of the Sinai peninsula to the norteastern edge of the Mediterranean. Further south, along the edge of the Arabian peninsula, on the Mediterranean Sea, seismic phenomena of strong intensity are also present (**Figure 2.2)**.

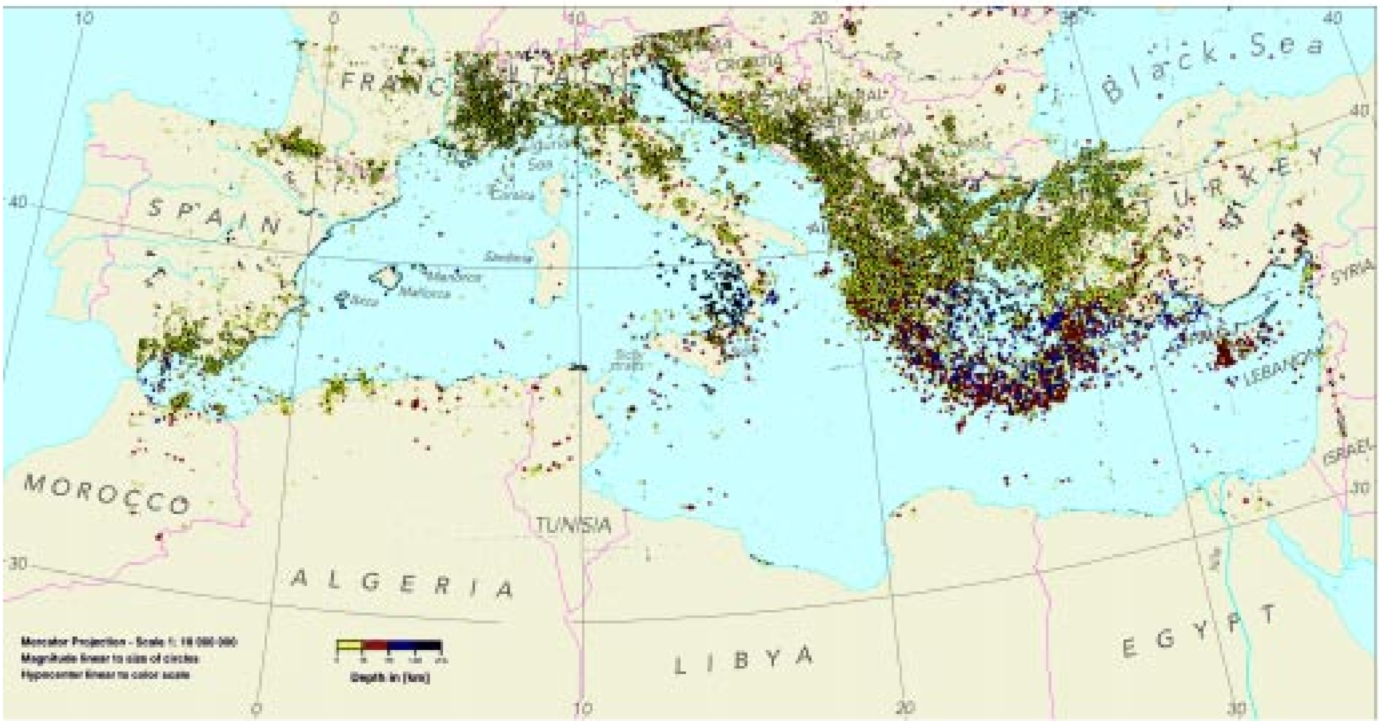
A diffused seismicity is also present to the north of the Sahara. There are very few earthquakes of great magnitude in this zone

Distribution of major earthquakes and active volcanoes in the Euro-Mediterranean region Figure 2.2



Source: Tiedemann, 1992

Seismicity of the Mediterranean Sea Figure 2.3



Source: USGSSource: NCMR

of northern Africa but it is possible to record many shocks of low to medium intensity.

Volcanoes are located in the middle part of the Mediterranean region: some in Italy, one in Greece and several submerged volcanoes in the Tyrrhenian plain. Active volcanoes are present along the magmatic arc of the Aeolian Islands, along the Italian peninsula (Etna and Vesuvius) and in Greece (Santorini) (**Figure 2.4**).

Etna's activity began during the medium-upper Pleistocene era (about 700 000 years ago) during which time it was submerged. It later rose to the surface as a result of a tectonic rise and the build-up of eruptive material. Vesuvius represents the actual prosecution of the existing volcanism on the entire Tyrrhenian edge from Tuscany to Campania, begun about 2 million years ago and continued during the Pleistocene (from 840 000 to 10 000 years ago) and the Holocene era (the last 10 000 years). At present, along the Italian peninsula, volcanic activity exists only in the Campania area in a pyroclastic form (with ash clouds and surges); it represents a phenomenon of great hazard for areas which in recent times have become more vulnerable.

The main manifestations of volcanic activity in Greece are the active volcanoes located along the Volcanic Arc in the Aegean Sea and the numerous thermal springs associated with major active fault zones distributed all over Greece. Within the caldera of the island of Santorini, the best known volcano within the Aegean Sea, four new islets were created during repeated eruptions in the last 2 000 years (46 A.D., 1570, 1707 and 1866) while a violent eruption of the volcano in antiquity is believed to have been responsible for the termination of the Minoan civilisation of Crete.

2.3. Climate

The Mediterranean climate is subjected to both subtropical and mid-latitude weather systems. It is characterised by a windy, mild, wet winter and a relatively calm, hot, dry summer; the transition periods April-May and September-October being too short to appear as well-defined seasons. The seasonal features are associated directly with the motion and development of the great pressure systems: the permanent Azores anticyclones, the great continental anticyclone of Eurasia, the low pressure over the north African desert and the tropical Atlantic. The winter months are characterised by low pressure centres over the Tyrrhenian, east Ionian and Aegean seas and high pressure over the land. In summer, the pressure pattern is dominated by competition between a ridge of high pressure from the Azores and low pressure over the Middle East originating from the south Asian monsoonal low, creating a dominantly east-west pressure gradient across the Mediterranean Sea. Most depressions (about 70%) occurring in the Mediterranean area are formed in the Gulf of Genoa although North Africa, south of the Atlas Mountains, is an important source in spring. Around one tenth enter from the Atlantic, mainly through

Figure 2.4 **Map of volcanism in the Mediterranean area**

Source: NCMR

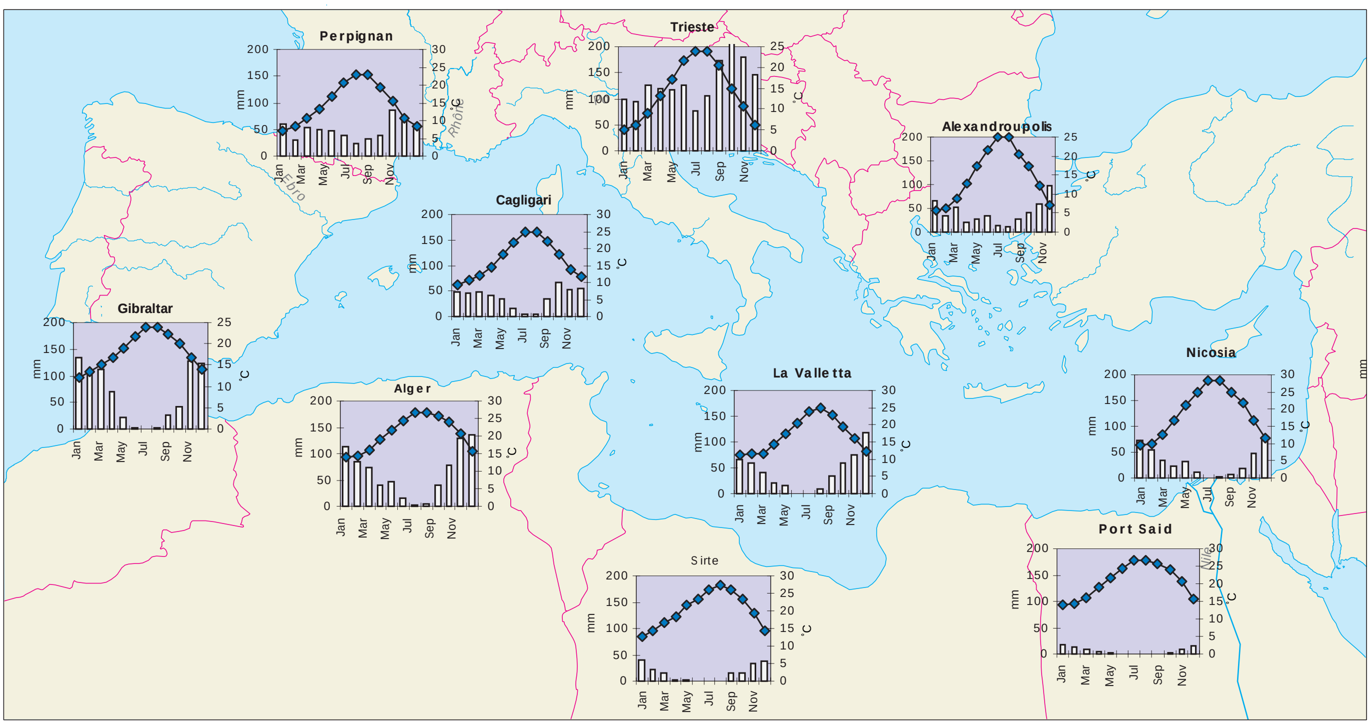
the Strait of Gibraltar or the Garonne-Carcassonne gap. In the central and eastern Mediterranean the formation of new depressions can occur in the northern Ionian Sea, the southern Aegean and in the region of Cyprus; but this is rare and limited to the winter months.

The orographic effects of the continental masses surrounding the Mediterranean basin are crucial for the vertical motion of air masses and give rise to regional and local winds. Several persistent regional wind systems are present, the strongest of them being the Mistral and the Etesian winds. The Mistral is an intense, cold, dry, north-westerly wind blowing mainly during winter down the Rhône valley between the Pyrenees and the Alps. It reaches the Gulf of the Lion and spreads over a wide area of the western Mediterranean region. The Etesian winds (or Meltems in Turkish) are the dominant winds in the eastern Mediterranean. They are northerly winds, strongest in late summer or early autumn, which are funnelled onto the Aegean Sea through the gap between the mountains of the Balkans and Anatolia. Other important wind systems are the Bora, a strong but infrequent winter wind flowing over the north Adriatic; the westerly Vendaval, flowing through the Strait of Gibraltar into the Alborán Sea between Spain and Morocco; and the Scirocco or Khamsin, a warm southerly wind from the desert areas of Africa and Arabia. Gales over the Mediterranean basin mainly occur during winter; especially in the Gulf of the Lion (with about 27 gales per year), the Aegean Sea and the Sardinian Channel (with, on average, 12 and 10 respectively).

Air temperature differences between winter and summer are generally limited to about 15°C. Nevertheless, local meteorological and geographic factors can result in extreme, exceptional conditions. The highest air temperatures are recorded near the coasts of Libya and Egypt between March and June, when they may reach as much as 50°C. High temperatures occur regularly at a number of places in the Mediterranean area, such as the lee side of the Corsican mountains, the northern coasts of Sicily, Crete and Cyprus. High air temperatures also occur in Spain when tropical continental air spreads north from Africa. Lowest temperatures are reached during winter on the shore of the Gulf of the Lion, on the north-eastern part of the Aegean Sea and the Adriatic (**Figure 2.5**).

During the wet season, from late autumn to early spring, rainfall accounts for more than 90 % of the total annual precipitation (**Figure 2.5)**. Precipitation decreases southward but geographical distribution is modified by the orography. Snow at sea level is relatively rare,

Monthly mean air temperature and precipitation from ten coastal meteorological stations in the Mediterranean area Figure 2.5



Source: May, 1982

the most affected areas being the north-eastern Adriatic and the northern part of the Aegean with about six days of snow each year, and the Gulf of the Lion and the French and Italian Riviera with an average of two or three days per year. Thunderstorms are more frequent in northern Italy and in the Balkans, especially during summer, and are also common in the western and central Mediterranean region during autumn.

2.4. Hydrography and physical oceanography

The main river flowing into the Mediterranean Sea is the Nile, with a length of 4 132 km and a catchment area of 3 350 km^2 (excluding the upper Nile); it has a discharge of 89 km^3/year at the level of the Aswan dam, but it diminishes to less than 5 km^3/year as it reaches the Mediterranean Sea. It could therefore be considered as a minor river in terms of discharges. Apart from the Nile, the main rivers are concentrated in the northern Mediterranean region. River basins are generally small, the main catchment areas being those of the Rhône, Ebro and Po extending to 96 000, 84 000 and 69 000 km^2 respectively. Nevertheless, nearly 60 % of the land area of the Mediterranean basin is occupied by catchments of less than 10 000 km^2 .

The Mediterranean Sea is characterised by high evaporation, especially under the influence of cold, dry winds. It can be defined as a 'concentration basin' because evaporation exceeds precipitation (about 800 km^3/year) and river run-off, giving an estimated freshwater deficit of about 2 500 km^3/year (**Table 2.2**).

Table 2.2 **Water contribution from main sources (in km^3/year)**

Source: Bethoux, 1980; Hopkins, 1985

Atlantic Ocean inflow-outflow	1,700
Black Sea inflow-outflow	164
Rivers	
Rhône	54
Po	46
Ebro	17
Neretva	12
Drni	11
Meriç-Evros/Ergene	10
Seyhan	8
Tiber	7
Adige	7
Other minor rivers (including Nile)	50

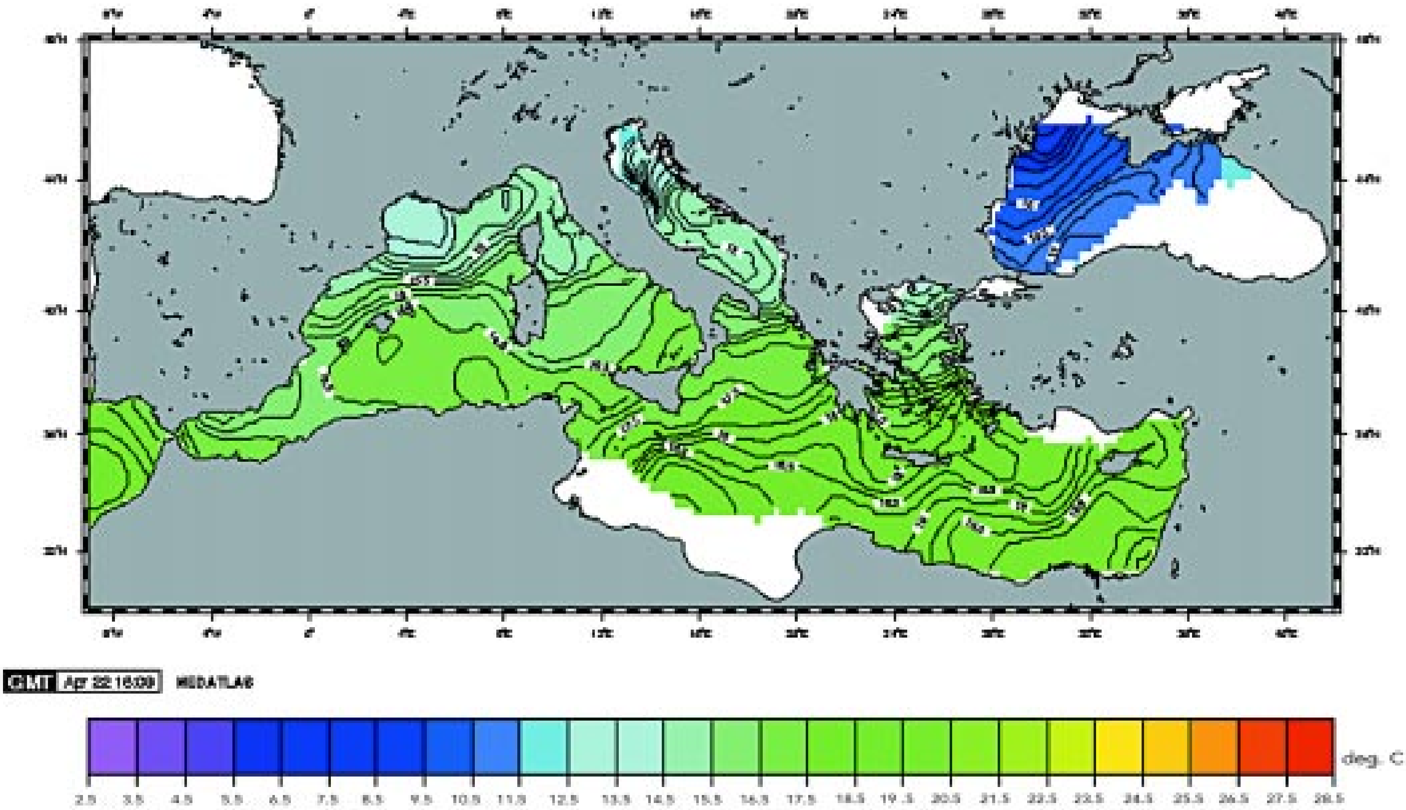
This deficit is mainly compensated for by the inflow of Atlantic Water through the Strait of Gibraltar and the water contribution from the Black Sea through the Strait of Istanbul (Bosphorus). Water exchange through the Suez Canal is considered negligible (**Table 2.2**). The limited exchange with the Atlantic Ocean and its great depth make the estimated residence-time quite high, around 75-100 years. Due to the Gibraltar Sill, the deep and cold oceanic waters cannot reach the Mediterranean Sea, whose temperature below 200 m is warmer than 12°C. Waters entering from the Atlantic in the surface layer are warmer and fresher than those flowing out (15.4°C and 36.2 psu; 13°C and 37.9 psu respectively), hence the Mediterranean Sea imports heat and exports salt.

Schematically, the Mediterranean Sea can be considered as comprising three main water masses:

- the Atlantic Water, found in the surface layer, having a thickness of 50-200 m and characterised by a salinity of 36.2 psu near Gibraltar to 38.6 psu in the Levantine basin;
- the Levantine Intermediate Water formed in the Levantine basin, lying in depth between 200-800 m, and characterised by temperatures of 13-15.5°C and salinity of 38.4-39.1 psu;
- the Mediterranean Deep Water formed in both the western and eastern basins. The Western Mediterranean Deep Water is characterised by a temperature of 12.7°C and a salinity of 38.4 psu while the Eastern Mediterranean Deep Water is characterised by a temperature of 13.6°C and a salinity of 38.7 psu.

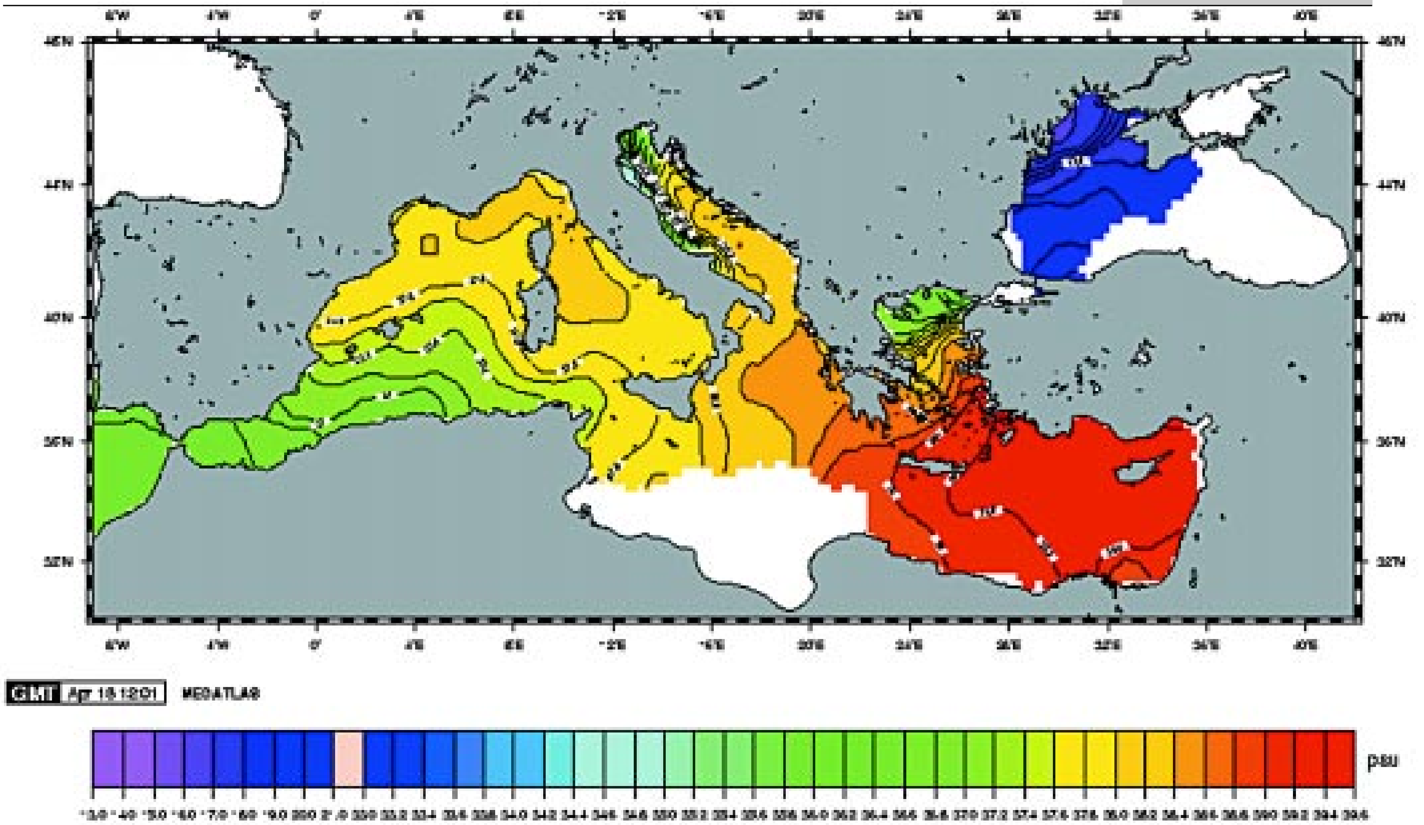
Surface temperature and salinity of the Mediterranean Sea in winter is shown in **Figure 2.6 and Figure 2.7.** However, the physical characteristics of the water masses have changed from the late 1950s (Bethoux et al., 1990). In particular, the temperature and salinity of the Western Mediterranean Deep Water have increased by 0.13°C ($3.2x10^{-3}$ °C/year) and 0.04 psu over the last 40 years (Bethoux et al., 1998); the temperature and salinity of the Levantine Water in the Sicilian Channel was observed to increase by 0.003°C/year and 0.002 psu/year (Sparnocchia et al., 1994). The causes of such changes are still debated - whether they are due to global change, or to the diversion

Sea surface temperature: climatological monthly mean (January) Figure 2.6



Source: MEDATLAS CD-ROM, IFREMER/SISMER (F), 1997

Sea surface salinity: climatological seasonal mean (winter) Figure 2.7



Source: MEDATLAS CD-ROM, IFREMER/SISMER (F), 1997

of fresh water input such as the reduction of water discharge from the Nile after the construction of the Aswan dam in 1970. Recent changes in the Eastern Mediterranean Deep Water have also been observed. Hydrographic surveys for the entire eastern Mediterranean Sea since early this century until 1987 showed that the dominant source for water below 1,200 m came from the Adriatic Sea. A survey conducted in 1995 showed that an influx of Aegean sea water replaced 20% of the Eastern Mediterranean Deep Water (Roether et al., 1996).

The large-scale circulation of the Mediterranean Sea has recently been described as being composed of sub-basin scale and meso-scale gyres interconnected and bounded by currents and jets with strong seasonal and inter-annual variability. This general circulation flow impinges on the coastal regions and strongly influences the local dynamics of currents. In fact, shelf areas in the Mediterranean are comparatively small and are separated from the deepest regions by steep continental shelf breaks. This configuration makes possible the intrusion of the large-scale flow field on the coastal / shelf areas and the direct influence of the large-scale currents on the coastal flow. Transport of material from the coastal areas to the open ocean is enhanced by this mechanism with important consequences for the maintenance of the ecological cycles in the basin.

Eddies and local current systems are also essentially part of the general circulation, due to the complexity of the topography and the presence of islands. From observational and modelling studies (Millot, 1991; POEM Group, 1992; Roussenov et al., 1994), the following major structures (**Figure 2.8**) can be identified:

- the Atlantic water jet, entering from the Strait of Gibraltar;
- the Algerian-Provençal basin features;
- the Gulf of the Lion gyre;
- the Tyrrhenian large-scale gyre;
- the Atlantic-Ionian Stream which exits in the Sicilian Channel and meanders into the Ionian Sea;
- the mid-Mediterranean jet which is an intensification of the Atlantic-Ionian Stream in the Levantine basin;
- the Rhodes and Ierapetra gyres;
- the Mersa-Matruh and Shikmona gyres.

Circulation in the intermediate levels mainly consists of the spreading of Levantine Intermediate Water, which flows out into the Atlantic through the Gibraltar Sill after a long journey from the Levantine basin. Levantine Intermediate Water also circulates cyclonically into the Tyrrhenian Sea, whence it reaches the Ligurian Sea and flows southwestward to the exit along the French and Spanish coasts.

Currents in deep layers are generally weak: circulation is mainly driven by local deep-convection events associated with intense vertical movements, while the topography limits the exchanges between the Mediterranean sub-basins. Deep-water formation is one of the most dramatic air-sea interaction processes. It generally occurs once or more each winter, in a few isolated areas predisposed to convective overturning, when atmospheric surface forcings trigger these events. Dense waters are also produced in the Adriatic Sea in the northern shelf regions during strong Bora events and circulate southward, deepening along the bottom to reach the Ionian Sea. Estimates of surface water transformed into deep water are 3 800 km^3 / year in the western Mediterranean Sea, 1 500 km^3 / year in the Adriatic and 4 500 km^3 / year in the Levantine Sea. Some circulation features which are frequently observed in some areas off the Sicilian coast produce upwellings from below the sea surface.

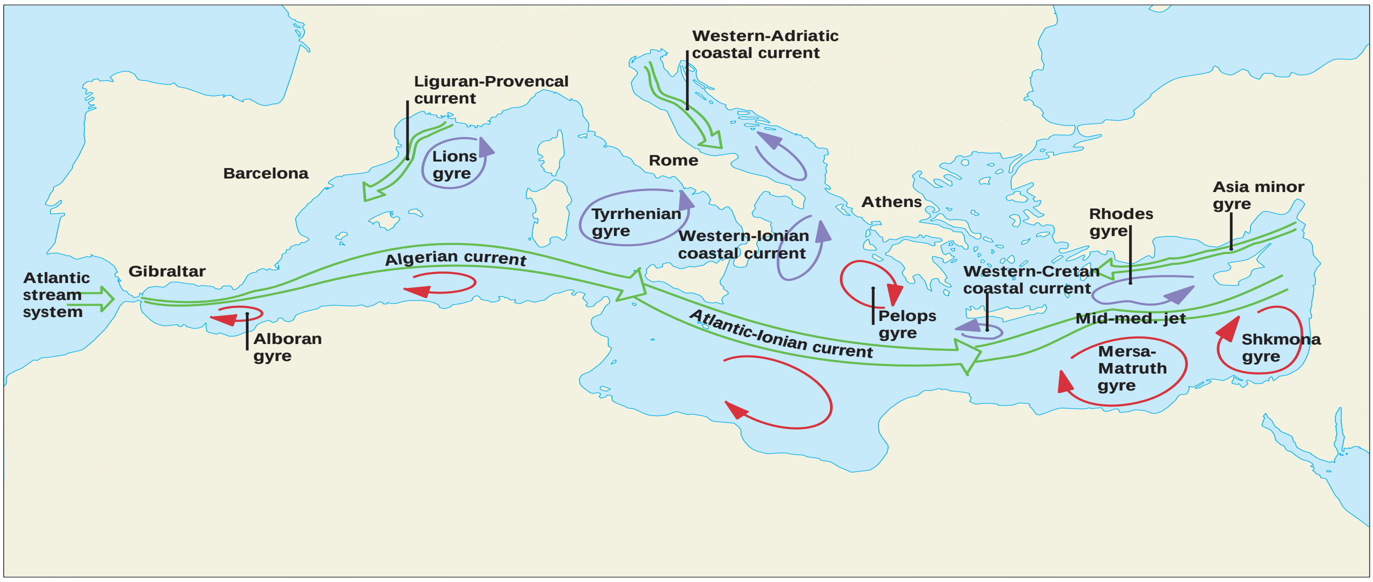
Coastal sea level variations in the Mediterranean region are generally limited to tens of centimetres, mainly due to atmospheric pressure variations and tides. Tidal amplitudes in the Mediterranean Sea are small, with prevailing semi-diurnal components. In addition, the narrow continental shelves prevent tidal amplification along the coasts, so that important tidal movements are only observed in the northern Adriatic Sea, especially when associated with particular meteorological conditions (‘acqua alta’) and, to a lesser extent, in the Gulf of Gabès in Tunisia.

2.5. Chemical oceanography

The Mediterranean Sea has long been known as an impoverished area with nutrient levels too low to support a large biomass (McGill, 1961). Recent observations confirm the general depletion of nutrient resources compared with other parts of the world’s oceans (Souvermezoglou, 1989, Salihoglou et al.,1990, Krom et al., 1991a; Krom et al., 1991b). There is a limited supply of nutrients to the surface waters of the Mediterranean Sea, both from its lower layers and from external sources (the Atlantic inflow, riverine

Main circulation features in the Mediterranean Sea

Figure 2.8



Source: Pinardi et al., 1997

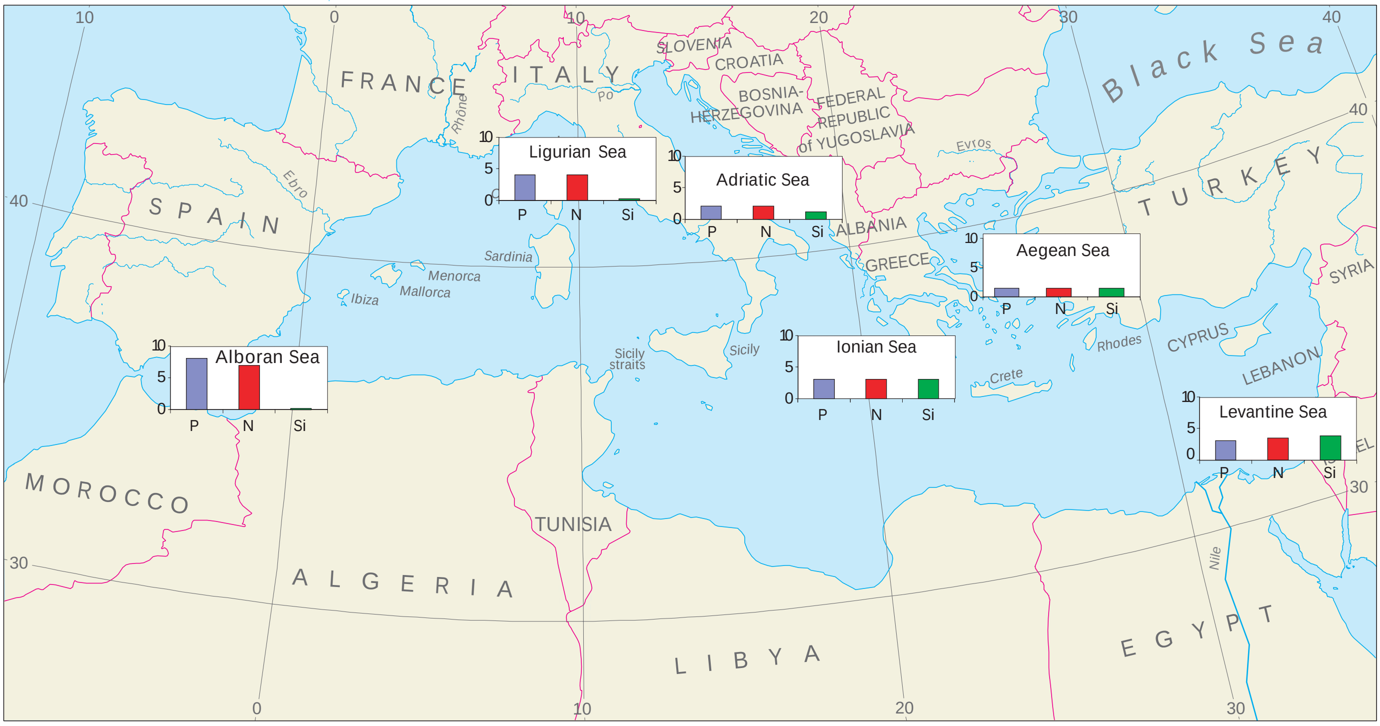
discharges, atmospheric input) but the principal reason for this poverty is related to the Mediterranean's hydrology and circulation as a concentration basin (Souvermezoglou, 1988).

The nutrient deficit in the Strait of Gibraltar varies widely with the wide range of concentration of nutrients in the inflowing and outflowing water (according to different authors). The surface water entering from the Atlantic Ocean North Atlantic Water (NAW) carries nutrients directly available for photosynthesis, but this water is low in nutrients. Estimates of inorganic forms in the inflowing waters range from 0.05 to 0.20 µM for phosphate-phosphorus, 1 to 4 µM for nitrate-nitrogen and nearly 1.2 µM for silicate-silicon (Coste et al., 1988a). Important density gradients develop in the lower part of the inflowing Atlantic waters thereby preventing the exchange with nutrient-rich subjacent basin waters (Western Mediterranean Deep Water). The nutrient content of the surface water is reduced along its propagation in the Mediterranean Sea, due to mixing with nutrient-poorer basin water and biological activity. On the other hand, the outflow of a mixture of Western Mediterranean Deep Water (EMDW) and LIW of the basin into the Atlantic Ocean, over the Gibraltar Sill, constitutes a permanent loss of nutrients and reduces their accumulation in the deep layers.

Using the nitrogen data collected during the Mediprod IV cruise and the water fluxes from Lacombe, (1971) and Bethoux, (1980), Coste et al., (1988a) calculated a nutrient deficit of about 10 % for the total nitrogen and phosphorus outflow and about 50 % for the total silicon outflow. The nutrient budgets for the total river run-off of the Mediterranean Sea also vary widely. McGill (1969) suggests that river run-off supplies the Mediterranean Sea with 30 % of the total input of nitrogen and phosphorus. The phosphorus budget by Bethoux (1981) based on UNEP (1977) data considers the contribution of terrestrial discharges to be about 80 % of the total input to the basin.

The deep waters of the different sub-basins in the Mediterranean are separated from each other through the existence of successive sills. McGill (1969) first discusses the considerable depletion of nutrients from the western to the eastern part of the Mediterranean Sea. The nutrient concentration in the Aegean Sea is twelve times lower than in the Atlantic Ocean and eight times lower than in the Alborán Sea. **Figure 2.9** represents the variation in nutrient concentration in the different regional seas, as factors of increase over the level in the Aegean (nutrient levels in the Aegean, PO_4: 0.1µM , NO_3: 2.0µM , SiO_3 : 3.0µM). The oxygen and nutrient data collected in the eastern Mediterranean Sea during the past decade, through national and international research programmes, confirmed the above observations and showed the depletion of nutrients in the following order: Levantine > Ionian > Aegean (Souvermezoglou, 1989; Stergiou et al., 1997). This depletion is of the same order of magnitude as that reported by McGill (1961, 1965).

Figure 2.9 **Relative concentrations of nutrients in the different regional seas. Aegean concentration = 1**



P = phospate, N = nitrate, Si = silicate
Source: McGill, 1965

The vertical distribution of oxygen and nutrients in the Mediterranean Sea is typical of an oligotrophic region. The surface layer generally shows very low concentrations of phosphate (<0.05 µM) and nitrate (<0.2 µM), while containing 0.5µM of silicate. This surface layer is separated from the lower layers of intermediate and deep water by a 100-200 m thick transition layer, within which the concentration of nutrients increases rapidly. The concentration of nutrients in the intermediate and deep waters in the western Mediterranean Sea are: 0.4 µM for phosphate, 8.5 µM for nitrate and 8.5 to 9.5 µM for silicate (Coste, 1987). In the eastern Mediterranean Sea the concentrations are: 0.2 to 0.3 µM for phosphate, 6.0 µM for nitrate and 8 to 9.5 µM for silicate (Souvermezoglou et al., 1992, Yilmaz & Turgul, 1997). These concentrations are considerably less than those found at the same depths in oceanic regions. The oceanic concentration of phosphate varies from 1.0 µM in the deep waters of the Atlantic to 3.0 µM in the deep waters of the Pacific, and nitrates vary from 20 µM to 40 µM respectively (Ivanoff, 1972). Oxygen levels are almost saturated in the surface layer (6 ml/l in winter and 4.8 ml/l in summer). A sharp decrease in oxygen is seen in the transition layer between LIW and DW, while in the deep water it is around 4.5 ml/l in the western and 4.2 ml/l in the eastern Mediterranean Sea. The relatively high oxygen concentrations indicate the recent character of the deep waters. A distinct minimum at intermediate depth (200-600m) cannot be observed in the eastern Mediterranean Sea as it can in the western Medieteranean Sea. This is related to the lower phytoplankton biomass and primary production found in the eastern Mediterranean Sea.

The results obtained during recent years have shown that, although the Mediterranean Sea is on the whole oligotrophic, locally and temporary high planktonic biomasses can be found. In the cyclonic regions, phytoplankton biomass and primary production are higher than in the anticyclonic regions, thereby limiting the nutrient input to the surface waters during winter mixing (Salihoglu et al., 1990; Krom et al., 1992; Souvermezoglou and Krasakopoulou, 1999a). Other reasons for the relatively high productivity are: intensive convective mixing during winter leading to vertical homogenisation; upwelling of waters from intermediate layers to the euphotic zone; and nutrient enrichment in the river plume areas.

The circulation in the north-western Mediterranean Sea (Ligurian Sea) is characterised by a permanent cyclonic circulation pattern and vertical mixing which can exceed 1 000 metres in winter. Chemical analysis revealed low oxygen and high nutrient concentrations exceeding 5 µM for N-NO_3 and 0.15 µM for P-PO_4. The primary production in this area can reach 2 $gCm^{-2}d^{-1}$ and the phytoplankton biomass 3 mg m^{-3} of chlorophyll a (Coste, 1987). The annual primary production in the western basin is reported to be about 80 $gCm^{-2}y^{-1}$ (Minas et al., 1993).

The Rhodes gyre, which occupies an extensive area in the northern Levantine Sea, is a permanent cyclonic feature within the eastern Mediterranean Sea. Convection occurring in intermediate and occasionally at great depths (Siokou-Frangou et al., 1997) leads to upwelling of nutrient-rich deep water in the euphotic zone and hence increased primary production (Salihoglu et al., 1990, Yilmaz & Turgul, 1997). The importance of these processes is more apparent when taking into account the general oligotrophy of the eastern Mediterranean Sea.

A typical example of nutrient enrichment in the river plume areas is given by the northern Adriatic Sea, one of the most productive regions in the Mediterranean (Sournia, 1973; Degobbis and Gilmartin, 1990).

The Mediterranean waters, apart from their relative nutrient poverty, usually contain more nitrogen than phosphorus and are characterised by a nitrate-phosphate atomic ratio which differs from that of the open ocean, particularly the Atlantic. The N:P ratio lies between 20 and 26 which is higher than that of the Atlantic, which conforms to the Redfield ratio (N:P = 16:1); (Redfield et al., 1963). Thus the Mediterranean Sea appears to be an exception in that phosphorus is the most important limiting factor (Berland et al., 1980). In order to explain the high N:P ratio, several hypotheses have been proposed in the literature. Bethoux & Copin-Montegut, (1986) suggest nitrogen fixation by cyanobacteria; Coste et al., (1988b) try to connect the high ratio to internal processes in the basin; and the hypothesis of Krom et al., (1991a) is based on phosphate removal by the absorption of Saharan dust particles rich in iron oxides in the eastern Mediterranean Sea.

Intensive research during the past decade revealed an unusual evolution of oxygen and nutrients in the deep and bottom layers of the eastern Mediterranean Sea. The hydrographic surveys showed that after 1987 the Adriatic Sea ceased to be the dominant source of Eastern Mediterranean Deep Water (EMDW) and Cretan Deep Water (CDW) became an important contributor (Roether et al., 1996).

The CDW flows out towards the Levantine and Ionian seas through the deeper straits of the Cretan Arc, sinks and occupies layers below 1 000-2 000 m displacing upwards the old EMDW of Adriatic origin (Souvermezoglou & Krasakopoulou 1999a). This modification provoked an increase in oxygen and a corresponding decrease in nutrients in the deep and bottom layers, not only in the open ocean adjacent to the Aegean Sea, but also in long tracts of the Ionian and Levantine seas. Since 1991, the CDW outflow is compensated by an intrusion of a water mass between LIW and EMDW Transitional Mediterranean Water (TMW) in the intermediate layers of the Cretan Sea (Balopoulos, 1997; Souvermezoglou & Krasakopoulou 1999b). This water, which is low in salinity, temperature and oxygen but rich in nutrients, fills the intermediate layers (200-600m) of the entire Cretan Sea, thus drastically changing the chemical conditions of the region. Furthermore, after 1994 a new ‘nutrient-rich’ and ‘oxygen-poor’ intermediate layer was formed in the entire Cretan Sea. The concentrations of nutrients in this layer were sometimes twice those found during previous years.

In the western Mediterranean Sea, Bethoux et al., (1992) showed an increase in phosphate and nitrate concentrations in the deep layer and tried to relate this augmentation to increasing agricultural, industrial and urban activities since the 1960s.

2.6. Biological oceanography

The characteristics of Mediterranean marine life reflect the main forcing factors of the abiotic environment (e.g. nutrient deficiency, deep-water temperature >13°C, tidal phenomena of low amplitude), as well as old and recent geological events (e.g. Tethys restriction, Quaternary glaciations). Thus, knowledge of physical constraints is fundamental to an understanding of the pelagic ecosystem.

The general scheme of annual plankton evolution is based on strong phytoplankton blooms in spring and, to a lesser extent, in autumn. This is associated with a maximum variability in temperature and salinity gradients. Pelagic blooms are at a minimum in summer and winter when physical parameters are much more stable.

As in other systems, life in the water column is ruled by trophic relations: primary producers depend on light, carbon dioxide, and nutrients.

Compared to other seas or oceans, primary productivity in the central parts of the eastern and western Mediterranean Sea as well as in many of the coastal areas away from the influence of major rivers or urban agglomerations, is rather low. Several factors may contribute to this: the distribution in time and space of fertilising mechanisms; the surface and deep circulations forced by the water exchanges taking place through the main straits; and the input of substances through rivers, run-off and atmosphere. All are of great importance to the understanding of the cycling of many important elements, including nutrients (Cruzado, 1993).

As an example, detailed hydrodynamic studies of the Ligurian Sea have shown the importance of upwelling in bringing deep nutrient-rich waters to the surface and explaining seasonal blooms in areas where water masses converge, sometimes in rather deep, offshore waters (Jacques, 1994).

Herbivorous zooplankton include copepods, salps and appendiculariae while carnivorous plankton is represented by gelatinous organisms: medusae, ctenariae, siphonophores, chaetognates, crustaceans and very small myctophidae pelagic fishes (Bellan-Santini et al., 1994).

Within their annual evolution, as already mentioned, interactions between groups of organisms and their response to natural changes are specific to each Mediterranean sub-region or physical sub-system. One of the best studied examples, thanks to a long-term series of observations going back as far as 1775, is the annual cycle of the jellyfish Pelagia in the Ligurian Sea. This is the first model of pluri-annual fluctuations in the Mediterranean Sea for a non-commercial holoplanktonic species, and a first step in understanding the mechanisms involved in pelagic ecosystems (UNEP, 1991). In these systematic observations, a close relationship between the food quality of the phytoplankton and the successive zooplankton populations has been highlighted.

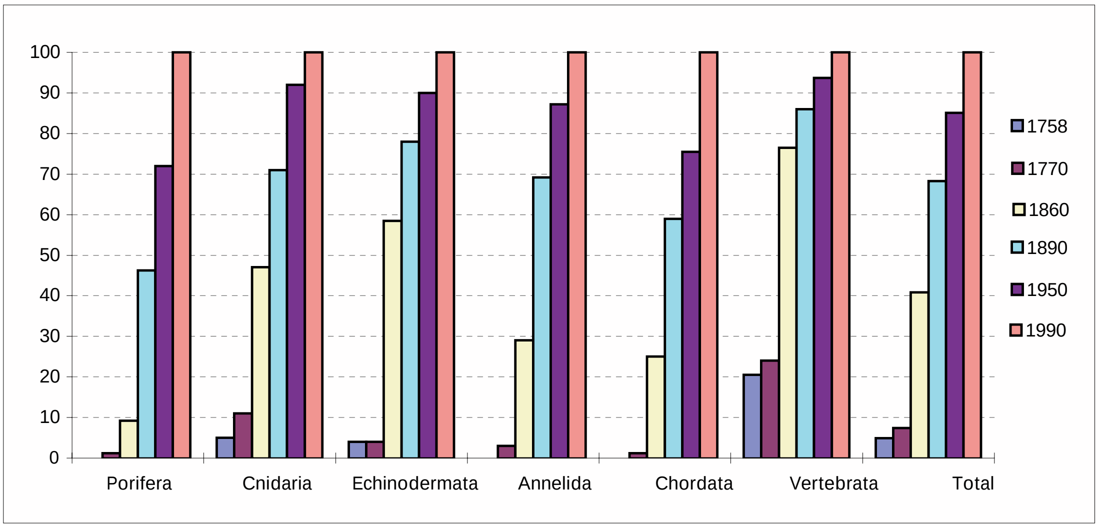
Long-term series of data regarding the fluctuations of pelagic species are thus a prerequisite to understanding the interrelation of physical and biological parameters, considering each species as a component of the whole system.

In general terms, the character of Mediterranean marine life can be summed up as having low biomass and high diversity.

With regard to diversity the Mediterranean Sea (representing only 0.8% of the area and less than 0.25% of the volume of the world

Figure 2.10 **Known number of species for 6 taxonomic groups from 1750 to 1990**

Source: Fredj et al., 1992



oceans), includes about 7% of the known world marine fauna and 18% of the world marine flora of which 28% are endemic to the Mediterranean Sea. A total of 10 000 to 12 000 marine species (with 8 500 species of macroscopic fauna) have been recorded for the Mediterranean Sea (Fredj et al., 1992; UNEP, 1997) but the progress of knowledge from the 1750s to today for new species is still increasing (**Figure 2.10**).

The most typical and well-known assemblage of communities is represented by the marine plant Posidonia oceanica ecosystem which develops as large meadows (**Photo 2.1**) in the infralittoral zone (to a depth of 25-40m) in the western as well as in the eastern basin of the Mediterranean Sea.

There are some other important areas of biodiversity such as the calcareous algal rims formed by Lithophyllum lichenoides in the mediolittoral zone; the sea caves (mediolittoral / infralittoral zones) which support several rare and endemic species (e.g. sponges and red coral) which are also found very often in the bathyal zone; and the coralligenous communities (circalittoral zone) which constitute the most spectacular underwater scenery in the Mediterranean Sea (**Photo 2.2**). On land, among others the coastal wetlands and sandy beaches are worth mentioning.

The distribution of species throughout the Mediterranean Sea is not homogeneous: it is greater in the western than in the eastern Mediterranean Sea (by a factor of two for fauna) (UNEP, 1997). In addition, the distribution of Mediterranean fauna and flora varies with depth as shown in **Table 2.3.**

This diversity is observed also at the community level. Compared with the Atlantic, the Mediterranean marine communities are rich in species with smaller individuals (Mediterranean nanism) having a shorter life cycle (Bellan-Santini et al., 1994).

As in the other seas, the relationship between species diversity and ecosystems is still poorly understood. In the context of increasing human pressure the question arises as to how far the integrity of ecosystems can be sustained in spite of the drastic decrease, not to say near disappearance, of certain species in the Mediterranean Sea (see the list of endangered Mediterranean marine species in section 5.2.2 on 'Conservation activities in the Mediterranean').

Posidonia oceanica meadow (northern Tyrrhenian Sea) Photo 2.1

Photo: Sergio Sgorbini

Corals (Ligurian Sea) Photo 2.2

Photo: Sergio Sgorbini

Table 2.3 **Variation of species according to depth zones (in %)**

Source: Fredj et al., 1992

Zones	Depth (m)	Species (%)
Infralittoral zone	50	63%
Circalittoral zone	100	44%
Bathyal zone	150	37%
Bathyal zone	200	31%
Bathyal zone	300	25%
Bathyal zone	500	18%
Bathyal zone	1,000	9%
Abyssal zone	2,000	3%

While scientific knowledge has still a long way to go before answering this question, the conservation of the rich Mediterranean biodiversity, as it is still observed in certain areas today, will require good ecosystem management practices, now and in the future.

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3. Human activities and pressures

This chapter describes the Mediterranean Sea and its coastal zone by reviewing the human activities (or driving forces), including urbanisation in coastal areas, tourism, loads and discharges from agriculture, maritime traffic, industry, and the influence of fisheries and aquaculture which exert pressures on the marine and coastal Mediterranean environment.

The starting point is the population issue, with its growth scenarios where north-south and urban versus rural development trends are clearly visible, enhanced in the region by strong seasonal / tourism-induced variations, especially along the coastline. Analysis of environmental pressure caused by sewage outfall, as an immediate consequence of dense coastal population and urbanisation, is carried out. The information provided under the sections on population growth and tourism is based on the work of the Blue Plan, which is one of MAP's regional activity centres (See Chapter 6. under the Mediterranean Action Plan for reference to all Regional Activity Centres (RACs). The Blue Plan has developed scenarios looking into different time horizons, envisaging different types of economic development, on a set of hypotheses concerning environmental awareness.

Main human activities are also reported in light of pressures on the environment. Pressures through rivers to the basin's water environment, are described in the river loads section, while the section on agriculture takes into account one, possibly the largest, of the non-point sources of environmental pressures.

Other strong features of regional human activities are recognised in the two sections dedicated to oil industry, and fisheries and aquaculture. The oil industry is analysed under the profile of crude oil inshore and offshore exploration which is increasing in the region, but mostly looking at refineries as well as pipelines and terminals, thus the kind of infrastructure which constitutes potential risk or is already classified as "hot spot". Fisheries are examined not only under the landings data profile, but also with a view to indirect pressures on the environment. Aquaculture is assessed in terms of the interactions with the surrounding environment.

Although it is recognised that air pollution based on energy and domestic and industrial wastes plays a very important role in the contamination of the Mediterranean basin, the available data unfortunately did not permit a full analysis of this issue and hence has not been included in this chapter. Finally, as the Mediterranean Sea is a major route and convergence area for international trade since ancient times, the maritime traffic was analysed.

3.1. Population growth

The population of the coastal states of the Mediterranean was 246 million in 1960, 380 million in 1990 and 450 million in 1997. Depending on the development scenarios applied, Blue Plan estimates that population will rise to 520-570 million in the year 2025 and is expected to reach approximately 600 million in the year 2050 and possibly as much as 700 million at the end of the 21st century (**Figure 3.1).**

The distribution of population between the northern and southern countries in the Mediterranean varies dramatically: in 1950, the 'north' represented two-thirds of the total population, while today it is only 50 % and may be one-third in 2025, and one-quarter in 2050.

The present rate of increase is 1.3% per annum but is showing a tendency to diminish, mainly due to a decrease in the birth rate which began in the 1970s. This coincided with an actual reduction in the mortality rate. In addition, improved health care has led to increased life expectancy.

The increase of population and activities in coastal regions is a world phenomenon. One-third of the Mediterranean population is currently concentrated in the Mediterranean coastal regions (**Figure 3.2**).

Whichever type of development is pursued, urbanisation will continue at a fast pace. The share of rural populations is decreasing dramatically, especially in the countries of the eastern and southern Mediterranean. For example, in Lebanon the rural population was 50% in 1965 but only 13 % in 1995. In Turkey, the respective figures are 66 % and 32 % and

Figure 3.1 **Increase of the population in the different Mediterranean countries**

Source: Blue Plan databases

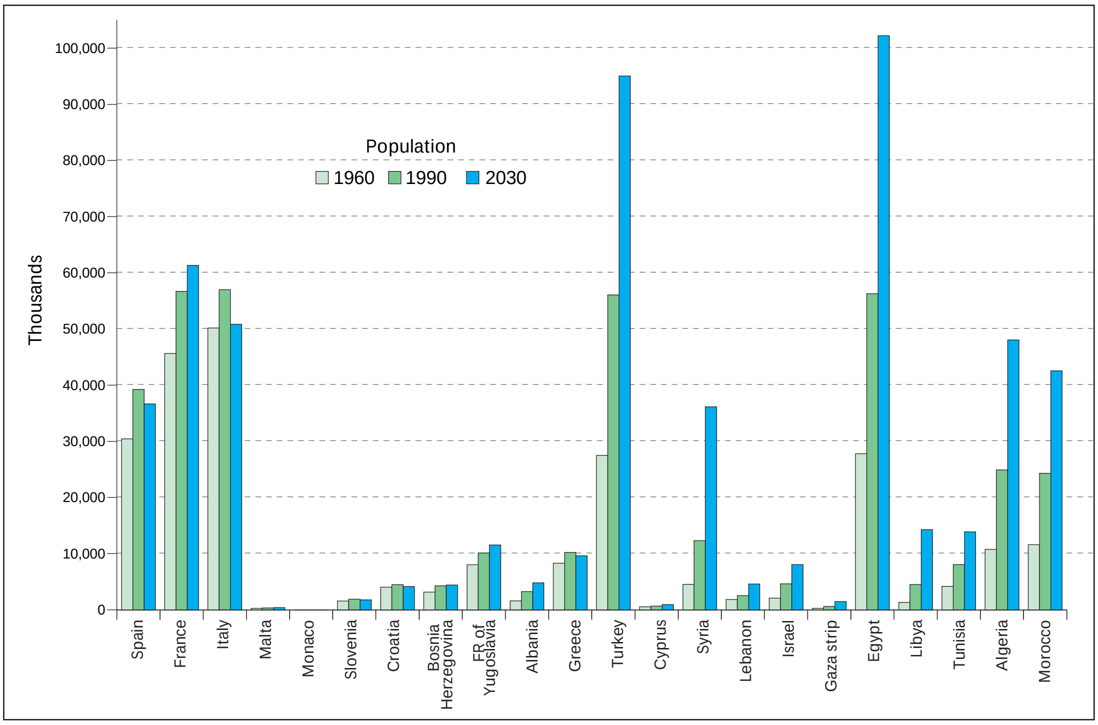
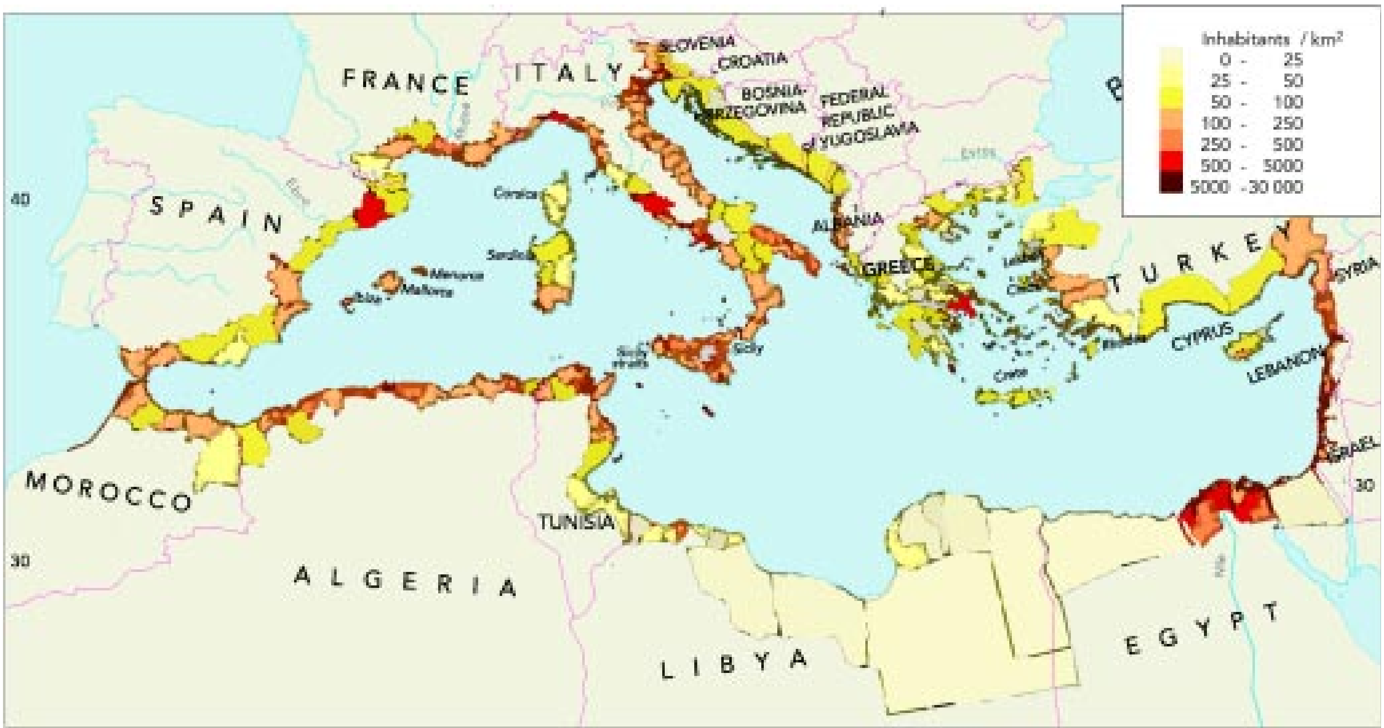


Figure 3.2 **Population density in coastal regions**



Source: Blue Plan databases

in Tunisia 60 % and 41 %. This is predominantly a direct result of migration to towns. It is estimated that in the year 2025, 380-440 million people will be living in cities. Today the number is just over 200 million **(Figure 3.3).** Between the two extreme scenarios, there is a difference of 60 million city-dwellers - about six cities of the size of present-day Cairo.

The rate of urbanisation in absolute and relative figures follows that of the increase in the population. The number of cities in the Mediterranean with populations greater than 750 000 was 26 in 1965 and 32 in 1990, Istanbul and Cairo being the biggest.

The migration to big cities and to the coast reflects population changes in the region and necessary measures will need to be taken to alleviate the effects on natural resources and the environment. The quality of life in these areas will depend largely on physical planning policies and their determined application.

3.2. Tourism

The Mediterranean region became attractive to tourists in the mid-nineteenth century because of the region's cultural heritage, the beauty and variety of the surrounding countryside, and its mild climate and special lifestyle. Up until the 1930s, tourists were generally well-off and few in number. The effect on the local environment and its inhabitants was relatively minor at that time, but it did lead to the beginning of the urbanisation of the region (e.g. the 'Riviera').

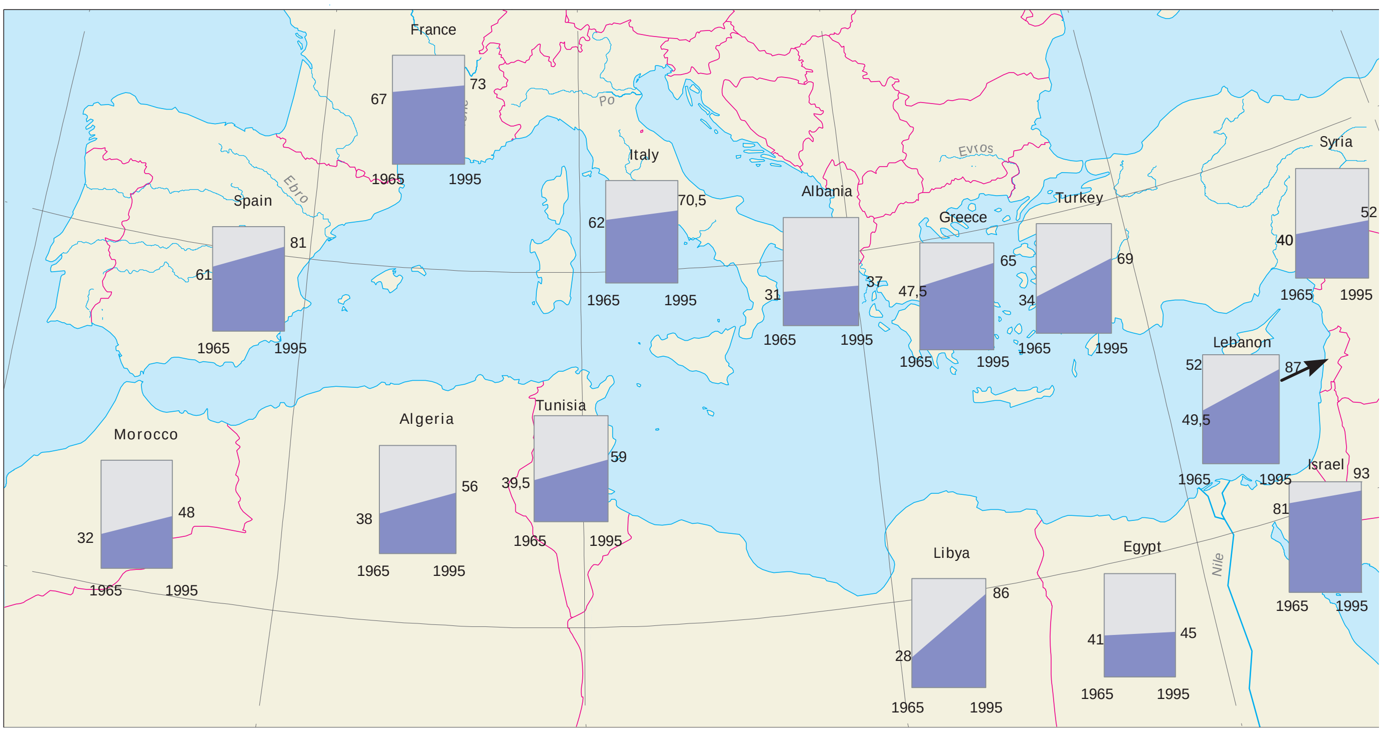
From the 1930s onwards and especially after the Second World War, mass-tourism started to develop mainly due to increased incomes in many countries, paid holidays and more leisure time. This phenomenon was amplified by the development of transport facilities and mainly concentrated in seaside areas.

Nowadays, the Mediterranean is the biggest tourist region in the world, accounting for 30 % of international tourist arrivals and for 25 % of the receipts from international tourism. Tourism - both international and domestic - is one of the most active sectors in the basin, and seems to be little affected by the unevenness of economic growth in the countries of origin. It concerns all Mediterranean countries, which all have ambitious plans to develop their tourism, international first of all, but also domestic tourism.

According to Blue Plan scenarios, the number of tourists in the Mediterranean countries will increase from 260 million in 1990 to 440-655 million in 2025. At the same time, the number of tourists in the Mediterranean coastal region will increase from 135 million in 1990 to 235-355 million in 2025 (**Figure 3.4**). The majority of these tourists will be of European origin.

The Mediterranean basin is also a destination for Mediterranean peoples. In fact, domestic tourism (at the Mediterranean level) is as important as international tourism. A breakdown of arrivals by nationalities in 1993 (World Tourist Organization statistics) shows that out of the 160 million international tourists visiting the Mediterranean countries, about 24 % come from Mediterranean countries.

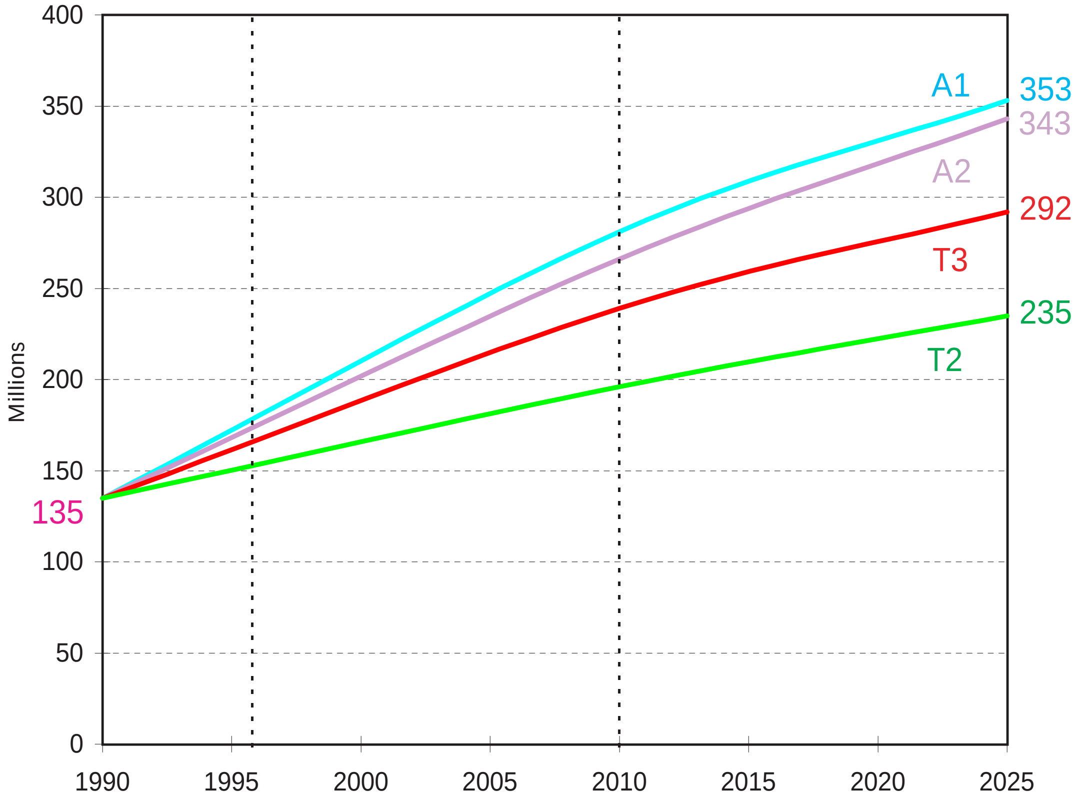
Rate of increase of urban Population (as % of the total) in the Mediterranean countries from 1965-1995 — Figure 3.3



Source: Blue Plan databases

Figure 3.4 **Alternative estimates of number of tourists in the Mediterranean coastal regions (according to different Blue Plan scenarios)**

Source: Blue Plan data from 1995



Mediterranean tourism is characterized by three basic features:

- It is increasingly concentrated on the coast. In 1990, estimations of nearly 135 million tourists (international and domestic) visited the Mediterranean coastal regions. This figure represented more than half of the total tourism arrivals in the Mediterranean countries (about 255 million international and domestic tourists). In some countries, coastal tourism represents up to 90 % of all tourism.
- It is heavily seasonal, the high summer season of about three months culminating in four weeks of particularly heavy business. This leads to a notorious under-exploitation, even 'wastage' of tourist lodgings and installations during the low season.
- The north-western Mediterranean dominates the tourist market (**Figure 3.5**). According to the Blue Plan scenarios, they will continue to do so, despite comparatively faster growth in other regions.

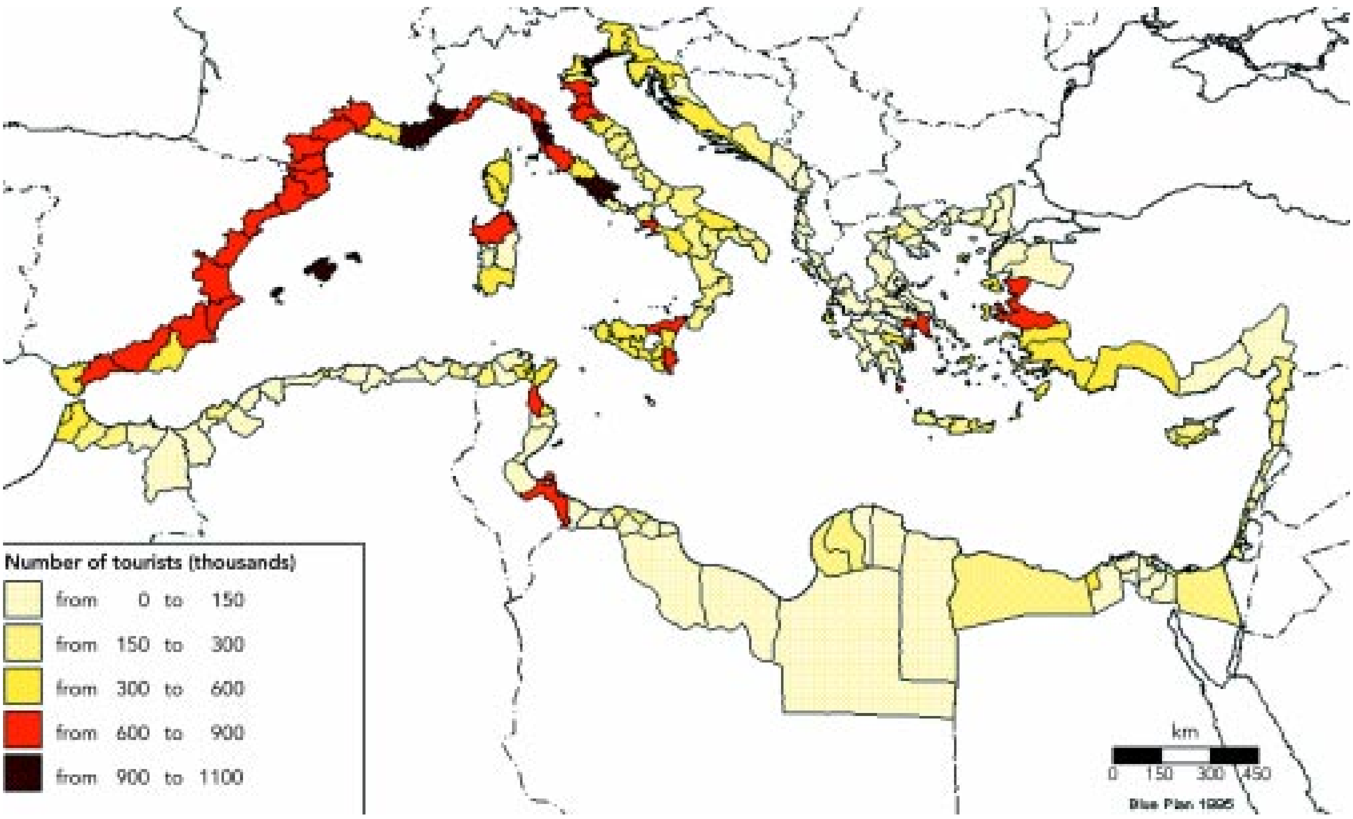
The economic importance of tourism for the Mediterranean is such that no riparian state can do without this sector. Through its economic and social weight, its contribution to the balance of trade, and its potential for development, tourism has become an unavoidable issue for most countries. Tourism is currently the first foreign currency source in the Mediterranean region and its contribution to GNP (Gross National Product) can average up to 22 %, as is the case for Cyprus, or 24 % for Malta. More than six million people are employed directly or indirectly in the tourist and leisure industry or the culture sector which attracts tourists. It is expected that the tourist sector will employ eight million people by 2010. For the tourist and hotel industry, domestic tourism plays a notable role in regulating the international cycle of tourism. For certain areas which are in a less fortunate geographical situation (island regions) or are facing difficulties (hinterland), tourism would appear to be the only activity capable of counter-balancing the decline in traditional economies and stabilising the population, possibly even reversing migratory trends. Tourism also provides for mutual cultural contact between visitors and hosts and brings about social developments of major importance for the local population.

It is impossible to imagine the long-term development of tourism without preserving the quality of the environment, as the relationship between tourism and environment is multiple and interdependent. Environmental awareness amongst tourists (particularly from northern Europe) is growing with time and experience. The interactions between tourism and the environment in the region are seen in the following issues: land use; consumption of water resources; pollution and waste and physical and socio-cultural pressures. These issues often result in the abandonment of traditional activities (e.g. agriculture and fisheries), the degradation of coastal and marine ecosystems and the deterioration of human conditions, i.e. quality of life, unemployment and poverty. A serious consequence of mass tourism is the rapid degradation of fragile natural habitats and the deterioration of historic sites. However, in recent years, the requirements of tourism itself have produced a strong incentive for the protection of the landscape and the improvement of the quality of the environment (e.g. bathing waters, beaches, etc.). Nautical tourism also creates problems; it was estimated that more than one million pleasure boats of all sizes were moored or registered in Mediterranean ports in 1997.

It is recognised that the development of various types of tourism (mass tourism, health tourism, congress tourism, ecotourism, etc.) should be monitored closely by each country, which should aim at improving its distribution spatially and temporally throughout the year. An effort should also be made to raise the awareness of tourists on environmental issues. The importance of tourism has been accepted as one of the major issues for the Mediterranean region; the Mediterranean Commission on Sustainable Development has selected it as one of its priority themes for the development of the region. Recent, related activities with qualified experts and concerned participants carried out more in-depth analysis as a basis for further strategic recommendations to be proposed for countries and partners.

Several financial mechanisms aiming at better integration of tourism in sustainable development are under study: taxes for the environment, requirements to reinvest profit in regions with tourist installations, with penalties in cases of non-compliance and

Estimation of tourism during the peak period in the Mediterranean regions Figure 3.5



Source: Blue Plan databases

subsidies for agro-tourism and development in difficult areas.

It is increasingly recognised that tourism could make a much greater contribution to the protection, management and best possible use of the sites that it exploits. A greater effort is needed to rehabilitate older destinations (sites, buildings, tourist infrastructures etc.), and to protect and make the best use of the natural and cultural heritage exploited by tourism. Tourist development in less favoured (island) or difficult regions (hinterland), requires many more technical and financial means than those presently implemented, together with adequate and efficient institutional measures and structures.

3.3. Agriculture

In most countries, all types of agricultural practices and land use which include activities such as irrigation, cultivation, pasture, animal feedlots, dairy farming, orchards and aquaculture are considered as non-point sources of water pollution.

Through the mechanisms of run-off water, sediment transport and leaching, phosphorus, nitrogen, pesticides, metals, pathogens, salts and trace elements are carried into ground waters, wetlands, rivers and lakes and finally reach the sea in the form of sediments and chemical loads.

The main pressure of agriculture on surface and groundwater are:

1. fertilising: run-off of nutrients, especially nitrates and phosphates that can lead to eutrophication;
2. tillage: sediments carry phosphates and pesticides adsorbed to sediment parti cles;
3. pesticides: run-off of pesticides leads to pollution of surface waters. Dust and wind also carry pesticides and contaminate aquatic systems;
4. manure spreading: fertilising by animal manure spreading leads to contamination by pathogens and pollution by phosphates and nitrates;
5. cattle and sheep breeding: contamination by nitrates, phosphates and pathgens;
6. irrigation: irrigation can waterlog soil or increase soil salinity (salt level) to the point where crops are damaged or destroyed. This problem is now jeoardising about one-third of the world’s irrigated land.

3.3.1. Use of fertilizers in agriculture

From very early times the Mediterranean area has been subjected to exhaustive farming, uncontrolled grazing and destruction of forests. Several factors affect the land-based pollution of the Mediterranean, such as the climate (desert and arid in the North African regions and temperate in the European regions) and the changes in natural vegetation.

Attention must be given to nitrogen, phosphorus and organic carbon in soil sediments, as sources of eutrophication of the Mediterranean Sea. Nitrogen, phosphorus and organic carbon are transported into rivers and the sea mainly by run-off waters, either in dissolved form (particularly nitrogen) or bound to a solid load.

In the agricultural lands of the Mediterranean basin, particularly on the southern coast, the pressure of use of more fertilizer in the catchment basin and along the coastal zones is very strong. Moreover, an increasing part of arable land is lost to urbanisation and other infrastructures. In the countries on the northern and western coasts, specialised monocultures achieve good yields and induce a gradual abandonment of marginal land. Therefore important decreases of agricultural land (**Figure 3.6) -** and strong increases of agricultural land under irrigation - are observed in the north and west (**Figure 3.7).** In the south and east, demographic pressure constantly increases and cultivated surfaces continue to expand at the expense of forests and grazing land (**Figure 3.6 & Figure 3.7).**

Figure 3.8 shows the fertiliser consumption used in agricultural lands in all Mediterranean countrie. The intensive use of fertilisers in Egypt, Israel and Cyprus was higher in 1993 than in countries where agricultural practices are more advanced, such as France, Italy and Spain.

In addition, run-off waters cause a remarkable transport of sediments, mostly in regions with a higher degree of soil erosion. Besides the large river basins of the Rhône and the Po and following a tentative ranking of the risk of soil erosion and nutrient losses (UNEP/MAP, 1997), the first six drainage regions on the ranking list, which discharge the largest amount of nutrients into the sea, are found in peninsular Italy, Sicily and Sardinia, Greece, Turkey and Spain. (**Table 3.1**).

Inadequate management practices can increase the amount of pollutants transported to the sea and can decrease productivity of soil and economic efficiency of agriculture. The control of phosphorus is closely connected to run-off and erosion phenomena. In fact, this nutrient is often associated with the sediment and run-off losses directly linked to erosion. Intensive agriculture systems determine the risk of nitrogen pollution in surface and ground waters. Such risks increase in irrigated crops.

3.3.2. Use of pesticides in agriculture

Pesticides used in various formulations can be classified as insecticides, herbicides and fungicides.

Pesticide utilisation in agriculture has increased greatly during the last twenty years, primarily due to conversion to intensive agriculture. Intensive use of these compounds threatens ground and surface waters, human health and ecosystems.

Generally, the undesired effects of pesticides are delayed and are particularly linked to chronic illness, including possible cancer risk and damage to the reproductive and neurological systems.

Statistics of pesticide utilisation were provided for some Mediterranean countries. A certain amount of the presticides applied in agriculture reaches the marine environment via the atmosphere and riverine inputs because the pesticides are not degraded rapidly. The largest amounts of active ingredients applied in agriculture are used in the north-western area and are: 36 000 tonnes in France (1990); 33 000 tonnes in Italy (1987) and 23 700 tonnes in Spain (1989) (Fielding et al., 1991). Among the other countries Greece used 8 080 tonnes in 1989, Algeria 5 950 tonnes in 1993, Egypt 13 200 tonnes in 1990, Turkey 34 400 tonnes in 1989, Morocco 9 400 tonnes in 1989 and Yugoslavia 3 300 tonnes in 1992.

Agricultural run-off through rivers and streams is by far the largest input of pesticides to the marine environment.

Pesticide manufacture is sometimes located in areas where pesticides are used for agricultural purposes. Therefore it is not always possible to distinguish whether the pesticides found in surface and groundwaters stem from agricultural run-off or directly from industrial discharges. The most relevant point-sources of agricultural pollution in Mediterranean countries are large rivers such as the Rhône in France, the Ebro in Spain, the Po in Italy, the rivers Axios, Loudias and Aliakmon in Greece and the Nile in Egypt (Provini et al., 1991).

Decreases of agricultural use of land in the north west and increase in the south and east of the Mediterranean basin (% of total land)

Figure 3.6

Data source: The World Bank, Social Indicator of Development, 1996

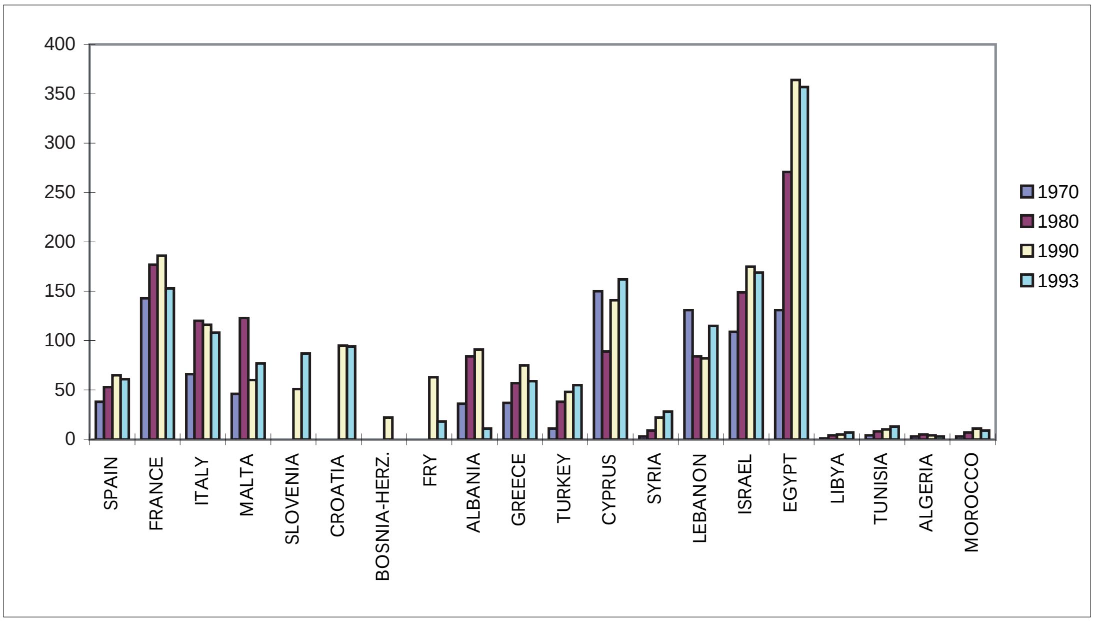


Figure 3.7 **Expansion of irrigated land in almost all the countries in the Mediterranean basin (% agricultural land)**

Data source: The World Bank, Social Indicator of Development, 1996

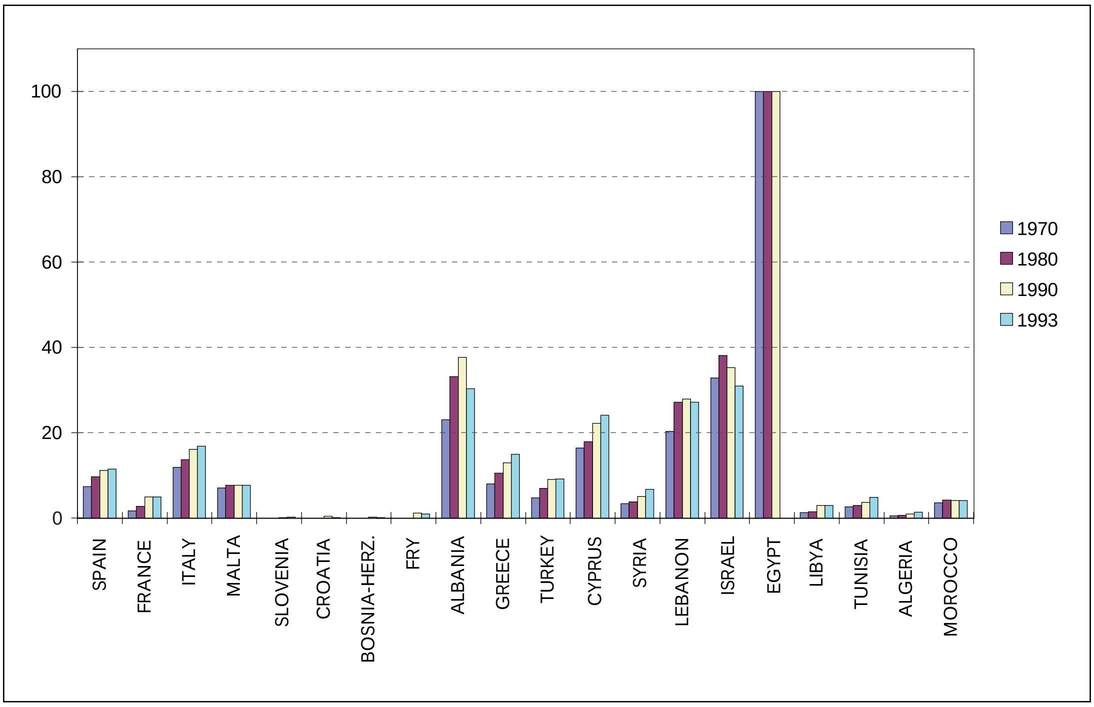


Figure 3.8 **Fertiliser consumption in the Mediterranean countries from 1970 to 1993 (kg/ha)**

Data source: The World Bank, Social Indicator of Development 1996

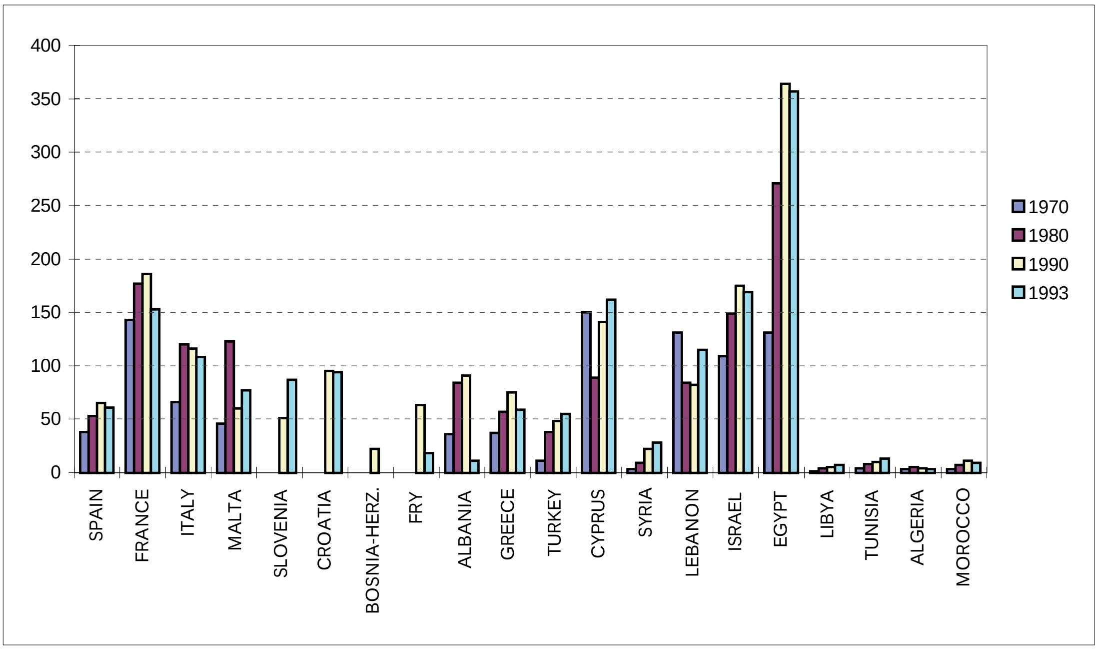


Table 3.1

Soil erosion estimates and discharges of phohorus (P), nitrogen (N) and organic carbon (Org C) to the Mediterranean Sea from agricultural land

Source: UNEP/MAP, 1997

Country	Drainage Area km^2	Soil 10^6 t	Total P 10^3 t	Total N 10^3 t	Total Org C 10^3 t	Estimated average of annual soil loss $t.ha^{-1}$
Albania	30,400	6.8	3.7	6.7	74.1	2.24
Algeria	99,100	55.8	15.9	41.4	387.6	5.3
Cyprus	9,100	14.1	6.9	20.3	161.1	15.49
France	130,000	38.2	25.6	51.7	565.0	2.94
Greece	106,100	207.5	146.7	268.7	2492.3	19.56
Israel	10,300	3.8	1.3	3.2	33.0	3.69
Italy	279,300	410	341.7	619.4	6574.4	80.13
Lebanon	7,800	25.7	6.5	17.4	196.4	32.95
Morocco	62,800	43.7	9.1	29.7	502	6.96
Spain	180,300	116.1	103.1	177.3	1801.1	6.44
Syria	5,700	34	14.8	27.4	267.9	59.65
Tunisia	34,400	54.9	28.7	56.5	571.0	15.96
Turkey	153,700	296.9	129	250.9	3315.0	19.32

Moreover, industrial effluents containing herbicide compounds may be discharged directly into surface waters through pipelines from onshore plants.

A third source of pollution is the aerial transportation of these compounds: volatilisation as well as wet and dry deposition probably contribute a considerable amount of pesticide contamination to the marine environment. The following pesticides have been detected frequently in many important rivers that outflow into the Mediterranean Sea: atrazine, simazine, alachlor, molinate and metolachlor (Albanis et al., 1997). The residues in the rivers have been measured and their minimum and maximum measured concentrations are presented in **Table 3.2.**

Detectable levels of some pesticides are present also in estuarine and coastal waters, but their concentrations are generally much lower than in corresponding rivers.

According to the classification of the U.S. Environmental Protection Agency (USEPA) and the International Agency for Research on Cancer (IARC), alachlor is evaluated as probably carcinogenic; the others are possible carcinogenic compounds.

The annual mean concentrations of some important pesticides analysed in marine waters in the Adriatic Sea are lower than 0.1 µg/l (Galassi, 1991). In contrast the annual mean concentration for molinate in the Gulf of Thermaikos (Albanis et al., 1994) and the

Table 3.2

Pesticide residues of important Mediterranean rivers

Source: Albanis, 1997

River /Herbicides	Alachlor (µg/l)	Atrazine (µg/l)	Metolachlor (µg/l)	Molinate (µg/l)	Simazine (µg/l)
Po (Italy)	<0.03-0.106	0.021-0.118	<0.03-0.605	<0.03-1.750	0.06-0.081
Rhône (France)	<0.001	0.022-0.386	-	-	0.018-0.372
Ebro (Spain)	<0.001-0.267	<0.001-0.190	<0.001-0.554?	<0.001-0.568	0.010-0.138
Evros/Meriç (Greece/Turkey)	nd-0.37	nd-0.63	-	-	nd-0.32
Axios (Greece)	<0.05-1.30	<0.05-0.70	<0,10-0,50	<0.001-0.90	<0.06-0.30
Aliakmon (Greece)	nd-1.20	nd-0.74	nd-0,63	nd-0.94	nd-0.06
Nile (Egypt)	<0.001	<0.001	<0,001	<0.001	<0.001

annual mean concentration for molinate and metolachlor in the Gulf of Amvrakikos (Albanis et al., 1994) are higher than 0.1 µg/l.

3.4. Fishing and aquaculture activities

3.4.1. Marine fisheries

Total marine catches by Mediterranean countries varied from 1.1 million tonnes in 1984 to 1.3 million tonnes in 1996, with an overall increase of about 17.5 %. The major groups represented in the catches are marine fish, followed by molluscs, crustaceans and diadromous fish (FAO, 1998).

Among the marine fish the main increase was seen for 'group 33' (redfish, bass, conger, etc.), which gained about 59 % in the period. 'Group 37' (mackerel, snoeks, cutlassfish), increased by 55 %, followed by 'group 34' (jack, mullet, saurie) which increased by 25 %, and 'group 32' (cod, hake, haddock, etc.), which increased by 10% (**Figure 3.9**).

The mollusc catch increased from 1984 to 1996 by about 67 % (**Figure 3.9**), the major group landed being mussels with an increase of 117 %, followed by clams (98 %) and oysters (37 %). Other groups, such as 'group 57' (squid, cuttlefish, octopus, etc.) increased by 7 % and 'group 55' (scallops, pectens, etc.) by 642 %, mainly in Turkey (308 t in 1994) (**Figure 3.9**).

The catch of crustacea increased a little (**Figure 3.9**), mainly on 'group 42' (sea-spiders, crabs, etc.) by 84 %, followed by lobsters, spiny-rock lobsters, etc. (36 %), while 'group 45' (shrimps, prawns, etc.) decreased by 13 % in the same period.

As regards the diadromous fish, a drastic decrease happened in the Mediterranean (-46 % in the period 1984-1996), mainly due to the reduction of catch on river eels (Anguilla anguilla) –66 %.

3.4.2 Fishing techniques

There have been relatively small changes in fishing techniques in the Mediterranean area during recent years. The available data, the way in which they are summarised and the method adopted to determine tonnage differs from one country to another and hence may not provide the exact picture of the structure of the fisheries fleet in the Mediterranean. However the indicative numbers suggest that there was an increase in the number of vessels from 1980 to 1992 (overall increase 19.8 %) (FAO, 1994) (**Figure 3.10**).

In the industrialised EU countries fleet technology is very high and there has been a shift from labour-intensive to more capital-intensive vessels, such as larger trawlers and multi-purpose vessels. The amount of 'passive' fishing has generally increased but the number of trawlers has remained steady since 1982 (**Figure 3.11**).

The number of trawlers in the northern Mediterranean is decreasing in Spain (-21.1 %) and Italy (-30.2 %), while increasing in France (+22.3 %) and Greece (+10.2 %). In the southern Mediterranean the number of trawlers is increasing dramatically (Algeria +137 % and Morocco +170 %). With regard to the composition of the fishing fleet in the Mediterranean, multi-purpose vessels are 22 %, trawlers 16 %, followed by gill-netters 13 %, seiners 7 %, liner 3 % and trap setters 1 %. The remaining 39 % are other fishing vessels which include dredgers, lift netters, vessels using pumps for fishing, platforms for mollusc culture, recreational fishing vessels, fishing vessels, etc. (**Figure 3.12**).

In the Mediterranean, coastal countries have their own national fisheries policy, although the EU coordinates the national policies of its members through the General Fisheries Council for the Mediterranean (GFCM). Management focuses on measures such as control of licences and subsidies to the sector, rather than quota control.

3.4.3 Interaction between fishing activities and the environment

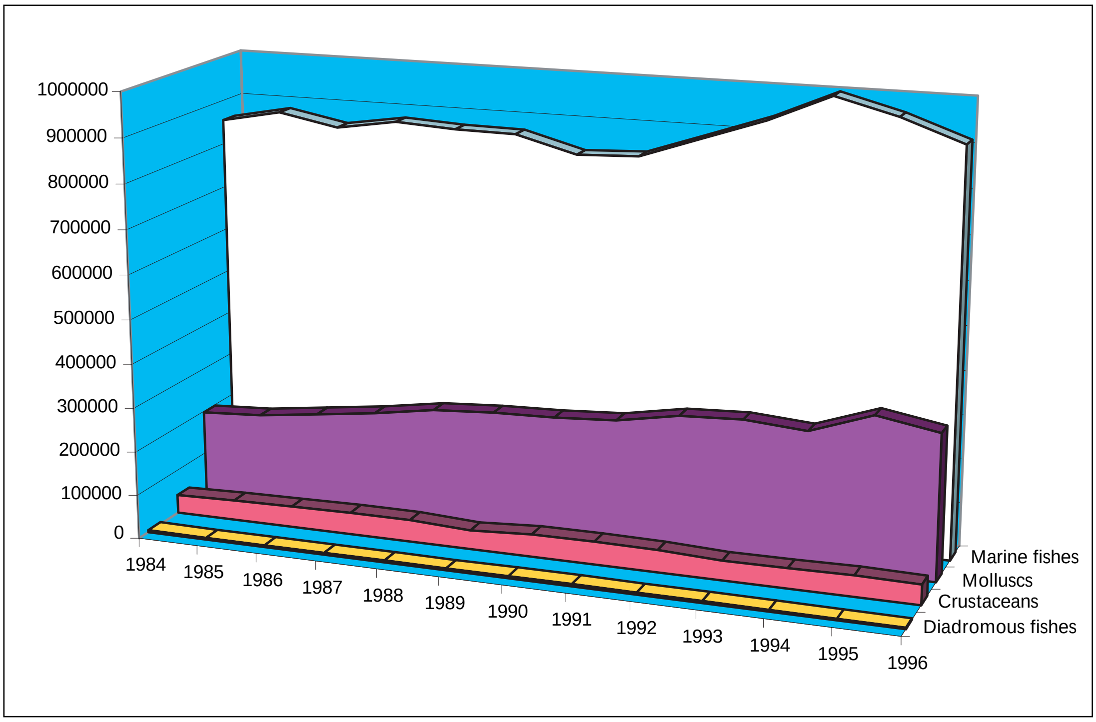
Fishing not only reduces the abundance of the target species but also, as a secondary effect, that of other species, thereby reducing their abundance or modifying their relative size composition. These effects can be direct, by killing specimens, or indirect through the alteration of transfers of energy through trophic levels, leading to a decrease in the number of species (Caddy & Sharp, 1986).

Fishing also imposes selective pressure on determinate age classes. With time, it may affect the genetic variability of a population with time, or can directly affect, for example, the reproduction of hermaphrodite species with sex determination by age. The adopted European standard for minimal catch size (Lleonart & Recasens, 1996) does not really

Total landings (in tonnes) of marine catches by Mediterranean countries: Fluctuation of major groups from 1984 to 1996

Figure 3.9

Source: FAO GFCM-PC release 1998 and FAO Fishstat-PC, release 1998



solve the problem in species where the minimum legal size is lower than their length at first maturity. To improve this situation, less selective gear, such as trawls, could be limited in favour of others such as small-scale gillnets, purse seines or long-lines.

Fisheries also affect the marine biodiversity. The Mediterranean is a sea with a high level of biodiversity, concentrated mainly between the surface and a depth of 50 m. The impact of fishing activities is very important along the coast. A decrease in biodiversity is

Number of trawlers per country from 1980 to 1992 (1989 data non available for France, Spain, Algeria and Israel)

Figure 3.10

Source: FAO Fischery Information, Data and Statistics Service, 1994

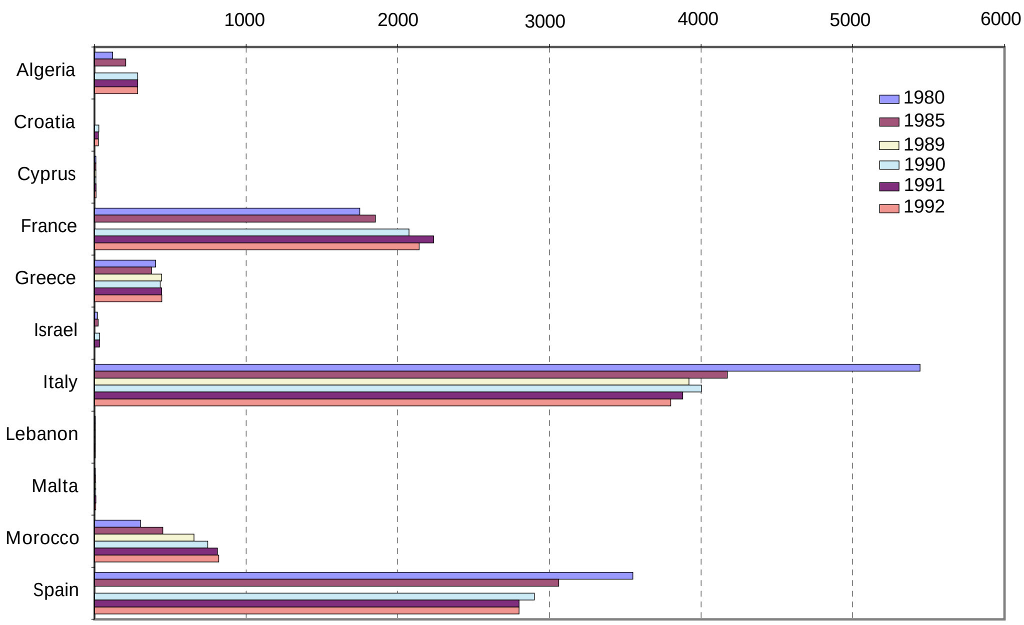
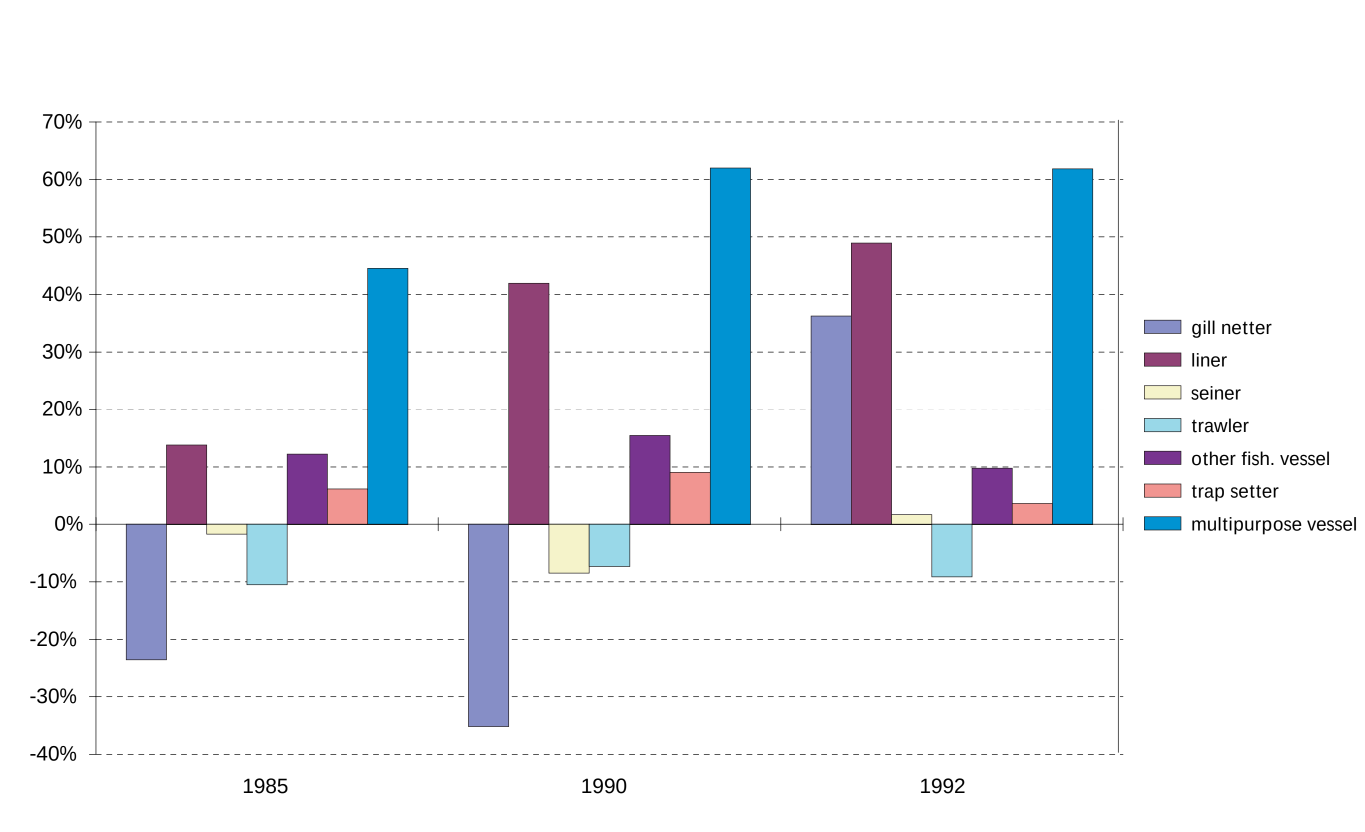
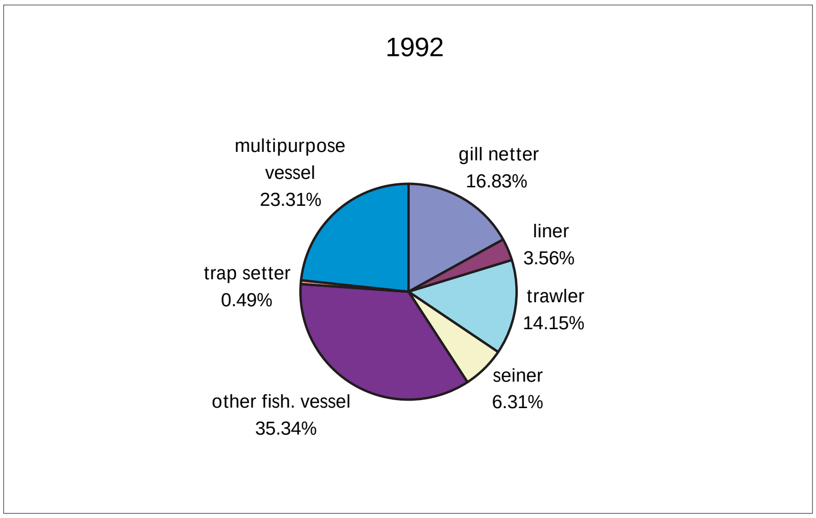


Figure 3.11 **Variation (%) in the number of fishing vessels compared to the situation in 1980**



Source: FAO Fischery Information, Data and Statistics Service, 1994

Figure 3.12 **Composition of Mediterranean fleet in 1992**



Source: FAO GFCM-PC release 1997 and FAO Fishstat-PC, release 1998

evident, not only in the local disappearance of species, but also in the reduction of habitats.

A significant impact is seen on protected species such as marine mammals, especially whale and dolphin populations. On the one hand they get caught accidentally in drift-nets, on the other hand they compete directly with fishermen for small pelagic resources ('fodder species') such as anchovies and squid which are common in their diet (Northridge, 1984).

For turtles, the main causes of mortality are drift-nets, pelagic long-lines, plastic and other debris, which the turtles ingest, mistaking them for jellyfish.

Because the Mediterranean is open to international high-sea fleets, impact also increases according to the size of gear (large scale drift-nets and long-lines), and fishing capacity of foreign industrial fleets targeting mainly blue-fin tuna and swordfish. An increase of 12 % in the total catch of these species was observed between 1984-1994; the non-Mediterranean countries caught about 4 % of the total in 1994.

From 1 January 2002, drift-nets used to fish tuna and swordfish will have disappeared from all EU seas, except the Baltic Sea. Maritime Member States will have to reduce the number of fishing vessels using drift-nets before 2002 by at least 40 %, compared to the period 1995-97. In the Mediterranean, due to the absence of an EEZ (Exclusive Economic Zone) this applies only to territorial waters of EU Member States. EU fishermen will not be allowed to use drift-nets on their boats to catch various species of tuna, shark, swordfish, oceanic sea bream and others inside territorial waters.

This method of fishing, which threatens the survival of certain fish species as well as mammals and seabirds, has been denounced for many years. The ban may, in the short term, have a negative economic impact on fishing communities, but no ban at all would have even more serious consequences.

To help fishing communities make the transition to more acceptable techniques, the EU, in cooperation with Member States, will adopt accompanying technical and socio-economic measures to allow the shifting to more reliable selective fishing methods, thus minimising the economic impact.

Fisheries also modify the marine community by altering food availability through the impact of discards directly rejected at sea. Less selective gear such as trawls (pelagic and bottom) and drift-nets produce more discards even though this gear has a higher economic productivity. On the other hand, there are some species, such as octopus, crabs, sea birds, etc., which benefit from discards as a supplementary food source and feed extensively on them.

Another secondary negative effect on marine life is 'ghost fishing', a phenomenon seen when gear (mainly gill-nets or traps) is accidentally or deliberately lost and continues to catch fish for a certain amount of time thereafter.

The benthic structure can be damaged, or even destroyed, by the use of dredges, trawls, and other bottom-towed gear. Related directly to fishing activity is the decline of Posidonia oceanica beds, and other shallow meadows of marine phanerogams (Boudouresque et al., 1991). These meadows provide important spawning and nursery grounds for many species with a high biodiversity index as well as beach protection from wave erosion. These ecosystems are threatened by trawling (legal and illegal when carried out in forbidden areas and with banned gear) and drag-net activities and are in obvious decline.

Rocky and coral bottoms support rich and complex communities, which are threatened by the use of dragging gear for coral. Moreover, this type of seabed is damaged by the 'rollers' used by some bottom trawlers to pass over rocks without damaging the nets, but in turn destroy benthic communities.

Sandy and muddy seabeds are generally poorer environments and hence the negative effects of fishing are less, but bottom trawlers affect grain-size distribution, sediment porosity and chemical exchange processes. Moreover, there is an increase in suspended sediment. This effect can be dangerous in areas where contaminant concentrations are relatively high, for example in areas affected by major industrialisation.

3.4.4. Aquaculture

The regional aquaculture production increased from 78 180 tonnes in 1984 to 248 460 tonnes in 1996 (freshwater aquaculture not considered). (**Figure 3.13).**

In the period 1984-1996 the aquaculture production of marine fish in the marine environment increased about 400-fold **(Figure 3.13)**, mainly due to the development of cage technologies as seen in Greece; the production of the same group but in a brackish environment increased less than ten-fold. This last data confirms a renewed interest in a more compatible and sustainable aquaculture in natural environments.

The leading mussel producer in the region is Italy, with a total production of about 140 300 tonnes in 1996 (in the marine and brackish environments).

3.4.5. Interaction between aquaculture and the environment

The expansion of marine aquaculture activities in the Mediterranean should take place in a broader frame of integrated planning and regulation with the aim of minimising impacts. A balanced development of the coastal zone requires integrated management plans that should be prepared at a national or regional level. Hence any marine aquaculture enterprise (brackish, on-land or offshore) must pay particular attention to site selection in order to ensure appropriate conditions for a successful activity, which should also be related to the ability of local ecosystems to absorb impacts without lasting harmful effects (EC Directorate General for Fisheries, 1995).

In many cases, assessing interaction with the surrounding environment (and its capacity to absorb such interaction) is neglected. Intensive fish farming results in the production of waste, which can stimulate and distort productivity and alter the abiotic and biotic characteristics of the water body (oxygen depletion, sedimentation with benthic enrichment, hyper-nutrification and eutrophication).

In the field of aquaculture expansion in the Mediterranean, microbial contamination is probably the most pressing issue today. The use of therapeutic chemicals which have long-term effects on the environment may result in bio-accumulation in benthic organisms and sediments; and the accumulation of uneaten food and faeces induces conditions favourable to blooms of algae and fungi.

The effects of introducing aquaculture activities in a marine or brackish environment vary according to an area being closed, semi-closed, or open. The effects of produced biomass and availability of nitrogen and phosphorus may be forecast, considering hydrodynamic, seabed, benthic communities and all the ecological characteristics of the site.

Some (e.g. intensive) aquaculture activities should require an environmental impact assessment (EIA). Nowadays these assessments are generally imprecise, especially if the mathematical models become commonly used. However, the cost of collecting data for an EIA is high and may prevent its use by small-scale farms.

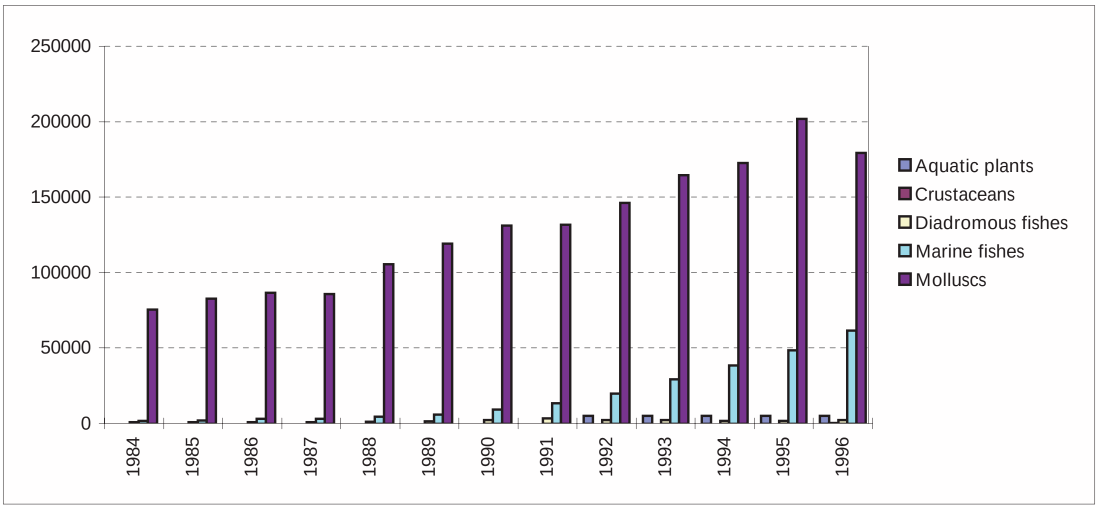
The introduction of new organisms and alien (exotic) species nearly always poses a risk to the environment / ecosystem involved in the introduction, and therefore requires the greatest possible circumspection.

As breeding and biotechnological techniques are increasingly used to produce specific varieties for mariculture purposes, there is a serious potential danger of unforeseen competitive effects of these cultured species with their wild counterparts as a result of escapes (often accidental during coastal storms, but perhaps also intentional). An example of this potential risk is provided by the production of the Asian clam (*Tapes semidecussatus*) that, mainly in the Italian brackish area of the North Adriatic, increased from a pilot stage in 1985 to 40 300 tonnes in 1996. Owing to its rapid growth and resistance to anoxic conditions, this species supplanted the autochthonous species (Tapes decussatus) so much so that it could also be fished in other coastal areas.

The kuruma shrimp (Penaeus japonicus) that was introduced to the Mediterranean, due to its rapid growth in aquaculture facilities, provides a similar example. Nowadays, owing to its presence in natural stocks, and because entering from Suez Canal, it

Figure 3.13 **Aquaculture production (in tonnes) by major groups in the Mediterranean Sea from 1984 to 1996**

Source: FAO Aquacult-PC, release 1998



can be considered as a Mediterranean species.

3.4.6. Nitrogen and phosphorus loads from aquaculture

The total amount of nitrogen (N) and phosphorus (P) entering the aquatic environment is calculated on the basis of simple formula used by Ackefors & Enell, (1990) and depends on the amount of Nitrogen and phosphorus in food and produced biomass. The relation between food and biomass is expressed by the Food Conversion Ratio (FCR = kg of food / kg of living biomass), for which a mean value of 1.5:1 was applied for all countries (Ceccarelli & Di Bitetto, 1996). Under these conditions the estimated load of total P is about 3 kg / produced biomass / year and about 66 kg / produced biomass / year of total N. **Table 3.3 and Table 3.4** show the total release when these values are applied to the production data of each Mediterranean country.

Other models can be used in order to evaluate the fate of total nitrogen and phosphorus from an aquaculture 'box' (**Table 3.5**).

3.4.7. Conservation of living marine resources

Although fishing fleets in the EU Member States – Spain, France, Italy and Greece – accounted for 89 % of the total number of vessels in the Mediterranean, the EU system for the conservation of marine resources adopted in 1983 (EC Council Regulation, 1983) did not apply to the entire Mediterranean fisheries. The EU Common Fisheries Policy (CFP) represents the most significant fisheries policy with the primary aim to balance fisheries capacity with the available and accessible resources for the Euro-Mediterranean countries, but it does not apply for all the Mediterranean countries. This apparently special status was not due to the state of the Mediterranean resources but because it was felt at the time that rules and management by capture quotas which could be applied to the Atlantic and the North Sea would not be appropriate in the multi-species Mediterranean fisheries.

The narrowness of the continental shelf means that most of the marine resources in the Mediterranean are confined to the territorial waters of the coastal states. For this reason and because the geographical narrowness of the Mediterranean Sea does not allow for unilateral extensions of 200 miles, coastal states have not tried to create exclusive economic zones in which a community conservation policy would have been meaningful.

Estimated loads of phosphorus (P kg/produced biomass/year) from production of marine and diadromous fish in marine environment — Table 3.3

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Croatia									3402.6	1621.8	2003.4	2679.2	2003.4
Cyprus	8	8	8	15.9	39.8	206.7	397.5	453.2	564.5	1351.5	1653.6	2766.6	2766.6
Egypt								11448	11448	17068.7	11448	731.4	1486.7
France	39.8	477	556.5	993.8	2265.8	1749	2226	3211.8	4770	12791.6	26163.5	29168.6	19898.9
Greece			715.5	834.8	1828.5	4929	12720	27427.5	62399.6	92013.3	107325	150533.3	205078.2
Israel			238.5	375.8	477	636	667.8	564.5	429.3	1232.3	3180	7393.5	5557.1
Italy			1590	1192.5	1033.5	5167.5	4372.5	3696.8	3259.5	4372.5	7155	17092.5	47302.5
Malta								1590	3975	5167.5	7163	7163	12338.4
Morocco							1248.2	2393	2806.4	6328.2	9142.5	9102.8	9738.8
Slovenia									79.5	151.1	596.3	389.6	596.3
Spain		159	151.1	206.7	151.1	198.8	222.6	318	278.3	119.3	143.1	206.7	198.8
Tunisia							2289.6	2067	1335.6	8	8		
Turkey			8	238.5	278.3	413.4	818.9	6972.2	7218.6	25368.5	17220.6	22045.4	41419.5
Socialist Republic of Yugoslavia	15.9	198.8	874.5	675.8	1033.5	2385	1669.5	1033.5					

Source: Data elaborated from FAO Aquacult-PC, release 1998.

Table 3.4 **Estimated loads of nitrogen (N kg/produced biomass/year) from production of marine and diadromous fish in marine environment**

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Croatia									28269.4	13474.2	16644.6	22258.9	16644.6
Cyprus	66.1	66.1	66.1	132.1	330.3	1717.3	3302.5	3764.9	4689.6	11228.5	13738.4	22985.4	22985.4
Egypt								95112	95112	141809.4	95112	6076.6	12351.4
France	330.3	3963	4623.5	8256.3	18824.3	14531	18494	26684.2	39630	106274.5	217370.6	242337.5	165323.2
Greece			5944.5	6395.3	15191.5	40951	105680	227872.5	518426.5	764462.7	891675	1250657	1703826
Israel			1981.5	2972.3	3963	5284	5548.2	4689.6	3566.7	10327.8	26420	61426.5	46169
Italy			13210	9907.5	8586.5	42932.5	36327.5	30713.3	27080.5	36327.5	59445	142007.5	392997.5
Malta								13210	33025	42932.5	59511.1	59511.1	102509.6
Morocco							10369.9	19881.1	23315.7	52575.8	75957.5	75627.3	80911.3
Slovenia									660.5	1255	4953.8	3236.5	4953.8
Spain		1321	1255	1717.3	1255	1651.3	1849.4	2642	2311.8	990.8	1188.9	1717.3	1651.3
Tunisia							19022.4	17173	11096.4	66.1	66.1		
Turkey			66.1	1981.5	2311.8	3434.6	6803.2	57925.9	59973.4	210765.6	147225.5	183156.7	344120.5
Socialist Republic of Yugoslavia			132.1	1651.3	7265.5	5614.3	8586.5	19815	13870.5	8586.5			

Source: Data elaborated from FAO Aquacult-PC, release 1998.

When in 1996 the regulations were adopted by the EU Council (EC Council Regulation, 1994 and 1996), they enhanced the protection of resources and the environment by harmonising different national rules in accordance with available scientific studies. However, there is still a strong need for improved enforcement. Cooperation with non-member countries bordering the Mediterranean or fishing in this area is essential in order to establish a harmonised system which will ensure the conservation and management of living resources in the Mediterranean. This action will be carried out in cooperation with the General Fisheries Council for the Mediterranean (GFCM), a regional agency of the FAO, and according to the FAO Code of Conduct for Responsible Fisheries (FAO, 1996).

Table 3.5 **Fate of total phosphorus (P) and nitrogen (N) in percent of P and N introduced in an aquaculture 'box' as food and juveniles**

Fate	P	N
Dissolved	25-30 %	48 %
Sedimentation:	50-57 %	23 %
Benthic accumulation	47-54 %	12-20 %
Benthic flux	2-4 %	1-3 %

Source: Holby & Hall (1991) and Hall et al., (1992)

3.5. Industry

3.5.1. Industries in the Mediterranean basin

The Mediterranean basin has never been a major mining region and thus was not involved in the period of industrial development based on coal and iron. It is better endowed in oil and natural gas (Algeria, Egypt, Libya, Syria and Italy), leading to the establishment of many refineries all around the Mediterranean basin.

Taking into consideration the world's sixteen most important raw materials, the Mediterranean countries' production (in decreasing order) of mercury, phosphates (Tunisia and Jordan), chromite (Turkey), lead, salt, bauxite (Bosnia, Croatia, France, Greece, Slovenia, ex-Yugoslavia) and zinc (Spain and Morocco) is higher than the world average. Submarine mining in the Mediterranean comprises mainly drilling for oil and gas and dredging of gravel and sand, but this particular type of activity can be considered to be at a relatively early stage of development.

Steel manufacturing, another symbol of industrial and military power, is concentrated in the north (Italy, France, Spain, Croatia, Turkey and Greece) with a few producers in the south (Egypt, Algeria and Tunisia).

Generally, to date, the gap in industrial development between the northern and south-eastern sides of the basin remains considerable. In terms of added value, within the Mediterranean basin proper, Italy, France, and Spain together are predominant with 87% over the rest of the Mediterranean countries. Data obtained for OECD countries in the Mediterranean basin since 1991 (Spain, France, Italy, Greece and Turkey) show that there is an increase in recent years of most of their industrial activities that imply pressures on the environment (**Figure 3.14**).

Apart from the chemical / petrochemical and metallurgy sectors, the other main industrial sectors include: waste treatment plants, paper, paints, plastics, dyeing and printing, and tanneries.

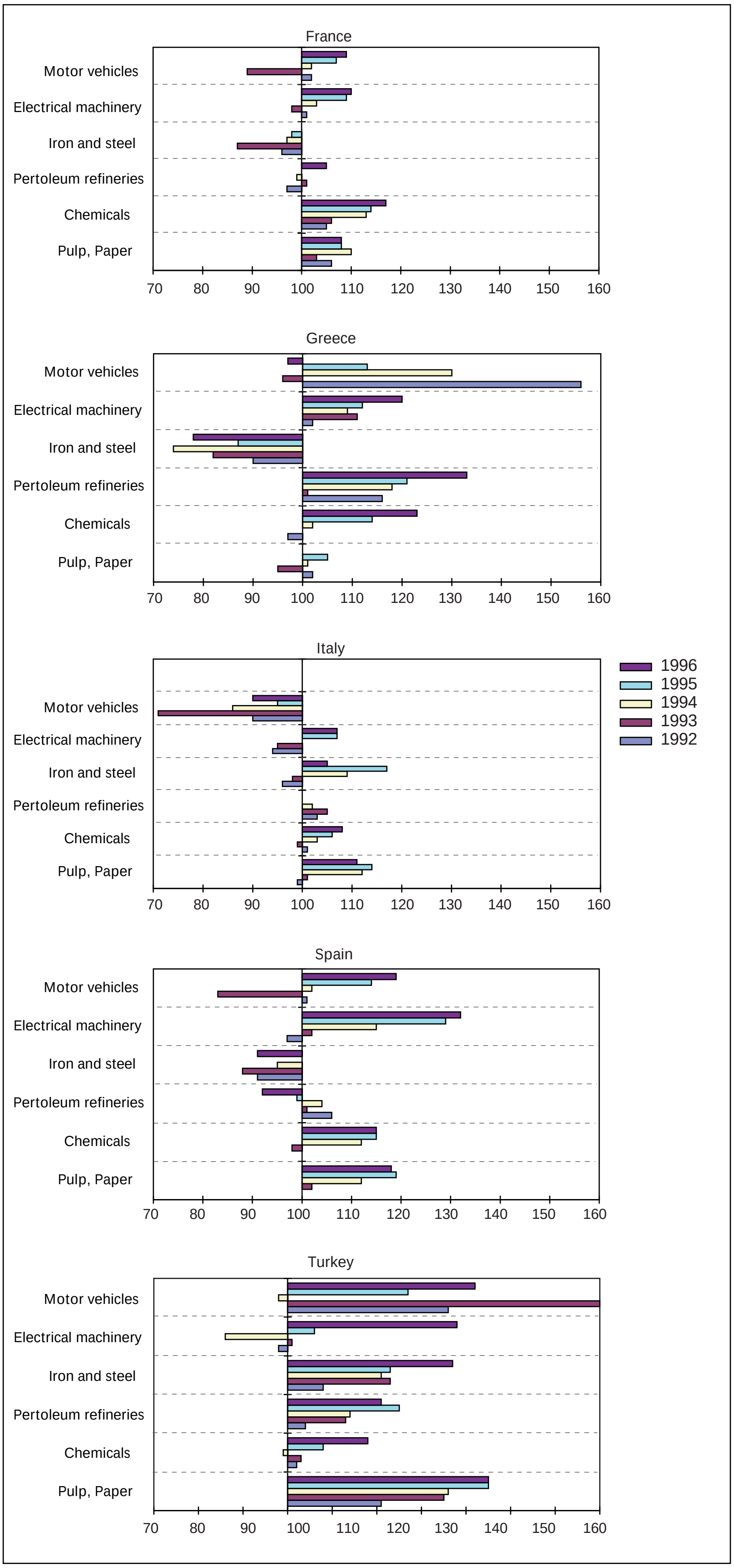
3.5.2. Distribution of industrial activities

One way of looking at the production activities occurring all over the Mediterranean basin is to look at the importance of export specialisation in each country (**Figure 3.15**).

In that respect, one can easily distinguish three groups of countries:

- The first group is very specialised in some export products, the rest being imported. This is typical of oil producing countries such as Algeria, Syria, Egypt and Libya. The current situation does not give any sign of change in the short term in spite of some exceptions like Egypt, which shows a certain diversification with some manufactured goods (textiles, shoes, etc.);
- The second group is less specialised, exporting goods even in a situation of comparative disadvantage with other countries. Thus, their exports are more diversified. This is the case for countries like Tunisia, Morocco, Turkey, ex-Yugoslavia, Cyprus and Malta. All these countries export manufactured goods such as clothes, textiles, and leather, but each one has more specific productions (chemistry, oils and lubricants in Tunisia; chemistry and fertilizers in Morocco; textile fibres, wool, cotton, paper, cement in Turkey and FR Yugoslavia);
- The third group is strongly diversified

Industrial activity of the OECD Mediterranean countries in comparison to 1991 (=100) Figure 3.14

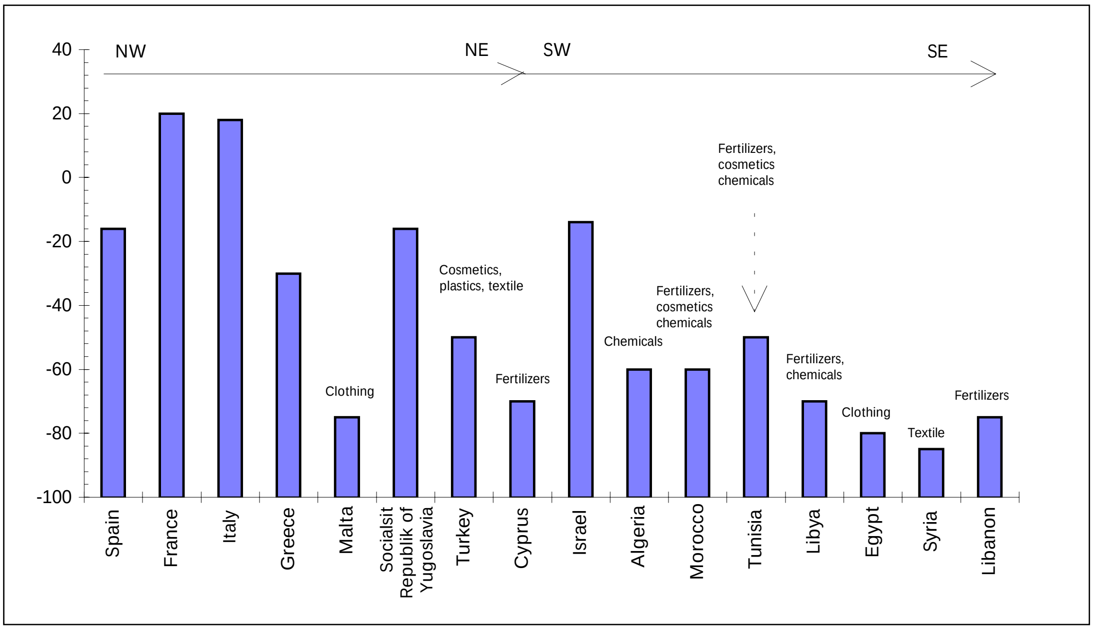


Source: OECD, 1997

Figure 3.15 **Specialisation coefficient in Mediterranean countries foreign trade (1989)**

The ratio indicated is an indicator of comparative advantage between exported and imported products (in value): if it is equal to -100, it means that the country does not export, while a ratio of +100 means that it does not import. Main export industries have been indicated for the most specialised countries (below - 40).

Source: 'La Méditerranée économique' - CEFI, 1992.



and thus much less specialised. It com prises the EU Member States. As mentioned earlier, they account for the biggest part of the petrochemical industry in the Mediterranean. Located fully in the Mediterranean basin, Italian industry is certainly the biggest, with basic manufactured goods, machines, transport equipments, etc.

Industry, besides occupying land area, may also use the land to dispose of solid wastes, for example in the form of landfill; this is particularly true of mining since it often involves the dumping of mine tailings and ore slurry on land, into rivers or to the sea directly. It may also include the ash from processes such as steel-making.

3.5.3. Industrial contaminants persistence: the case of TBT

From the industrial activities described above, industry can be considered primarily a land-based (and atmospheric) source of pollutants to the Mediterranean, especially with regard to those known as 'toxic, persistent and bio-accumulative' (TPBs), as is the case for tributyltin (TBT) used as a biocide in anti-fouling paints.

Because TBT is closely related to maritime transport of all kinds, it is spread all over the Mediterranean basin, although it is particularly concentrated in hot spots like marinas, harbours, etc. Maximum concentrations measured in marinas and harbours ranged from 2 to 12,150 ng/l of TBT (UNEP/MAP, 1996).

In aquatic environments, sediment will be the main reservoir for TBT. It degrades by biological means and photolysis within a 'reasonably' short time scale, breaking down into other organotin compounds.

Although the concentrations reported can be compared to a 'No Observed Effect Level' of tributyltin of 20 ng/l, a WHO review concludes that a provisional safe level of TBT of about 10 ng/l may be appropriate to protect seafood consumers, noting that measures to protect aquatic life will also protect human health (WHO, 1990).

Case study: In France, regular monitoring of TBT in sediments all along the French Mediterranean coast (military ports, harbours, leisure ports, shellfish beds and offshore waters) first showed a decreasing phase (1980-1990), which reflected restrictions on the use of organo-tin-based marine antifouling paints (imposed in France on boats less than 25 m long). More recent monitoring (1997) indicates that concentrations remain reduced at a number of sites (mainly ports) above 63 ng/l.

Although there is a large range of different industrial activities (from mining to manufactured products) scattered all around the Mediterranean basin, there are a number of hotspots generated by heavy industry complexes and large commercial harbours, more specifically concentrated in the north-west.

The response of industrialised countries to increased pollution and to resulting environmental impact has evolved with time. As environmental impact grew, perception of environmental risk might be reflected in new environmental management strategy, as recently emphasised: 'It is now necessary to put the emphasis on cleaner production and eco-efficiency, aiming at reducing the generation of polluting waste where it appears in the production process through preventive approaches, and at the same time making efficient use of raw materials, energy and water'. (Barcelona Resolution, Consultation on Article 6, Marseilles, 2-4 October 1996).

3.6. Oil industry

The oil industry is particularly active in the area of the Mediterranean Sea. Several important producers of OPEC and non-OPEC member countries are located in this area. Refineries are distributed all around the Mediterranean basin. Some of the riparian countries are both producers and exporters while others need to import oil for their refineries and consumption. A number of them focus on privatisation efforts (e.g. Italy and Turkey) while others have significant hydrocarbon concessions for onshore and offshore exploration opportunities.

The promotion of indigenous oil production as a way to reduce import dependence remains an important policy objective in most of the countries. In some countries, domestic oil production is relatively small and exploration has picked up within these countries over the last years (e.g. Italy, Greece and Turkey).

Two of the world oil transit points, known as 'choke-points', can be found in the Mediterranean region: the Strait of Istanbul (Bosphorus) and the Suez Canal-Sumed Pipeline. The first point, located in Turkey, has a 160-mile long waterway and includes the Marmara Sea and Çanakkale Strait and connects the Black Sea with the Mediterranean Sea, with oil flows of 1.4 million barrels per day (estimated in 1995). The second connects the Red Sea and the Gulf of Suez with the Mediterranean Sea with oil flows of 2.9 million bl / d (0.8 million bl / d through Suez Canal, 2.1 million bl / d through Sumed pipeline) (**Table 3.6**).

3.6.1. Exploration and production

Complex geology and vast unexplored regions contribute to the uncertainty in ascertaining the size of hydrocarbon resources in the Mediterranean region (including both onshore and offshore areas). The total known oil reserves are estimated at more than 45 billion barrels per day. Exploration is the focus of most of the national / international companies operating in the area.

Following nationalisation of the countries' oil industries, as well as the European Union hydrocarbon licensing directive forbidding the granting of exclusive drilling rights to one company in a single geographic area, production-sharing agreements with many oil companies are proliferating. Several international oil companies are currently engaged in exploration / production agreements with national oil companies in each Mediterranean country. Exploration could account for more than 3.5 million barrels / day in major oil producing countries of the Mediterranean basin (**Figure 3.16**)

The most attractive exploration regions in terms of new discoveries are located in both onshore and offshore areas. For instance four in Algeria (at Ghadamis and Illizi basins near the Algeria-Tunisia-Libyan borders), three in Libya (at Sirte, Ghadamis and Murzuq basins), six in Egypt (at Ashrafi in the Gulf of Suez, East Tanka – offshore, Western Desert, Meleiha, Qarum and Abu Gharadiq), four in Greece (at northwest Peloponnesos, Ioannina, Aitoloakrnania and at the Gulf of Patraikos – offshore, two in Italy (at the Val d'Agri in the southern region of Basilicata and Abruzzo – offshore – and in the lower Adriatic Sea off Brindisi).

3.6.2. Refining and petrochemicals

Extensive refining and petrochemical industries are operating in the Mediterranean region. The number of major refineries located in the Mediterranean region are more than 40 in total with a current (1997) combined capacity of more than 685,500 billion bl / d (**Figure 3.19)**.

Most of them are located in the northern countries. Petrochemical industries are involved in the production of ammonia, methanol, urea, ethylene, naphtha, propylene, butane, butadiene, aromatics, etc. Countries with a low use of secondary processes at the various facilities must continue to rely on imports, even though they are capable of meeting almost all of their country's domestic requirements. This results in high seaborne oil trade in the Mediterranean Sea.

Table 3.6 **Overview of some oil industries in Mediterranean Sea region**

Country	Known oil reserves in billions (bl/d)*	Oil production (bl/d)*	Oil consumption (bl/d)*
Libya	29.5	139 0000	125 000
Syria	2.5	618 000	208 000
Egypt	3.7	979 000	455 000
Algeria	9.2	135 0000	250 000
Greece	0.012	14 000	366 000
Israel	0.004	<1000	204 000
Italy	0.620	128 000	1840 000
Turkey	0.260	71,200	600 000
TOTAL	45.8 billion	4.55 million	4.05 million

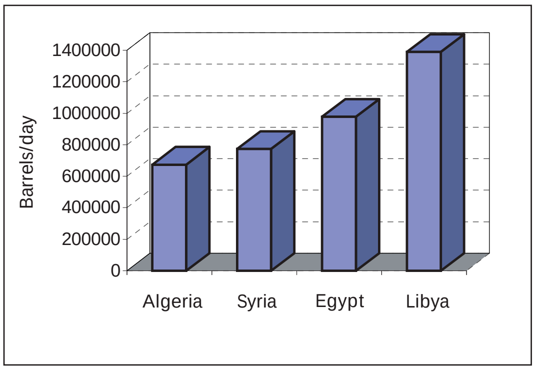
***** barrels per day**

Source: EIA, 1996-1997

3.6.3. Pipelines and terminals
An extensive network of crude oil pipelines and gas line systems exists mainly in the countries of production, linking their oilfields to their refineries and port terminals or to other countries as shown in **Figure 3.17.**

3.6.4. The Mediterranean seaborne oil trade
A comparison between the 1985 and 1994 regional traffic and transit flows for crude oil and refined products shows that the total Mediterranean seaborne oil trade has remained more or less stagnant during this period (**Figure 3.18**). In 1994 the amount of crude oil was only 8 % higher than the corresponding figure for 1985. In contrast, the volume of refined products was 14 % lower than recorded in 1985.

Figure 3.16 **Production of major oil producing countries in the Mediterranean region**



Oil Fields in countries:
Algeria*: Hassi Messaoud (North), Hassi Messaoud (South), Tin Fouye Tabankort Ordo, Zarzaitine, Haoud Berkaoui/Ben Kahla, Rhourde Nouss, Alrar, Rhourde el-Baguel, El-Gassi el-Agreb, Ait Kheir, Hassi R'Mel*
Syria*: Deir el-Zour, Karatchuk, Maleh, Qahar, Sijan, Azraq, Tanak, Jafra*
Egypt*: Belayim, Morgan, Badri, Ras Burdran*
Libya*: Murzuk, Kabir, Bu Attifel, Bouri*

Although it is difficult to predict, given that the oil production market by its very nature is unstable, the offshore oil production in the Mediterranean might remain limited in the next few years (1.3 % of the world production in 1995), compared with other well (or intensively) prospected fields (North Sea, Gulf of Mexico, South-East Asia and South America).

3.7. Maritime Traffic

3.7.1. Major traffic routes in the Mediterranean
It is estimated that about 220 000 vessels of more than 100 tonnes cross the Mediterranean each year, which is estimated at 30 % of the total merchant shipping in the world and 20 % of oil shipping. Daily, an estimated 2 000 vessels cruise the Mediterranean, of which 250-300 are oil tankers.

Among the transported products, the oil market is at the core of commercial links between countries of the north and south Mediterranean with an annual flux of about 360 million tonnes (MT) mainly coming from the Middle East (about 150 MT going through the Suez Canal and the Sumed pipeline; mainly loaded at the Sidi Kerir terminal).

There are thus three major passage-ways to and from the Mediterranean: the Strait of Çanakkale / Sea of Marmara / Istanbul Straits, the Strait of Gibraltar and the Suez Canal.

The major axis (90% of the total oil traffic) is from east to west (Egypt-Gibraltar), passing between Sicily and Malta and following closely the coasts of Tunisia, Algeria and Morocco. **(Figure 3.19)**

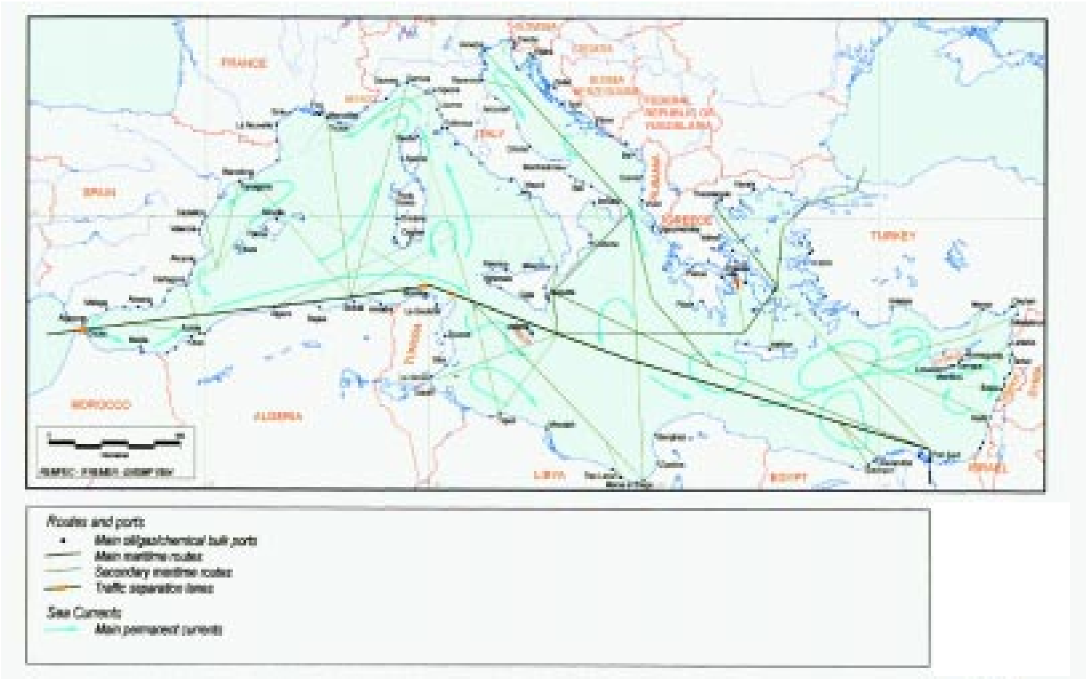
Traffic on the main axis reduces gradually as it moves westwards and branches off towards unloading terminals near Piraeus in Greece, the northern Adriatic, the Gulf of Genoa and near Marseilles; it is intersected by tanker routes connecting Algerian and Libyan loading terminals (about 100 MT) with the northern Mediterranean oil ports (**Figure 3.19**).

The second important route (presently used only partially due to the Iraqi embargo) connects crude oil terminals in the Gulf of Iskenderun and on the Syrian coast with Gibraltar and the northern Mediterranean ports.

A third route, from the Black Sea through the Istanbul Strait / Sea of Marmara / Çanakkale

Risk routes and ports from countries of production, linking their oilfields to their refineries and port terminals or to other countries — Figure 3.17

Source: UNEP/IMO



Straits (about 70 MT) leads westwards to join the main axis.

In total, the annual number of tankers (crude oil and refined product carriers with a cargo amounting to 50 MT) passing through the Strait of Gibraltar is estimated to represent 4 400-4 500 units, i.e. about one fifth of the world total. **Table 3.7** shows the most important crude-oil terminals from the 305 ports (spread) around the Mediterranean.

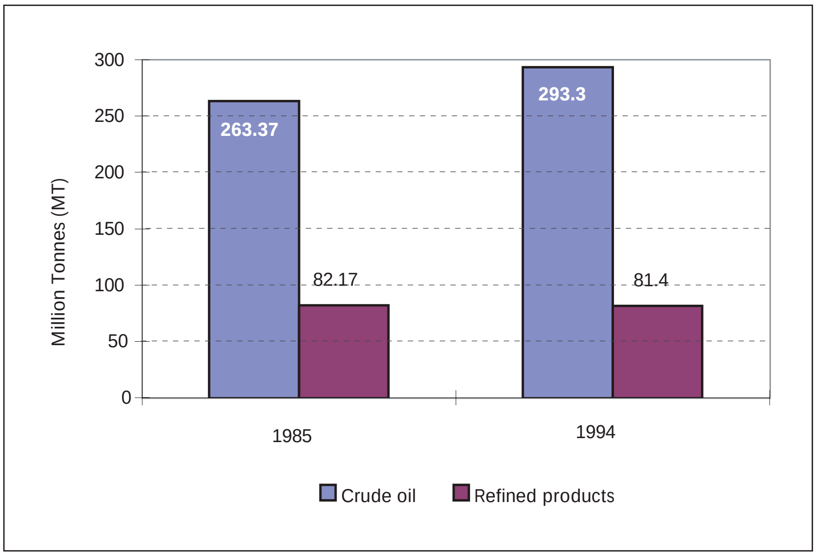
3.7.2. Pressure of maritime traffic in connection with maritime accidents

On average, there are about 60 maritime accidents in the Mediterranean annually, of which 15 involve ships causing oil and chemical spills. Ports, oil terminals and their immediate surroundings are usually most at risk (about 60 %). **Figure 3.20** shows the number of major accidents reported in the region in the period 1987-1996.

3.7.3. Reported damage from accidents

Damage inflicted by oil spills is of two kinds: ecological and economic, with a range of impacts not necessarily in proportion to the amount of oil spilt. The extent of the accident impact will depend on the accident site (offshore or close to urban areas or coastal amenities), type of the product spilled and

Actual 1985/1994 Mediterranean seaborne oil trade evolution — Figure 3.18



Data sources: ECOMAR 1991; The Tanker Market (Drewry Shipping Consultant, 1996) its quantity. In general, the direct ecological impact is mainly on birds and marine mammals, less so on fish or invertebrates. Although no definite conclusions can be drawn from the number of accidents, available data show an overall decrease in the number of accidental oil spills and in the quantities of oil spilled in the Mediterranean Sea over the last decade with a sustained decrease since 1991 when more than 12 000 tonnes of oil were spilled according to REMPEC 1996.

From the economic point of view, the most directly affected activities are usually fishing, fish farming and tourism. The perception of environmental and economic impact of spills, likely public pressure and consequently the damage assessment, will largely depend on press coverage of an oil spill accident and on general socio-economic situation in the affected country. As regards the risk of pollution and the envisaged damage assessment, the Mediterranean can be divided into three regional categories: importing regions, exporting regions, and regions close to oil shipping routes. The countries falling into the first category are: France, Italy, Spain, Turkey, Israel, Greece and Croatia. Any accident in these regions will have a great economic impact and will be used as a model for future events of this type. The second category comprises Algeria, Egypt, Libya, Syria and Tunisia. The pressure from the public will not be the same and the likely damage will be underestimated. Countries in the last group include Albania, Cyprus, Lebanon, Malta, Morocco and Slovenia.

Between 1987 and the end of 1996 an estimated amount of 22 000 tonnes of oil entered the Mediterranean Sea as the result of shipping incidents. This figure was derived by REMPEC from reports on all spill incidents in the Mediterranean region, which are regularly received from its National Focal Points and from Lloyd's Casualty Reporting Service. The figures for individual years vary between some 12 tonnes reported in 1995 and approximately 13 000 tonnes in 1991 (**Figure 3.21**).

Most oils spilled in the Mediterranean in recent years belong to the category of persistent oils.

It should be noted that the major incident in the Mediterranean recorded during the ten-year period 1987-1996 was the 'Haven' incident that occurred on 11 April 1991 off Genoa, Italy, when Cypriot MT 'Haven' caught fire and subsequently suffered a series of explosions. Although the entire cargo of approximately 144 000 tonnes of crude oil was lost, most of it burned out and it is estimated that 'over 10 000 tonnes of fresh and

Figure 3.19 **Activities of the oil industry in the Mediterranean Sea**

Source: RAC/REMPEC

partly burnt oil were spilled into the sea' (IOPC Funds, Annual Report, 1996).

The second large accident that affected the Mediterranean Sea during that period was the collision between 'Sea Spirit' and 'Hesperus' in August 1990, west of Gibraltar, outside the Mediterranean. This accident resulted in a spill of some 12 200 tonnes of heavy crude oil that entered the Mediterranean carried by currents and winds, and threatened the coast and sea off Morocco, Spain and Algeria.

Although there is a trend in recent years for spilled quantities to become exclusively persistent oils, 370 million tonnes of oil are transported each year in the Mediterranean Sea (in transboundary trade), and therefore ship-generated oil accidental pollution has contibuted only marginally to the overall ecological risk, represented by hydrocarbons, for the Mediterranean marine and coastal environment.

3.8. Discharge from sewage outfalls

3.8.1. State of major coastal cities

Within the framework of the MED POL Programme, information was collected through different projects completed or partially completed, namely 'the Survey on Land-Based Sources of Pollution' (WHO / UNEP, 1996b) and 'the Identification of Priority Pollution Hot Spots in the Mediterranean' (WHO / UNEP, 1997), on the sewage discharged from the main Mediterranean coastal cities.

Despite the efforts made in order to collect adequate information, the data is not complete and cover only 68 out of 86 cities with a population of more than 100 000 inhabitants, and 162 out of 380 cities with a population between 10 000 and 100 000 inhabitants.

The difficulty in collecting data through different programmes has resulted in fragmented information with findings of little practical use. In order to improve the situation, a particular activity related to the state of wastewater treatment plants in the Mediterranean has commenced.

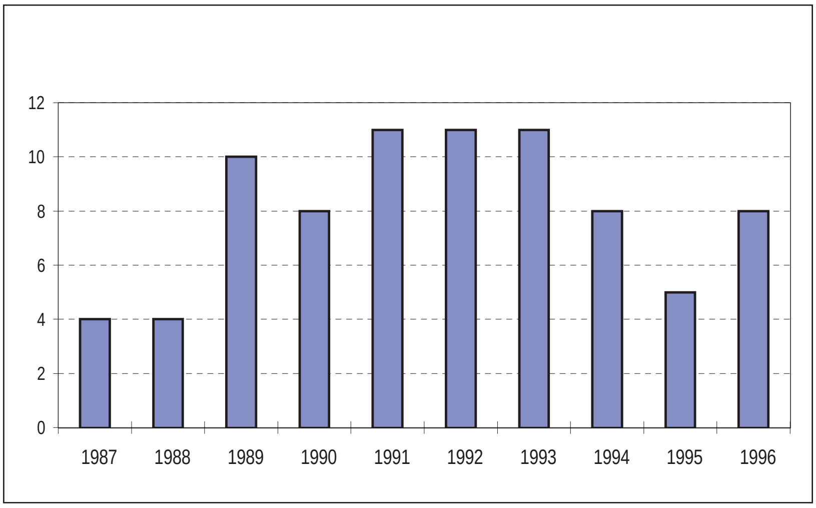
Although there is substantial improvement in some countries, according to the data received from WHO / MAP for ten Mediterranean countries, about 33 % of the population are not yet served by municipal sewage treatment.

Most important loading and unloading oil terminals Table 3.7

Loading: Ports	Load, MT*	Unloading: Ports	Load, MT
• Sidi Kerir and Suez	120+	• Marseilles	40+
• Libya (Sirte, Es Sides, etc.)	60+	• Trieste	30+
• Cyhan	(not operating; Iraqi embargo)	• Genoa	20+
• Arzew	10+	• Siracusa	10+
		• Cagliari	10+
		• Piraeus	10+

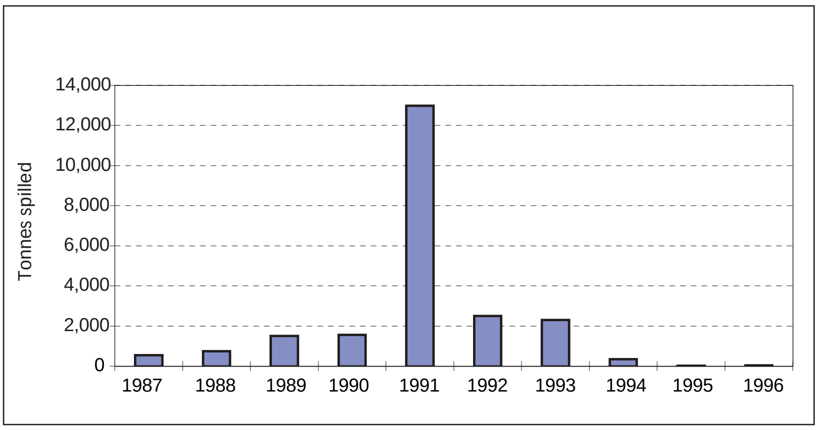
* = Million tonnes

Number of oil spill accidents in the Mediterranean Sea (1987-96) Figure 3.20



Source: REMPEC

Quantity of oil spilled in the Mediterranean Sea from 1987 to 1996 Figure 3.21



Source: REMPEC

3.8.2. Permanent population and seasonal increase

In coastal cities the population usually increases during the tourist season. The histogram of **Figure 3.22** shows the permanent population and seasonal variation due to tourism for the coastal cities of the Mediterranean countries for which data was made available.

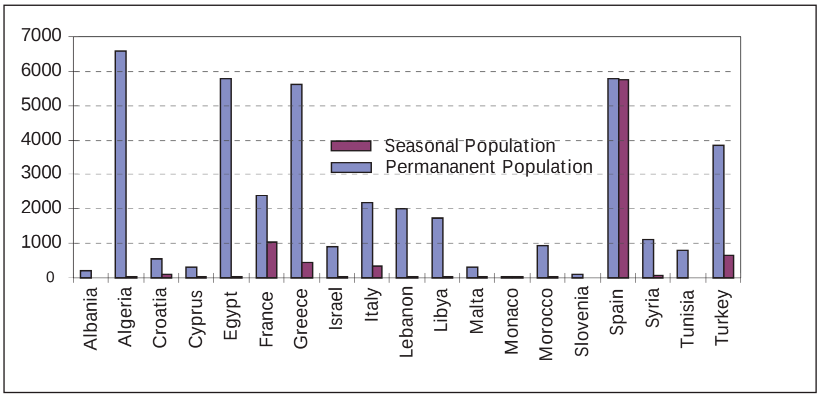
Not all the coastal cities under review are equipped with wastewater treatment plants for their sewage. **Figure 3.23** shows the cities served by such treatment plants, irrespective of the degree of treatment and according to the existing population; while **Figure 3.24** gives a picture of the degree of treatment, when it exists, expressed as a percentage of the total number of treatment plants.

3.8.3. Discharge at sea

All the Mediterranean coastal cities discharge their effluents, whether treated or not, into the marine environment using, appropriately or not, sewage outfalls. Sometimes the treated effluents are reused, mainly for irrigation purposes.

Figure 3.25 shows the amount of wastewater discharged into the sea every year from coastal cities for which data is available to WHO/MAP, either (a) treated, which means Biological Oxygen Demand (BOD) is reduced by 25 % to 95 % depending on the treatment method used, or (b) untreated. It also shows the amount of wastewater treated and reused, thus not discharged into the sea. The proportion of reused water is still very limited (0.49 million m^3/year).

Figure 3.22 **Seasonal variation of population in the cities included in the survey, by country**



Source: WHO/MAP, 1996a

3.9. Discharges via rivers

3.9.1. Major rivers and loads of nutrients

About 80 rivers contributing significantly to pollution inputs to the Mediterranean Sea have been identified. However, not all of them are monitored for all water quality determinants. In addition, the specific features of the Mediterranean hydrology must also be noted: it is very heterogeneous, ranging from an alpine regime with early summer maximum, to a typical Mediterranean regime with winter high flows, to the semi-arid regime of the south coast with a gradual increase of summer drought and development of episodic floods. All metals, some micro-pollutants and some nutrients and organic carbon are attached to the particles and carried to the sea in such episodic events.

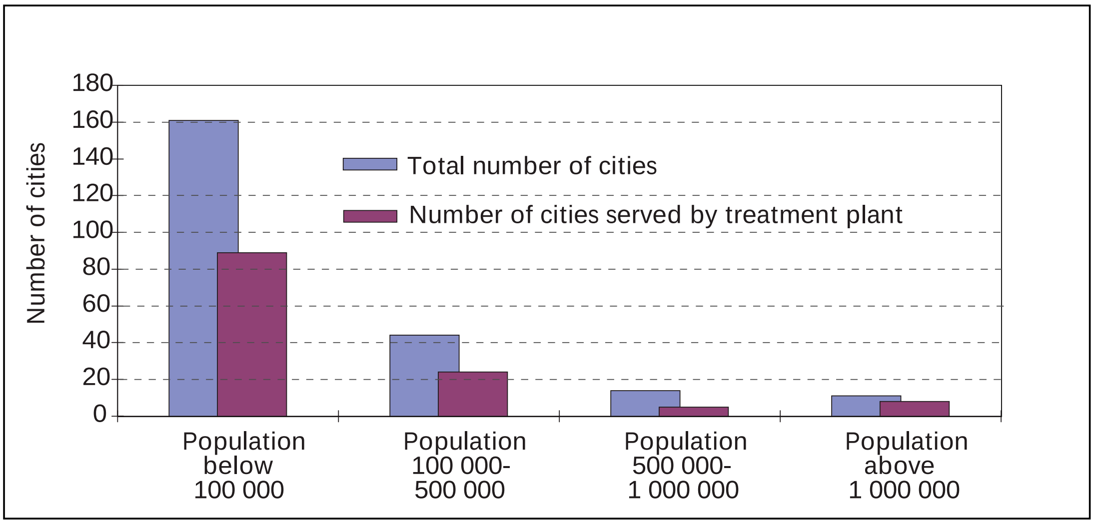
The nutrient levels found in Mediterranean rivers are about four times lower than those in western European rivers. In all documented cases, nitrate levels are increasing, although the trend for ammonia is variable depending on the method of sewage collection and treatment carried out. Phosphate concentrations may increase dramatically, as seen in Greece, or steadily as found in France, or decrease when phosphate restriction measures are imposed (phosphate ban on detergents as in Italy). Although some local coastal eutrophication events do occur (as in the northern Adriatic), the main body of the Mediterranean as a whole is not yet seriously threatened with eutrophication over the last decades. Depending on the river size and location, the concentration ranges are enormous, over an order of magnitude for nitrate and more for ammonium and phosphate.

3.9.2. Harmful substances from rivers

Mediterranean rivers are less contaminated with heavy metals than most western European rivers. This may be the result of dilution of urban and industrial sources by high levels of suspended solids in highly erosive environments (UNEP/MAP, 1997). Metals are very much linked with particulates, i.e. 80 % to 99 % of heavy metals carried by rivers are in the particulate phase. Their analyses show that natural variations of heavy metals can sometimes account for a doubling of levels with regard to the reference values ('pristine' river analysis) but, above this rate of change, pollution is likely. However, budgets of heavy metal inputs from rivers to the Mediterranean are quite difficult to establish: (i) many rivers are still unmonitored for metals associated

Number of cities served by treatment plants Figure 3.23

Source: WHO/MAP, 1996a



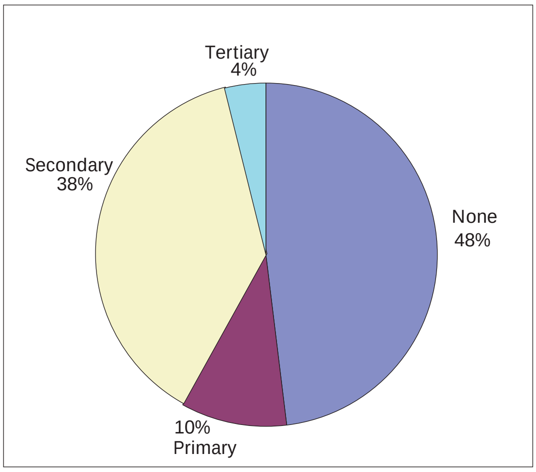
with particulate, or not adequately monitored; (ii) water inputs have been changed, sometimes drastically as for the Nile; and (iii) river sediments, including their attached load of metals, are now retained behind reservoirs.

In spite of the uncertainty of data available, some major points can be made: (i) most metal fluxes are still associated with particulate matter; (ii) reservoirs are probably storing much of the metals originating from human activities; (iii) due to this retention, the net inputs to the Mediterranean Sea are stable for cadmium, but may decrease for copper, lead and zinc. The case of mercury is very specific because of its significant remobilization during estuarine mixing, and / or in near-shore deposited sediments, resulting in a two-fold increase in dissolved mercury, certainly in the north-western Mediterranean (Cossa & Martin, 1991).

Organic micropollutants discharged by rivers are not adequately monitored in order to assess loads even though they are important. However, contamination by industrial products is documented for large rivers (Po, Ebro and Rhône) for polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and solvents (Meybeck & Ragu, 1997).

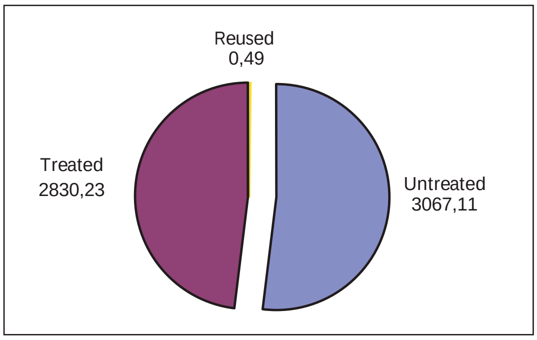
Evidence of high pesticide concentrations (concentrations >1mg / L) have been found in some specific studies and are believed to occur in many small rivers which are affected by intensive agriculture. The type of pesticides found in rivers may vary greatly from one country to another and the same is probably true from one river to another.

Degree of sewage treatment in coastal cities Figure 3.24



Source: WHO/MAP, 1996a

Annual amounts (million m³/year) of waste water discharged into the sea from coastal cities for which data was made available to WHO/MAP Figure 3.25



Source: WHO/MAP

Bacterial contamination ranges from none in a few sparsely populated basins, to a dramatic amount (>100 000 faecal coliforms / 100 ml) in some southern rivers. In north-western rivers the contamination, although still present, has usually dramatically decreased since the general application of sewage collection and treatment in the last two decades.

Although not well established, the water inputs to the Mediterranean Sea have decreased dramatically over the last 40 years, not only for the Nile (probably more than 90 % reduction), but also for many other rivers (20 to 30 % reduction) due to damming and irrigation. Even the Rhône river discharge, one of the largest inputs after the Nile, has decreased by more than 10 times (90 %). The south Levantine, Alborán, south-west Aegean seas, and the central and northern Levantine basins are probably those most affected by this reduction.

The impact of dams on sediment loads is drastic: they are sometimes reduced by more than an order of magnitude. When considering the Nile water discharge reduction, and possible reduction for many other rivers, the total sediment load to the Mediterranean Sea may have been reduced by 70 % (which could partly explain the decrease in certain heavy metal concentrations).

To better understand the current situation and its evolution, accurate river water budgets to the Mediterranean for each sub-basin should be carefully re-established. A register of the 20 largest river basins, which are regularly updated every 5 years for simple socio-economic attributes related to water management (e.g. total basin population, land use ratio, industrial indices, etc.), should be established. On the other hand, it is vital to list the few remaining small river basins which are still in near-pristine condition in order to ensure the conservation of typical Mediterranean rivers (Krka, Neretva, Tavignano, etc.). It will also be important to establish an inventory of these through in-depth water quality investigation.

Table 3.8 represents the major Mediterranean rivers in decreasing order of present water discharge to the sea, and documented rivers for dissolved nutrients.

Loads of disolved nutrients from major Mediterranean rivers in the Mediterranean Sea Table 3.8

Rivers	Flow km^3/year	Nitrate ($N-NO_3^-$) mg/l	Ammonium ($N-NH_4^+$) mg/l	Phosphate ($P-PO_4^{-3}$) mg/l	Country
Po	48.90	2.03	0.21	0.084	Italy
Rhone	48.07	1.48	0.124	0.101	France
Drini	11.39				Albania
Neretva	11.01	0.269	0.029		Croatia
Buna	10.09				Albania
Ebro	9.24	2.3	0.167	0.029	Spain
Tevere	7.38	1.37	1.04	0.26	Italy
Adige	7.29	1.25	0.111	0.03	Italy
Seyhan+	11.30	0.43	0.7	0.14	Turkey
Ceyhan+	13.30	1.03	0.13	0.04	Turkey
Evros/ Meriç	6.80	1.9	0.05	0.36	Greece/Turkey
Vijose	6.15				Albania
Isser	6.12				Algeria
Akheloos	5.67	0.60	0.035	0.02	Greece
Manavgat Creek+	3.81	0.22			Turkey
Axios	4.90	1.584	0.065	0.48	Greece
Buyuk Menderes+	0.40	0.75	0.33	0.07	Turkey
Mati	3.25				Albania
Volturno	3.10				Italy
Semani	3.02	0.24			Albania
Strymon	2.59	1.236	0.053	0.11	Greece
Goksu+	3.60	0.59	0.18	0.06	Turkey
Brenta	2.32				Italy
Arno	2.10	0.912	0.042	0.50	Italy
Shkumbini	1.94	0.73			Albania
Gediz+		1.18	0.005	0.14	Turkey
Pescara	1.70				Italy
Krka	1.61	0.45	0.031	0.029	Croatia
Moulouya	1.58				Morocco
Var	1.57	0.18	0.031	0.006	France
Reno	1.40				Italy
Aude	1.31	1.42	0.09	0.09	France
Cheliff	1.26				Algeria
Jucar	1.26				Spain
Aliakmon	1.17	0.395	0.05	0.10	Greece
Nestos	1.03	1.24	0.071		Greece
Herault	0.92	0.61	0.06	0.045	France
Orb	0.86	0.67	0.44	0.14	France
Ter	0.84		1.2		Spain
Pinios	0.672	2.32	0.167		Greece
Llobregat	0.466	1.9	3.2	1.2	Spain
Metauro	0.43	1.36	0.0	0.005	Italy
Tet	0.40	1.8	1.5	0.47	France
Argens	0.38	0.74	0.09	0.11	France
Fluvia	0.36		0.054		Italy
Nile	0.30*				Egypt
Besos	0.130	1.9	3.1		Spain
Kishon	0.063				Israel
Tavignano	0.06	0.34			France (Corse)

Source: UNEP/MAP, 1997

Note:
+ Average values in 1996, Ministry of Energy and Natural Resources of Turkey
**** Estimates of actual discharge from 'Rosetta' and 'Damietta' branches.***

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4. Environmental state and threats

This section describes the Mediterranean Sea and its coastal zone by reviewing its environmental state and the main threats, including the state of eutrophication, land use in coastal zones, chemical contamination, oil and microbial pollution and radioactive contamination. Historical data series, problems and successes in policy and management implementation are discussed.

Assessment of some of the issues contained in this section, such as eutrophication and its effects, are still far from being completed and they are based on the existing data and information provided by the riparian countries.

The inconsistent availability of data throughout the Mediterranean Region, which has already been reported in chapter two of the report has shown to be a common trait also in the MED POL databases, with the problem being more acute for the southern countries.

The presence of heavy metals and chlorinated hydrocarbons in the marine environment has been dedicated a specific chapter in this section, as these classes of contaminants present potential risks to marine life and to human health through consumption. The section on coastal zones covers the main pressures on coastal zones, with some discussion of potential conflicting uses. Coastal erosion is also part of this chapter. However, the lack of information and the difficulty in accessing dispersed data constitute a serious obstacle in assessing the state of the erosion process, and this difficulty is also reflected in the text coverage.

The section on oil pollution focuses mainly on the effects of oil industry and maritime transport, previously discussed in chapter three of the report (driving forces and pressures).

The section on microbiological contamination discusses sources, dispersion and fate of contaminants, the standards adopted and the state of microbiological pollution in bordering countries in the Mediterranean.

Finally, the section on radioactive contamination takes into account present levels and historical data series for the main radionuclides which are present in the sediment, water column and organisms.

4.1. Eutrophication

4.1.1. General

The Mediterranean is one of the most oligotrophic seas in the world and most of its biological productivity takes place in the euphotic zone (UNEP, 1989).

Eutrophication is the process by which waters enriched with nutrients, primarily nitrogen and phosphorus, under favourable physico-chemical conditions stimulate aquatic primary production (Vollenweider, 1968; 1981). Its most serious consequences are algal blooms (‘red tides’), algal scum, enhanced benthic algal growth and, at times, a massive growth of submerged and floating macrophytes. Occasionally, these manifestations are accompanied by, or alternate with, cycles of visible bacterial blooms (Aubert & Aubert, 1986) and fungal growth leading to oxygen depletion in bottom waters and fish kills. The recent report on the ‘adverse biological effects in rivers, lakes, reservoirs, estuarine coastal and marine waters, caused by excessive inputs of nutrients’, published by the European Environment Agency, reflects the situation in the European part of the Mediterranean Sea along with the other European regional seas.

Scientists reviewing the existing information have concluded that the main body of the Mediterranean Sea will not be seriously threatened by eutrophication over the next few decades (UNEP/FAO/WHO, 1996); whereas climatic change scenarios predict that this oligotrophy will be even more pronounced in the offshore ecosystem in the future, (Sestini, 1993).

The oligotrophy of the Mediterranean can be attributed to lower nutrient inputs than the outflow through the Strait of Gibraltar (estimated nitrogen outflow/inflow ratio is 5.7/1.9 (= 3/1), from data reported in UNEP/FAO/WHO, 1996). According to reported calculations, the Atlantic surface-water inflow compensated for about 71% of the deep-water outflow. Terrestrial inputs accounted for approximately 29 % (UNEP/FAO/WHO, 1996).

Other scientists (Bethoux et al., 1992) have argued that terrestrial and atmospheric inputs are greatly underestimated. These authors presented and discussed data showing an increase in the nitrogen and phosphorus budgets in the deep sea of the western basin. They recalculated the terrestrial inputs, the Atlantic/Mediterranean water exchanges and the biogeochemical cycles and provided results different from previous estimates.

It must be noted that the importance of nutrient budgets in deep offshore waters (>1 000-2 000 m) could be negligible as far as eutrophication trends are concerned, since they are excluded from the photosynthetic processes taking place in the euphotic zone, and as areas of upwelling only exist as a local phenomenon in the Mediterranean.

However, considerable care must be given to the control of loads in order to prevent a deterioration of water quality on a basin scale. Although the concentrations of nitrates and phosphates found in the intermediate and deep waters of the Cretan Sea are higher than those found during the last ten years (Souvermezoglou et al., in press), the hypothesis of Bethoux et al., (1992) does not to apply to the whole eastern basin, since lower concentrations have been found in the Levantine Basin (Souvermezoglou et al., 1996).

Both hypotheses could be true and further work, through focused monitoring programmes aimed at the confirmation of either hypothesis, is necessary if trends and possible scenarios are to be predicted. However, future research work should concentrate on coastal areas where control measures are expected to take place.

The concept of nutrient limitation, considered as limitation of the growth rate of phytoplankton populations currently present in the water body, adds uncertainty to the general assessment. The importance of the nutrient limitation concept stems from the need to identify the main factors triggering eutrophication and to provide a choice of appropriate response measures targeting either one of the two prominent chemical elements: nitrogen and phosphorus.

According to Krom et al., (1991) primary production in the eastern Mediterranean (data from the Levantine basin) is limited by phosphorus. On the other hand, recent data from the eastern basin seems to suggest that nitrogen is the limiting factor in offshore waters. In the south-east Ionian, Cretan and north-west Levantine seas, chlorophyll concentrations in 1993 rarely exceeded 0.5 mg/m^3, while nitrate and phosphate levels ranged from 0.01-5 µM and 0.00-1.7 µM respectively (Souvermezoglou et al., 1996). Compared with values taken during the previous ten years, nitrate did not exceed 3.0 µM and phosphate 0.12 µM in the western basin, according to recent monitoring programmes. In surface waters of the Ligurian Sea, the following mean values have been reported: 0.2-5.4 mg/m^3 for chlorophyll a, 0.02 µM for nitrate and 0.04 µM for phosphate (Bethoux et al., 1992); thus showing a slight tendency for nitrogen to be the limiting factor.

Other authors (Chiaudani et al., 1980; Marchetti, 1985) show phosphorus limitation in the Adriatic Sea, an area often subjected to eutrophication events, while Mingazzini et al., (1992) suggest that P is the limiting factor in the coastal waters of Emilia-Romagna. It must be said, however, that the high nutrient inputs from inland sources and the shallow depth of the Adriatic provide very different conditions from those encountered in deeper and more open seas.

It is not possible to derive conclusions with regard to nutrient limitation from a restricted number of local measurements, as multiple factors concur to change the situation at seasonal level. Sediment resuspension and nutrient emissions from sediments, along with the nutrient inputs from the land/sea boundaries, provide variable seasonal patterns in nutrient concentrations. Water circulation and the geomorphology are also of great importance since they determine the residence time of the enriched water within the Mediterranean at a sub-basin scale (e.g. Adriatic Sea, Cretan Sea, Straits of Cretan Arc).

4.1.2. Eutrophication in coastal areas

Although the problem of eutrophication in the Mediterranean appears to be limited largely to specific coastal and adjacent offshore areas, several (sometimes severe) eutrophication events occur. This is especially seen in enclosed coastal bays which receive anthropogenically-enhanced nutrient loads from rivers and the direct discharges of untreated domestic and industrial waste-waters. Furthermore, uncontrolled expansion of aquaculture may cause local environmental problems, especially in the eastern Mediterranean.

Figure 4.1 summarises the most important sites of reported eutrophication events in coastal and lagoon areas of the Mediterranean (UNEP/FAO/WHO, 1996). The situation at basin level is clearly illustrated in the satellite image in **Figure 4.2**, where chlorophyll variations in surface waters reveal that the highest concentrations are found close to river deltas and estuaries or near large urban agglomerations, even in areas which are not covered by 'grey' literature. The image has been produced from 1979-1985 data, due to be updated with a new operating satellite.

Conversely, open sea waters of the Mediterranean appear oligotrophic or even ultra-oligotrophic, except in areas where upwelling of deep nutrient-rich waters occurs (see Chapter 2). Almost all coastal countries are affected by eutrophication, although at different levels.

Although the northern shores are the most affected, serious eutrophication problems exist also in the south and the phenomenon should not be underestimated, as the limited number of recorded events may well be due to the poorer monitoring gathered by the southern Mediterranean countries. Eutrophication problems are likely to increase in the future due to rapid population expansion, applied production technologies and inadequate environmental policies and enforcement.

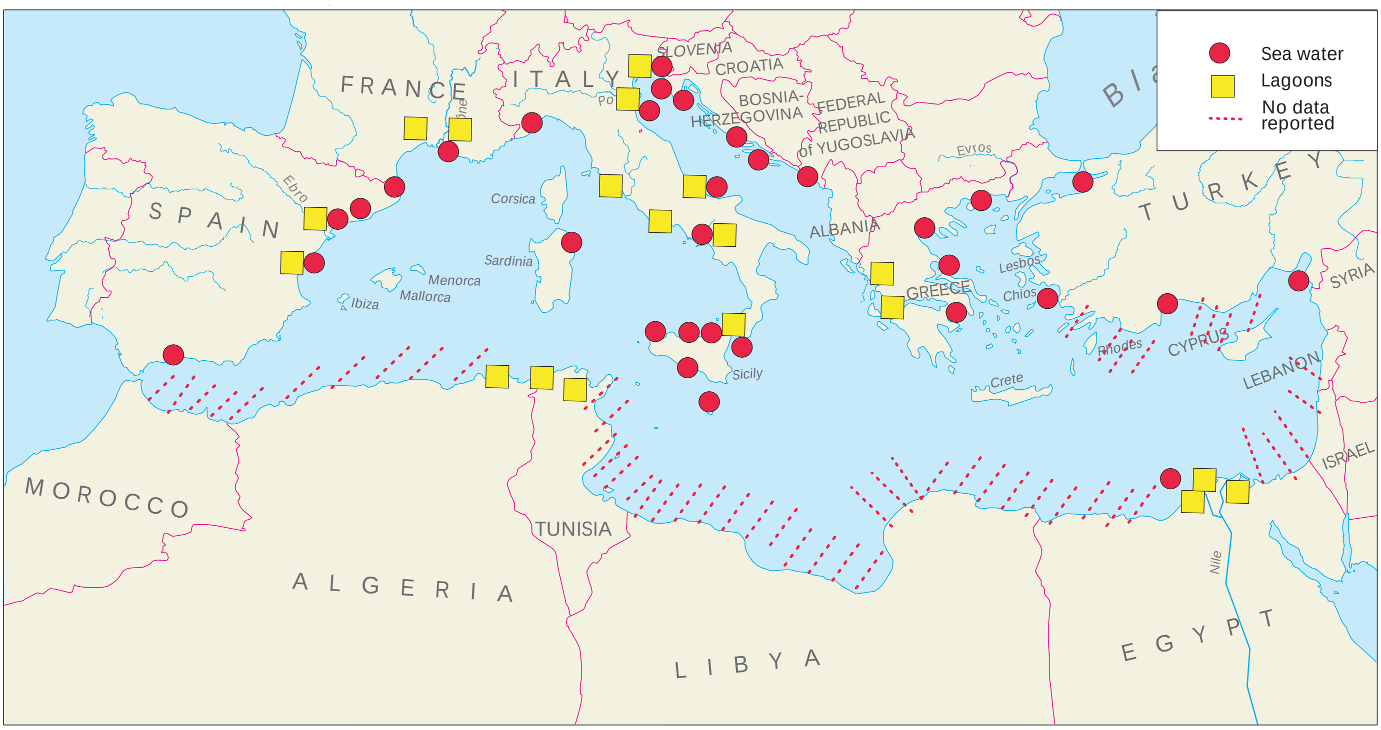
These local and regional eutrophication problems can negatively affect not only marine life, as will be discussed later, but can also have a socio-economic and potential adverse impact on tourism, aquaculture, fisheries and other water uses.

4.1.3. Algal blooms in the different seas

It is not feasible to assess the Mediterranean eutrophication phenomena solely on nutrient concentrations.

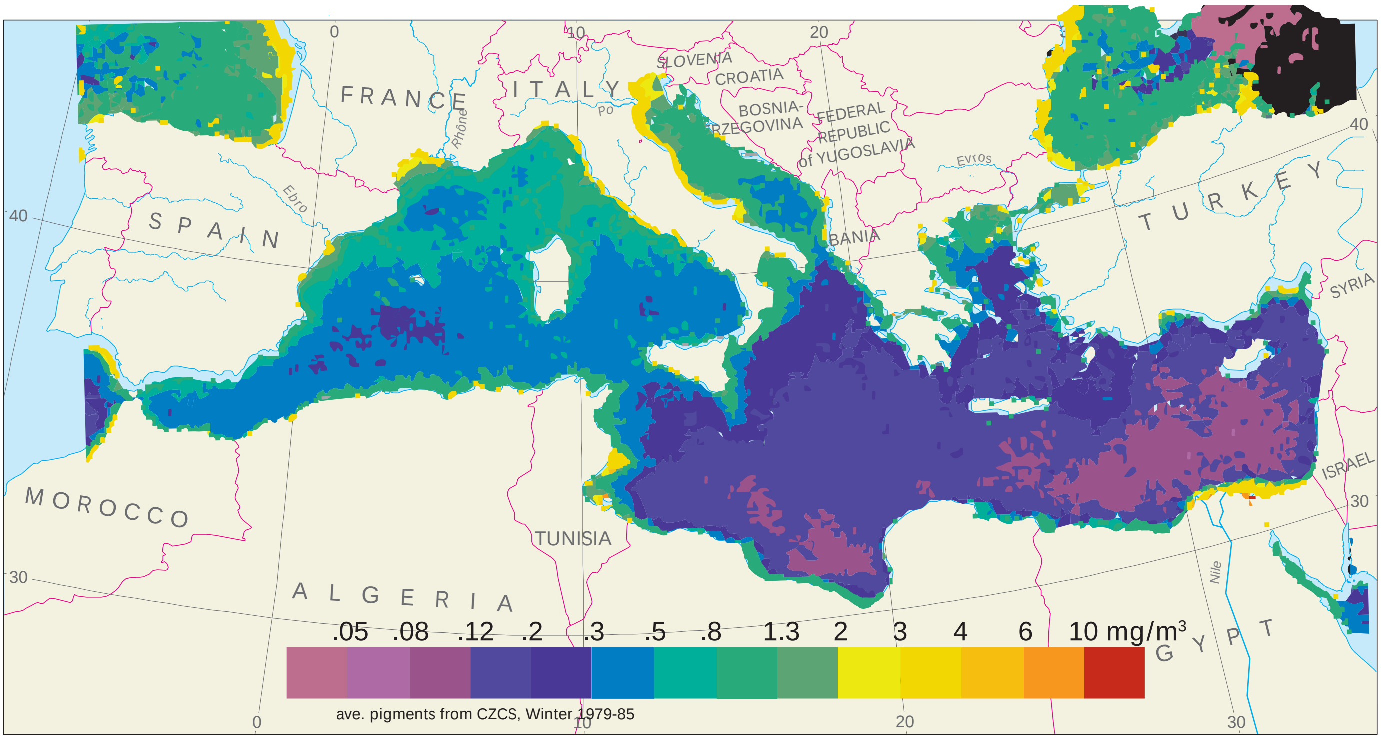
Since eutrophication affects marine life, an effort has been made to present, in a synoptic and yet informative way, a review of eutrophication effects recorded by the different coastal countries of the Mediterranean Sea. However, it must be noted that the manifestation of eutrophication is not the same in all cases and the effects and related

Figure 4.1 **Mediterranean areas where eutrophication phenomena were reported**



Source: UNEP/FAO/WHO, 1996 (Modified)

Satellite image illustrating average chlorophyll variations in surface waters of the Mediterranean Sea, winter 1979-85 Figure 4.2



Source: JRC, Ispra

events depend on several physical features, such as the degree of dilution of nutrients, hydrodynamics, seasonality, climate, etc.

The most important cases of eutrophication are found along the northern and western coasts of the Adriatic Sea which, due to the Adriatic's circulation characteristics and shallowness, are mainly affected by river loads and by sediment / water exchange processes. Vukadin (1992) estimates 250 000 tonnes / year nitrogen and 82 000 tonnes / year phosphorus inputs from rivers to the Adriatic Sea. ARPA's (Agenzia Regionale Emilia Romagna per l'Ambiente) monitoring programme in 1996 reports: 7 - 19.3 mg / m^3 chlorophyll, 11.5 - 27.9 mmol / l NO_3, 0.14 - 0.4 mol / l P (ARPA, 1996) along the coast of Emilia Romagna in north-east Italy. Past records show an increase in the frequency of eutrophication-like phenomena in the northern Adriatic in the last 20 years (Margottini & Molin, 1989). On the Italian coast the most affected areas are along the Emilia-Romagna coasts, the lagoons around Ravenna, the Gulf of Venice and the Gulf of Trieste. The Slovenian coastal area also suffers from eutrophication, whereas the southern coasts of the eastern Adriatic basin are protected due to their morphology (e.g.orography); eutrophication generally occurs in ports and bays influenced by sewage outfalls and industrial effluents (Bays of Pula, Rijeka, Kastela, Sibenik and Dubrovnik in Croatia and the Bay of Kotor in Montenegro).

Nevertheless, the nutrient concentrations in seawater do not always provide a clear picture of the state of the Adriatic ecosystem and fail even in forecasting the appearance of exceptional events. This is due to the Adriatic's shallow basin in which climate as well as release of nutrients from sediments to the water column coincide to trigger the most critical events in an often unpredictable way.

Over recent years considerable environmental changes have been recorded in the coastal waters of Cyprus by the Ministry of Agricultural Resources and Environment, including the pronounced proliferation of ephemeral macroalgae such as Ulva spp., Enteromorpha spp and Cladophora spp., as a probable result of excessive nutrients entering the marine environment (e.g. fish farms and seepage of the coastal ground water horizon to the marine environment).

Table 4.1 summarises recorded eutrophication incidents (algal blooms) and related side effects (hypoxia / anoxia of the waters near the seabed, dystrophy, toxins, bottom fauna kills, mucilage, water discoloration, reduced transparency, etc.) in

Table 4.1 **Mediterranean countries, where algal blooms and other eutrophication side effects have been reported, with some characteristic environmental values recorded from such events**

Countries	Hypoxia/ Anoxia	Algal blooms (AB) and other effects	Dominant species[1]	Cells/L	CHL-A (μg/l)	NO_3 (μM)	PO_4 (μM)
Spain							
1. Alborán Sea	?	AB, PSP toxins[2]	33, 53	>3 x 10^3		?	?
2. East Coast & Balearics	?	AB, PSP toxins	4, 16, 17, 21, 33	7.2 x 10^6- 2.8 x 10^7	8 1-15	?	?
3. Lagoons,bays, estuaries	yes	AB, dystrophy	52, Ulva	10^4-2 x 10^6	10-340	5-390	0.1-113
France							
1. Western zone (Spanish border & Rhône delta)	yes	AB, dystrophy	24, 30, 34, 35, 42, 54	?	8(chl·),- 4kg ww/ m^2(Ulva)	50-120	3-8
2. Eastern zone (Rhône delta Italian border)	yes	AB, DSP[2], PSP, dystrophy	24, 30, 34, 35, 42, 54	?	19	?	?
Italy							
1 Tyrrhenian Sea lagoons	yes	AB, PSP,fish mortality, mucus	33	6 x 10^6	22	0.6	0.5
2. Gulf of Naples	?	AB	2, 9, 15, 48	3.5-112 x 10^6	46-176	0.60.7(TIN)	0.10.2
3. Sardinia	yes	AB, fish & molluscs mortality	13, 34	?	?	0.3-138	0.1-13
4. Sicily	yes	AB, DSP, fish mortality	23, 24, 49	2-40 x 10^3	30	20-158	1.6-360
5. Ionian Sea	no?	AB, ?	52				
6. Southern & central Adriatic	yes	AB, putrefaction, bottom fauna mortality, dystrophy	34, 37, 52	?	?	?	?
7. Emilia-Romagna coasts	yes	AB, dystrophy, fish & bottom fauna mortality, mucilage, water discolouration, poor transparency, smell, DSP, PSP	4, 11, 15, 16, 18, 24, 25, 26, 27, 28, 34, 36, 41, 44, 45, 46, 52, 53	1-230 x 10^6	600	?	?
8. Lagoons in the north-western Adriatic[4]	yes	AB, deterioration of lagoon ecosystem	52, Ulva	?	?	?	?
9. Gulf of Venice	yes	AB, H_2S, hypertrophy,	4, 9, 13, 14, 15, Ulva	36 x 10^6	15kg/m^2 (Ulva)	?	?
10. Gulf of Trieste	yes	AB, bottom fauna mortality	28, 38, 40, 46, 53	5-7 x 10^6	?	?	?
Slovenia							
	yes	AB, poor transparency, benthos mass mortality, mucilage, hypertrophy	as for northern Adriatic	?	?	?	?
Croatia							
	yes	AB, red tides, fish & bottom fauna mortality	7, 12, 15, 28, 31, 34, 41, 42, 53	3-18 x 10^6	120	1.6-59	0.6-2.9
Malta	no	AB, poor transparency	?			26.4	1.6
Greece							
1. Gulf of Saronikos (Aegean Sea)	yes	AB, water discolouration, fish mortality	7, 11, 16, 32, 34, 46, 55	3 x 10^5- 6 x 10^7	50-90	0.2-29	0.1-0.7
2. Gulf of Thermaikos 8(Aegean Sea)	yes	AB, water discolouration, fish mortality	1, 3, 8, 10, 12, 14, 15, 16, 39, 41, 42	1-7.5 x 10^7	13-17	0.1-6.7	0.1-3.7
3. Other Aegean gulfs and bays	no	AB, water discoloration	5, 6, 11, 20, 28, 33	12 x 10^6- 10^7	86	1-17.9	0.5-1.0

Countries	Hypoxia/ Anoxiayes	Algal blooms (AB) and other effects	Dominant species[1]	Cells/L	CHL-A (μg/l)	NO_3 (μM)	PO_4 (μM)
4. Ionian Sea gulfs and bays	yes	AB, fish & bottom fauna mortality	14, 20, 51, 52	10^6-10^8	22-137	0.1-3	0.2-10
Turkey							
1. Western coasts	yes	AB, bottom fauna mortality, PSP	17, 28, 29	10^6-10^8	?	1.0	2.5
2. Southern coasts	?	?	?	?	?	5-12	0.1-0.5
Egypt							
1. Coastal waters and ports	yes	AB, water discolouration, H_2S	17	?	23-27	1.6-14	0.32
2. Lagoons in the Nile delta	yes	AB, water discolouration, H_2S	?	?	21	?	?
Tunisia							
1. Lake of Tunis	yes	AB, H_2S, fish mortality	34, 41, Ulva	?	1.5g/m^2 (Ulva)	130-780 (TIN)	1.4-63
2. Lagoon of Ichkeul	?	AB, ?	?	?	60		
Algeria							
1. Lake of El-Mellah	yes	AB, dystrophy	22, 30, 34				

[1]: *Code numbers for reported dominant blooming species as in Table 4.2.*
[2]: *PSP, DSP for Paralytic and Diarrhoetic Shellfish Poisoning produced by toxins in certain dinoflagellates and chrysophyceae.*
[#] *Countries/places not shown in the Table do not necessarily imply that do not have eutrophication problems; it could also mean lack of appropriate information.*
? *= questionable*

Source: UNEP/FAO/WHO, 1996

Table 4.2

Microalgae and macroalgae species reported to cause abnormal (exceptional) algal blooms in the Mediterranean Sea

A. Microalgae		
Diatoms		
1. *Cerataulina bergonii*	7. *Leptocylindrus* spp	13. *Rhizosolenia firma*
2. *Chaetoceros* sp.	8. *L. minimus*	14. *Rh. fragilissima*
3. *Ch.s socialis*	9. *L. danicus*	15. *Skeletonema costatum*
4. *Ch.s simplex*	10. *Nitzschia closterium*	16. *Thalassiosira* sp.
5. *Cyclotella* sp.	11. *N. delicatissima*	
6. Cyclotella subtilis	12. *N. seriata*	
Dinoflagellates		
17. *Alexandrium minutum*	27. *G. quadridens*	37. *Peridinium depressum*
18. *A. tamarensis*	28. *Gonyaulax* sp.	38. *P. ovum*
19. *Amphidinium curvatum*	29. *G. spinifera*	39. *Prorocentrum dentatum*
20. *Cachonina niei*	30. *G. polyedra*	40. *P. lima*
21. *Chattonella subsalsa*	31. *Gymnodinium* sp.	41. *P. micans*
22. *Dinophysis acuminata*	32. *G. aureolum*	42. *P. minimum*
23. *Dinophysis* spp.	33. *G. adriaticum*	43. *P. scutellum*
24. *D. sacculus*	34. *G. breve*	44. *P. triestinum*
25. *Glenodinium foliaceum*	35. *G. catenatum*	45. *Protogonyaulax tamarensis*
26. G. lenticula	36. *Katodiniumrotundatum*	46. *Scrippsiella trochoidea*
Coccolithophores		
47. Coccolithus pelagicus	48. *Emiliania huxleyi*	
Other Flagellates		
49. *Chlamydomonadaceae*	52. *microflagellates*	55. *Pyramimonas* sp.
50. *Cryptomonas* spp.	53. *Noctiluca miliaris*	56. *Spirulina jenneri*
51. *Cyanobacteria*	54. *N. scintillans*	
B. Macroalgae		
57. *Ulva sp.*		

coastal Mediterranean countries that have reported incidents. Furthermore, values of some other characteristic parameters recorded during such events are presented (whenever this information was available), such as the type of algal species **(Table 4.2)** causing such an event, biomass (as chlorophyll a), ranges of vegetal population densities and nitrate and phosphate concentrations. However, it must be noted that information is not always available, partly because of insufficient environmental monitoring throughout the basin.

4.1.4. Effects on marine life, fish and shellfish

It is well known that eutrophication affects marine life in general. Visibly, eutrophication and its side effects cause water discolouration and reduced transparency, whereas dense macrophyte and macro algae agglomerations choke channels, lagoons and estuaries.

As a negative feedback the decaying excessive organic material, deriving from vegetal biomass, consumes or even depletes oxygen, causing a series of secondary problems such as fish mortality; formation of corrosive and other undesirable substances such as CH_4, H_2S, and NH_3; taste and odour-producing substances; organic acids; mucilage; and toxins (among others.) The environmental effects of eutrophication range in severity and in extent. There can even be beneficial effects, within limits. Filter feeders, like shellfish that utilise phytoplankton directly, can benefit from modest algal blooms. Increases in zooplankton and bottom fauna can affect higher trophic levels, due to increased food supply, augmenting commercially valuable fish stocks. Nevertheless, eutrophication is most often detrimental to the environment.

Within the range of eutrophication events there are many intermediate stages that vary in time and in space, due to a combination of factors such as morphological and hydrodynamic characteristics, water-renewal time, natural life cycle fluctuations and climatic features.

Although the impact of eutrophication is more serious for the benthic ecosystem, the structure of the pelagic ecosystem also changes when eutrophication grows to levels in which its effects induce stress factors on the environment, causing pelagic food web changes. The more tolerant species predominate among both producers and consumers. Phytoplankton increases in abundance at greater rates than zooplankton. Thus, as energy is trapped in phytoplankton, diversity decreases, rarer species are eliminated and sometimes jelly fish predominate. In the shallow environments, important changes due to increased water turbidity and sediment transformation involve the phytobenthos and often lead to a marine angiosperm decline (e.g. Posidonia oceanica meadows), substituted by chlorophyta. Since the sea meadows are important nurseries for demersal fish, biodiversity is hampered and even fishing activities are affected.

Anoxia of the bottom waters strongly affects the benthic food web of shallow basins causing significant changes in the whole biological community.

Sticking algal material and high pH can cause dermatitis and conjunctivitis, whereas ingestion of toxic algae can cause diarrhoea in sensitive individuals. Blooms of toxin-producing algae when accumulated in fish, particularly in shellfish, could lead to a threat to human health.

4.2. Coastal zones

4.2.1. Introduction

The Mediterranean coastal zone is an important area for human habitation, agriculture, industry, location of power plants, military facilities, fisheries, protected areas and tourist resorts. This often leads to a conflict over the use of resources. Physical modifications such as urbanisation, transport infrastructure and tourist facilities can result in the loss of habitats. The damming of rivers can alter the hydrological regime which could in turn have serious consequences on the coast. In fact, reducing freshwater flow generally means a reduced sediment load, which may cause coastal erosion and coastal evolution. In some areas, the latter affects coastal areas and land use in the coastal zones.

Information at basin scale about the coastal zones and their use does not exist in the Mediterranean area. However, the following general remarks can be made regarding the main pressures, already mentioned in Chapter 3, for the Mediterranean coastal zones.

Urbanisation

The Blue Plan reports that in 1985 almost 90 % of urbanised land in the Mediterranean was located in the coastal zones of Spain, France, Greece, Italy and former states of Yugoslavia. By 2025, the percentage of the population of these countries living in coastal cities is projected to be more than 85 % on average, and as high as 96 % in Spain (Grenon and Batisse, 1989). The distribution of the population between the northern and southern countries within the Mediterranean basin also varies considerably: in 1950, 'the north' represented two-thirds of the total population, while today it is only 50 % and may be one-third in the year 2025, and one-quarter in 2050 (Grenon and Batisse, 1989).

Tourism
The Mediterranean is the leading tourist destination world-wide, accounting for 30 % of international tourist arrivals and for 25 % of the receipts from international tourism. The industry is suffering from increased competition and a decline in quality due to the impacts of mass tourism. According to Blue Plan scenarios (see Chapter 3), the number of tourists in the Mediterranean coastal region will increase from 135 million in 1990 to 235-355 million in the year 2025 (Mediterranean Commission for Sustainable Development, 1998). The trade-off of pressures and benefits to Mediterranean tourism, is characterised by three basic features:

a) it is heavily and increasingly concentrated on the coast;
b) it is heavily seasonal; and
c) the north-western Mediterranean dominates the tourist market and will continue to do so.

Agriculture
In the Mediterranean basin, intensive agriculture and farming is limited by the topography of the terrain, being concentrated in the few alluvial plains (Ebro, Rhône, Po and Nile). Countries on the northern and western coasts are specialised in monocultures and achieve good yields. In the south and east, demographic pressure constantly increases and cultivated surfaces continue to expand at the expense of forests and grazing land.

Fisheries and aquaculture
Fisheries in the Mediterranean are managed by the General Fisheries Council for the Mediterranean (GFCM) which focuses mainly on measures such as control of licences and subsidies to the sector, rather than quota control.

The regional aquaculture production in the Mediterranean shows a sharp increase of about 174 % in a decade (89 707 tonnes in 1986 to 248 460 tonnes in 1996). A continuation of this trend in this region is expected which could increase the conflict of land use in several areas (e.g. between tourism and aquaculture).

Industry and energy
The Mediterranean basin is better endowed in oil and natural gas than in industrial development based on coal and iron, leading to the establishment of many refineries all around the Mediterranean basin. Generally the gap in industrial development between the northern and south-eastern sides of the Mediterranean basin remains considerable.

Transport
In the Mediterranean basin the major commercial transportation between countries is via the sea, mostly by ferry. Road traffic in the coastal zones, especially in the Euro-Mediterranean zone, is well developed and very dense, while railways appear to be in decline.

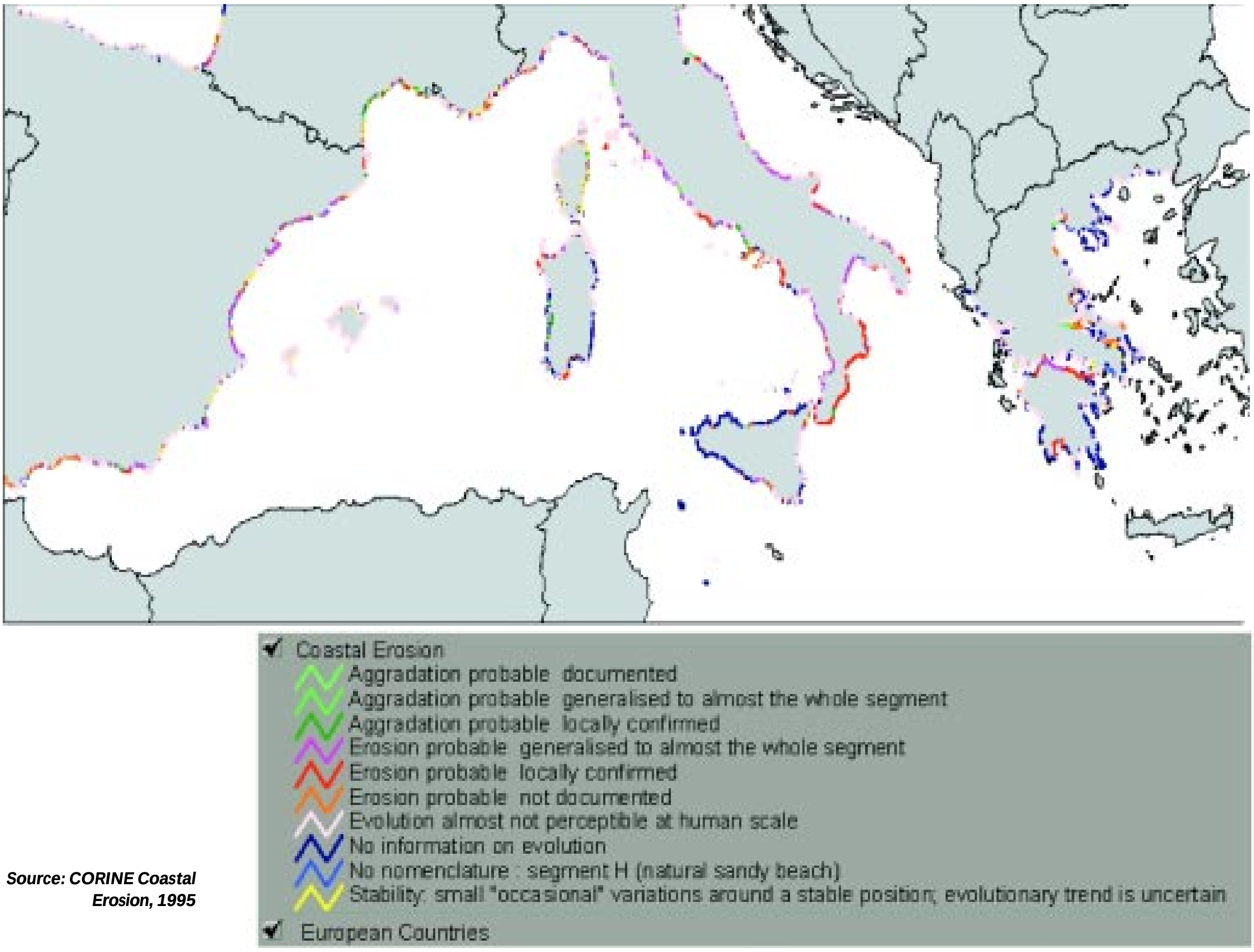
4.2.2. Coastal evolution
Studies of the coastlines confirm that their evolution is often caused or accelerated by human intervention. The causes of modification of the morphology of the coastal system fall within two non-exclusive categories (CORINE, 1995):

i) Major natural events:
- phenomena of slow variation: subsidence and rising of the marine level;
- severe or paraseismic events: storms and unusually high tides, earthquakes, and mass movements (see other relevant paragraphs on the subject).

ii) Human activities causing variations in the sedimentological regime:
- reduction of river contributions;
- development of estuaries, artificialization of the coast;
- construction on the coastal dunes:
- harbour work and coastal defence construction;
- destruction of dune vegetation, of algal areas and of underwater seagrass meadows;
- sediment, water, gas or oil extraction, etc.

Erosion level in the basin
The state of knowledge of the way the coastline is evolving varies from one country (or one administrative region) to another; similarly, evaluating this phenomenon, the storing and processing of data, as well as the display of results are also very variable. The

Figure 4.3 **Different levels of erosion in the EU countries and possible trends**



Source: CORINE Coastal Erosion, 1995

situation is such that interregional comparisons are very difficult to make.

The lack of information and the difficulty in accessing dispersed data constitute a serious obstacle in assessing the state of the erosion process and the implementation of policies of protection and management of the coastal environment at local, national and regional levels (CORINE, 1995).

For EC countries two projects on coastal erosion were launched after recognising the gravity of the problem (CEC, 1995). However, nation-wide coastal erosion monitoring networks do not exist for the other Mediterranean countries. CORINE Coastal Erosion (data is presented in **Figure 4.3**) and LACOAST are the two main projects under which information on erosion around the Mediterranean basin is being collected (only for the EU countries).

Erosion data showed that 1500 km of artificial coasts can be found in the EU marine area (Balearic Islands, Gulf of the Lion, Sardinia, Adriatic Sea, Ionian Sea and Aegean Sea) (EC, 1998). Harbour areas were contributing to the total with 1237 km (EC, 1998).

Based on CORINE data, about 25 % of the Italian Adriatic coast and 7.4 % of the Aegean Sea show evolutionary trends of erosion while about 50 % of the total coastline of the Euro-Mediterranean area is considered to be stable (**Table 4.3**). In addition 1500 km in the Euro-Mediterranean marine area are considered to be artificial with harbours and ports contributing the major part (1250 km).

Iniatitives on the coastal erosion problem for EU Member States include the following:

In Spain, cartographic and photographic documents of the coastal area at the scale 1/50 000 from PIDU ('Plan indicativo de Usos del dominio público litoral') were published by the Ministry of Public Works and Town Planning from 1976 to 1981. They cover almost the whole of the Spanish coast and

Table 4.3

Evolutionary trends of some coasts of the European part of the Mediterranean Sea for both rocky coasts and beaches as % of coasts

Source: EC, 1998

Maritime regions in the Mediterranean Sea	No information	Stability	Erosion	Sedimentation	Not applicable	Total (Km)
Balearic islands	0.5	68.8	19.6	2.4	8.7	2861
Gulf of Lion	4.1	46.0	14.4	7.8	27.8	1366
Sardinia	16.0	57.0	18.4	3.6	5.0	5521
Adriatic Sea	3.9	51.7	25.6	7.6	11.1	970
Ioanian Sea	19.7	52.3	22.5	1.2	4.3	3890
Aegean Sea	37.5	49.5	7.4	2.9	2.6	3408

contain summary information on the physical characteristics of the coast and evolution of the beaches. A survey carried out in Spain by MOPT ('Ministério de Obras Públicas y Trasportes, Direccion General de Costas') has produced some data concerning the Spanish coasts until 1993.

In France, the continuous inventory of the coast (IPLI), carried out by the Interdepartmental Committee of Regional Planning (CIAT) led to the publication in 1982 of 147 land-use maps at the scale of 1/25 000. The data on the physical nature and the development of the coast available in existing catalogues were not included. However, the series of sedimentological catalogues of the French coasts, published from 1984 to 1988 by the direction of seaports and inland waterways, contain numerous data on the coastal processes, and the nature and development of the coast.

In Italy, a survey carried out by the World Wide Fund for Nature (Italy) has produced some alarming statistics concerning the occupation and loss of the Italian coastal zone up to September, 1996. According to this report, 42.6 % of the entire Italian coast is subject to intensive human occupation (areas which are completely occupied with the presence of built up nuclei and infrastructure; 13 % has an extensive occupation (free zones occupied only by extensive building and infrastructure); and only 29 % of the territorial coast is completely free from buildings and infrastructure.

Greece: In some cases**,** sparse, widely dispersed information obliged the experts to conduct major compilations in universities and supplement them with field checks. Other sources of information, such as scientific publications and reports of the administrative bodies and consultants, generally cover the coastal areas where developments have taken place or are planned. Although incomplete, especially in area coverage, they comprise most of the information available on the coast of this country.

Thus, the coastal evolution trends were often considered on the basis of expert judgments in the absence of studies or of preliminary measurements. This is true of Greece, where the absence of information prevented carrying out an inventory of coastal erosion in the Greek islands (CORINE, 1995).

4.3. Heavy metals and chlorinated hydrocarbons

4.3.1. Introduction

The presence of heavy metals and chlorinated hydrocarbons in the marine environment has received a lot of attention worldwide as these pollutants may present potential risks to marine life and to human health.

Heavy metals, such as mercury in the marine environment originate from natural and man-made sources. Natural inputs to the sea result from weathering processes and reach the sea mainly through river inputs and runoffs. In the Mediterranean Sea, heavy metals arise mainly from natural processes (Bryan, 1976; Bernhard, 1988) and the contribution from anthropogenic activities has a limited influence on local pollution problems. The relative importance of the various sources is still difficult to estimate due to the limited data available.

Chlorinated hydrocarbons, on the other hand, are of entirely anthropogenic origin. The overall anthropogenic load of these contaminants (heavy metals and chlorinated hydrocarbons) in the Mediterranean is difficult to assess, but their total production in the area can give an indication of the amount of contaminants reaching the marine environment.

The present chapter mainly uses data generated through the MED POL programme of UNEP / MAP and the RNO of the IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer). It must be noted that the MED POL database has certain temporal and geographical gaps which are more acute in the southern region. Quality of data from national monitoring programmes is guaranteed by the comprehensive quality assurance programmes operating in the Mediterranean region and especially the MED POL QA programme executed by IAEA's Marine Environmental Laboratory in Monaco. However, only recently the MED POL data has been scrutinized, cleared and classified according to its reliability. This means that data published earlier may differ from the data presented in this report (Gabrielides, 1994). As it is not feasible to monitor all contaminants in all the marine matrices, the MED POL programme concentrated mainly on mercury and cadmium as regards heavy metals and on DDTs and PCBs as regards chlorinated hydrocarbons. Other heavy metals such as copper, lead and arsenic and other chlorinated hydrocarbons such as lindane and the 'drins', have also been analysed by many laboratories in view of their potential risk (Bryan, 1976; Reilly, 1991).

As far as matrix is concerned, it is known that surface sediments are the ultimate sink for most contaminants. Therefore, the study of their contaminant content is an important indicator for pollution studies. However, difficulties may arise in the interpretation of the results due to lack of uniform sampling and analytical procedures. Marine species are also used for studying the contamination levels in the environment since they bioaccumulate many contaminants. On the contrary, sea water is not used for long-term studies and its analysis presents a number of difficulties. The MED POL programme mainly concentrated on analysing contaminants in biota, bearing in mind that these results could also be used for the protection of human health. The species recommended for analysis represented different ecotypes. The mussel Mytilus galloprovincialis was selected as representative of the filter-feeding bivalves which are good indicators of local pollution. As this species is not found in the eastern Mediterranean, other bivalves such as the shell Mactra corallina, were used. The red mullet (mullus barbatus) was selected as representative of the demersal fish, the sardine (Sardina pilchardus) represented the pelagic plankton feeders while the blue-fin tuna (Thunnus thynnus) and the swordfish (Xiphias gladius) represented the higher trophic level pelagic fish which – as they migrate extensively - are less affected by local pollution sources. Crustaceans were represented by the deep water pink shrimp (Parapenaeus longirostris) but the prawn (Penaeus kerathurus) and the red shrimp (Aristeus antennatus) were also used.

The MED POL databank is used here to give a general indication of the distribution of concentrations of some heavy metals and chlorinated hydrocarbons in the most commonly used species from the entire Mediterranean. One convenient way of presenting results is through the box-and-whisker plot, where the box includes 50% of the values, usually referred to as the inter-quartile range; outliers appear beyond the whiskers. The mean and median values appear in the box as a cross and a horizontal line respectively. Only data after 1987 was used. The information cannot always be utilised to compare concentrations between species, since data comes from areas of different contamination levels, but also because bio-accumulation depends on a number of factors which are not the same in all cases. For example, the data for tuna originate from small specimens having mercury concentrations far below the levels documented in the region for the larger specimens.

4.3.2. Heavy metals

4.3.2.1. Mercury

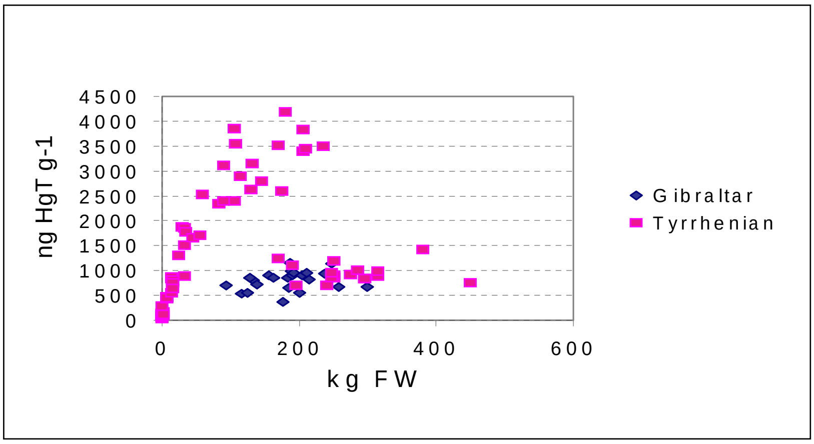
Values in this section refer to total concentrations, but it must be pointed out that a large percentage of mercury in marine biota is present as methyl mercury which is the more toxic form and is taken up with very high efficiency (about 90 % from the prey), while for inorganic mercury the percentage is only 7 % (GESAMP, 1987). Mercurial compounds have found widespread use in measuring devices, electrical conductors and coolants, pesticides and pharmaceuticals. However, the world production and use of mercury has declined since 1973.

From the onset of the MED POL programme it was apparent that total mercury values (organic and inorganic mercury) in Mediterranean species were generally higher than those found in the Atlantic. A characteristic example was the distinction of two blue-fin tuna populations in the western Mediterranean based on their mercury levels. The high-mercury population came from the Mediterranean and the low-mercury population from the Atlantic (Bernhard, 1988). The Mediterranean population had a significant higher mercury concentration than the Atlantic tuna (**Figure 4.4).** André et al. (1991) observed a similar phenomenon with dolphin populations. These high mercury levels in the Mediterranean Sea are of natural origin and can be explained by the fact that the region is part of the Circumpacific-Mediterranean-Himalayan mercuriferous belt (Moore and Ramamoorthy, 1984).

In coastal areas, this mercury belt can cause additional mercury enrichment of the marine environment. In Tuscany, total-mercury concentrations in red mullet were much higher near the geochemical mercury anomaly of Mount Amiata than in red mullet from other areas (Bernhard, 1988).

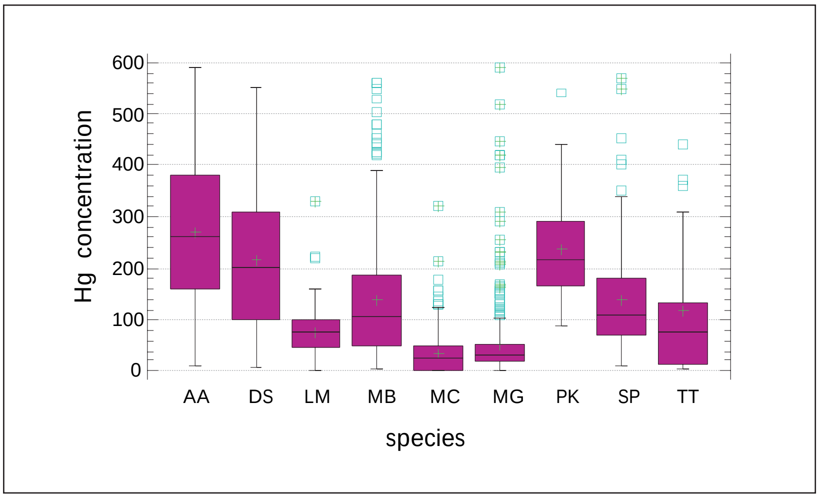
Reported high mercury values in seafood created justifiable concern for human health as seafood is the main source of mercury for humans. For this reason a study was initiated by MED POL to investigate whether in fact the Mediterranean population in general was at risk. The countries chosen for this study were Italy, Croatia and Greece and the populations were high-risk groups such as fishermen and their families. After preliminary screening of more than 4 000 people through dietary surveys, a total of 1,098 hair samples (659 from Greece, 241 from Italy and 198 from Croatia) were analysed for total mercury and, where appropriate, for methyl mercury. The results confirmed that there is a positive correlation between seafood consumption and levels of total mercury and methyl mercury in hair. On the basis of the criteria adopted (25 ppm of mercury in hair for adults and 6 ppm in maternal hair for newborns) no at-risk individuals were identified in Croatia and only very few people in the other countries exceeded these concentrations. However, no clinical effects were detected, since FAO / WHO's Provisional Tolerable Weekly Intake (PTWI), established in 1972, incorporates an assumed 'safety factor' of 10 from an intake that has caused a 5 % prevalence of symptomatic methyl mercury poisoning (WHO / FAO / UNEP, 1989).

Concentration of total-mercury (HgT) in blue-fin tuna of Mediterranean and Atlantic origin (The fish size is given as kg fresh weight (FW) — Figure 4.4



Source: Bernhard, 1988

Box-and-whiskers plots showing the distribution of data for concentrations (in ng/g fresh weight FW) of mercury in selected species from the Mediterranean Sea — Figure 4.5

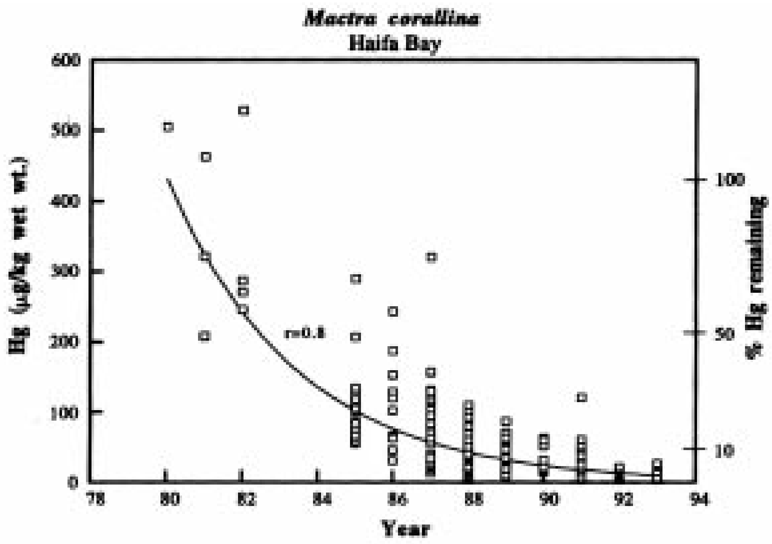


(AA=Aristeus antennatus, DS=Diplodus sargus, LM=Lithognathus mormyrus, MB=Mullus barbatus, MC=Mactra corallina, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

As can be seen in **Figure 4.5**, the great majority of the mercury values in biota from the MED POL databank after 1987 are below 500 ng / g FW (medians and means below 300 ng / g) which is the minimum legal limit adopted by the countries for seafood for human consumption. Sample specimens came from all over the Mediterranean except for the red shrimp Aristeus antennatus which came only from Spain and those for Mactra corallina and the fish Diplodus sargus which came only from Israel. The bivalves showed the lowest concentrations. It must also be noted that no data from the Tyrrhenian Sea was reported during this period. Data reported with a mean concentration for mercury of 36 ng / g are also well below legal limits. Total mercury concentrations exceeded 1 000 ng / g only in the case of the swordfish from the central Mediterranean and the gastropod

Figure 4.6 **Decrease of mercury concentration (in µg/kg wet weight) in *Mactra corallina* from Haifa Bay from 1980-1993**



Source: Herut et al., 1996

Gibbous nassa from Israel (not indicated in **Figure 4.5**).

Coastal industrial zones with high mercury concentrations were identified in the early 1970s; the Tyrrhenian Sea (Tuscany), the Adriatic (Kastella Bay near Split), the Sardinia Channel (S. Gilla Lagoon), and the most eastern Mediterranean (Haifa & Alexandria). Contamination generally decreases with the distance from the outfall (documented, for example, for the Solvay plant on the coast of Tuscany); at a distance of about 20 km from the outfall, background concentrations are reached.

In several cases, levels of contamination have decreased with time as was seen a few years after the chlor-alkali plants in Tuscany and Haifa Bay reduced their disposal of mercury significantly. Mercury concentrations in specimens of the bivalve Mactra corallina collected in Haifa Bay, between 1980 and 1993, showed an exponential decrease with time (**Figure 4.6,** Herut et al., 1996). The decrease curve is also expressed in terms of the percentage of the mercury concentration in the initial year of study. On the basis of this calculation, the half-life of mercury in Mactra corallina is two years. The same study showed a half-life of five years for fish and 6-33 years for sediments.

The influence of the mercury belt is also evident in sediments. Even though there is a problem of comparability for concentrations in sediments, in general 0.05-0.10 mg kg^{-1} can be considered as background concentration with values reaching 5 mg/kg in polluted areas (Gabrielides, 1994). Even higher values have been detected in certain coastal areas (e.g. St. Gilla Lagoon in Sardinia) while the lowest values are detected in deep sea sediments (Scoullos, 1983).

4.3.2.2. Cadmium

Cadmium and its compounds have found increasing applications in a variety of industrial products and operations, for example electroplating, pigments, plastic stabilisers, batteries, electrical and electronic applications, alloys, etc. Thus, its production has increased recently. The toxicity of cadmium itself, assessed from toxicity tests, is generally smaller than that of copper and methyl mercury, but higher than that of lead, nickel and chromium (Bryan, 1976).

The concentrations of cadmium in the most commonly used species of the MED POL programme are shown in **Figure 4.7**. As in the case of mercury, specimens came from all over the Mediterranean except for the red shrimp Aristeus antennatus which came only from Spain and those for Mactra corallina and the sea bream Diplodus sargus which came only from Israel. The mean and median values do not exceed 200 ng/g FW. However, much higher values have been reported for some other species. For example, the gastropod Nassarius gibbosulus from Israel, the bivalve Scapharca inequivalis from Italy and the limpet Patella caerulea from Greece displayed, in many cases, concentrations higher than 1,000 ng/g (not indicated in **Figure 4.7**).

The concentrations of total cadmium in blue-fin tuna from the Mediterranean appear to be comparatively low and unlike mercury, do not show significant differences between the eastern and western Mediterranean. Also, cadmium concentrations do not appear to increase with the size and age of the species.

The cadmium concentrations in the surface sediments of the entire Mediterranean range approximately from 0.05 to 1 mg/kg dry weight. These values are lower than the limits adopted by different countries for sediment quality criteria (Baudo et al., 1990). Values ranging from 0.07 to 0.62 mg/kg dry weight have been documented for the north-western Mediterranean (Hoogstraten & Nolting, 1991). However, much higher values (up to 50 mg/kg) have been reported for polluted lagoons and other hot spot areas (UNEP, 1989).

4.3.2.3. Arsenic

Arsenic occurs widely in the earth's crust but no commercially exploitable ore is known and thus it is obtained as a by-product of copper and lead smelting. This metalloid is mainly used in pharmaceuticals, preservatives and agriculture chemicals. The use of products containing arsenic has recently been restricted widely because of their toxicity and persistence.

In algae, most of the arsenic is present in the inorganic form (60 to 80 % as As (III)). In crustaceans, molluscs and fishes more than 80 % is arsenobetain. This distinction is important because the toxicity of arsenic and its compounds is related to the chemical form of the element. The inorganic compounds are the most toxic, followed by the organic arsenials and finally by the gas, arsine (Reilly, 1991; GESAMP, 1986).

Despite its low levels in sea water, arsenic accumulates in large quantities in marine organisms. The data which appear in **Figure 4.8** for a number of species all come from Spain.

Means and medians do not exceed 10 µg/g FW; similar results (means of 3-13 µg/g) were reported by Stegnar (1991) for fish from the Ligurian and Adriatic seas. Pelagic species appear to reflect the lowest concentrations while the highest ones are reported for the blue-leg crab Liocarcinus depurator and the purple-dye murex Bolinus brandaris (not indicated in the **Figure 4.8**).

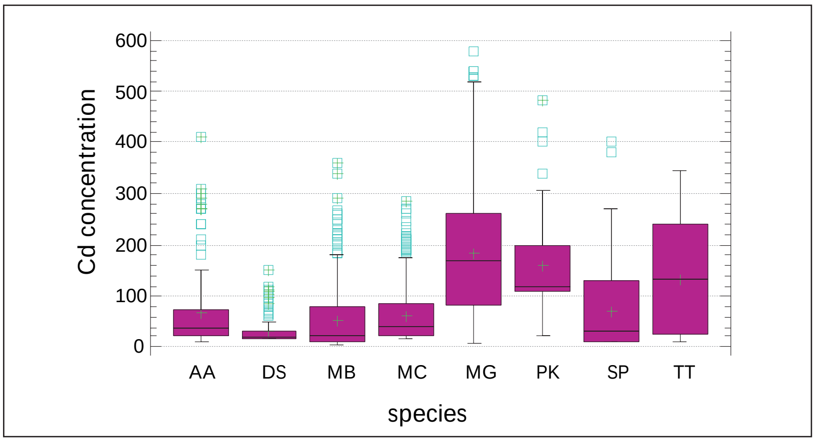
Stegnar (1991) reported arsenic concentrations in sediments ranged from 4-30 ng/g dry weight from the Adriatic and the Ebro delta.

4.3.2.4. Copper

Copper is widely distributed in nature. Two-thirds of the world's copper reserves are situated around the Pacific rim and the mountain belts in south-eastern Europe and central Asia. This metal is used primarily in electrical, construction and piping industries and has important pharmaceutical and agricultural uses. Its production decreased in recent years as users have switched to cheaper materials. Copper is highly toxic to most aquatic organisms in relatively low concentrations and only mercury is consistently more toxic (Moore & Ramamoorthy, 1984; Rilley, 1991). In the Mediterranean region, an important source of copper in the coastal marine environment is its use as a fungicide in vineyards. Following the restrictions in the use of anti-fouling paints containing TBTs, the use of copper-based paints has increased.

Total copper concentrations in marine organisms at wide-basin scale are shown in **Figure 4.9** (as before, the data for Mactra corallina and Diplodus sargus came only from Israel). The concentrations in fishes are much lower than those in molluscs and crustaceans and, in general, do not exceed 1 µg/g FW. The mean value in mussels was 1.4 µg/g FW while in red

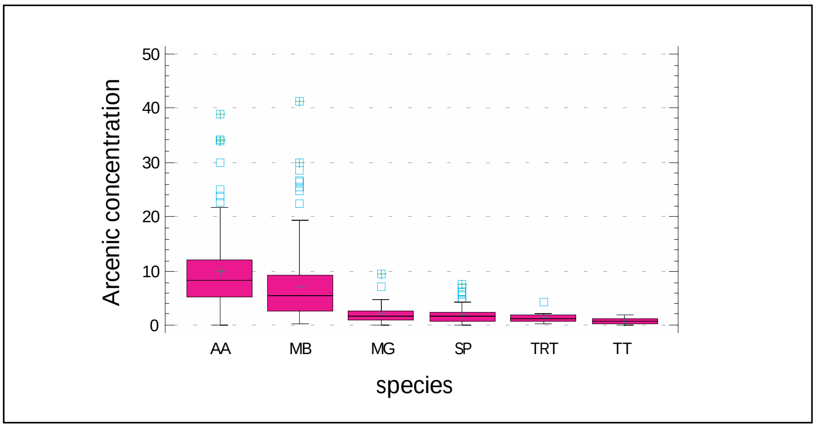
Box-and-whisker plots for concentrations (in ng/g fresh weight FW) of cadmium in selected species from the Mediterranean Sea — Figure 4.7



(AA=Aristeus antennatus, DS=Diplodus sargus, MB=Mullus barbatus, MC=Mactra corallina, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

Box-and-whisker plots for concentrations (in µg/g fresh weight FW) of arsenic in selected species from the Mediterranean Sea — Figure 4.8

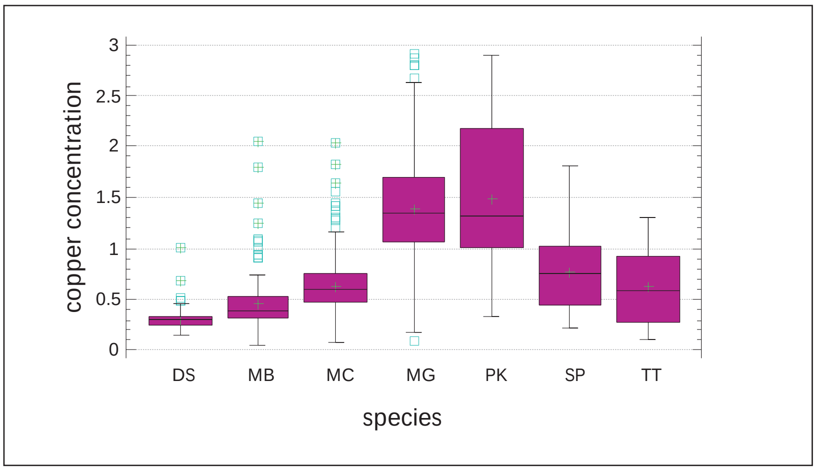


(AA=Aristeus antennatus, MB=Mullus barbatus, MG=Mytilus galloprovincialis, SP=Sardina pilchardus, TRT=Trachurus trachurus, TT=Thunnus thynnus)

Source: MED POL database

Figure 4.9

Box-and-whisker plots for concentrations (in µg/g fresh weight FW) of copper in selected species from the Mediterranean Sea



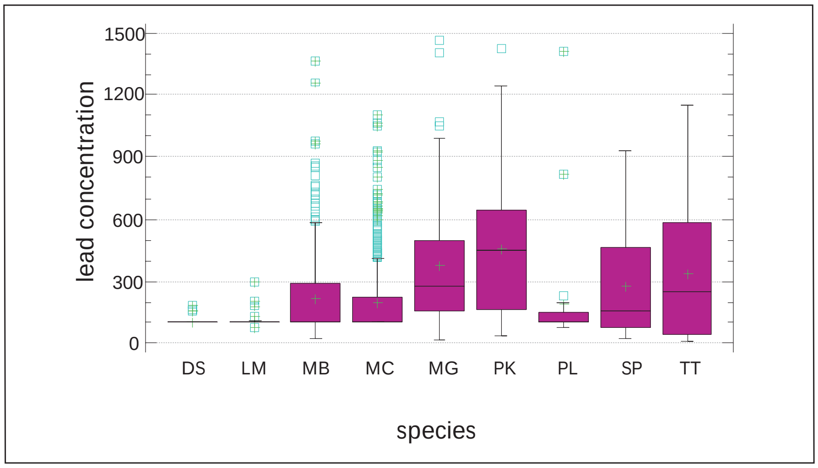
(DS=Diplodus sargus, MB=Mullus barbatus, MC=Mactra corallina, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

mullet and white sea bream they were 0.46 and 0.31 µg/g respectively. In tuna (from the eastern Mediterranean) the mean value was 0.60 µg/g. Similar observations are true for other seas (GESAMP, 1987). The concentrations observed are well below the maximum permissible limit (20 µg/g) set in some countries for seafood consumption (Montelogo et al., 1994). The highest concentrations observed were in the gastropod

Figure 4.10

Box-and-whisker plots for concentrations (in ng/g fresh weight FW) of lead in selected species from the Mediterranean Sea



(DS=Diplodus sargus, LM=Lithognathus mormyrus, MB=Mullus barbatus, MC=Mactra corallina, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, PL=Parapenaeus longirostris, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

Nassarius gibbosulus from Israel where a mean value of 10 µg/g was observed.

Concentrations of copper in Mediterranean surface sediments for the entire basin range approximately from 5 to 30 mg/kg which are smaller than the limits established for sediment quality criteria adopted by different national bodies (40-100 mg/kg; Van Gemert, 1988; Baudo et al., 1990). Values in various Meditterranean regional seas varied from 1.7 to 31 mg/kg for the north-west Mediterranean (Hoogstraten & Nolting, 1991) and from 4 to 29 mg/kg in the Aegean and Ionian seas (Voutsinou-Taliadouri, 1984).

4.3.2.5. Lead

Global production of lead from both smelting and mining operations has been relatively high throughout this century. Lead, since medieval times, has been used in piping, building materials, solders, paint, metal types, etc. and, more recently in batteries, metal products, chemicals and pigments. Combustion of oil and gasoline account for more than 50% of all anthropogenic emissions. Atmospheric fallout is usually the most important source of lead found in marine ecosystems (Moore & Ramamoorthy, 1984; Rilley, 1991). Inorganic lead is less toxic to aquatic life than mercurials and copper. However, it can cause acute or chronic effects in low concentrations (0.002-670 mg/l).

Lead concentrations in marine organisms from the Mediterranean basin are shown in **Figure 4.10** (as before, data for Mactra corallina and Diplodus sargus come only from Israel). The concentrations in demersal fish species are very low and in general do not exceed 600 ng/g FW. The respective mean concentrations for red mullet, mussels and tuna are 220, 380 and 350 ng/g. Some sea breams (e.g. Diplodus vulgaris and Lithognathus mormyrus) showed even lower values.

Lead concentrations found in surface sediments appear to be equally distributed in the Mediterranean. Concentrations from the north-western basin range from 5.2 and 23.2 mg/kg and are similar to those from the Ionian (13 mg/kg) and the east Aegean seas (11-22 mg/kg). Increased levels are recorded near highly industrialised coastal areas, and lead concentrations in estuarine sediments drop off rapidly within a few kilometres from known anthropogenic point sources (Voutsinou-Taliadouri, 1984). The values reported above are lower than the legal limits adopted by different national bodies (55-500 mg/kg) for sediment quality criteria (Giesy and Hooke, 1990; Baudo et al., 1990).

4.3.3. Chlorinated hydrocarbons

Organochlorines are a group of organic compounds containing chlorine. They are by far the most important group of persistent organic pollutants (POPs), since they are characterised by high resistance to photolytic, biological or chemical degradation. This fact, in combination with their low water and high lipid solubility, leads to their accumulation in fatty tissues of marine organisms. They are widespread in the environment and it is unlikely that any significant part of the biosphere is uncontaminated by them. The two main categories of the organochlorines measured in the MED POL programme are chlorinated pesticides and polychlorinated biphenyls (PCBs).

a) Chlorinated pesticides

The most widely distributed group of chlorinated pesticides is the DDT family. Apart from DDT, its main metabolites (DDE and DDD) are also widely observed in the marine environment and may in some cases have greater environmental impact. Hexachlorocyclohexanes (HCHs), aldrin, dieldrin, endrin, toxaphene, and heptachlor are other compounds belonging to the same category. Starting in the 1940s, these compounds were produced and utilised in vast quantities all over the world as insecticides. Subsequently, in the 1950s and 1960s there was an alarming decline in the populations of several seabirds and marine mammals. This fact, in combination with evidence from laboratory experiments indicating toxic effects on organisms exposed to organochlorines, led many countries in the northern hemisphere to ban or strictly regulate the use of such compounds in the 1970s. Most Mediterranean countries reported to FAO that in 1985 no chlorinated pesticides were used for agricultural purposes, with the exception of gamma-HCH (Lindane), which is considered one of the least persistent organochlorines and is still used. According to GESAMP(1989) the major route of entry of organochlorines into the marine environment is through the atmosphere.

b) Polychlorinated biphenyls (PCBs)

PCBs have been produced industrially since 1929 and were manufactured in many industrial countries, including some on the Mediterranean. They are complex mixtures of biphenyl compounds with different degrees of chlorination. 209 homologues and isomers (congeners) exist. In the past they were used as dielectric fluids in transformers and capacitors and in hydraulic and heat transfer fluids, but now there are restrictions in their use. The elimination of old electric appliances remains an important source of environmental pollution by these compounds. Combustion of PCBs can lead to the formation of toxic chlorinated furans and dioxins.

4.3.3.1. Concentration levels of chlorinated compounds in the Mediterranean

Organochlorines in the Mediterranean show a wide range of concentrations making any sensible comparison with other seas difficult. However, it should be mentioned that differences in measured concentrations might arise from methodological uncertainties and different analytical efficiencies of the various laboratories. Furthermore, different laboratories have quantified PCBs using different isomers. Data on PCB congeners are not yet available to MED POL. Intercalibration exercises have shown a large dispersion of results and therefore the evaluation and comparison of data is difficult (Gabrielides, 1994).

a) Seawater

Generally, the organochlorine concentrations in seawater from the Mediterranean area are very low and in most cases below the detection limits (UNEP/FAO/WHO/IAEA, 1990). In a study carried out along the Mediterranean coast of Spain during 1989-1990, only hexachlorocyclohexanes were identified with concentrations ranging from 1.3-2.3 ng/l, while DDTs and PCBs were not detected (<0.02 ng/l) (Prats et al., 1992).

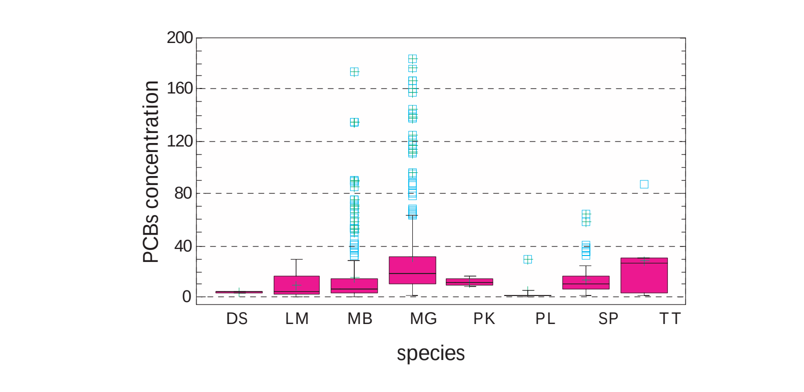
b) Marine sediments

Organochlorinated compound concentrations have been reported in sediments from the north-western Mediterranean (Tolosa et al., 1995). DDT concentrations ranged from 1.4 ng/g dry weight in open-sea sediments to 675 ng/g dry weight in the Rhône delta. This concentration is considered extremely high and is comparable to values obtained in heavily polluted locations. PCBs concentrations were lower, varying between 2 and 228 ng/g dry weight.

c) Marine organisms

Marine organisms have been extensively used as bioindicators for monitoring organochlorine pollution, as they have the ability to accumulate these lipophilic sub-

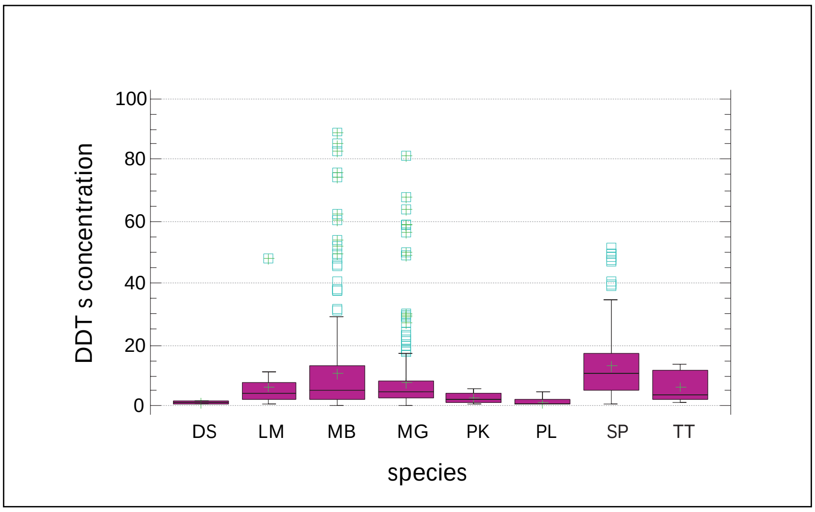
Figure 4.11 **Box-and-whisker plots for concentrations (in ng/g fresh weight FW) of PCBs in selected species from the Mediterranean Sea**



(DS=Diplodus sargus, LM=Lithognathus mormyrus, MB=Mullus barbatus, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, PL=Parapenaeus longirostris, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

Figure 4.12 **Box-and-whisker plots for concentrations (in ng/g fresh weight FW) of DDTs in selected species from the Mediterranean Sea**



(DS=Diplodus sargus, LM=Lithognathus mormyrus, MB=Mullus barbatus, MG=Mytilus galloprovincialis, PK=Penaeus kerathurus, PL=Parapenaeus longirostris, SP=Sardina pilchardus, TT=Thunnus thynnus)

Source: MED POL database

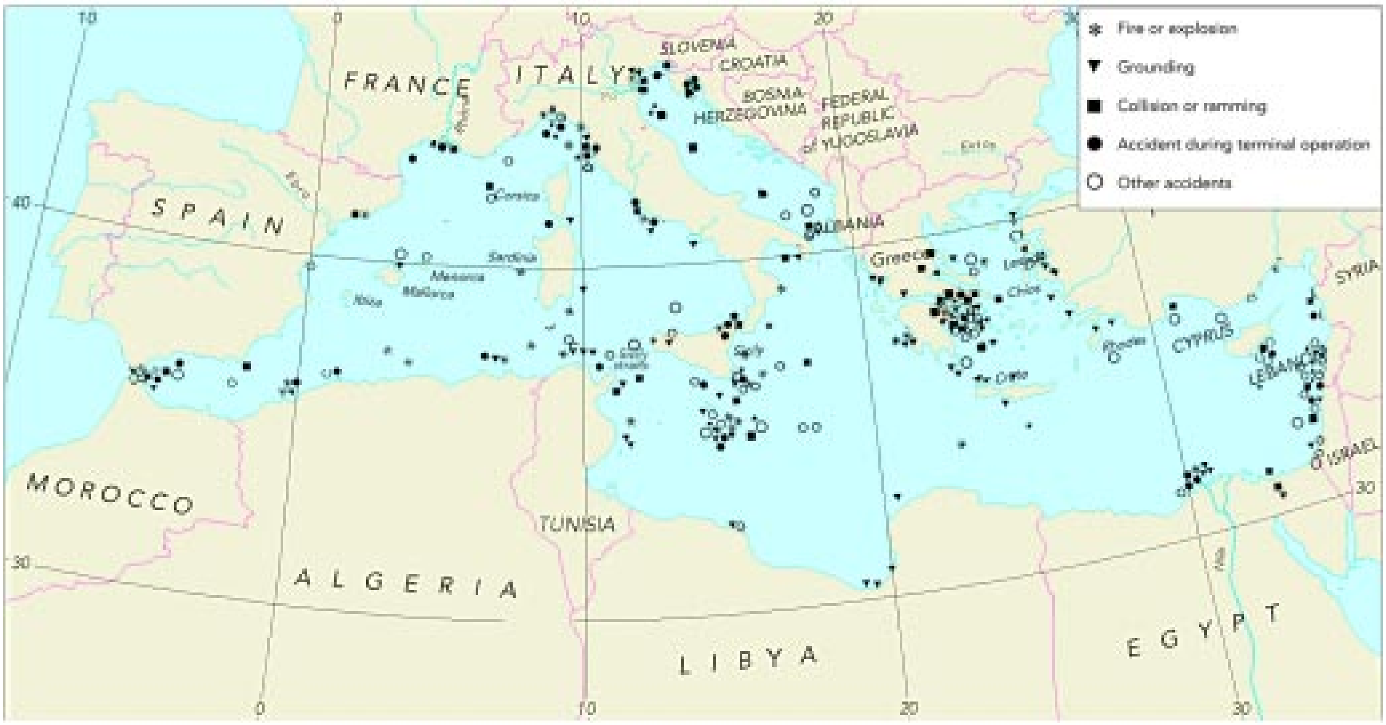
stances in their tissues. In **Figure 4.11 and Figure 4.12 ,** box-and-whisker plots indicate the distribution of values for PCBs and DDTs, in a number of species from the Mediterranean. The data for sardine and tuna come only from Spain. In all cases, the concentrations are lower than in previous years; average PCB values do not exceed 30 ng/g FW and those of DDT 20 ng/g. However, sardines from the north-western Mediterranean and swordfish from the central Mediterranean exceeded these values.

A large number of data on various DDTs, lindane and PCBs in mussels come mainly from the Aegean, east Ionian, east Adriatic and north-west Mediterranean seas. Only few data from the south-eastern Adriatic Sea and along the southern Mediterranean coast have been obtained. The concentrations vary widely and no trends can be detected. However, local downward trends which have occurred in the east Adriatic for PCBs and DDTs (in the proximity of an agricultural run-off near the city of Dubrovnik) have been reported. Maximum values reported for DDT and PCBs are much lower than the permissible limits (1-5 µg/g) for seafood consumption adopted in certain countries (WHO/UNEP, 1995).

It has been estimated that 1.5 million tonnes of PCBs have been produced globally since 1930 of which about 20-30 % has entered the environment (Tanabe 1988) and is consequently out of human control. About 1 % has reached the open sea. In some hot spots (eg. the Baltic) awareness and restrictions have led to a downward trend in PCB concentrations. On a global level releases can be expected to at least maintain present day levels unless control of releases becomes more widespread (Tanabe 1988).

Marine mammals as, on the whole, top predators, are the most susceptible to the highest concentrations of PCBs and other organochlorines bioaccumulated in the food chain. Also because the sea is the final destination of the bulk of PCBs released into the environment, marine mammals demonstrate lipid concentrations far in excess of those found in terrestrial top predators. The lipid-rich blubber of marine mammals exacerbates their PCB accumulation potential, making them a sink for PCBs. There is increasing evidence of linkages between high levels of PCBs and certain anomalies, especially reproductive ones, in marine mammals.

Locations of 268 reported alerts and oil pollution accidents that occured in the Mediterranean region between 1977 and 1995 | Figure 4.13



Source: RAC/REMPEC, 1996

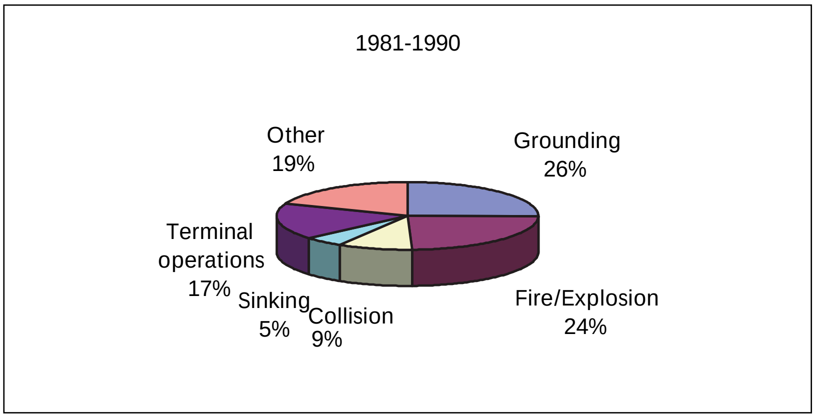
4.4. Oil pollution

There are already more than 40 oil-related sites (i.e. pipeline terminals, refineries, offshore platforms, etc.) distributed along the Mediterranean coastal zone, from and to which an estimated 0.55 and 0.15 billion metric tonnes of crude oil and petroleum products respectively are annually loaded, unloaded and transported by oil tankers (Clark, 1994; EIA, 1996-97) (See Chapter 3.7 Maritime Traffic (**Figure 3.19**).

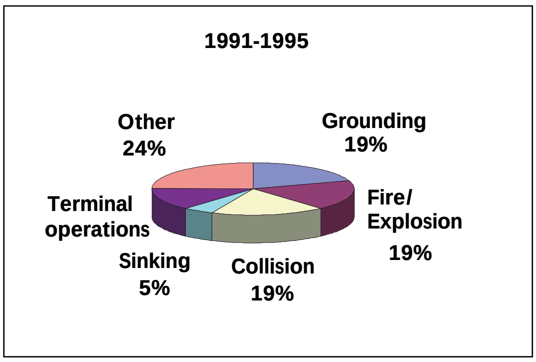
Although the Mediterranean has been declared a 'special area' by the MARPOL 73 / 78 Convention in which deliberate petroleum discharges from ships are banned, there is still ample evidence of numerous, repeated offences.

Severe pollution by oil tankers is usually the result of major accidents, such as foundering, grounding, fire, explosion, collision at sea with other vessels, or contact in a port with a quay, pier or bridge. The risk of shipping accidents in the Mediterranean Sea is very high. During the 1981-1990 period, 14.8% of a world total of accidents took place in a geographic area covering the Mediterranean, Black Sea and the Suez Canal.

Oil pollution accidents by type of accident during 1981-1990 and 1991-1995 | Figure 4.14



Source: RAC/REMPEC, 1996



This percentage of the world total is only exceeded by the north-western European area (21 %) and the Far East and Australian area (18.4 %) (ITOPF, 1997)

Figure 4.13 shows approximate locations of shipping accidents causing or likely to cause pollution of the Mediterranean Sea by oil, based on the reports received between 1977 and 1995 by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) located in Malta. According to the March 1996 edition of REMPEC's 'List of alerts and accidents', during the 1977-1995 period the Centre received reports on 268 alerts and accidents. The most accident-prone areas are: the Strait of Gibraltar and the Strait of Messina, the Sicilian Channel and the approaches to the Straits of Çanakkale, as well as several ports and their approaches, particularly Genoa, Livorno, Civitavecchia, Venice / Trieste, Piraeus, Limassol / Larnaka, Beirut and Alexandria. The geographical distribution of these pollution hotspots is related to the density of shipping traffic on the various Mediterranean routes. Out of 268 accidents listed by REMPEC for the 1977-1995 period, more than three-quarters involved oil. **Figure 4.14**, reproduced from the MAP / REMPEC (1996) report, analyses the accidents by type for two successive periods: a ten-year period (1981-1990) comprising 99 events; and a five-year period (1991-1995) comprising 81 events.

The most common types of accidents during both these periods were groundings and fire / explosions. A significant increase in the number of collisions can be noted in the 1991-1995 period (81 events)as compared to the previous decade (99 events). It is worth recalling that collision appears to be the type of accident most likely to produce an oil spill, according to the records for the Mediterranean Sea kept by REMPEC. Among the accidents registered in 1994 and 1995, 53 % occurred in the open sea and 47 % in or near ports. The fact that a disproportionately high percentage of accidents is registered in a very small percentage of the area occupied by ports and their approaches is related to very high traffic density caused by a large number of daily shipping movements in such areas. A contributing factor might also be the absence or the poor quality of the local vessel traffic systems in some of the Mediterranean ports.

It should be noted that not all reported accidents resulted in oil spillages.

In addition to the Haven and the Sea Spirit accidents described in Chapter 3.7, the only other oil-spill accident in which more than 10 000 tonnes of hydrocarbons were spilt in the Mediterranean Sea during the 1981-1995 period was the Cavo Cambanos incident in 1981. MT 'Cavo Cambanos', laden with 18 000 tonnes of naphta (non-persistent refined product), suffered an explosion off the port of Tarragona (Spain) on 31 March 1981 and partly sunk. After three months drifting between Spain and France the tanker was scuttled by the French Navy off Corsica on 5 July 1981. Her entire cargo was released under controlled conditions in the open sea; however, it quickly evaporated and no environmental damage was reported. During the same period there were four incidents in which between 1 000 and 5 000 tonnes of oil were spilled in the Mediterranean Sea.

According to REMPEC's records, national authorities of the countries concerned or private clean-up contractors responded to the majority of oil pollution incidents that necessitated a clean-up operation. Exceptions are some oil spills that occurred very far off shore, and those which occurred in adverse weather conditions that rendered response operations impractical. Mechanical oil removal techniques were used in most cases, and the use of dispersants was reported in 13 % of spill response operations.

4.4.1. Effects of oil pollution

World-wide, information shows that the effects of oil pollution (e.g. petroleum hydrocarbons and crude oil) can be far-reaching and pose a threat to the economy, health and ecology of the affected area. Recreational activities, local industry, marine life on shorelines and the open sea, marine mammals and reptiles, birds that feed by diving or form flocks on the sea, and fishes in mariculture facilities are among the resources that can be adversely affected by oil pollution. There is, however, only little information available on the effects of oil pollution in the Mediterranean. This information is based on regional contingency plans and on limited research, which is of only modest use in providing knowledge of the effects in general (EIA, 1996-1997). Nevertheless, the many geo-morphological conformations, the lack of registered data and limited investigations carried out, have contributed to this lack of information. Whereas limited investigation indicates threats from an ecological point of view, there is no information available to estimate threats to the economic and public sectors. Information on the amount of oil found in the water and on beaches (tar) has increased in recent years (UNEP / IOC, 1988), but information is still scarce on the levels found in sediments and organisms (Danavaro et al., 1995).

4.5. Microbiological contamination

4.5.1. Source of contamination

Pathogenic and other micro-organisms enter the marine environment mainly through municipal wastewater discharges. As is the case in other regions, microbiological pollution of the Mediterranean Sea is principally the direct result of the discharge of untreated or partially treated sewage into the immediate coastal zone. However, rivers may add a considerable amount of microbiological pollution, mainly from upstream wastewater discharges. Their actual relative contribution to pollution of the Mediterranean Sea by micro-organisms (pathogenic and otherwise) has not been assessed, and it has been assumed that the high concentrations of micro-organisms in wastewater discharges directly into coastal waters make these discharges the major source of microbiological pollution reaching the Mediterranean Sea (WHO / UNEP, 1985).

The atmosphere may also serve as a pathway for the entry of pathogenic and other micro-organisms into the coastal marine environment. Winds blowing from the continents towards the sea carry, inter alia, bacteria, viruses and parasites, while rain facilitates the deposition of these pollutants into rivers and oceans. One other possible source, which affects mainly coastal recreational areas, is bathers. Recreational waters not affected by sewage effluent discharges can be contaminated with enteroviruses (Shuval, 1986), and possibly also other bacterial and fungal infections (Papadakis et al., 1992). There is currently an increasing amount of evidence linking adverse health effects with bathing in high-population-density beaches, and the contribution of bathers as a source of pollution of recreational waters by pathogenic micro-organisms (WHO / UNEP, 1995).

Apart from pathogenic micro-organisms (principally bacteria, viruses and fungi) discharged into the marine environment in municipal sewage effluents or from other terrestrial sources, another group of naturally occurring marine micro-organisms can pose a similar threat to human health when present in large numbers. These are mainly dinoflagellate algae, which can be considered

Pathogenic bacteria recorded in Mediterranean coastal waters — Table 4.4

Pathogens	Location
Salmonella spp.	Widespread throughout region
Shigella spp.	East and south
Vibrio cholerae	Algeria, Egypt, France, Italy, Morocco, Spain
V. alginolyticus	Widespread throughout region
V. parahaemolyticus	Widespread throughout region
Staphylococcus aureus	Widespread throughout region
Pseudomonas aeruginosa	Widespread throughout region
Clostridium perfringens	Widespread throughout region
Campylobacter spp.	Widespread throughout region
Aeromonas hydrophila	Widespread throughout region

Source: WHO/UNEP, 1996

Viruses isolated in the Mediterranean marine environment — Table 4.5

Virus		Location
Enteroviruses		
	Poliovirus	Greece, Italy
	Echovirus	France, Greece, Italy
	Coxsackie virus A	France, Italy
	Coxsackie virus B	France, Greece
	Hepatitis A virus	France, Greece, Spain
	Unspecified, non-polio	France
Other viruses		
	Adenovirus	France, Greece, Italy
	Rotavirus	Spain

Source: WHO, 1991

as pathogenic through their ability to produce various toxins, to which man is exposed mainly through the consumption of contaminated shellfish. These micro-organisms constitute a phenomenon known as algal bloom, or “red tide”, which occurs when their concentration in sea water reaches levels of 10^4 to 10^6 cells per litre.

In a review of the problem (Shumway, 1990) a number of factors are thought to enhance algal blooms, including nutrient enrichment (eutrophication), decreased grazing pressure, large-scale hydrometeorological changes, upwelling of nutrient-rich bottom water, heavy precipitation and run-off, and even the presence of previous blooms of other phytoplankton species.

A recent assessment of the state of pollution of the Mediterranean Sea by pathogenic micro-organisms (WHO / UNEP, 1996), listed the records available to date. Pathogenic bacteria recorded are listed in **Table 4.4**. It should be noted that, up to the present time, the majority of records are from the northern coastline of the Mediterranean, and efforts have recently commenced to obtain more information regarding the situation in other areas.

One current area of concern is that of viruses. Those so far isolated in the various matrices of the Mediterranean marine environment are listed in **Table 4.5**. In this case, the geographical imbalance of data is more acute, resulting from the relative difficulty involved (and hence resources required) in the isolation and quantification of viruses, as opposed to bacteria. Even in the northern part of the Mediterranean, virology is still beyond the reach of most laboratories performing microbiological analysis of sea water on a routine basis.

4.5.2. Dispersion and fate of micro-organisms in the Mediterranean marine environment

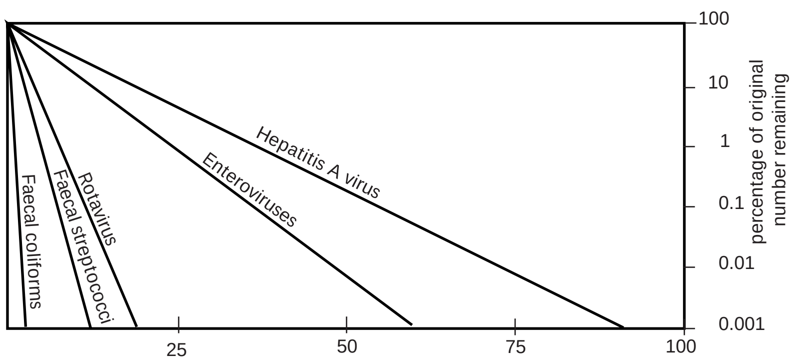
Micro-organisms contained in sewage are dispersed by the mixing of effluent and marine waters where they are discharged into the sea. On discharge into sea water, they are rapidly adsorbed on to particles of various kinds that float in the water (plankton, mineral particles, assorted organic debris) and, when routine counts are made, this adsorption results in an apparent reduction in the number of micro-organisms per unit of volume of sea water (Brison, 1976). These particles are diluted, dispersed, flocculated, sedimented or carried back to the coast. The coarse particulate matter contained in sewage has a tendency to settle rapidly in seawater, fixing micro-organisms which are adsorbed onto it.

The physico-chemical processes of flocculation of microbial cells, and their subsequent sedimentation to the sea floor have also been considered as the mechanism responsible for the microbial enrichment of sediments in the areas surrounding waste water discharges (Mitchell & Chamberlin, 1975). Natural turbulence and marine currents can become a plausible mechanism by which the contaminated sediments can be re-suspended, with the consequent impairment of the microbiological quality of the overlying seawater (Volterra & Aulicino, 1981; Velescu, 1983).

Total coliforms and faecal coliforms are inactivated in seawater rather rapidly and progressively under natural conditions, whereas faecal streptococci show a lower inactivation rate, as well as a smaller long-term percentage reduction (**Figure 4.15**).

Uptake of viruses by shellfish has been clearly demonstrated (Metcalf & Stiles, 1965) and numerous studies have similarly demonstrated that shellfish can concentrate viruses in their tissues at densities much greater than those in the surrounding waters (Geldreich, 1985). Like bacteria, the majority of viruses are concentrated in the digestive system of the host and, once they are inside a shellfish, the survival of viruses appears to be prolonged (Metcalf & Stiles, 1965).

Figure 4.15 **Typical survival characteristics of faecal bacteria and human enteric viruses**



Source: WHO/UNEP, 1995 (adapted from Wheeler)

4.5.3. Microbiological criteria and standards for Mediterranean coastal areas

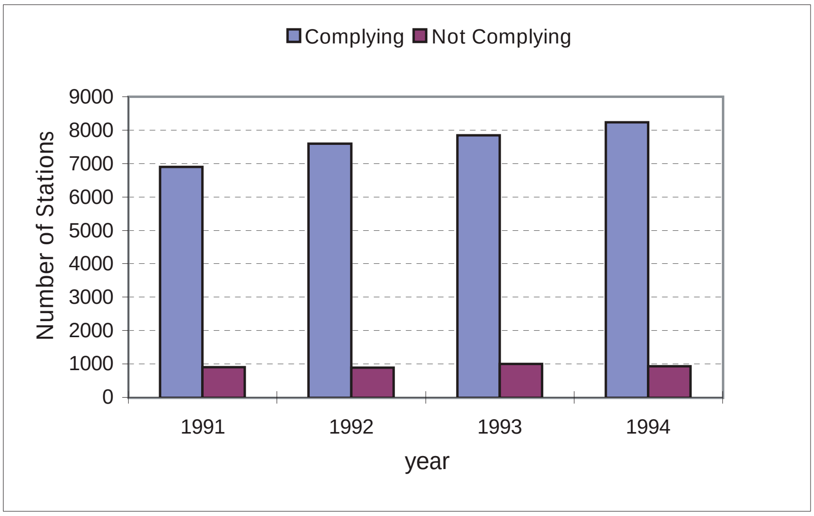
Monitoring programmes in the Mediterranean, aimed at the estimation of the state of pollution of marine recreational and shellfish waters continue to rely largely on concentrations of one or more bacterial indicator organisms as an index of sanitary acceptability or otherwise, while the main risks to human health through bathing or seafood consumption depend on the presence and density of pathogenic micro-organisms which are the real agents of disease. In line with global practice, recreational and shellfish water quality standards in the Mediterranean are based on acceptable concentrations of bacterial indicator organisms (mainly faecal coliforms, supplemented to a lesser extent by faecal streptococci) and, in some instances, pathogens, such as Salmonella spp. and enteroviruses.

Standards and criteria for both recreational and shellfish waters exist in practically all countries of the region but, particularly in the case of recreational waters, differ to a large extent both as to the particular micro-organism(s) monitored, and the acceptable levels (WHO, 1989). In terms of the above, Mediterranean countries have adopted interim environmental quality criteria for recreational waters based on microbiological parameters while the EU Directive 76/160/EEC (EC, 1976) on the quality of bathing water which affects four Mediterranean countries, contains both microbiological and physico-chemical parameters.

4.5.4. The state of microbiological pollution of sensitive Mediterranean coastal areas

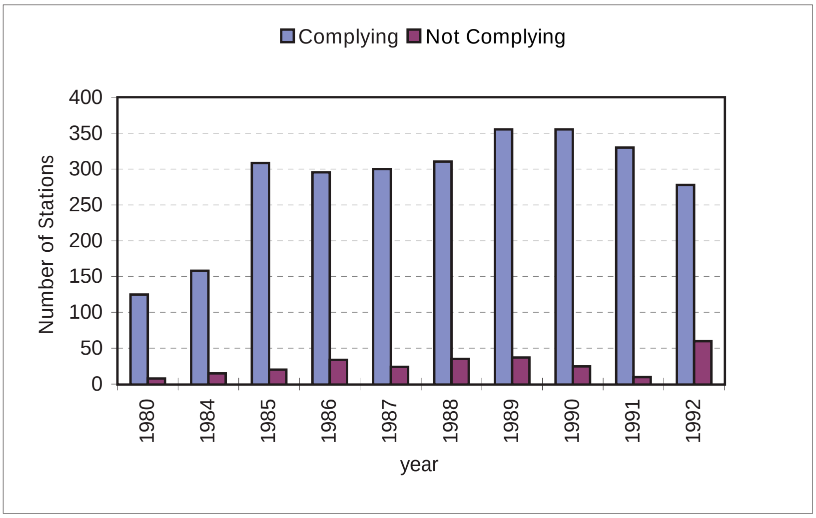
Within the framework of the Mediterranean pollution monitoring programme, an assessment based on the availability of data was made for the period 1983 to 1992 (WHO/UNEP, 1996). Due to different standard values used in Mediterranean EU and non-EU countries, a comparative evaluation of the microbiological quality of recreational waters in the stations monitored is not accurate, although it can provide an overall picture of the situation. **Figure 4.16 & Figure 4.17** show the numbers of stations complying and not complying with the respective microbiological quality parameters, in EU and non-EU countries respectively (WHO/UNEP, 1996).

Stations in the Mediterranean non-EU Countries complying and non-complying with microbiological standards — Figure 4.16



Source: WHO/UNEP, 1996

Stations in the Mediterranean EU Countries complying and non-complying with microbiological standards — Figure 4.17



Source: WHO/UNEP, 1996

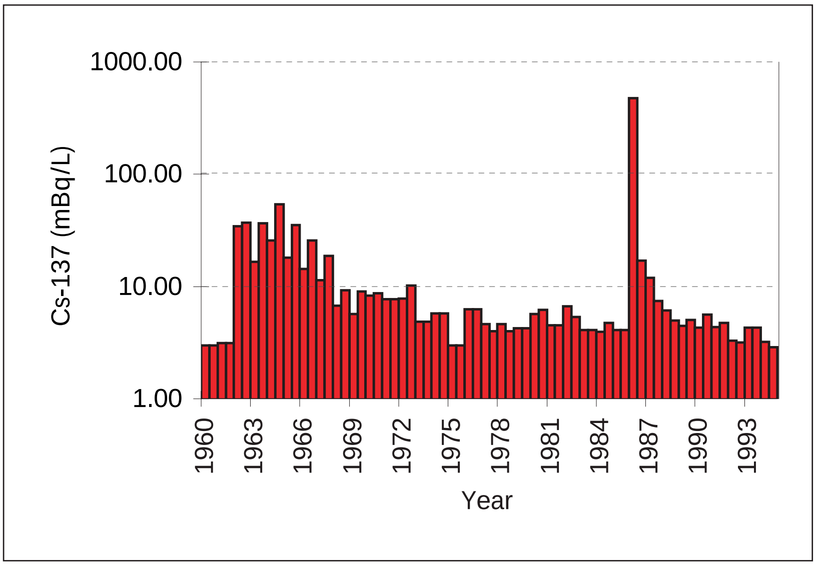
4.6. Radioactive contamination

The following analysis is concerned with two anthropogenic radionuclides: caesium-137 and plutonium-239,240. The first one has a relatively long half-life (30 years), is conservative, present in sea water in dissolved form, is the more abundant man-made radionuclide in the Mediterranean Sea, and easily measurable in most marine matrices. The second one has a very long half-life (24 000 years), is the more abundant among the transuranics, is non-conservative in sea water and shows high affinity for particulate matter.

4.6.1. Sources

The global inputs of ^{137}Cs and $^{239,240}Pu$ to the Mediterranean Sea up to 1996 have been estimated to be 15 and 0.19 PBq, respectively (Holm et al., 1988; MED POL, 1992; Papucci et al., 1996). For both radionuclides the major source is atmospheric fallout from nuclear weapon testing in the early 1960s. The Chernobyl accident produced an additional ^{137}Cs input of approximately 2.8 PBq (+20 % of the global input up to 1986) that mainly affected the northern and eastern basins, with a patchy distribution. Of this amount 0.3 PBq derives from exchanges with the Black Sea, which was heavily contaminated by the accident. All the other sources (input from rivers, nuclear industry, exchanges through the straits) amount to no more than 10 % of the total delivery from fallout. Inputs deriving from nuclear industry and from accidents (other than Chernobyl) are negligible if considered in terms of contribution to the total budget, but might lead to local enhancement of radioactivity levels. For

Figure 4.18 ^{137}Cs concentration in surface sea water of the Tyrrhenian Sea (1960-1995)



Data Sources: Giorcelli & Cigna, 1975; ENEA, 1975-1992; ANPA, 1992-1995; ENEA, 1978-95

instance, the discharges from the Marcoule reprocessing plant in southern France have been 0.03 PBq of ^{137}Cs and 0.3 TBq of ^{239,240}Pu up to 1995; that is, less than 0.2 % of the total delivery to the Mediterranean. The amount of radionuclides released by the atomic bomber crash in Palomares, southern Spain, in January 1966 has not been quantified, but measurements carried out in the adjacent marine area indicate that a maximum of 1.22 TBq of plutonium derived from the accident is presently stored in the marine sediments nearby (Anton et al., 1995).

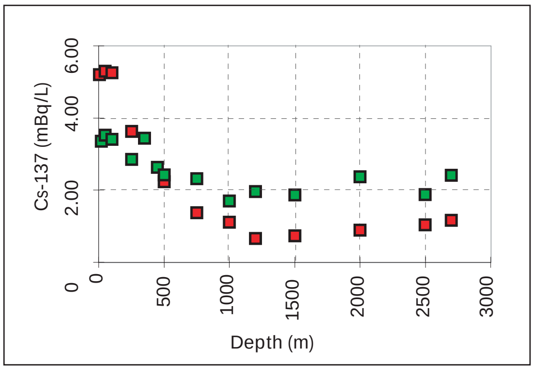
4.6.2. Radionuclides in sea water

The time trend of ^{137}Cs concentration in sea water at a coastal site of the Tyrrhenian Sea in the period 1960-1995 is shown in **Figure 4.18**. ^{137}Cs level increases from the early to mid-1960s and levels off after the 1970s. These changes are due to the decrease in radionuclide fallout, physical decay, and transport from surface to underlying water masses through diffusion and convection processes.

The fallout from the Chernobyl accident produced, in the first days of May 1986, a sharp increase (two orders of magnitude) in ^{137}Cs concentration in surface sea water of the north-western Mediterranean (Delfanti & Papucci, 1988; Whitehead et al., 1988). In this area, the decrease of ^{137}Cs levels after the accident was quite rapid due to mixing with 'uncontaminated' waters from the southern Mediterranean basins and from the Atlantic Ocean. In the Adriatic Sea, ^{137}Cs levels were systematically higher than in the western basin, due to the higher Chernobyl deposition in the area, to run-off from the major Italian rivers and probably also due to the general circulation pattern that brought to this basin 'contaminated' waters from the eastern Mediterranean. In 1990, ^{137}Cs concentrations were usually back to pre-Chernobyl values (~ 5 mBq.l^{-1}) all over the Mediterranean Sea, except for some areas of the Aegean Sea that in 1993 still showed enhanced levels, especially near the Strait of Çanakkale, due to direct input of contaminated water from the Black Sea (MARINAMED, 1995, Florou et al., 1995).

Figure 4.19 Time trend of ^{137}Cs vertical profile in the water column of the western Mediterranean

Data Sources: Kautsky, 1997; Fukai et al., 1980; Ballestra et al., 1984; IAEA, 1991; Delfanti et al., 1995



^{137}Cs vertical profiles in the water column are characterised by decreasing concentrations from surface to bottom (**Figure 4.19).** In the period 1970-1982 (Kautsky, 1977; Fukai et al., 1980; Ballestra et al., 1984) average ^{137}Cs concentrations in the water column were in the order of 5.4 ± 2.1 mBq.l^{-1} in the surface layer, 2.2 ± 0.6 mBq.l^{-1} in the Levantine Intermediate Water (300-600 m) and 1.0 ± 0.5 mBq.l^{-1} in the Deep Water (600 m to bottom). Diffusion and convection processes progressively transported ^{137}Cs from surface to deeper layers as shown by systematic studies conducted in 1991-1994 (Delfanti et al., 1995). Although the levels in the intermediate water have not changed significantly, there is a decrease in caesium concentration in surface water and a clear increase in the deep waters, in which the average level is at present 1.7 ± 0.5 mBq.l^{-1}.

Based on the vertical profiles of ^{137}Cs in 1991-1994 data, the present inventory of ^{137}Cs in the Mediterranean water column is estimated to be 13.6 PBq. This corresponds to an increase, after the Chernobyl accident, of about 25% and accords well with the estimated global input of 15 PBq to the whole Mediterranean.

An analysis of published $^{239,240}Pu$ levels in surface sea water for the period 1970-1994 **Figure 4.20** shows, as for ^{137}Cs, a decreasing trend with time (Papucci et al., 1996 and references therein). Present concentrations (8-15 mBq.l^{-1}) are less than one-third of those reported in 1970. The removal of transuranium nuclides from surface water is controlled by the same physical processes active for ^{137}Cs, but also by the association with suspended matter and subsequent sedimentation processes. In fact, the sinking of particles through the water column is the main mechanism determining the shape of transuranic vertical profiles, which are characterised by subsurface maxima at intermediate depths (250-400 m) (Fukai et al., 1982). At these depths decomposition of organic matter takes place, releasing the associated nuclides to the soluble phase. The time trend of the vertical profiles in the period 1970-1990. **Figure 4.21** shows a marked decrease in plutonium concentration in the surface and intermediate layer and doubled values in the deep waters (IAEA, 1991).

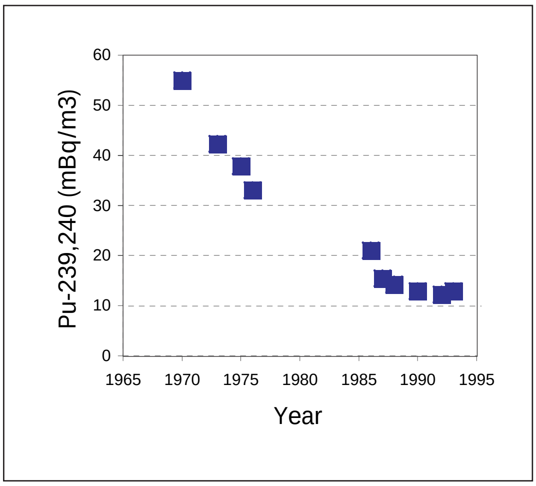
4.6.3. Sediments

Concentrations of radionuclides and the total quantity per unit area in sediments are highly variable, being usually highest on the continental shelf and near river mouths, and lowest in deep-sea environments.

Recent data indicate that ^{137}Cs in the sediment of the western Mediterranean, at water depths of about 1,000 m is in the order of 230 Bq.m^{-2}, corresponding to 5-10 % of the cumulative fallout deposition. More complex is the situation on the continental shelf and in the areas influenced by river discharges, which can carry important amounts of radionuclides to the adjacent continental shelves, thus increasing the sediment content (Arnaud et al., 1995). In these areas, particularly where the Chernobyl deposition on the hinterland was significant (northern Adriatic and Liguro-Provençal areas), ^{137}Cs content ranges between 2,000 and 30,000 Bq.m^{-2}.

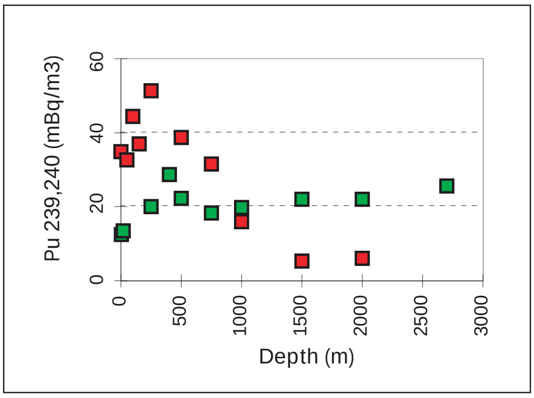
$^{239,240}Pu$ concentrations in sediments ranged from 100 to 200 Bq. m^{-2}, two to three times higher than the cumulative fallout deposition (82 Bq.m^{-2}). These values are found in fine-grained sediments of the continental shelf, characterised by higher particle population leading to an efficient scavenging of pluto-

$^{239,240}Pu$ concentration in surface sea water of the western Mediterranean (1970-1994) — Figure 4.20



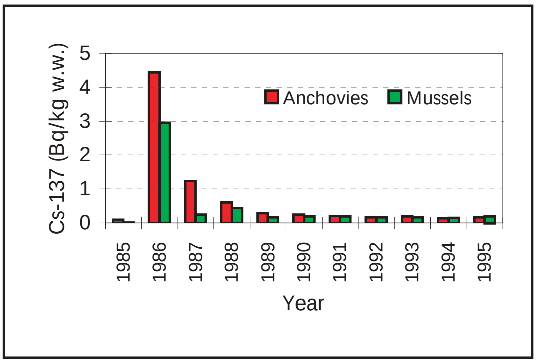
Source: Holm et al., 1980; Murray & Fukai 1978; Fukai et al., 1976; Fukai et al., 1979; Fowler et al., 1990; Savall, 1992; Mitchell et al., 1995; Pareja, 1997

Time trend of $^{239,240}Pu$ vertical profile in the water column of the western Mediterranean — Figure 4.21



Data Sources: Fukai et al., 1982; IAEA, 1991; MARINA MED, 1995

^{137}Cs concentration in anchovies and mussels of the northern Adriatic Sea (1985-1995) — Figure 4.22



Source: ENEA/CRAM, 1995

nium. In contrast, in deep-sea environments that do not receive significant particulate input, Pu inventories are as low as a few $Bq.m^{-2}$, in the marine area affected by the Palomares accident, $^{239,240}Pu$ inventories are in the range 200 - 1,500 $Bq.m^{-2}$. It has been estimated that a maximum of 1.22 TBq of plutonium deriving from the Palomares accident has been deposited in the sediments (Anton et al., 1995).

4.6.4. Organisms

The analysis of the time-trend evolution of radioactivity levels in the marine organisms of the Mediterranean is practically restricted to ^{137}Cs, which is the only anthropogenic radionuclide systematically analysed by the different countries, through their own national networks for monitoring environmental radioactivity. The marine organisms for which data exist on a large scale are: i) fish, which are essentially measured for health assessment, and ii) filter-feeding molluscs, which are sampled both for health assessment and as bio-indicators.

Figure 4.22 shows, as an example, the time trend of ^{137}Cs concentration in anchovies and mussels from the Adriatic Sea from 1985-1995. The Chernobyl fallout produced a sharp increase in ^{137}Cs concentration in the marine biota of the most contaminated areas. In June 1986, ^{137}Cs concentration in anchovies and mussels of the Adriatic Sea was two orders of magnitude higher than before the accident. In the same period, in Greece, the ^{137}Cs concentration in anchovies and mussels were reported to be up to 33 and 66 $Bq.kg^{-1}$ w.w., respectively (Florou et al., 1990). The sharp Chernobyl signal reveals a rapid depuration time both in mussels and in fish. Pre-Chernobyl concentrations were reached again in 1989. The concentration factor for ^{137}Cs in both organisms is generally low (100 for fish and 30 for mussels) due to the abundance in the marine environment of the corresponding stable isotope and of potassium, which competes with the radionuclide for biological uptake.

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5. Ecosystem sensitivity and impacts

This section deals with the ecosystem sensitivity and impacts arising from climate change, the changes in biodiversity and ecosystems, and health risks in the area induced by human impacts on the environment.

One of the main potential risks expected from climate change is the impact on the coastal zone caused by human-enhanced sea level rise, which is discussed through site-specific casestudies prepared by the Oceans and Coastal Areas Programme Activity Centre of the United Nations Environment Programme (UNEP), in cooperation with the Intergovernmental Oceanographic Commission (IOC) of UNESCO, as a systematic approach to assessing the likely impacts of climatic changes in several geographical areas. Assessment of potential impacts from climate change in the Mediterranean, based on case studies performed in the region, include those from changes in temperature, precipitation, moisture, extreme events (droughts and floods) and changes because of the sea level rise. Responses together with risk assessment and planning are also discussed together with the presentation of recent research data obtained in the Mediterranean Sea.

Biodiversity and ecosystem changes take into account the effects of perturbations that may directly or indirectly result from anthropogenic activities. Effects on the ecosystem and biodiversity are discussed for pollution, overexploitation of marine resources, habitat erosion, climatic changes (e.g. through the greenhouse effect), and the introduction of alien species.

Finally, health risks stemming from marine pollution in the Mediterranean Sea are discussed, covering issues such as the public health implications and risks from microbiologically contaminated marine areas and polluted seafood.

5.1. Climate change

The UN Framework Convention on Climate Change (a major outcome of the Rio UNCED conference on sustainable development) implies, for ratifying countries, an engagement in developing specific environmental and socio-economic assessment tools to define the impacts, on the national scale, of the implications of global changes (Carter et al., 1994).

Variations in world climate will be reflected in the Mediterranean region. Although the form of the change is uncertain, certain changes will have an impact on environmental and socio-economic activities in the region. Potential impacts include drought, decline of water quality, floods, changes in soil erosion and desertification, storms, coastal erosion, changes in seawater temperature and salinity, sea level rise and biodiversity reduction. Most authors conclude that such impacts will only exacerbate the problems that already exist and that are increasing in some coastal countries (UNEP, 1992). How serious these consequences will be depends partly on the extent to which adaptation measures will be implemented in the coming years and decades.

The ability to trace possible scenarios for the future and the consistency between data collected and simulations is rapidly evolving and improving, due to the improvement of research and modelling procedures used in the assessment tools. Although the effects in the Mediterranean environment can mainly be forecast, as mentioned above, data obtained on a Mediterranean spatial scale is still somewhat unreliable for the assessment and solution of practical problems. A programme of monitoring and compiling data on a Mediterranean regional scale and the analysis, usually conducted on temperatures and precipitation, needs to be extended to other variables to obtain a more coherent picture and a better understanding (Casaioli & Sciortino, 1997).

5.1.1. Sea level rise: a global issue

While climate changes are essentially still measured through variations in temperature and precipitation, in coastal zone management it is the prediction of sea level rise, potentially accelerated by anthropogenic activities, which becomes one of the most important aspect of the impact of climate change likely to affect coastal zones. From a management perspective, it is the future rate of relative (or local) sea level rise in coastal zones that must be considered, which includes the absolute rise of sea level, but also land subsidence or uplift which may be more significant at local level (Nicholls & Leatherman, 1995).

Changes in coastal zones continue; the Intergovernmental Panel on Climate Change (IPCC) concluded that: '….average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice sheets'. For the IS92a scenario, assuming the 'best estimate' values of climate sensitivity and of ice-melt sensitivity to warming, and including the effects of future changes in aerosol concentrations, models project an increase in sea level of about 50 cm from the present to the year 2100. This estimate is approximately 25% lower than the 'best estimate' made in 1990, due to the lower temperature projection, but also reflecting improvements in the climate and ice-melt models. Combining the lowest emission scenario (IS92c) with the 'low' climate and ice-melt sensitivities, including aerosol effects, gives a projected sea level rise of about 15 cm from the present to the year 2100. The corresponding projection for the highest emission scenario (IS92e) combined with 'high' climate and ice-melt sensitivities, gives a sea level rise of about 95 cm from the present to the year 2100.

Regional sea level changes may differ from the global mean value owing to land movement and ocean current changes (IPCC, 1996). In addition, as in the case of global predictions, regional predictions may be used only for general policy guidance. Only site-specific studies could lead to practical management and policy decisions and actions of relevance to each particular location.

This is particularly true when assessing the impacts of future climatic changes given the influence of local geographic factors on rainfall and temperature patterns and microclimate, and in the case of sea level where tectonic movements, sediment compaction and extraction of oil, gas and water may result in local sea level changes several orders of magnitude greater than the predicted global mean sea level rise.

The Oceans and Coastal Areas Programme Activity Centre of the United Nations Environment Programme (UNEP), in cooperation with the Intergovernmental Oceanographic Commission (IOC) of UNESCO, launched, in late 1987, a systematic approach to assessing the likely impacts of climatic changes in the geographical areas covered by the UNEP-sponsored Regional Seas Programme. By early 1995, 11 task teams had been established for regions covered by the Programme (Mediterranean, Caribbean, South Pacific, East Asian seas, South Asian seas, South-west Pacific, West and Central Africa, eastern Africa, Persian / Arabian Gulf, Black Sea and Red Sea).

The physical impact of sea level rise on the Mediterranean lowland coasts can be predicted, even modelled quantitatively on the basis of the presently available data and information on morphology, hydrodynamics, sediment budgets, land subsidence and the effects of artificial structures. The effects of sea level rise are most predictable even though the extent of sealevel rise is difficult to foresee. A global sea level rise of 16 cm by 2030 and 48 cm by 2100 was assumed on the basis of Wigley and Raper's analysis (Wigley and Raper, 1992) as modified by the available information on local tectonic trends, land movements and past trends in relative sea level. A mean sea level rise in the Mediterranean region comparable to global mean, of about 96 cm by 2100 is likely to happen (Jeftic et al., 1992; Warrick et al., 1996) taking into account the past trends (Jeftic et al., 1992) and projected global increases given by IPCCs mid-range scenario. The worst affected regions appear to be the large river deltas of the Nile, Thessaloniki and Venice which are currently subsiding. The Near East and Alexandria may experience lower rates of sea level rise as the land appears to be rising slightly (Karas, 1997).

Among the most likely consequences of sea level rise will be: increased direct wave impact on exposed coasts (e.g. the coastal barrier of the Venice Lagoon, beach resorts of the Rhône Delta) and on harbour installations (e.g. Alexandria, Port Said, La Golette-Tunis); increased frequency and intensity of flooding of estuaries, canals and lagoons, with potentially serious consequences for agriculture, aquaculture, lagoon fisheries and wildlife (e.g. the delta of the Ebro and Ichkeul / Bizerte); and worsening of existing shore erosion problems (e.g. the deltas of the Nile and Rhône).

Seawater intrusion into coastal aquifers will intensify with an elevation of mean sea level, and worsen the already quite widespread fresh water supply difficulties experienced in a number of locations (e.g. Malta) along the shores of the Mediterranean.

5.1.2. Potential impacts and responses to climate change in the Mediterranean region

In the framework of the Mediterranean regional study, six site-specific case studies were prepared during the period 1988-1989 (deltas of the rivers Ebro, Rhône, Po and Nile; Thermaikos Gulf and Ichkeul/Bizerte lakes). The final results of this work were published by Jeftic et al. (1992). As a follow-up to the studies completed by 1989, another five Mediterranean site-specific studies were prepared during the period 1990-1993 (Island of Rhodes (UNEP, 1994a), Kaštela Bay (UNEP, 1994b), Syrian coast (UNEP, 1994c), Maltese Islands (UNEP, 1994d), and the Cres-Lošinj archipelago (UNEP, 1994e). Finally three studies were launched (Fuka-Matrouh region in Egypt, the Albanian coast, Sfax region in Tunisia) in the framework of the wider, Coastal Areas Management Programmes (CAMPs) of the UNEP-sponsored Mediterranean Action Plan.

The scenario covering the Mediterranean basin (Palutikof et al., 1992), and the more focused subregional and local-scale scenarios, were completed only after the completion of the first six site-specific case studies.

Potential impacts from climate change in the Mediterranean region, based on the studies performed, include those from changes in temperature, precipitation, moisture, extreme events (droughts and floods) and the changes due to sea level rise. **Table 5.1** shows the potential impacts of the climate change in the Mediterranean region.

Following the potential threats, the major potential response measures identified in the studies revealed that, in the beginning, the recommendations produced had little value to policy and decision-makers, since they emphasised mainly the need for better models, improved monitoring, information and databases, risk assessment and scenario building (**Table 5.2**). Later on, however, more concrete proposals were generated for response measures, including the need for changes to codes and standards such as those covering construction and engineering works, and the need to take the identified potential impacts into consideration in the future planning and management plans for coastal areas and resources (**Table 5.2**).

5.1.3. Forecast of sea level rise in the Mediterranean region

All present estimates of Mediterranean Sea rise are based on mathematical models, themselves based on analysis of climatic historical data series which, at best, cover only 100 years. This limited period of observation and data collection is considered inadequate for a precise assessment.

Paleoclimatic studies deriving from the application of dating techniques which are based on radiocarbon isotopes, applied to mollusc shells found on rising coastal lines, have been used more recently in conjunction with models based on climatic data, to double-check and mitigate the wide oscillations found in forecasted scenarios by present models. Paleoclimatic studies provide upward curves which are based on geological indicators data that have a sure connection with the level of the sea and that are collected from tectonically stable areas[1].

Proceeding this way, the most recent rising sea level time-series in the Holocene[2] era - which includes present times - have been obtained through the dating of fossils or coral reefs (Bard et al., 1990). The objective of such paleoclimatic approach is to enable a reconstruction that would also take into account the natural fluctuations (as opposed to variations caused by human activities) in a long period of time, as a more correct basis for a realistic model for future prediction.

A similar research has been carried out very recently in the Mediterranean area by applying increasingly precise dating techniques to submerged speleothemes and archaeological sites, and has, through numerous double-checked data, enabled the construction of a detailed time-series of sea level rise which provides a good prediction basis for the near future scenarios (year 2100) (Alessio et al., in press; Antonioli et al., 1994).

Research relevant to the variations in sea level stems from the need to understand and assess the practical environmental impact resulting from a rise in sea level in the Mediterranean Sea. In addition, the socio-economic impacts on the coastal zones, namely in coastal plains and deltas, which are particularly at risk, will also need assessing.

While the increase in sea level in the next century is not disputed, the extent of the increase is still a very controversial matter. Both climatic data, and the prediction models into which they are fed, are still weak points in assessing future environmental impacts of climatic changes on the coastlines.

[1] Areas which are not subject to earth crust movements.

[2] The Holocene is the most recent era, covering the last 10,000 years, and the late Holocene includes roughly the last 3,000 years to the present.

Table 5.1	Major potential impacts identified in the studies
Delta of Ebro, Spain	increased coastal erosion; reshaping of coastline; loss and flooding of wetlands; reduced fisheries yield
Delta of Rhône, France	erosion of unstable or threatened parts of coastline; reduction of wetlands and agricultural land; increased impact of waves; increased salinization of coastal lakes; destabilization of dunes; intensified tourism
Delta of Po, Italy	increased flooding and high-water events; increased coastal erosion; retreat of dunes; damage to coastal infrastructure; salinization of soils; alteration to seasonal water discharge regimes; reduced near-shore water mixing and primary production; increased bottom water anoxia
Delta of Nile, Egypt	increased coastal erosion; overtopping of coastal defences and increased flooding; damage to port and city infrastructure; retreat of barrier dunes; decreased soil moisture; increased soil and lagoon water salinity; decreased fisheries production
Ichkeul-Bizerte, Tunisia	increased evapotranspiration leading to decreased soil moisture, reduced lake fertility and enhanced salinity; increased salinity of the lakes and shift to marine fish fauna; reduced extent of wetlands and loss of waterfowl habitat
Thermaikos Gulf, Greece	inundation of coastal lowlands; saline water penetration in rivers; drowning of marshland; increased sea water stratification and bottom anoxia; decreased river run-off; salinization of ground water; decreased soil fertility; damage to coastal protective structures; extension of tourist season
Island of Rhodes, Greece	increased coastal erosion; salinization of aquifers; increased soil erosion
Maltese Islands, Malta	salinization of aquifers; increased soil erosion; loss of freshwater habitats; increased risk for human health, livestock and crops from pathogens and pests
Kaštela Bay, Croatia	inundation of Pantana spring and Zrnovica estuary; increased salinization of estuaries and groundwater; negative impact on coastal services and infrastructure; accelerated deterioration of historic buildings; increase in domestic, industrial and agricultural water requirements
Syrian coast, Syria	increased soil erosion; modification of vegetation cover due to increased aridity; increased salinization of aquifers; erosion of beaches and damage to coastal structures and human settlements due to exceptional storm surges
Cres-Lolinj, Croatia	increased salinization of lake Vrana; extension of tourist season; increased risk from forest fires
Albanian coast, Albania	salinization of coastal aquifers and shortage of adequate quality of drinking water; soil erosion (physical); extension of summer drought; extension of tourist season
Fuka-Matrouh, Egypt	increased evapotranspiration and decreased rainfall; extension of summer aridity; increased coastal erosion; flooding in eastern part; decreased soil fertility
Sfax coastal area, Tunisia	salinization of ground water; increased rainfall; possible flooding

Source: UNEP/MAP

The time-series shown in **Figure 5.1**, built on paleoclimatic data from the Mediterranean, indicates a significant decrease in sea level rise in the late Holocene of 12-15 cm in the past 100 years (Pirazzoli, 1991). The rate of increase, however, was much higher prior to that (Antonioli et al., in press). Even when taking into account an anthropogenic influence on climate change, capable of doubling such rate of change, the sea level rise scenario for year 2100 should be within the range of 12 to 30 cm. This scenario, built on recent research data from the Mediterranean, is also compatible with the lower range of IPCC forecast (20 cm) and with the most recent modelling available, based on glaciers melting rates, which forecasts a rise in sea level of between 9 and 30 cm for the year 2100 (Gregory & Oerlemans, 1998).

5.1.4. Risk assessment and planning for sea-level rise

While the extent of sea level rise for the future remains uncertain, the trend is towards an increase. An integrated coastal-zone management approach is required to minimise the impacts of natural or accelerated sea level rise. Sectoral approaches addressing the impacts of climatic changes will not lead to their successful long-term solution. To avoid or mitigate the eventual negative impacts of expected climatic changes, the most promising general policy option is the broad application of integrated coastal zone planning and management. This should take into account, among other factors, the long-term trends in climatic conditions. In this context, the long-term national socio-economic development plans will have to be re-examined in order to take into account not only the presently obvious trends and available resources, but the influence the changed

Major potential response measures identified in the studies Table 5.2

Delta of Ebro, Spain	study of coastal processes; establishment of long-term data series; assessment of possible changes in insect pest populations; redefine the Ebro management unit; re-evaluate the existing delta development plans in the light of findings of the case study
Delta of Rhône, France	areas at risk; identification of natural indicators of vulnerability and plants suitable to counter erosion; modelling biological system response under differing environmental conditions
Delta of Po, Italy	analysis of future trends and preparation of scenarios
Delta of Nile, Egypt	conditions; establish database for future planning purposes
Thermaikos Gulf, Greece	readjustment of present flood defences; possible damming of Thessaloniki Bay and engineering control of water level
Island of Rhodes, Greece	readjustment of coastal building standards; water resources management and exploration for additional water resources; reforestation; study of the consequences of the changes to tourist season and services in relation to the island economy and population
Maltese Islands, Malta	possible impact of climatic change; assessment in detail of the impact of sea level rise and the local climatic changes on the local aquifers; prevention of soil erosion by maintenance of existing dry stone walls and terrace systems and by planting of trees; assessment of vulnerability of humans, livestock and crops to future increase in pests and pathogens
Kaštela Bay, Croatia	construction projects in the region; re-evaluation of existing land-use plans and zoning policies for buildings; revision of major policies and programmes of flood-hazard mitigation measures
Syrian coast, Syria	include development of water management plans, solution to problems of soil and coastal erosion and increased salinization, monitoring programmes and establishment of a data bank on natural and cultivated vegetation
Cres-Lošinj, Croatia	mainland; artificial recharge of the karstic underground aquifers during the prolonged summer dry season; elevation of coastal defence structures in order to protect valuable existing buildings and structures; periodic revision of physical and urban development plans; assessment of the requirement of the extended tourist season in the light of demand for additional space and services; application of suitable protective measures against forest fires
Albanian coast, Albania	the prevention of climatic impacts including a monitoring system and local inventories of impacts
Fuka-Matrouh, Egypt	Promotion of drought-tolerant vegetation; fresh water management
Sfax , Tunisia	Management of water resources; prohibition of agriculture development; replanting of littoral zone with suitable species

Source: UNEP/MAP

climate may have on these trends and utilisation of resources. In addition to an unplanned “do nothing” approach, three conceptually distinct planned responses to sea level rise have been recognised (IPCC, 1992):

- Planned retreat - allowing land loss to occur progressively with minimal loss of associated infrastructure;
- accommodation - changing the way the land is used as water levels rise, e.g. raising buildings on piles above the new flood levels;
- protection - building dikes, levees, beach nourishment, etc.

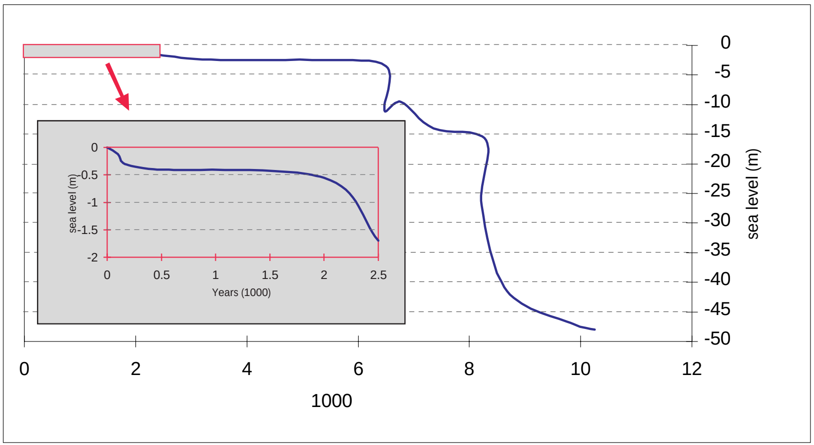
Historically, doing nothing, accommodation or protection has been the norm, reflecting a tendency for a reactive approach to change, mainly due to the poor understanding of risk and vulnerability.

An event-driven, reactive response to forthcoming sea level rise should be avoided in the future. The progressively increasing risk of disaster can be contained at an acceptable level by anticipatory action, such as raising dikes or land use planning; thus, risk analysis will probably be an important tool for planning in the coastal zone (Nicholls & Leatherman, 1995). Raising public awareness of the problems that may be associated with expected climatic changes is of great importance as it may facilitate societal decision-making and generate the necessary public support for measures and expenditures that may seem, to an uninformed public, unjustified.

Vulnerability and risk assessment have to be carried out on a local level, taking into account the following:

- coastal zone vulnerability depends not only on morphological features but on

Figure 5.1 **Sea level rise in the Mediterranean region over the past 10 000 years**



Source: Pirazzoli, 1991, Antonioli et al., in press

the degree of development and economic value of the shore;

- levels of earth subsidence or uprising in coastal plains often exceed the increase in sea level rise. This makes the relative increase impossible to assess except on a local scale, which demands accurate data collection on site.

5.2. Biodiversity and ecosystem changes

Mediterranean fauna and flora have evolved during millions of years into a unique mixture of temperate and subtropical elements, with a large proportion (28 %) of endemic species (Fredj et al., 1992), and Mediterranean-specific biotopes. A total of 10 000 to 12 000 marine species have been registered for the Mediterranean Sea (with 8,500 species for macroscopic fauna), a rich biodiversity which represents 8-9 % of world seas species richness (4-18 % according to the group considered, Bianchi et al., 1995). The present day biodiversity of the Mediterranean cannot be completely understood without taking into account at least that of the neighbouring areas: the eastern Atlantic and the Red Sea, to which it is intimately linked.

Mediterranean coastal zones are currently experiencing increased pressures due to rapid urbanisation, development of tourist facilities, aquaculture and efficient exploitation of marine resources. High diversity coastal ecosystems are more vulnerable to environmental perturbation than low diversity ones (May, 1973) and therefore their impact is expected to be more significant in the Mediterranean than in northern temperate marine ecosystems. Such perturbations may directly or indirectly result from anthropogenic activities and can be put into the following categories:

- Pollution;
- over-exploitation of marine resources;
- habitat erosion;
- climatic changes (e.g. through the greenhouse effect);
- introduction of alien species.

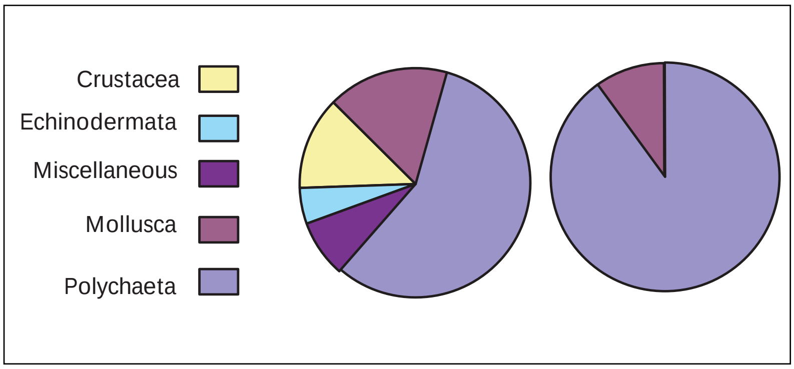
5.2.1. Impacts on biodiversity

Pollution in the Mediterranean is a highly localised phenomenon, not affecting the offshore system or the general ecological features of the area; but extensive regional problems have been reported in sub-areas such as the Adriatic Sea. However, coastal eutrophication or other environmental degradation could be of high importance since the ecological role of these ecosystems is significant, both in terms of their productivity and as nursery grounds for populations which affect the functioning of the entire ecosystem. GESAMP (1990) have identified nutrient discharge and eutrophication as major threats to the marine ecosystems due to the common practice of sewage disposal at sea and agricultural run-off from fertiliser-treated fields.

Benthic communities in undisturbed areas (**Figure 5.2**) in the eastern Mediterranean, for example, present high species diversity in coastal waters which declines with depth. They consist of polychaetes (pol.) (50-65 %), molluscs (mol.) (15-25 %), crustaceans (cru.) (10-20 %), echinoderms (ech.) (5-8 %) and miscellaneous taxa (misc.) (5-10 %). In areas ranging from heavily disturbed to polluted, echinoderms, crustaceans and miscellaneous taxa largely disappear, while a small number of polychaete species account for 70-90 % of the total abundance (Stergiou et al., 1997). The same applies to the western Mediterranean communities, where increasing disturbance also leads to reduction in species richness. Among the first species to disappear under heavy stress conditions are benthic animals with large body size, whose bioturbating activities are of considerable importance for the benthic ecosystem. When organic enrichment exceeds the potential for remineralisation by benthic organisms, anoxic (azoic) zones are established (Pearson & Rosenberg, 1978) and the seabed is covered by bacterial mats. Although this type of ecosystem change is in general reversible, there could be severe consequences when the affected seabed is a critical habitat.

In undisturbed areas zooplankton communities are dominated by copepods whose mean relative abundance ranges between 55-85% in the western and 65-70% in the eastern Mediterranean. Cladocerans are the second most abundant group, followed by Appendicularians, Chaetognaths, Doliolids, Siphonophores, etc. In disturbed coastal areas copepods and cladocerans prevail, reaching extremely high abundances, whereas most of the other zooplanktonic groups disappear. In such areas, communities are highly dominated by one or two species compared to the undisturbed areas, where plankton communities are more diversified. The highest diversity is generally observed in offshore waters due to the presence of epi- and meso-pelagic species.

Composition of Benthic communities in an undisturbed (left pie) and in a polluted area (right pie) — Figure 5.2



Source: ETC/MCE compilation, data from NCMR

The effects of heavy exploitation of marine resources have become evident in the case of some fish stocks, as well as in other target species such as the red coral (Corallium rubrum) in the western Mediterranean (Santangelo et al., 1993). The collection of some edible bivalve species, such as Lithophaga lithophaga is one of the most destructive human activities along the Italian coasts (Fanelli et al., 1994).

One of the most important sources of environmental degradation is habitat loss for some endangered species, due to competition with human activities. The coastal zone in the Mediterranean is an important resource, since the tourist industry is a main source of income for most Mediterranean countries.

The development of tourist facilities on sandy beaches (see section 3.2 of this report) has frequently resulted in the restriction of space available for the reproduction of sea turtles. The death of monk seals, dolphins and turtles, which are considered to be endangered species has also been reported as a consequence of the interactions with commercial fisheries (Venizelos, 1990). Particular problems have been reported such as the mortality of dolphins (in the early 1990s) due to infection by a mobilivirus in several sub-areas in the Mediterranean. It is also believed that the severe sponge disease epidemic was caused by bacteria which under certain conditions become virulent (Vacelet, 1994). Several hypotheses have attempted to link the outbreaks of the diseases to environmental degradation which results in a weakening of the immune system of the affected organisms. However, there is still a lack of adequate scientific evidence and further research is needed in order to get a definitive answer as to whether these are unpredictable episodic events or symptoms of ecosystem degradation.

Wetland loss and degradation has been identified as a serious threat to nine out of the 33 breeding colonial water bird species found along the Mediterranean coastline (Erwin, 1996).

Climatic fluctuations play a predominant role in affecting the marine ecosystems by:
- Directly affecting the organisms, causing changes in survival, reproductive success, dispersal pattern;
- causing effects which modify biotic interactions;
- affecting ocean currents indirectly.

Climatic changes may act positively on biodiversity, favouring the co-existence of species potentially redundant functionally and thus allowing the formation of species-enriched assemblages. As in places outside the Mediterranean, such as the English Channel, northward expansions of the geographical range of warm-water species have been observed in Mediterranean areas, e.g. the Ligurian Sea, following an increase in water temperature (Astraldi et al., 1995). There is some recent evidence that Mediterranean species richness patterns are presently facing changes (Astraldi et al., 1995) related to increasing seawater temperature.

5.2.2. Non-indigenous species
The introduction of new organisms, in the form of exotic species or highly cultivated strains of endemic species, nearly always

poses a risk to the ecosystem involved. Diseases, introduced as a consequence of human activities, such as the Nodavirus affecting the sea bass mariculture in the Mediterranean (Comps et al., 1996), may have a profound impact on reared and wild populations.

The non-indigenous (also known as allochthonous or exotic) species in the Mediterranean can be classified into three categories: the natural invaders; those that have been passively transported; and other (unknown cases):

1. the natural invaders can be further divided into those that have entered through the Suez Canal (Lessepsian migrants), those coming through the Strait of Gibraltar and those coming from the Black Sea;
2. the species that have been passively transported can be divided into those that have been carried out accidentally by ships (fouling, sessile forms, clinging, vagile forms as well as planktonic forms transported through ballast waters) and those that have been intentionally and unintentionally introduced for aquaculture (baits, aquariums, commercial species, planktonic organisms from imported live shellfish);
3. some other cases are known where exotic species have been successfully established in the Mediterranean basin for unknown reasons. Finally, there are cases of exotic species erroneously reported in Mediterranean areas.

Most allochthonous species have entered through the Suez Canal. The massive invasion of Red Sea and Indo-Pacific migrants initially along the Israeli coasts and later in the eastern Mediterranean basin, a phenomenon known as Lessepsian migration has been extensively studied and documented by Por (1978; 1990). The geographic limits reached by the Lessepsian migrants both west and northwards, show a certain consistent stability. The northern barrier of the 'Lessepsian Province' in the Ionian Sea has still not been fully investigated, but in the Aegean Sea it represents an imaginary line from Izmir in Turkey to the island of Evvoia in Greece. To the west of Egypt, along the North African coast, the extent of the 'Lessepsian Province' is still unknown.

Accidental or ship-borne expansion seems to be also more important than previously thought. Among the species passively transported and worth mentioning are those that have entered with ballast waters like the ctenophore Mnemiopsis leidyi found in the Black Sea and the Sea of Azov. The latter has not only been successfully established, dominating the pelagic zone in the Black Sea but has also expanded its geographic distribution southwards to the eastern Mediterranean, around Mersin (Kideys & Niermann, 1993), along the Syrian coast (GESAMP, 1997) and from observations in significant densities in the northern and central Aegean Sea (NCMR, experimental data).

Some 500 Indo-Pacific species have entered the Mediterranean since the construction of the Suez Canal (Por, 1978). Zibrowius (1991) listed 53 more exotic species, besides the Lessepsian migrants which have entered through Gibraltar strait (2), or as fouling organisms (22), or have been introduced for or with aquaculture (20), or from aquariums (1) and through unknown ways (7). It is clear that the true number becomes even greater. Among the marine taxa, the four best known are Macrophyta, Mollusca, Crustacea: Decapoda & Stomatopoda, and fish. **Figure 5.3** illustrates the various ways of introduction to the Mediterranean for Macrophyta (after Ribera & Boudouresque, 1995), Mollusca (National Centre for Marine Research, Greece data; CIESM, 1999c), Decapoda & Stomatopoda (CIESM 1999b) and fish (CIESM 1999a.). The accuracy of the numbers in **Figure 5.3**, is open to criticism as:

1. Most reviews refer to Lessepsian migrants only;
2. colonisation of allochthonous species is a dynamic process;
3. the task undertaken by the CIESM (International Commission for the Scientific Exploration of the Mediterranean) experts is still in progress.

Thus the numbers in **Figure 5.3,** considering the vast bibliography available, must be considered as indicative only of the phenomenon.

The need to compile all available information was recognised by the CIESM. It was decided to tackle the impact of allochthonous species in the Mediterranean by assigning a group of specialists in the field and to support, in time, the publication of an updated digital atlas.

Of the 61 well established imacrophyta species in the Mediterranean (Ribera & Boudouresque, 1995), one worth mentioning is the chlorophycea Caulerpa taxifolia, distributed in tropical seas which was recorded for the first time in the Mediterranean in 1984. Its spreading routes and density fronts, which reach 350 m (amplitude of patches), have been well documented in the Mediterranean **(Figure 5.4)** Besides C. taxifolia, its con-generic C. racemosa (a pan-tropical species) is now expanding in the eastern Mediterranean and has recently been observed in Genoa and Marseilles. The distribution of both species in the Mediterranean and their impact on the marine ecosystem were thoroughly discussed by experts from the MAP countries (UNEP, 1998).

Mollusca is one of the leading taxa of Lessepsian migrants (132 species), and the group most studied. It is estimated that 90-100 molluscs have entered the Mediterranean through the Suez Canal so far. Regarding the distribution pattern of the new species, it is worth noting that many have successfully established and expanded their populations. For instance, the Lessepsian migrants have moved mainly to the north and west. A striking example can be seen in the gastropod Rhinoclavis kochi, initially reported from Haifa Bay (in 1963) and now collected in large numbers not only along the Israeli coasts but also along the coasts of southern Turkey and Cyprus.

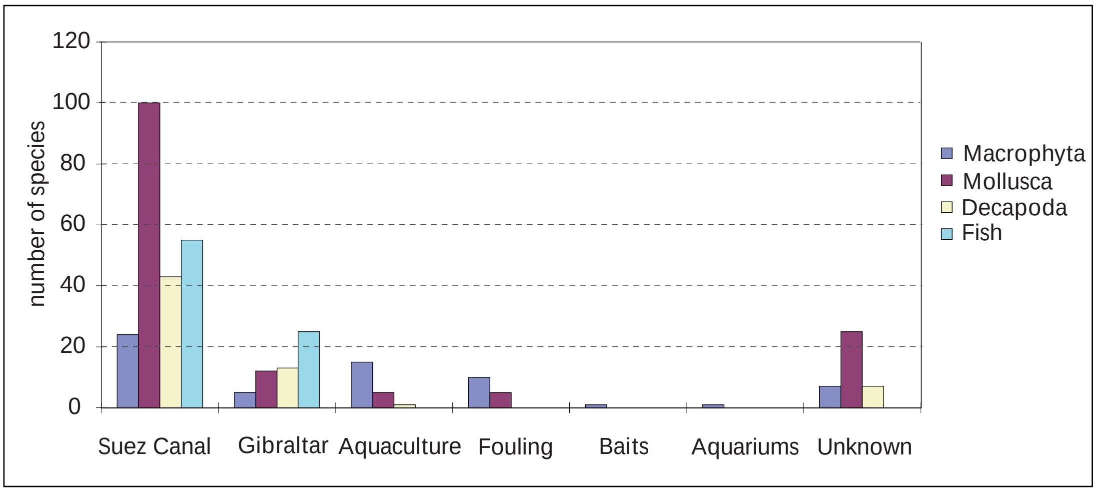
Today 63 decapoda and stomatopoda species have migrated into the Mediterranean (CIESM 1999b). Of these, the portunid crab Callinectes sapidus Rathbun, 1896, a western Atlantic species commercially fished along the coasts of North America, was first recorded in the Bay of Biscay (Bouvier, 1901) and was introduced with ballast water gradually into the Mediterranean Sea (**Figure 5.5)**. It has proved to be a successful coloniser and has become of local economic importance in the Mediterranean (CIESM 1999b).

Among the Lessepsian migrants, fishes have always received great attention. Their expansion is continuous without any sign of decline (Ben-Tuvia, 1978: 35 species; Ben-Tuvia, 1985: 41 species; Golani & Ben-Tuvia, 1989: 48 species; Golani, 1997 - CIESM 1999a: 84: species).

Although it must be assumed a priori that the colonisers compete with some of the native species there is no evidence of a drastic change in abundance of any of the Mediterranean commercial fishes that could be attributed to a new competitor. Furthermore, there is no information about the interaction between colonisers and non-commercial species. However, there are observations indicating changes in abundance of species among the migrants. Some of these non-indigenous species now form dense populations and are important in commercial catches.
Generally speaking, 80 % of introduced species have no effect on the indigenous communities. On the other hand, other introduced species do have an impact on the indigenous species or communities, which are referred to as ‘biological pollution’. These include:

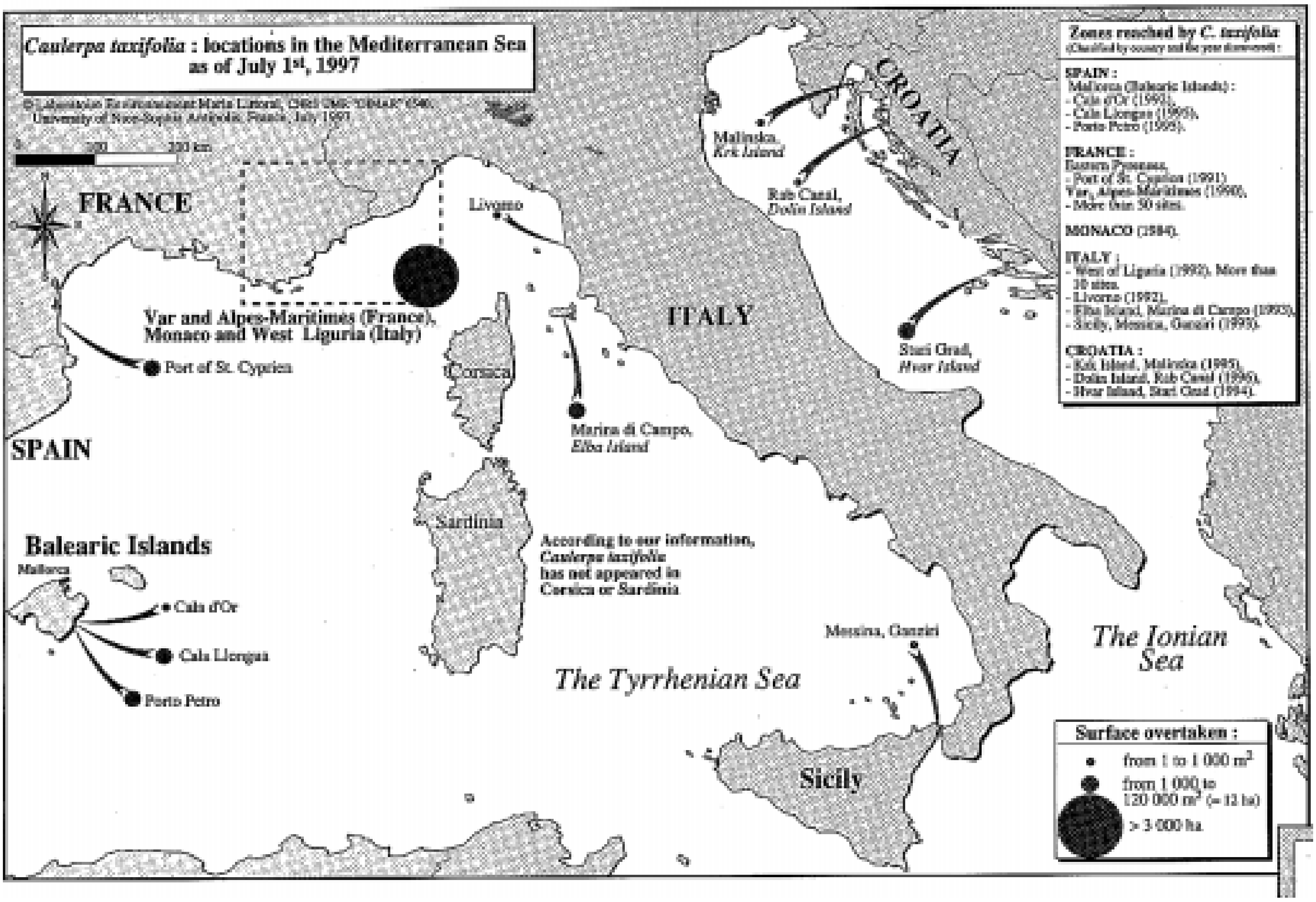
- Immediate ecological impact at the community level through changes in inter-specific competition and predation;
- changes in the nature of the environment itself through the influence of certain organisms and possible genetic degradation of indigenous stock.

Example of introduction routes for non-indigenous species in the Mediterranean Sea Figure 5.3



Data sources: ETC/MCE compilation based on: Ribera & Boudouresque, 1995; National Centre for Marine Research, Greece data; CIESM 1999a; CIESM 1999b

Figure 5.4 **Distribution of the macroalgoe *Caulerpa taxifolia* in the Mediterranean Sea**



Source: MAP/UNEP

The establishment of non-indigenous species has resulted in far-reaching changes to the faunal composition of many of the world's enclosed and semi-enclosed areas, estuaries, and coastal marine waters.

In the Mediterranean, changes in the faunal composition of the marine ecosystem have been noticed in:

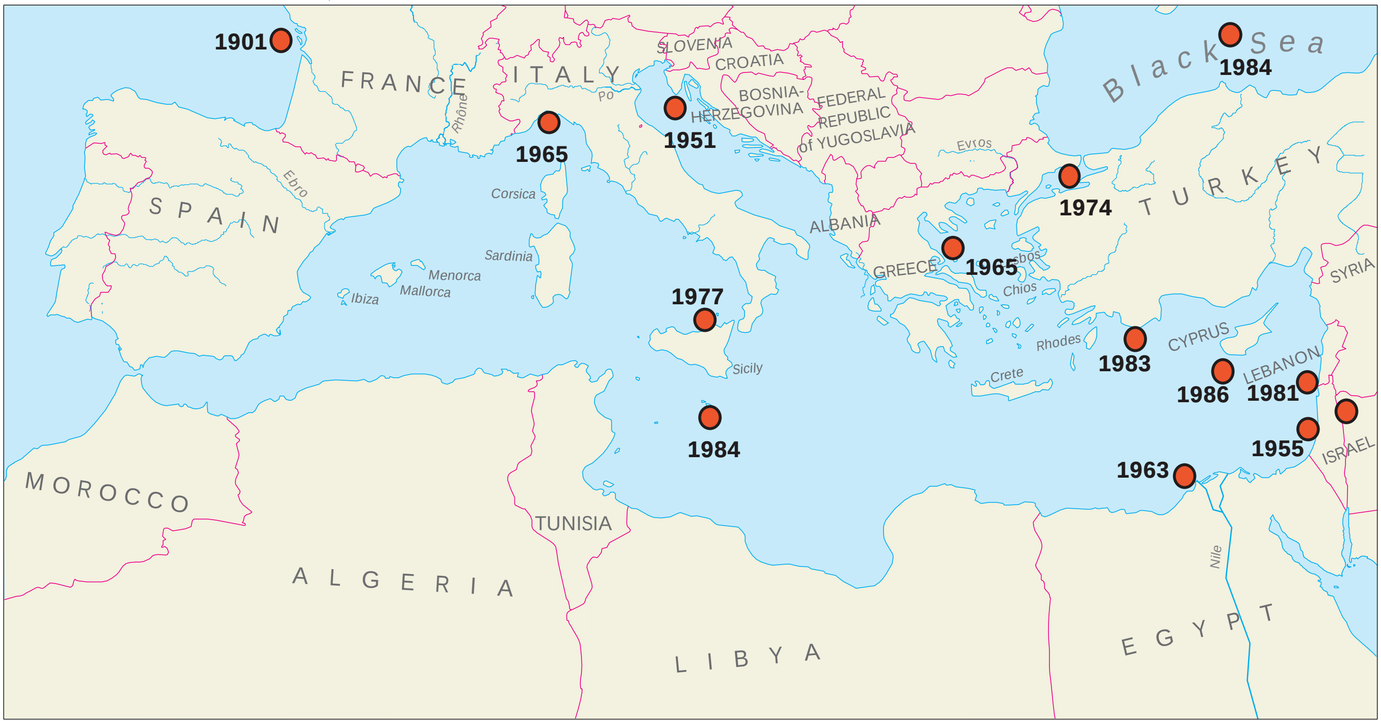
- Haifa Bay: massive penetration of four Indo-Pacific species;
- Izmir Bay and Thessaloniki Gulf: dominated by the bivalve Scapharca demiri;
- western coast of the middle Adriatic Sea: Scapharca inaequivalvis, Rapana venosa and in coastal waters: Caulerpa taxifolia.

According to Boudouresque & Ribera (1994), the biotopes most affected by marine species (other than Lessepsian migrants) in the Mediterranean are the lagoons and ports. An equilibrium with native species often becomes established in due course.

In the case of fish and decapods, the successful establishment of certain species may lead to changes at the community level due to a shift in the ecological niche observed. In the case of macrophyta however, the impact on the natural environment is negative, affecting activities such as fishing (by clogging the nets), aquaculture (reducing the light, adding weight, etc.), shipping (accidents may be caused by jamming the propellers of ships), public health and tourism (proliferation of toxic algae).

Most of the exotic species have entered the Mediterranean actively either via the Suez Canal or the Strait of Gibraltar. Little can be done to prevent this from happening. However, introduction of species by other means should be prevented or minimised. Today it is possible to transport anything virtually anywhere in the world. Thus species imported for bait, aquaculture, aquariums, etc. can prove to be catastrophic for the ecosystem. Great caution must prevail in importing any marine species intentionally. Moreover, due to the increase in maritime traffic a large number of species appear to have entered with ballast waters, that is, unintentionally. Monitoring of ballast waters appears to be the only way to prevent further transport of such species.

Occurrence of the crab *Callinectes sapidus* in the Mediterranean Sea Figure 5.5



Data source: ETC/MCE compilation of data from Froglia et al., 1998

5.2.3. Conservation in the Mediterranean

The Barcelona Convention (1976) and its relevant protocols, initially oriented towards protection of the Mediterranean Sea against pollution, have been updated with the adoption of new protocols. One of the later instruments, in the MAP framework, was the Protocol concerning Specially Protected Areas (SPA, Geneva, 1982). In the latest Convention (Barcelona, 1995) a new protocol, called the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean Sea, was conceived as a tool for the practical implementation at regional scale of the most recent concepts and international legislation concerning in situ conservation (e.g. UNCED, CBD). Contrary to the Geneva protocol, the new protocol did not restrict its geographical coverage to territorial waters. The new protocol decided the establishment of a list of Specially Protected Areas of Mediterranean Importance (SPAMI) which includes areas that:

- are of importance for the conservation of the components of biological diversity in the Mediterranean;
- contain rare, unique ecosystems and rare or endemic species in the Mediterranean area;
- contain the habitats of endangered species;
- are of special interest at the scientific, aesthetic, cultural or educational levels.

Related measures include:

- protection and conservation of species;
- regulation of the introduction of non-indigenous or genetically modified species;
- environmental impact assessment of any projects or activities likely to affect protected areas.

There are 122 Specially Protected Areas designated under the SPAMI protocol (**Figure 5.6**). Among these, 45 cover marine spaces either exclusively (15) or as part of mixed (land and sea) space (30). These have been defined, according to the legal status governing the protection of each area, as: nature reserves (52); national parks (24); marine reserves (14); natural parks (10); fishery reserves (2); game reserves (2); monuments of nature (1); etc.

Outside the Barcelona Convention system, several pan-European or world conventions exist (Bonn Convention, 1979: The migratory species of wild animals; Berne Convention, 1979: The conservation of European wildlife and natural habitats RAMSAR, 1971: The conservation of wetlands of international importance, especially as water fowl habitat, etc.). Some of them, repeatedly amended, have provided the legal framework for the conservation of natural habitats in the Mediterranean. Thus, a special agreement under the Bonn Convention was made in 1996 for the Conservation of Small Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic area (ACCOBAMS).

In parallel, EU initiatives have provided for the establishment of relevant directives such as the EC Birds Directive (EC/79/409) for Special Protection Areas, the Habitat Directive (EEC/92/43) on the conservation of natural habitats of wild fauna and flora, which requires EU Member States to designate marine sites (for both habitat types and species of community interest). The establishment under the Habitats Directive, of Special Areas of Conservation (SAC) which will be listed and prioritised as a part of a European network of protected areas, the so-called NATURA 2000 network, has not been implemented yet in all Mediterranean countries. Spain, Italy and Greece have included many marine sites in the NATURA 2000 network while France still lags behind.

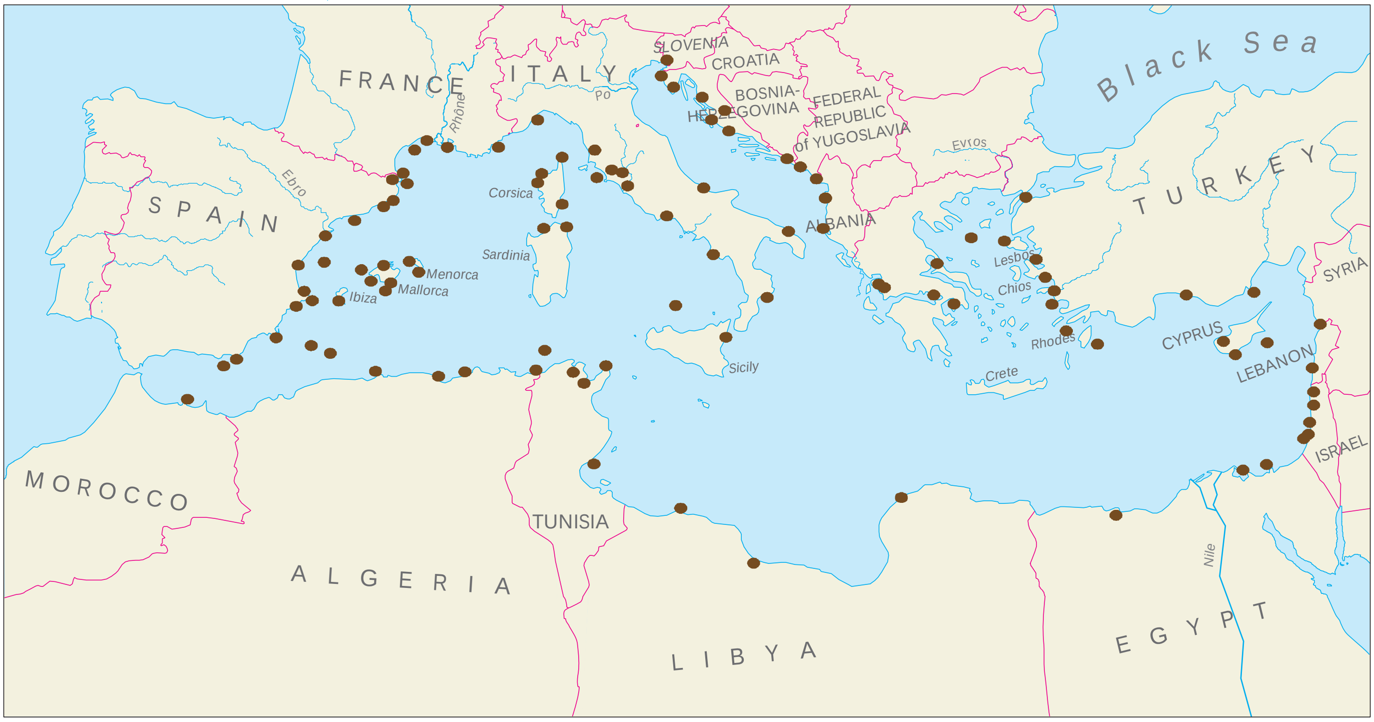
Several EU research programmes have addressed issues relevant to marine biodiversity (MAST, FAIR) while other programmes (LIFE) have promoted the sensitisation of the public to critical environmental issues, including marine biodiversity. Interregional development programmes (INTEREG, MEDA) have also included in their aims the protection of the environment and biodiversity.

The latest global initiative on marine biodiversity research is the DIVERSITAS Core Programme on Biodiversity Science Research, established in 1991 and sponsored by intergovernmental organisations (UNESCO) and non-governmental ones. This showed that large parts of coastal and open sea areas of Europe, among them the eastern Mediterranean, have been studied insufficiently.

Despite the fact that the Mediterranean is known for the considerable diversity of its fauna and flora as well as for the high rate of endemism, programmes on biodiversity and its conservation often rely on fragmentary and incomplete data. A specific, inter-Mediterranean approach to the monitoring of marine biodiversity and the identification of the importance of risks threatening the present state of the environment is still missing.

At present, no species appear to have disappeared yet from the Mediterranean as a result of human activity. However, numerous species appear to be threatened; some of these are actually on the verge of extinction, either because of their rarity which makes them vulnerable, or because they rapidly decline in numbers. (Within the MAP meetings of experts have been held in order to determine the list of marine endangered species in the Mediterranean, which has led to the adoption of a list including 89 marine and fresh water species without considering birds (Annex II of the Protocol concerning Specially Protected areas and Biological Diversity

Figure 5.6 **Designated marine and coastal protected areas in the Mediterranean**



Source: ETC/MCE compilation; data from RAC/SPA in the Mediterranean Sea adopted in the Barcelona Convention in 1996). This list was revised in the Berne Convention on the Conservation of European wildlife and Natural habitats (Council of Europe, [S / TPV98 / TPVS12A.98] **(Table 5.3)** and was further distinguished into two categories: protected and strictly protected flora and fauna species.

Within MAP three actions have been adopted by the parties of the Barcelona Convention. They concern:

- Management of the Mediterranean monk seal;
- conservation of the Mediterranean marine turtles;
- conservation of cetaceans in the Mediterranean Sea.

Other international treaties to which Mediterranean countries are parties have provisions for the conservation of species in special need of protection (African convention,

List of endangered or threatened marine and fresh water species in the Mediterranean. (Annex II of the Protocol concerning Specially Protected areas and Biological Diversity in the Mediterranean Sea adopted in the Barcelona Convention in 1996; revised in the Berne Convention, 1998). Table 5.3

Magnollophyta			
Posidonia oceanica	*Zostera marina*	*Zostera noltii*	
Chlorophyta			
Caulerpa ollivieri			
Phaeophyta			
Cystoseira amentacea	*Cystoseira sedoides*	*Cystoseira zosteroides*	
Cystoseira mediterranea	*Cystoseira spinosa*	*Laminaria rodriguezii*	
Rhodophyta			
Goniolithon byssoides	*Ptilophora mediterranea*		
Lithophyllum lichenoides	*Schimmelmannia schoubsboei*		
Porifera			
Asbestopluma hypogea	*Axinella polypoides*	*Ircinia foetida*	*Petrobiona massiliana*
Aplysina cavernicola	*Geodia cydonium*	*Ircinia pipetta*	*Tethya sp. plur.*
Axinella cannabina			
Cnidaria			
Astroides calycularis	*Errina aspera*	*Gerardia savaglia*	
Echinodermata			
Asterina pancerii	*Centrostephanus longispinus*	*Ophidiaster ophidianus*	
Bryozoa			
Hornera lichenoides			
Crustacea			
Ocypode cursor	*Pachylasma giganteum*		
Mollusca			
Charonia lampas lampas	*Lithophaga lithophaga*	*Patella nigra*	*Ranella olearia*
Charonia tritonis variegata	*Luria lurida*	*Pholas dactylus*	*Schilderia achatidea*
Dendropoma petraeum	*Mitra zonata*	*Pinna nobilis*	*Tonna galea*
Erosaria spurca	*Patella ferruginea*	*Pinna rudis*	*Zonaria pyrum*
Gibbula nivosa			
Pisces			
Acipenser naccarii	*Carcharodon carcharias*	*Huso huso*	*Pomatoschistus tortonesei*
Acipenser sturio	*Cetorhinus maximus*	*Lethenteron zanandreai*	*Valencia hispanica*
Aphanius fasciatus	*Hippocampus hippocampus*	*Mobula mobula*	*Valencia letourneuxi*
Aphanius iberus	*Hippocampus ramulosus*	*Pomatoschistus canestrinii*	
Reptiles			
Caretta caretta	*Dermochelys coriacea*	*Lepidochelys kempii*	
Chelonia mydas	*Eretmochelys imbricata*	*Trionyx triunguis*	
Mammalia			
Balaenoptera acutorostrata	*Globicephala melas*	*Monachus monachus*	*Stenella coeruleoalba*
Balaenoptera borealis	*Grampus griseus*	*Orcinus orca*	*Steno bredanensis*
Balaenoptera physalus	*Kogia simus*	*Phocoena phocoena*	*Tursiops truncatus*
Delphinus delphis	*Megaptera novaeangliae*	*Physeter macrocephalus*	*Ziphius cavirostris*
Eubalaena glacialis	*Mesoplodon densirostris*	*Pseudorca crassidens*	

CITES, Berne Convention, Bonn Convention, RAMSAR, ACCOBAMS).

Marine protected areas get a good deal of both public and political attention in many parts of the world, especially since marine conservation has been adopted as part of the global biodiversity scheme. A variety of conservation policies are practised in the Mediterranean, and there are considerable differences among Mediterranean countries with respect to technologies used to minimise pollution, monitoring schemes to assess environmental impacts and efficiency in enforcing the environmental regulations. Thus, although in most cases fishing is prohibited or strictly regulated in all or part of the marine SPAs, there is a huge diversity of regulations concerning these areas in terms of navigation, anchoring, collection of marine products, swimming and diving, introduction of species and discharge of pollutants. Only Italy, among the signatories of the SPA protocol (under the Barcelona Convention) has specific legislation for the establishment of marine protected areas. Most of the other countries have adopted legislative texts permitting the establishment of such areas without detailed rules concerning regulation and management.

The frame of intergovernmental procedures, such as MAP, Berne Convention or other conventions, helps in providing a certain degree of consistency. None of the new or updated instruments has entered into force yet. This seems, however, to be due more to the time-consuming domestic procedures in implementing treaties than to any lack of political will.

The Pan-European Biological and Landscape Diversity Strategy already includes the development of a network approach to conservation. In the second phase report of the European coastal and marine ecological network, it was concluded that protected areas only provide part of the means of maintaining biodiversity. Use of existing institutional mechanisms such as the UNEP Regional Seas Programmes and their wider influence on coastal and marine policy may be equally if not more important.

European initiatives and targeted funding are needed in order to promote the integration of these environmental management strategies in a consistent regional scheme. In particular, there should be a focus on priority topics, such as species introductions and habitat loss to avoid biodiversity reduction; coastal zone management strategies integrating environmental protection into economic development; research on processes related to ecosystem changes; and rehabilitation of degraded coastal ecosystems.

As seen from the above, the biogeographic picture of the Mediterranean marine biota is changing under the influence of both climate and man. Mechanisms for assessing changes in marine biodiversity exist and the pressure exerted on the environment by some of them increases with time. However, assessing changes in Mediterranean biodiversity (let alone the prediction of future change) is only feasible if a specific monitoring programme is established together with a science plan for the study of processes related to biodiversity maintenance or reduction.

5.3. Health risks from marine pollution in the Mediterranean

5.3.1. General health risks

In the Mediterranean basin, the majority of the socio-economic consequences of marine pollution can be expressed as immediate or long-term effects on human health. In this context, the two main types of human exposure to pollutants in the marine environment are through direct contact with polluted seawater and / or beach sand (including ingestion of the former while swimming or bathing), and consumption of contaminated seafood. Unfortunately, countries are reluctant to report information on such exposure.

The main risks to human health arise from:
1. intake of pathogenic micro-organisms (e.g. faecal streptococci and coliform bacteria) from infected sea water;
2. direct contact with polluted sea water and beach sand;
3. consumption of seafood contaminated by heavy metals and chemicals (e.g. mercury in tuna and related species, lead in mussels) in which the amount consumed and toxicity are important factors;
4. consumption of seafood contaminated by certain bacteria (e.g. salmonella, shigella), viruses (e.g. hepatitis A), fungi (e.g. Candida albicans) and phytoplankton toxins (e.g. from dinoflagellates, usually related to red tide conditions) (WHO / UNEP, 1995);

However, the particular conditions applicable to bathing in the Mediterranean, including relatively long and frequent exposure periods, beach overcrowding and admixture of populations, are more conducive to disease transmission and contraction than would be expected in more temperate regions, such as northern Europe.

5.3.2. Health risks from microbiologically contaminated coastal areas

On a general level, pathogenic micro-organisms present in seawater, sediments, beaches and shellfish can be broadly divided into two categories: those that affect the gastrointestinal tract, and those that affect other parts of the body. As far as the former category is concerned, all the diseases which are spread by the faecal-oral route, and whose aetiological agents are shed in the faeces of diseased individuals or carriers, could be contracted by swimming in sewage-polluted waters. Such diseases include: (a) bacterial diseases such as salmonellosis (including typhoid and paratyphoid fevers), shigellosis (bacillary dysentery), cholera and gastro-enteritis caused by enteropathogenic E. coli and Yersinia enterocolitica; and (b) viral diseases such as hepatitis A and hepatitis E; illnesses caused by enteric viruses (polioviruses, coxsackie viruses A and B, echoviruses, reoviruses and adenoviruses) and gastro-enteritis caused by the human rotavirus, Norwalk virus, Adenovirus serotype 40, 41, calicivirus and parvo-like viruses; and (c) diseases caused by a variety of protozoan and metazoan parasites, such as amoebic dysentery, giardiasis, and ascariasis (WHO / UNEP, 1996a). **Figure 5.7** shows the probability of gastroenteritis among bathers.

Indirect effects also arise through the consumption of marine organisms themselves 'infected' or 'polluted' with the above-mentioned micro-organisms. This is particularly the case for shellfish cultured for human consumption, because of the concentration of the species under mariculture conditions and their frequent proximity to their main market - the coastal urbanised populations, hence to the main sources of contamination: sewage outfalls.

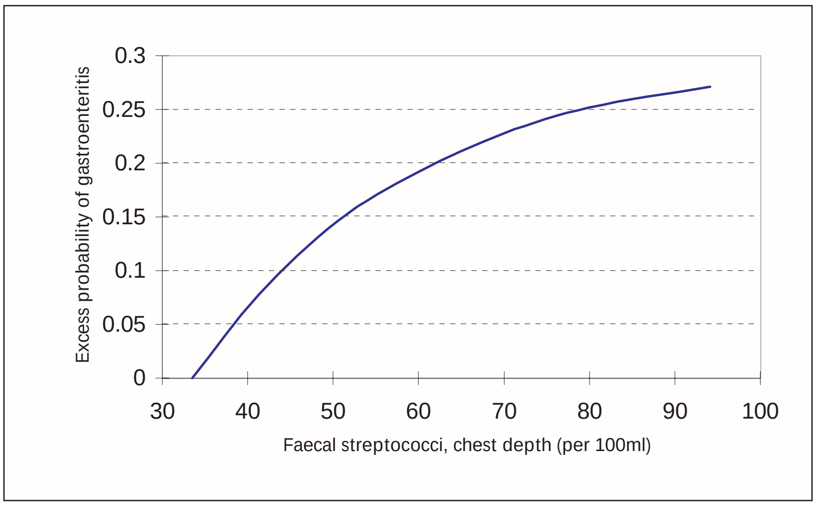
With the exception of those associated with pathogens in a relatively low ineffective dose, diseases affecting the gastrointestinal tract are much more easily contracted by humans through the consumption of raw or partially cooked food, particularly shellfish. A number of epidemics and outbreaks of various diseases attributed to the consumption of contaminated shellfish have occurred, and the number of individual cases, particularly of the less insidious diseases, is likely to be high. Where conditions favour the proliferation of certain species of algae (resulting in 'red tides' or 'algal blooms') which produce toxins, shellfish become contaminated by these algae and on ingestion by humans the toxins cause a number of diseases, mainly Paralytic Shellfish Poisoning (PSP) and Diarrhoetic Shellfish Poisoning (DSP) (WHO / UNEP, 1992).

Apart from diseases affecting the gastrointestinal tract, a number of diseases or disorders affecting the eyes, ears, skin, upper respiratory tract and other parts of the body have been associated with bathing. This particular category of infective conditions may be caused by micro-organisms such as Staphylococcus aureus, Pseudomonas aeruginosa, Clostridium welchii and Candida albicans, and also classical adenoviruses 1-39, which may cause infection as a result of being forced into cracks or tears in the skin, or into ruptures in delicate membranes in the ear or nose resulting from the trauma associated with diving into water. These micro-organisms have been described as often present in man, but giving rise to opportunistic disease only when, for one reason or other, the resistance of the individual who harbours them is lowered (**Table 5.4**).

5.3.3. Health risks from chemically polluted seafood

The possible health risks of chemicals in marine waters used for shellfish and seafood growing purposes are from the presence of trace metals, radionuclides, pesticides, agricultural waste, oils, detergents and illicit

Probability of gastroenteritis amongst bathers exposed to increasing faecal streptococci densities from samples taken at chest depth Figure 5.7



Source: Kay et al., 1994

dumping of toxic waste. Following entry into the marine environment, these chemicals accumulate in plants and animals as they pass through the marine food chain, reaching their highest levels in filter-feeders, such as bivalve molluscs, and in large predatory fish such as tuna and swordfish. Effects on humans through the consumption of chemically contaminated seafood are essentially long-term, depending on the chemicals themselves, and the rate and amount of intake. In general, the principal risk is restricted to those individuals consuming seafood more than two to three times a week, although the risk varies with the type of seafood, the concentration of pollutants and the circumstances of the consumer.

In seafood, the levels of chemical contamination give cause for concern. For example, many shellfish can accumulate trace metals, radionuclides and pesticides at levels several thousands times higher in their body tissue than those found in the surrounding sea water. The bioaccumulation of mercury in tuna and shellfish, cadmium in mussels as well as arsenic, organotin compounds from antifouling paints, organohalogen compounds (particularly PCBs), some pesticides and polycyclic aromatic hydrocarbons (PAHs) can cause sufficiently high levels that could interfere with commercial harvesting and sales of shellfish and other seafood. However, in assessing potential risks from chemicals, the situation is complicated by the fact that any amount taken in through seafood is only a variably sized fraction of the total intake, the bulk of which is normally associated either with terrestrial food, or with routes other than ingestion (WHO / UNEP, 1992).

Table 5.4 **Pathogenic micro-organisms and disease caused**

Pathogenic micro-organisms	**Disease caused**
Salmonella	• typhoid and paratyphoid fever, food poisoning and gastro-enteritis
Shigella	• bacillary dysentery
Vibrio	• cholera (*Vibrio cholerae*), gastro-enteritis, otitis, throat and wound infections
Staphylococcus	• infections of the skin, skin glands and mucus membranes • meningitis, furunculosis, pyaemia, osteomyelitis • food poisoning (*S. aureus*)
Pseudomonas	• infection of the ear and eye, of wounds, burns and the urinary tract, enteritis
Aeromonas	• diarrhoea, pneumonia, abscesses, wound infections
Enteroviruses	• paralysis, meningitis, respiratory disease, rash • diarrhoea, fever, herpangina, miocarditis • pleurodynia, encephelitis, haemorrhagic conjunctivitis

Source: WHO/UNEP

In addition, seafood consumption patterns are greatly influenced by food preference, prices and availability. In general, seafood is more available in the coastal area than in the hinterland, especially in the less developed countries. Certain population sectors such as fishermen, fish vendors and their families have greater access to seafood than other people. Also, people on a diet may preferentially eat fish. No general seafood consumption studies have been carried out in Mediterranean countries. It is probable, however, that relatively mild effects have gone unnoticed, or have not been correctly associated with contaminated seafood because, in a number of cases, as with mercury, the symptoms which affect the nervous system are not specific, and the condition can easily be attributed to other causes (WHO / UNEP, 1995).

5.3.4. Public health implications

Many pathogenic micro-organisms (bacterial, fungal and viral) which are recognised as causing human disease, are prevalent in the coastal marine areas of the Mediterranean, with a number of species found in various geographical zones. The situation is currently resulting in adverse health effects on both the local and the tourist population. Although, undoubtedly, a proportion of illnesses was associated with the consumption of unsanitary food or unsafe drinking water (as well as other types of exposure), there was ample evidence that a major source of illness in areas where the sea was polluted, resulted from consumption of sewage contaminated shellfish and / or bathing near sewage contaminated beaches.

While such records provided evidence of occurrence and indications of magnitude, the extent of damage to health on a Mediterranean-wide basis still has to be determined. The same conclusion can be applied to the situation regarding pathogen incidences. In this respect, while the references that have been taken into account can be considered as a fairly representative cross-section of relevant literature in the region, the fact that such records, many from different specific locations, have a chronological span of one and a half decades, makes it difficult to arrive at any accurate assessment of the overall situation at the present time. Furthermore, there are still large stretches of the Mediterranean coastal zone, mainly in the southern and eastern parts, from which records are sparse.

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6. Regional activities and state of action

This section of the report presents a brief overview of responses within the DPSIR assessment framework (Driving forces / Pressures / State / Impacts / Response), with special reference to programmes launched at regional or at least trans-national level in the basin. Specific attention is given to the Barcelona Convention which provides a precious framework for environmental protection in the Region, and to EU-funded programmes.

The information on what is being carried out by single countries, multilateral bodies and agencies and / or international NGOs is very dispersed. The picture that emerges is clearly incomplete, in spite of the extensive search for information on the 'response' taken to tackle regional environmental problems, a response that has surely increased in pace in the past decades.

The section includes a description of the Mediterranean Action Plan activities, objectives and present structure, as well as a review of international and EU programmes concerning the environment in the Mediterranean region.

Attention has been given not only to the programmes intended to improve knowledge of the environment through research and provision of raw or analysed data sets, but also to programmes in which the management and the socio-economic approach or specific use of technology for environmental protection purposes – such as remote sensing – are predominant.

6.1. International environmental programmes

The Mediterranean region is not only largely influenced by natural changes – especially global climate changes – it is also very sensitive to changes in global world economies, land policy and demography, which in combination have considerable impact on sustainable development. Although the Mediterranean Sea encompasses different economic and political systems, there is shared concern over many common environmental problems. Furthermore, there is considerable potential for research around the basin. These outstanding features make the Mediterranean region an exemplary area for international, integrated research into change-related impacts.

As an example of good integration of problems and research needs, the work of the recent ENRICH / START (European Network for Research in Global Change) Workshop on the Mediterranean and global changes (Toledo, Spain, September 1996) may be cited (ENRICH / START, 1997). The recommendations of the Workshop are all related to the fact that earth sciences will not be able to explain reality without integrating human activity and behaviour as another component of the biosphere. Nevertheless, following these recommendations, fundamental knowledge about land-sea interactions, including the influence of large-scale marine processes, will depend more specifically on the development of programmes devoted to:

- The interaction of the socio-economic development of the Mediterranean region and the environment, with special emphasis on changes which may be influenced by the predicted global change (e.g. programmes of UNEP / IOC, the Blue Plan and the Coastal Area Management Programmes - CAMPs - of the Mediterranean Action Plan);
- the Adriatic Sea as a case study for the impact of large riverine systems on the Mediterranean Sea; and
- the interaction of general dynamics of Mediterranean water masses with local circulation, and their significance for the Mediterranean basin, e.g. POEM (Physical Oceanography of Eastern Mediterra nean), PRIMO (a similar programme for the western Mediterranean), and more recently MATER (the second phase of the EU Mediterranean Targeted Project).

Within these topics, the main issues are:

1. discharge of nutrients into coastal areas from land-based sources and resulting eutrophication;
2. river systems, with special reference to the impact of water management;
3. effects of land-use policies and practices on coastal and marine ecosystems, with special reference to soil degradation and desertification; and

4. potential impact of global change (sea level change in particular), on coastal and marine environment, socio-economic development, and use of natural resources on a sustainable basis.

The observations and measurements of variables should conform to the methodology adopted for large-scale global or regional international programmes; this will facilitate comparison of results on Mediterranean and global scales, regarding marine parameters (MEDATLAS, MEDGOOS, MED POL, etc.) as well as socio-economic parameters (Blue Plan, CAMPs, the World Bank Mediterranean Programme METAP, etc.).

Capacity building is essential to the success of the recommended or existing programmes as cited above. It could be achieved through the following main activities: (i) broad and intensive north-south cooperation and promotion of participation of southern and eastern institutions and scientists in the proposed research topics (IOC/TEMA, MAP, EUROMED); (ii) strengthening of the rele vant, existing databases, with preparation of a directory of relevant databases and information on their contents and how to access them (IOC/IODE, ENRICH as mentioned above, etc.).

EuroGOOS (European Global Ocean Observing System) established in 1994, is the European association of agencies which promote the Global Ocean Observing System (GOOS) objectives. For the Mediterranean, EuroGOOS activities include a summary of methods for observations, existing real-time systems, meteorological network, meteorological buoys at shelf-edge etc. in the Mediterranean. The Mediterranean component of GOOS, to be known as MedGOOS, is now being developed.

6.2. The Mediterranean Action Plan

6.2.1. Legal component

In 1975, the Mediterranean countries and the EEC adopted the Mediterranean Action Plan (MAP) and in 1976 the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention). The Convention envisages the preparation of technical protocols. Six protocols of the Convention have already been signed by the contracting parties; the Barcelona Convention has also been recently amended. (**Table 6.1**).

Presently, the Contracting Parties are in the process of discussing amendments to the Emergency protocol as well as appropriate rules and procedures for the determination of liability and compensation for damage resulting from pollution of the marine environment in the Mediterranean Sea area which may result in a new protocol.

6.2.2. Programme and objectives

Although the initial focus of MAP was on marine pollution, experience soon confirmed that socio-economic trends, combined with poor management and development planning, are at the root of most environmental problems; and that meaningful and lasting environmental protection is inseparably linked to social and economic development. Therefore, the focus of MAP gradually shifted from a sectoral approach of pollution assessment to pollution control and integrated coastal-zone planning and management as the key tools through which solutions are being sought.

In 1995, a new phase of MAP was approved. MAP Phase II, renamed ‘Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean’, was designed taking into account the achievements and shortcomings of MAP’s first twenty years of existence, as well as the results of recent developments such as the United Nations Conference on Environment and Development (Rio de Janeiro, 1992).

The main objectives of MAP Phase II are to:

- Ensure sustainable management of natural marine and land resources and to integrate the environment in social and economic development and land-use policies;
- protect the marine environment and coastal zones through the prevention of pollution, and by the reduction and, where possible, the elimination of pollutant inputs, whether chronic or accidental;
- protect nature, and protect and enhance sites and landscapes of ecological or cultural value;
- strengthen solidarity among Mediterranean coastal states in managing their common heritage and resources for the benefit of present and future generations;
- contribute to the improvement of the quality of life.

Although it is difficult to assess progress achieved, there is direct and indirect evidence that a large number of concrete actions were taken by many countries in

Table 6.1 **Barcelona Convention and its Protocols**

Title	Adopted	Entered Into Force	Amended	New Title
Barcelona Convention				
Convention for the Protection of the Mediterranean Sea Against Pollution	Barcelona, Spain, 16.2.1976	12.21978	Barcelona, Spain, 9 - 10.6.1995	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean
1 Dumping Protocol				
Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	Barcelona, Spain, 16.2.1976	12.2.1978	Barcelona, Spain, 9 - 10.6.1995	Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft or Incineration at Sea
2 Emergency Protocol				
Protocol Concerning Cooperation in Combating Pollution of the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency	Barcelona, Spain, 16.2.1976	12.2.1978		
3 Land-Based Sources (LBS) Protocol				
Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources	Athens, Greece, 17.5.1980	17.6.1983	Syracusa, Italy, 6-7.3.1996	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities
4 Protocol Concerning Specially Protected Areas				
Protocol Concerning Mediterranean Specially Protected Areas	Geneva, Switzerland 3.4.1982	23.3.1986	Barcelona, Spain, 9-10.6.1995 The new Protocol includes Annexes which were adopted in Monaco, on 24.11.1996.	Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean
5 Offshore Protocol				
Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil	Madrid, Spain, 14.10.1994	In process of ratification		
6 Hazardous Wastes Protocol				
Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal	Izmir, Turkey, 1.10.1996	In process of ratification		

Source: UNEP/MAP

conformity with the requirements and provisions of MAP, thus influencing the environmental policies and practices of the Mediterranean countries. MAP has been a significant instrument for change and progress concerning environmental matters in the Mediterranean. Among achievements of particular importance are the creation of awareness of the importance of a healthy environment for the present and future of the Mediterranean and its people; a marked change of attitude towards the protection of the environment at the policy-making level; and the creation of a sense of solidarity together with the need to act collectively for a better future of the Mediterranean.

The major shortcomings in the protection of the Mediterranean marine environment and its coastal region are recognised to include:

- inappropriate management of the coastal zone;
- continuing weaknesses in the protection of species and habitats;
- continuing high level of loads of pollutants from land-based sources.

This situation, which improves only slowly, is related to the still recent emergence of environmental policies and from the still insufficient mobilization of human and financial resources and concerned socio-economic actors.

6.2.3. Organisation

The Contracting Parties have designated the United Nations Environment Programme as responsible for carrying out the functions of the Secretariat to the Barcelona Convention. To ensure this function, the Executive Director of UNEP has established an office in Athens, Greece, to act as the Regional Coordinating Unit for the programme. The Unit prepares the meetings of the Contracting Parties and of the Bureau and acts as secretariat to the Mediterranean Commission on Sustainable Development (MCSD). It also prepares the programme and budget and is responsible for following up the decisions taken. It maintains relations and coordinates its activities with international and non-governmental organisations and reports regularly on its activities and those of the Regional Activity Centres.

A **Mediterranean Commission on Sustainable Development (MCSD)** was established as advisory body to the Contracting Parties, to identify, evaluate and examine major economic, ecological and social problems included in Agenda MED 21 and MAP Phase II, make appropriate proposals thereon and enhance regional cooperation for the integration of environment and development issues. The Commission agreed on a programme built around activities corresponding to some of the priority needs of the Mediterranean region, such as: sustainable management of coastal regions; management of water demand; sustainable development indicators; tourism, information awareness and participation; free trade and environment; industry and sustainable development as well as urban and rural development.

Six Regional Activity Centres (RACs) have so far been established to implement various components of the Action Plan. All but one of these centres are national centres with a regional role to play on behalf of MAP. The Regional Oil Combating Centre (ROCC), renamed '**Regional Marine Pollution Emergency Response Centre (REMPEC)**', in Malta, is a UN Centre run by IMO and was created to assist the Contracting Parties in their commitments to the Emergency Protocol. It is instrumental in strengthening the capabilities of countries to prepare for and intervene against pollution, through the implementation of national contingency plans, bilateral / multilateral agreements (i.e. implementation of sub-regional systems) and by facilitating cooperation among states in the case of accidents.

The **Blue Plan Regional Activity Centre (BP / RAC)** which is located in Sophia Antipolis (France) undertakes prospective studies of the development trends and their environmental impacts in the Mediterranean region. This task also requires the objective observation and assessment of the state of the environment as well as of the capacity for action of individual Contracting Parties which is followed through the establishment of the Mediterranean Environment and Development Observatory (MEDO).
The objective of the **Regional Activity Centre in Split, Croatia, known as PAP / RAC (Priority Actions Programme)** is to address immediate problems of a development nature and their effects on coastal environment and resources, through priority actions in a number of fields, with a view to inducing sound environmental management practices required for sustainable development. A major tool used is Integrated Coastal Area Management (ICAM). The Centre is assisting countries by providing technical support for the institutional capacity building within the sphere of its expertise. PAP / RAC has initiated and coordinated MAP Coastal Area Management Programmes (CAMP). The projects within this programme are aimed at the practical implementation of all knowledge and experience of RACs in solving environment / development problems at specific sites in selected Mediterranean countries. The involvement of local and national experts in CAMP activities is the core of capacity building objectives within these projects. PAP / RAC and Blue Plan are especially involved in the activities undertaken through the MCSD.

The **Regional Activity Centre in Tunis**, known as **SPA / RAC (Specially Protected Areas)** has been created to assist countries in the technical implementation of the SPA Protocol. The main fields covered by this assistance include the identification, establishment and management of marine and coastal protected areas, the conception and implementation of research, monitoring and conservation activities for threatened species, the preparation of inventories of the components of biological diversity, the drawing up of legislation, the formulation of biodiversity conservation strategies and the enhancement of national capabilities through training programmes. With a view to promoting exchange and dissemination of information, SPA/RAC holds several directories and data-bases. The Centre has also a coordinating role in the implementation of the three action plans concerning endangered species (monk seal, marine turtles and cetaceans) adopted within the Mediterranean Action Plan.

The **Environment Remote Sensing Regional Activity Centre(ERS/RAC)** is located in Palermo, Italy, and its task is to improve the overall knowledge and understanding of the environmental state and changes in the Mediterranean, supporting planning and decision-making processes towards sustainable development, by promoting and applying the use of remote sensing and its integration with other sources of information. The Centre is also assisting the countries in their efforts to upgrade their capacity building.

The **Regional Activity Centre for Cleaner Production (CP/RAC)** was introduced in 1996 to spread the concept of clean production and pollution prevention, its techniques and practices and its advantages in the improvement of the industrial sector. Its main activities include the encouragement and cooperation in initiatives and programmes for waste reduction at the source, the information and advice about cleaner technologies, the promotion of technology transfer between countries of the Region, the promotion of exchange of experts and training activities and the coordination of a network of national focal points.

The RACs are responsible for carrying out specific activities, agreed upon by the Contracting Parties, under the general guidance and supervision of the Coordinating Unit of MAP.

6.2.4. The MED POL programme

The MED POL programme, which is the scientific and technical component of MAP, was initially the major component. Its first phase (1975-1981) played a leading role in upgrading the technical capabilities of most Mediterranean countries and in establishing a network of institutions undertaking marine pollution work, and its second phase (1982-1996) in developing and maintaining national monitoring programmes in the region. A set of common measures for the control of pollution were proposed to and adopted by the Contracting Parties.

MED POL has entered its third phase shifting the emphasis from pollution assessment to pollution control. The objectives of MED POL Phase III are:

- Assessment of all (point and diffuse) sources of pollution, the load of pollution reaching the Mediterranean Sea, and the magnitude of the problems caused by the effect of contaminants on living and non-living resources, including human health, as well as on amenities and uses of the marine and coastal regions;
- assistance to countries (including capacity-building), in the development and implementation of national action plans for the elimination of marine pollution, in particular from land-based activities;
- assessment of status and trends in the quality of the marine and coastal environment as an early warning system for potential environmental problems caused by pollution;
- formulation and implementation of action plans, programmes and measures for the prevention and control of pollution, for the mitigation of impacts caused by pollution and for the restoration of systems already damaged by pollution; and
- monitoring of the implementation of the action plans, programmes and measures for the control of pollution and the assessment of their effectiveness.

Through a Global Environment Facility (GEF) project, a transboundary diagnostic analysis was prepared for the problems of the region and pollution ‘hot spots’ were identified which led to the elaboration of a Strategic Action Programme to Address Pollution from Land-based Activities (SAP), which was adopted by the Contracting Parties in 1997. The Programme analyses the main pollution problems of the region, elaborates control measures and interventions and establishes a time-table for their implementation. An extended three-year GEF Project was approved by the GEF Council in 1998 for the implementation of a number of preparatory actions leading to the long-term implementation of the SAP.

Despite the efforts of the MED POL programme, not all Mediterranean countries are yet in a position to produce sufficient and good quality data for decision making; temporal and geographical gaps still exist in the regional databases. Financial resources should be mobilised to replace the analytical equipment which is now obsolete installed through the MED POL programme in many laboratories, but also to provide training and equipment necessary for the new types of monitoring envisaged in MED POL Phase III (trends, biological effects, compliance).

6.3. EU international projects

The information on environmental programmes, funding and projects within the EU is fragmented, the environment being a transversal issue which is dealt with increasingly by several of the Directorates General in the Commission, as an ongoing result of the integration of environmental concerns in sectoral policies and planning demanded by the consolidated EU treaty (the Amsterdam Treaty).

Thus the information presented here is far from being complete and may be influenced by availability in the EU databases, namely those under CORDIS and EUROPA servers which are precious instruments for searching information but still provide an incomplete output when looking for ‘horizontal’ subjects such as environmental programmes in the Mediterranean.

Not all of the financial instruments, programmes, and approved projects, are research-targeted and they do not necessarily address the collection or production of data directed at giving better information on the state of the environment. Nevertheless, they often produce information that is relevant to more than one country or can be used in assessing current trends in response to environmental threats within the EU and other participating parties, thus helping in the construction of a European environmental perspective.

6.3.1. Brief outline of the principal programmes and projects concerning the Mediterranean

Part of the EU funded environmental programmes concerning the Mediterranean have significance only for the EU Member States, but others aim at achieving a regional perspective.

The MEDA programme, under the responsibility of DG External relations as part of the creation of an Euro-Mediterranean free-trade zone will have accompanying studies and measures, and the second Euro-Mediterranean Ministerial Conference has stressed the need for continuing cooperation in the sectors of energy policy, environment, water policy, maritime transport, agriculture, reducing food dependency, developing regional infrastructure, and the transfer of technology.

As part of this work plan, experts’ meetings were held in 1996 on the protection of wetlands in the Mediterranean area and on local water management. There was an experts’ preparatory meeting on fish stock management in the Mediterranean and a second Diplomatic Conference on Fish Stock Management in the Mediterranean.

The Short and Medium-term Priority Environmental Action Programme (SMAP) is a framework programme of action for the protection of the Mediterranean environment, within the context of the Euro-Mediterranean Partnership. It was adopted unanimously by the Euro-Mediterranean Ministerial Conference on the Environment, held in Helsinki on 28 November 1997. SMAP is intended to become the common basis for environmental purposes (as regards both policy orientation and funding) in the Mediterranean region.

The environment ministers also identified desertification and integrated coastal zone management as environmental priorities in the Mediterranean, together with the conservation and sustainable use of biodiversity as a ‘horizontal’ environmental issue.

Similar achievements are carried out within the PHARE programme in the Countries of Central and Eastern Europe (CCEE). Its objective is to help rejoin the mainstream of European development and build closer political and economic ties with the EU. Within this integration process, environmental harmonisation work is carried out through projects or specific facilities such as the DISAE (Development of Implementation Strategies for Approximation in Environment) aiming at the harmonisation of legislation in environmental matters.

DG Environment has established programmes for environmental assessment and protection at a regional and local scale; in close cooperation with other DGs as is seen in the demonstration programme for Integrated Coastal Zone Management (ICZM). The principal EU financial instrument, solely devoted to the environment, is LIFE, for three major areas of action: Environment, Nature and Third Countries. LIFE has funded approximately 50 projects for the Mediterranean basin. While all three areas aim to improve the environment, each has its specific priorities.

LIFE Third Countries in 1998 included 15 Mediterranean countries and provided funds for technical assistance in the establishment of environmental administrative structures. LIFE Nature provides conservation activities and demonstrations to promote sustainable development. The aim of the funded actions must also comply with the aims of the Community policy and legislation.

The main EU projects concerning the Mediterranean Sea on a basin scale are carried out as research projects launched by DG research in the framework of the DG research MAST initiatives. The projects carried out in the past involved the collection of physical, chemical and biological data, data analysis and modelling of marine circulation and the ecosystem. They were established by the European Commission in 1993 and have been coordinated as a Mediterranean Targeted Project (MTP). MTP represents a major effort in the understanding of the Mediterranean Sea today (both western and eastern basins). The MAST programmes have improved significantly the understanding in the oceanographic community of the major physical and biological phenomena occurring at sea. The programmes are now running with an interdisciplinary approach, aimed at understanding the relationship between vertical transport of nutrients in the euphotic zone and primary productivity. The MAST programmes can provide a significant amount of quality data for the assessment of status and trends in many Mediterranean regions. Within these programmes the MTP II - MATER (1995-1998) objectives are to study and to quantify the triggering and controlling mechanisms of mass and energy transfer between the differ-

Coastal management: towards an integrated approach

The need for better management of coastal zones has led, in different degrees since the early 1970s, to political commitments and numerous measures.

In some countries this has resulted in specific legislation and national strategies, regional management schemes, studies, inventories, and research. A considerable body of legislation and instruments already exists which, if applied, should help to protect the coastal environment. However, this has not halted the deterioration of the environment, which continues apace in many areas. Recent studies on this question tend towards the same conclusions: existing legislation and instruments are relatively complete, but are not as effective as they could be due to the lack of coordination between the many parties influencing the development of the coast.

This lack of co-ordination not only concerns the horizontal relations between sectors of activity, but also the intermeshing of the policies and actions carried out at various levels of territorial authority (local, regional, national or European). Over-zealous application of the subsidiarity principle too often leads to a parcelling out of responsibilities, which are simply distributed between the levels of competence, with no scope for taking account of the numerous interactions between them. The complex relations between human activities and the coastal environment are thereby neglected and the isolated measures often fail to achieve their goal or may even be mutually contradictory.

Although the attempt to launch an EU framework directive on ICZM was unsuccessful, a growing quest at local level for management tools, capable of jointly tackling local environmental problems and social and economic growth, has spurred the launch by the EU Commission of a specific demonstration programme with the close cooperation of three Directorates: DG environment; DG XIV: fisheries:, DG XVI regional policies; and with the participation of DG research: JRC (Joint Research Centre) and EEA.

It shuld be noted that, in the wake of the EU environmental policy orientation, all the selected programmes since the beginning have involved the private sector in an effort to overcome through a participatory approach the limits of enforcement in the traditional ‘command and control’ framework, which unfortunately have become apparent in coastal management.

For the purposes of the demonstration programme, the coastal zone is defined as “a strip of land and sea of varying width depending on the nature of the environment and management needs”. It seldom corresponds to existing administrative or planning units or the natural coastal systems involved. The latter may extend well beyond the limit of territorial waters, and many kilometres inland.

Thirty-five coastal zone management projects have been selected by the Commission for this demonstration programme, with over a dozen located in the Mediterranean basin. Each of these projects will study the operation of the integrated management and cooperation procedures and their efficiency, with the objective of evaluating policy consistency and management options.

The projects were selected chiefly in the context of the financial instrument LIFE-Environment and the TERRA programme, while a transnational European dimension is being provided by the INTERREG IIC programmes which often include a topic on integrated coastal zone management. This will enable them to contribute a strategic vision and framework to the ICZM demonstration programme.

The geographic coverage reaches from the Mediterranean and French and Italian Alps, involving three countries, some fifteen regions and a population of 65 million, to the eastern Mediterranean INTERREG IIC programme, which encompasses two countries and ten regions.

ent compartments (land - sea, sea - atmosphere, water - sediment, living - non living, pelagos - benthos), in contrasting trophic environments (from eutrophic to oligotrophic) of the Mediterranean Sea and to investigate the ecosystem response to such a transfer. The major input appears to be the improving knowledge of the variability of the marine system, considering the Mediterranean Sea as a reduced ocean. The programme is designed to assess the processes at various time and space scales, from the entire basin down to the local scale, and from daily processes up to inter-annual variations. The project gathers 54 research groups from ten EU Member States and three non-EU states with a budget over 1.2 million ECU.

Other important initiatives are some of the DG Research Climate and Environment programmes, in which research results are used in the solution of environmental problems and management of the coastal areas with major focus on European Land-Ocean Interaction StudiEs (ELOISE). The ELOISE project plan was drafted by representatives of the EU Environment and Marine Science and Technology (MAST) programmes in collaboration with the Scientific Steering Committee of the IGBP Core Project on Land-Ocean Interactions in the Coastal Zone (LOICZ). The objective is to develop a coherent European research approach to the coastal ecosystem issue in the context of LOICZ, designed to elucidate issues concerning the role of coastal zones in the global climate system and the potential response of coastal systems to global change.

ELOISE is being developed in the framework of MAST III Programme and the Environment and Climate Programme. It supports two groups of 15 projects each, taking place all along the European seas. The Mediterranean Sea hosts several projects, including:

1. METRO-MED (Dynamics of Matter Transfer and Biogeochemical Cycles: their Modelling in Coastal Systems of the Mediterranean Sea) with the aim to study and model the key processes of matter transfer (exchange and storage) and the biogeochemical cycles in the coastal zone system. These processes will be studied in two sites in the Mediterranean Sea: Thermaikos Gulf in northern Greece and Gulf of the Lion in southern France.
2. DUNES (Integrated management methods: monitoring environmental change in coastal dune ecosystems) with the object to develop integrated management methods for environmental monitoring in coastal dune ecosystems. The development of this management tool is being prepared via an innovative computerised checklist system for European dune systems and includes two sites in the Mediterranean in which to examine in detail how human activity affects vegetation structures and vulnerability.
3. ROBUST (The role of buffering capacities in stabilising coastal lagoon ecosystems) with the objective to define the biotic and abiotic components of internal processes in coastal lagoon systems and quantify their buffering capacities against external forcing processes. The project includes the lagoon Sacca di Goro on the Adriatic coast.
4. NICE (Nitrogen Cycling in Estuaries) with the overall aim to obtain an over view of nitrogen removal in European estuaries and to understand how this is affected by climate, tidal amplitude, and benthic primary producers.
5. MAMCS (The Mediterranean atmos pheric mercury cycle system) with the objective to improve the scientific knowledge on biogeochemical cycle of mercury in the Mediterranean Sea.
6. CHABADA (Changes in bacterial diversity and activity in Mediterranean coastal waters as affected by eutrophication) to determine the spatial and temporal variations in genetic and phenotypic diversity of a microbial community by using an in situ simulated model with a Mediterranean coastal water sample to which artificial eutrophying conditions are applied. The validity of the conclusions originating from the comparison between diversity and cell activity obtained by the in situ experiments will be tested in the Adriatic Sea. The CHABADA project will then be linked to the results of the multidisciplinary EC project PALOMA which will provide taxonomic data on the naturally occurring microflora.
7. KEYCOP This project examines the key coastal processes (flow and cycling of carbon, nutrients and trace substances) in the water column and sediments between pelagic and benthic systems. It focuses on the comparative study between Skagerrak in the North Sea and the northern Aegean Sea in the Mediterranean.
8. FECTS (Feed-backs of estuarine circulation and transport of sediments on phytobenthos) with the aim to investi-

gate the ecosystem loops in estuarine environments involving phytobenthos communities, hydrodynamics, nutrient cycling and sediment transport.

As for international science and technology cooperation with the Maghreb and the countries of the Mediterranean basin, the programme AVICENNE covered areas of action such as organic and inorganic pollutants and their effects on the environment and the evaluation of risks to human health; clean technology and treatment or utilisation of waste; desertification in Mediterranean zones; improvement and conservation of water resources; development and circulation of scientific and technical information; and promotion of cooperation between universities and enterprises in Member States and Mediterranean third countries concerned, in the priority areas retained. The Mediterranean third countries concerned are Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Morocco, Malta, Syria, Turkey and Tunisia.

The budget allocation for the initiative in 1992 was ECU 5 million and in 1993 it was ECU 5.3 million. Two calls for proposals have been made under this initiative and 48 projects have been funded and are described in the CORDIS projects database.

The FAIR programme was also launched in the fourth framework plan for research and development in place of previous programmes, with the aims of promoting and harmonising research in the major European primary food and non-food sectors including agriculture, forestry, fisheries and aquaculture and their links with the input and processing industries, together with the rural activities, the end-user and the consumer. Research topics include: integrated production and processing chains (including the biomass and bioenergy chain); forestry and rural development; reformed CAP (Common Agricultural Policy); optimisation of methods, systems and primary production chains; agriculture-environment interactions; policy-relevant economic analysis and impact assessment; and the impact of environmental factors on aquatic resources, ecological impact of fisheries and aquaculture.

Other programmes have also been launched by DG Transport. Based on GIS and marine environmental information, such projects aim at improving the management of coastal and port areas (eg. ECOPORT).

Also in the framework of DG the telecommunication and information market and exploitation of research (e.g. ESPRIT and Telematics for the Environment) programmes concerning technology development and projects providing information on the coastal areas have been launched, as part of implementation of GIS, or development of telematics / monitoring networks for the control of the environment.

Important projects dealing with the environment are carried out under DG Regional Affairs, RECITE and ECOS OUVERTURE programmes, stimulating inter-regional cooperation among EU member states and third countries in the Mediterranean basin on topics which are relevant at regional level.

Other DG programmes which have funded projects in the Mediterranean area include TERRA and INTERREG.

INTERREG funds actions and studies for transnational strategies, notably the identification of environmentally sensitive areas, actions to improve the territorial management of the marine areas at the periphery of the Union, from the point of view of both economic development and environmental protection and improvement (e.g. integrated coastal development, prevention and control of sea pollution, and environmental protection); economic development measures with a view to sustainable development (e.g. the promotion of high-quality tourism and of technology transfer and cooperation networks). INTERREG II expenditure is estimated at ECU 415 million for the period 1995-1999.

TERRA programme is implemented by DG XVI within the framework of Article 10 of the European Regional Development Fund (ERDF) Regulation.

The programme is implemented by calls for proposals for the establishment of cooperation networks to carry out innovative and / or demonstrative pilot projects on spatial planning. Networks must provide for participation by a small number of local authorities in the European Community that share specific geographical and / or structural features. An indicative list of such specific features is as follows:

- Areas suffering from erosion or desertification;
- areas at risk from forest fires;
- remote island areas;

- mountain areas;
- areas subject to earthquakes and volcanic areas;
- river basins;
- coastal areas;
- areas where natural assets are endangered;
- areas where cultural assets are endangered.

6.3.2. Use of remote sensing

Remote sensing from airplanes and satellites offers the opportunity to detect large-scale changes in the biological properties of the Mediterranean (e.g. use of colour data) to detect changes in land uses in coastal areas; and to detect and monitor accidental pollution (CEO - Centre for Earth Observation programmes, and programmes OCEAN, LACOAST). Under these programmes, important aspects, such as desertification and inland waters in the Mediterranean, were also taken into consideration. One specific project is relevant to at least the European coastal zones: AWATER (Wetland and Aquatic Ecosystem Research) provides a strategic approach within the Environment and Climate Programme (DG Environment) with the specific research objectives of investigating the key processes and functioning of wetland and aquatic ecosystems.

References and websites

ENRICH / START, 1997. Workshop of ENRICH / START Toledo, Spain, September 1996. MEDIAS Newsletter, May 1997, No 9.

CORDIS database: **http://www.cordis.lu/**

DG Environment ICZM Demonstration Programme: **http://europa.eu.int/comm/dg11/iczm/home.htm:**7. Conclusions and Recommendations

UNEP/MAP:http://www.unepmap.org/

7. Conclusions and recommendations

7.1. State of the Mediterranean Sea

The state of the open waters in the Mediterranean Sea, based on the available information presented and assessed in this report, is considered to be generally good. In coastal areas, the presence of pollution 'hot spots', located generally in semi-enclosed gulfs and bays near important harbours, big cities and industrial areas, is probably the major problem of the Mediterranean Sea. Waters in the open sea are classified among the most poorest in nutrients of the world ocean; marine ecosystems still seem to function well and the Mediterranean Sea is characterised by a high diversity of marine species. Nevertheless, in several cases, natural peculiarities (e.g. sea water movement and circulation patterns) determine the state of the Mediterranean Sea and, together with pressures deriving from coastal anthropogenic activities, create 'hot-spots' which pose adverse local environmental impacts and could be persistent.

In contrast to relatively favourable conditions of the Mediterranean Sea itself, only a small percentage of its coastal zone is still in pristine condition, of which an even smaller proportion is protected. This report shows that the current threats (e.g. localised eutrophication, heavy metals, organic and microbial pollution, oil spills, introduction of non-indigenous species) are mainly the results of pressures from anthropogenic activities and hence more attention to their management and control is needed.

Land-based activities (urbanisation, industry and agriculture) represent the main source of pollution into the Mediterranean Sea, although many uncertainties remain regarding their respective contribution, the different fluxes (rivers, atmosphere, non-point sources, etc.) and the fate of the contaminants they generate. In the case of urban and industrial pollution, the main problem is the rapid population growth along the southern coasts of the Mediterranean, where there are fewer legal instruments and lesser environmental infrastructure investments.

The pressure from tourism is one of the problems that have to be managed effectively to avoid any further degradation of the marine and coastal environment.

7.2. Recommended measures

The report also identifies several major issues, which need to be addressed to ensure higher environmental quality and better integrated information from the region:

1. **Climate change:** Multidisciplinary research is still needed to assess the major environmental and socio-economic problems that may follow from accelerated sea level rise, erosion and desertification, floods and other threats that originate from climate change, and to distinguish natural fluctuations from the effects of anthropogenic activities.
2. **Biodiversity:** The creation of marine parks and protected areas for conservation purposes is often not sufficient as an impact-limitation measure, since many of the impacts derive from pressures that are not locally originated. Mediterranean wilderness and important habitats need to be protected as the Mediterranean Sea is recognised as one of the richest biotopes in the world with about 6% of the global total of higher species. Protection of the wilderness and habitats of the Mediterranean Sea requires integrated environmental management. As the coasts are heavily populated and coordinated action plans for environmental management are still lacking in most places, there is a threat that the number of important habitats will decline and impacts on biodiversity will become more evident.

   The following actions should be considered in order to further protect the ecosystem balance:
   - Develop national and Mediterranean-wide coordinated plans for environmental management and infrastructure development, with specific attention to the coastal zones;
   - introduce effective measures for environmental protection from threats arising from sea transport, coastal works and sea exploitation activities;
   - promote the implementation of the provisions of the CBD (Convention for Conservation of Biological Diversity) and of the Mediterranean protocol on specially protected areas and

biodiversity at national level in the Mediterranean, including the development of national strategies for the conservation of biodiversity, adopting the biogeographic regional approach suggested by technical bodies of the CBD;
- promote the implementation of the existing action plans for the protection of the threatened species in the Mediterranean;
- increase protection of the remnants of pristine areas.

3. **Sewage discharges:** Sewage treatment plants are still missing from urban areas along the coasts and about 60% of urban waste disposed in the Mediterranean Sea is still untreated. Based on the existing information, sewage should be discharged after advanced treatment in adequately designed treatment plants. The technology is available and reasonably cheap. As analysed convincingly by several studies, the health costs and other economic losses, especially in tourist areas due to contamination of coastal waters, is much higher than the investment necessary for achieving an acceptable sewage effluent quality.
4. **Agriculture practices:** In most Mediterranean countries, all types of agricultural practices and land use are treated as non-point sources of water pollution. It is very difficult to estimate the input from these diffused sources into the Mediterranean Sea quantitatively. Countries should adopt a holistic approach to water-resource management, based on the integrated assessment of water quality and ecosystem health, from the coastal waters to the entire catchment area.
5. **Fisheries**: A control of fishing effort is an urgent priority identified by the General Fisheries Council for the Mediterranean (GFCM); although one must not forget that coastal fisheries by small scale boats play an important social and economic role along the Mediterranean coast.
6. **Marine aquaculture:** The careful selection of sites, with precise definition of their carrying capacity, needs to be regulated and enforced. Open sea practices should be further developed to avoid adverse coastal impacts.
7. **Oil pollution:** Oil reception facilities should be recommended for all big ports along the basin. The areas around straits and ports already appear to be top priorities for planning and protection.
8. **Coastal zones:** An integrated approach to coastal zone management and physical planning are still missing. Decisions and management of the coastal zones should be made at regional, national and local level, taking into account the driving forces and pressures of the human activities including tourism in order to integrate environmental protection into economic development. Integrated coastal zone management can be a success story only if the experience and expertise are maximised and the allocation of budgets to projects which take into account the holistic environmental dimension is enhanced. Organisational and legal instruments - including market-based instruments - should be developed to control and manage coastal development, land reclamation and groundwater exploitation.

7.3. Improvement of data availability

One of the major concerns identified in the report, which emerges from the different issues dealt with in individual chapters, is the scarcity or unavailability of comparable and, in some cases, reliable data for the Mediterranean basin as a whole. For the assessment of the state and pressures of the marine and coastal Mediterranean environment, the following missing elements in information have been identified:

1. **Coastal erosion:** Information - and access to existing information for its compilation at the regional level - is not available throughout the basin. Dispersal of the data among different administrative bodies, lack of knowledge of the existing inventories, data contained in reports considered confidential (or accessible only through long and hard administrative procedures) make the problem worse. Uncertainties about the evolution of numerous coastal segments still exist in cartographic atlases. The coastal evolution trends are thus often considered on the basis of expert judgements in the absence of studies or preliminary measurements.
2. **Contaminants:** Although a large effort has been made through the MED POL programme, there is still a scarcity of data from some regions. The monitoring capabilities of some Mediterranean countries have to be improved.
3. **Oil pollution:** Attention should be given at the planning stage to identifying areas

that need protection, their order of priority and the techniques to be used.

4. **Microbial pollution:** The problems of the effects of microbial pollution in the Mediterranean coastal zone persist and are mainly related to urban waste water. Further research and data on virus contamination is required on a basin scale. The geographical imbalance of data is more acute. Intake of pathogenic micro-organisms causing damage to health on a Mediterranean-wide basis still has to be determined. Furthermore, there are still large stretches of the Mediterranean coastal zone, mainly in the southern and eastern parts, for which records are very sparse.
5. **Sewage discharges:** There is a need for further data and information on water quality and the operation of sewage treatment plants to be available.
6. **Radionuclides:** Information on radionuclide distribution is missing from some areas of the Mediterranean Sea, particularly from the eastern and southern basins; background data should be established in these areas.
7. **Fisheries:** Knowledge of Mediterranean fisheries needs to be improved. This will much depend on the quality of statistics, which is still one of the main weaknesses in dealing with real amounts of catches for the different species, as well as the structure and capacity of the different types of fishing fleets.
8. **Biodiversity**: A specific inter-Mediterranean approach to the monitoring of marine biodiversity - and the identification of important risks threatening the present state - is still missing. Special attention is essential in species introductions and habitat loss, to avoid biodiversity reduction. Research on processes related to ecosystem changes and rehabilitation of degraded coastal ecosystems is also required.

The information collected by the countries around the Mediterranean Sea is not easily accessible as it is scattered in various departments and institutions and in many cases it is not available in electronic form. It is vital that this information is centrally gathered in electronic form in a national database, as for example the exercise with the National Oceanographic Data Centres (NODC), so that it can be utilised easily by decision makers in the administration and by other partners.

The EEA, its European Topic Centre for Marine and Coastal Environment (ETC/MCE) and MAP could help establish the databases by giving guidance at the relevant technical level in the Mediterranean countries following the standard procedures that were adopted at basin level under the MED POL programme and making use of the experience and involvement in this field of the European Information and Observation Network (EIONET), co-ordinated by EEA.

7.4. Mediterranean monitoring

Development of an effective, common Mediterranean monitoring system of measurements of contaminants and their effects is still missing, although monitoring in the Mediterranean has been in place for a long time (for example, the MED POL programme initiated monitoring activities in 1975). Unfortunately, this monitoring has not been very effective and data is often unavailable. However, the plan of data gathering from Mediterranean Countries has not been consistent and large data gaps can be identified both temporally and geographically. Effective monitoring would include the following elements:

- information useful for the protection of human health, e.g. levels of contaminants in seafood; microbial quality of bathing and shellfish growing waters; algal toxins;
- information useful for the assessment of the effectiveness of pollution control and abatement measures taken (trends);
- support for implementation of the protocol of the Barcelona Convention in order to contribute to the reduction of pollution from land-based sources, especially the 'hot-spots';
- information useful for coastal zone management;
- an early warning system (bio-markers). Research would probably be needed in order to identify sources of pollution (e.g. non-point sources in agriculture) and biological effects of long-range pollutants.

Quality assurance and control procedures should be further developed and implemented to ensure data quality and reliability. Allocated resources should increase to enable a continuous flow of high quality data. An assistance component should be developed which could include training and establishment of contacts with more advanced laboratories (sister approach). The latter could be further developed through training and intercalibration exercises between laboratories.

Future action could include the facilitation and coordination of responses to transboundary issues and problems. International cooperation between EU and non-EU countries, European Community bodies (CEC, EEA). MAP and other Mediterranean Institutions (CIESM, GFCM) should be further strengthened. Full implementation of the Barcelona Convention and its six protocols should be promoted at national level. Existing agreements, programmes and other co-operative efforts should be further developed to achieve maximum results and avoid duplication; while moves towards sustainable development should be reinforced at regional level.

Action is needed at all policy levels; international cooperation, which should involve European Community bodies, should therefore play a fundamental role in the field of policy, research and information gathering through adequate resources directed to activities in the region.