

Human Pressure, State and Impacts on Mediterranean Ecosystems

Coastal Ecosystems and Landscapes

Pollution

Eutrophication

Marine Litter

Marine Noise

Non-indigenous Species

Commercially Exploited Fish and Shellfish

Sea-floor Integrity

Hydrographic Conditions

Marine Food Webs

Biodiversity

Cumulative and Concurrent Impacts

The ability to suggest measures in order to reach the objectives agreed within the framework of the Ecosystem Approach is grounded on the systematic analysis of the major issues identified. The following chapters include information on the pressures, state and impacts associated with each of the major issues, moving progressively from pressure dominated to state dominated and from coastal to offshore focussed issues. The amount of information related to each of the issues varies depending on how much focus has been placed in the past on that specific issue and it does provide an initial indication of where further work is needed if the objectives related to them are to be fulfilled.

Coastal Ecosystems and Landscapes

Coastal landscapes

Many centuries of interactions between natural and human-induced processes have created a complex landscape mosaic in the Mediterranean Basin (Bratina-Jurkovič 2011). This evolution has been shaped by major historical developments. In recent times, the period of population growth, industrialisation and technical and technological advances following the Second World War precipitated major land-use changes, especially increased urbanisation and agricultural intensification. New pressures on Mediterranean ecosystems came with these changes, including increased need for arable land and fresh water and increased demand for land and sea transportation. The expansion of urbanised and cultivated land and marine traffic caused multiple impacts, including habitat loss, reductions in freshwater and sediment discharges by rivers, salinisation of coastal aquifers, soil and coastline erosion and eutrophication of some coastal waters. These continuing pressures and their associated impacts now threaten natural and cultural landscape integrity and diversity in the region, altering the fine-grained and multifunctional landscape and limiting options for sustainable development.

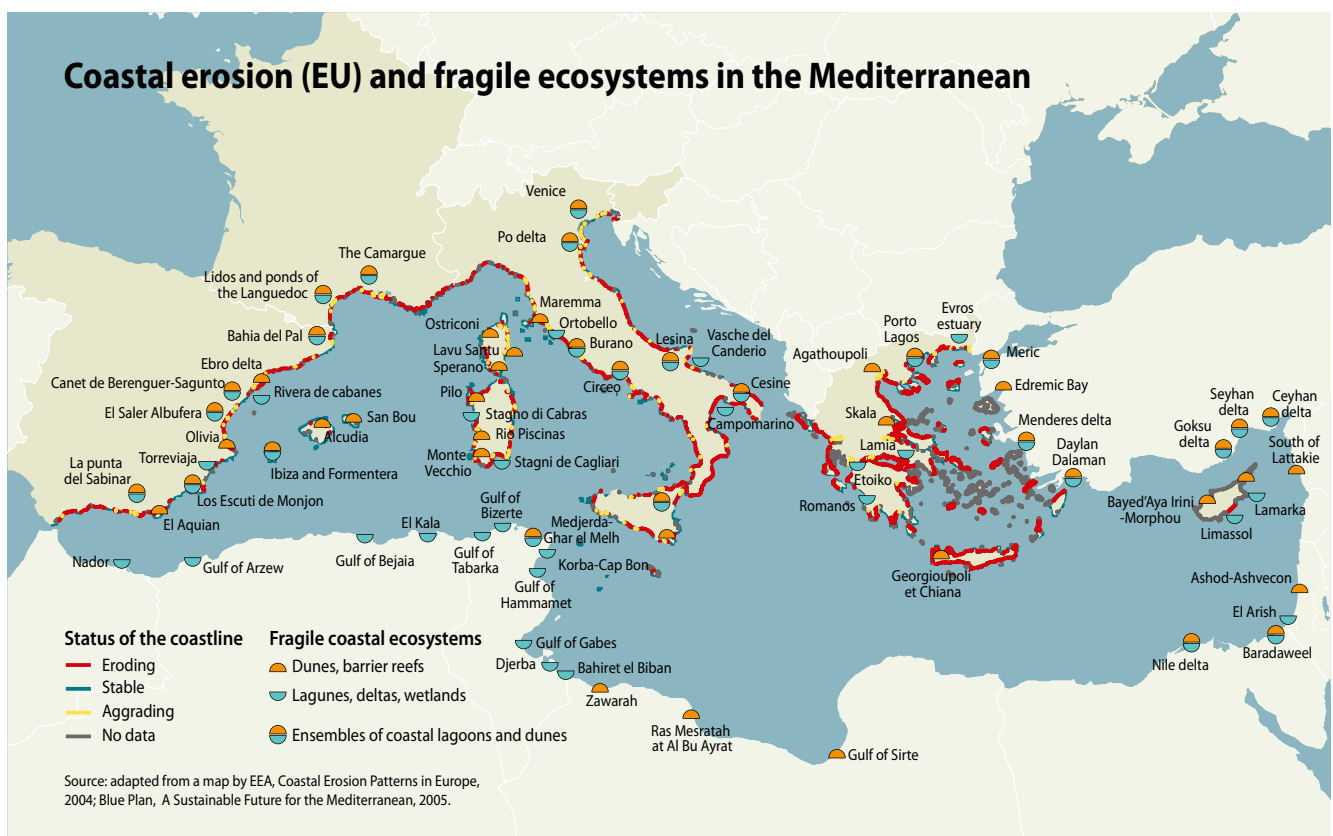
In the Mediterranean Basin, the areas that have experienced the most human-induced change are those most intensively exploited due to ready availability of the natural resources needed for settlement. Deltas are good examples, with low-lying terrain suitable for construction of dwellings, arable land, freshwater resources and easy access to the sea.

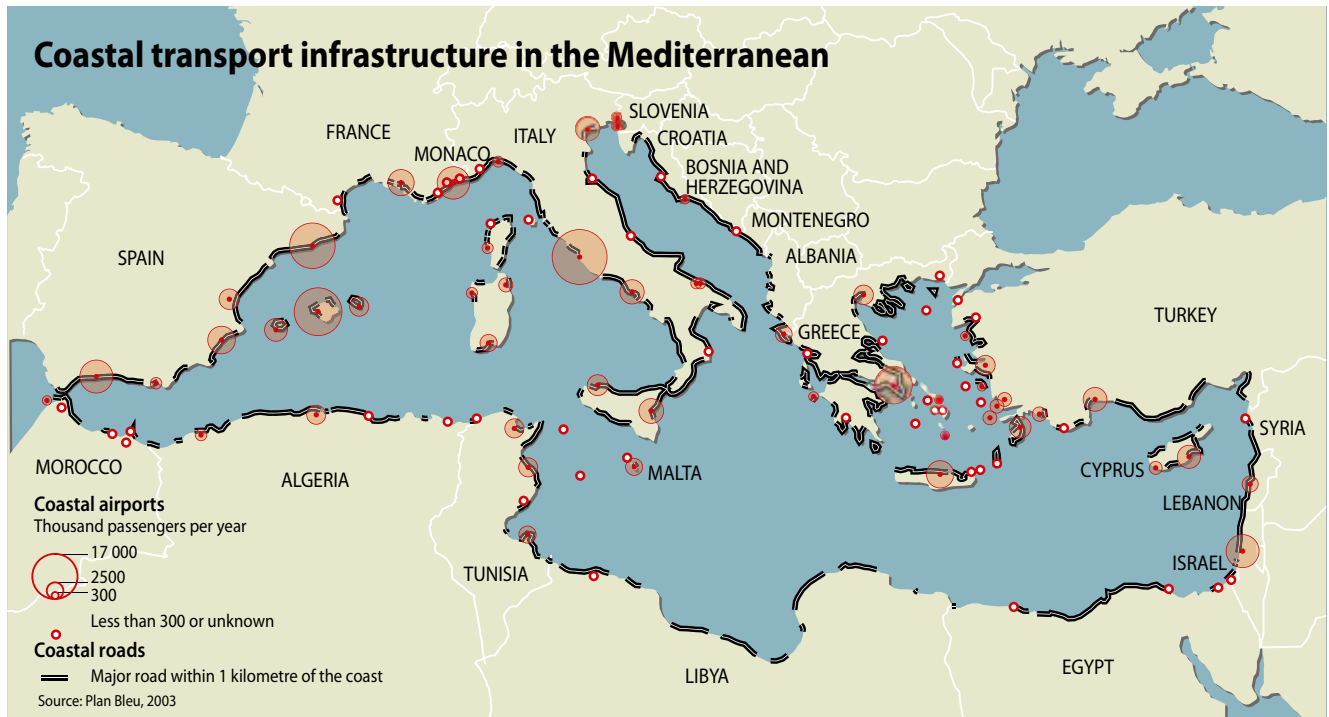
Coastline stability and erosion

The Mediterranean coastline is approximately 46.000 km long, with nearly 19.000 km of island coastline. 54 % of the coastline is rocky and 46 % is sandy coast that includes important and fragile habitats and ecosystems such as beaches, dunes, reefs, lagoons, swamps, estuaries and deltas. Low-lying sedimentary coasts are more dynamic than rocky coasts. The balance between sea-level rise, sediment supply and wave and coastal current regimes will determine whether the coastline advances (accretes), remains stable, or retreats (erodes).

Model predictions for the extent of sea-level increase in the Mediterranean for the 21st century range up to 61 cm (in a worst-case scenario) for the Eastern Mediterranean (Marcos and Tsimplis 2008). Satellite altimetry data on variations in the level of the Mediterranean Sea between January 1993 and June 2006 indicate that sea level will rise more in the Eastern Mediterranean than in the Western Mediterranean. Delta areas, due to their topography and sensitive dynamics, are most vulnerable to impacts from sea-level rise.

Coastline stability is also affected by the increase in artificial structures, both within the drainage basin (especially reservoirs) and along the coastline (the proliferation of marinas and other urban and tourist-industry infrastructure). About 45 % of the sediments that would be delivered by rivers to the Mediterranean annually are either retained behind dams or extracted from river beds for sand and gravel, leading to an overall deficit





of sediments on the coast (UNEP/MAP 2009). Artificial structures associated with beach-dune complexes and waterfronts, the destruction or degradation of sea grass beds and dune vegetation, and the extraction of gas, water and sand may also affect the cycling and redistribution of sediment in neighbouring coastal areas, especially if modifications to the coastline have not been properly planned and designed (EEA and UNEP 1999).

Systematic research and documentation of coastline erosion has been carried out only on the Mediterranean states that are members of the EU, as part of the LaCoast, CORINE (Coordination of Information on the Environment), and EuroSION projects. Approximately one-fourth of the EU Mediterranean coastline suffers from erosion, with variation among countries. Sea defences to control erosion have been constructed along 10 % of the European coastline. These defences, however, often cause undesirable impacts, including increased erosion in other areas.

CORINE coastal data showed that, by the last years of the 20th century, 1.500 km of the EU Mediterranean coast had been transformed to “artificial coast” (mostly concentrated in the Balearic Islands, Gulf of Lion, Sardinia, and the Adriatic, Ionian, and Aegean seas). European harbours accounted for 1.237 km of this total (EC 1998). Even for EU states, the lack of information and the difficulty in accessing dispersed data have been obstacles to assessing the status and trends in erosion. This has

hampered implementation of policies for the protection and management of the coastal environment at local, national and regional levels (CORINE 1995).

Among the many impacts erosion has on coastal ecosystems are the destruction of soil surface layers, leading to groundwater pollution and to reduction of water resources; degradation of dunes, leading to desertification; reduction of biological diversity; adverse effects on beach dynamics; reduction of sedimentary resources; and disappearance of the sandy littoral lanes that protect agricultural land from the intrusion of seawater, resulting in soil and groundwater salinisation (EEA and UNEP 2006).

CORINE data were used to produce an inventory of natural sites of high ecological value that are affected by coastal erosion. The Gulf of Lion, the Ligurian Sea, the Tyrrhenian coast of Italy, and the Po Delta all contain many such sites. One of the major findings of the CORINE project was that coastal erosion management practices often indirectly use protected natural areas established under Natura 2000 (an EU network of protected areas) as sources of sediment. As Natura 2000 sites were selected because they are considered critical to the survival of Europe’s most threatened habitats and species, these practices have significant implications for long-term coastal biodiversity and ecosystem resilience (Salman *et al.* 2004).

Pollution

Marine and coastal pollution affects water, sediments, and biota. It can be related to oxygen-depleting substances, heavy metals, persistent organic pollutants (POPs), hydrocarbons, microorganisms, nutrients introduced by human activities or debris. The latter two sources of pollution are discussed in the chapters on Eutrophication and Marine Litter respectively. Many different kinds of pollutants enter the Mediterranean Sea from its shores (land-based sources) either via discharge points and dumping grounds (point-source pollution) or from surface fluvial run-off (non-point-source pollution). Pollutants also enter the marine and coastal environments through atmospheric deposition, while others are introduced directly by marine activities such as shipping, fishing, mining, and oil and gas exploration.

Research on the impacts of pollutants on the environment has tended to focus on pollutants known to be most harmful to human health (for example, mercury). The geographical distribution of studies is poor, with little known about impacts from contaminants in many regions of the Mediterranean.

Concentration, distribution and potential impacts of priority contaminants

Wastewater organic matter

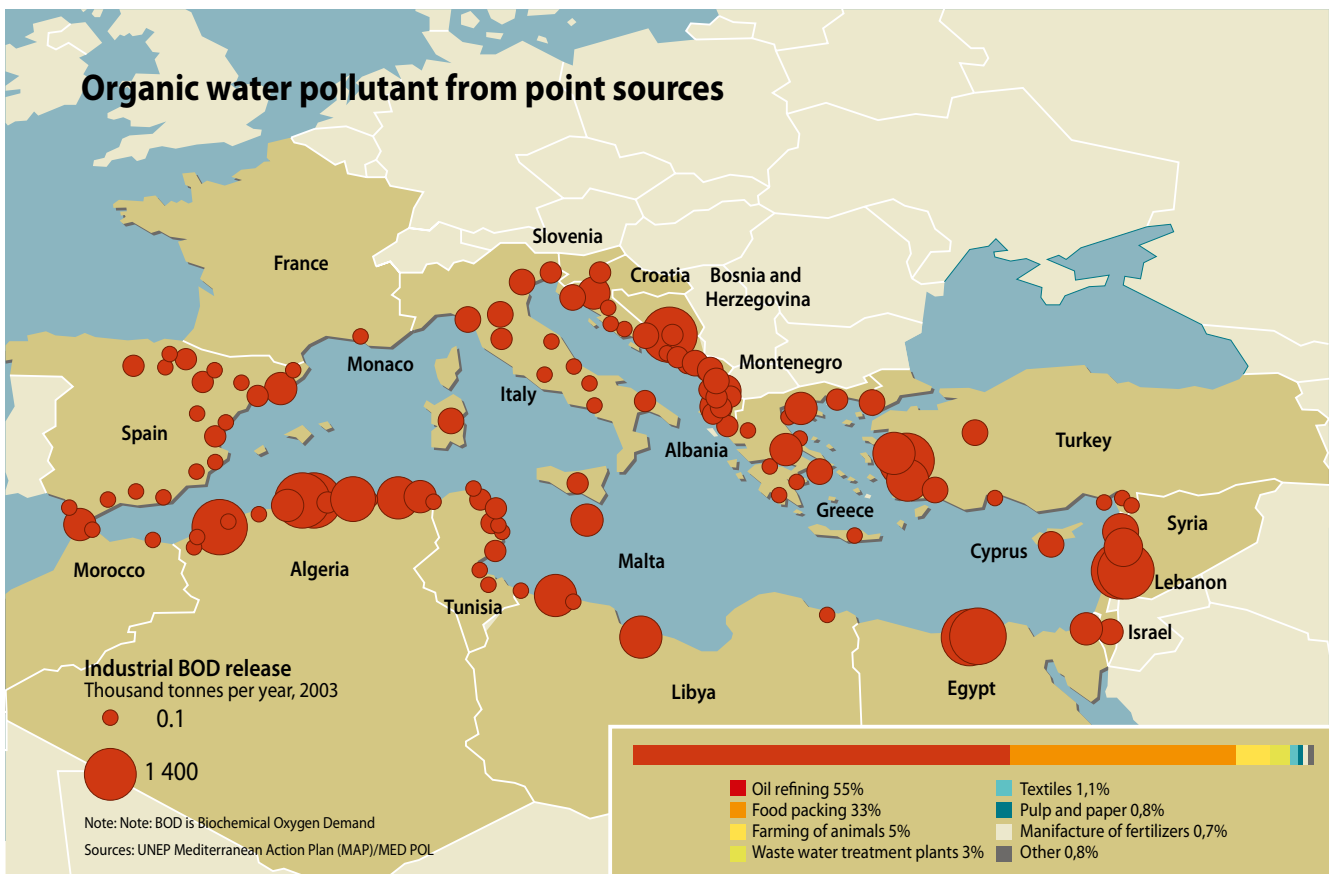
Organic matter in coastal and marine waters originates mostly from urban/domestic and industrial wastewater entering marine waters through direct point-source discharges or through rivers. The extent of organic matter pollution is measured as the Bio-

chemical Oxygen Demand (BOD), the amount of oxygen needed by microorganisms to oxidise organic matter in the water.

The distribution of coastal cities that either lack wastewater treatment facilities or have inadequate treatment facilities (defined as those removing less than 70 to 90 % of the BOD) can be used as a proxy to identify areas where potentially deleterious amounts of organic matter are being added to the marine environment. Effective removal of pollutants from wastewater is achieved through secondary treatment that removes, through physical and biochemical processes, organic matter responsible for 70 to 90 % of the BOD. About half of organic-matter pollution from sewage originates from direct, untreated discharges, while less than one-third is in discharges of inadequately treated sewage.

63 % of coastal settlements with more than 2.000 inhabitants operate a wastewater treatment plant, while 37 % do not. Secondary treatment is mostly used (67 %) in Mediterranean treatment plants, while 18 % of the plants have only primary treatment (UNEP/MAP/MED POL and WHO 2010). The distribution of treatment plants is not uniform across the Mediterranean region, with no sewage treatment in many cities on the southern shore of the Western Basin, in coastal Sicily, the Eastern coast of the Adriatic, the Aegean, and the northeastern corner of the Levantine Basin.

Organic-matter pollution in industrial wastewater was documented by MED POL through an inventory of industrial point



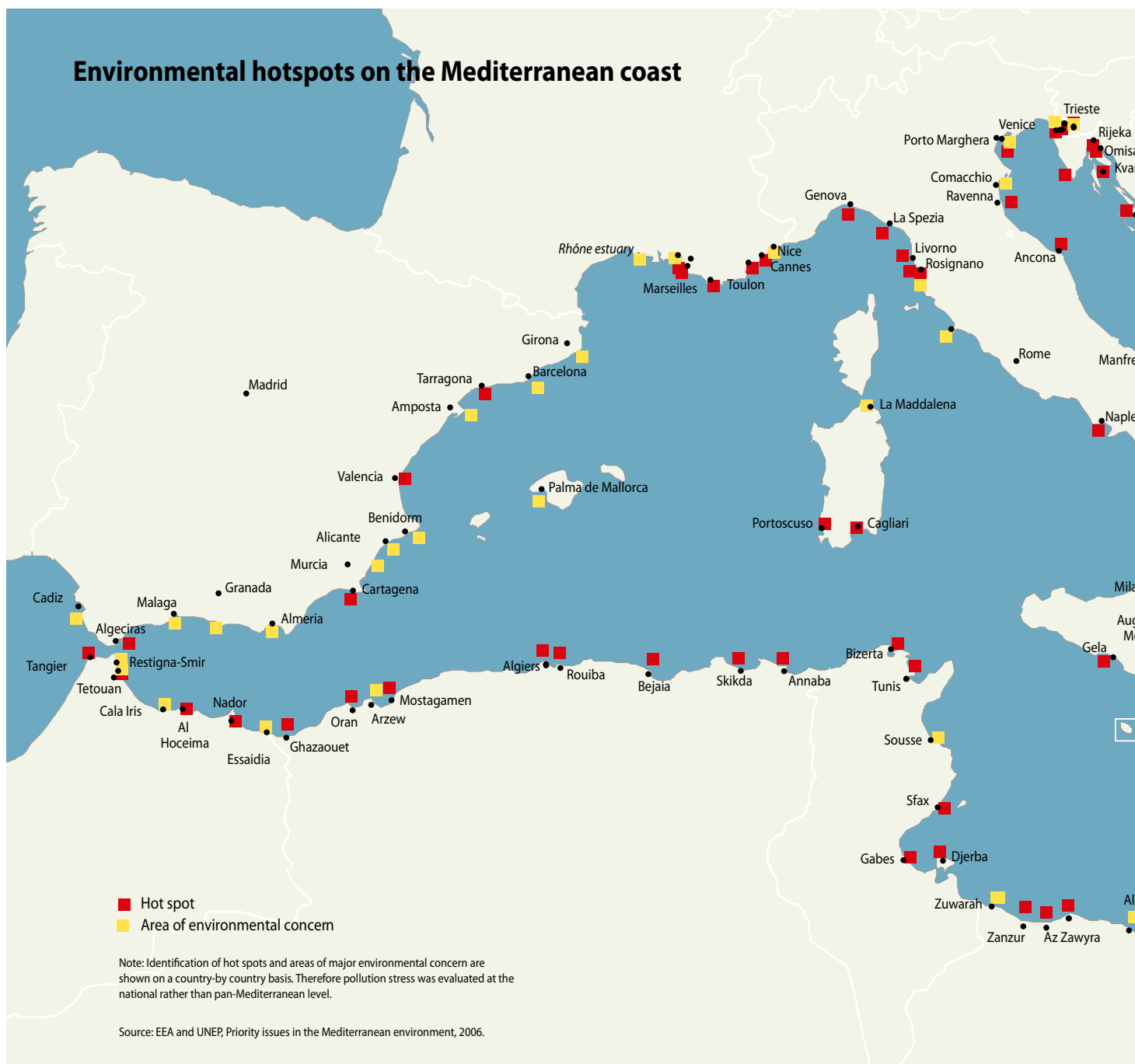
sources of pollution in 2003. The areas with the highest BOD are the southern shore of the Western Basin, the eastern coast of the Adriatic, the Aegean and the northeastern sector of the Levantine Basin. These regions, in general, also have insufficient sewage wastewater treatment facilities. This indicates that there is likely a cumulative effect of elevated organic matter in coastal waters from a combination of domestic and industrial sources (UNEP/MAP 2012). In the northern Mediterranean BOD is mainly released by wastewater treatment plants and the food industry, while in south and eastern Mediterranean other sectors like oil refining, farming of animals, textiles, paper or fertilisers are important emitters (UNEP/MAP/MED POL 2012).

For marine animal and plant communities, oxygen depletion caused by either human-induced eutrophication or by input of organic matter in wastewater may be fatal. Addition of organic matter and eutrophication (resulting from productivity increasing because of the extra supply of nutrients) often stem from the

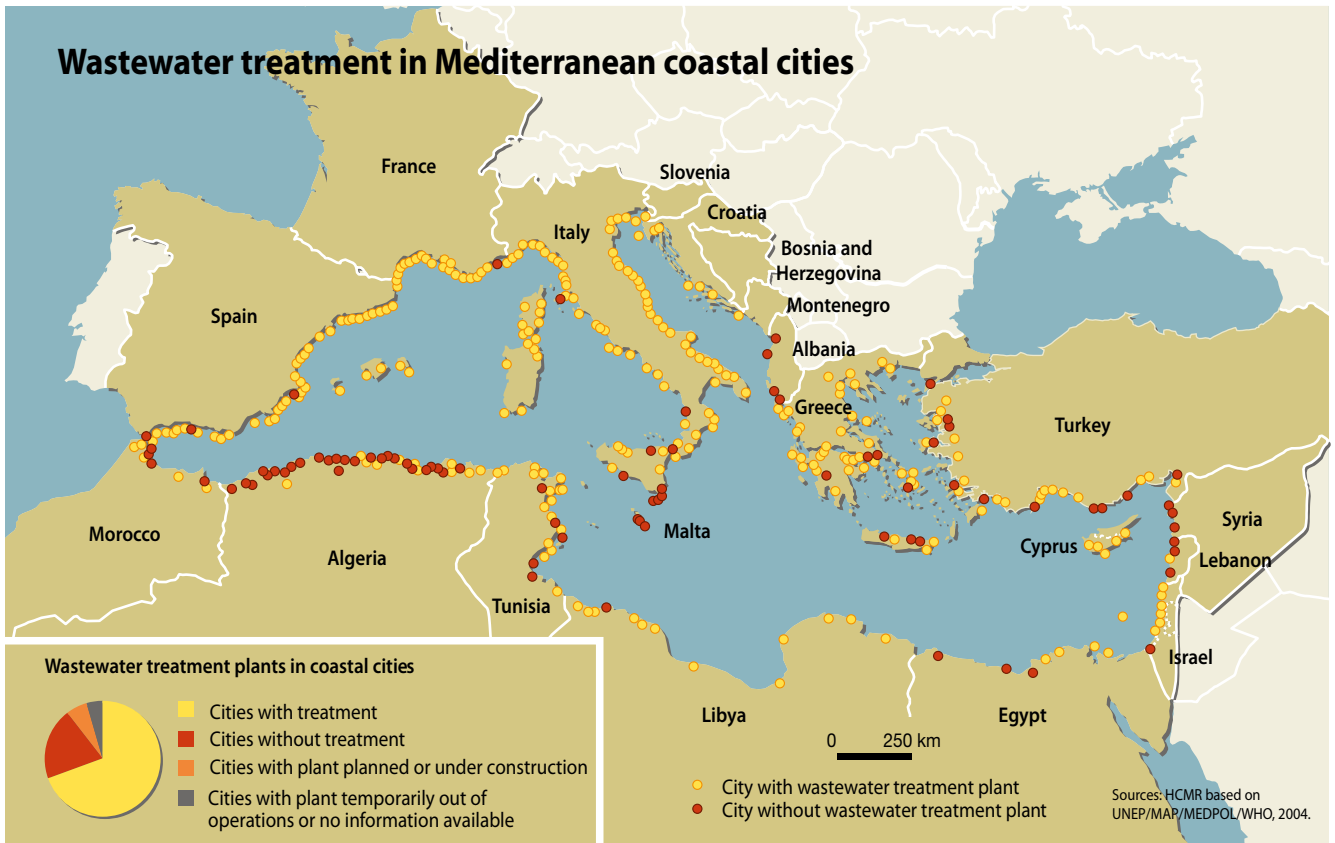
same sources and act together to deplete oxygen. See the Eutrophication chapter for further discussion.

Oxygen is reduced by organic matter carried by wastewater through two processes. First, the increase in particle concentration reduces light penetration in water, reducing the depth of the zone in which photosynthesis occurs. The net effect is a reduction in the release of oxygen from the water column. Secondly, introduced organic matter uses up oxygen as it decomposes, especially near the bottom where particulate organic matter settles. In the Mediterranean, many instances of fish and shellfish kills have been recorded, as these species are the first to be affected by oxygen limitation.

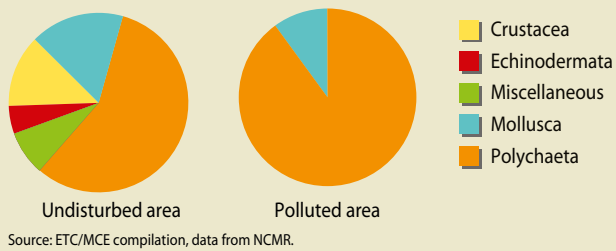
Benthic communities are among the first to disappear under conditions of heavy stress. Benthic organisms play an important ecological role by reworking the sediments, which affects the flux of nutrients across the sediment-water interface. Thus



Wastewater treatment in Mediterranean coastal cities



Composition of benthic communities



their loss is a liability to the ecosystem as a whole. In undisturbed areas in the eastern Mediterranean, benthic communities have a high diversity of species, consisting of polychaetes (50–65%), molluscs (15–25%), crustaceans (10–20%), echinoderms (5–8%) and miscellaneous taxa. By contrast, in areas ranging from heavily disturbed (e.g., sewage outfall vicinity) to polluted (e.g., urbanised bay), echinoderms, crustaceans and miscellaneous taxa largely disappear, while a small number of polychaete species

account for 70–90% of the total abundance (Stergiou *et al.* 1997). The same applies to the Western Mediterranean benthic communities, where increasing disturbance also leads to reduction in species richness.

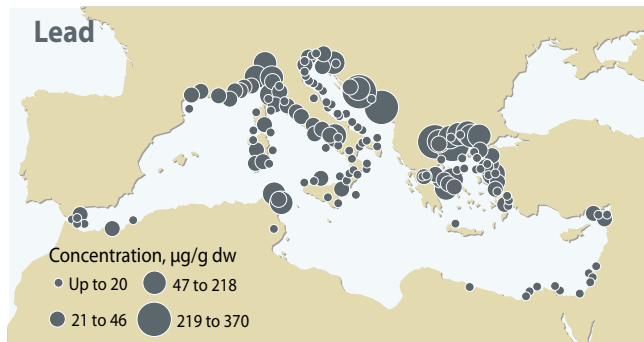
When the effects from organic enrichment exceed the potential for remineralisation (transforming the organic matter into inorganic matter) by benthic organisms, anoxic zones are created and bacterial mats cover the seabed. Although this type of ecosystem change is in general reversible, there could be severe and long-lasting consequences when the affected seabed is a critical habitat like the meadows of the sea grass *Posidonia oceanica* (UNEP/MAP/MED POL 2005).

Heavy metals

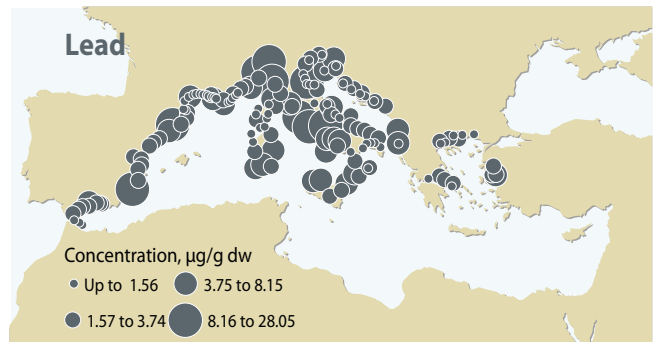
The term *heavy metal* is used here for potentially toxic metals that persist in the environment, bioaccumulate in human and animal tissues, and biomagnify in food chains. Metals and organometallic compounds are commonly included in emission inventories and monitoring networks, specially mercury, cadmium

Mean concentrations of trace metals

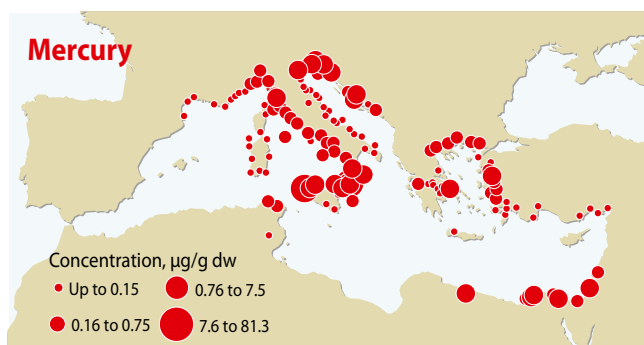
In sediments



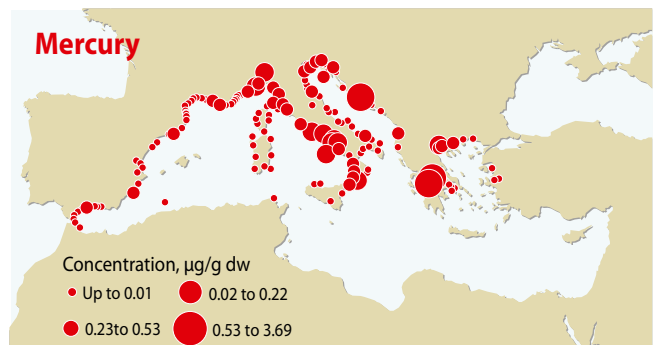
In Blue Mussels (*Mytilus galloprovincialis*)



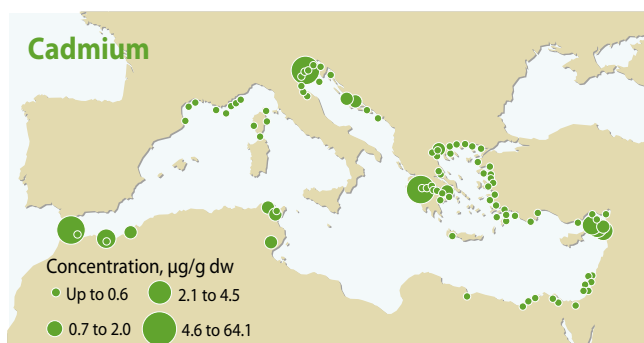
Mercury



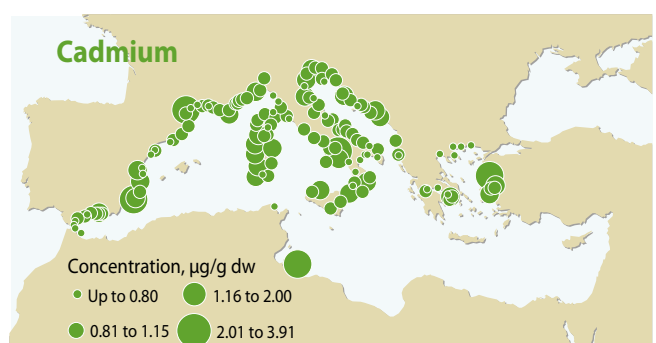
Mercury



Cadmium



Cadmium



and lead. Urban and industrial wastewaters, atmospheric deposition and run-off from metal contaminated sites constitute the major sources of toxic metals.

In the Mediterranean countries, according to the National Baseline Budget (NBB) inventory, atmospheric emissions of metals are mostly related to the cement industry (Hg, Cu), production of energy (As, Cd, Ni) and the metal industry (Pb, Zn). Water releases appear to be mostly related to the fertiliser industry (Hg, As, Pb), metal industry (Ni, Zn) and wastewater treatment plants (Cd, Cu), with important contributions also from the energy sector and the chemical industry. Oil refining is the main source of chrome releases, both to air and water (UNEP/MAP/MED POL, 2012).

Aside from direct discharges from urban and industrial sources, rivers and streams are the major contributors of metals of anthropogenic and natural origin to coastal areas, although metal enhancements in local geology may also influence sediment metal content. Heavy metals from land-based sources may not

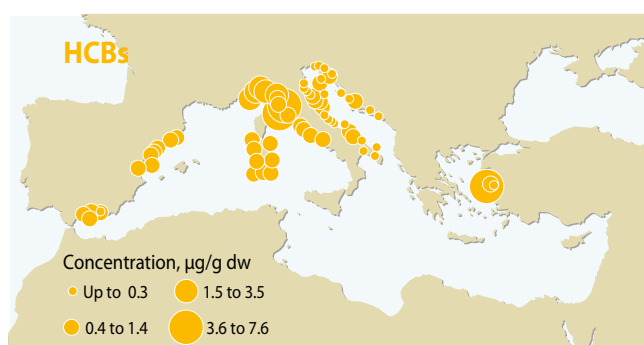
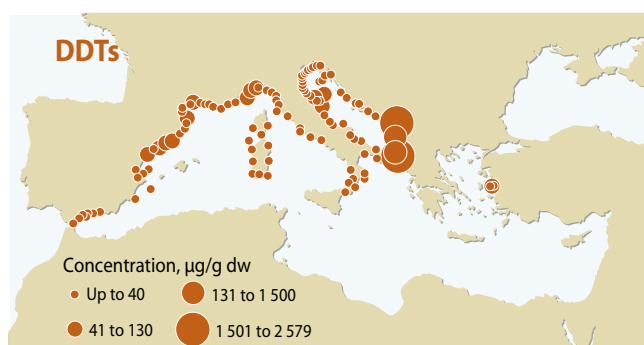
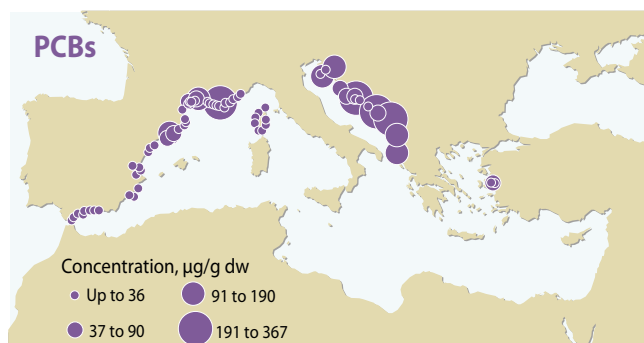
only accumulate in the coastal zone but may also move into the deeper areas of the continental margin through advection, and even into the deep basin through downslope transfer processes. Atmospheric deposition is the main pathway for heavy metals to enter open-water regions. Metals entering the sea through air-sea exchange may accumulate through the food web, becoming concentrated in higher marine organisms, or they may adhere to particles and sink to the seafloor where they accumulate in the sediments.

A recent study (UNEP/MAP/MED POL 2011) provides an overview based on the MED POL database and recent publications on the distribution and trends of heavy metals (lead, mercury, cadmium, zinc and copper) in coastal sediments and biota (mainly in blue mussel, *Mytilus galloprovincialis*, and red mullet, *Mullus barbatus*). The distribution of information is not ideal as the southern Ionian, Aegean, and the Levantine Basin are under-represented. Nonetheless, the results can be used for comparative purposes, especially results for cadmium, mercury and lead, for which the spatial sampling coverage is slightly better.

Lead levels are high in sediments in the area of Marseille-Fos and Toulon (France), Cartagena (Spain), along the western Italian coast, around Naples and in the Gulf of Genoa. Lead levels are also elevated in sediments in the Gulf of Trieste, along the southern coast of Croatia, in the Aegean Sea (especially the northern coast near Thessaloniki and Kavala and the region around Athens), along the Aegean coast of Turkey (Izmir Bay) and in Tunis and Bizerta lakes in northeastern Tunisia. These sites with high levels of lead in sediments are correlated with locations of industrial and domestic waste discharges and harbour activities. In biota (blue mussel), lead concentration is consistently high at locations with Pb-contaminated sediments: the western coast of Italy from the Gulf of Genoa to Naples, at locations in the Tyrrhenian Sea, along the Italian west coast, along the coast of northern Sicily (Palermo) and in the southern part of Sardinia (Portoscuso). Also, elevated levels of lead in biota have been detected at some locations along the southern coast of France (Marseille Gulf and Hyeres Bay) and the coast of Spain

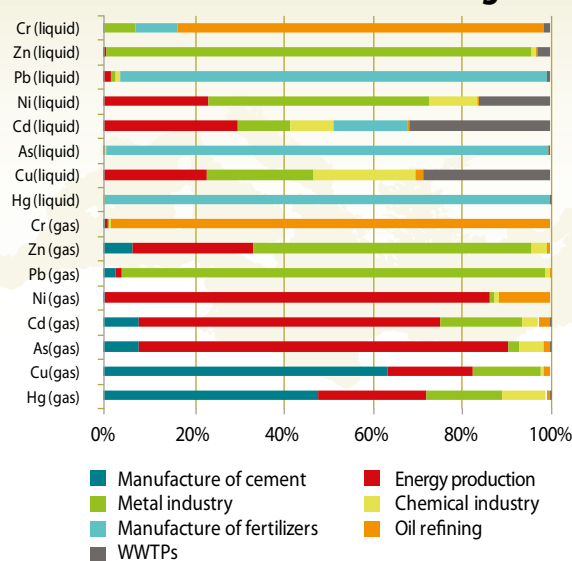
Mean concentrations of Persistent Organic Pollutants (POPs)

In Blue Mussels (*Mytilus galloprovincialis*)



Source: UNEP/MAP, Hazardous Substances in the Mediterranean: A Spatial and Temporal Assessment, 2011

Major industrial sectors emitting metals in the Mediterranean region



Source: MEDPOL; Releases, emissions and sources of pollutants in the Mediterranean region. An assessment of 2003-2008 trends; 2012.

(Barcelona, Cartagena and Malaga). In the Adriatic Sea, high levels of lead have been recorded in biota in the Venice lagoon and in the areas affected by the Po River discharges (consistent with the distribution pattern of urban and industrial discharges), the Gulf of Trieste, Vlora Bay and close to Durres. In general, the distribution of elevated lead levels in biota is correlated with the distribution of discharges and non-point sources of pollution from mining, industry and sewage.

Mercury levels are high in sediments around Messina, Palermo and Reggio Calabria in Sicily, potentially influenced by natural contributions from volcanic and geothermal sources of the southern Tyrrhenian Sea. Mercury sediment anomalies in some islands of this region may also be explained by proximity to volcanic and geothermal sources of mercury. Elevated levels of mercury have also been recorded in sediments in the Po Delta region, the Gulf of Trieste, the Aegean Turkish coast and Israel (e.g., Haifa Bay). High mercury concentrations were measured in biota along the northwest Italian coast (Gulf of Genoa, Portofino, Palermo), the coastal waters of the Tyrrhenian Sea (especially between Fiumicino and Naples and around Messina), Skikda (Algeria), Cartagena (Spain) and at Kastela Bay (near Split) on the western Adriatic coast. Significant concentrations of cadmium have been reported in sediments along the coast of France (Marseille-Fos), Spain (Cartagena), Morocco (Tangier-Martil and Nador), in the northeastern corner of the Levantine Basin between Cyprus and Turkey (including Iskenderun Bay) and the northern coast of Syria. In biota, relatively high levels of cadmium were recorded in biota at sites along the southern and southeastern coasts of Spain (Cabo de Gata, Almeria, and Cartagena), an intensely mined region, and at a few sites along the western coast of Italy (Naples), the southern shores of the Tyrrhenian Sea (Messina and Palermo), western Sardinia and France (Sete and Nice). In the Adriatic, high levels of cadmium are found in biota in the Po Delta and in Kastela and Rijeka bays (Croatia), due to the discharge of untreated urban and industrial wastewaters. Scattered samples of organisms in the Central and Eastern Levantine basins allow identification of some sites with high concentrations of cadmium in biota. Cadmium is also elevated in biota along the western coast of Turkey (Izmir Bay), Piraeus (near Athens) in the Aegean Sea and in Vlora Bay (Albania) in the Adriatic.

Despite the work of the MED POL programme, short time series and differences among sampling conditions mean that most available pollution data for the Mediterranean are not yet adequate for robust trend analysis (UNEP/MAP/MED POL 2011). Preliminary analyses show mixed trends. For example, data from Haifa (Israel) and the Gulf of Lions (France) indicate that heavy metals in sediments are declining, while no change is observed in mercury concentrations in the Gulf of Trieste, despite the closure of mining in Idrija (Slovenia).

Trends in heavy metals in biota were examined at sites with data for periods of at least five years starting in the late 1990s. These analyses showed that, while trends at individual sites tended not to be significant, there was a general pattern of stable to declining trends. A few stations with high levels of metals in biota in the Western Mediterranean (e.g., Marseille, Fos and Pombino) and in the Adriatic (e.g., Rijeka and Kastela bays in Croatia and Durres and Vlora Bay in Albania) showed slightly increasing trends. By contrast, Naples, Genoa and Bizerta Lagoon (Tunisia) showed decreasing trends. Additionally, in several cases there

was an apparent decline of outlier values, such as in locations in Italy, which may reflect a general improvement in areas with particularly high levels of metal pollution.

The exposure of marine and coastal organisms to elevated concentrations of heavy metals exacerbates the ecological stress they are regularly subjected to by natural stressors, such as temperature and salinity fluctuations. The presence of toxic substances in the marine environment, even at low levels, will give rise to biochemical reactions that may cause stress to marine organisms. Among the results of prolonged stress is the suppression of the immune system, increasing susceptibility to infection. Although new techniques measuring the total response of organisms to all possible stressors have been developed, none of them can give accurate estimates of levels of acute or sublethal toxicity of contaminants. Sensitive *in situ* bioassays are needed to measure water and sediment toxicity using indigenous organisms (UNEP/MAP/MED POL 2005).

Mercury is a highly toxic element that is found in elevated concentrations in Mediterranean marine biota. Studies conducted in the 70's in pelagic fish but also recent studies revealed that Hg concentrations in Mediterranean fish are twice those found in the same species living in the Atlantic Ocean. The presence of cinnabar deposits and volcanoes in the Mediterranean, as well as the anthropogenic emissions from various land based sources, are the possible Hg sources, which are transported to the marine environment through river and point land based emissions, as well as through atmospheric precipitation (Cossa and Coquery, 2005). Risks to Mediterranean ecosystems also stem from the effects of cadmium on top predators and from lead on predators of shellfish (UNEP/MAP/MED POL 2005).

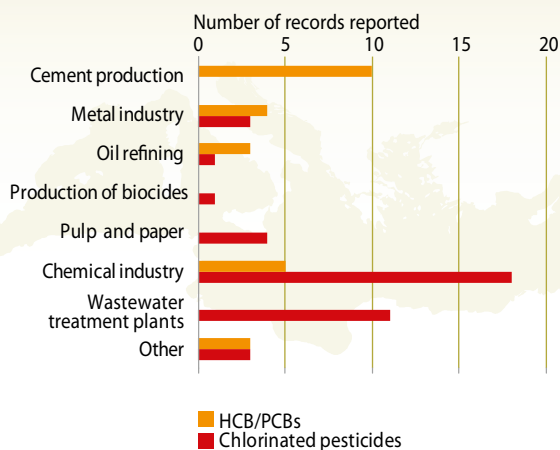
Persistent Organic Pollutants (POPs)

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. POPs persist in the environment, are capable of long-range transport, bioaccumulate in human and animal tissue, biomagnify in food chains, and have potentially significant impacts on human health and the environment. POPs include certain chlorinated pesticides and industrial chemicals such as polychlorinated biphenyls (PCBs), most of which have already been prohibited in Mediterranean countries. However, POPs can also be unintentionally released, mainly as a result of combustion processes or as by-products in some industrial processes. Some examples are dioxins and furans, hexachlorobenzene (HCB), PCBs, or polycyclic aromatic hydrocarbons (PAHs).

The MED POL NBB inventory report (UNEP/MAP/MED POL 2012) states that in the Mediterranean, very high levels have been historically measured in the marine environment, especially in top predators and cetaceans. However, a general decrease of POPs concentrations has been observed over the last years, although in some cases concentrations still remain relatively elevated.

The inventory includes very few reports for the already prohibited organochlorines, which confirms that they are no longer released from industrial point sources. HCB and PCBs are mostly released as unwanted by-products in the cement and metal industry, while chlorinated pesticides are emitted by the organic chemical industry, or by wastewater treatment

Chlorinated pesticides and HCB/PCBs releases by sector, 2008



Source: MEDPOL; Releases, emissions and sources of pollutants in the Mediterranean region. An assessment of 2003-2008 trends; 2012.

plants, which may collect pesticides contained in sewage and runoff waters.

Data published between 1971 and 2005 were included in a regional assessment of pollution of sediments by certain POPs, namely polychlorinated biphenyls (PCBs) and chlorinated pesticides like dichlorodiphenyltrichloroethane and its degradation products (DDTs) and hexachlorobenzene (HCB) (Gomez-Gutierrez *et al.* 2007). Despite the shortcomings in the combined datasets, the authors were able to conclude that contamination of sediments by POPs is more a local problem, mainly associated with urban/industrial and river discharges, as well as with coastal enclosures (harbours and coastal lagoons), rather than a widespread issue. They also concluded that the northern Mediterranean coast is the area of most concern for sediment pollution by POPs and that POPs have declined – with this decline being more evident for DDTs than for PCBs. This could indicate an ongoing input of PCBs, which highlights the need for improved management of the potential sources.

The recent MED POL study (UNEP/MAP/MED POL 2011) included PCBs and chlorinated pesticides (DDTs, HCB, aldrin, endrin, dieldrin and lindane). It provides an updated view of the geographical distribution and trends of POPs in biota, summarising the data mainly for blue mussels and red mullet.

PCBs were found in the vicinity of industrial and urban sites, as well as around the mouths of major rivers. Areas of concern with regard to levels of PCBs in biota include northwestern Mediterranean coastal areas, with generally high levels, especially around the cities of Barcelona, Marseille (with the highest values of up to 1.500 ng/g dry weight) and Genoa. Particularly high levels of PCBs were also found in biota from the coastal strip from Livorno to Nice and the mouths of the Rhone and Ebro rivers (indicating that rivers and wastewater discharges are major sources of PCBs). In the Adriatic Sea, PCBs were elevated in biota from the eastern bank and along the coasts of Croatia and Albania. Levels were generally lower in the Eastern Basin, but medium to high levels of PCBs were recorded in red mullets from Cyprus and Turkey and high values, also related to industrial and urban effluents, were recorded offshore from the Athens port of Piraeus.

Assessment of regional trends in PCBs is made difficult by changes in analytical and reporting methods. At coastal sites in the northwestern Mediterranean (France and Italy), where trend analysis is possible, the PCB concentrations in biota remained relatively constant or, in some cases, increased slightly. Similar trends were recorded at stations in the Eastern Mediterranean (Athens, Greece, and Izmir and Mersin, Turkey).

Despite monitoring of chlorinated pesticides by MED POL since the 1990s and the improvement of systematic monitoring during the past decade, spatial data coverage is not sufficient for drawing conclusions about the regional distribution of these compounds. Available data indicate that contaminants are not uniformly distributed throughout the Mediterranean and some hot spots have been identified for specific pesticides.

In the Western Mediterranean, areas of particular concern include estuaries (Rhone and Ebro), ports, bays and gulfs (Barcelona, Marseille-Fos, Liguria, Nador Lagoon, and the bays of Algiers, Tunis, Naples, and others). These areas have moderate levels of aldrin, HCB and DDTs. There is evidence that river inputs represent the most important source of pesticides entering the Western Mediterranean Sea.

Several stations along the Italian coast of the Adriatic Sea had moderate values of aldrin and dieldrin, while Durres and Vlora Bay (Albania) had very high levels of DDTs and lindane. Moderate concentrations of lindane and DDTs were found in the Gulf of Trieste and the Marche region (Italy), respectively. In the Eastern Mediterranean, concentrations of DDTs in biota were quite low, although moderate concentrations of DDTs were present in Izmir Bay (Turkey), at three stations south of Cyprus, as well as in Saronikos, Thermaikos and Amvrakikos Gulf (Greece) where the concentrations of aldrin and dieldrin were also very high, probably due to agricultural activities in the area.

The levels of chlorinated pesticides in mussels have declined since the 1990s, which is consistent with the banning of production and use of these compounds. The median values of pesticides in mussels from Croatia and France exhibit clear decreasing trends, as do the outlier values in the data from France. The only exception seems to be Albania (e.g., Durres and Vlora Bay), due probably to stockpiles of obsolete chlorinated pesticides. In Mersin (Turkey), chlorinated pesticides in mussels are decreasing, although occasional increases were recorded in Izmir Bay (Turkey). In general, the decrease is slower for DDT than for lindane and other chlorinated pesticides, which is consistent with the longer half-life of DDT.

The last two groups of POPs that are of concern in the Mediterranean Sea are mostly related to maritime traffic and boating. These are biocides (mainly organotin compounds such as tributyltin, known as TBT) used in antifouling paints and polycyclic aromatic hydrocarbons (PAHs) resulting from hydrocarbon oil discharges and accidental spills, among other sources. PAHs are considered along with oil pollution in the next section.

Organotins have been detected in Mediterranean waters and sediments since the late 1980s and continue to be present in substantial concentrations despite the ban on their use in 1990. TBT degradation is slow, with a half-life ranging from weeks in shelf waters to years in deep sediments (Abdulla and Linden

2008). Distribution data are poor but adequate to show that TBT has been detected in all water and sediment samples analysed in the Alboran Sea, North-western Mediterranean, the Tyrrhenian coast of Italy, the Venice lagoon, the Gulf of Saronikos (Greece), the southern coast of Turkey, the coasts of Israel and Alexandria. Surveys show an improvement following the ban on their use, especially in recreational marinas, but also show that TBT has been transported to areas far away from its sources (Abdulla and Linden 2008).

In addition to those described above (PCBs and organochlorine pesticides), industrial and domestic-use POPs, like brominated flame retardants (polybrominated diphenyl ethers, or PBDEs) have also been found in marine biota, including blue mussels.

POPs have been shown to disrupt the endocrine systems of a number of organisms and to modify the reproductive systems of Mediterranean swordfish, which may constitute a threat to the survival of the species. There is also evidence for potential trans-generational effects in small cetaceans (Abdulla and Linden 2008).

The effects of organotin biocides have been well documented in the Mediterranean. TBT is considered the most toxic substance that is intentionally introduced into marine environments. It affects non-target biota, especially in areas with high vessel density and restricted water circulation such as harbours and marinas. Marine invertebrates are very sensitive to TBT. Effects include morphological changes, growth inhibition, suppressed immunity, reduced reproductive potential and changes in population structure. Another known effect of TBT (from laboratory studies) is the development of male sexual characters in female prosobranch gastropods. This has been shown to occur at TBT concentrations well below those detected in water and sediments of the Mediterranean Sea. This development of reproductive abnormalities has been recorded in gastropods collected in areas subject to both high and low shipping activities since the early 1990s along the Catalan and Ligurian coasts, near Naples, and off the coasts of northwestern Sicily, Malta, Venice (Italy), Rovinj (Croatia) and Bizerte (Tunisia). Besides the impact on gastropods, TBT and its degradation products accumulate in tissues of marine organisms and move up the food chain. Very high concentrations have been found in top predators including the bottlenose dolphin, bluefin tuna, and blue shark collected off Italy (Abdulla and Linden 2008).

Oil pollution and polycyclic aromatic hydrocarbons

Marine transport is a main source of petroleum hydrocarbon (oil) and PAH pollution in the Mediterranean Sea. A recent IUCN report by Abdulla and Linden (2008) looked into maritime traffic effects on biodiversity in the Mediterranean Sea covering amongst others the pressure and impact of ship-borne oil discharges. Nine thousand tanker trips were recorded in 2006, carrying over 400 million tonnes of crude oil. Most trips originated or ended at port facilities in the Mediterranean. According to certain studies, approximately 0,1 % of the crude oil transported ends up deliberately dumped every year in the sea as the result of tank washing operations (Solberg & Theophilopoulos 1997; UNEP/MAP 2006). All other types of vessels are also potentially a source of discharge of oily waste. Other releases of oil from ships include amongst others loading/discharging, bunkering, dry-docking operations and discharging of bilge oil (Abdulla and Linden 2008).

Despite the importance of the maritime sector and the potential implications of oil discharges, data on the subject are scarce. Illicit vessel discharges can be detected using satellite images, allowing the estimation of the spatial distribution of oil-spill density and the identification of hot spots (Abdulla and Linden 2008). This provides evidence that the distribution of oil spills is correlated with the major shipping routes, along the major west-east axis connecting the Straits of Gibraltar through the Sicily Channel and the Ionian Sea with the different distribution branches of the Eastern Mediterranean, and along the routes toward the major discharge ports on the northern shore of the Adriatic Sea, east of Corsica, the Ligurian Sea and the Gulf of Lion (Abdulla and Linden 2008).

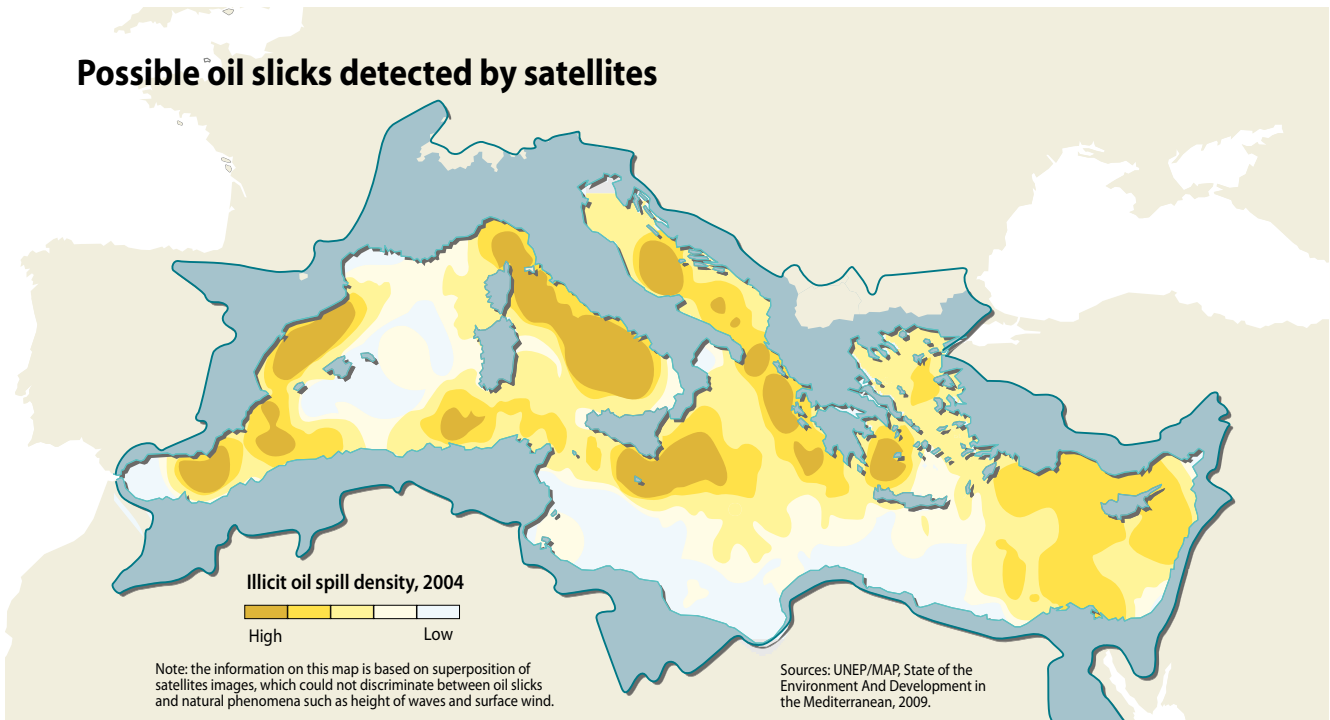
Crude oil is composed of thousands of complex compounds of which PAHs are the most toxic. The amount of PAHs entering the Mediterranean Sea varies according to the types and amounts of oil discharged. Annual input is estimated at between 0,3 and 1.000 tonnes (EEA and UNEP 2006). PAHs are also introduced into the Mediterranean Sea by aquaculture activities (Tsapakis *et al.* 2010) and atmospheric particulates from the combustion of fossil fuels and incomplete combustion of biomass and solid waste (EEA and UNEP 1999).

Releases of mineral hydrocarbons and phenols are mostly (99 %) reported by the oil refining sector in a few southern countries like Egypt, Libya, Algeria or Tunisia. This sector also accounts for 66 % of volatile organic compound releases, which are also emitted by the organic chemical industry, manufacture of textiles, transport and energy production. Between 2003 and 2008, emissions of these pollutants were reduced in some countries like Algeria, Syria or Tunisia, but increased in others like Egypt or Turkey. Some countries also report data on water emissions of oils and grease. This parameter includes also non-mineral oils, and accordingly the food industry appears as the major source in Mediterranean countries, accounting for 83 % of total releases, followed by the oil refining sector (13 %) and wastewater treatment plants (3 %) (UNEP/MAP/MED POL 2012).

In some areas PAH levels are higher in offshore waters than they are nearer to land. Abdulla and Linden (2008) considered this to be due to intensive ship traffic and direct discharges from ships offshore. In nearshore waters, PAHs in sediments are generally higher near ports and industrial areas, up to 100 times higher than in the overlying water column. This is due to the adsorption of PAHs onto particles, where they become even more resistant to degradation (De Luca *et al.* 2005). Concentrations of PAHs in marine biota tend to be correlated with oil-related facilities, including refineries, terminals and ports. Most studies, however, have been carried out in the northwestern part of the Mediterranean. In addition, there is an almost total lack of information on levels in deep-sea areas. In order to be able to assess the state of contamination by petroleum hydrocarbons in the Mediterranean, more studies are needed, particularly along the southern coasts and also along major shipping routes (Abdulla and Linden 2008).

PAHs are known to affect different species at the genetic, cellular, biochemical and physiological levels. Genetic damage may result in chromosomal aberrations, impacts on embryonic stages and long-term effects such as carcinogenic and mutagenic growth in vertebrates. Some of these effects have been found as long as ten years after an oil spill incident off the coast of Liguria in Italy. Some water-soluble PAHs have been shown

Possible oil slicks detected by satellites



to disrupt biochemical membranes, causing changes in enzymatic and receptor activities in affected organisms. Experimental studies have also shown that exposure to petroleum hydrocarbons may lead to various impacts on blood chemistry. Both laboratory and field studies have shown that petroleum hydrocarbons may result in oxidative stress. Fish exposed to petroleum hydrocarbons under chronic conditions often exhibit various types of lesions. Several field studies have shown such histopathological changes in biota from waters contaminated by oil. For example, after the Haven accident outside the port of Genoa, fish sampled in the contaminated area had lesions as long as nine years after the accident. Behavioural abnormalities resulting in lowered chances of survival in the natural environment are also observed among aquatic organisms exposed to oil spills (Abdulla and Linden 2008).

Community-level changes were detected off Livorno after the 1991 Agip Abruzzo oil spill, where several different species in the meiobenthic community reacted differently by either decreasing or increasing their population numbers. Foraminifera, turbellarians, and nematodes were particularly sensitive, while populations of copepods increased. Further research indicated an acute initial response among these organisms with rapid recovery. This indicates a high resilience to single oil spill incidents. Benthic macro-fauna may also be resilient to the effects of petroleum hydrocarbons, particularly weathered oil. Samples from the Haven oil spill showed no significant differences between tar-contaminated sites and control sites. However, other studies indicate clear impacts on the growth of shallow-water sea grass over extensive areas and for as long as eight years after a spill (Abdulla and Linden 2008).

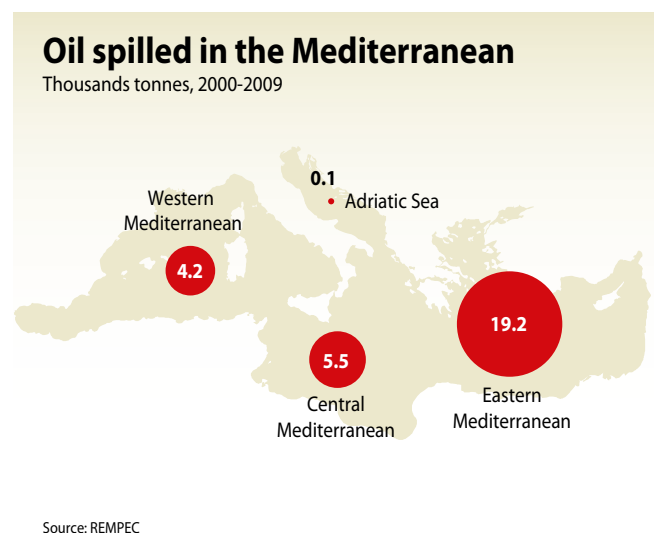
Acute pollution events

Data used in this section are extracted from the Alerts and Accidents database maintained by REMPEC. They include incidents that have caused, or could have caused, pollution damage. The main sources of information are Lloyd's Casualty Reporting Service (LCRS) and the emergency reports sent to

REMPEC by national focal points in Mediterranean countries. This database cannot be considered a comprehensive list of all the spills occurring in the Mediterranean Sea. Other incidents that are not reported in the database could also have had significant impacts on the ecosystems, such as damage to the seabed or input of organotin compounds from paints during ship groundings.

In the last decade, nearly half of the accidents leading to significant spills (of more than 100 tonnes) that were reported to REMPEC occurred in the Western Mediterranean Sea (seven accidents representing 47 % of all accidents). A third of the accidents occurred in the Eastern Mediterranean (five accidents representing 33 % of the total) and a fifth of the accidents occurred in the Central Mediterranean. No accidents were reported for the Adriatic Sea.

The cumulative amount of toxic substances spilled per year follow a different pattern. A single accident can lead to the spill of a large amount of substance, and thus the cumulative quantities are variable. The worst spill in the Mediterranean was related to



the fire and explosions on the MT Haven in 1991, sinking in the Gulf of Genoa and spilling 20 % of its 145.500 tonnes of crude oil into Italian waters. The Haven spill contaminated the Ligurian coastline as well as the coastlines of Monaco and France, as far west as Toulon.

The Eastern Mediterranean accounts for two-thirds of the total quantity spilled in the last decade. If the Lebanese spill of 2006 is taken out of the calculations, the Western Mediterranean, Central Mediterranean, and Eastern Mediterranean spilled roughly

the same quantities (between 4.000 and 6.000 tonnes), while less than 100 tonnes was spilled in the Adriatic, according to the information made available to REMPEC.

The most common type of accident leading to a spill is a failure during cargo operations, and in most cases these incidents lead to small spills. Other types of accidents, in order of frequency, are: collisions/contacts, groundings, sinkings, and, finally, fires/explosions. In addition, a wide range of infrequent accident types are reported, including pipeline leaks.

Eutrophication

Human sources of nutrients

Nutrients in seawater present a paradox. Nutrients are, of course, essential for life. In the oligotrophic environment of the Mediterranean, the ecosystems with the most nutrients are generally the most productive and diverse. At the same time, many Mediterranean nearshore areas are threatened by nutrient over-enrichment due to coastal and watershed development. Municipal sewage is the big offender, followed by fertiliser run-off from agricultural areas, lawns and golf courses. The problem is particularly acute in shallow sub-basins with limited flushing, common features in parts of the Adriatic and along the Mediterranean's southern shore.

Many developed coastal areas suffer particularly from increased influx of dissolved nitrogen and phosphorus. Sources include untreated human sewage, animal waste, transportation, fertilisers and industrial discharges. The largest emitters of nitrogen are urban wastewater treatment (45 %), livestock farming (24 %) and the organic chemical industry (2 %). Ammonia emissions from animal manure used as fertiliser also contribute nitrogen. The main sources of phosphorus are fertiliser manufacturing (40 %), livestock farming (39 %) and urban wastewater treatment (13 %) (UNEP/MAP/MED POL 2012). Although the overall inputs of nitrogen (about 1,5–4,5 million tonnes per year) and phosphorus (about 0,1–0,4 million tonnes per year) are low compared to some other seas (e.g., Black Sea), these nutrients are problematic in coastal areas (UNEP/MAP/MED POL 2005). According to National Baseline Budget 2008 data, total nitrogen is mostly emitted by wastewater treatment plants, animal farms, the organic chemical industry in the northern Mediterranean countries and the tanning sector in the southern and eastern shores. The fertiliser industry is the main source of total phosphorus, especially in those producer countries like Tunisia, Algeria, Lebanon or Greece. Aquaculture is also reported as an important source of nutrients and suspended solids. Although total discharges are not comparable to other sectors, they can lead to localised impacts in the marine environment. Spain, Greece, Turkey, Italy and Croatia are the countries with the largest marine aquaculture development (UNEP/MAP/MED POL 2012).

Eutrophication and the human impact

In natural aquatic ecosystems, high concentrations of nutrients can result in rapid growth of phytoplankton, a process called eutrophication (UNEP/MAP 2009). Algal blooms are a common natural phenomenon associated with eutrophication. In addition, there is a shift in phytoplankton species composition, with large species favoured over smaller ones. Long-living and slow-growing plants cannot compete with fast-growing algal species. Since the larger plants provide cover and food for fish and substrate for invertebrate organisms, biodiversity suffers. Although eutrophication is a natural aging process of a water body, added nutrients from human activity can greatly speed up the process with resulting negative impacts on the ecosystem.

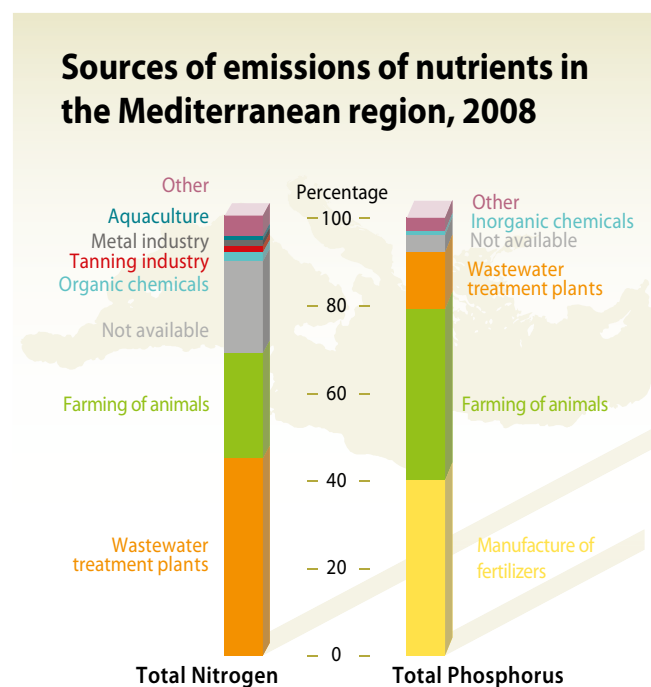
Agriculture is the largest non-point source of pollutants in the Mediterranean (UNEP/MAP 2011). Agriculture-related nutrients enter the sea through groundwater, lakes, wetlands, and rivers. Nitrogen consumption per surface unit of arable land is highest in countries of the northern watershed, with the exception of Bosnia-Herzegovina and Albania. In contrast, point-source release is highest on the eastern coast of the Adriatic. Other point sources of nitrogen are concentrated in the Ebro watershed, the eastern coast of the Levantine Basin and the western coast of Tunisia.

Direct effects of nutrient over-enrichment

The most eutrophic areas of the Mediterranean are linked to the mixing of nutrients from deeper waters through intense mesoscale circulation (Alboran Sea), local tidal mixing (Gulf of Gabes), or the input and alongshore redistribution of nutrients from large rivers. In addition, high chlorophyll and productivity levels have been found near large urban areas.

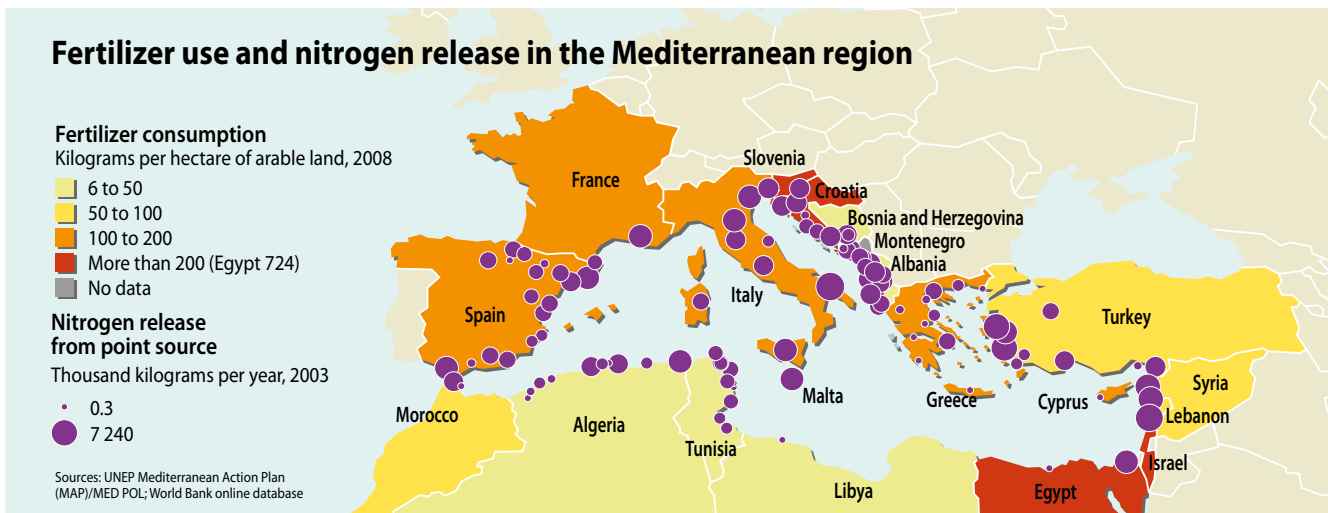
The Mediterranean phytoplankton community is not well described, but it is believed to be changing, along with the rest of the sea's ecosystem. Changes in nutrient concentrations and ratios suggest a shift in the distribution of nutrients and, therefore, of phytoplankton species (UNEP/MAP 2009). Macrophytes such as *Cystoseira* spp., *Dictyota* spp. and *Halymenia* spp. are in decline and are being replaced by short-lived algal species (UNEP/MAP/MED POL 2005).

One of the most serious effects of eutrophication comes from algal blooms or red tides. At least 57 species of algae are reported to cause algal blooms in the Mediterranean (UNEP/MAP/MED POL 2005). During blooms, algae accumulate quickly, causing a discoloration of the water column. When marine algae occur in significant numbers and produce biotoxins, the result is harmful



Source: MEDPOL; Releases, emissions and sources of pollutants in the Mediterranean region. An assessment of 2003-2008 trends; 2012.

Fertilizer use and nitrogen release in the Mediterranean region



Impacts of nutrient over-enrichment

There are numerous socio-economic impacts associated with eutrophication including:

- toxicity or mortality in commercial fish and shellfish species leading to reduced catches;
- loss of employment and income in fisheries related to reduced resource base;
- loss of aesthetic value resulting from algal blooms;
- loss of tourism related to deteriorating water quality;
- loss of employment and income related to tourism, especially sport fishing; and
- loss of cultural heritage (UNEP/MAP/MED POL 2005).

Most susceptible to the negative impacts of eutrophication are semi-enclosed basins, estuaries and lagoons, where excess nutrients are not easily dispersed (UNEP/MAP/MED POL 2005).

Red tides are a problem for some Mediterranean fisheries. Fishing and mollusc farming in the northwestern Adriatic have been damaged by blooms of the dinoflagellate, *Dinophysis* spp., which causes Diarrhoetic Shellfish Poisoning (DSP). The occurrence of this organism has been responsible for temporary and prolonged bans on the harvesting and sale of mussels in the coastal and lagoon areas of Emilia-Romagna (UNEP/MAP/MED POL 2005). *Alexandrium tamarensis*, a dinoflagellate that produces Paralytic Shellfish Poisoning (PSP) toxins has been observed in the northern Adriatic (UNEP/MAP/MED POL 2005).

The Initial Integrated Assessment data suggest that eutrophication is still a localised phenomenon in the Mediterranean Basin. Better monitoring regimes and analysis of resulting data to determine trends will, in the future, allow robust statements of the effect of eutrophication on the ecology, as well as on fisheries and other valuable ecosystem services (UNEP/MAP 2012).

Marine Litter

Marine litter in coastlines, water column and seafloor

The main source of marine litter in the Mediterranean is households. Other major sources are tourist facilities, municipal dumps, ships and pleasure boats.

Most studies of marine litter in the Mediterranean have focused on beaches, floating debris and the seabed (UNEP/MAP 2012). They show that there is more marine litter in bays than in open areas (Galgani *et al.* 2010), and it is concentrated in shallow coastal areas rather than deeper waters (Koutsodendris *et al.* 2008).

A large proportion of marine litter is plastics (UNEP 2009). The impact of large plastic material on the environment has been

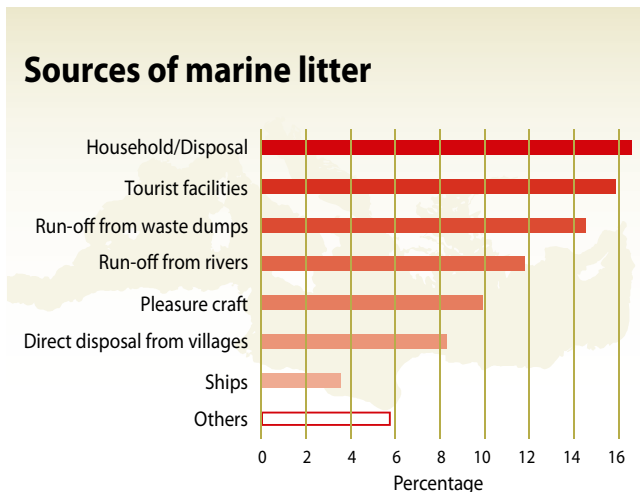
Marine litter is "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment." It reaches the marine environment through deliberate disposal or unintentional discharge, either at sea or from land by way of rivers, drainage systems and wind.

Source: Galgani *et al.* 2010

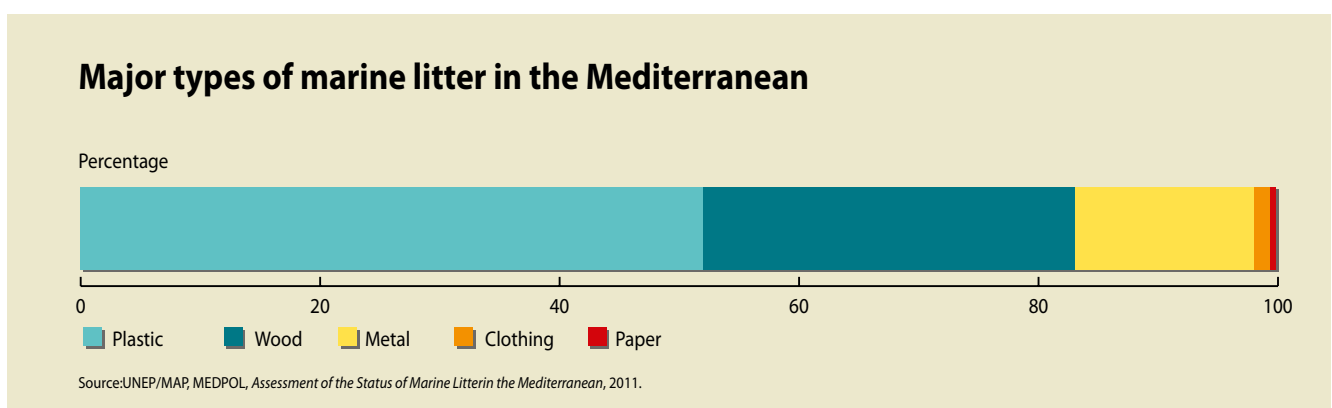
widely studied. Effects include entanglement of marine animals in plastic and ingestion of plastic by marine organisms (EEA and UNEP 2006). More attention is now being given to the impact of microplastics from such primary sources as feedstock in the plastics industry and from the breakdown of larger plastic items (GESAMP 2010). While evidence is growing that microplastics can also have negative effects on marine organisms, little scientific investigation has gone into the problem in the Mediterranean or elsewhere (GESAMP 2010). The additional challenge of microplastics is their small size, which makes them difficult to remove from the marine environment.

Impacts of marine litter on marine life

Around the world, marine litter kills more than a million seabirds and 100,000 marine mammals and turtles every year (UNEP/MAP 2012). Little information is currently available about the impact of marine litter on Mediterranean wildlife. The most significant effects come from entanglement in or ingestion of marine litter, especially plastics. Sea turtles in the Mediterranean, already seriously endangered through habitat loss and by catch, are further threatened by plastic marine litter, which they mistake for their main prey, jellyfish, and swallow (Galgani *et al.* 2010). The plastic can become lodged in the turtles' gastrointestinal tracts, resulting in injury or death.



Source: UNEP/MAP - BP/RAC, 2009.



Source: UNEP/MAP, MEDPOL, Assessment of the Status of Marine Litter in the Mediterranean, 2011.

Marine Noise

Underwater noise is a growing concern in the Mediterranean due to increasing maritime activity, particularly in the Western Mediterranean. Underwater noise affects the communication and behaviour of marine mammals and certain fishes (UNEP/MAP 2012; Notarbartolo di Sciara and Birkun 2010). Noise from human activities can drown out the sounds that the animals rely on for communication and orientation, sometimes with serious effects, even death.

The responses of cetaceans to human-created noise fall into three categories:

- Behavioural: changes in surfacing, diving, and heading patterns; abandonment of habitat.
- Acoustic: changes in type or timing of vocalisations; masking acoustic signal over large areas.
- Physiological: temporary and permanent hearing loss; mortality (Notarbartolo di Sciara and Birkun 2010; Abdulla and Linden 2008).

Beaked whales appear to be particularly vulnerable to noise (Notarbartolo di Sciara and Birkun 2010). Incidences of mass stranding and mortality of Cuvier's beaked whales have been reported in relation to the use of military sonar in the Mediterranean (Notarbartolo di Sciara and Birkun 2010). Seismic sonar (used in the oil and gas industry), the second major

Marine noise is human-generated sound from such activities as high-intensity sonar and seismic surveys and from the background sounds of commercial shipping and wind farms.

source of potential noise impacts on Mediterranean marine mammals, has received less attention. There is growing evidence that fish may also be negatively affected by noise. Possible impacts include impaired communication, stress, habitat abandonment, hearing loss, and damage to eggs (Abdulla and Linden 2008).

The impact of military sonar on marine mammals has influenced regional marine policy in the Mediterranean in recent years, but this has not yet been translated into mitigation at a broader scale (Dolman *et al.* 2011). In 2007, the Contracting Parties to the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) adopted *Guidelines to address the impact of anthropogenic noise on marine mammals in the ACCOBAMS area*. A recent ACCOBAMS status report, however, found that no significant progress has been made to address the problem of marine noise, nor have there been any systematic attempts to coordinate industrial activities with marine mammal conservation initiatives (Notarbartolo di Sciara and Birkun 2010).

Non-indigenous Species

Distribution and trends in abundance of non-indigenous species in the Mediterranean

Both the number and rate of non-indigenous introductions to the Mediterranean have been increasing in recent years (UNEP/MAP 2009). Currently, about a thousand non-indigenous aquatic species have been identified in the Mediterranean Sea, with a new species being introduced roughly every ten days. About 500 of these species are well-established; many others are one-off observations (UNEP/MAP 2012). In addition, there are also terrestrial non-indigenous species that have been introduced into the coastal zone of the Mediterranean but these species have so far not been systematically monitored.

Benthic, or seabed-living, animals are the most plentiful non-indigenous species in the Mediterranean. Most are molluscs, crustaceans, or sea worms (UNEP/MAP 2009). More non-indigenous species are found in the Eastern Mediterranean than in the Western Mediterranean.

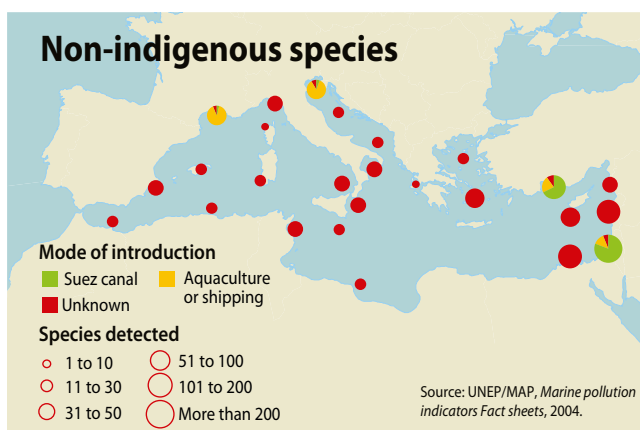
Major vectors of introduction

Non-indigenous species enter the Mediterranean through three broad avenues:

- Natural invasion through waterways such as the Suez Canal or Straits of Gibraltar;
- Transportation by ships through clinging or fouling on ship hulls, ballast water; and,
- Intentional and unintentional introduction by aquaculture activities, including commercial species, bait, and species for the aquarium trade (EEA and UNEP 1999).

Maritime transportation and aquaculture are the main ways non-indigenous species enter the Western Basin of the Mediterranean. Migration through the Suez Canal is responsible for most non-indigenous species in the Eastern Basin.

An estimated 47 % of non-indigenous species now in the Mediterranean entered through the Suez Canal, with 28 % transported by vessels and 10 % introduced through aquaculture (UNEP/MAP 2009). Species introductions from marine transport have increased because of the growth in shipping oil from the Middle East and consumer goods from Southeast Asia (UNEP/



Non-indigenous species, also known as alien species, are organisms that have entered ecosystems outside of their previously known ranges and that may survive and subsequently reproduce. They can be classified as unestablished, established, invasive (rapidly increasing numbers and range), or noxious (posing a risk).

Source: Occhipinti-Ambrogi and Galil 2004

MAP 2009). The waters around Israel and Turkey have the highest number of non-indigenous species, mainly because of their proximity to the Suez Canal (UNEP/MAP 2009).

Impact of non-indigenous particularly invasive species

The vulnerability of an ecosystem to non-indigenous species depends upon the health of that system (UNEP/MAP 2012). A polluted environment, for example, is more vulnerable than a pristine one. Physical damage from dredging, bottom trawling and other forms of habitat destruction also make an environment more vulnerable to the pressures brought by non-indigenous species (UNEP/MAP 2009).

Ecological impact

The effect non-indigenous species have on native biodiversity is poorly understood in most cases (UNEP/MAP 2012). Although no recorded extinctions of native Mediterranean species have been

Some documented ecological impacts of invasive non-indigenous species:

- Predation on native species affecting marine food chains
 - Invasive non-indigenous species of fish – parrotfish (*Thalassoma pavo*), yellowmouth barracuda (*Sphyræna viridensis*), and bluefish (*Pomatomus saltator*), for example – prey on commercial fish species.
- Competition with native species
 - Invasive non-indigenous algae of the genus *Caulerpa* displaced native sea grass (*Posidonia* spp.) meadows.
 - In Israel three native species – a starfish (*Asterina gibbosa*), a prawn (*Melicertus kerathurus*), and a jellyfish (*Rhizostoma pulmo*) – decreased in abundance at the same time as three non-indigenous species – also a starfish (*A. Burtoni*), a prawn (*Maruspenaues japonicas*), and a jellyfish (*Rhopilema pulma*) – increased in abundance.
- Changes to native communities
 - One invasive non-indigenous seaweed (*Caulerpa taxifolia*) can create dense mats that affect benthic communities and reduce spawning and feeding grounds for fish.
 - Another, related non-indigenous species (*C. racemosa*) can grow over other species of seaweed and has been linked to a decrease in sponges.

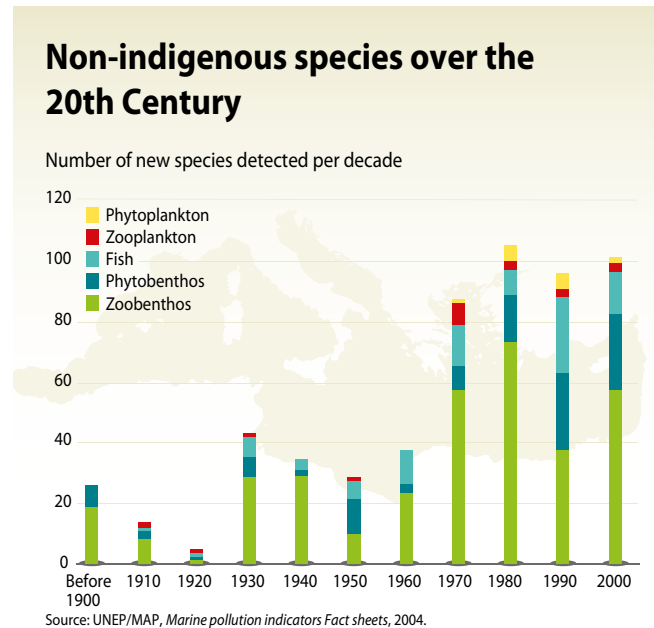
Sources: UNEP/MAP 2012; EEA and UNEP 2006

directly attributed to invasive non-indigenous species, sudden changes in abundance of native species, as well as some local extirpations associated with non-indigenous species, have been reported (UNEP/MAP/BP/RAC 2009).

Socio-economic impact

The economic impact of non-indigenous species touches a variety of sectors, including fishing (fouled nets), aquaculture (reduced light), shipping (clogged propellers, impaired navigation), public health (toxic algae), and tourism (nuisance) (EEA and UNEP 1999). Economic losses have been documented in France and Italy as a result of fishing nets being clogged by non-indigenous macroalgae (*Womersleyella setacea* and *Acrothamnion preissii*) (UNEP/MAP 2012). The jellyfish *Rhopilema nomadica* has a negative impact on tourism, fisheries, and coastal installations in the eastern Mediterranean. The tiny, single-cell dinoflagellate *Gambierdiscus*, found in waters off the west coast of Crete, causes ciguatera, a food-borne illness that results from eating certain species of reef fish (SOE 2009).

On the other hand, some non-indigenous species are or have the potential to be important fishery resources. Examples in the Mediterranean include conch (*Strombus persicus*), prawn (*Marsupenaeus japonicus*, *Metapenaeus monoceros*, and *Metapenaeus stebbingi*), crab (*Portunus pelagicus*), and fish such as mullids (*Upeneus moluccensis* and *U. pori*), lizard fish (*Saurida undosquamis*), Red Sea obtuse barracuda (*Sphyræna chryso-taenia*), clupeid (*Dussummeria acuta*, *Herklotsichthy punctatus*),



bluefish (*Pomatomus saltator*), and rabbitfish (*Siganus rivulatus*) (EEA and UNEP 2006). A non-indigenous species of prawn (*Metapenaeus monoceros*) has partially replaced the native prawn *Penaeus kerathurus* in Tunisia with no effect on the overall catch of prawns (UNEP/MAP 2012).

Commercially Exploited Fish and Shellfish

Exploitation of fish and shellfish

Fisheries are the greatest users of marine resources in the Mediterranean. Commercial fishing tends to be concentrated in in-shore areas, although there are fisheries for pink shrimp (*Penaeus duorarum*), deepwater rose shrimp (*Parapenaeus longirostris*), and hake (*Merluccius merluccius*) on the continental slope (UNEP/MAP 2009). Total fish landings increased exponentially from 1950 to 1980, with current production fluctuating around 800,000 tonnes annually (Garcia 2011) during the last three decades. Of that total, 85 % comes from six countries: Italy, Turkey, Greece, Spain, Tunisia and Algeria (UNEP/MAP 2012).

Mediterranean fisheries are primarily coastal. The abundance and distribution of exploited species in coastal waters vary according to depth, with the continental shelf being the most productive area. The shelf extends from the coast to a depth of approximately 250 m. Fisheries in this region are highly diversified, although non-industrial fishing from small boats – less than 15 m long – dominates (UNEP/MAP 2009). The entire Mediterranean fishing fleet was estimated at 85,000 boats in 2008 but the real number is likely much higher (Sacchi 2011).

Reproductive capacity of stocks

Many fish species in the Mediterranean are over-exploited as a result of growing pressure from both commercial and recreational fisheries (UNEP/MAP 2012). In the Mediterranean overall bottom-feeding stocks are dominated by juveniles, which could indicate high fishing pressure (EEA and UNEP 2006). The overfishing of juveniles can lead to changes in population structure, which ultimately affects the sustainability and recovery of stocks (UNEP/MAP 2012). Some species also have life cycles that make them more vulnerable to over-exploitation, such as slow growth rates and older age of maturity.

Fisheries tend to target larger, more valuable species higher in the food web. As the numbers of higher predators decrease

The main species of fish exploited in the coastal areas are sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) among the small pelagics, and hake (*Merluccius merluccius*), mullet (*Mullus* spp.), whiting (*Micromesistius poutasou*), angler fishes (*Lophius* spp.), sea bream (*Pagellus* spp.), octopus (*Octopus* spp.), squid (*Loligo* spp.), and red shrimp (*Aristeus antennatus*) among the demersals, and big pelagics like bluefin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*). Landings of these species represent 70–80 % of the total fish landings in the Mediterranean. Invertebrates are also exploited, including red coral (*Corallium rubrum*), many sponge species (*Spongia* spp., *Hypospongia* spp.), and natural beds of bivalves (*Lithophaga lithophaga*, *Acanthocardia* spp., *Callista chione*, etc.) (UNEP/MAP 2012).

due to over-exploitation, species further down the food web start to dominate the catch. This is known as “fishing down the food web”. This process appears to have been taking place in the Mediterranean at least since the mid-20th century (Pauly *et al.* 1998).

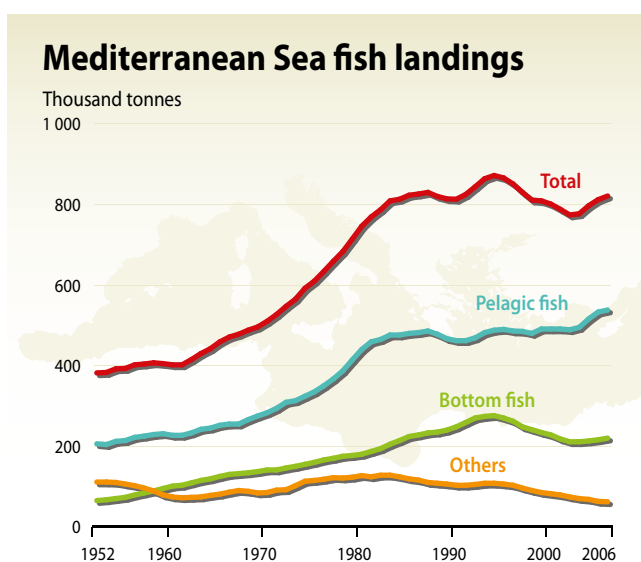
Key issues in Mediterranean fisheries

Over-exploitation

Over-exploitation of fish stocks is reported across the Mediterranean. More than 65 % of commercial stocks are fished beyond sustainable limits (UNEP/MAP 2012; Abdul Malak *et al.* 2011). Although commercial fisheries have the greatest impact, recreational fishing also places pressure on stocks. Some species, such as Atlantic bluefin tuna (*Thunnus thynnus*) and dusky grouper (*Epinephelus marginatus*), have been fished to such an extent that they are both listed as Endangered on the IUCN's Red List (Abdul Malak *et al.* 2011). Both croaker (*Sciaena umbra*) and shi drum (*Umbrina cirrosa*) have been listed as Vulnerable, while European plaice (*Pleuronectes platessa*), Baltic flounder (*Platichthys flesus*), European seabass (*Dicentrarchus labrax*), white grouper (*Epinephelus aeneus*), swordfish (*Xiphias gladius*), Atlantic chub mackerel (*Scomber colias*), and turbot (*Psetta maxima*) are listed as Near Threatened (Abdul Malak *et al.* 2011). Of the 86 shark, ray, and chimaera species in the Mediterranean, fifteen are Critically Endangered, nine are Endangered, and eight are Vulnerable (Abdul Malak *et al.* 2011). Another ten species are listed as Near Threatened (Abdul Malak *et al.* 2011). Recovery of many stocks has been hindered by factors other than fishing, such as pollution and increasing water temperature.

By catch

By catch – the accidental capture of non-target species in fisheries – is a serious issue in many parts of the Mediterranean. Species not eaten by humans are discarded overboard. Globally, one-quarter to one-fifth of all fish caught is thrown overboard (CMS [no date]). While some of the discards may be eaten by opportunistic ocean feeders, most are wasted (UNEP/MAP 2012). Longlines and driftnets result in significant by catch of sea turtles, marine mammals (especially whales and dolphins), seabirds, and sharks (Abdul Malak *et al.* 2011).



Direct and indirect impacts from fishing gear

Increasingly efficient fishing methods have a significant effect on many species. Changes include vessel engine power, size of gear and vessel characteristics, advances in navigation and fish-locating devices, and the development of fixed-gear fisheries that target the breeding class of several long-lived species in areas not effectively trawled in the past. All of these changes contribute to the decline of fish stocks (UNEP/MAP 2012 and UNEP/MAP/MED POL 2005). In addition, as fleets are modernised for longer voyages and navigation through rough seas, increased pressures can be expected on species in the open ocean and in deep waters (UNEP/MAP 2012).

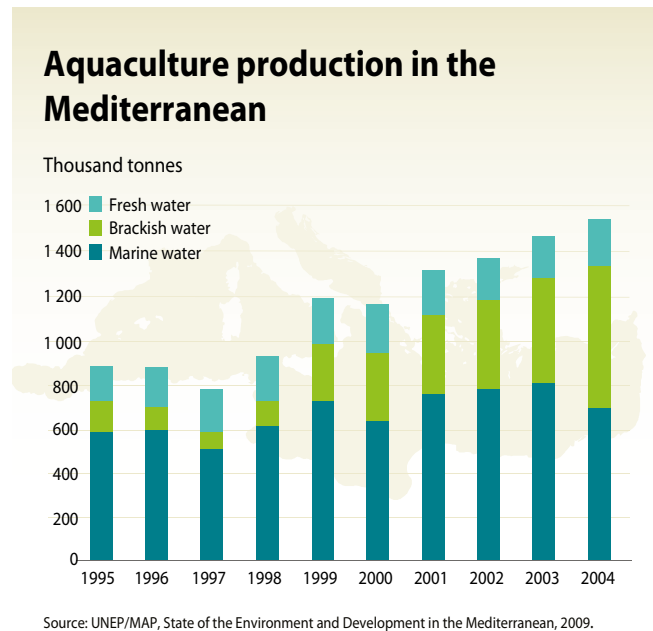
The selection of gear type affects both species and habitats. Non-selective fishing gear, such as “tonailles” – nets used for tuna – longlines, driftnets, fine-mesh nets and trawling, are the most harmful (UNEP/MAP 2012). Although driftnets have been banned in the Mediterranean, they are still in use (UNEP/MAP 2012). Ghost fishing – when lost or abandoned fishing gear continues to catch fish and other animals – is also a problem, most commonly with passive gear (e.g., longlines, gill nets, traps). The lost gear is a threat to marine species and a danger to passing boats if it becomes entangled in their propellers or in their own fishing gear.

Trawling is particularly destructive to benthic communities. It severely alters deepwater coral ecosystems and sea grass meadows and their associated fauna, reducing both the number of species and available habitat (UNEP/MAP 2012; Abdul Malak *et al.* 2011). Seamounts are particularly sensitive to fishing impacts due to their isolation and limited geographic distribution (UNEP/MAP 2012). Regulations limit the use of towed gear at depths greater than 50 m or at distances greater than 3 miles from the coast if the depth is less than 50 m. Despite the regulations, however, illegal trawl fisheries are still widespread (UNEP/MAP/MED POL 2005).

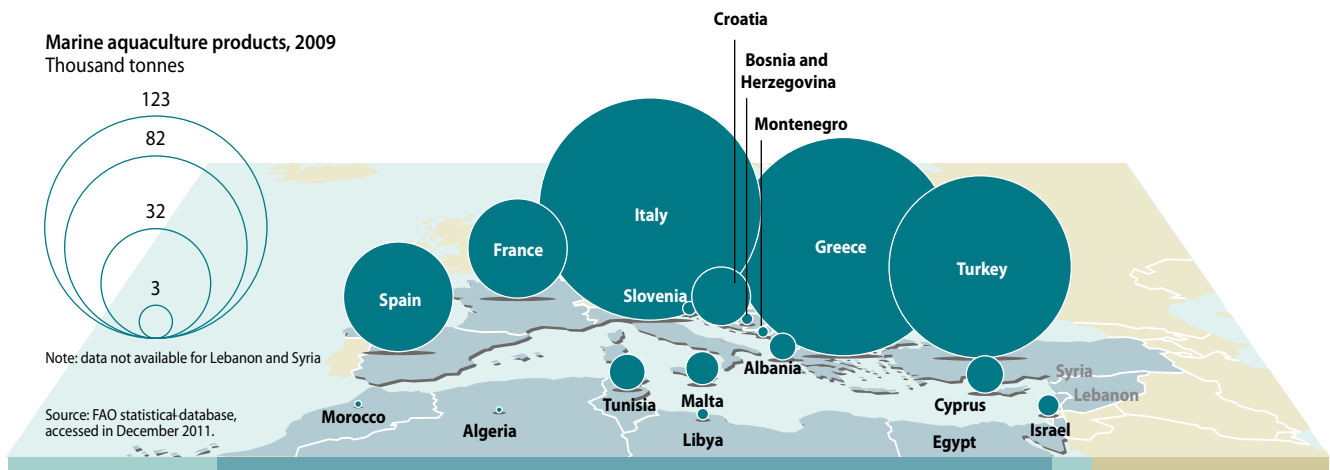
Using dynamite and poison to fish is illegal, but it is still practised in some regions (UNEP/MAP 2012). These non-selective techniques kill many non-target species and have significant negative impacts on entire ecosystems (UNEP/MAP 2012).

Artisanal fisheries, aquaculture and mariculture

The Food and Agriculture Organization defines artisanal fisheries as “traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export” (FAO/FD 2010). Ar-



Aquaculture in the Mediterranean and Black seas



tisanal fisheries continue to have a presence in the Mediterranean, although their socio-economic significance varies between countries and communities. In some regions, they represent an important source of income and food security.

Artisanal fisheries are believed to have a smaller impact on biodiversity than does industrial fishing because they tend to use lower-impact gear. Because of the wide variety of gear types and target species, however, it is difficult to determine the ecosystem effects of artisanal fisheries (UNEP/MAP 2012). At the same time, artisanal fisheries themselves can be negatively impacted by other stressors, such as pollution and the loss of important habitat.

Aquaculture is the fastest growing food sector in the world, with about one-third of global fish consumption coming from farmed fish. Although the Mediterranean region has a long history of fish farming, aquaculture and particularly mariculture have undergone a dramatic expansion since the 1990s. Decreasing wild fish stocks, combined with increasing consumer demand for fish, have spurred the growth of the industry. Of particular importance to Mediterranean aquaculture are gilthead sea bream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*), mussels (*Mytilus galloprovincialis*) and flat oysters (*Crassostrea gigas*). More than half of aquaculture production in the Mediterranean comes from western European countries (58%), but Greece is a global leader in the production of gilthead sea bream (UNEP/MAP 2012).

To meet the demand for fisheries products, aquaculture in the Mediterranean has expanded from land-based and inshore op-

erations to offshore cage farming (mariculture) (CIESM 2007). For some species, such as sea bass and sea bream, a majority of farms limit their land-based activities to hatcheries, with most of the growth taking place in sea cages.

While aquaculture offers considerable economic benefits, it can also have an impact on local biodiversity. Particular effects include: organic pollution and eutrophication from waste products and uneaten feed (in some cases leading to local hypoxia and anoxia); degradation of benthic habitats under cages, including valuable sea grass meadows; release of antibiotics and biocides; spread of benthic pathogens; and introduction of non-indigenous species (UNEP/MAP 2009 and CIESM 2007).

Grow-out facilities for tuna warrant special attention for their impact on bluefin tuna and other species. In these operations, schools of tuna are live-trapped by purse seine nets and then fattened in cages until they reach marketable size. In 2004, almost 225,000 tonnes of tuna were raised by this method in the Mediterranean (UNEP/MAP 2009). Since many of the catches are undeclared, there are no accurate figures for the size of the catch. It is estimated that in 2005, 44,000 tonnes were caught, a figure which is 37% over the legal quota and 77% above the quota recommended by experts (UNEP/MAP 2009). This practice increases pressures on both wild tuna populations and fish that are caught to feed the penned tuna (e.g., anchovies, mackerel, sardines). It is estimated that it takes 25 kg of fish to produce 1 kg of tuna (UNEP/MAP 2009). There are also ramifications for human populations dependent upon these food fish, most notably in West Africa.

Sea-floor Integrity

Distribution of physical damage on the sea floor

Fishing is one of the major contributors to habitat damage in the Mediterranean Sea. Most of this damage comes from trawling operations. Since fishing is most intense in the Western Mediterranean, it is not surprising that impacts on marine habitats are particularly severe there (UNEP/MAP 2012). Benthic, or sea-bottom, habitats and the communities associated with them are especially vulnerable.

In sea-bottom habitats of the open seas, deep-water coral ecosystems, the feather star (*Leptometra phalangium*), the sea pen (*Funiculina quadrangularis*), and bamboo coral (*Isidella elongata*) beds are considered most vulnerable to impacts from fishing (UNEP/MAP 2012). The location and extent of these habitats, however, are not well known. Even less is known about vulnerable deep-sea fauna that inhabit abyssal plains throughout the Mediterranean.

Impact of disturbance in key benthic habitats

Physical damage to the sea floor can result from a number of human activities, including offshore construction, dredging, and fisheries. The impacts of offshore construction in the Mediterranean, generally drilling rigs, wind farms, and other energy facilities, have not been systematically evaluated (UNEP/MAP 2012). The construction and operation of these installations could have direct and indirect impacts on the benthic community and ecology. The behaviour and ecology of pelagic organisms could also

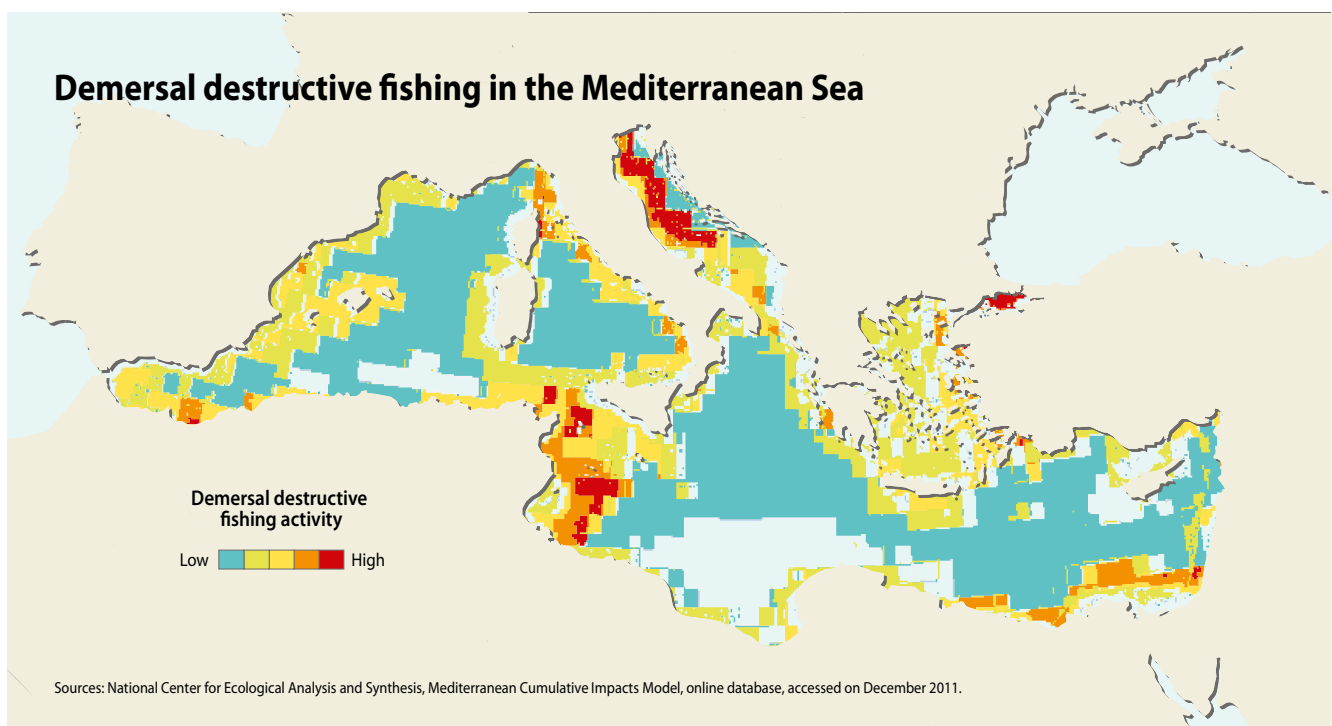
be affected (for example, through avoiding areas with these installations) (UNEP/MAP 2012).

Trawlers, dredges, and other kinds of bottom gear used in fishing can damage the seafloor in a variety of ways. These include:

- Re-suspension, or stirring up of sediment, which impacts aquatic plants, bottom-dwelling animals and bottom-feeding fish, as well as stirring up contaminants;
- Removal of large benthic species, such as bivalves and crustaceans, some of which are important to the movement and mixing of marine sediments; and,
- Changes in the structure of benthic communities.

The physical disturbance caused by trawls can have long-lasting effects on fragile marine ecosystems. Corals and sponge communities are particularly sensitive to disturbance. Deep-water coral ecosystems, found across the western Mediterranean, have been severely impacted by trawling (UNEP/MAP 2012). Trawling is responsible for the loss of coralline red algae communities across large areas of the Mediterranean (IAR 2011). Cold-water coral reefs can be destroyed by a single trawl (Gianni 2004 in EEA 2006).

Sea grass meadows provide important spawning and nursery areas for many fish species. Sea grass meadows, however, are declining, partly as a result of trawling and partly due to the mooring of boats (UNEP/MAP/MED POL 2005). Sea grass beds that are fished regularly show lower density and biomass (UNEP/MAP/MED POL 2005).



Hydrographic Conditions

Human-induced alterations to the dynamics of water flows can have a profound effect on the ecology of the sea and on the delivery of ecosystem services. Although some aspects of hydrographic conditions have been well-studied in some parts of the Mediterranean, the impacts of human activities on the hydrography of the region as a whole have not been systematically assessed.

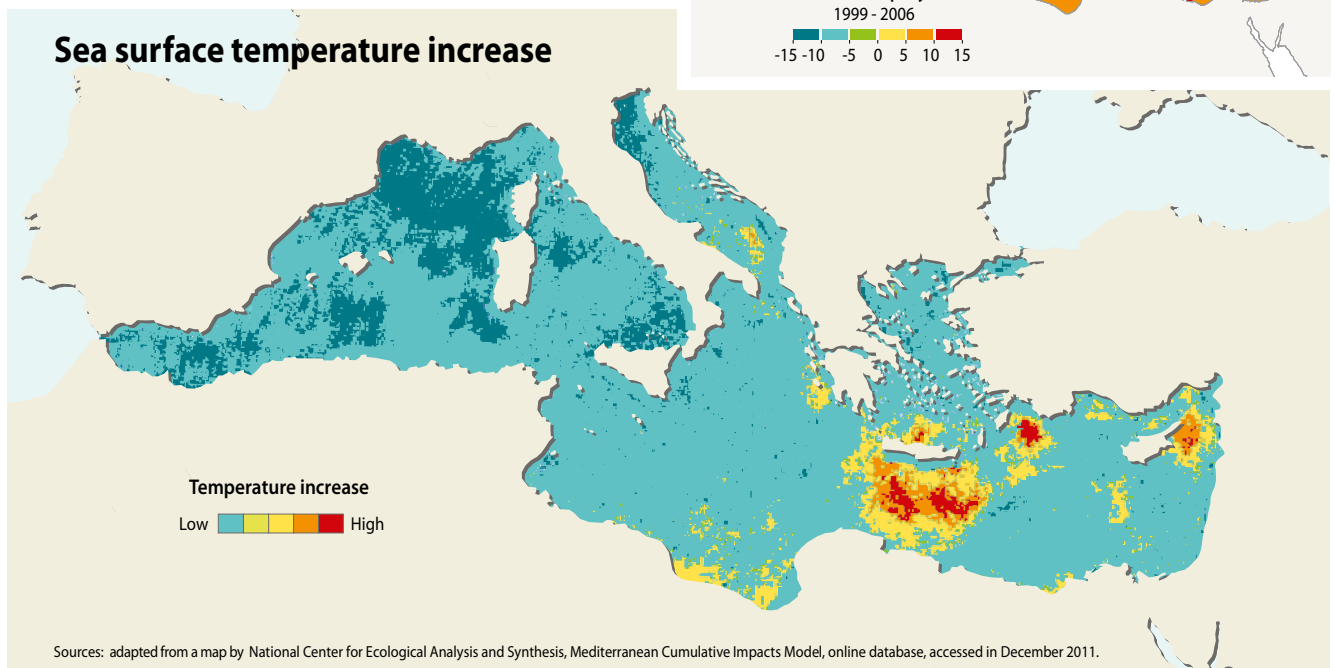
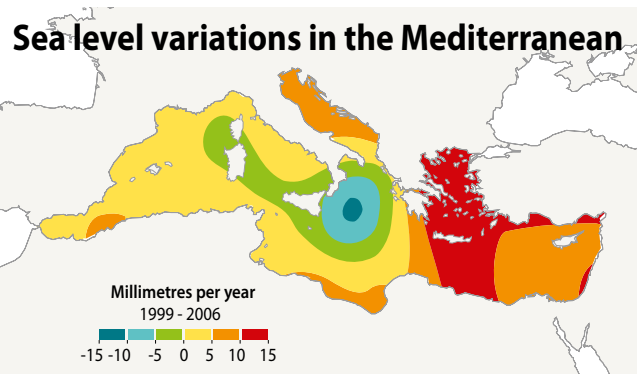
Semi-enclosed seas like the Mediterranean can become highly degraded from changes to their hydrology. Curtailing freshwater inflows to semi-enclosed seas robs them of recharging waters and nutrients. If the land around the sea is used heavily for agriculture and industry, the water reaching the basin is often of poor quality due to land-based sources of pollution (GESAMP 2001). This kind of degradation is evident in the Mediterranean Basin, especially in areas with major river drainages (Cognetti *et al.* 2000). Intensive agriculture on the limited coastal plains has come at the expense of coastal wetlands (EEA 2000), and the rate of coastal erosion is increasing due to unregulated sand mining, sprawling tourism infrastructure, urbanisation, and river damming.

The Mediterranean's typical pattern of dry periods and flash floods affects salinity at the local scale. Salinity patterns, along with temperature, influence the direction and strength of currents, which in turn affect the ecological processes that maintain these ecosystems. Local changes to salinity, triggered by a variety of causes, are a growing phenomenon in some arid portions of the Mediterranean Basin.

Sediment delivery to the coast is a key process in the maintenance of shorelines. Damming and other freshwater diversion reduce sediment delivery and can lead to coastal erosion. Sediment delivery is directly affected by changes to water flows in river basins, but sediment fate is also influenced by nearshore conditions. For example, the construction of seawalls, groynes, or placement of offshore construction can influence whether sediment that is deposited in coastal areas and on the shoreline actually stays there.

The ratio of sediment yield to annual runoff for the small mountainous rivers of the Mediterranean region is higher than the global average, yet this situation may be changing with land uses. Of the 20 Mediterranean rivers for which long-term discharge rates are known, only two (Segura and Rhone rivers) show an increase in discharge, while fourteen show a decrease of 30 % or more (Milliman and Farnsworth 2011). The result is a deepening of river channels, eroding shorelines, and eroding deltas (as in the case of the Nile, Ebro and Rhone rivers).

Climate change accelerates the rates of hydrologically-influenced degradation and can compound its impacts. According to CIESM, Western Mediterranean waters are experiencing a substantial warming trend (+0,2°C in last ten years), which could have a drastic impact on species adapted to more uniform temperatures, especially deeper water organisms accustomed to a near-constant temperature of 13°C. Sea level is rising significantly in the Eastern Mediterranean, with an average 12 cm rise registered on the Levantine coast since 1992. However, causes are not yet known, and a cause-effect relationship with climate change has not yet been established. Climate change is also expected to bring changes in both precipitation patterns and frequency of catastrophic storm events. These changes, in turn, affect coastal and offshore circulation, with effects on fisheries, biodiversity, shoreline stabilisation, sediment delivery to estuaries, land accretion, and other aspects of the ecosystem.



Marine Food Webs

Ecosystem dynamics across trophic levels

Most susceptible to the negative impacts of eutrophication are semi-enclosed basins, estuaries, and lagoons, where excess nutrients are not easily dispersed (UNEP/MAP/MED POL 2005).

Red tides are a problem for some Mediterranean fisheries. Fishing and mollusc farming in the northwestern Adriatic have been damaged by blooms of the dinoflagellate, *Dinophysis* spp., which causes Diarrhetic Shellfish Poisoning (DSP). The occurrence of this organism has been responsible for temporary and prolonged bans on the harvesting and sale of mussels in the coastal and lagoon areas of Emilia-Romagna (UNEP/MAP/MED POL 2005). *Alexandrium tamarensis*, a dinoflagellate that produces Paralytic Shellfish Poisoning (PSP) toxins has been observed in the northern Adriatic (UNEP/MAP/MED POL 2005).

The initial Integrated Assessment data suggest that eutrophication is still a localised phenomenon in the Mediterranean Basin. Better monitoring regimes and analysis of resulting data to determine trends will, in the future, allow robust statements of the effect of eutrophication on the ecology, as well as on fisheries and other valuable ecosystem services.

Proportion and abundance at different trophic levels

Overfishing is changing the distribution and abundance of a number of species in the Mediterranean. There is evidence that demersal, or bottom-dwelling stocks are becoming dominated by juveniles. Among the species affected are red mullet (*Mullus*

barbatus), striped red mullet (*Mullus surmuletus*), four-spotted megrim (*Lepidorhombus boscii*) and spotted flounder (*Citharus linguatula*) (EEA and UNEP 2006).

Overfishing in the Mediterranean has also caused a collapse in red coral beds (*Corallium rubrum*), date shell (*Lithophaga lithophaga*), some sponges, such as *Hypospongia communis* and some *Spongia* species and some *Decapoda* crustaceans, such as the European lobster (*Homarus gammarus*) and the European spiny lobster (*Palinurus elephas*) (UNEP/MAP 2012). Numerous fish stocks are overexploited and experiencing declines. They include the European eel (*Anguilla anguilla*), dusky grouper (*Epinephelus marginatus*), and brown meager (*Sciaena umbra*) (UNEP/MAP 2012). Hake (*Merluccius merluccius*), mullet (*Mullus barbatus*), deep sea pink shrimp (*Parapenaeus longirostris*), sole (*Solea solea*), sardine (*Sardina pilchardus*), and anchovy (*Engraulis encrasicolus*) are also overfished in various parts of the Mediterranean (UNEP/MAP 2012).

There is a particular concern with respect to the overfishing of many big pelagic species, including the Mediterranean bluefin tuna (*Thunnus thynnus*), swordfish (*Xiphias gladius*), albacore (*Thunnus alalunga*), and pelagic sharks, such as the blue shark (*Prionace glauca*) (UNEP/MAP 2012). Sharks are under particular pressure in the Mediterranean. A 2008 study of 20 shark species using records dating back to the early 19th and mid 20th century found sufficient data for only five species, and these five had all declined by more than 96 % (Ferretti *et al.* 2008). The decrease of top-level predators in the Mediterranean Sea is already altering marine food webs in many parts of the sea (Sala 2004).

Biodiversity

Species biodiversity

Mediterranean coastal and marine biodiversity is high by all measures. The basin supports some of the richest fauna and flora in the world and the habitat-level diversity is extraordinary. It is recognised as one of the world's 25 top biodiversity hotspots, defined as areas with rich biodiversity, a large number of endemic species – species unique to the region – and critical levels of habitat loss (Meyers *et al.* 2000). There are an estimated 10,000–12,000 marine species in the Mediterranean, comprising approximately 8,500 macroscopic fauna, over 1,300 plant species, and 2,500 species from other taxonomic groups (UNEP/MAP 2012). This represents 4–18 % of the world's known marine species, depending on the taxonomic group (from 4,1 % of the bony fishes to 18,4 % of the marine mammals), in an area covering less than 1 % of the world's oceans and less than 0,3 % of its volume (UNEP/MAP 2012 and Bianchi and Morri 2000).

The level of endemism in the Mediterranean is high compared with other seas and oceans, including the Atlantic Ocean with 50 to 77 % of Mediterranean marine species being Atlantic species (found also in the Atlantic Ocean); 3 to 10 % being pan-tropical species from the world's warm seas; 5 % being Lessepsian species – species that have entered the Mediterranean from the Red Sea – while the remaining 20–30 % are endemic species: that is, species native only to the Mediterranean Sea (UNEP/MAP 2012).

The percentage of endemism is very high for sessile or sedentary groups, including ascidians (50,4 %), sponges (42,4 %), hydroids (27,1 %), and echinoderms (24,3 %). Endemism is also considerable for the other groups, such as decapod crustaceans (13,2 %) and fish (10,9 %).

Species diversity in the Mediterranean Basin tends to increase from east to west with 43 % of known species occurring in the Eastern Mediterranean, 49 % in the Adriatic, and 87 % in the Western Mediterranean (UNEP/MAP 2012). The Western Mediterranean also has more endemic species than other regions of the sea. In addition, its proximity to the Atlantic Ocean and its seasonal frontal and upwelling systems provide nutrients. The Western Basin also supports the greatest diversity of marine mammal, sea turtle and seabird life of the Mediterranean (UNEP/MAP 2012). The southeast corner of the Mediterranean, the Levant Ba-

sin, is the most biologically impoverished area. While there is an ecological basis for lower diversity in the Eastern Mediterranean, this area has also not been as well studied as other parts of the sea (UNEP/MAP 2012).

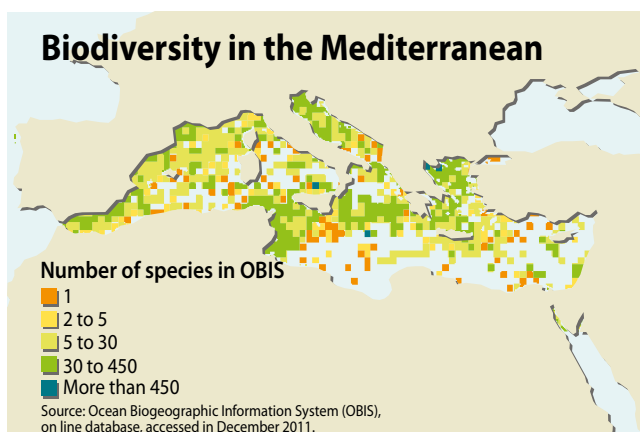
Species distribution also varies according to depth, with most flora and fauna being concentrated in shallow waters up to 50 m in depth. Although this zone accounts for only 5 % of Mediterranean waters, 90 % of the known benthic plant species are found here, as are some 75 % of the fish species (UNEP/MAP/RAC/SPA 2010). The high seas of the Mediterranean also support a great variety of marine life in areas of high productivity (gyres, upwellings and fronts) (UNEP/MAP/RAC/SPA 2010). Very little is known about the deep-sea areas of the Mediterranean.

Although the Mediterranean Basin is high in biodiversity, many of its species are threatened by a range of human activities. The loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*) and green (*Chelonia mydas*) marine turtles are all found in the region. While the loggerhead remains relatively abundant, it seems to have almost deserted the Western Basin. The other two species are becoming increasingly rare. Nesting sites for the herbivorous and migratory green turtle are in Cyprus, Turkey, Syria, Egypt, Lebanon and Israel. There is a total of only 2,000 nesting females at these sites, and this number is declining. Important nesting sites for the loggerhead turtle are on the coasts of Greece and Turkey, on a number of Mediterranean islands, and in Tunisia, Libya and Egypt along the North African coast. The leatherback turtle is more rare in the Mediterranean and has no permanent nesting sites, although there are some breeding records for Israel and Sicily.

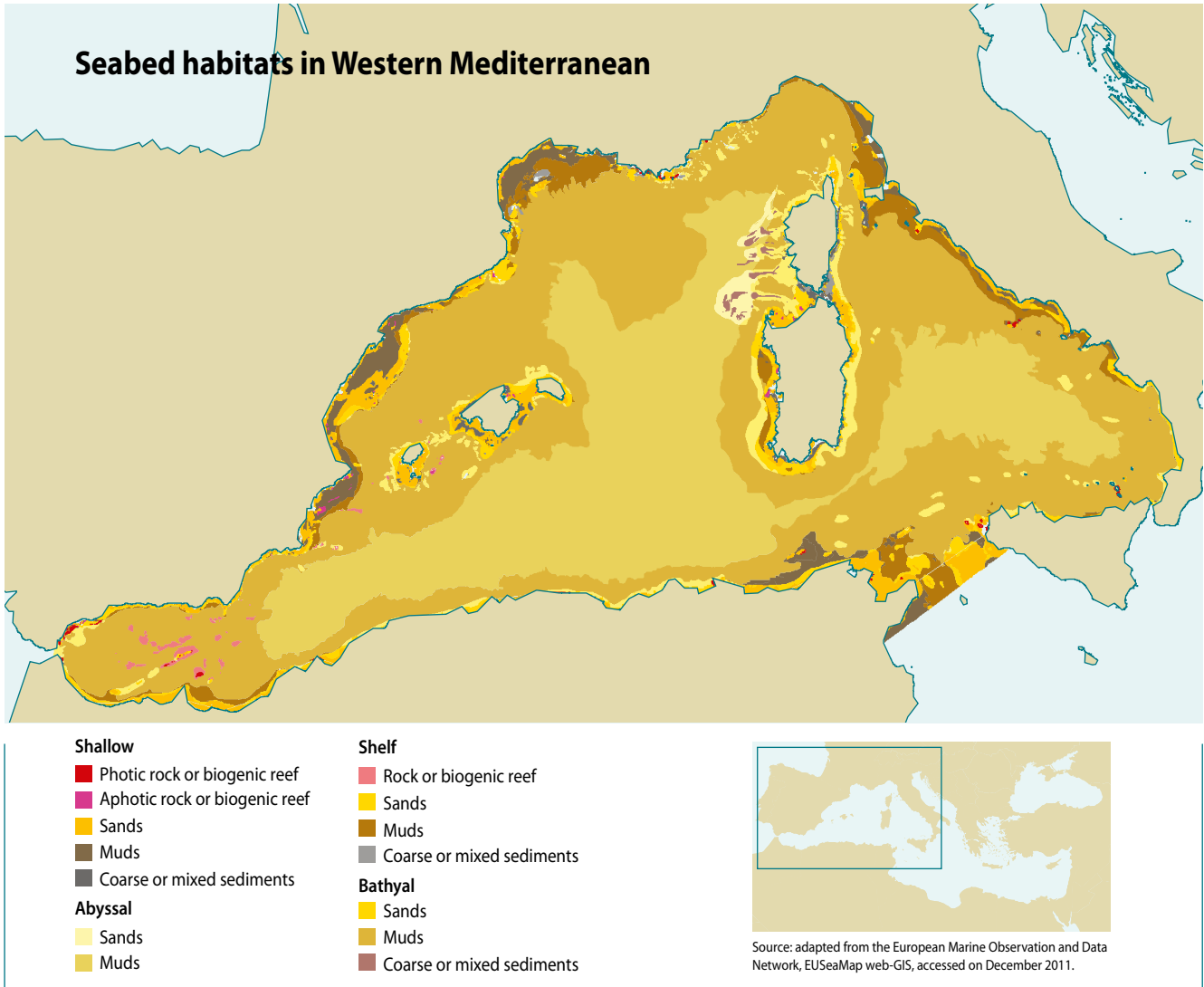
Populations of the Audouin's gull (*Larus audouinii*) have reached dangerously low levels, in part because the species depends on rocky islands and archipelagos as breeding sites free from disturbance and competition with opportunistic yellow-legged gulls. Several species of birds typical of the Mediterranean climatological region are threatened in their European and, possibly, in the whole of their Mediterranean range because of the loss of suitable disturbance-free habitat. Of particular note are the endangered white pelican (*Pelecanus onocrotalus*), Dalmatian pelican (*Pelecanus crispus*), great white heron (*Egretta alba*), and slender-billed gull (*Larus genei*).

The Mediterranean is very important for migratory birds. Twice a year, some 150 migratory species cross the narrow natural passages in the regions of the Straits of Gibraltar (between Spain and Morocco), Sicily Strait (between Tunisia and Italy), Messina (Italy), Belen Pass (Turkey), the Lebanese coast, and the Suez Isthmus (Egypt), taking advantage of the wetlands occurring on their way.

Several species of marine mammals have reached dangerously low population levels. Their survival has become questionable unless immediate measures are taken for their conservation. The species for which this is most evident is the Mediterranean monk seal (*Monachus monachus*) which breeds on rocky islands and archipelagos free from human disturbance. The population of these seals in the Mediterranean is probably fewer than 300



Seabed habitats in Western Mediterranean



individuals. Their greatest concentration occurs along the Turkish and Greek coasts. Very small populations remain in Cyprus, Croatia and maybe Libya, with vagrants occurring in Syria, Algeria and Tunisia.

About twenty cetacean species have been reported in the Mediterranean Sea, about half of which come from Atlantic populations entering the sea only sporadically. Only nine small cetacean species and three large whale species are sighted frequently in the Mediterranean Sea. They are the minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), short-beaked common dolphin (*Delphinus delphis*), long-finned pilot whale (*Globicephala melas*), Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), sperm whale (*Physeter macrocephalus*), false killer whale (*Pseudorca crassidens*), striped dolphin (*Stenella coeruleoalba*), rough-toothed dolphin (*Steno bredanensis*), bottlenose dolphin (*Tursiops truncatus*) and Cuvier's beaked whale (*Ziphius cavirostris*). The Aegean Sea is of particular importance to the harbour porpoise (*Phocoena phocoena*), a rare species not found elsewhere in the Mediterranean region except in the Black Sea (UNEP/MAP 2012).

The Mediterranean fish fauna is diverse, but fisheries are generally declining. Of the 900 or so known fish species, approximately 100 are commercially exploited. Unsustainable catch rates of rays (including the disappearance of certain taxa from commer-

cial catches) and other demersal species are of special concern (Tudela 2004). Fisheries impacts extend beyond elasmobranchs, finfish, or other target species. Longline fishing is a main cause of seabird mortality in the Mediterranean, while longline and other fisheries kill sea turtles incidentally (Tudela 2004). Longline fleets are a particular threat to the loggerhead turtle population, as are trawlers and small-scale gears in some areas, such as in the Gulf of Gabès. Driftnet fisheries and, to a much lesser extent, small-scale fisheries using fixed nets and purse seines, appear to account for the highest impact on the region's cetaceans. They are also responsible for the highest rates of direct human-induced mortality. The population of monk seals in the Mediterranean continues to be at risk from direct mortality by artisanal fishing crews and, to a lesser extent, by their gear.

Habitat biodiversity

The Mediterranean Basin has a wide array of habitats that include sea grass beds, intact rocky shorelines, persistent frontal systems, estuaries, underwater canyons, deepwater coral assemblages and sea mounts (UNEP/MAP 2012).

Sea grass meadows are among the most important and productive habitats in the Mediterranean, providing spawning and nursery grounds for many commercial species. Five species of sea grasses are found in the Mediterranean: *Cymodocea nodosa*,

Halophila stipulacea, *Posidonia oceanica*, *Zostera marina* and *Zostera noltii*. The endemic *Posidonia oceanica* meadows are considered to be the most important of the sea grass ecosystems, supporting 25 % of the fish species in the Mediterranean (UNEP/MAP/RAC/SPA 2010 and UNEP/MAP 2009). *Posidonia oceanica* meadows play a central role in stabilising the seashore and in maintaining water quality, particularly through oxygen production. The stability of the seashore is maintained by these meadows. In a number of places, the disappearance of sandy beaches has followed the disappearance of sea grass meadows (Batisse and de Grissac 1995). *Posidonia oceanica* meadows are among the most important fish nursery areas in the Mediterranean. Two sea grass species (*Posidonia oceanica* and *Zostera marina*) are among species considered Endangered (see List of Endangered or Threatened Species in Annex).

The total economic value of sea grasses is estimated at over 15.000 Euros per hectare (UNEP/MAP 2009). Despite their ecological and economic value, sea grass meadows are likely declining in areal extent. This is at least in part due to trawling activities (UNEP/MAP/MED POL 2005). Endemic sea grasses in the north-west Mediterranean are also threatened by the invasion of an exotic tropical species of sea grass, *Caulerpa taxifolia*, that was accidentally released in 1984 and has now spread.

Coralligenous communities, formed by the accumulation of calcareous algae – of the order Corallinales – are the next most important biodiversity hotspot in the Mediterranean after *Posidonia* meadows (UNEP/MAP/RAC/SPA 2010). These concretions are common throughout most of the Mediterranean and are found at 40–120 m in depth (UNEP/MAP 2009). They support over 17.000 species, including many species of commercial interest. Many small sharks also inhabit these reefs. Reef communities are particularly threatened by the use of bottom gear in fisheries.

Wetlands and lagoons are also highly productive, supporting both marine and coastal (terrestrial and freshwater) organisms. They perform numerous other functions related to flood control, recreation, tourism, fisheries, and agriculture, as well as chemical and physical reduction of pollution. Wetlands and lagoons provide breeding and wintering areas for a great variety of birds and are essential stopover points on the migratory routes of numerous bird species. Nonetheless, a significant number of Mediterranean wetlands have been “reclaimed” over history. Important lagoon systems remain in Spain (Valencia), France (Languedoc and Giens), Italy (Sardinia, Tuscany, Apulia, and Venice), Central Greece, Cyprus, Morocco (Nador), Algeria, in many places in Tunisia and across the entire Nile delta in Egypt. Estuaries constitute another important and widespread habitat, as there are some 70 sizeable rivers and streams flowing into the Mediterranean. Finally, the region’s rocky shores have characteristic biogenic constructions, including platforms with *Lithophyllum lichenoides* (a calcareous alga) on steep coasts and vermetid platforms (with built-up deposits of shells of the gastropod *Dendropoma*) on calcareous coasts (Batisse and de Grissac 1995).

These and other coastal ecosystems are also important for endangered species. The Mediterranean monk seal uses caves as terrestrial habitat. Endangered marine turtles use sandy beaches for nesting, sea grass meadows for feeding and sea grass meadows or muddy bottoms for wintering. Marine birds use wetlands, rocky shores or islands for nesting and resting.

High seas, areas lying outside of the territorial waters of the Mediterranean countries, comprise a large part of the Mediterranean (2,5 million km²) (UNEP/MAP 2012). This habitat type supports a great variety of marine species. Upwellings, gyres, and fronts (areas where water masses of different temperatures meet) are distinctive features of the high seas (UNEP/MAP/RAC/SPA 2010). Upwellings, in particular, are among the most productive marine ecosystems. The high seas are especially important to marine turtles, whales, and top predators such as sharks, dolphins, and seabirds.

Particularly vulnerable species and habitats

Mediterranean species and habitats face a number of pressures from human activities, including over-exploitation; degradation of critical habitats; invasive alien species; pollution, including excess nutrients, toxic pollutants, and litter; and the use of non-selective fishery gear (e.g., drift nets and purse seine nets) (UNEP/MAP/MED POL 2005).

While there is no evidence of species loss in the Mediterranean, the status of a number of species is of concern. As of 2012, over 120 marine and freshwater species have been identified under the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean Sea (see Annex). There is insufficient information to determine whether there has been a loss of genetic biodiversity.

Among the most endangered marine vertebrate species are: the Mediterranean monk seal; common bottlenose dolphin, short-beaked common dolphin, and striped dolphin; sperm whale; green turtle, leatherback turtle and loggerhead turtle; and cartilaginous fishes (sharks, rays, and chimaeras) (UNEP/MAP/MED POL 2005).

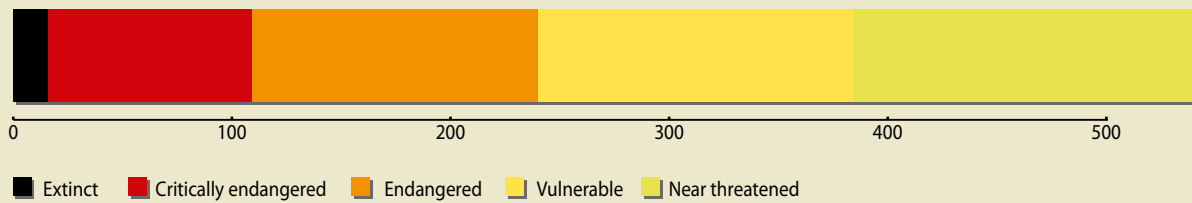
Monk seals were once present throughout the Mediterranean but are now limited mainly to the Aegean coast (UNEP/MAP 2012). Their numbers have been greatly reduced by poaching, by catch, habitat destruction, and population fragmentation (UNEP/MAP 2012). The Mediterranean monk seal is now listed as Critically Endangered on the IUCN’s Red List (UNEP/MAP 2009).

Dolphins are vulnerable to reduced prey availability as a result of overfishing, habitat degradation, by catch and pollution. It has been proposed that the common bottlenose dolphin and striped dolphin be listed as Vulnerable, while the short-beaked common dolphin has been assessed as Endangered (Notabartolo di Sciarra and Birkun 2010).

Sea turtles are vulnerable to human activities throughout their life cycle. Contributing to their decline in the Mediterranean are past exploitation; entanglement in fishing gear; loss of sea grass meadows which serve as feeding grounds for adult turtles; degradation of beach nesting habitat due to sand extraction, tourism, light pollution, etc.; pollution and plastic waste; and increased ship traffic. Approximately 2.500 sea turtles are caught annually as by catch by Eastern Adriatic trawl fisheries and over 4.000 are caught by Italian fisheries (UNEP/MAP 2012). Loggerhead and green turtles have been listed as Endangered by the IUCN while the leatherback turtle is listed as Critically Endangered (UNEP/MAP 2012 and Seminoff 2004).

Chondrichthyans (cartilaginous fishes) of the Mediterranean are in a particularly dire situation. Nearly 7 % of the world’s sharks, rays, and chimaeras live in the Mediterranean Sea.

Number of species in IUCN Red List categories from Mediterranean countries



Source: IUCN, *The Mediterranean: a Biodiversity Hotspot Under Threat*, 2008.

Note: this includes Amphibians, Birds, Cartilaginous fishes, Crabs and Crayfish, Endemic freshwater fishes, Mammals, Dragonflies and Reptiles

Thirty-six (42 %) of the 86 species that live and breed in the Mediterranean are threatened. Of these, fourteen species are Critically Endangered, nine are Endangered, and eight are Vulnerable (Abdul Malak *et al.* 2011). This compares with approximately 20 % of cartilaginous fishes being threatened at a global level (Abdul Malak *et al.* 2011). Ten Mediterranean species are Near Threatened, while only ten are classified as of Least Concern. A further 25 species are considered Data Deficient – not enough information exists to assess their condition. Twenty-four species are protected by the Barcelona Convention through listing in Annex II of the SPA/BD Protocol (see List of Endangered or Threatened Species in Annex of this report). The greatest threat to these cartilaginous fishes is from fisheries by catch, followed by pollution, habitat loss and degradation, and human disturbance. Their vulnerability is increased by their life history characteristics. They are slow growing, late to mature, and have low fecundity and productivity and long gestation periods.

Seabirds of conservation concern nest in the Western Mediterranean. The Spanish Mediterranean, in particular, has one of the most diverse communities of breeding and migratory seabirds in Europe, including all three endemic seabird species (Yelkouan shearwater, *Puffinus yelkouan*; Balearic shearwater, *Puffinus mauretanicus*; and Audouin's gull, *Larus audouinii*) (UNEP/MAP 2012). In the Eastern Mediterranean, seabirds are threatened by habitat loss due to drainage, water diversion, changes in annual water regime, eutrophication, reed cutting, and landfills, chemical pollution, and hunting (UNEP/MAP 2012).

Benthic communities including seamount communities, volcanic vent communities, bryozoans, corals, hydroids and sponges are vulnerable to human disturbance. The mechanical disturbance of marine habitats that occurs with some activities such as trawling, dredging, dumping, and oil, gas, and mineral exploration and extraction can substantially change the structure and composition of benthic communities (Froude 1998).

As in other heavily fished areas of the world, these benthic impacts are apparent in the Mediterranean (Dayton *et al.* 1995; Thrush *et al.* 1998). Fishing practices that have deleterious effects on the seabed involve the use of bottom trawling gears, namely otter trawls, beam trawls, and dredges. Some aggressive fishing practices that affect rocky bottoms are dynamite fishing and fishing for coral and date mussels (Tudela 2004). GFCM recommendation 2005/1 on bottom trawling in the Mediterranean leaving off-limits depths greater than 1.000 m may provide significant protection for benthic marine biodiversity if it is efficiently enforced. However, trawling also affects shallow-water sea grass beds, both by stirring up sediments and by directly damaging the mass of vegetation. These fisheries are a major threat to *Posidonia* beds.

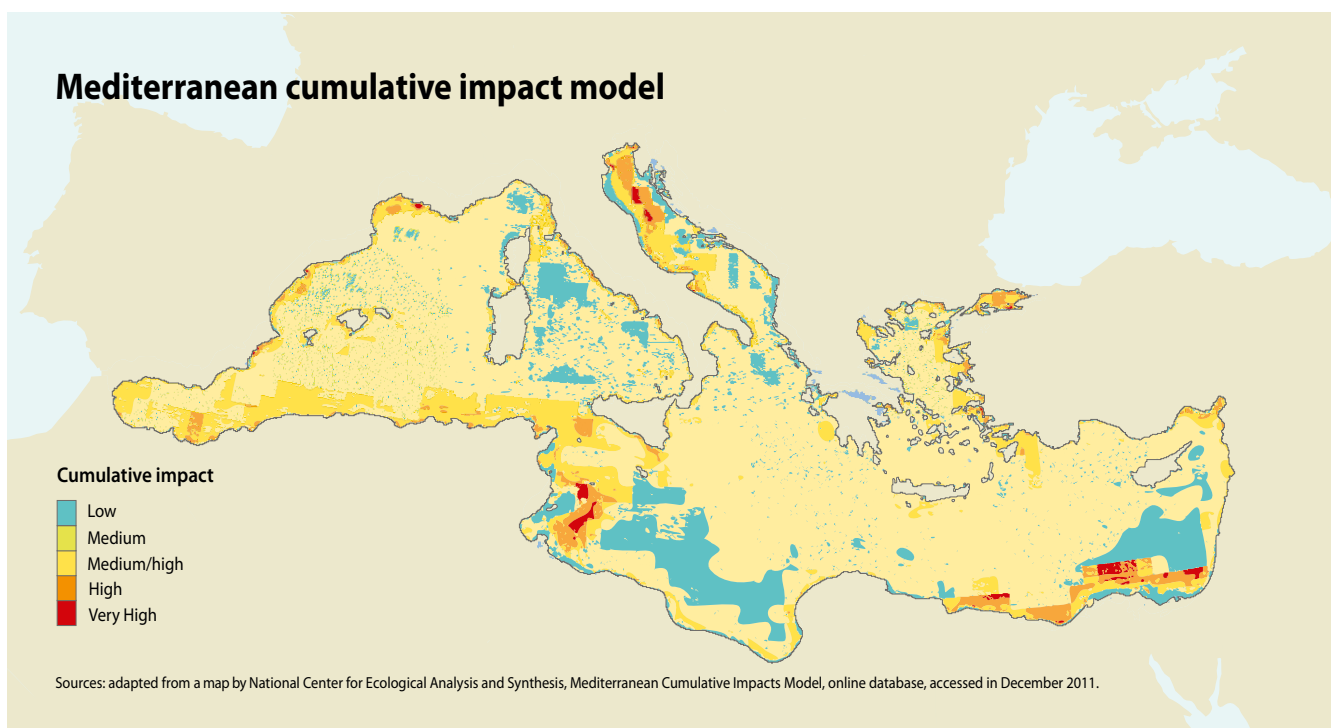
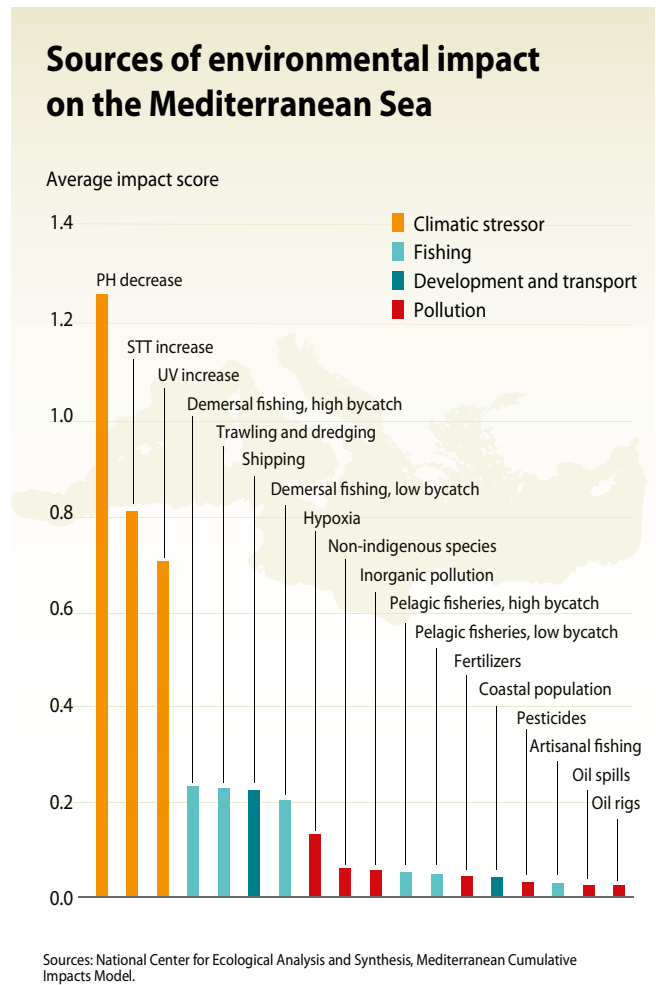
Overall, there are still considerable gaps in the knowledge of marine species and habitats in the Mediterranean, and the knowledge that does exist is patchy in distribution (UNEP/MAP 2012). The SPA & Biodiversity Protocol identifies over 100 species that are of special conservation interest in the Mediterranean. Even the information on these species and their habitats, however, is sometimes limited (UNEP/MAP 2012).

Cumulative and Concurrent Impacts

None of the factors affecting the Mediterranean Sea and its coasts, along with its inhabitants, exist in isolation. Different pressures act over time and in unison to affect the resilience of ecosystems and their ability to deliver ecosystem services. Increasing and multiple uses of ocean space increase the chances that certain threats will cause more impact when occurring simultaneously than the additive effect of individual pressures. Thus, nutrient over-enrichment can cause eutrophication more quickly when occurring in waters warmed by climate change, for example; introduced species can become more quickly invasive in ecosystems where food webs have been altered by fishing. The combined effect of nutrient over-enrichment, over-fishing of certain functional groups like grazing fishes, and climate change can act together to cause imbalances in nearshore ecosystems and loss of ecosystem services. Threats that work synergistically to cause even greater impact than individual threats acting alone should thus be monitored.

Nonetheless, understanding cumulative impacts – multiple impacts occurring through time – is notoriously difficult, especially in the absence of a monitoring regime that efficiently tracks pressures and their impacts. In the absence of such research regimes, as is the case in the Mediterranean, modelling helps us understand the impacts of multiple threats acting simultaneously.

The National Center for Ecological Analysis and Synthesis (NCEAS) has undertaken modelling to perform comprehensive spatial analysis and mapping of human pressures throughout the Mediterranean Basin. This work builds on a previous global analysis of cumulative human impacts (Halpern *et al.* 2008), including additional information to better reflect the specific pressures and ecosystems of the Mediterranean Sea and coasts. A total of



22 spatial datasets of human activities and stressors and 19 ecosystem types were assembled and used in the analyses and maps (NCEAS 2008).

The analysis concluded that pressures that exert the greatest impacts on Mediterranean marine ecosystems are climate change, demersal fishing, ship traffic, and, in coastal areas, run-off from land and invasive non-indigenous species. The lowest estimated impacts are associated with oil spills and oil rigs, due to a combination of the limited spatial extent of these pressures and their overlap with habitats with relatively low vulnerability to these potential threats. The analysis shows distinct spatial patterns in the distribution of cumulative human impacts.

Supporting the findings of the Initial Integrated Assessment done in support to the Ecosystem Approach process, the NCEAS modelling suggests that the Adriatic and Alboran seas are the most impacted by multiple human pressures, while the Western Mediterranean and the Tunisian Plateau/Gulf of Sidra are the least. Coastal areas within the territorial waters of nations, particularly Spain,

France, Italy, Tunisia and Egypt suffer the greatest cumulative impact from multiple pressures, with estimated cumulative impact scores up to ten times greater than in the high seas.

It must be noted that the modelling of cumulative impacts only suggests areas for further study. Ground-truthing is needed to see if the models accurately reflect the extent to which multiple human pressures are causing ecological impacts and potentially undermining the delivery of ecosystem services. In addition to establishing a systematic monitoring regime to derive needed information on condition and trends, future research will have to elucidate cause and effect relationships, not just correlations. The milestones recently achieved in the application of the Ecosystem Approach roadmap, namely the setting of ecological objectives and operational objectives, together with indicators, form the basis for such a rationalised approach to deriving information for all future assessments. Establishing targets, and analysing trend information to know when targets are being approached, will provide the kind of robust scientific information needed to allow management priorities to be determined and to guide effective ecosystem-based management.

