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IASON:International Action for the Sustainability of the Mediterranean and Black Sea Environment

Coordinator: Hellenic Centre for Marine Research, Greece

Report on Pressures and potential Hazards on the Marine Resources of the System, emanating either from natural variation or from anthropogenic activity (WP3)

(D3.2)

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1. The Mediterranean Sea

1.1. General description

The Mediterranean Sea is the largest of the semi-enclosed European seas. It is surrounded by 18 countries and has shores on three continents (Europe, Africa and Asia) with a combined population of 129 million people in the catchment draining into sea sharing a coastline of 46000 km.

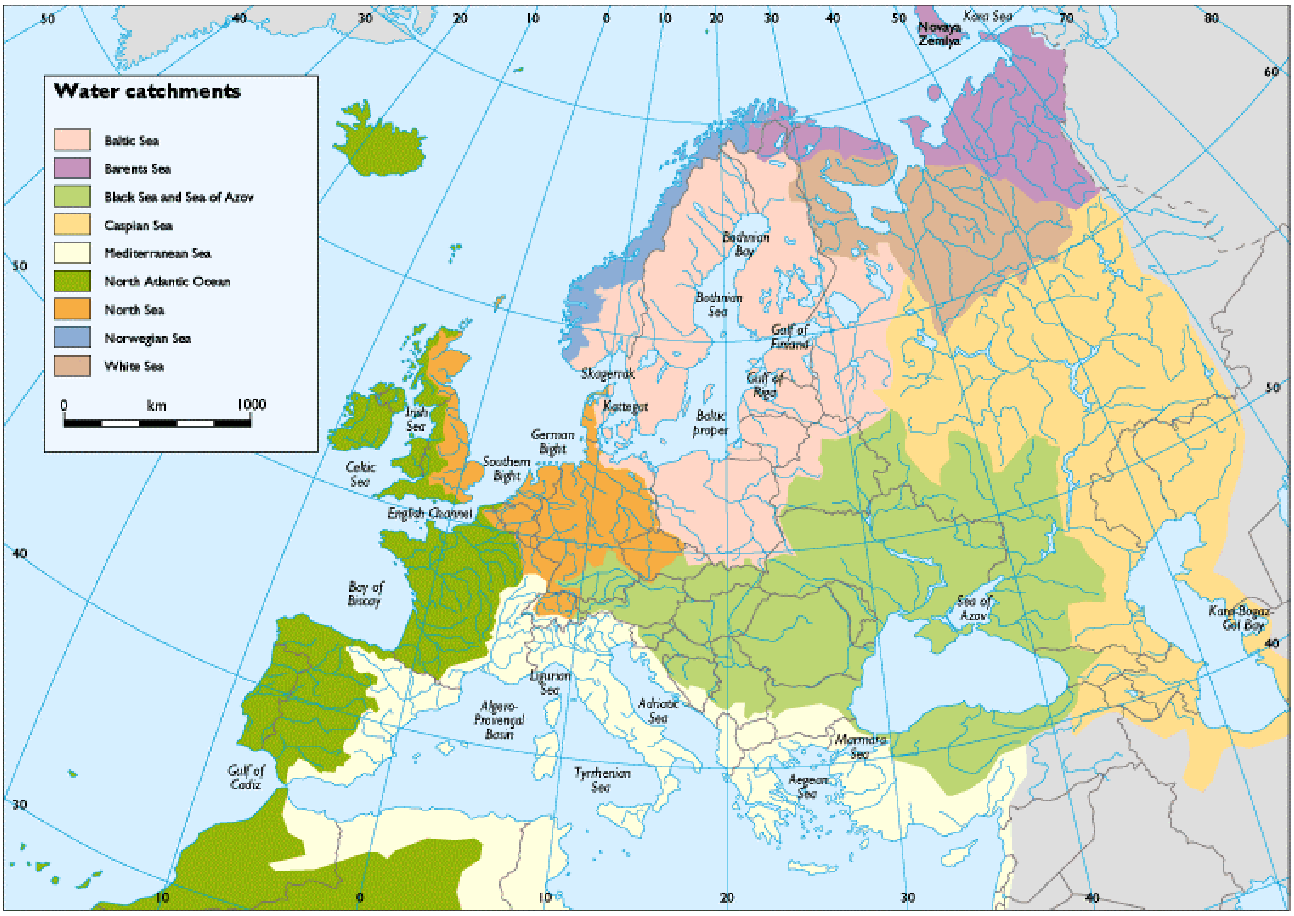


Figure 1. Map of European Seas and main catchment areas
(Source: Eurostat-GISCO)

The Mediterranean Sea has an average depth of 1.5 km, though more than 20% of the total area is covered by water less than 200 m deep (UNEP, 1989). The sea consists of two major basins, the eastern and the western. There are also smaller regional seas within the Mediterranean such as the Ligurian, Tyrrhenian, Adriatic and Aegean seas. It is linked to the Atlantic by the Strait of Gibraltar, with the Black Sea and Sea of Azov by the Dardanelles, the Sea of Marmara and the Bosporus, and with the Red Sea by the Suez Canal. The Mediterranean Sea is characterized by low precipitation, high evaporation, high salinity, low tidal action and relatively low nutrient concentrations outside the inner coastal zone and parts of some regional seas.

The coasts of the northwestern Mediterranean are the most affected by pollution because of the concentration of urban populations, industrial activities and discharges of major rivers. The Adriatic receives the discharge of the River Po. The North African coast, in contrast, is for most part arid with little urbanization or industrialization.

1.2. Physical characteristics

Surface water, entering the Mediterranean from the Atlantic, migrates generally towards the east. Evaporation processes transform this surface water into denser, deep water which flows east to west back into the Atlantic.

In fact, water loss by evaporation exceeds the water input from runoff and precipitation, resulting in the Mediterranean's characteristic high salinity (average 38.5 ‰, ranging from 37 in the west to 39 in the east). Strong vertical currents in winter ensure mixing of the water column and oxygenation of the deep waters. It takes on average about 80 years for the water in the Mediterranean to be completely exchanged.

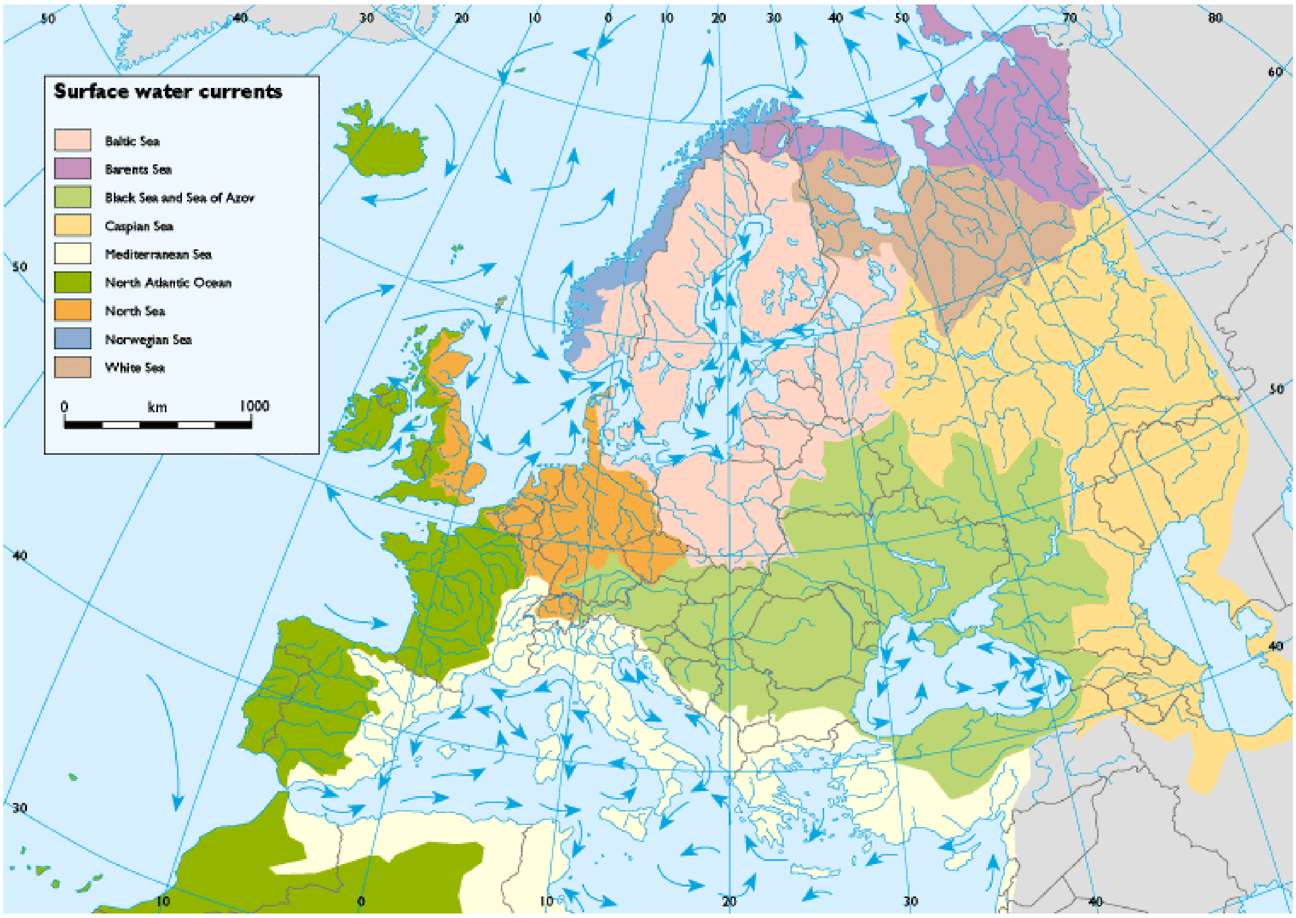


Figure 2. Map of European Seas showing main currents
(Source: Eurostat-GISCO and WRc)

1.3. Biological features

The Mediterranean Sea has a high species diversity but its biological productivity, while being extremely varied, is among the lowest in the world due to extremely low nutrient concentrations (UNEP, 1989). The total number of species of animals and plants has been estimated to be around

10000 (Boudouresque, 1993). Its fauna includes many endemic species and is notably richer than the fauna of the Atlantic coasts. The eastern and western Mediterranean, separated by the relatively shallow straits between Sicily and Tunisia, show differences in resident fauna and flora, indicating a degree of isolation between the two regions (Clark, 1986). The biodiversity of the western Mediterranean is also greater than that of the eastern (Boudouresque, 1993).
The most threatened species in the Mediterranean is the monk seal, *Monachus monachus*, which is one of the ten most threatened species of mammals in the world (IUCN, 1988).

The loggerhead turtle, *Caretta caretta*, and the green turtle, *Chelonia mydas*, nest regularly and in significant numbers in the Mediterranean (COE, 1990a) both are recognized by the IUCN as globally threatened species, the former being ranked as 'vulnerable' and the latter as 'endangered' (IUCN, 1988). There are on average 2000 female loggerhead turtles nesting annually in the Mediterranean, the majority in Greece and Turkey. Green turtles, as far as is known, nest only in the extreme southeast of Turkey and in Cyprus (COE, 1990a).

There are around nine species of whales and dolphins regularly found in the Mediterranean (Tethys Research Institute, 1991). The biggest populations are found in the particularly rich pelagic zone of the western Ligurian Sea.

The extensive sea-grass beds of *Posidonia oceanica* are an important part of the Mediterranean marine ecosystem, often occupying a considerable part of the littoral zone. A characteristic feature is the formation of *Posidonia seagrass* beds parallel to the shore in sheltered and shallow bays, isolating a coastal lagoon (Augier, 1982). These beds have suffered greatly from physical modifications of the coast. Posidonia plays an important role in the ecosystem: through the production of organic material at the base of the food-chain; as a primary oxygen producer; as a feeding and nursery area for numerous species of fish (many commercially important); through the stabilization of sediments; and through attenuation of wave and swell (protection of beaches) (Boudouresque, 1993). A tropical, non-indigenous alga, *Caulerpa taxifolia*, has been observed in the Mediterranean since 1984. First seen in the Monaco area (perhaps as a result of an accidental release from an aquarium in Monaco (Meinesz and Hesse, 1991), this alga had, by 1990, been found up to 150 km from Monaco at Toulon. At some locations it inhabits a wide range of substrates, including rock, mud and sand, and a wide range of depths, 3 to 35 m, and has achieved 100% coverage in some places. Wherever it becomes established it considerably modifies the vegetal communities in the infralittoral zone. It also contains a toxin which may inhibit some other organisms such as grazers, epiphytes and competitors. It appears to be consumed by only a few fish species.

There are important fisheries in the Mediterranean, with fish such as mullet *(Mugilidae)* and hake (*Merluccius* spp) being in most demand. Other fish such as anchovy (*Engraulis encrasicolus*), sardines (*Sardina pilchardus*) and mackerel (*Trachurus* spp) in the northwest are also intensively fished. Oil pollution in some parts of the sea has led to tainting of a variety of fish and bivalves.

Variation of species number according to the depth zone in the Mediterranean Sea		
Zones	Depth zone (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%

Table 1. Species variation per depth zone in the Mediterranean Sea, Fredj et al. (1992)

1.4. Inputs

Contaminants enter the Mediterranean from rivers, direct discharges (land-based and offshore), atmospheric deposition, and through water exchange primarily with the Atlantic Ocean and Black Sea. A major assessment of land-based inputs into the Mediterranean, reported by UNEP et al (1984), relied upon data collected by national monitoring networks. More recent work has indicated that these earlier estimates are too high (eg, CEC, 1992; Martin et al, 1989; Dorten et al, 1991). In particular, when non-conservative processes, which reduce gross loads passing through estuaries, are taken into account, and when the partitioning of contaminants between the dissolved and particulate phase are considered, the net riverine loads of metals, such as mercury, copper, lead and zinc, entering the main body of the sea are now calculated (Dorten et al, 1991; Martin et al, 1989) to be much lower than estimated in the earlier compilation.

The Mediterranean basin is unusual in that it is rich in mercury deposits (Zafiropoulos, 1986). Almost 65% of the world's mercury mineral resources are located in the region (Scoullos, 1993). Natural inputs of mercury (via rivers) can be locally very significant, for example into the Tyrrhenian Sea (Baldi, 1986), compared to anthropogenic sources. Dissolved mercury riverine inputs to the Mediterranean are now estimated to be between 1.7 and 20 tonnes per year (Dorten et al, 1991), compared with the original estimate of 120 tonnes per year (UNEP et al, 1984) from rivers.

Recent work in the northwestern basin has assessed the relative contributions of atmospheric and river inputs of about 40 elements including heavy metals, radionuclides and nutrients. For the majority of the elements analyzed the proportion of atmospheric deposition relative to total deposition (from rivers and atmosphere) did not exceed 20% (CEC, 1992). However, for heavy metals atmospheric input generally appears to predominate: this derives from both the heavily industrialised northern boundary and dust loads originating in the Sahara region (Dorten et al, 1991). For cadmium, lead and copper (in the dissolved phase) atmospheric inputs are much greater than riverine (50, 200 and 5 times respectively) (Martin et al, 1989). For inorganic nitrogen, atmospheric and riverine inputs are roughly equivalent, and in the case of inorganic phosphorus, riverine inputs are most important. Major anthropogenic contaminant loads are discharged from the rivers Nile, Rhone, Ebro and Po.

There is also an exchange of dissolved trace metals between the Mediterranean and the Atlantic Ocean through the Strait of Gibraltar, and also with the Black Sea via the Bosporus. Recent mass balance calculations (Martin et al, 1993) indicate that in the case of dissolved copper, nickel and cadmium there may be a net export to the Atlantic.

Inputs of oil to the sea are estimated at 635000 tonnes per year (UNEP, 1989). Of this, around half is spilt from tankers during ballasting and loading operations and during the washing of the bilge and tanks. Land-based sources account for 42% of total oil loads and the atmosphere accounts for 6%. Natural seeps have also existed over geological time-scales, particularly in the northeastern parts of the sea (UNEP, 1989). The coastal area off Libya receives the highest oil input.

Nuclear power stations are operating in three countries on the Mediterranean: Spain, France and Slovenia. However, it is the nuclear reprocessing plant at Marcoule in France that represents the most important source of artificial radioactivity in the sea. It is also apparent that atmospheric inputs are a significant proportion of the total input load of some radionuclides such as Cs-137 (Martin et al, 1989).

Contaminant levels in the system

In the Mediterranean Action Plan status report of 1989, it was reported that the concentrations of trace metals and chlorinated hydrocarbons in sea water and sediment should be considered (at that time) with caution, and typical concentrations could not be identified this was because of inadequate analytical quality control and different analytical methods. However, concentrations in biota were considered to be more reliable because extensive laboratory intercalibration had been carried out (UNEP, 1989). Over the last five years the CEC has funded research through a number of projects implemented in the western Mediterranean and some regional seas (eg, EROS 2000) as reported by Scoullos (1993).

State of heavy metals in the system

Only a few data have been found on the open-sea metal concentrations in the Mediterranean (Fowler, 1990). For mercury these concentrations are similar to concentrations in the adjacent North Atlantic, whereas for cadmium the concentrations (1 to 7 ng/l in the open sea), while still being well below accepted values for pollution, are generally higher than in the Atlantic. Recent analyses of cadmium show some relatively high values for certain coastal areas of Spain and Italy (5 and 10 ng/l, respectively). Lead values are also slightly higher than for Atlantic water between 20 and 40 ng/l in the northwest Mediterranean, compared with oceanic levels of 5 to 15 ng/l. Offshore concentrations of zinc are reported to range between 150 and 240 ng/l (Morley and Burton, 1991); higher levels of 410 ng/l are found in the north Adriatic (Scoullos, 1993). A gradient of increasing concentrations of cadmium, lead, copper and zinc from the south to the north of the Adriatic Sea is also reported.

Elevated concentrations of mercury, cadmium, zinc and lead in sediments are found at 'hot-spots', which are generally in the coastal zones receiving industrial effluents, solid waste and domestic sewage. For example, concentrations of up to 37 mg/kg dry weight of mercury have been reported, compared with a typical background of 0.05 to 0.1 mg/kg dry weight (Fowler, 1990). Zinc concentrations are reported to be as high as 6480 μg/g, 5930 μg/g and 2550 μg/g (dry weight) at 'hot spots' along the coasts of Spain, at Venice and at Marseilles, respectively (Scoullos, 1993).

The MEDPOL program has used two indicator species for monitoring contaminants, the mussel (*Mytilus galloprovincialis*) and the red mullet (*Mullus barbatus*). Mercury has been given special attention because recent data show that Mediterranean fish (eg, bluefin tuna, *Thunnus thynnus*, sardines, *Sardina pilchardus*, anchovy, *Engraulis encrasicolus*, and scads, *Trachurus* spp) and other marine animals generally have higher levels than those of the North Atlantic (FAO, 1986).

However, results are very variable and are available mainly for the northern parts of the sea.

State of synthetic organic compounds in the system

A three-fold decrease in PCBs has been detected in coastal waters of the northwestern Mediterranean between the mid-1970s and the period 1978 to 1982. This trend has also been confirmed by measurements made along the French coast in 1984. The limited number of measurements of organo-chlorines in sediments in the Mediterranean show a few 'hot spots'. For example, elevated sediment concentrations of PCBs have been found near the Athens sewage outfall; in the Bay of Naples; near the Marseilles outfall; and offshore from Nice (UNEP, 1989). Measurements on biota are scattered and variable, but again the industrialised regions and major estuaries stand out. Mussels containing elevated levels of PCBs have been observed at Toulon and Marseilles near the Rhone estuary (UNEP, 1989). Levels of PCBs and other organochlorines in red mullet and mussels show a general decrease from the more northern parts of the sea to the south and east. There are as yet not enough reliable data for trend analysis.

State of oil in the system

Oil pollution in the Mediterranean Sea is associated mainly with shipping routes, ports and oil and gas exploration activities. Data on concentration levels of hydrocarbons show increases over recent years, especially with regard to concentrations in water and on beaches. In general, concentrations of dissolved/dispersed petroleum hydrocarbons in open waters are between 0 and 5 μg/l, and values above 10 μg/l have been observed near the shore, particularly near industrialised areas and river mouths (UNEP, 1989).

The amounts of petroleum hydrocarbons in marine organisms and sediments in the area are poorly known. The available data cover mainly the coastal zone, and thus the contamination of the open waters is less well known. Results also show an increased level of petroleum hydrocarbons in sediments compared with the concentrations in water, which indicates that they may be accumulating in the sediments. Aliphatic and aromatic petroleum hydrocarbon concentrations in sediments range from 1 to 62 μg/g, and 2 to 66 μg/g, respectively, along the Spanish coast outside harbours, oil terminals and river mouths (Scoullos, 1993). Polycyclic aromatic hydrocarbons (PAHs) in the northwest Mediterranean range from 0.4 to 0.7 μg/g in the deep sea basin, from 0.3 to 0.5 μg/g on the continental shelf, and from 0.4 to 5 and μg/g off Barcelona (Tolosa et al, 1993).

Almost no observations exist about the effect of petroleum hydrocarbons on Mediterranean marine organisms (UNEP 1989).

State of microbiological contamination in the system

The results from the 1992 bathing season (CEC, 1993) indicate that 97% of the designated bathing waters around Greece complied with the mandatory standard of 2000 faecal coliforms per 100 ml, as specified in the EC Directive on the quality of bathing water, and 95% were within the guideline value of 100 per 100 ml. The bathing water quality around the Italian coastline was also reported to be of relatively high quality, with 92% complying with the mandatory standard and 85% with the guideline value. The main areas of non-compliance included the Naples and Caserta districts, around Genoa in northern Italy and along the north coast of Sicily around Palermo. Along the

Spanish Mediterranean coastline, approximately 95% of bathing waters complied with the mandatory standard: non-compliant waters included those around the Granada, Malaga and Valencia areas. In France, 95% of bathing waters complied with the Directive.

State of nutrients in the system

The open Mediterranean Sea is nutrient-depleted. Typical 'background' concentrations of nitrate nitrogen are 7 μg $N\text{-}NO_3$/l, in moderately eutrophic areas 21 μg $N\text{-}NO_3$/l, and in heavily eutrophic, 70 to greater than 110 μg $N\text{-}NO_3$/l (GESAMP, 1990). Corresponding values for phosphate are 0.93, 4.7 and 9.3 μg $P\text{-}PO_4$/l, respectively. It is generally Mediterranean shores adjacent to urban agglomerations and tourist resorts (such as the Adriatic coast) which show the highest nutrient concentrations.

State of biological effects in the system

The Mediterranean Sea is generally considered to be oligotrophic (poor in nutrients) and does not have widespread problems arising from nutrient enrichment. However, coastal areas which receive anthropogenically enhanced nutrient loads from rivers and the direct discharge of untreated domestic and industrial wastewater are most susceptible to eutrophication. Examples can be observed in many coastal lagoons, estuaries and semi-enclosed bays, particularly in northern areas (eg, bays of the Ebro delta, the Albufera of Valencia, the coastal lagoons of southeastern France, the lagoon of Tunis, the Kastela Bay in Croatia and the Izmir Bay in Turkey (Estrada, 1993).

Two areas show extensive cultural eutrophication: the Gulf of Lions and the Northern Adriatic Sea. In the Northern Adriatic extensive dinoflagellate and diatom blooms occur in the spring and autumn: on occasions massive quantities of mucilage are produced (Estrada, 1993). However, the species responsible for this mucilage or gel production or the trigger mechanism is not yet fully known (Barth and Fegan, 1990). The key features of the North Adriatic which make it vulnerable to gel production are believed to be: shallowness (under 35 m); low turbulence during the summer and the high riverine nutrient input (Estrada, 1993). Studies in the Emilia-Romagna coastal waters of the northwest Adriatic
(to the south of the River Po delta) have indicated that phosphorus rather than nitrogen is the prevailing limiting nutrient (Vollenweider et al, 1992). However, in some circumstances in this area, such as in the summer and when nitrogen supply is low, nitrogen may also become limiting. The most severe eutrophic conditions are restricted to semi-enclosed bays and to the areas within the estuarine plume of the Po, which dominates the freshwater inputs. Numerous point sources are also important nutrient inputs. In response to the increased nutrient load, primary productivity increases with a maximum in the Emilia-Romagna area. During summer this area has suffered from persistent heavy algal blooms whose eventual decomposition causes anoxic conditions and mass kills of fish and benthic fauna. In 1990 the accumulation of gelatinous material produced by *Phaeocystis* spp on the beaches of Benicasim (Spain) had an adverse effect on the tourist trade.

'Red' tides also occur in the Mediterranean, often associated with the dinoflagellate *Noctiluca scintillans* (eg, frequently along the Catalan coast since the 1970s) (Estrada, 1993). Toxic algal episodes are also reported, for example, paralytic shellfish poisoning (from *Alexandrum minutum* and *Gymnodinium catenatum*) and diarrhetic shellfish poisoning (from *Dinophysis* spp). There is increasing evidence to suggest that mass development of toxin-producing unicellular algae is related to eutrophication. However, a cause-effect relationship between increased productivity and toxin production has not been proven (Barth and Fegan, 1990).

There has been a marked reduction in the *Posidonia oceanica* (seagrass) beds over the last decades. The reduction has been particularly noticeable around large industrial ports (eg, Barcelona, Marseilles, Toulon, Nice, Genoa, Naples, Athens and Algiers). The depths at which *Posidonia* is able to grow has also decreased. This has been associated with an increase in water turbidity reducing the amount of light exposure on the sea bed. Because of the role *Posidonia* plays in the Mediterranean ecosystem (see above, on biological features), its reduction is considered to have severe economic consequences (Boudouresque, 1993).

2. Human activities and pressures on the Mediterranean Sea system

2.1. Urbanisation

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, the estimates indicate 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. The distribution of population between the northern and southern countries in the Mediterranean varies dramatically: in 1950, the North Mediterranean 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. One third of the Mediterranean population is currently concentrated in the Mediterranean coastal regions.

2.2. Tourism

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.

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. The majority of these tourists will be of European origin.

Through its economic and social weight, its contribution the economic importance of tourism for the Mediterranean is such that no riparian state can do without this sector. 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.

2.3. 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. fertilizing: run-off of nutrients, especially nitrates and phosphates that can lead to eutrophication;
2. tillage: sediments carry phosphates and pesticides adsorbed to sediment particles;
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: fertilizing 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 pathogens;
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 jeopardizing about one-third of the world's irrigated land.

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 urbanization and other infrastructures. In the countries on the northern and western coasts, specialized monocultures achieve good yields and induce a gradual abandonment of marginal land. Therefore important decreases of agricultural land and strong increases of agricultural land under irrigation - are observed in the north and west. In the south and east, demographic pressure constantly increases and cultivated surfaces continue to expand at the expense of forests and grazing land.

The intensive use of fertilizers 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.

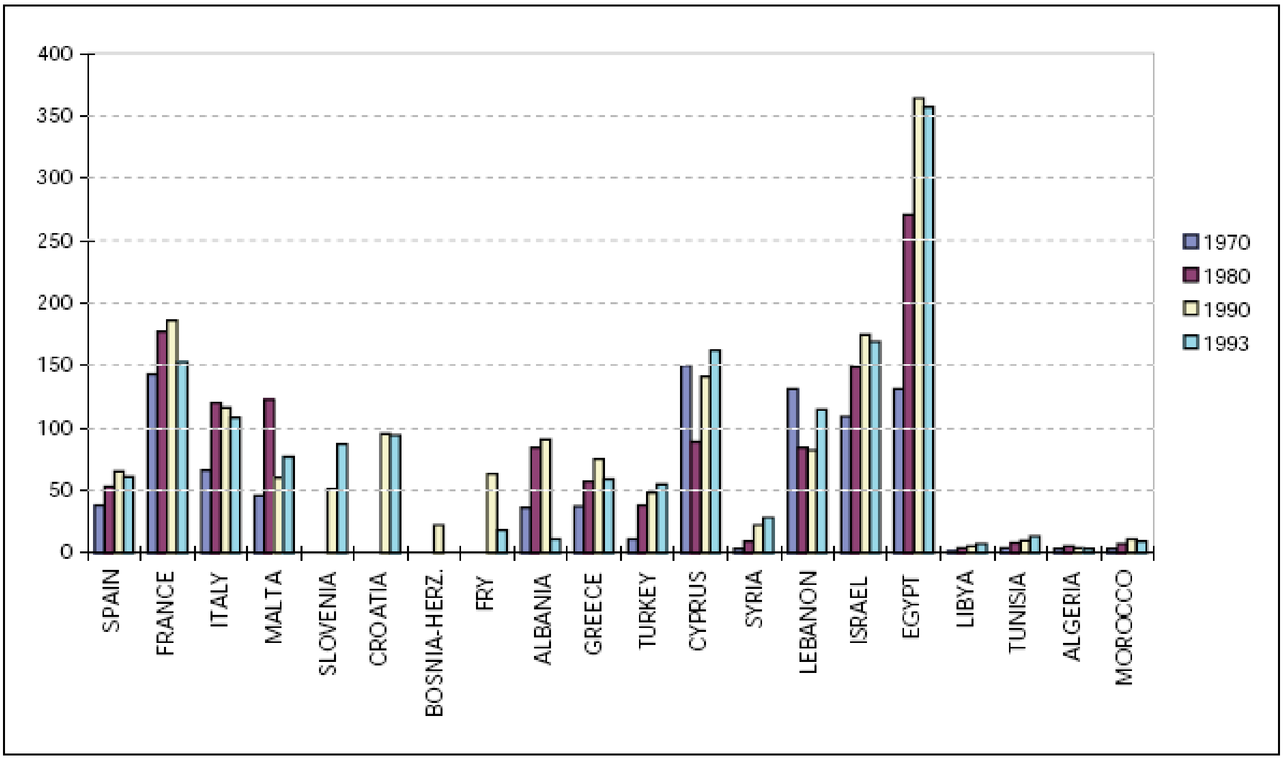


Figure 3. Fertilizer consumption in the Mediterranean countries from 1970 to 1993 (kg/ha) (Source: The World Bank, Social Indicator of Development 1996)

Country	Drainage Area, 10^6 t	Soil, 10^3 t	Total Phosphorous, 10^3 t	Total Nitrogen, 10^3 t	Total Organic Carbon, 10^3 t	Estimated average of annual soil loss, t/ha
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

Table 2. Soil erosion estimates and discharges of phosphorus, nitrogen and organic carbon to the Mediterranean Sea from agricultural land (Source: UNEP/MAP, 1997)

2.4. Fisheries and aquaculture

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), increased by 55%, followed by 'group 34' (jacks, mulletts) which increased by 25%, and 'group 32' (cod, hake, haddock, etc.), which increased by 10%. The mollusc catch increased from 1984 to 1996 by about 67%, 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). The catch of crustacea increased a little, 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*) by 66%.

Member State	Catches live (tonnes weight)	Fleet subsidies (EURO)	EURO/tonne fish
BE	29,799	2,874,000	96.44
DK	1,534,074	17,901,000	11.66
DE	205,245	7,529,000	36.68
GR	99,292	14,573,571	146.77
SP	994,739	152,286,000	153.09
FR	667,082	30,283,000	45.39
IRL	282,925	1,653,000	5.84
IT	299,955	43,075,000	143.60
NL	495,804	6,625,713	13.36
AU	859	0	0
PT	187,846	12,984,000	69.12
FI	158,453	1,879,000	11.85
SW	338,537	4,649,000	13.73
UK	746,294	15,160,000	20.31
Total	6,040,904	311,472,284	51.56

Table 3. Country by country analysis of catches in tonnes live weight, and public aid for fleet restructuring in 2000.

The regional aquaculture production increased from 78 180 tonnes in 1984 to 248 460 tonnes in 1996 (freshwater aquaculture not considered). In the period 1984-1996 the aquaculture production of marine fish in the marine environment increased about 400-fold, 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 141000 tonnes in 1996 (in the marine and brackish environments) while in relation ot marine fish, Greece is the leader in Europe with more than 80000 tonnes of sea bass and seabream and minor amounts of other euryhaline species (2003).

2.4.1. Fishing techniques

Fisheries target both demersal (bottom living) and pelagic fish (living and feeding in the open sea), with the following main types of fishing gear and methods:

- **Pelagic** fisheries: pelagic trawls and purse seines.
- **Demersal** fisheries: otter trawls, pair trawls, twin trawls, seines, gillnets, beam trawls.
- **Industrial-scale** fisheries: otter trawls, pelagic trawls, and purse seines.
- **Small-scale fisheries**: small vessels using various gears
- **Other fisheries**. Small scale fleets in European waters may fish for crustaceans such as *Nephrops*, *Pandalus,* and brown shrimp (*Crangon crangon*). A variety of artisanal gears such as dredges, pots and traps may be used for fishing bivalve molluscs, or pots may be used for trapping gastropod molluscs.

The term "**small-scale fisheries**", attempts to integrate aspects of "coastal" and "artisanal" fisheries and to avoid the inconsistencies of previous definitions. This term was introduced in 1990 by the European Commission in a proposal [COM(90) 358 final] of 7 September 1990, which amended Regulation 4028/86 on measures to improve and adapt structures in the fisheries and aquaculture sectors.

Many different types of fishing gears are used in European waters, and these can be divided into two groups. **Active gears** include trawls and seines, which move through the water and herd or surround the fish. **Passive gears** include hooks, gill nets, long-lines and traps, which rely on attraction or on the natural movement of fish to make contact between fish and gear.

EU fishing fleets operating in European waters are dominated by trawlers, purse seiners and small multi-purpose vessels exploiting different fisheries resources. In terms of numbers, 'passive' gear vessels have generally increased while numbers of trawlers have remained steady, as a result of the EU fleet reduction programmes.

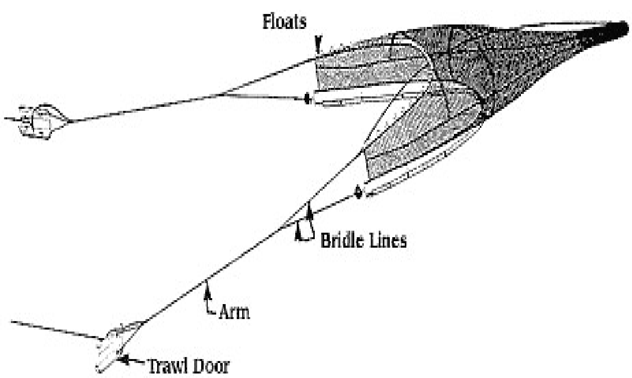


Figure 4. Otter trawl (active gear)

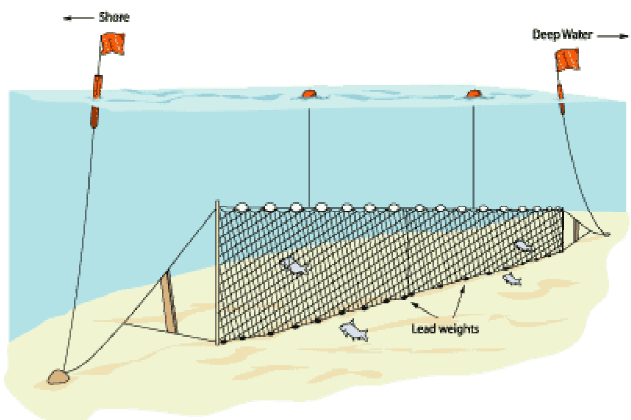


Figure 5. Gillnet (passive gear)

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. 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 licenses and subsidies to the sector, rather than quota control.

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). 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. Fleet technology is sometimes very advanced, and there has been a progressive shift from labour intensive to more capital intensive fishing vessels such as larger trawlers and multi-purpose vessels. Technological developments have radically changed fisheries since the 1960s, such as the development of the beam trawl fishery for flatfish, purse seines in the fishery for pelagics, and the replacement of drift nets by large pelagic trawls. New and more effective fishing gears have been introduced, but there have also been substantial improvements of existing gears such as bottom trawls, longlines, and handlines. In recent years, twin trawls have been introduced into the fisheries for flatfish and roundfish. The introduction of power blocks in the 1960s enormously increased the fishing power of purse seiners. Continuing right up to the present time, new developments of electronic equipment such as satellite navigation, fish finders, and sonar have constantly increased the fishing efficiency of fleets.

2.4.2. Impact of fishing on the Mediterranean Sea system

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 and 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 and Recasens, 1996) does not really 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 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).

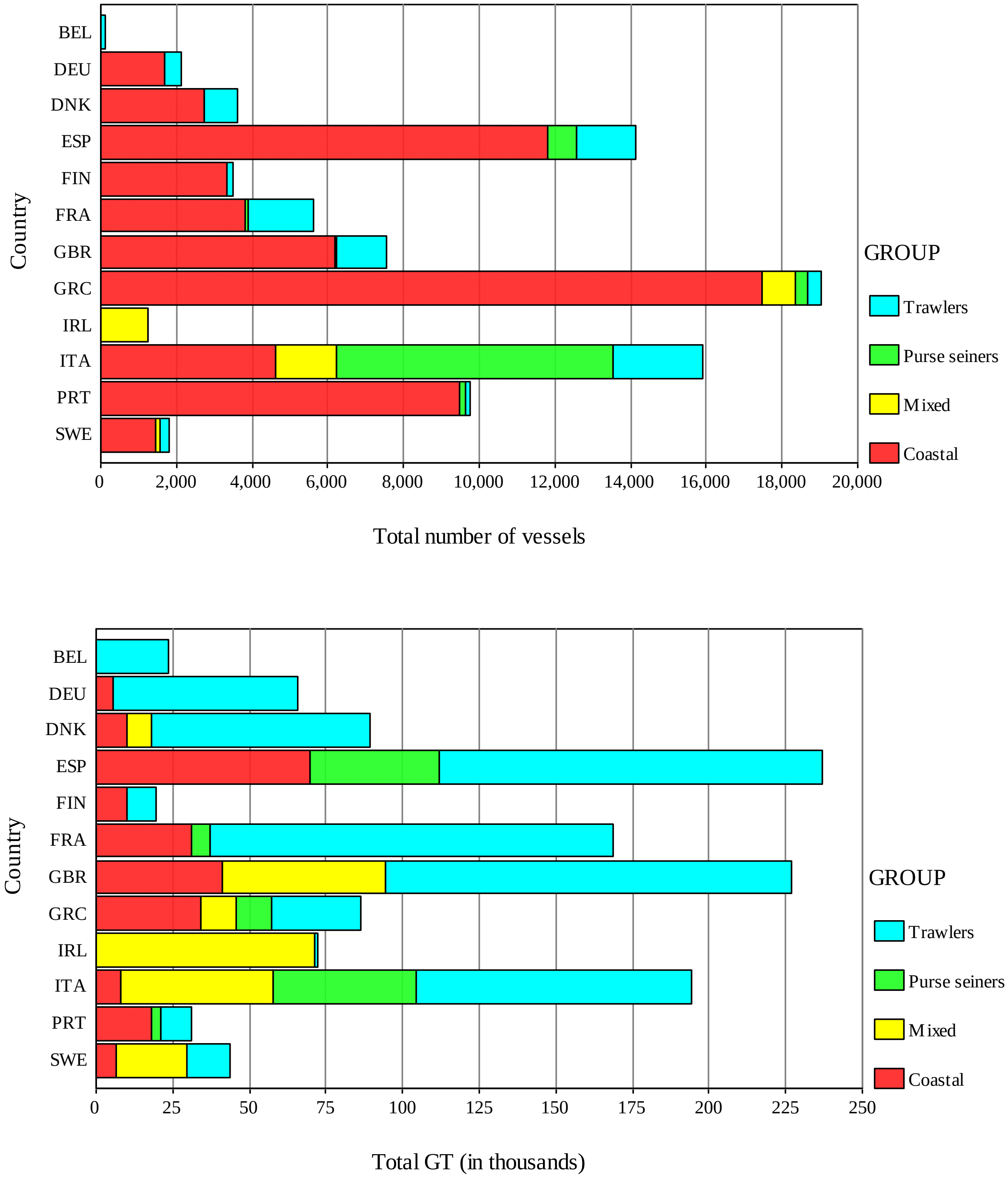


Figure 7. (a) Numbers and (b) tonnage of EU vessels operating inside Community waters, by country and type of fishery

Note: The following gears are included in each group: Trawlers (otter trawls, beam trawls, pelagic trawls, dredges), seiners (purse seines), mixed gears (trawls and purse seines), passive gears.

(Source: European Commission, Fishing vessel register 2003)

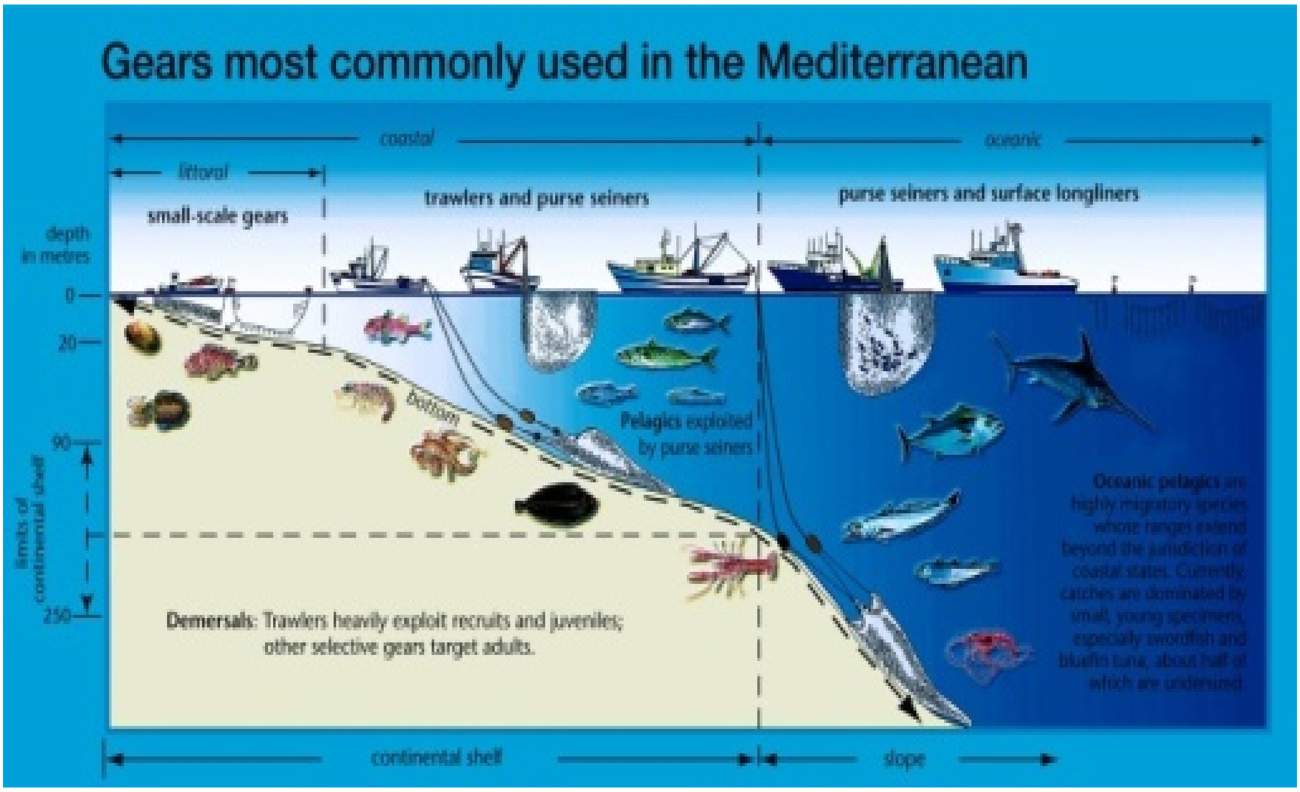


Figure 6. Most common used gears in the Mediterranean Sea
(Source: www.fao.org)

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 bluefin 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.

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.

(A) Dredging

Most dredges are rakelike devices that use bags to collect the catch. They typically remove molluscan shellfish from the seabed, but occasionally are used for crustacea, finfish, and echinoderms. Dredges take either epifauna or infauna; the design details of the gear are fauna specific. On soft bottoms, the dredge flattens the microrelief on the seabed (wave-ripples) and resuspends fine sediments. On hard rocky bottoms, the dredge scrapes off epibenthic organisms and disturbs the substrate.

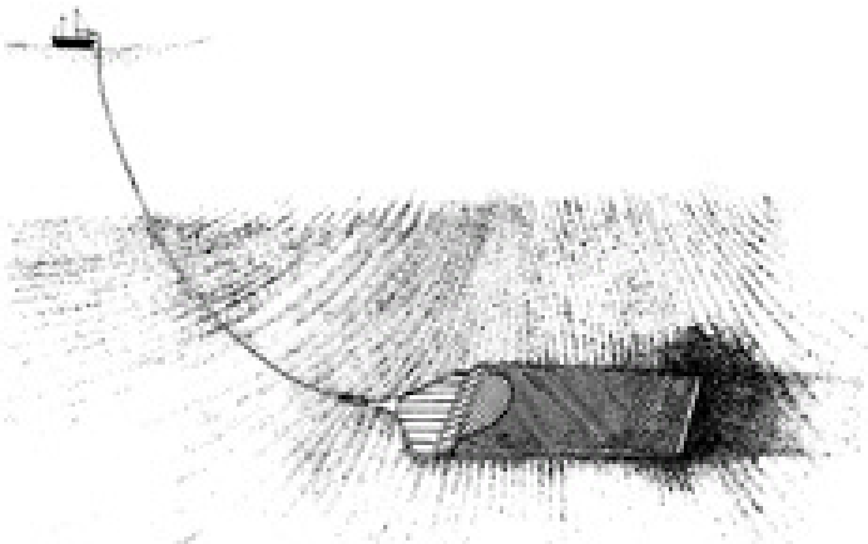


Figure 7. Action of a scallop and mussel dredge as it is dragged over a soft bottom seabed (DeAlteris et al., 1999).

Management of effort in dredge fisheries is generally achieved with time and area closures and with restrictions on the size (blade width and weight) of dredges, the number of dredges, and the size and horsepower of the towing vessels.

(B) Trawling

Bottom trawl disturbance of the seabed is principally a function of bottom type. On sand and mud bottoms, the trawl door scars consist of small mounds of sediment adjacent to a trough. Turbulence created by the passage of the trawl door resuspends fine sediment into the water column, as does the sweep of the trawl net when it scrapes the sand and mud seabed. On gravel, cobble, and bedrock bottoms, the trawl doors and the net sweep scrape along the seabed, removing epibenthic organisms and disturbing otherwise stable substrate. Small inshore trawlers (15 m), powered by 100+ HP engines, tow small nets (20 m sweep length), have short bridles (10 m) and ground gear (20m), and have a 20 m span between the trawl doors. Large offshore trawlers (50 m), powered by 1000+ HP engines, tow large nets (50 m sweep length), have long bridles (50m) and ground gear (200 m), and spread the opening 100 m between the trawl doors. Large vessels with bigger gear sweep larger areas of the seabed. The trawl doors, ground gear, and sweep all disturb the seabed as the gear is towed on the bottom. The magnitude of the interaction is a function of the design and operation of the specific trawl component and the nature of the seabed. Otter doors range in design from the traditional flat, rectangular boards that create great turbulence in their wake to the modern slotted or foil board that reduces turbulent drag by maximizing hydrodynamic efficiency. Trawl sweeps range in design from simple looped chain sweeps used on smooth, soft bottoms to large roller and rockhopper sweeps used on hard, rough bottoms. The development of this more sophisticated trawl sweep technology (rollers and rockhoppers)—combined with sonar technology and the precise navigation afforded by GPS—allows fishermen to trawl areas of the seabed previously considered too rough to fish with mobile gear.

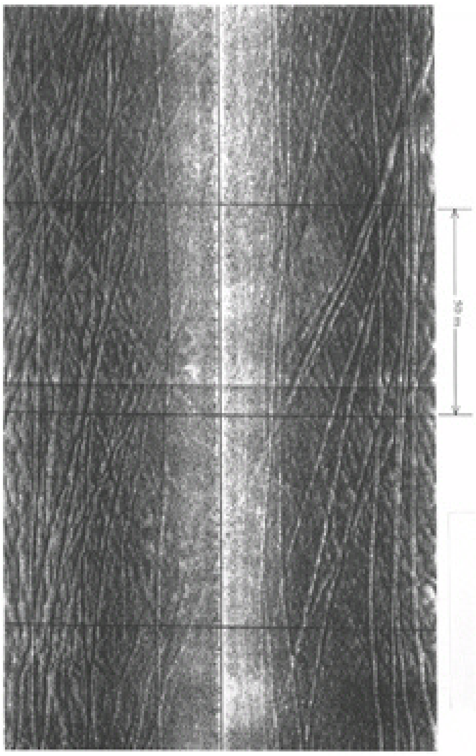


Figure 8. Side-scan sonar digital image (50 m × 100 m) showing 10+ bottom scars generated by mobile fishing gear (De Alteris et al., 1999)

Figure 9. Sand cloud generated by a trawl door as it is towed over a flat sand seabed (Main and Sangster, 1981)

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 industrialization.

Finally, illegal fishing using methods and means destructive for the system are known to be used in the Mediterranean Sea. Most important is dynamite fishing or blast fishing. The use of such method not only kills more fish than required or can be harvested but also causes extreme damages to the sea floor and sedentary fauna and flora.

Figure 10. Use of home-made dynamite is very common in tropical areas

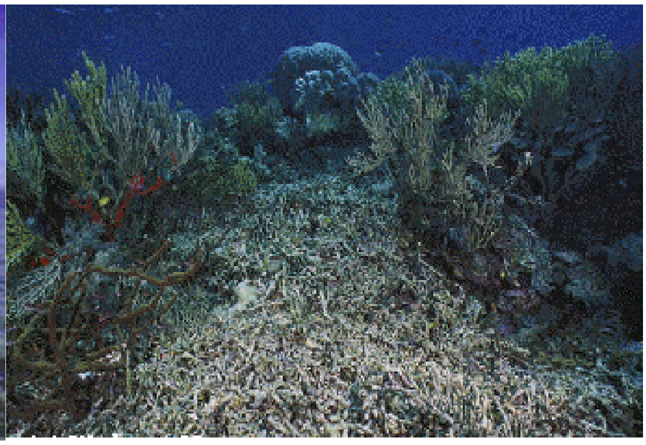


Figure 11. Blast fishing causes extreme damages on the sea floor

2.4.3. Mediterranean Sea Fisheries Management approaches

In general, fisheries management in the Mediterranean employs relatively few measures compared to North Atlantic fisheries, and if anything, has tended to focus on socio-economic, geographic and market controls rather than catch control. Fresh fish prices in the Mediterranean are generally higher than elsewhere in Europe, and this contributes to the high share Mediterranean catches make up of the value of the European total production. Close links exist to supplying the tourist trade in some countries, and a relatively minor component of processed products are produced from local catches, which, as for frozen products, do not necessarily exceed in value the fresh product which sells at a premium. TAC and quota systems are not applied except for the bluefin tuna fishery, largely because the trawl fisheries are predominantly small-scale, with a large number of species in the catch and many landing points, which would make quota control difficult to implement.

Mesh-size regulations are set at small sizes (generally 40 mm stretched mesh in the cod end) relative to scientific recommendations, although paradoxically, the market and high price paid for small fish and small fish species (such as small cephalopods and shrimps) makes for a reluctance to move to higher mesh sizes. In fact, an incidental but unlooked for result of the low mesh sizes in shelf trawl fisheries is the apparently low availability of large mature fish to capture by small mesh trawls: one reason being that larger fish of a species are often found in untrawlable areas, which are relatively common on the Mediterranean shelf, and apparently are less easily caught by fine mesh gears. In fact, despite the relatively low level of technical measures applied, Mediterranean landings appear not to have suffered from the serious collapses in demersal stocks that have characterized North Atlantic fisheries, nor has spawning stock depletion, which results from targeting older fish with large mesh sizes apparently reached critical levels. Studies have shown (Caddy and Seijo, 2002), that the Mediterranean trawl fishery for hake is predominantly aimed at immature fish, but that the economic contribution from capturing mature female fish or potential spawners older than age 4-5, (close to the age at maturity), is less than their potential reproductive contribution to future harvestable generations. These considerations have contributed to a reluctance to raise mesh sizes to Atlantic levels, for fear of larger mesh gear targeting the few mature fish that are able to escape small mesh trawl gear. Using larger mesh sizes would also mean not catching those small species which are highly appreciated components of local traditional dishes (such as small shrimp species, cephalopods, gobies, etc).

The General Fisheries Commission for the Mediterranean (GFCM) has strongly recommended effort limitation, but such measures are not always rigorously applied. Despite this, there has been some progress towards management by closed seasons and areas, and this has provided some positive results. Fisheries legislations vary widely in the different Mediterranean countries, but the wide variety of conservation/management measures they contain can be broadly separated into two major categories: those aiming to keep fishing effort under control, and those aiming to make the exploitation patterns more rational. The first set of measures is based on restricting the number or fishing capacity of the vessels, rather than on catch limits. Among these measures, there are some that seek to limit the expansion of the number of vessels through a licensing system and could be characterized as direct measures, while others place upper limits on the fishing capacity of individual vessels, through engine power and tonnage limitations, and can be characterized as indirect.

The second set of measures is based on provisions concerning gear specification, gear deployment, fishing practices and techniques, as well as fishing seasons and areas and resource exploitation patterns, and are collectively known as technical measures. A number of technical measures have already been incorporated into the national laws of all FAO/GFCM Member States, including limitations on vessels licensing, minimum mesh size, minimum landing sizes, etc.

Since the early 1990's, the Community has taken a number of initiatives to try to improve fisheries management in the Mediterranean. These included harmonization of technical measures, increasing the selectivity of fishing gears (including a ban on driftnets), and strengthening international co-operation. However, the results did not meet expectations: both international co-operation and the strengthening of GFCM procedures are progressing slowly, while internal measures suffer from a lack of acceptance (and therefore compliance) by fishermen, and from poor monitoring by Member States. The reformed CFP, takes into account the specific characteristics of the region, and considers that the following actions should be undertaken:

- Member States should co-ordinated initiatives to establish wider fisheries protection zones;
- Community-level management is necessary for high1y migratory fish stocks and other shared stocks, such as certain small pelagic and demersal stocks;
- A revision of current technical conservation measures in the Mediterranean Sea, such as mesh sizes and minimum landing sizes, with a view to ensure coherence with Community-level management;
- Management schemes for shared stocks are required to be based on effort limitation;
- Co-operation between fishermen's associations in the Mediterranean region should be encouraged;
- For all other issues within 12-mile zones, national management should apply;
- Community initiatives should be aimed at strengthening international co-operation for fisheries management in the region, in particular through regional fisheries organizations.

2.4.4. Marine Reserves

Marine Protected Areas (MPAs) are considered promising as measures for conserving fish stocks (e.g. Gell and Roberts, 2003), although the small size of many existing MPAs may make their contribution to spawning stocks of exploited species in MPAs and no-take zones rather limited.

Nonetheless, these measures are strongly recommended for incorporation within conventional fishery management frameworks. As noted in Caddy (1998), the high diversity of habitats and species along the narrow Mediterranean shelf inevitably calls for the use of spatial measures such as MPAs, and smaller management units allowing some devolution of management responsibility to local government entities.

Badalamenti et al. (2000) listed 33 MPA's in EU Mediterranean waters in 1999; many of them very small (less than 100 ha) with 8 greater than 10,000 ha in surface area. It seems evident nonetheless that though MPAs form a small fraction of Mediterranean shelf areas, some increases in the abundance of large species within them has already become evident. Specifically, from 89 studies of MPAs that have been at least partially closed to fishing, Halpern (2003) concluded that 63% increased the abundance of protected animals, 80% increased their average size, 90% increased biomass, and 59% increased diversity (number of species per unit of census area). The magnitude of gains was independent of the size of the MPAs. Theoretical studies predict that protecting 20-40% of fishing grounds by a network of local-scale reserves would produce maximum benefits to fisheries. The rates of population build-up are usually rapid, especially in the early years following protection.

A review of the above-mentioned set of MPAs (Halpern and Warner, 2003) found that beneficial effects were evoked quickly; with average long-term mean values reached within 1-3 years after protection and that they then remained stable for long periods. One controversy (that also applies to the installation of artificial reefs as conservation tools) is between those scientists that say they lead to stock enhancement, and others who suggest they simply aggregate the existing fish populations. Again, this seems a function of the fraction of the stock area within the reserve – large closed areas are most likely to be effective given seasonal migratory behaviours of many species. Another controversy relates to the main purpose of fishery closed areas: the protection of nursery areas in shallow water was the main objective of earlier closures such as the 'Plaice box' in the North Sea. In Europe, studies in MPAs have shown that these reserves can also provide effective protection to seagrass habitats of importance for finfish recruitment. More recent EC regulations promoting stock recovery have supported the closure of deeper water areas where formerly there were concentrations of larger spawning cod, and given the growing appreciation of the critical importance of conserving older spawners, we may see further development of deeper water closed areas. Experience shows that fisheries in adjacent areas may benefit from increased or more consistent catches and improved incomes for local fishers

2.4.3. Impact of aquaculture on the Mediterranean Sea system

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 minimizing 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.

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.

The total amount of nitrogen (N) and phosphorous (P) entering the aquatic environment is calculated on the basis of simple formula used by Ackefors and 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 and 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.

	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					

Table 4. Amounts of phosphorous (P) loads into the Mediterranean Sea system from intensive aquaculture activities
(Source: European Environmental Agency, 1999)

	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			

Table 5. Amounts of nitrogen (N) loads into the Mediterranean Sea system from intensive aquaculture activities
(Source: European Environmental Agency, 1999)

2.5. Industry

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 16 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.

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.

In respect to **exports**, three groups of countries can be distinguished:

- The first group is very specialized in some export products, the rest being imported. This is typical of oil producing countries such as Algeria, Syria, Egypt and Libya;
- The second group is less specialized, 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 fibers, wool, cotton, paper, cement in Turkey and FR Yugoslavia);
- The third group is strongly diversified and thus much less specialized. It comprises 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.

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 privatization 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 (Bosporus) 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).

2.6. Shipping

It is estimated that about 220000 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 2000 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. 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. 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 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.

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%). Between 1987 and the end of 1996 an estimated amount of 22000 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 13000 tonnes in 1991.

3. Natural processes and pressures on the Mediterranean Sea system

3.1. 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 program 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 and Sciortino, 1997).

3.1.1. Sea level rise

One of the most important aspect of the impact of climate change likely to affect coastal zones is the prediction of sea level rise, potentially accelerated by anthropogenic activities. 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 and Leatherman, 1995).

According to the Intergovernmental Panel on Climate Change (IPCC) the average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice sheets. 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 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 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 physical impact of sea level rise on the Mediterranean lowland coasts can be predicted, even modeled 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 sea level 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, 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.

3.2. 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 10000 to 12000 marine species have been registered for the Mediterranean Sea (with 8500 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 urbanization, 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 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 fertilizer-treated fields.

Benthic communities in undisturbed areas in the eastern Mediterranean, for example, present high species diversity in coastal waters which declines with depth. They consist of polychaetes (50-65%), mollusks (15-25%), crustaceans (10-20%), echinoderms (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 polychaet 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 and 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.

3.3. Introductions of non-indigenous species – Lessepsian migrants

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, 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 (CIESM, 1989abc).

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 and Stomatopoda, and fish.

4. The Black Sea

4.1. General Description

The Black Sea is kidney-shaped inland sea located between Europe and Asia. The Black Sea system is composed of the central Black Sea basin and the Sea of Azov. It exhibits an are of 423000 km² plus 32000 km² of the Sea of Azov. The maximum depth of the central basin is 2258 m while the depth of the Sea of Azov is 13 m. The average depth of both basins is 1272 m and 8 m respectively. The thickness of the water layer which exhibits dissolved oxygen concentration in the central basin is 50-100 m only out of the 2258 m of maximum depth.

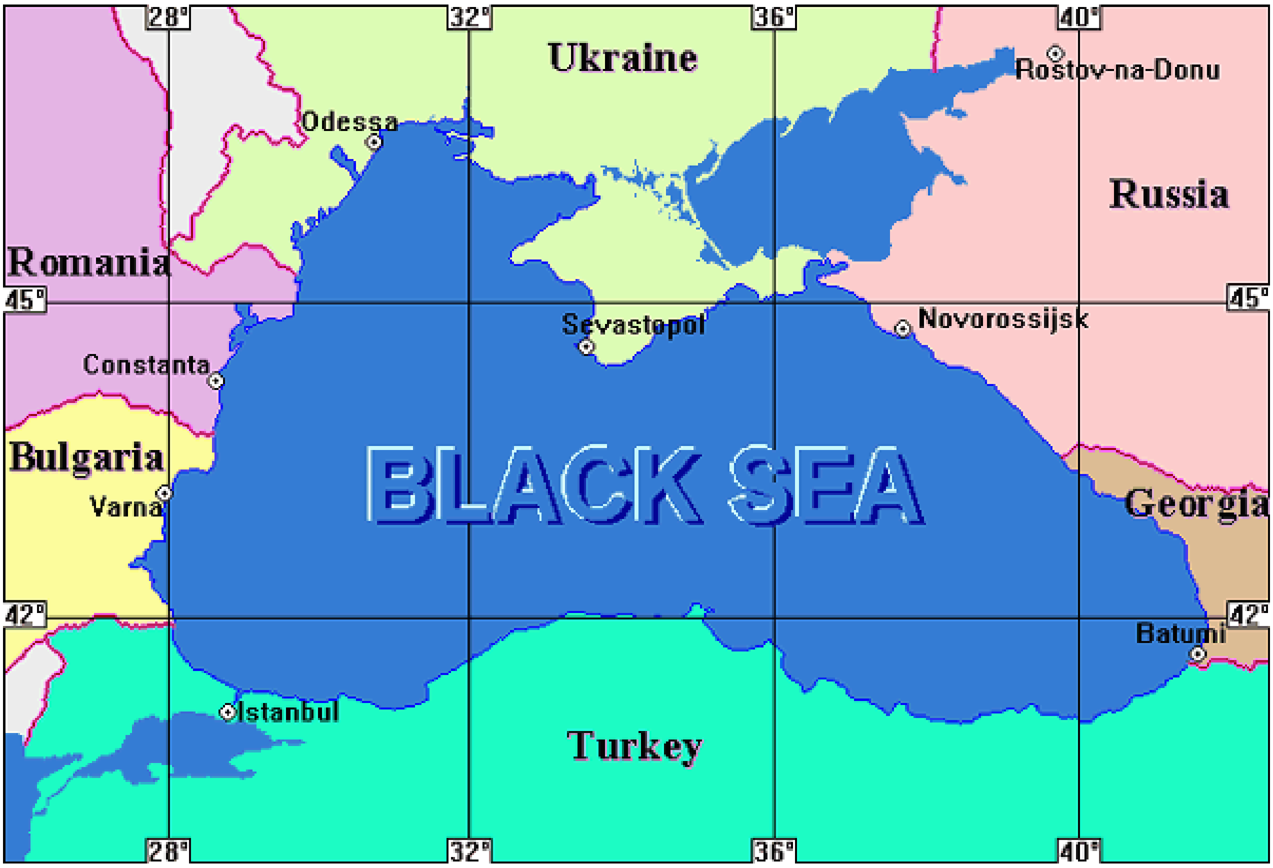


Figure 12. Political map of the Black Sea reagion

The Black Sea system is surrounded by Romania, Bulgaria, Turkey, Georgia, Russia and Ukraine. The most important rivers that flow into the Black Sea are the Danube and the Dnieper while in the Sea of Azov outflows the river Don.

4.2. Physical characteristics

The Black Sea system is geographically very isolated from the open sea and therefore, coastal pollution and outflow from the rivers into the basin are the main driving forces for the environmental quality of the basin and the effects on the resources. Those rivers are:

Danube river:
Beginning in the Black Forest region of Germany, it flows across central Europe and the countries of Austria, Hungary, Croatia and Yugoslavia. It then forms the border between Romania and Bulgaria, turning north across Romania to eventually end in the Black Sea. It's 2850 km in length, and one of the most significant commercial waterways on the continent.

Dnieper river:
Rising in the southwestern part of the Russian Federation, it flows generally south through Belarus, then southeast through Ukraine, ending in the Black Sea. Overall it's 2285 km in length.

Don river:
Beginning it the southwestern Russian Federation, to the south of Moscow, it flows southeasterly towards the Volga, then turns abruptly west, ending in the Sea of Azov. Overall it's 1969 km in length.

In total, the rivers that outflow in the Black Sea are:

Name	Catchment Area, km^2	Length, km	Total Runoff, km^3/year	Sediment Discharge, 10^6 t/year
Danube	817 000	2860	208	51,7
Dnieper	505 810	2285	51,2	2,12
Dniester	71 990	1328	10,2	2,50
Southern Bug	68 000	857	3,0	0,53
Chorokh	22 000	500	8,69	15,13
Rioni	13 300	228	12,8	7,08
Inguri	4060	221	4,63	2,78
Kodori	2030	84	4,08	1,01
Bzyb	1410	-	3,07	0,60
Yesilrmak	-	416	4,93	18,0
Kizilrmak	-	1151	5,02	16,0
Sakarya	-	790	6,38	

Table 6. Main river systems in the Black Sea region

Almost a third of the total land area of the European continent drains into the Black Sea through major rivers such as the Danube, Dnieper, and Don. The 700-mile-long Black Sea is nearly landlocked: its only connection to the world's oceans is through the narrow Bosporus. Thus, it takes nature hundreds of years to replenish the Black Sea's bottom waters with fresh seawater. Due in large part to natural conditions, over 90% of the Black Sea is devoid of oxygen. It has the largest "dead zone" — where no oxygen exists — in the world. Only its thin surface layer contains oxygen, and it is here where almost all of its marine life dwells. However, the biological diversity of the Black Sea has declined dramatically in the past 40 years. Large nutrient inputs from untreated sewage and other sources have fueled blooms of algae that eventually rob the water of oxygen as the tiny plants are decomposed. Overfishing, industrial pollutants, and a recent invasion of alien jellyfish delivered via the ballast water of foreign ships are among the many other factors that have affected the local resources and environmental quality.

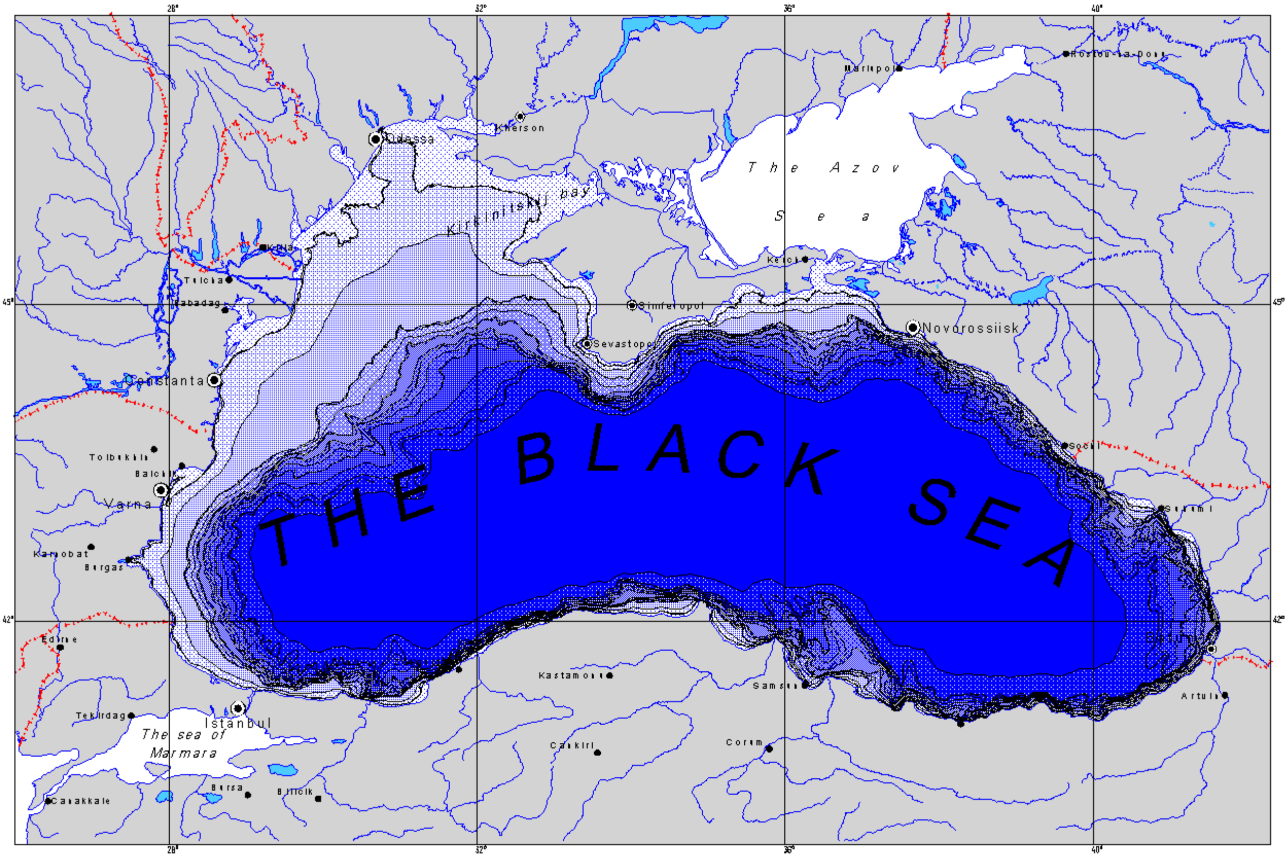


Figure 13. Main geographic features, bathymetry and river network of the Black Sea basin

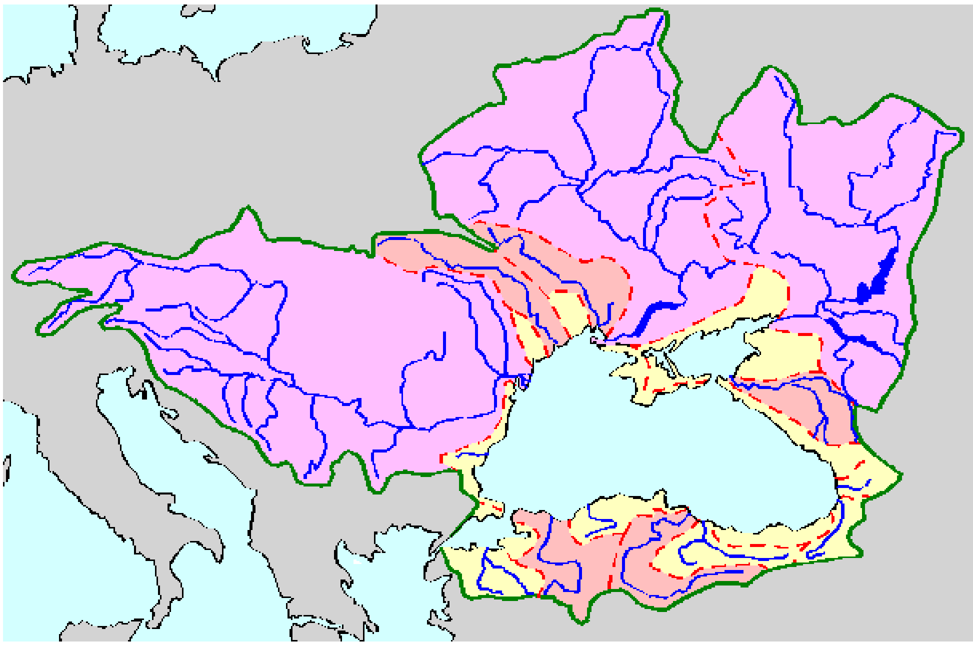


Figure 14. Drainage area of the Black Sea basin

4.4. Biological features

The most biologically productive areas of the Black Sea include the northwestern and northeastern parts of the basin, including the Azov Sea. This is because these areas receive enhanced nutrient loads from the inflowing rivers as well as being subject to efficient vertical mixing.

There are 180 species of fish in the Black Sea, more than half of which are also present in the Mediterranean Sea as well as 3 species of dolphin. The brackish nature of the Black Sea restricts the number of species of organisms present. Because the water below about 100-150 m contains no oxygen it is largely devoid of life, except for anaerobic bacteria.

The Ukrainian part of the Black Sea has 4 conservation/nature reserves which comprise extensive marine areas (COE, 1990b). The Danube Delta Protected Area has a rich and varied marine fauna, with 92 fish species including salmon, sturgeon and *Clupeidae* (including many endemic species). The area also has great ornithological value with 225 species of aquatic birds. Chernomosk National Reserve includes large marine areas (11000 ha) of the Black Sea and Sea of Azov: its waters are productive with extensive mats of *Zostera* and *Phyllophora*. Its rich fauna includes the very rare Black Sea herring. Karadag Park in the Crimea (809 ha) also has extensive beds of *Zostera*, rocky shores and many nesting sea-birds. Mys Martjan Park, Crimea, holds many species that have disappeared from other areas.

4.4. Inputs

The nutrient load to the Black Sea has increased markedly in recent decades, probably as a consequence of the widespread use of phosphate detergents and intensification of agriculture. This has been reflected in an increase in the concentrations of nitrogen and phosphorus compounds. Between 1970 and 1991 a two- to three-fold increase in the nitrate maximum, just above the halocline, has been reported. During the same period a seven-fold increase in phosphate concentration was observed along the Romanian shelf (Mee, 1992).

According to EEA Indicator Fact sheet WEU7, the main origin of nitrogen and phosphorous in the Black Sea are domestic waste, industrial wastes and riverine waters by 4.4, 33.3 and 62.2% for nitrogen respectively for nitrogen and 18.4, 7.9 and 73.7% for phosphorous respectively. Given the extremely wide catchment area and the development policies of the Balkan countries the last 40 years, the extremely low environmental quality of the basin is expected. A recent study (Ludikhuize, 1992) commissioned by UNEP (for the Global Environment Facility) gave a preliminary assessment of inputs to the Black Sea. It suggests that 65% of the nitrogen input to the Black Sea is via rivers, 40% alone from the Danube River (that is, 340 kilotonnes total inorganic nitrogen). This study also estimated the inputs of nitrogen from different sources of which agriculture and domestic wastewater contributed the largest share (31 and 26%, respectively). Other important inputs were from industry and atmospheric deposition. However, data about the different sources were very limited in this study and values are rough estimates. There are few data on phosphorus inputs but the same study estimates that the Danube River is again the most imporant source, contributing some 60 kilotonnes of total phosphorus input to the Black Sea.

The annual oil load of the Danube River in the period 1988 to 1989 has been estimated at 50000 tonnes. Few data exist about sea-based sources, which are expected to account for the oil pollution along shipping lanes and in ports. Oil drilling along the Romanian coastline may be another potential source of oil pollution. However, several active oil rigs have been subject to protective measures and monitoring has not yet detected adverse effects (Balkas et al, 1990). Inadequate port reception facilities and deballasting activities add further inputs of oil.

There are also 16 official waste disposal sites within the western Black Sea on the continental shelf: dredging spoils are disposed of at these sites and these would add an unquantified load of contaminants to the offshore zone of the sea.

State of heavy metals

There are few published data on heavy metals in the Black Sea, and those available reflect high and very variable concentrations. This is probably due to analytical difficulties caused by their low concentration in sea water. Concentrations of metals in water are generally higher in the nearshore zones than further offshore and in the open sea. In particular, high levels of cadmium are found along the coastline of Romania (up to 1.6 μg/l compared with open sea levels of 0.05 μg/l), and high levels of mercury and copper along the Bulgarian coast (up to 2.6 μg/l mercury and 83 μg/l copper, compared with open sea levels of 0.1 μg/l and 0.5 μg/l, respectively (Dechev, 1990).

State of synthetic organic compounds

There are generally no validated data on pesticides in the Black Sea, though levels of up to 200 to 300 ng/l total organochlorine pesticides have been reported in the River Don, compared with general levels of 10 to 30 ng/l in water of the Sea of Azov, and 5 ng/l in the open Black Sea. In addition, mean and maximum water column concentrations of *HCH and *HCH (lindane) are reported to be 5 ng/l and 23 ng/l, and 1 ng/l and 5 ng/l, respectively.

Total DDT water concentrations in the Kerch Strait range from 8 to 20 ng/l, approximately two orders of magnitude higher than in the Mediterranean Sea (Mee, 1992). Measurements made in 1981 and 1982 indicated DDT water levels of 32 to 486 ng/l in the region of the Danube delta and

20 to 550 ng/l of lindane. Total DDT levels in two fish species were reported to be in the order of 1 μg/g (dry weight) for *Gobius* spp and 4.6 μg/g (dry weight) for *Sprattus* spp.

Surfactants (synthetic detergents) are reported to be widespread in the surface waters of the Black Sea and Sea of Azov, ranging from 0.6 mg/l around Odessa to 0.1 mg/l in the open waters of the Black Sea, and 1.2 mg/l in the coastal zone to 0.1 mg/l in open waters of the Sea of Azov (Mnatsakanian, 1992). There are also 'hot spots' of phenol in water, such as up to 14 ng/l in the Odessa area and 18 ng/l in other northern coastal areas. Levels of phenol in water up to 3 ng/l have been found along the western shores around the Danube, along eastern shores and in the Sea of Azov.

Stat of oil

Areas of the Black Sea are severely polluted with oil, particularly those areas subject to river discharge and ports. Sevastopol Bay, which serves as the major port for the Black Sea navy, is the most polluted, with an average annual concentration of 5 mg/l, over 100 times higher than the maximum permissible concentration (MPC) allowed by the Russian Federation water standards. Even the average open sea oil concentration of 0.1 mg/l exceeds the MPC by a factor of two, and is two orders of magnitude higher than oil concentrations in the open North Sea (1 to 3 μg/l). Oil pollution along shipping lanes is especially heavy (typically around 0.3 mg/l) and is suggested to be caused by deballasting and bilge discharges. Some ports (Odessa and Novorossiysk) have facilities for this but others do not (eg, Varna, Burgas and Sevastopol).

State of nutrients

Associated with the increasing loads of nutrients into the Black Sea over the last 25 years, there has been a long-term change in nitrogen and phosphorus concentrations. For example, between 1960 and 1975 the nitrate and phosphate concentrations along the Romanian coast have increased between 5-fold and 10- to 20-fold respectively (Mee, 1991). Ammonia and phosphate concentrations increase, and nitrate decreases, with depth in the Black Sea; this is caused by the decomposition of organic matter under anoxic conditions. Mean surface water concentrations of ammonia, nitrate and phosphate were reported to be 2.8 mg N/l, 0.8 mg N/l and 0.4 mg P/l, respectively (Dechev, 1990). At 500 m nitrate is no longer present but ammonia concentrations are some 21 times greater (58.5 mg N/l) than at the surface, and phosphate some 14 times greater (5.6 mg/l).

State of microbiological contamination

There are few data on the bacterial level of municipal wastewater and the level of bacteriological pollution of coastal waters, but a large number of beaches have been known to suffer from bacteriological contamination. This led to the closing of many Ukrainian beaches during the summer of 1989. The beaches of the easternmost part of the Sea of Azov and Taganrog Bay were also closed in 1989 because of alleged bacterial contamination.

State of radionuclides

Deposition of Chernobyl radionuclides occurred in the Black Sea, but there are limited data on the resultant concentrations within sea water, sediments and biota. Available information indicates that sea water concentrations in the Crimea area ranged between 190 and 650 Bq/m^3 Cs-137, and 79 and 320 Bq/m^3 Cs-134 during 1986: these had decreased to between 90 and 120 Bq/m^3 Cs-137 and to between 20 and 55 Bq/m^3 Cs-134 during 1987 at the same place (Stepanets et al, 1992). Other sources of information report that Cs-137 concentrations in the Black Sea ranged from 41 to 165 Bq/m^3, and Cs-134 from 17 to 78 Bq/m^3, following the Chernobyl accident (Balkas et al, 1990).

4.4. Human Impacts on the Black Sea system

Eutrophication

The evidence is overwhelming that a major part of the Black Sea is critically eutrophic (Mee, 1992). Eutrophication is especially apparent in the northwestern shelf area because of the heavy anthropogenic nutrient load carried by the rivers. Other areas suffering from eutrophication include Crimea, Kavka and near Batumi. The consequences of eutrophication in the Black Sea and Sea of Azov include:

- increased algal blooms;
- gradual basin-wide shallowing of the euphotic zone (eg, Secchi disc depths have decreased from 50 to 60 m in the early 1960s, to present values of 35 m, or as little as 10 m in parts of the coastal zone);
- a massive loss of shallow water macrophytes (large algae and rooted plants);
- widespread reduction in dissolved oxygen concentrations;
- occasional formation of anoxic benthic layers of hydrogen sulphide distinct from the permanent anoxic layer in the main basin;
- changes in the food-chain; and
- severe reductions in fish stocks.

Eutrophication has caused the base of the food-chain to change, resulting in an increase in the development of monospecific blooms of plankton. Higher levels within the food-chain have subsequently also been changed with massive basin-wide biomasses of jellyfish (*Aurelia aurita*) and a predatory comb jelly (*Mnemiopsis leidyi*). The decomposition of the massive quantities of these two species has resulted in widespread hypoxia and has caused a large reduction in the number of macrobenthic marine species. These changes to the marine ecosystem of the Black Sea have contributed to the demise of the fisheries and reduced its tourist potential.

Opportunistic species

A number of opportunistic species, brought into the Black Sea in the ballast water of ships, have found ecological niches in which they thrive. Some of these species have had important ecological consequences for the Black Sea and Sea of Azov:

- *Rapana thomasiana* (a predatory sea snail from Japan) has been blamed for a decrease in commercially harvested oyster populations and a decrease in biodiversity.
- *Mya arenaria* (a soft-shelled clam) successfully established itself on the Romanian shelf and reached densities of over 1000 individuals/m^2. This species has actually been beneficial to the environment in this area by improving the ecosystem's capacity for self-purification.
- *Mnemiopsis leidyi* (a predatory comb jelly) has attained a gigantic biomass in the Sea of Azov. It feeds on zooplankton and fish larvae and is itself at the end of the food-chain. The

decomposition of the large numbers of individuals is exacerbating the problem of hypoxia, especially in shallow waters of the Sea of Azov and the northwestern shelf area, although it is also affecting the entire basin area.

Fisheries

The combination of reduced river discharge, increased water pollution, recruitment failure and overexploitation has adversely affected fish stocks in the Black Sea and Sea of Azov. Commercial fishing in the Dnepr and Dnestr estuaries has been much reduced and some valuable species such as pike (*Esox lucius*), perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), bream (*Abramis brama*) and vimba (*Vimba vimba*) have disappeared altogether. In fact, of the 26 commercial fish species abundant in 1970, only five are left in commercial quantities today: the anchovy (*Engraulis encrasicolus*), sprat (*Sprattus sprattus* and *Clupeonella cultriventris*) and horse mackerel (*Trachurus mediterraneus* and *Trachurus trachurus*). Depletion of the stocks of the dominant predators such as bonito (*Sarda sarda*), bluefish (*Pomatomus saltatrix*) and dolphins in the 1970s coupled with the increase in primary productivity and zooplankton biomass has resulted in this increase in biomass of small pelagic fish.

The main fisheries biological resources of the Black Sea basin are:

- red mullet
- horse mackerel
- mackerel
- gray mullet
- Atlantic bonito
- shad
- sprat
- anchovy
- turbot
- sturgeon
- thornback ray
- dogfish

The main grounds of these species distribution is close to the Danube river delta and therefore, they have suffered significantly from the outflow of contaminated fresh water while the persistent anoxia below 100 m also has affected their migrations and their feeding grounds.

The collapse of the pelagic fishery in the Black and Azov Seas had grave consequences for the economic and social conditions of fishermen and the fishery industry of the respective coastal countries. Before the outbreak, the catch of former USSR States reached 250000 tons; now they are about 30000 tons. Turkish catches before and after the collapse were of a similar order of magnitude. Fishing vessels are for sale in many countries, and fishermen are abandoning their profession. Therefore, the organization of international control of the use of Black Sea resources and of investments in the fishery industry is vital and urgent.

It could be supposed that the fishery suffers not only from the anthropogenic impacts (pollution, overfishing, introduced *Mnemiopsis*) but possibly also from climatic changes. The long-term fluctuations of the fish stocks of exploited species have taken place concurrently with changes of the taxonomic composition of the catch. From 1940 to 1960, the catch was dominated by pelagic plankton feeders, anchovy and horse mackerel, with some additional larger predators. In the catch from 1960 to 1970, the large predators (horse mackerel, bonito, mackerel, bluefish) were abundant. In the early 1990's, up to 95% of the catch was composed of the pelagic plankton-feeders, anchovy, sprat and horse mackerel. Thus the catchable stock of fish has been reduced in biodiversity, resulting in a possible greater vulnerability of the fishery to external impacts (Caddy and Griffiths, 1990).

The total catch of all coastal countries around the Black Sea increased significantly over several decades, until the collapse in 1989. The peaks of the catch in CIS countries occurred in the late '70s-'80s, then stabilized. In contrast, Turkish landings continued to rise in the 1980s to become dominant. After 1988, the total Black Sea catch went down sharply as a result of the *Mnemiopsis* invasion (GFCM, 1993). The total fish stock before 1988-1989 was estimated at 3.5-4 million tons, of which the anchovy, sprat and horse mackerel made up about 2-3 million tons, include 1.5 million tons in the CIS area. The same situation existed with fish stocks and catches near the Turkish coast. Thus, after 1981, the highest annual fish catches among all Black Sea (as well as all Mediterranean) countries have been achieved in Turkey. The 60-72% of the total fish production of Turkey consisted of Black Sea anchovy between 1980 and 1988. After 1988, the Turkish Black Sea anchovy and consequently the total Black Sea catch decreased sharply. Acoustical studies showed that the total stock of anchovy in the Turkish Exclusive Economic Zone between 1989 and 1992 ranged from only 150 to 360 thousand tons. In the same period, 22-44% of fish were estimated to be caught.

The anchovy catches decreased drastically after 1988, largely as a consequence of the *Mnemiopsis* invasion (GFCM, 1993). Sprat catches also decreased, but later - after 1990 - as a consequence of the decrease in fishing efforts by CIS countries. At this time, the fishery faced serious socio-economic problems, notably, shortages of fuel for fishing boats. The stock of sprat is now estimated to be high. Thus, in the CIS zone, the stock of sprat is estimated to be about 500000-700000 tons.

Simultaneously, the harvestable stocks of horse mackerel, anchovies and red mullet declined severely, suffering from the *Mnemiopsis* invasion which decreased the concentration of available zooplankton. Some improvements in 1992-1993 could be deduced from the Turkish fish landing data for those years. Data on catches of the Black Sea anchovy by traps along Romanian and Ukrainian coasts (the north-western part of the Sea) show a trend of increasing anchovy catches during the summer season of 1993-1994. Increasing anchovy catches, from 70000 to 100000 tons, were also occurring along the Turkish coast (Kideys, 1994).

Horse mackerel stocks are currently in decline. Trap catches by Ukrainian fishermen show some quantities of fry and young fishes (age 1+). However, forecasts are not good for an increase of horse mackerel stocks in the coastal zone of Romania, Ukraine and Russia in the near future. In 1993-1994, the Ukrainian fishery landed a total of about 22-40 thousand tons of fish from the Azov-Black Sea region: approximately the same catch was obtained in 1992, but this was several times lower than catches between 1980-88 (Volovik et al., 1993). The same situation was noted in the Romanian fishery where catches of commercial fishes were approximately 3.3-4.0 thousand tons in 1993-1994, which is 4 times less than catches in previous decades. Fisheries in Bulgaria have failed almost entirely in recent years, too.

The catch declines described above were a consequence not only of the *Mnemiopsis* impact but also a result of the economic and social crisis in CIS nations. In such a situation, careful monitoring of international co-operation has to be established.

Invasive species

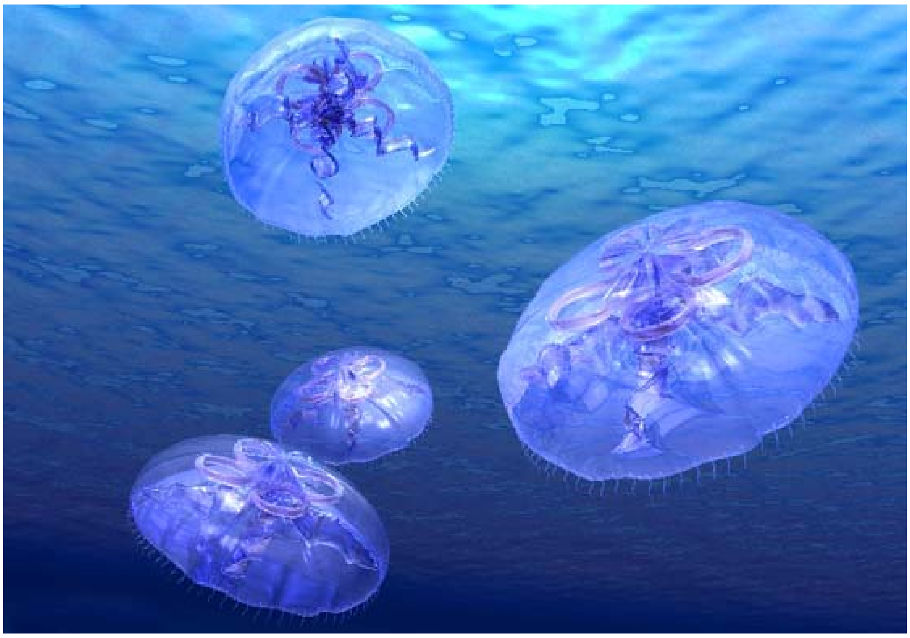
During the last 50 years, the Black Sea ecosystem has changed dramatically. Urbanisation, over-fishing and uncontrolled agricultural runoff are the apparent reasons. Targeted commercial fishing on the apex carnivorous fish at the top of the food chain, allowed their prey species, including jellyfish, to multiply with little resistance. In the late 1960s and 1970s, mackerel, a major predator, were eliminated from the Black Sea ecosystem, which may be why severe outbreaks occurred of a formerly uncommon jellyfish, *Rhizostoma pulmo.* The second stimulus for jellyfish (scyphozoans) and comb jelly (ctenophores) outbreaks in coastal areas of the Black Sea has been the release of excessive nutrients into its waters through agricultural runoff.

Jellyfish of the Black Sea

Two members of the scyphozoan phylum that have made dramatic appearances in the Black Sea are *Rhizostoma pulmo* and *Aurelia aurita. Rhizostoma pulmo,* is native to the Mediterranean, North Sea, Black Sea, and Sea of Azov. Feeding on zooplankton plus the eggs and larvae of fish and shellfish, this jellyfish was not formerly considered an important link in the Black Sea's animal community. In fact, in some parts of its range, this jellyfish was considered beneficial as it offered protection to certain fish larvae and served as food for sea turtles. However, in the late l960s and 1970s, conditions in the Black Sea enabled its numbers to swell to such an extent that it proved a great nuisance on area beaches. In the 1970s, *Aurelia aurita* populations surged so powerfully in the Black Sea that scientists claimed this species of jellyfish, alone, was consuming 62% of all zooplankton produced in that body of water — food that previously supported important fisheries. Today, *Aurelia aurita* are still extremely common over the Black Sea's open waters.

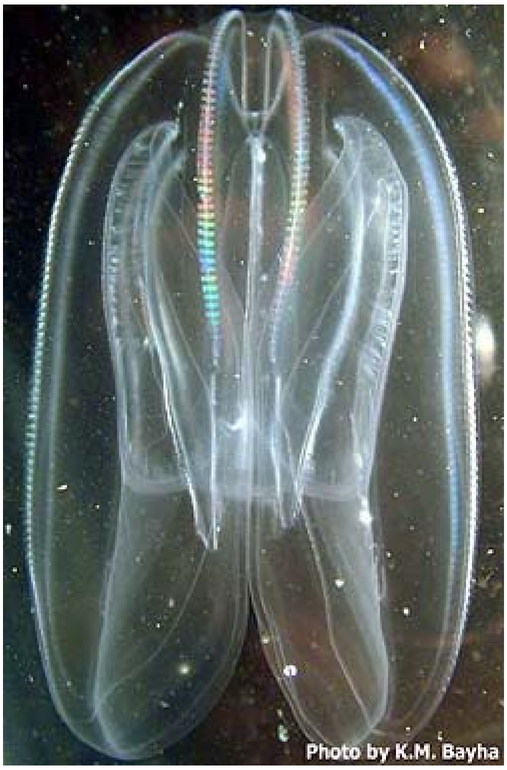
Comb Jellies of the Black Sea

Though the jelly-like comb jellies are classified in a different animal phylum than jellyfish (which signifies a distant relationship), they also share the jellyfish's preference for zooplankton, along with the eggs and larvae of fish and invertebrate animals. Ctenophores commonly found in the Black Sea are *Pleurobrachia pileus, Mnemiopsis* (various species)*, and Beroe ovata.*



Aurelia aurita

Beroe ovata



Mnemiopsis

Pleurobrachia pileus, which uses two tentacles to grab food, occurs mostly in deeper, low-oxygen water, where it enjoys large quantities of *Calanus* copepods.

Mnemiopsis is a comb jelly native to the Atlantic coastal region between Massachusetts and southern Argentina. In its natural range, it has been known to heavily impact ecosystems by consuming vast quantities of zooplankton, eggs, and the larvae of fish and invertebrates that would otherwise support populations of more desirable species. *Mnemiopsis* was first observed in the Black Sea in the early 1980s, where it is thought to have been transported and dropped by the ballast water of freighters arriving from distant shores in the western Atlantic. By the late 1980s, populations of *Mnemiopsis* soared, populations of its favored zooplankton food plummeted and coincidentally, commercial catches of the zooplankton-eating anchovy (*Engraulis encrasicolus*) were drastically reduced. A few years ago, *Mnemiopsis* was accidentally introduced into the Caspian Sea, where a similar impact is beginning to be seen.

Beroe ovata also is native to the same general region as *Mnemiopsis*. However, unlike most ctenophores, *Beroe* feeds on crustacean zooplankton, but prefers dining on other ctenophores. Interestingly, the primary food for *Beroe ovata* is *Mnemiopsis*. Considering that *Beroe* was first detected in the Black Sea in l997, this relationship offers one explanation for why *Mnemiopsis* populations have declined in recent years. It is now thought that purposely introducing *Beroe* may be a potential solution to the problem of *Mnemiopsis* in the Caspian Sea.

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