Assessment of coastal pressures in the MSFD sub-regions of the SES

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EXECUTIVE SUMMARY / ABSTRACT

The analysis of historical data sets and the results obtained from field studies about the pressures exerted on coastal ecosystems in 18 sites of the Mediterranean and the Black Sea showed that :

Inputs form Po and Danube rivers showed a high interannual variability. After an increase of eutrophication over the 70-80s, a decrease of nutrients inputs, especially of phosphate, was recorded since 1990. Positive impacts are seen on phytoplancton communities.

In the vicinity of most coastal big cities the policy measures taken in order to reduce polluted water discharges show their effectiveness although some local issues still exist.

Chemical contaminants levels decrease rapidly when the distance increase from point sources. However a large amount of coastal inputs is exported offshore. Attention should be paid to the fate and the impact of new emerging pollutants. At the basin scale, contaminant concentrations in biota show very different patterns depending on substances. For some substances, the biogeochemical background and the environmental conditions play a important role in the contamination of marine organisms.

There is globally no evidence of neither degradation nor clear trends regarding seagrass meadows. The status of seagrass habitats is correlated to water quality. It can be concluded that human pressures have not affected seagrass meadows in a irreversible way. Seagrass habitats can recover (slowly) when pressures decrease.

The rate of new introductions of Non Indigenous Species has been increasing at all coastal study areas after 2000. An increase of the Lessepsian species migration is seen, in link with climate change.

The analysis of 18 years of data about demersal fish communities showed a geographic variability in functional group (FG) biomass trends. Nearly half of the studied Mediterranean areas shows an increase of FG biomass. Changes respond mainly to nutrient inputs trends and to a lesser extent fishing pressure.

Marine litter is increasing pressure on marine ecosystems. The majority of items were made of plastic often exceeding the global average of 75%. Some harmful effects on fauna are documented (birds, turtles…) but impact is poorly known.

The lack of standardized methods for underwater noise measurements make difficult to assess the level of the pressure and the impact on marine ecosystems.

SCOPE

This deliverable presents a global synthesis of the work performed in the work package 2 of PERSEUS that was focused on the understanding of pressures and their impacts at costal level in the Mediterranean and the Black Sea. This synthesis is mainly based on the results which are described in details in the 4 following project deliverables :

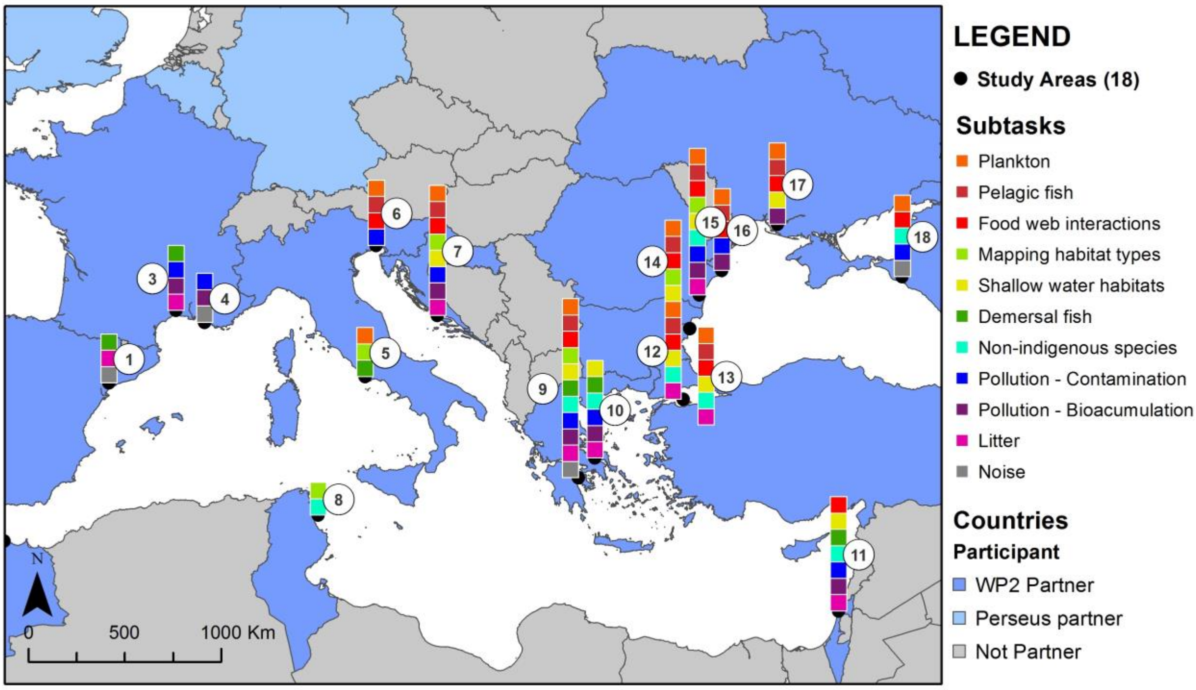
- D2.5 : Response of pelagic ecosystems to coastal pressures in different sub regions of the SES
- D2.6 : Response of benthic ecosystems to coastal pressures in different sub regions of the SES
- D2.7 : Impact of pollution (including contaminants, litter and noise) on coastal ecosystems in the SES
- D2.8 : Impact of NIS on coastal ecosystems in the SES

A summary of the results obtained from the analysis of very diverse data sets and from the field studies is given and presented by marine sub-region.

0 - Introduction

The studies carried out in PERSEUS on the pressures and impacts at coastal level were focused on the 18 coastal sites shown on Fig. 1 which can be described as "hot spots" because the high level of anthropogenic pressures they face.

In PERSEUS work package 2, a broad range of thematic fields were addressed, including the functioning of coastal pelagic and benthic ecosystems and their response to various pressures. Each thematic study was performed on a subset of selected areas. The map below (Fig. 1) shows on which sites various thematic studies have been performed.



WP2 STUDY AREAS:

Barcelona (1), Mediterranean coastal area of Morocco (2), Rhone River and Marseilles (3-4), Naples (5), Northern Adriatic (6), Southern Croatia (7), Gulf of Tunis (8), Saronikos gulf and Athens (9-10), Haifa (11), Sea of Marmara and Istanbul (12-13), Varna (14), Costanza and Danube mouths (15-16), North-western Black Sea and Sevastopol bay (17), Gelendzhik (18)

Figure 1: Map of the study areas selected for the research work carried out on the pressures exerted on coastal ecosystems in the SES

An effort was made to coordinate the work between all the study areas in order to get standardized data. The aim was to be able to compare the pressures and their impact in the different areas and to draw out as much as possible a basin wide view of the response of coastal ecosystems to pressures in the SES and of the risks of non achievement of Good Environmental Status (GES).

The document is structured as follows:

In a first part, general characteristics of the marine sub-regions of the Mediterranean and Black Seas (according to the EU Marine Strategy Framework Directive) are presented.

In a second chapter, a short description of the 18 coastal study areas is given.

The summary of the results of the scientific studies performed in PERSEUS coastal study areas is given sub region by sub region in the third part.

The final part of the document present a synthetic view of the results which are summarized in tables showing levels and trends of the pressures for each sub-region.

1 - MSFD sub-regions in the SES

The Marine Strategy Framework Directives determines regions and sub-regions taking into account hydrological, oceanographic and biogeographic features. The purpose is to facilitate the implementation of the Directive by the definition of coherent ecological entities. Regions and sub regions are appropriate scale for the definition of Good Environmental Status and the coordination of preservation measures.

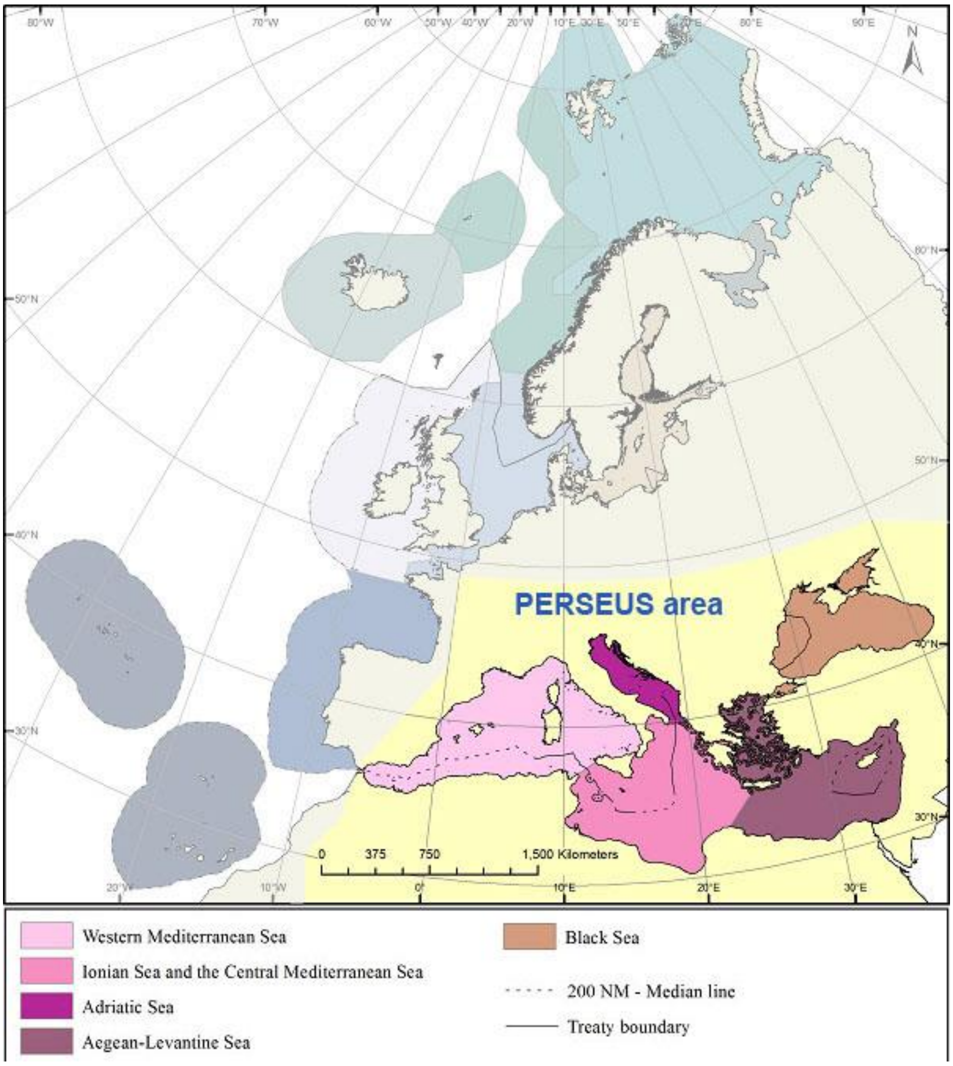


Figure 2: Map of the regions and subregions of the MSFD (Source EIONET/EEA)

The scope of PERSEUS project is the Southern European Seas, i.e. the Mediterranean and the Black Seas. Five marine regions/sub-regions are concerned:

- the Western Mediterranean Sea
- the Adriatic Sea
- the Ionian Sea and the Central Mediterranean Sea
- the Aegean-Levantine Sea
- the Black Sea

Geographical settings

The surface area of the Mediterranean Sea is 2.5 10^6 km^2 with an average water depth of 1500 m. The deepest point (5200 m) is located in the Ionian Sea.

Figure 3: Bathymetric map of the Mediterranean and Black Seas

The Mediterranean basin natural features are characterized by high gradients, mainly from West to East and from North to South (e.g. surface temperature, riverine inputs) .

The **Western Mediterranean** (WMED) is directly connected to the Atlantic Ocean via the Strait of Gibraltar and is subdivided in two sub-basins, the Algero-Provencal basin and the Tyrrhenian Sea. In the latter, the maximum depth exceeds 3500 m. The system of the Straits of Sicily can be associated both to the Western, as in this report, or to the Eastern basin, even though the morphology of the connection with the Western basin separates the Straits of Sicily system from the so called Triangle (Sicily-Sardinia-Tunisia) and forces all the intermediate water (LIW) coming from the Eastern Basin to circulate in the Tyrrhenian Sea. Large eddies, especially those associated with the Atlantic Water flowing as a strong current (Algerian current) along the southern part of the basin and widespread mesoscale activity.
One of the key processes of the WMED is the deep water formation within the basin, with an impact on the transfer of matter and tracers at depth. The water mass turnover time of the basin is quite short (tens of years for the bottom layer).

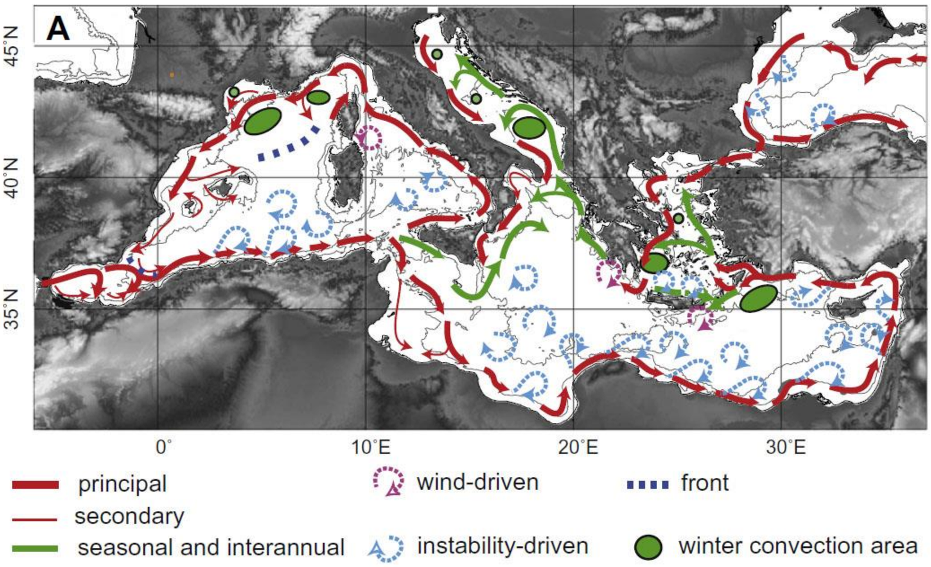


Figure 4: Surface currents in the Mediterranean and the Black Sea (from Durrieu de Madron et al 2011)

The Alboran Sea, which is the interface with Gibraltar, has a different dynamics with strong vertical, mesoscale and upwelling processes.

The continental shelf is generally very narrow with a few exceptions, e.g., the Gulf of Lion.

The **Adriatic Sea** is a semi-closed basin that stretches from the northern continental shelf (35 m of averaged depth) to the southern Adriatic Pit (1220 m of depth). The Adriatic is connected to the Ionian Sea through the Otranto Strait. The North **Ionian Sea** is featured by lower coastal development and human population than other areas of the Mediterranean Sea. The Adriatic Sea plays an important role also for the large scale dynamics of the Eastern Mediterranean, being the site of formation of the dense water, which is the dominant component of the Eastern Mediterranean Deep Water.

The **Aegean-Levantine Sea** is connected with the Black Sea through the Marmara Sea and the Dardanelles and Bosphorus Straits where a surface flow brings less saline waters into the Mediterranean. In the South East part of the sub-region, the Suez Canal give a pathway towards the Red Sea and Indian Ocean. The Eastern Mediterranean is also a area of deep convection.

A clear positive gradient from West to East can be seen for the temperature and the salinity of the surface waters.

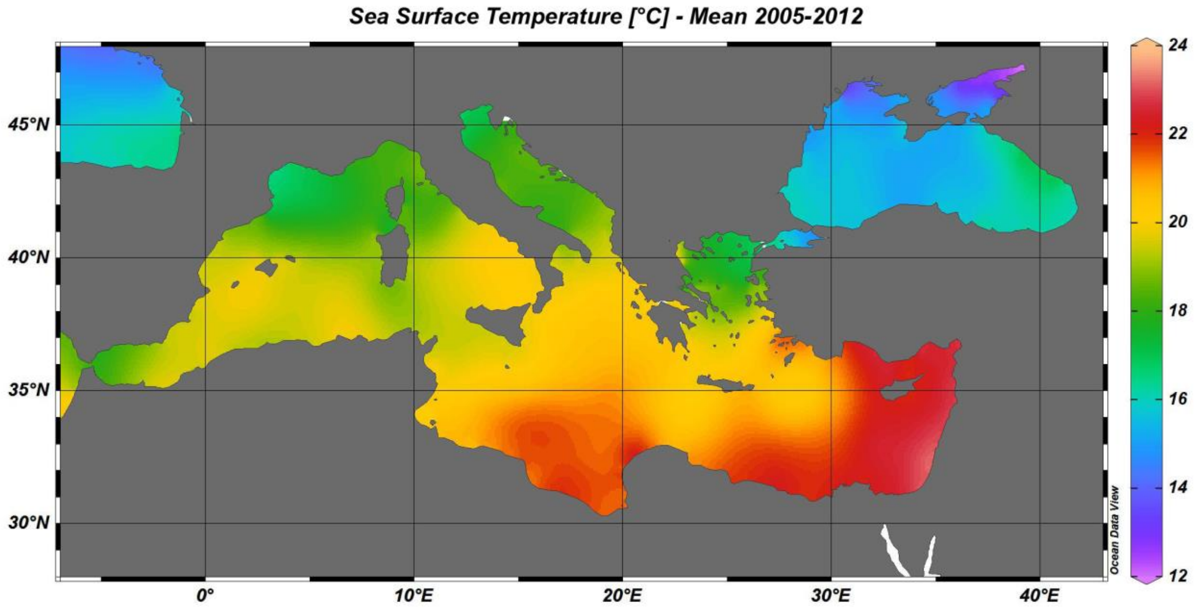


Figure 5: Average Sea Surface Temperature 2005-2012 (WOA 2013)

The **Black Sea** covers an area of 423,000 km[2], is over 2 km deep and drains an area of 1.9 million km[2] (one-third of continental Europe) containing over 160 million inhabitants. The Sea is enclosed by land and continental shelf surface of 144,000 km2 which represents approximately. 25% of the total surface. Its only connection with the World's Oceans being via the Turkish Bosphorus Strait, which links it with the Mediterranean (via the Sea of Marmara). The exchanges with the Mediterranean Sea through the Bosphorus is however reduced. Some 90% of the Black Sea is naturally anoxic (contains no oxygen), but the top 150 m layer represents an area of great biological productivity.

The major circulation component of the Black Sea is the quasi-permanent cyclonic current (main RIM current) which encircles the whole basin. The main source of the energy is the driving force of local winds and density gradients.

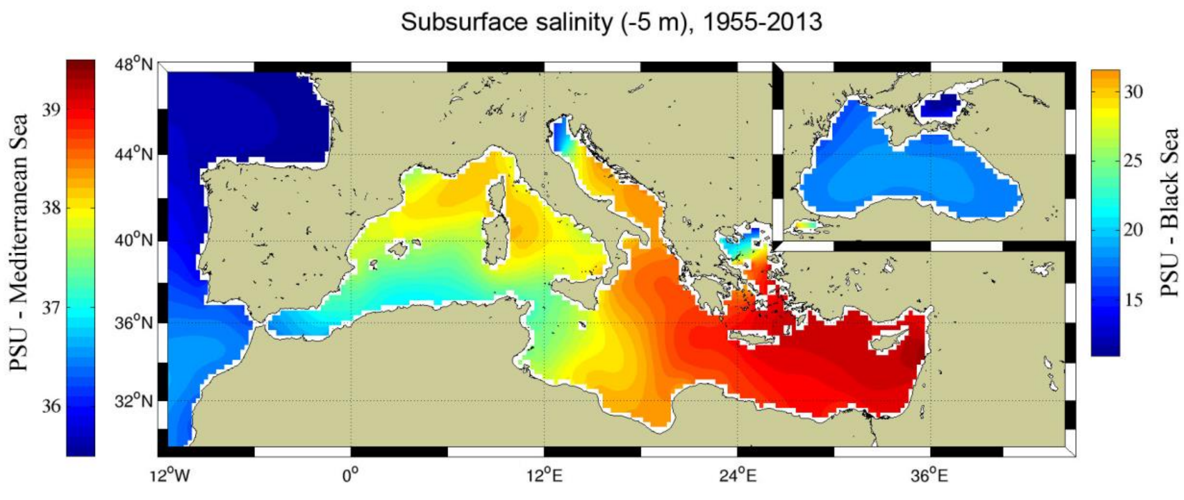


Figure 6: Average subsurface salinity in the Mediterranean and the Black Sea 1955-2013 (WOA 2013)

In the Mediterranean the continental **freshwater inputs** occur mostly in the Northern part. The main rivers are : Rhone (1721 m3/s), Po (1569 m3/s) and Ebro (416 m3/s). The discharge of Nile River has be significantly reduced since the damming at Aswan. Despite its huge drainage basin (3.3 Millions km^2), the average flow of the Nile river is estimated to 475 m3/s [Ludwig et al 2009]. The main tributary rivers of the Black Sea are Danube, Dnieper, Dniester, Bug and Kuban. 80% of Black Sea tributaries are flowing into the northwest continental shelf, the largest share being Danube River, which is 70% of tributary flows from the northwestern Black Sea. Danube drains 1/3 of the catchment area along the 2780 km, with a flow of about 6500 m3/s.

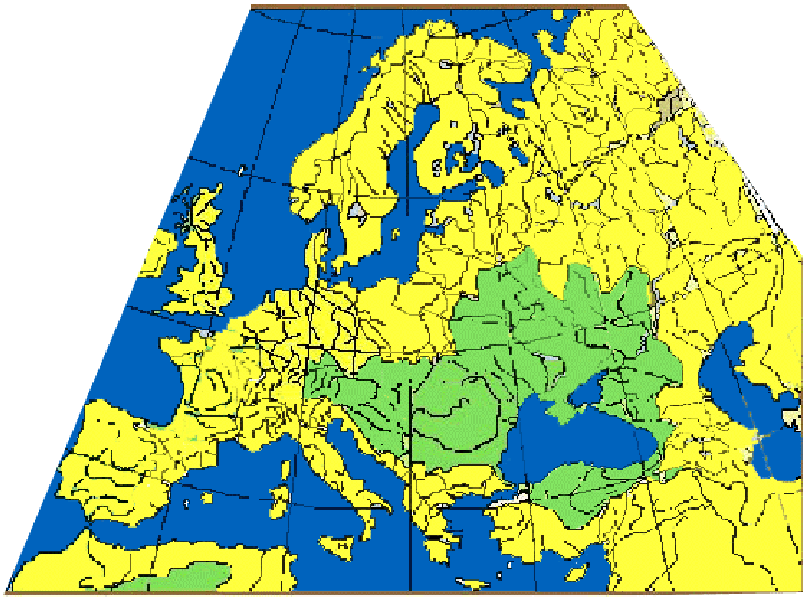


Figure 7: Black Sea hydrological basin

Marine primary production is not equally distributed in the area. In open sea, the oligotrophic character of the Mediterranean is more accentuated in the Levantine basin. Coastal areas and water masses under the influence of riverine input or straits appear to be hot spots of productivity. Due to the high amount of freshwater flowing to the Black Sea, it is often cited as an example of a ecosystem natural eutrophicated due to permanent river nutrient input.

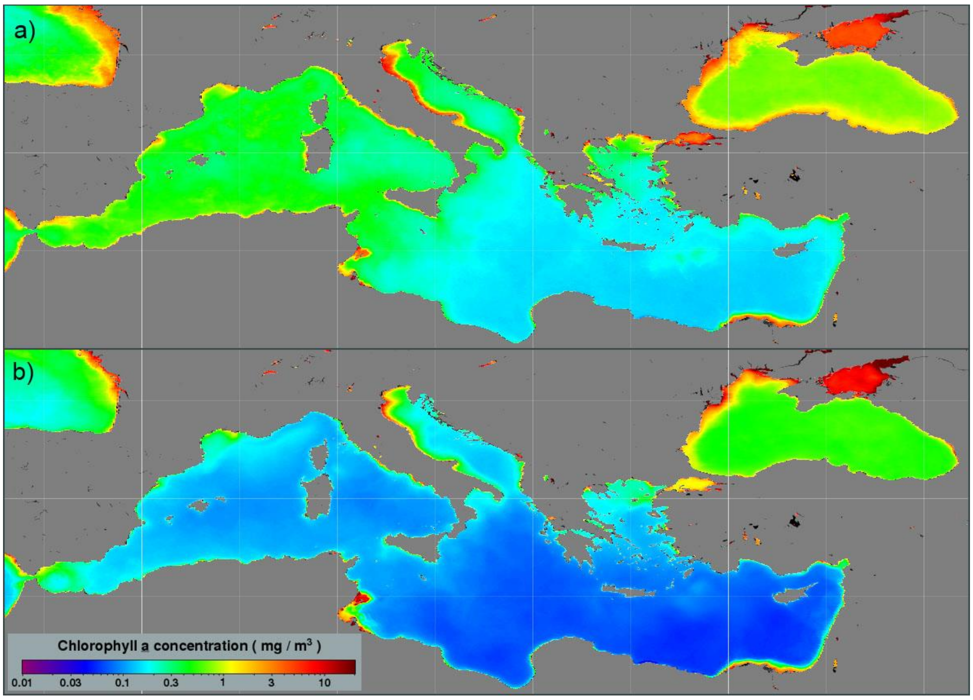


Figure 8 : Chl-a seasonal concentration 2012-2015. a) winter, b) summer (oceancolor.gsfc.nasa.gov)

The Mediterranean area is recognized as a hot spot of **biodiversity** with a high ratio of endemic species. In a relatively small marine region (less than 1% of the world ocean surface), the Mediterranean Sea hosts from 4 to 18% of the whole marine diversity depending of the phylum considered.

The Mediterranean and the Black Seas are highly populated areas . In 2010, the total population of the Mediterranean countries amounted to 466 million with a increasing rate of 1.3% per year (UNEP/MAP 2012). More than half of the population lives in Southern shore countries.

Coastal cities concentrate a large fraction of the population living in countries bordering the Mediterranean. In 2005 there were 13 cities with over 1 million inhabitants on the Mediterranean coast. Istanbul agglomeration which lies on the border of the Mediterranean and the Black Sea has 13 million inhabitants. The coastal zone of the Black Sea contains a population of 39 million people.

Coastal cities are growing continuously in southern and eastern countries of the basin. They are generally associated with industrial and port activities and transport infrastructures.

The development of coastal areas is partly due to the strong seasonal pressure of tourism in the Mediterranean countries. This could lead, according to scenarios developed under the prospective Blue Plan (UNEP / MAP), with 50% artificial coastline to 2025.

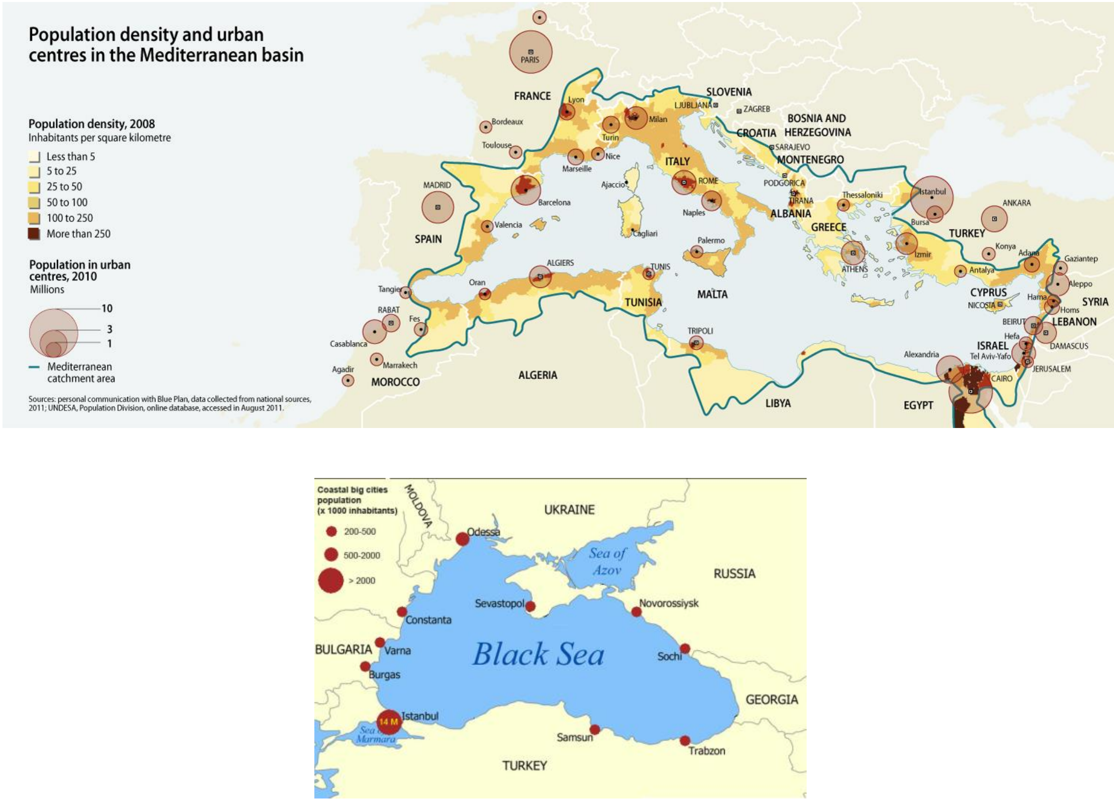


Figure 9: Map of large coastal cities in the Mediterranean and the Black Seas

In the Mediterranean, the goods traffic exchanges result of its riparian countries through several major ports, but also from the fact that the Mediterranean, with 20% of world traffic in its waters is a major international shipping routes. As a seaway connecting the Black Sea to the Mediterranean and to the world ocean, the Marmara and Aegean Seas are areas of dense traffic.

The Mediterranean is also a leading region for passenger transport either by ferry or cruise.

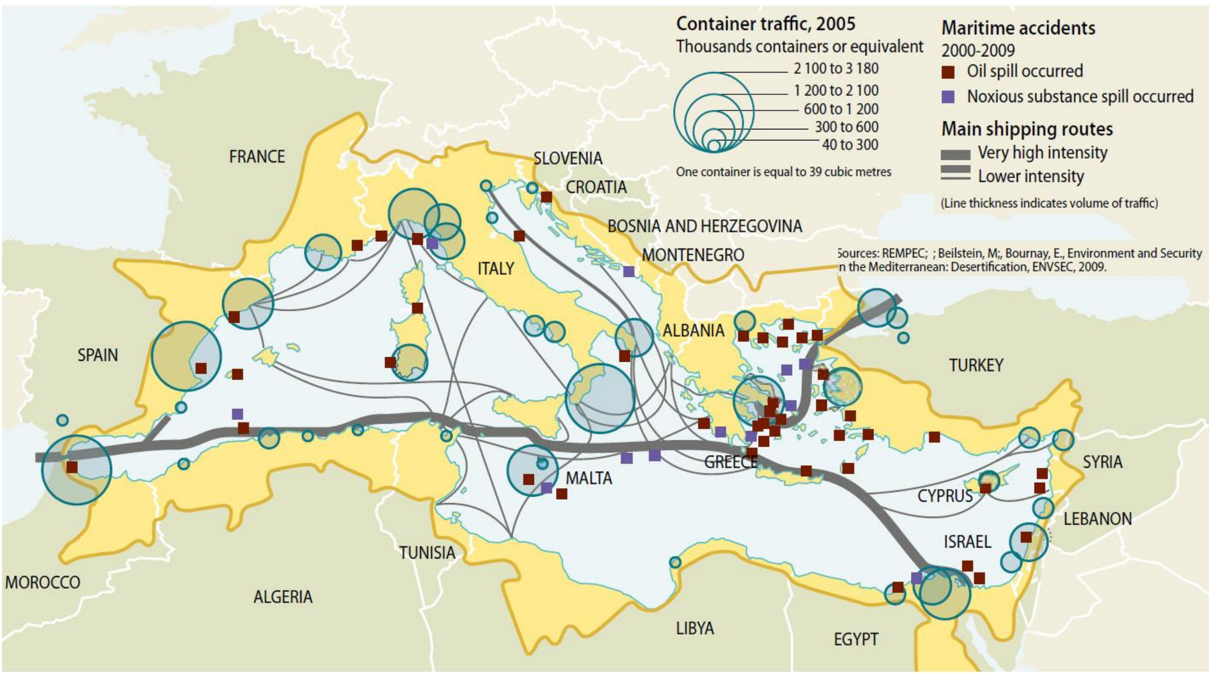


Figure 10: Maritime Traffic in the Mediterranean (source UNEP/MAP)

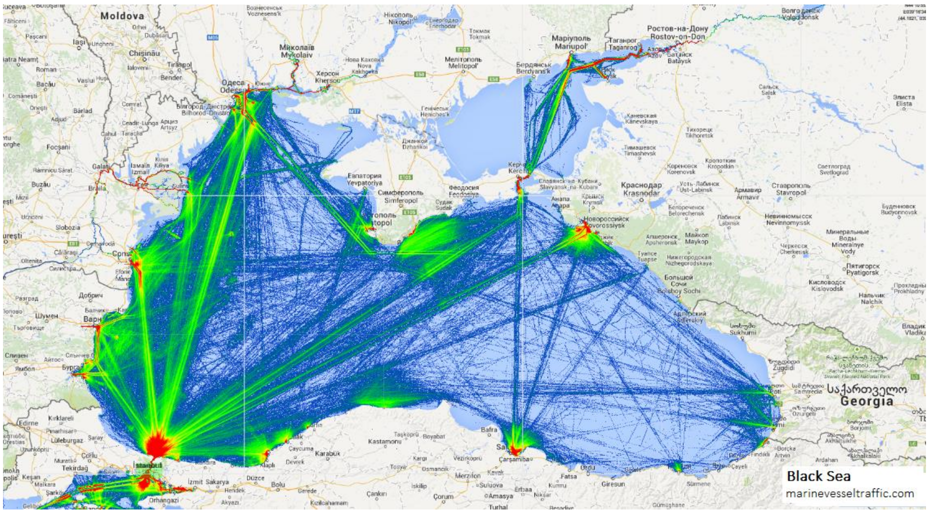


Figure 11: Black Sea Vessel traffic density (source: marinevesseltraffic.com, AIS data)

2 - PERSEUS coastal study areas

This section presents the different coastal study areas of PERSEUS. It is based in particular on the reports drawn up for each site in the initial phase of the project.

2.1 Barcelona (area 1)

Barcelona is located on a almost rectilinear coast with a narrow continental shelf (around 20 km in front of the city.

The Ebro River which is the main Spanish river flowing to the Mediterranean has its mouth 120 km in the South West of Barcelona city. The surface of its catchment area is 85600 km². Its mean river discharge is 300 m³/s. The interannual variability of the discharge is high but due to water extraction, damming and changes in soil uses, a significant decrease of the flow of Ebro River has been observed reduces from the mid of XXth century (more than 500 km3/s) in to the years 2000 (300 km3/s).

Among the small rivers of the Catalan coast, 2 small rivers : Llobregat et Besos rivers (20 m3/s and 4 m3/s) flow through the city of Barcelona.

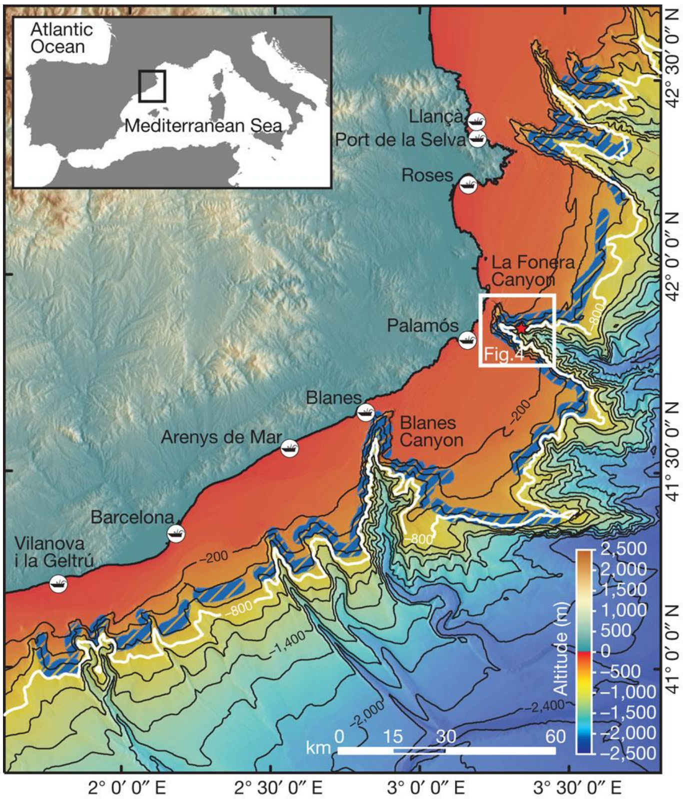


Figure 12: Bathymetric map of the northern Catalan margin showing the main trawling grounds on the open continental slope and canyon flanks (blue hatching). Largest ports of the area (vessels in white circles) and the 800-m isobath (white thick contour) are highlighted (Puig et al. 2012).

Barcelona, which population of the town area reach 5 M, is the main city of the Catalan coast located in the NW Mediterranean Sea and extending from the Ebro river at the south up to the France border at the North. It is one of the richest and most rapidly developing regions in Spain. Of the total population of Catalonia more than 45% lives in just 7% (70 coastal municipalities) of the total surface area (Brenner et al. 2006). The actual socioeconomic structure is based on typical coastal activities such as tourism, commerce, agriculture, and residential developments. Industrial and commercial activities are strongly associated with the metropolitan areas of Barcelona (Central) and Tarragona (South) but are less significant along the rest of the coast, where other economic activities (mainly tourism) dominate.

In Catalonia, tourism and other human activities has led to a high degree of artificialization of the coast. In addition to the major harbours (Barcelona and Tarragona), 45 small and medium fishing harbours/marinas are scattered along the Catalan coast (1 every 15 km). The total fish landing for these harbours was about 55.000 tons in 2011. 22 sites of artificial reefs have been created in Catalonian coastal water for a total surface of 14.000 ha.

2.2 Mediterranean coastal area of Morocco (area 2)

The Mediterranean Moroccan sea counts around 500 km. Close to Gibraltar Strait, the Eastern coast of Morocco is open to the Alboran Sea, area of strong currents and turbulence resulting from the water exchanges between the Mediterranean sea and the Atlantic Ocean. Incoming Atlantic waters are circulating in the upper layer while more dense Mediterranean waters flow out close to the sea bottom. Off the Moroccan coast, the width of the continental shelf does not exceed 15 km.

The coast is bordered by the region of Tangiers –Tetouan which occupies a big economical role in the country thanks to industry, tourism and to its geographical proximity to Europe. Urbanization and development of touristic infrastructures is growing in the Northern part. Agriculture is well developed especially in the Southern part of the area.

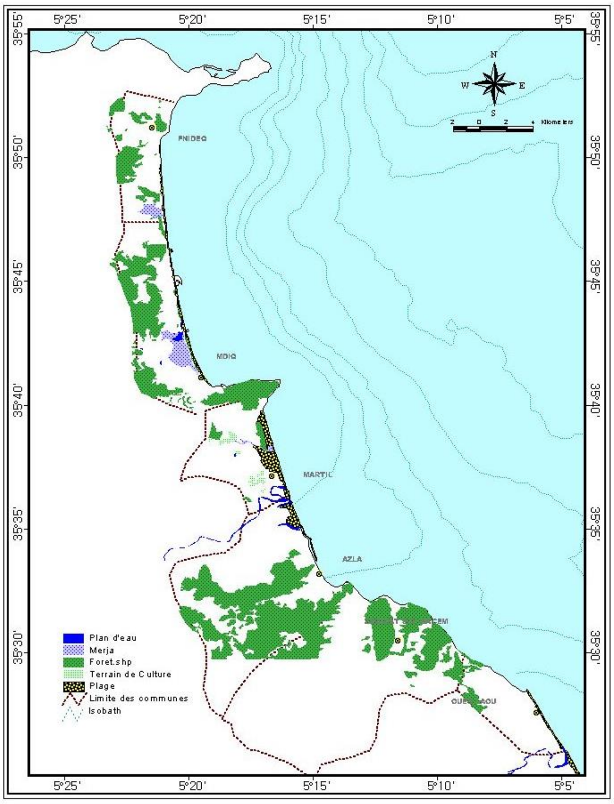


Figure 13: Map of the western part of the Mediterranean Moroccan coast

An upward trend of the bacteriological contamination of waters is observed in the Kabila-M'diq zone. It can probably be attributed to the increase input to the sea of precipitation runoff as well as urban discharges.

The almost permanent presence of paralytics biotoxin PSP in the shellfish red hull, and the appearance of diarrheic biotoxin DSP contamination events in recent years should be noted.

Fishing is a maritime activity of first importance in Morocco. Although this sector is much more developed on the Atlantic side (where the coast is much longer), artisanal and coastal fisheries are found on the Mediterranean coast. A stock assessment[1] reported the quantity of 22 tons for small pelagic fish landing in 2013 for the Mediterranean part of Morocco.

2.3 Rhone river and Marseilles areas (areas 3-4)

The Rhone river mouth and Marseilles city are located in the Noth-Eastern part of the Gulf of Lions. With an average flow of 1700 m3/s the Rhone river is the major contributor to riverine discharge to the Mediterranean Sea. The surface of the Rhone catchment area is 95.6 km^2. The Rhone is marked by episodes of strong discharges that can occur not only in winter periods and exceed 10 000 m3/s for extreme floods. In winter, the Rhone provides fresh and cold water to the shelf. The river sediment input have built a shelf that extends up to 80 km offshore.

In the eastern part of the Rhone river mouth, the coast is mainly rocky. Some of the numerous bays and promontories have steep edges (e.g. the Calanques of Marseilles/Cassis). The Camargue - the Rhône River delta area - as well as most of the coast of the Languedoc Roussillon region facing the Gulf of Lions in the West are flat and sandy. Several coastal lagoons can be found behind the coastline. In relation with this diversity in physical features the area shows a large variety of benthic habitats : soft and sandy sediment biocenosis, rocky bottoms, coralligenous assemblages, seagrass beds.

In the Gulf of Lions, dense water can be formed in winter over the shelf under north winds [22] but the process is limited by the presence of river diluted waters and by the short residence time of water masses over the shelf. The Roussillon coast, the gulf of Aigues Mortes, the gulf of Fos or the area of Marseilles are favorable areas. The dense water formed over the shelf tends to deepen and sink in the canyons of the shelf break (which is called cascading), especially at the Cap Creus at the east. Even if this process is much less intense that the dense water formation over the abyssal plain, it plays an important role in across shelf exchanges.

Water turbidity is generally quite low. Nonetheless, turbid plumes of considerable variability can be observed at the outlet of rivers, notably in the West of the Rhone river mouth.

With 1.5 M inhabitants, Marseilles is ranked 3rd town of France. The growth of the population is continuous and the whole area is facing urban sprawl and suburban expansion. The WWTP was upgraded a few years ago and the quality of waste water discharge has significantly increased over last decades. Heavy rain events are known to bring pollutants into the sea, especially through several small rivers flowing across the city and places where industrial plants were actives in last century.

Marseilles/Fos harbour is the only large seaport in the marine sub-region and is France's largest cargo port. It handles nearly 90% of goods traffic of all the French ports on the Mediterranean (out of a total of 85 million tons in 2012).

[1] Etat des Stocks et des Pêcheries au Maroc en 2013 - INRH

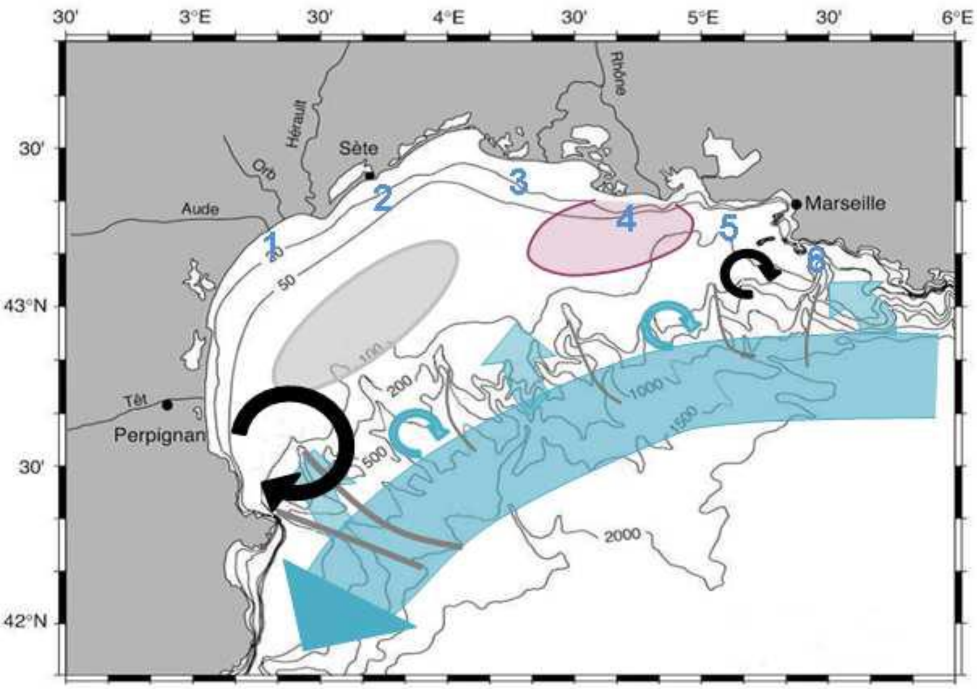


Figure 14: Major processes in the Gulf of Lions: the North Current, its meanders, eddies and possible intrusions (blue arrows), the Rhone dilution area (in pink) and the upwellings (in the numbered areas in blue), the privileged area of formation of dense water on the shelf and its descent along the slope (in grey) and the temporary eddy structures (black arrows). Source: Ifremer (2011).

The traffic is distributed in two places :

- the port located in the city of Marseilles where the passenger traffic is a large part of the activity
- the port of Fos-sur-Mer in the Gulf of Fos, located 30 km west of the city of Marseilles. Fos concentrates the oil, bulk and container cargo traffic. Built in the 60s, the port of Fos-sur-Mer is part a large industrial area extending around Berre lagoon.

Regarding passenger traffic, this maritime area covers 30% of movements recorded at national level (i.e. about 10.3 million passengers). This volume is explained by maritime links with Corsica and North Africa. The ports of Bastia and Marseilles are among the most dynamic in France with a total of 5 million passengers in 2010.

The Southern coast of France in a region of intensive tourism. The tourist accommodation capacity of the municipalities of the Mediterranean coast accounts for 45% of supply at French sea resorts and amounted to 3.1 million beds in 2011.

In 2004, the proportion of the French Mediterranean coast modified by human activities (ports, backfills and dikes) represented 18% of the coastline. Some parts of the coast, especially in Camargue near the Rhone River mouth, are facing strong erosion issues. Coastal management programmes have been implemented combining riprap building and beach replenishment.

With several important fishing harbours the Gulf of Lions is an area of intense fishing activity. For demersal fish, the general trend of population evolution in the Gulf of Lions shows stability on short term after major changes during the 1980s. Regarding the 15th last years, beyond inter-annual variations for some populations, there is no identifiable evolution trend (Ifremer, 2009). In the longer term, *i.e.* considering data since 1970s, the picture is more nuanced. Indeed, on this longer period, the diversity of *Actinopterygii* stayed stable, but the *Elasmobranchii* class (shark and skate) has been affected by a marked decline for species of commercial interest, first on the continental shelf then along the slope, since the middle of the 1980s.

Anchovies and sardines populations show signs of depletion (Roos D. 2010) from which stocks of sprat appear to profit. In fact, a high and unusual abundance of small sprat (from 7 to 10 cm) has been recorded in recent years, in almost all the Gulf of Lions, area which is usually occupied by anchovies and sardines.

In order to preserve and favour the benthic fish population, artificial reefs have been installed along the Côte Bleue (rocky coast between the Gulf of Fos and Marseille town) and more recently in the shallow waters of the bay of Marseilles.

In 2012, a new protected area, the National Park of Calanques, has been created in the south of Marseilles. It stretches over more than 20 km of coast and includes land and marine areas.

2.4 Naples (area 5)

The city of Naples is located in a coastal embayment (Gulf of Naples) open to the Tyrrhenian Sea which is the deepest basin of the western Mediterranean. The main exchanges between the Tyrrhenian Sea and other sub-basins occur through the Corsica Channel (sill depth at about 450 m) with Liguro-Provencal Sea and through the opening between Sardinia and Sicily.

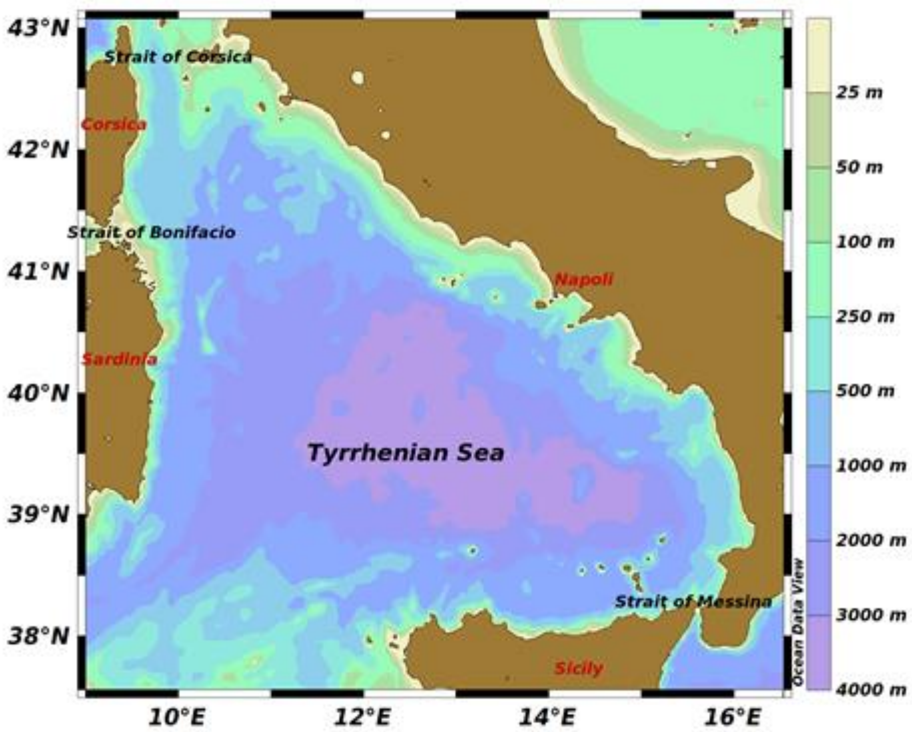


Figure 15: Map of the Tyrrhenian Sea.

Most of the Tyrrhenian basin is characterized by low level phytoplankton biomass with the exception of the northern gyre and the coastal areas exposed to minor river run-off (including the Sarno River flowing into the Gulf of Naples) or to inputs from urbanized areas. The overall biotic dynamics of the basin closely resembles the functioning of the Ionian, thus making the Tyrrhenian quite different from the more productive Algero-Provencal basin.

The Gulf of Naples has an average depth of 170 m and an area of approximately 900 km^2. The continental shelf width ranges from 2.5 to 20 Km. Two canyons opening to the deep sea originates from the gulf. The morphology of the coasts varies from North to South: the sandy coasts present in the northern and eastern part of the gulf are replaced by rapidly declining calcareous cliffs in the south.

In the Gulf of Naples, the underwater landscape changes radically from the north-west to the south-eastern parts. The first sector is characterized by a rough irregular seabed, with the presence of two deep canyons and a large number of shoals (usually the remains of submarine volcanoes), which have a great biological interest. The second sector, on the other hand, is mostly a large muddy, flat-bottomed surface that gently slopes toward the west up to about 200 m depth. The interaction between natural and anthropogenic processes along with their complex geomorphology have led to the presence of an extreme variety of habitats.

In recent years, a negative chl *a* trend over the time series was recorded and associated with positive surface salinity and negative nutrient trends. Physical and meteorological conditions apparently exert a strict control on winter blooms.

Besides its natural peculiarities, the region of Campania, and the Gulf of Naples in particular, is subject to an intense anthropogenic pressure. Along its 512 kilometers of coastline, human activities range from dense urban settlements to industrial areas located on the coast and intense maritime traffic. The town area of Naples has more than 4 million inhabitants. In the Gulf of Naples the land runoff of the polluted Sarno River influences the quality of the coastal waters. The area is also an internationally renowned touristic location, not only for its historical and environmental attractions, but also for swimming and leisure activities spring through fall.

Available data show that in Campania region there are numerous uncontrolled or not appropriately depured industrial and municipal wastewater discharges. That ressults in prohibited bathing in a large part of the coast.

Naples is an important commercial Italian harbor with a traffic of 21 Mt reported for 2011.

The region of Campania has characteristics similar to many other Mediterranean coastal zones in which activities, such as fishing, aquaculture and tourism are carried out. According to the data collected by the IREPA for the region of Campania, the total commercial fishing catches was 14.144 tons (approx. 7% of the total Italian catches) in 2011, including more than 5000 tons of small pelagic fish. The fishing fleet had 1178 fishing boats in 2010.

2.5 Northern Adriatic and Southern Croatia (areas 6, 7)

The Adriatic Sea is a semi-closed basin that stretches for 770 km from the northern continental shelf (35 m of averaged depth) to the southern Adriatic Pit (1220 m of depth), being it connected to the Ionian Sea through the Otranto Strait (75 km wide, 800 m of depth). It is composed by three main sub-basins (northern, central and southern). The most important orographic characteristics of the Adriatic are the presence of a northern seafloor area slowly sloping until the depth of 100 m, of the Pomo Pits (down to 260 m of depth) and the Pelagosa Sill in its central basin, as well as of a southern pit that contain most of its water. The Adriatic has a small total volume ($\approx$ 35000 km^3), a feature that determines a rapid (a few years) turnover of its waters, mainly because of the exchange with the Ionian.

Hydrological processes in the Adriatic modulate the marine ecosystem at different scales: large (seasonal stratification and thermohaline circulation, water mass exchanges among sub-basins), regional (dense water formation, gyres, wind induced circulation) and meso (coastal fronts, upwelling, cascading). The general circulation of the Adriatic is cyclonic, although variable and even opposite transports may occur at sub-regional scales. A southward flowing North Adriatic Current in the area of Po Delta converges in the larger West Adriatic Current, whereas a northward flowing East Adriatic Current is present along the eastern coast. Three large cyclonic gyres are formed in each sub-basin mainly during summer and autumn.

More than 70% of the coast is high, whereas the remainder is of alluvial nature.

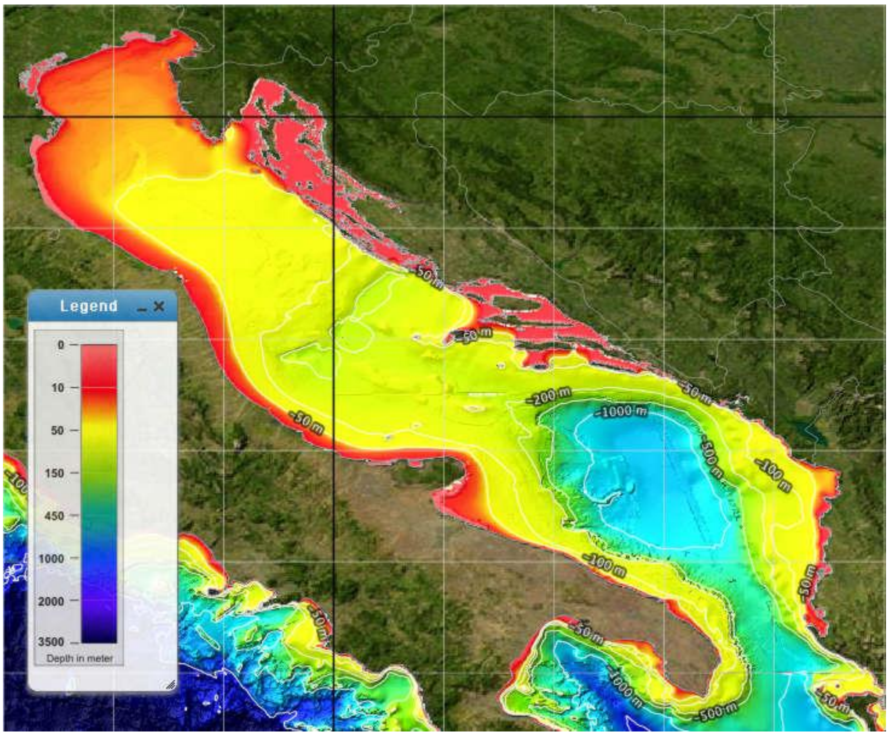


Figure 16: Map of the Adriatic Sea.

The largest part of the Adriatic Sea shows predominant oligotrophic characteristics, even if a highly productive coastal zone is present along its western coast, in particular in the northern area. River loads of nutrients, in particular nitrate and silicate, and organic matter can trigger here intense production events, if the ambient conditions are favourable for plankton growth and the availability of phosphorus in the marine environment is not limiting.

<u>*Northern Adriatic*</u>

Po River, with an average water load of 47.17 $km^3\ yr^{-1}$ during the period 1917-2008 (range from 20.54 to 82.49 $km^3\ yr^{-1}$) is the major contributor to river water load in the Adriatic. The Po river watershed is one of the most agriculturally developed and populated areas in Europe, with over three millennia of human activity. Almost two third of the drainage basin is composed of a wide low-gradient alluvial plain. Its annual solid discharge of 12.2 $Tg\ yr^{-1}$ represents 26% of total fluvial input in the western Adriatic continental shelf from Trieste to the Gargano promontory.

The Northern Adriatic coast does not have large coastal cities. The largest population center is the area of Venezia with almost 1M inhabitants but located in a lagoon connected to the Sea through 3 inlets. It includes the large industrial site and harbour of Marghera.

In the eastern part of the Northern Adriatic the city of Trieste has around 200 thousands inhabitants. The Isonzo river is known to be the main source of mercury pollution in the Gulf of Trieste, due to the presence of the Idrija mining district in the Slovenian sector of its river drainage basin.

Since the 1960s the development of oil and gas industry has been continuous in the Adriatic. A cumulative number of 137 platforms, mainly located along the western coast, has been recorded over the period.

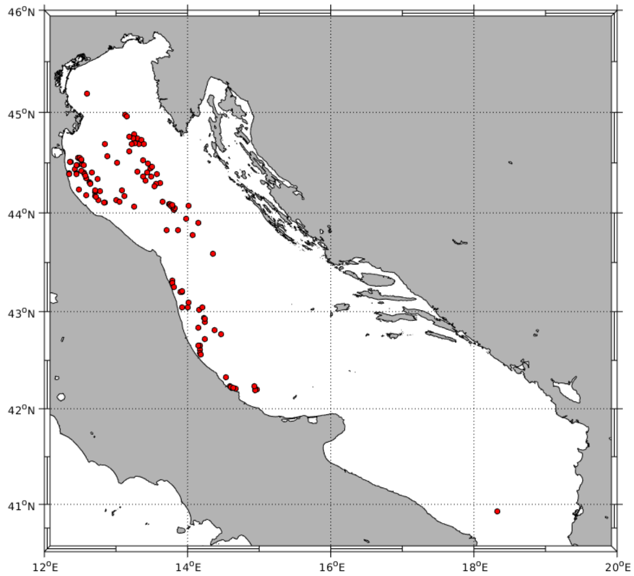


Figure 17: Locations of offshore platforms in the Adriatic Sea (by M. Šiško)

Southern Croatia

Along the Croatian Coast of the Adriatic (1800 km), several water courses like Mirna, Raša, Rječina, Zrmanja, Krka, Cetina collect the runoff from Dinarides, with the main contribution being constituted by Neretva (average flow : 342 m^3/s) that also collects continental waters from the territory of Bosnia-Herzegovina.

Kaštela Bay with its total area of 61 km^2 and a volume of 1,4 km^3 is the largest semi-enclosed bay in the coastal region of the Middle Adriatic Sea. The Bay is under strong anthropogenic influence due to agricultural areas extending along its northern coast and municipal and industrial effluents that enter the Bay.

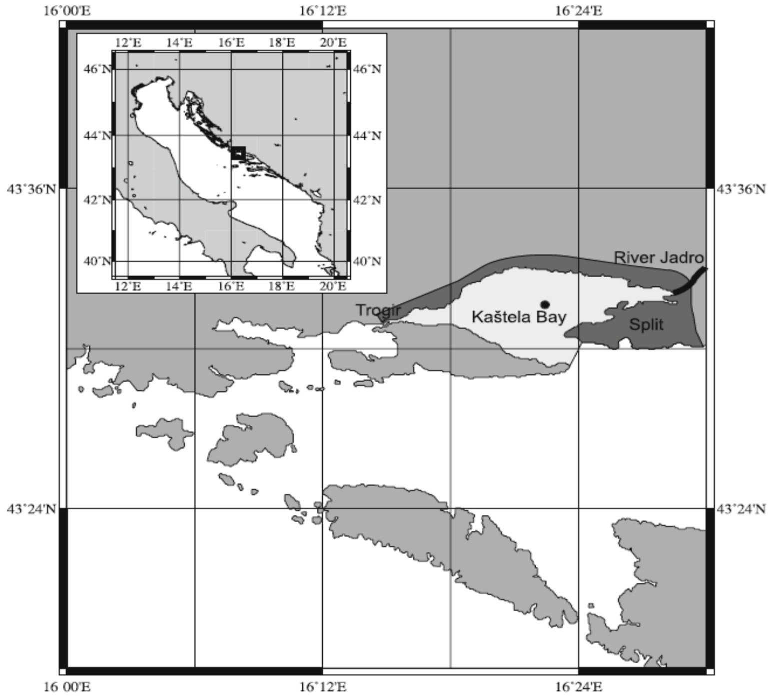


Figure 18: Kaštela Bay and its location in the Middle Adriatic.

In Kaštela Bay, the runoff is generated by Jadro River and by the drainage systems of the municipalities of Split, Solin, Kaštela and Trogir (≈ 380000 inhabitants). These continental inputs has generated in the past hypoxic events and red tide phenomenon in the bay (Marasović, 1989), whereas the recent increase of human pressure has pointed out the need of a better integrated management of wastewater systems in the area.

Living resources in the area are exposed to a very high level of exploitation, especially in the last 40-50 years. Due to the high fishing effort and low recruitment, majority of demersal fish species in the Adriatic Sea show negative trends in the biomass in the recent time. This is situation with most commercially important species as hake, anglerfish, Pandora, John Dorry, all Selachians (sharks and rays), while catch of short-living species as red mullet is more or less stabile over time.

2.6 Gulf of Tunis (area 8)

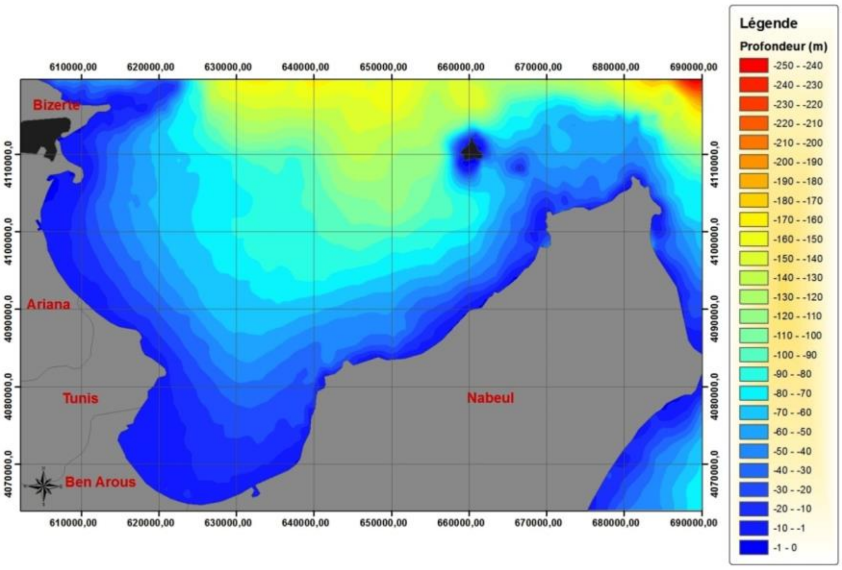


Figure 19: Bathymetry in the Gulf of Tunis

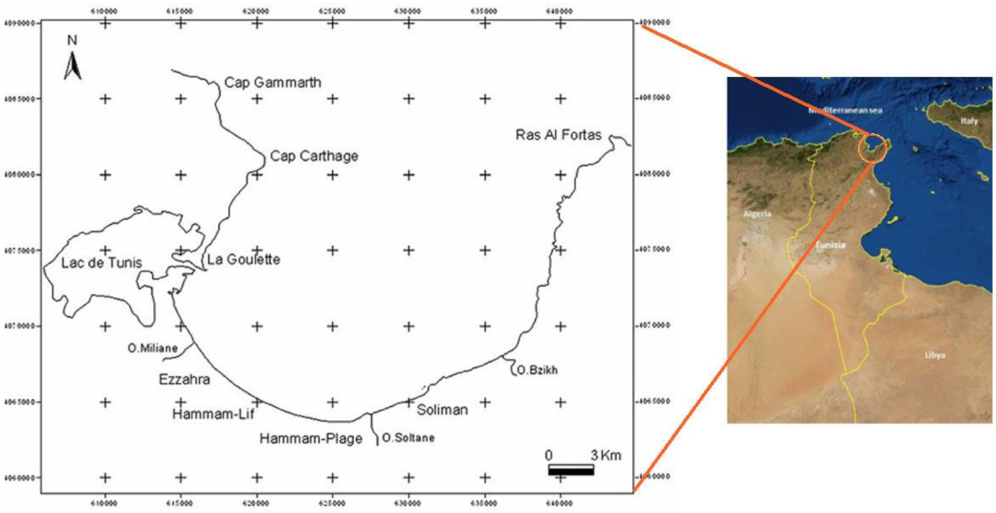


Figure 20: Geographic Position of the Gulf of Tunis

The Gulf of Tunis is located on the southern coast of the Eastern part of the Strait of Sicilia which plays a key role in the interaction between the western and eastern Mediterranean basins. The Gulf of Tunis is formed by a little gulf (known as the bay of Tunis) and a subjacent larger one. It is characterized by a heterogeneous structure (lagoons, bays and estuaries) connected to an hydrological system made of several small rivers and lakes (Wadi Medjerda, lake of Tunis and its wadis, Wadi Méliane, Wadi ElBey, Wadi Bézirk et Wadi El Abid). The Merdjeda river is the most important of them, with its basin in the scope of 23,500 km^2 and its length of 430 km. Its average flow is 29m3/s.

A broad diversity of habitats can be found in the Gulf of Tunis, including Posidonia and Cymodocea meadows on soft bottom as well as coralligenous assemblages and rocky habitats.

Tunis bay is a depression in the south of the Tunis gulf of approximately 350 km^2. Its depth is relatively shallow, not exceeding 31 m. For few years, the littoral of Tunis gulf has been subjected to industrial, urban and tourist development. Significant commercial and fishing activities in the Harbour of La Goulette, Radès and Tunis have been noted, as well as thermal discharges of the Radès power station. The gulf of Tunis is bordered by the largest city in the country as well as other smaller towns. The population around the Gulf of Tunis was estimated to 3 412 000 inhabitants in 2011.

Several plants have been built in the area for waste water treatment. However some untreated used water discharge still exist in the gulf.

The harbour of Tunis (La Goulette - Rades) is the first national port for both passenger traffic and goods (around 44.8% of goods unloaded). The traffic of goods recorded for the 1rst quarter of 2012 was 213 ktons. Several fishing harbours and marinas are also located in the Gulf of Tunis. Fisheries activities in the gulf are based on the coastal fishery. With 448 fishing boats (2004), the fleet of the area of Tunis represents 4.2% of all fishing boats Tunisia. In the 2000s, the annual fish landing was around 3000 tons.

Some part of the coast are subject to erosion, which has lead to the building of breakwater and coastal defence structures in several parts of the bay.

2.7 Saronikos gulf and Athens (areas 9, 10)

The Saronikos Gulf is a semi-enclosed embayment of the Aegean Sea (northeast Mediterranean) lying between 37°30’N and 38°00’N. The length of the coastline is about 744 km, the surface about 2.866 km2, the maximum depth about 400 m and the mean depth about 100 m. The Saronikos Gulf is bordered by the coasts of Attica in the north and by the coasts of the Peloponnese in the west and south west. The gulf communicates with the Aegean in the east through an approximately 50 km wide open connection. Rocky calcareous shores are the dominant element of the coastline.

At the north of the Gulf lies the Elefsis Bay, with a depth range of ~20 to 30 m; it connects to the Gulf via two narrow channels with sill depths of ~10 m at the west and ~30 m at the east.

The Gulf is subjected to a strong seasonal cycle of heating/cooling, with air temperatures ranging from ~0° to ~40°C. The predominant winds throughout the year blow from northern directions. Northerly winds called etesians or meltemia prevail consistently during summer, whereas in fall, winter, and spring, apart from the frequent northerly winds, westerly and southerly winds may also blow. No major river input exists except during heavy rainfall when the water runs rapidly into the sea through a couple of point sources in the northeast.

Seasonal flows are modified by the wind, while recurrent structures (cyclonic and anticyclonic) appear between the seasonal flows and the coast of Attica.

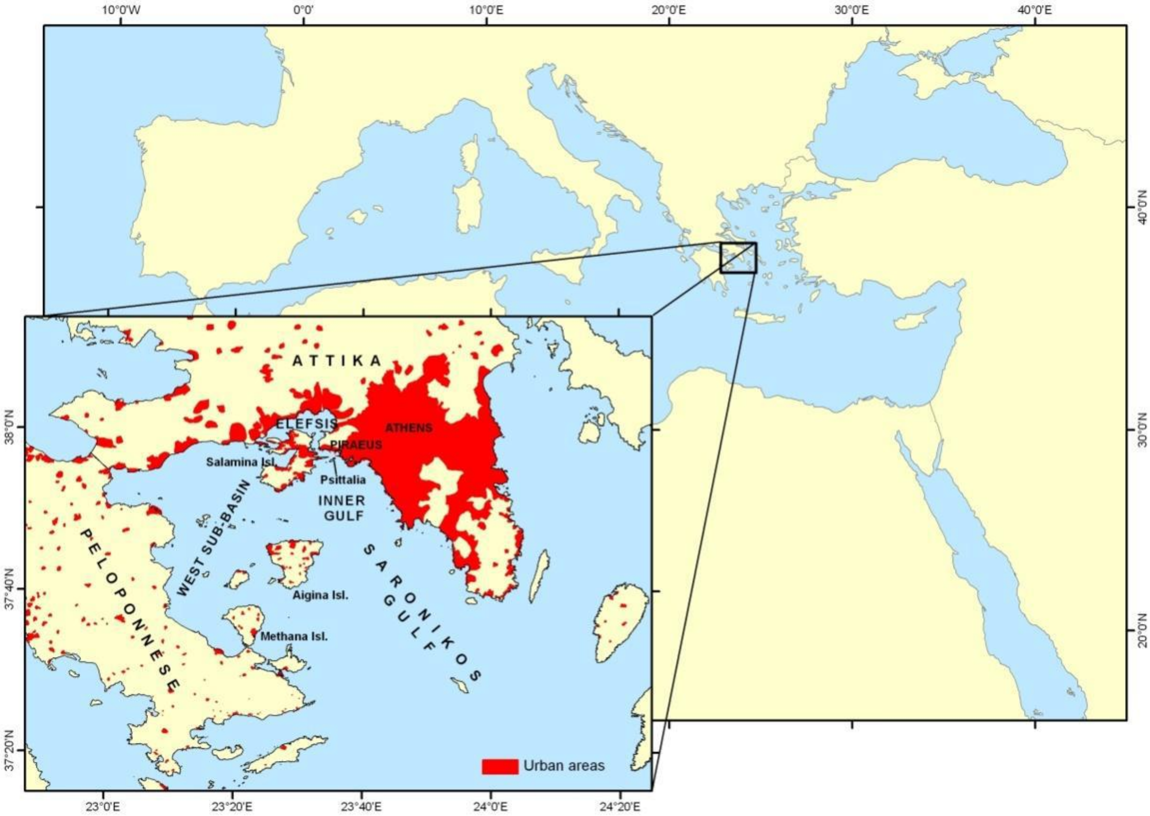


Figure 21: Saronikos gulf and urban areas

The Saronikos Gulf constitutes the natural marine gateway of the city of Athens and the Piraeus harbour and receives industrial and waste water from an area of ~4 million people. Domestic and industrial sewage water are treated since 1994. The quality of discharge water has been improved in 2004 by a secondary stage commissioned at the Psittalia Sewage Planthas.

Saronikos Gulf presents different types of habitats and high diversity of species within each family is met. These habitats include sandy and muddy soft bottom, coralligenous biocenosis. Seagrass beds are present all along the coastline of Saronikos Gulf*: Posidonia oceanica* is the dominant species in the eastern part of the gulf and *Cymodocea nodosa* in the western part.

A typically multi-gear and multi-species fishery exists in Saronikos Gulf, which is exerted by trawlers, purse-seiners and small-scale fishing vessels. The capacity and horsepower of the fishing vessels increased, till 1990s when measures for the limitation of licenses were enforced.

According to the Hellenic Fleet Register during 1991-2009 for the region under study, the overall number of fishing vessels corresponding to small-scale fisheries showed a decreasing trend (2812) active vessels were registered in 1991, while in 2009 the active were 2061. The overall landings for the period 1990-2009, displayed a clear decreasing trend. The total landing (fish + molluscs+ bivalves) declined from more than 100 ktons in the 90s to around 80 ktons at the beginning of the years 2000. The landings of small pelagic fish and particularly anchovy and sardine, according increased in Argosaronikos gulf during the early '90s and after a peak in 1997 (4200 t) they started to decline reaching constant levels at around 1400 t for the recent years.

With the harbour of Pireus - one of the largest seaport in the Mediterranean and the connection with the gulf of Corinth via the Corinth canal, the gulf of Saronikos is an area of intense shipping traffic. The number of 2615 ship arrivals has been registered in 2008. A decline in shipping traffic is however obvious after 2001.

2.8 Haifa Bay (area 11)

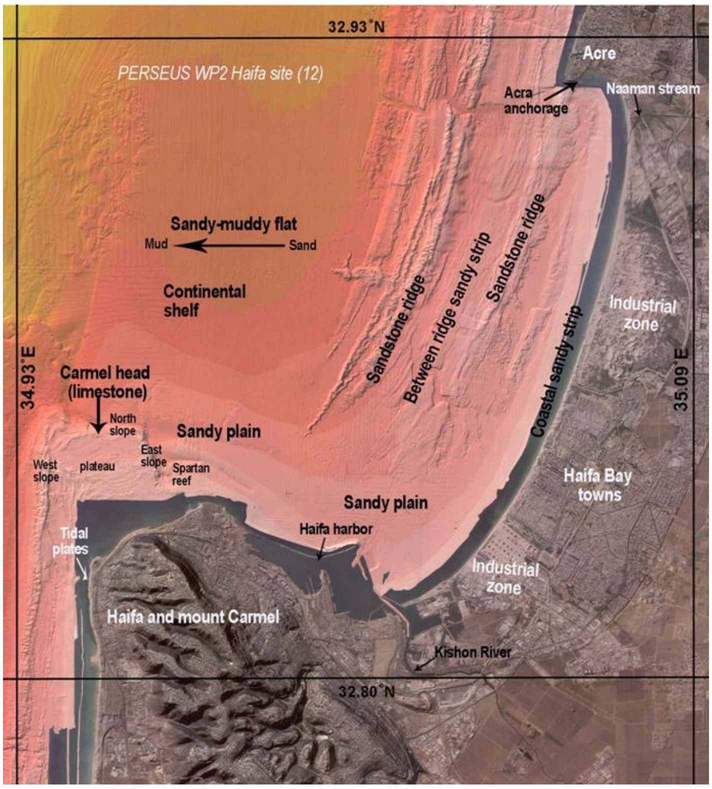


Figure 22: Map of Haifa Bay

Haifa Bay is the only Bay along the otherwise straight line Israeli Mediterranean coast. The size of the opening of the bay, i.e. the distance between both land promontories delimiting the bay, is 12 km. The depth of the Haifa Bay continental shelf goes down to 90 m.

Haifa Bay is unique in terms of its current regime in comparison to the remainder of the Israeli Mediterranean coastline. The current is affected by both the general patterns of currents along the Israeli coastline and by local winds.

Haifa Bay is characterized by a variety of habitats. The benthic habitats are divided into soft bottom and hard bottom ones. The hard bottom habitats include: 1) Two major forms of reefs, one is the sandstone ridges (locally termed kurkar, originated from ancient dunes), parallel to the shore. Biogenic intertidal plates existing along the coast southern and adjacent to the Bay, recently declared a nature reserve. The soft bottom habitats include: 1) Coastal sandy strip located parallel to the bay's eastern coast. The strip is broadened to a sandy plain in the southern part of the Bay. 2) The sandy valleys between and adjacent to the sandstone ridges which are divided into two habitats, 2a) a fine sand habitat and 2b) a fine sand habitat which includes a coarser fraction eroded from the biogenic crust of the sandstone ridges. 3) A relatively broad sandy-muddy flat is located in the north-west part of the bay in depths of 25-90m.

Haifa is utilized by Israel for a variety of purposes. It is an urban, heavily populated region and the coast is used for recreation of the locals. In addition it hosts heavy industry, a major commercial port, two fishing anchorages and two marinas, and a variety of other commercial facilities.

Two cities are located at the northern and southern edges of the bay, Acre and Haifa. Acre is a small city of 46,000 inhabitants with a rich history of more than two thousand years. Haifa is relatively new major city of the Bay, started its rapid expansion around 150 years ago. It was developed because of the need for larger and deeper modern port. 270,000 inhabitants live in Haifa and with the Haifa Bay population they amount to ~500,000.

Two streams are drained into the Bay, the Qishon and the Naaman. In addition, a drainage pipe of hypersaline water coming from the food industry of the northern part of Israel is drained into Haifa Bay 1 km offshore. The domestic waste of the bay area, Haifa, and Acre is treated in advanced treatment plants. The effort that has been devoted during the last 10-20 years to reduce and treat urban and industrial discharge led to a dramatic decrease of the levels of chemical pollutants in Haifa Bay.

The Haifa harbor is one of the two major ports of Israel, located in the south part of the Bay. The major source of harbor effect is caused by its maintenance and expansion.

Fishing is a major source of ecological pressure to the Bay fauna. From the two fishing harbors in Haifa and Acre, fishing vessels using a variety of methods are exploiting the Bay. Trawling, purse seining and gillnets are used on the soft bottom and longlines in the rocky habitat.

Regarding pressures exerted on the marine ecosystem, it should be noted that, being located in the eastern Mediterranean, Haifa Bay is strongly exposed to invasion of none-native species immigrating mostly through the Suez Canal.

2.9 Sea of Marmara and Istanbul (areas 12, 13)

The Sea of Marmara with an extension about 11,110 km2 (3,380 km3) and average water depth of about 400 m (maximum depth: 1,390 m) is connected to the Black Sea via the İstanbul Strait (Bosphorus) and to the Mediterranean Sea through the Çanakkale Strait (Dardanelles). The Sea of Marmara is 300 km in the length from northern to shouthern and nearly 90 km in the width at its greatest. Midstream of the İstanbul Strait is 31 km long, its width varies from 700 m to 1500 m and it is characterized by several sharp turns. The depth of the strait varies from 35 to 120 m in midstream. The Çanakkale Strait is a 62 km long, Its width varies from 1.2 to 7 km. The average depth of the strait is 55 m. The strait channel extends to the deep basin through a canyon, which reaches a water depth of about 200 m in the Sea of Marmara.

The Sea of Marmara consists of a complex morphology including shelves, slopes, ridges and deep basins. The shelf areas cover 55% of the total area of the sea. The northern shelf is much narrower (5-10 km) than the southern shelf (up to 30 km).

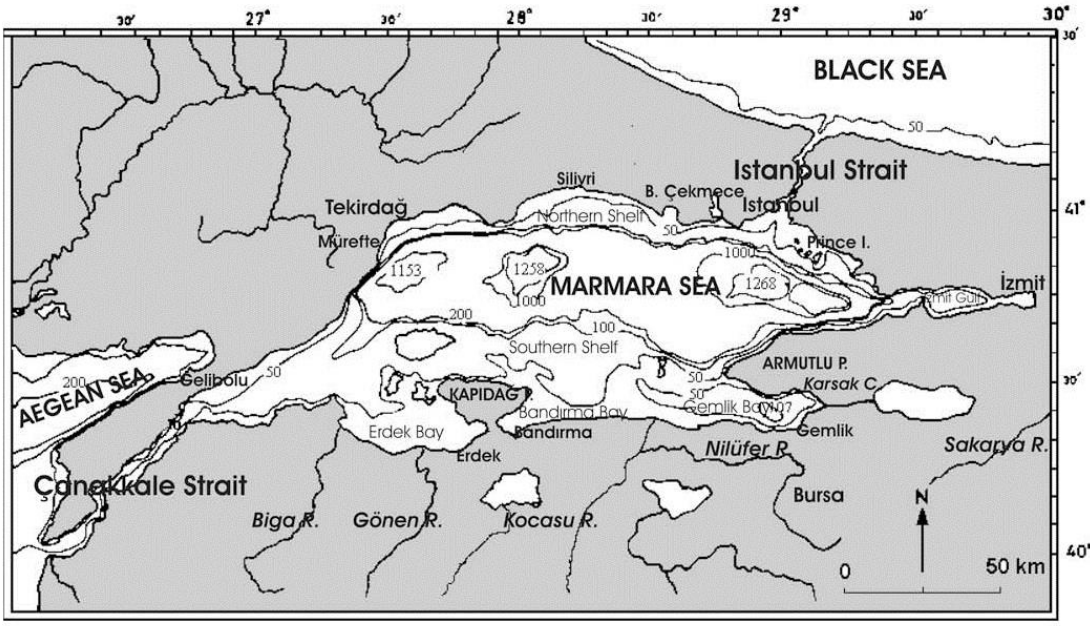


Fig. 23: General location and physiographic features of the Sea of Marmara (from Gazioğlu et al, 2002)

A two layered flow regime exists in the Sea of Marmara, Çanakkale and Istanbul Straits resulting from water exchange between the Black and Mediterranean Seas. The water layers are separated from each other throughout the year by a steep halocline at 25-30 m depth. The upper layer is occupied by the less saline (22-26 psu) and cold water (7–24°C) originated from the Black Sea. The subhalocline water is the Mediterranean Sea origin and possesses nearly constant salinity (38.5–38.6 psu) and temperature (14.5–15.0°C) throughout the basin. It is renewed on avearge in 6–7 years by the Mediterranean inflow via the Dardanelles undercurrent. The current velocities of the subsurface waters are high in the straits (20-50 cm/s in the Çanakkale Strait, and 10-70 cm/s in the Istanbul Strait).

The Sea of Marmara is an intermediate position between the Black and Mediterranean Seas in terms of primary production. The studies showed that the primary productivity (in g $Cm^{-2}year^{-1}$) range from 52 to 250 in the Black Sea, from 60 to 100 in the Sea of Marmara, around 36 in the Aegean Sea, and from 16 to 25 in the NE Mediterranean Sea.

Mainly three rivers discharge into the Sea of Marmara from the southern region (Kocasu, Biga and Gönen rivers). The total discharge of these rivers is 184 m3/s of freshwater.

The Sea of Marmara is a biological corridor between the Mediterranean and Black Seas. Biota contains species originated from both the Mediterranean and Black Seas. It is also important as an "acclimatization zone", especially for migratory species.

A broad diversity of facies can be found in the sea bottom, e.g. muddy sea floors with invertebrate fauna, rocky areas and islands, seagrass beds.

2.10 Varna (area 14)

Varna Bay is located in the northern part of Bulgarian Black Sea coast, locked between cape Galata and cape St. George (27°55' and 27°59' E, 43°10' and 43°13' N). It is the second largest bay along Bulgarian Black Sea coast after Burgas Bay. Its maximum depth is 18.5 m. On the west it is artificially linked by two canals to Varna Lake, which has a major impact on it. The bay length is 4.5 km and width - 7.5 km, with a surface area of about 20 km^2. The north coast is high while the western one is a destroyed spit separating the sea from the lake. The southern coast is steep with beaches. The bay has flat bottom sloping towards east. The coastline is ESE generally oriented. Two wave energy fluxes with opposite directions determine the long-shore sediment transport along the coast of Varna Bay : the first one with SW direction and the second with W direction, which at Galata form zones where the fluxes diverge, while the western part of Varna Bay (the Asparuhovo beach) is the zone of their convergence.

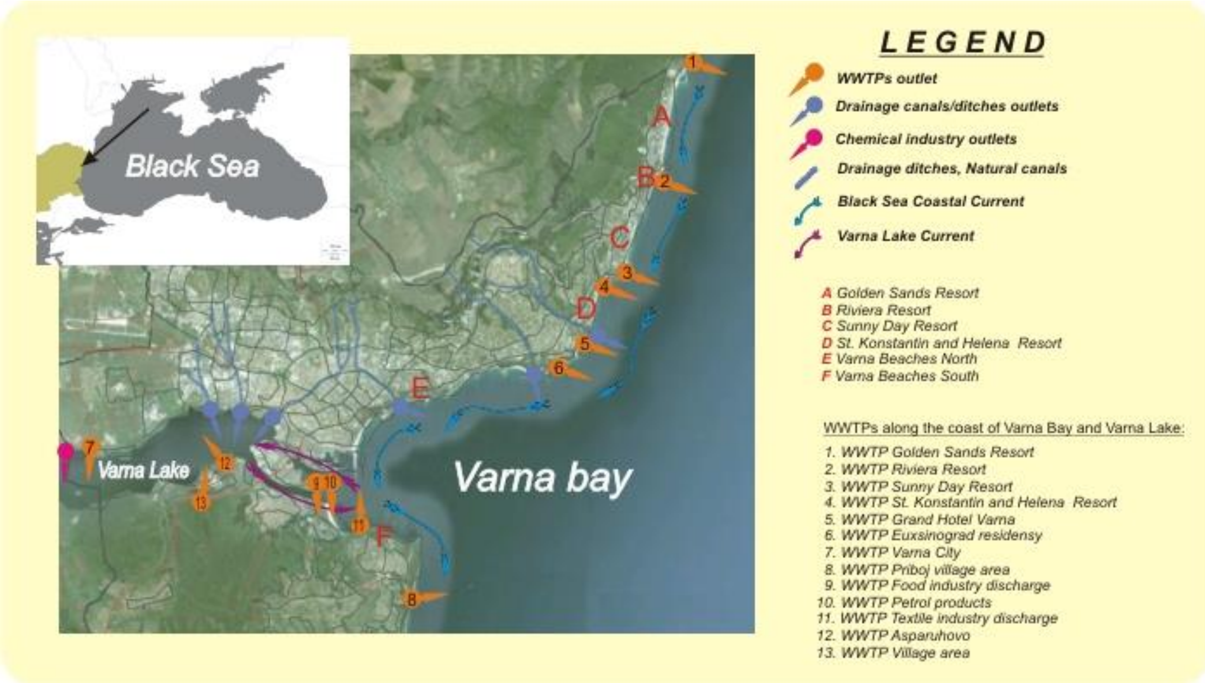


Figure 24: Map of Varna Bay-Varna Lake system-environmental pressures and their pathways: Varna Lake Current, Black Sea Coastal Current, Waste Water Treatment Plants (WWTPs) (source: Moncheva et al., 2012)

Varna Bay is connected via two artificial canals with Varna Lake which is fed by 2 small rivers (Devnia and Provadiiska rivers) and provides freshwater inflow forming an area of lower salinity in the western part of Varna Bay. There is no direct riverine discharge into the bay. The bay is microtidal (range < 1m) and the salinity is between 5-6 and 18-20 ‰. The monthly average water temperatures range from 5°C in winter to 25° in summer.

For the period 2002-2012 the predominant wind direction in the area was ESE-SE from March to October, the W-NNW wind dominating in winter that influence the circulation pattern in the area and the intensity of Varna lake-Varna bay current input.

Varna Bay seabed is occupied by three major biotopes: (i) sands dominated by bivalve molluscs *T. tenuis* and *L. mediterraneum* along the southern coast; (ii) silty sands co-dominated by thallassinid mud shrimps *U. pusilla* and bivalves *A. inequivalvis* and *T. tenuis* in the north-western area, and (iii) sandy silts dominated by thallassinids and polychaete worms in the central and eastern part. Seagrass beds of *Zostera noltii* can also be found in the bay.

The coast of Varna region is exposed to coastal erosion. Since the beginning of the XXe century, numerous structures have been built in order to stabilize the shoreline.

The economy profile of Varna district includes chemical industry, port activity, shipping, ship repair, tourism, textile, machine industry, building, food industry and agriculture (Analysis of the socio-economic development trends of the coastal territorial units of Bays of Varna and Bourgas within the period 1998-2006).

Varna district (including the three municipalities of Varna, Devnya and Beloslav) is ranked third in the country by population number (456 915 inhabitants in 2007). During the high tourist season the population almost doubled. The tourist resorts expanded dramatically after the mid-90's, and tourism became one of the area's main sources of income, wealth and employment. From 2000 to 2004 the number of hotels almost doubled, from 130 to 282.

Nutrient enrichment in runoff and discharge waters was high in the period 1970-1990. During the last decade the reduction in the chemical industry production, the upgrade of WWTP discharging into the Varna bay, resulted in substantial reduction of pollutant loads in freshwater inputs to the sea.

Varna harbor is the main port of Bulgaria. It includes also an important shipyard activity. 2150 ship visits were recorded in 2011. The cargo traffic for the same year was 9.1 Mtons.

Varna port is one of the main ports used by fishermen for landing of the catches although fishing activities are located along the entire coast. During the last decade, the fishing pressure increased, affecting the populations of both commercially exploited fish and non-target (by-catch) species. The Bulgarian fleet (December 2010) includes 2340 vessels. Sprat is the fish species of highest commercial importance, its landings contributing to 57 % for the period 2003-2010. The second significant species for the fisheries during last 10-15 years is the mollusk *Rapana venosa* (which is a non indigenous species). Other fish species of commercial importance are horse mackerel, gobies, anchovy, pontic shad and turbot.

Review of historic data indicate a severe decline in the overall catch of species from the Black Sea within the last two decades. The catches of large pelagic fish, such as Atlantic mackerel, bonito and bluefish decreased to very low levels and were replaced by small pelagic species as sprat, anchovy and horse mackerel.

2.11 Constanta and Danube mouths (areas 15, 16)

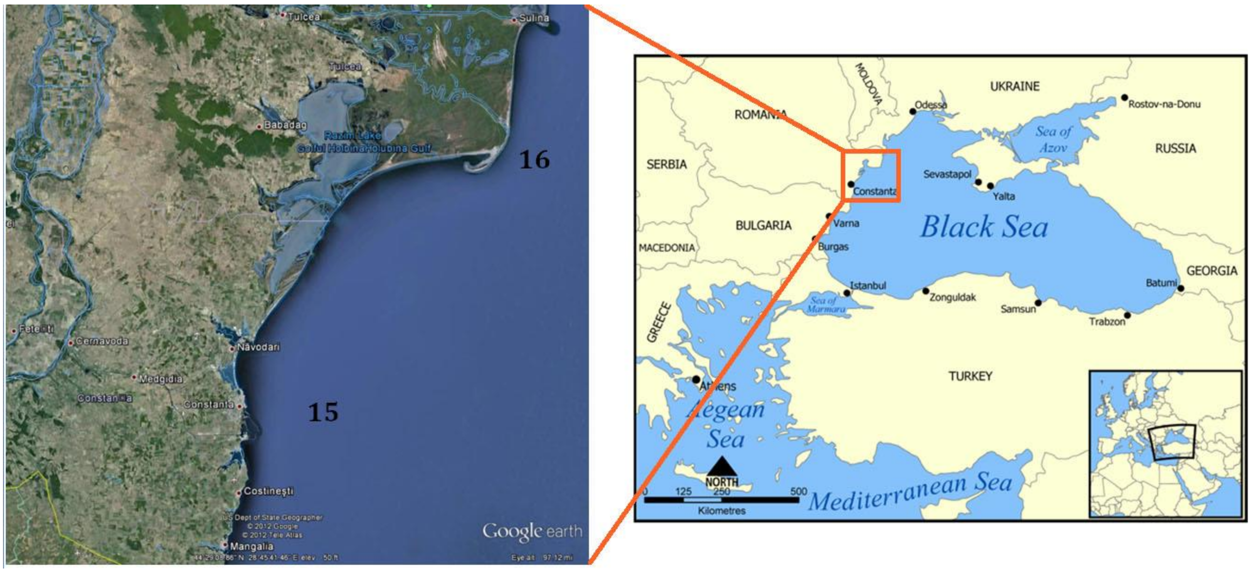


Figure 25: Romanian Black Sea coastal zone

The Romanian littoral (between Sulina and Vama Veche) has a length of about 245 km, representing approximately 6% of the entire Black Sea coast. It runs from the border with Ukraine in the North to the boundary with Bulgaria in the South and it is a part of a historic region named Dobrogea. Dobrogea region has a surface of 15,485 sq. km, representing 6.5% of the Romanian territory. Dobrogea region holds two coastal counties, Tulcea and Constanta.

Romanian coastal zone topography consists of low elevation shores, beaches (80%) and relatively high shores, cliffs (20%). From the typological point of view, it includes both natural coastline (beaches and cliffs - about 84%) and about 16% "built" shore. These built areas include three commercial harbors (Constanta, Mangalia and Midia), marinas and some protecting constructions against erosion in the Southern area (groynes, breakwaters, etc). There are beach segments on 70.4% of the overall length of the Romanian shoreline, from which 62% are within the territory of the Danube Delta Biosphere Reserve.

The Romanian coastline can be divided into two major geographical and geomorphological units:

- The Northern unit (165 km in length) extends from the Musura Bay to Midia Cape and forms a limitrophe shore to the Danube Delta, including the lateral lagoon complex Razim-Sinoe, consisting of alluvial sediments with extensive lowlands marshes and lagoons, and beaches formed of Danube sediments; the contour of the seaward delta front is smooth and nearly linear except for mouths of Sf. Gheorghe and Sulina branches of the Danube. This area is characterized by sandy beaches, low altitude and gentle submarine slope. The sediments of the superficial layer present great variety of mollusc shells and clay. Fine and very fine sands cover more than 75% of this area.
- The Southern unit, between Midia Cape and Vama Veche (75 km), is predominantly covered by active or inactive cliffs (52.6%); with beaches (28.8%) and harbours (Midia, Constanta and Mangalia 18,5%). Cliff heights differ from one place to another (from 3-4 m up to 35 m). It is subdivided in two sub-sectors: Cape Midia - Cape Singol (characterized by the appearance of the first promontories with active, high cliffs until 35-40 m, separated by large zones with accumulative beaches) and Cape Singol-

Vama Veche, where active or inactive cliffs are predominant and only interrupted by beaches. The south section specific features are dominance of wave-cut relief consists of abrasive and accumulative forms: cliffs, benches, beaches and sandy barriers in front of littoral lakes (Techirgiol, Costinesti, Tatlageac). The cliff comprises Sarmatian and Pontic limestones. It has been transformed as a result of intensive development: ports, coastal protecting structures, urban and touristic infrastructures.

The Romanian continental shelf up to the 200 m isobath is 22.998 km^2. Its width is considerable ranking from 100 km in the northern sector to about 80 km in the southern one.

Along the coast, surface water temperatures range from a few degrees (minimum ~3°C) in winter to ~24 ° in summer. The Black Sea waters are typical brackish waters, with an average salinity 17.0 -18.0 PSU. The salinity of the Romanian Black Sea waters is directly influenced by the Danube's input (~6500 m3/s) and the mixing water phenomena. The fluvial input influence extends up to 50-100 km.

A large diversity of benthic habitats can be encountered in Romanian waters including various types of sandy or muddy bottoms, biogenic reefs, seagrass meadows (Zostera)and rocks. Along the Romanian Black Sea coast there are found 8 Natura 2000 sites (marine protected areas) which shelter 7 types and 23 de subtypes of habitats and numerous species of flora and fauna.

While the north unit is designated for nature conservation (Danube Delta Biosphere Reserve – RBDD), the south unit was heavily developed from socio-economic point of view. Heavily urbanized, economic activities prevail in this area: tourism, port activities and maritime, petrochemical industry.

The main anthropogenic pressures identified at the Romanian coastal zone in 2011 come from the development of the following socio-economic activities: tourism, agriculture and food industry, shipping industry, expansion of the existing touristic ports, construction works, petrochemical industry, nuclear power industry, manufacturing industry, military activities.

Apart from the major pressure exerted by the Danube river (the three arms Chilia - Vâlcov, Sulina and St. George), the main land-based sources on the Romanian coast of the Black Sea are concentrated in the central and southern part of the littoral, an area with the main urban settlements and industrial activities (Fig. 26).

The Port of Constanta is located on the Western coast of the Black Sea, at 179 nM from the Bosphorus Strait and 85 nM from the Sulina Branch, being the largest port of the Black Sea and the 4th in Europe. It covers 3,926 ha of which 1,313 ha is land and the rest of 2,613 ha is water. Constanta Port has a handling capacity of over 100 million tons per year and 156 berths. It allows the accommodation of tankers with capacity of 165,000 dwt and bulkcarriers of 220,000 dwt. Currently, there are several projects in progress, in order to build new facilities for cargo handling and to improve the transport connections between Constantza Port and its hinterland.

Additionally to port and industrial activities and urbanization, exploration of the natural sources (oil and gas) offshore the Romanian coast are on a growing trend.

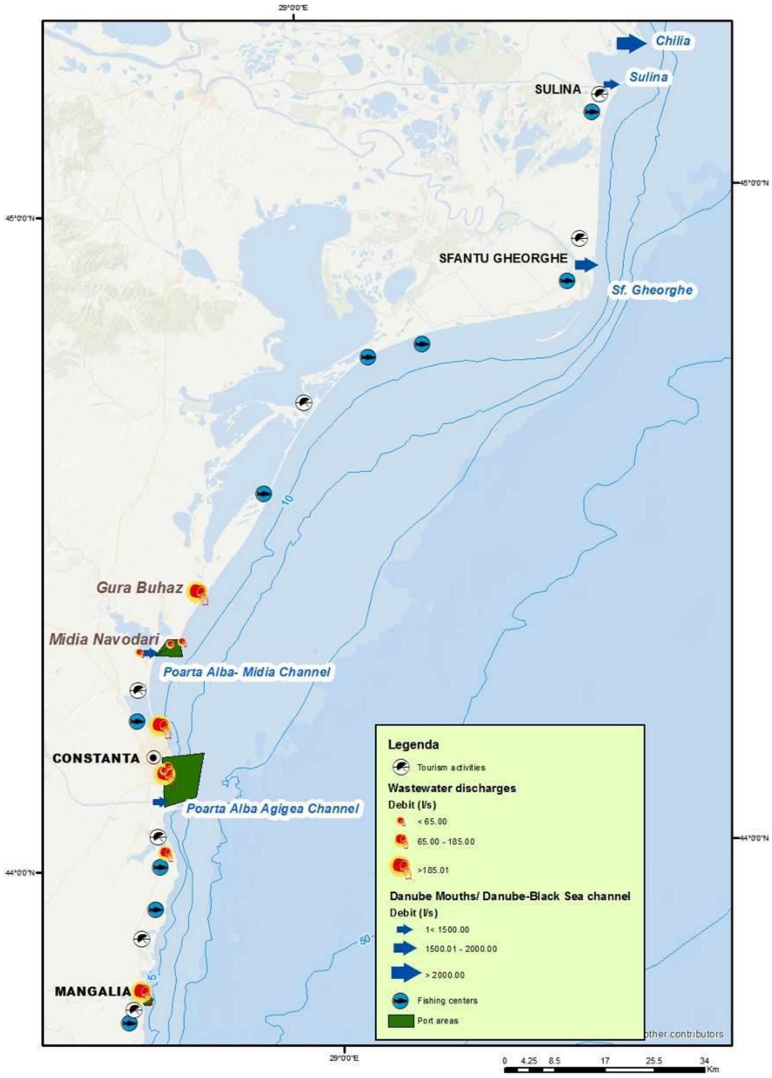


Figure 26: The main land based pollution sources at the Romanian Black Sea coast (Golumbeanu&Nicolaev, 2015)

Romanian Black Sea coast concentrates 43% of the country's tourism potential. Touristic activities are developing, especially in summer. Ecotourism is developed in the Danube Delta region in Tulcea County and mass tourism is developed and concentrated in the Black Sea coast in Constanta County, with 19 beach zones (out of which 13 resorts), with a significant infrastructure. In 2009, there were 361 hotels and 567 touristic villas and bungalows along Romanian seaside. Every summer it is estimated that over 1 million tourists visit the Romanian seaside (1.04 million in 2012). Basically, during the summer, the population doubles in Constanta County. There are three leisure ports (marinas) on the Romanian seaside (Mangalia Tourist, Tomis Constanta, Eforie), and two more are planned to be constructed in the near future.

Fisheries concern both pelagic and demersal species. The main demersal species caught are whiting, sharks and turbot. Pelagic fish dominated in terms of quantity in catches in recent years, the most important pelagic species being sprat.

The fishing depths range between 2 - 20 m and sometimes up to 60 m, when practicing specialized turbot, shad or dogfish fisheries.

The fishing effort in 2012 continues the trend of reduction reported since 2000. Thus, in 2012, in the case of active fishing (using the mid-water trawl), only one vessel was active and in passive fishing 157 crafts, namely 34 boats (below 6 m), 121 boats (6-12 m), one vessel (12-18 m) and one vessel (18-24 m) were active.

In the area, several actions of protection and rehabilitation of the coastal zone have been undertaken.

2.12 North Western Black Sea - Sevastopol bay (area 17)

The north-western Black Sea is characterized by the vastest shallow-water zone of the Black Sea stretching to the west of the line connecting the Tarkhankut Peninsula (Ukraine) with Cape Kaliakra (north of Bulgaria).

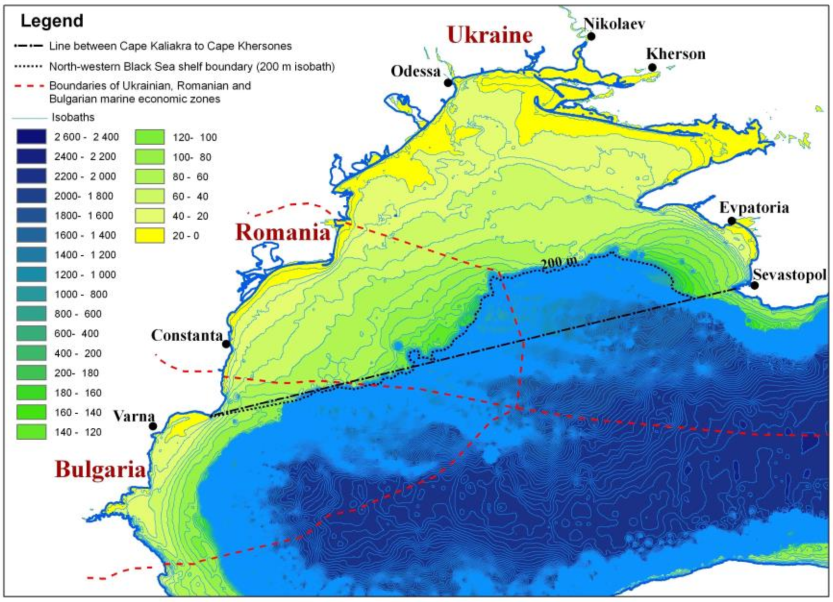


Figure 27: Map of North-western part of the Black Sea

The Black Sea coast is formed under the influence of many factors and under different conditions, which caused the diversity of the coasts. In the northern most part of the shoreline is subject to erosion, however some parts are increasing due to sediment accumulation.

Between the Danube mouth and the Crimea peninsula, several rivers flow into the Sea through estuaries or deltas. The main ones are Dniepr and Dniester Rivers with an average discharge of respectively ~1600 m3/s and ~300 m3/s and a catchment area of 504000 km^2 and 72000 km^2. The Dnieper is among the biggest recipients of pollutants in Ukraine, receiving discharge of untreated or insufficiently treated wastewaters from industry or urban areas and runoff from agricultural areas.

About 4 million people live in the 10-km coastal strip of the NWBS coast. the main town Odessa with more than 1 million inhabitants. The 15 ports located on the Ukrainian coast of the NWBS are considered as a major source of pollution. In 2011 the total traffic of all these ports was estimated to 85 million tons of cargo.

In this area like in other regions of the Black Sea oil pollution, originated from maritime traffic and from offshore oil industry, is considered is a important issue.

2.13 Gelendzhik Bay (area 18)

Gelendzhik Bay is located on the Caucasian coast in the North eastern part of the Black Sea. Along this coast, the shelf is narrow (4-5 km) and the continental slope (from 100 to 1500 meters depth) is steep.

Figure 28: Map of Gelendzhik Bay located at the NE coast of the Black Sea

The Gelendzhik Bay is located on the Russian coast of the Black Sea. The entire 12-km coastline between the capes Tonkiy and Tolstyi falls within the boundaries of Gelendzhik. Beaches take up about two thirds of shoreline. Further inland raise the low Markotkh Mountains. The maximum depth of the bay is 11 meters. Its banks are composed partly by clay and loam, in part by sand, partly by flysch rocks. Retention time of water varied from 0.6 to 6 days.

The town of Gelenzhik has around 60000 inhabitants. With sand beaches and some historical relics the place is a touristic place that is still under development. At a distance of 25 km of Gelenzhik, in a bay located north-westward, the port of Novorossiysk is a main port of Russia for shipping with more than 100 Mt of annual cargo traffic.

The Gelenzhik bay receives the poorly treated waste water discharge from the urban area and from the industrial activities located in the bay.

There are about 25 medium and small rivers along the Russian coast. The main rivers are the Pshada, Vulan, Tuapse, Psezuapse, Sochi. The medium rivers are characterized with annual average stream flow about 10-15 m3 s-1. The total average annual runoff from the territory of Russia is about 7 km3 per year, i.e. about 2% from all freshwater inflow into the Black Sea.

In Gelendzhik region as well as along the entire Russian coast stable growth in the Tourism sector has been reported.

The seabed of Gelendzhik Bay and adjacent shelf regions is characterized by sandy biotopes. Rocks, boulders and blocks also occur occasionally over the shelf.

3 - Main results of dedicated field studies

The results are presented by thematic domain. For every domain, the main outcomes of the studies are given and analysed sub-region by sub-region.

A template similar to the one used in deliverable D2.1 (preliminary gap analysis) is applied to present the conclusions in terms of pressures/impact relationships based on the results of the studies and to expert judgement.

3.1 Changes in environmental parameters and impacts on plankton

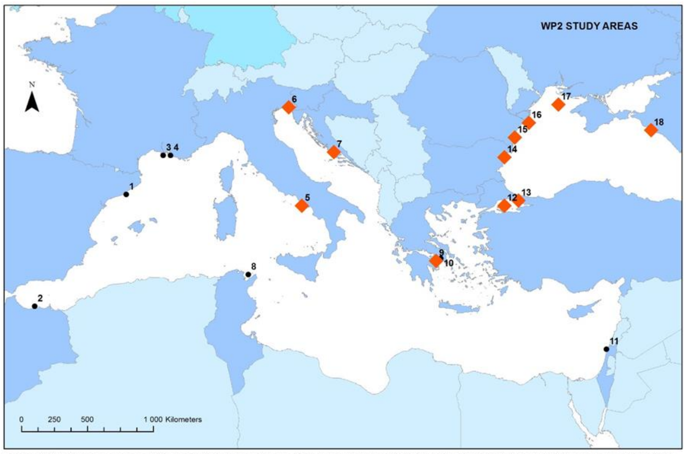


Figure 29: Selected areas for the study of the changes in environmental parameters and impacts on plankton

A comparative study of long term nutrients and phytoplankton biomass and diversity in selected sites of the Mediterranean and Black Seas revealed improvement of the eutrophication status of the ecosystems in most areas. The trends observed since the 1990s show less hypoxia events, phytoplankton biomass decrease and species abundance increase. These changes were coupled with those of nutrients.

Decreasing trends for chlorophyll *a* were revealed for Gulf of Trieste and the whole northern Adriatic, Saronikos Gulf and Varna Bay and an increasing trend in Stončica. It can be concluded that :

- The policy measures aimed at controlling phosphorus and fertilizers seem to be effective on both coastal and open sea scales, although some local issues still exist.
- regional climate changes will have in the future important consequences on the runoff in these coastal marine ecosystems and, as a consequence, on their status and productivity.

Out study indicates that the following main aspects should be considered when the response of pelagic/benthic systems to the pressure of river loads is assessed: a) The temporal (seasonal, interannual and decadal) oscillations and trends of freshwater and nutrients loads by the rivers in the coastal zones; b) The effect of Si/DIN/PO4 and TN/TP ratios on the ecosystem productivity and on the selection of plankton communities; c) The prevalent inorganic form of nitrogen in the TN pool, due to a large presence of NO3, with respect to a greater abundance of organic phosphorus in TP pool

Adriatic Sea

The dynamics of Po River is complex and characterized by strong interannual oscillations (20.5-65.3 $km^3 yr^{-1}$).

In N. Adriatic a long term increase of the TN transport was observed since the 1960s, whereas TP transport was stabilized in the 1980s and reduced during the following decades. During 2004-2012 the total riverine transports of TN and TP reached up to ~25% of the total load in the Mediterranean basin.

The observed environmental changes in N. Adriatic reflected in: a) a reduction of the phytoplankton biomass due to a decrease of TP concentrations, particularly in the western NAd; b) a reduction in the intensity and frequency of late winter diatom blooms since 1994; c) a general trend toward small size species, which can explain the decrease of chlorophyll a concentration. These changes are indicative of an oligotrophication process, which, coupled with overfishing could severely impact different level of the trophic web.

In the period 1989-1994 significant changes in the species composition occurred, with a shift to smaller size species. Investigations were extended to the period 1972-2009. Regime shift analysis identified upward shifts in the 1980s and a major downwards shifts in 2000 of the total phytoplankton. The abundances of all principal fractions (diatoms, dinoflagellates and nanophytoplankton) were markedly lower in the period 2000-2009 than in the period 1972-2009. These changes were related mainly to significant decrease of Po River outflow in the 2000-2009 period, that was accompanied by a change in salinity and nutrient budget of the entire northern Adriatic.

Eastern Mediterranean

In Saronikos Gulf (C. Aegean) the water masses around the sewage outfall until 1994, were characterized by high chlorophyll-a concentrations and frequent algal blooms throughout the year, due to the continuous nutrient enrichment. Due to the lowering of the trophic status in the most eutrophic areas after the operation of the new waste treatment plants after 1995 no significant phytoplankton blooms were reported.

Long term (1987-2010) time series of nutrients, chlorophyll *a* and zooplankton biomass from 3 areas with different levels of impacts were studied. Concentrations of all parameters were higher in all time-series in the northernmost Elefsis Bay. Annual anomalies and cumulative sum analysis showed the temperate seasonal cycle with spring maxima in chlorophyll *a* and minima during the warm period, the increase in chlorophyll *a* concentrations during 2000-2004 and the significant decrease the last decade.

Black Sea

In Istanbul Strait, a study during 2013-2014 showed no significant relationship between nutrients and the total phytoplankton, which might be the result from high dynamic oceanographic characteristics. However, a significant negative correlation between the total phytoplankton and zooplankton was observed. During the study, some potential harmful phytoplankton species were common and observed in spring and autumn with high abundance. The increasing abundance of some opportunistic algae, jellyfish blooms (*Aurelia aurita*, in winter), *Noctiluca* dominance in 2014, and heterotrophic dinoflagellates could imply environmental stress and decreasing water quality due to the influence of both the Black Sea inflow and local discharge of the megacity of Istanbul.

The Danube River average discharge contributes for 55% of the freshwater discharge to the Black Sea. The NW shelf of the Black Sea, a shallow semi-enclosed basin receives not only the discharge of Danube, but also from the rivers Dniepr and Dniestr. Nutrient discharges into the Black Sea have increased continuously since the early 1960s, specifically during the 1980s. In the 1990s, human-induced eutrophication has been reported as causing extensive damages to the pelagic and benthic communities. The actual assessment of the eutrophication state of the Romanian Black Sea waters confirms the phenomenon complexity and the vulnerability of the NW Black Sea ecosystem.

Phosphates input from 1995 to 2008 showed continuously decreasing concentrations and loads.

In Romanian coastal waters, the eutrophication state is generally influenced by two main sources – the Danube's input (and probably other rivers from NW) and the anthropogenic input of the Constanta coastal zone.

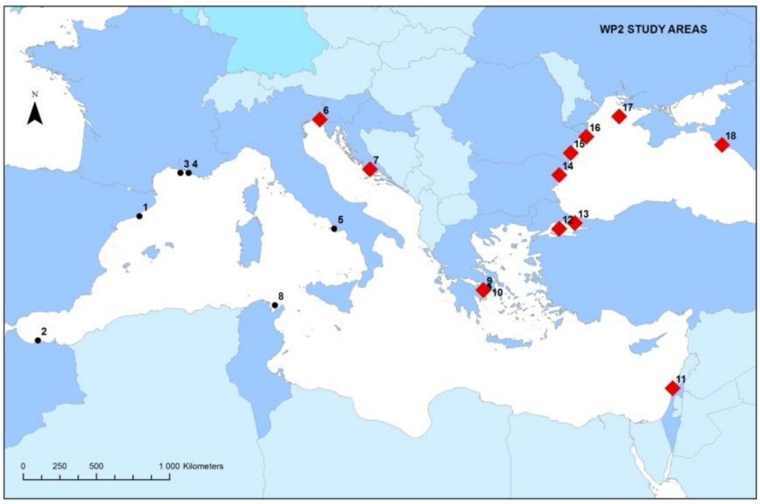
The climate changes manifested through the alteration of the Danube's hydrological regime, seawater temperature increase, intensification of the water masses stratification, etc., are important influencing factors of the actual eutrophication state.

In Varna region, the results suggest that climatic variables (temperature & precipitation) could be key factors controlling the ecological conditions for phytoplankton growth in the coastal area, especially in summer.

In the Zmiinyi Island coastal waters, potentially toxic microalgae number of species increased almost 2-fold during the past decade. About 14% of the total number of phytoplankton species recorded during 2013-2014 belong to the group of potentially toxic species, and some of them reached extremely high abundance and biomass values.

In Gelendzhik Bay, during 2007 to 2014 a decreasing trend of Si and PO_4 was observed. The study area is characterized by the high N:P ratio in most seasons due to low concentration of phosphate.

3.2 Food web interactions including fish, jellyfish and interaction with microbial communities



Barcelona (1), Mediterranean coastal area of Morocco (2), Rhone River and Marseilles (3-4), Naples (5), Northern Adriatic (6), Southern Croatia (7), Gulf of Tunis (8), Saronikos gulf and Athens (9-10), Haifa (11), Sea of Marmara and Istanbul (12-13), Varna (14), Costanza and Danube mouths (15-16), North-western Black Sea and Sevastopol bay (17), Gelendzhik (18)

Figure 30: Selected areas for the study of food web interactions

Adriatic Sea

The study has highlighted the importance of picoplankton community in the coastal Adriatic Sea. A significant quantitative and structural response of microbial community to nutrients loads and ratios has been demonstrated. Linking the functional responses of the microbial community to nutrient conditions may serve as a strong food web indicator of ecosystem status and its response to eutrophication pressure.

The analysis of long term time series of primary production revealed synchronized changes in open sea and coastal waters indicating the prevalence of climate and naturally driven variability over anthropogenically induced variability.

Primary production and phytoplankton biomass changes in the eastern Adriatic Sea could be divided in three periods: pre-eutrophication period from 1960s to 1980s, eutrophication period from 1980s to mid 1990s and oligotrofication process starting in late 1990s. Increasing phytoplankton biomass in the 1980s has been reported throughout the northern hemisphere and should be attributed to regional climate changes.

Jelly fish play a significant role in the pelagic food web. Reported species include endemic and Non Indigenous Species. Negative effects of jelly fish blooms on human enterprise and ecosystem in the Mediterranean Sea include impacts on fisheries and aquaculture, tourist industry (incl. human-health threat) and impacts on coastal industry that uses sea as cooling water. They however may have also positive effects on ecosystems as thet serve as a prey to a number of marine organisms including charismatic marine turtles, large fish like sunfish, swordfish, bluefin tuna and little tunny.

It was shown that artificial structures and in particular those established offshore provide favourable subtrates for some jellyfish polyp attachment, e.g. *Aurelia spp., Rhopilema nomadica*. Newly set up additional substrate thus enables forming of a new polyp population in the formerly unpopulated open waters and facilitates dispersal of shore-based polyp populations to distant locations, contributing to more frequent and intensive jellyfish (*Aurelia*) blooms.

Black Sea

In Gelendzhik area, data from 2005 on gelatinous predators' biomass show a variation from 110 to 330 mg C/m^2 with *Aurelia aurita* contributing up 50-90% of the total biomass. *Mmenpiosis leidyi* played a noticeable role (40% of total biomass) in 2007-2009, however, afterwards its share in total biomass decreased to 3-10%. The contribution of native species, *P. pileus*, to the total jellyfish biomass varied from 5% to 15%. In summary, over the last decade, the observed trends consist of decreasing of *Mnemiopsis* biomass and increasing of *Aurelia* and *Pleurobrachia* biomass.

Mesocosm experiments demonstrated that both NIS ctenophores *B. ovata* and *M. leidyi* induced changes in the chemical properties of the water and in the growth, productivity and taxonomic structure of plankton communities.

In the Black Sea data on anchovy diet under *Mnemiopsis* depleted zooplankton conditions showed a switch to different food source (planktobenthos and phytoplankton) and give an indirect evidence of the poor zooplankton state.

The analysis of data regarding small pelagic fish in the Black Sea indicates that, at regional level, catches and fishing effort increase beyond the natural recovery capacity of stocks in spite of evident decline of stocks. Thus:

- stocks of sprat are exploited close to the maximum;
- stocks of anchovy and horse mackerel are over exploited;

Fishery is the most affected sector by the changes of the Black Sea ecosystem, and changes in the ichthyofauna composition have primarily involved alterations in the number of individuals in specific populations.

In the last three decades fish catches in Romanian marine area continuously decreased, e.g. catches of anchovy had a very severe decline in 1989-1990, from 6,500 tons to several tons. During the period 1993-2005 catch values ranged around 150-300 tons, and then fall back to a few tens of ton.

Stomach content analysis of small pelagic fish (anchovy, sardines) indicate that they generally prefer animal prey, although plant components were also found in their stomachs. It is hypothesised that they feed on phytoplankton when zooplankton food is particularly scarce such as during outbreaks of jellyfish (Mnemiopsis leidyi). Clear seasonality in diet was also observed.

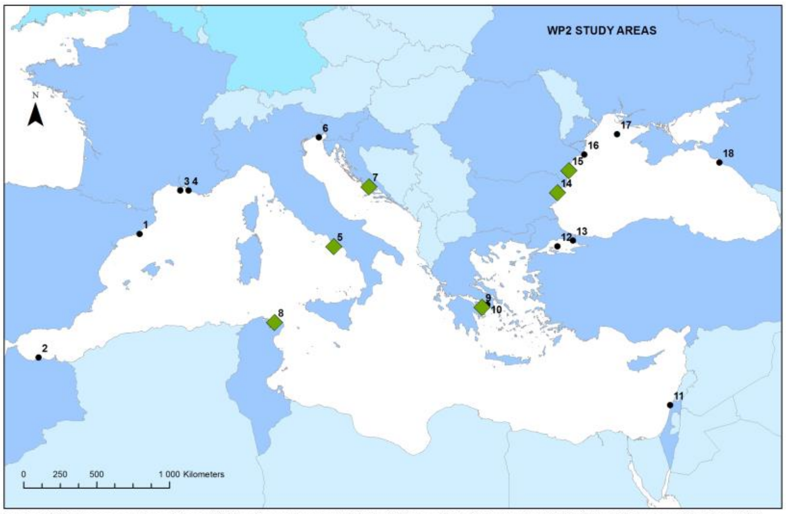
A summary of anthropogenic pressures which may be related to jellyfish blooms and links to MSFD is presented in Table X.

Table 1: Human activities that may benefit jellyfish populations and links to MSFD

Pressure	Problem/mechanism	Link to MSFD
Extraction of organisms	Overharvest of forage fish reduce competition for plankton food Extraction of jellyfish predators (jellyfish-eating fish, turtles) releases populations from predatory pressure	Fish/turtles/food web changes
Input of nutrients	Greater biomass of plankton and increased turbidity favour jellyfish as non-visual predators vs. fish (belonging to the same trophic level as jellyfish) as visual predators Episodes of hypoxia/anoxia negatively impact benthic animals but jellyfish polyps survive unfavourable periods; medusae also seem to be tolerant to low oxygen levels	Eutrophication
Marine constructions	New hard substrates like harbours, breakwaters, platforms, aquaculture, off-shore energy (wind, wave, tidal) installations provide suitable substrate for sessile stages of jellyfish (polyps). Some scyphozoan planulae preferentially settled on artificial substrates.	Physical disturbance
Transport of organisms	Some introduced gelatinous species are among most successful invaders in European waters such as *Mnemiopsis leidyi*, *Rhopilema nomadic* , possibly *Aurelia* spp. (cryptic species) Marine litter as possible vector of polyp dispersal	Non-indigenous species

Climate change	Regime shifts and warmer climate: -direct effect on metabolism, growth and/or reproduction, -indirect effects via ecosystem interactions (food web changes that favour smaller sized phytoplankton and flagellates vs. diatoms may give advantage to jellyfish rather than forage fish)	Food webs

3.3 Response of seagrass meadows to pressures



Barcelona (1), Mediterranean coastal area of Morocco (2), Rhone River and Marseilles (3-4), Naples (5), Northern Adriatic (6), Southern Croatia (7), Gulf of Tunis (8), Saronikos gulf and Athens (9-10), Haifa (11), Sea of Marmara and Istanbul (12-13), Varna (14), Costanza and Danube mouths (15-16), North-western Black Sea and Sevastopol bay (17), Gelendzhik (18)

Figure 31: Selected areas for the study of the Response of seagrass meadows to pressures

An example is the maintaining of good status of sea grass meadows as a result of a better control of pollution pressures. The presence of sea grass in the Mediterranean /Black Seas signifies good water quality. PERSEUS carried out a comparison of the coverage of sea grass meadows with historical data in 6 highly anthropized coastal areas (e.g. Naples) of the Mediterranean and there is no evidence of neither degradation nor clear trends. The meaning of these finding is that human pressure has not permanently affected sea grass meadows in the Mediterranean and the Black Sea.

Western Mediterranean

In the case of the Gulf of Tunis, the comparison of the different previous studies shows a decline at the upper limit of the *C. nodosa*, due to the impacts of human activities in this area. A regression of the barrier reef of *P. oceanica* was also observed. The regression of the *C. nodosa* and *P. oceanica* meadow can be also explained by the presence of the invasive and competitive species *Caulerpa racemosa*, which settles the C. *nodosa* and *P. oceanica* habitat and which are more frequently observed in this area.

Finally, we can conclude that the seagrass of this area are threaten by several pressures such as fishing activity, discharges of wadis and the introduction of competitive and invasive species which is considered as an indirect impact of human pressures.

In the case study of Naples study area, the large scale pattern of the meadow is similar to the historic maps.

Adriatic Sea

Better conditions of seagrass beds are observed over years. This is attributed to the improvement of waste water discharge treatment.

Local differences in meadow coverage from one period to another could be attributed to factors not directly linked to human activity (e.g. seasonal development of epiphytes).

Eastern Mediterranean

In the case of Saronikos Gulf, comparing the observations of seagrass distribution pattern carried out in the framework of PERSEUS with the existing similar observations from the last 2-3 decades, no significant large scale changes were detected. The time scale of changes in the distribution pattern of *P. oceanica* is very slow and probably 2 or 3 decades is not enough time for the distribution pattern to reflect the changes of the environmental conditions.

Black Sea

Seagrass meadows in Burgas Bay area have stable distribution in recent decades. Eutrophication is the major factor determining ecological state of seagrass meadows in the study area.

Using extent of occurrence, the **reduction in quantity** of *Zostera noltei* in Romania, over the last 45 years is estimated at a 95% decrease. Near-extinction of the species and habitat occurred during the Black Sea eutrophication maximum (1980s-90s), coupled with earlier large-scale anthropogenic habitat destruction (hydrotechnical works) and natural extreme events (extreme winter storms with ice scour).

At present the situation of *Zostera noltei* meadows in Romania is **stable** and a **trend** of slow increase can be maintained if present environmental conditions are maintained and proper management measures enforced.

The **main pressures** are, in this order:

1. Direct anthropogenic habitat destruction by coastal protection and harbour-building hydrotechnical works.
2. Extreme weather events (winter storms with ice scour).
3. Eutrophication, which at present is decreasing.

Other anthropogenic disturbances: bait collection by fishermen, trampling by tourists.

While there are several anthropogenic impacts on seagrass meadows (past and planned coastal protection constructions, bait-harvesting by fishermen, anchor-damage), at this moment the observed trends in distribution and cover seem to be driven mainly by weather patterns and extreme events (ice-scour).

3.4 Impact of coastal development and urbanization on shallow water habitats

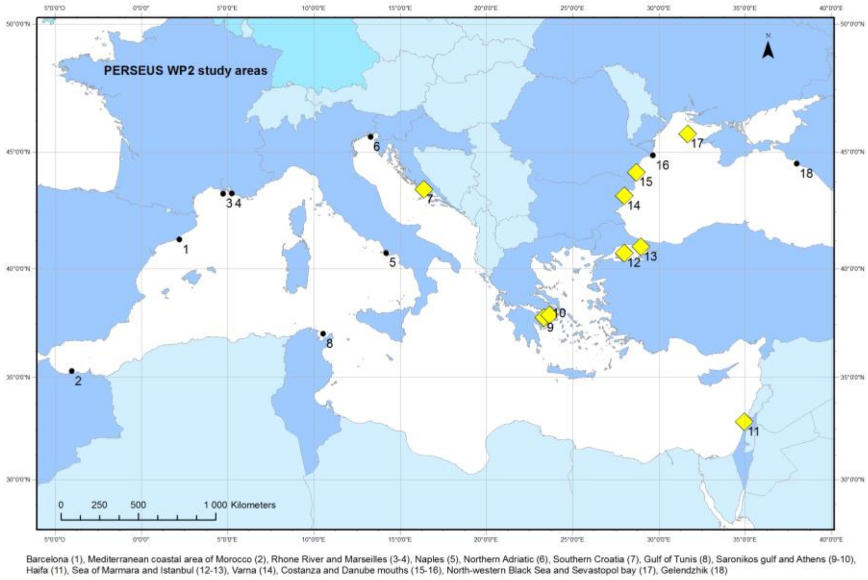


Figure 32: Selected areas for the study of the Impact of coastal development and urbanization on shallow water habitats

The test of several bottom benthic community indices shows in most of the cases a clear negative correlation between anthropogenic pressures, in particular pollution and benthic population diversity and abundance.

Adriatic Sea

In the Split area, it was seen that due to pollution and eutrophication, infralittoral algal communities react on way that gradual increase the qualitative and quantitative dominance of opportunistic species. Lower quality conditions are connected with decrease circulation of water in the ports and marinas and untreated waste water discharge.

Eastern Mediterranean

In Saronikos gulf, all biotic indices showed statistically significant correlations with most contaminants though Bentix showed the stronger (highest P-value) for TOC, and TN. A trends analysis including Bentix index revealed a change in the trends of most benthic indices after 2004, especially in the more adjacent to the outfall zones, when the advanced secondary biological treatment plant was completed and commissioned. Sediment parameters' trend patterns indicate a delayed reaction to recovery processes in relation to benthic indices.

In the Haifa region, several ecologically-important species (a reef-building vermetid gastropod, sea urchins and a large predatory snail) exhibited major population collapses while several key taxonomic groups (gastropods and bivalves and to some extent fish) are completely dominated by IndoPacific invaders. These findings are evidence for a multi-species range contraction at the edge of the Mediterranean Sea, adding to the regional ecosystem phase-shift already driven by massive bioinvasions. The state of native species is better in Cyprus and Crete than in Haifa, and the presence of invasives was much less apparent in these areas, while the commercial fish status is similarly bad in most sites.

Black Sea

In Marmara Sea, the study concluded that :

- Polluted Areas displaying low diversity and bad ecological status.
- Diversity index around Istanbul has decreased from 2000 to 2009

Constanza area: in areas under the influence of the point sources WWTP (Mangalia, in shallower depths) the distribution of ecological species groups showed the dominance of the tolerant taxa to an organic matter excess followed by opportunistic species and indifference taxa of the gradient pressure excess In the studied area the percentage of the sensitive species group did not exceed 5%.

Among biotic indices, AMBI correlates with Cr and M-AMBI with TOC and PAHs.

In Varna area, the ecological status of macrozoobenthos reflect the impact of the pressure gradients in the shallow coastal zone up to 13m depth. The nitrogen load seems to be the major factor influencing the ES of benthic ecosystems in the shallow coastal zone of the studied area.

3.5 Analysis of functional community changes in demersal fish aggregation

An analysis of data collected by MEDITS scientific bottom trawl cruise programme was performed. It allowed to draw out information about demersal fish communities changes in several areas of the Mediterranean. The results which regards the **Western Mediterranean**, the **Adriatic Sea** and the **Eastern Mediterranean** are presented together.

The analysis of biomass trends of 13 functional groups (FG) defined according to morphological traits showed correlation with either fishing pressure (FAO catches) or environmental parameters (mainly nitrate and temperature) depending on FG.

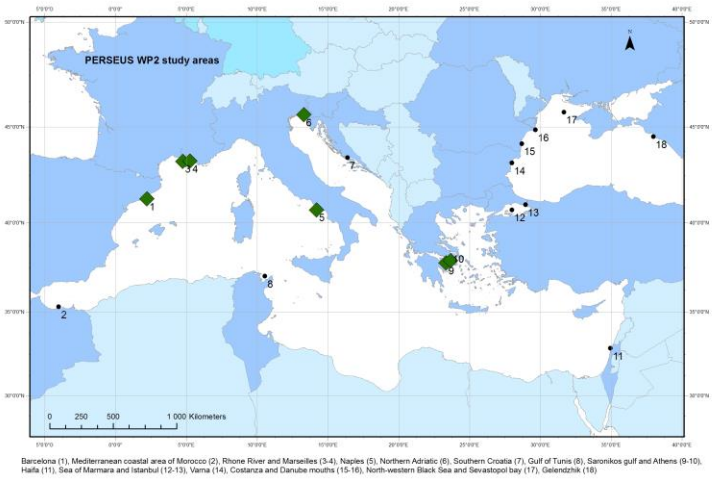


Figure 33: Study areas for the Analysis of functional community changes in demersal fish aggregation

Over the last two decades nearly half of the functional groups showed increasing biomass in the Mediterranean areas while a quarter of them decreased and the last quarter remained stable. The relative changes in functional group biomass in the bentho-demersal food web components of the Mediterranean Sea did not show any longitudinal nor latitudinal trends but were mainly associated to the variability in near nitrates and sea floor temperature, and to a lower extent to the level of exploitation. Together, those three variables explained over 46% of the total variance.

Analyses of the relative changes in functional group biomass identified four spatial patterns of FG temporal trends.

The figure 34 below shows the difference between the different areas (based on MEDITS scientific bottom trawl cruise programme) which can be grouped into 4 classes.

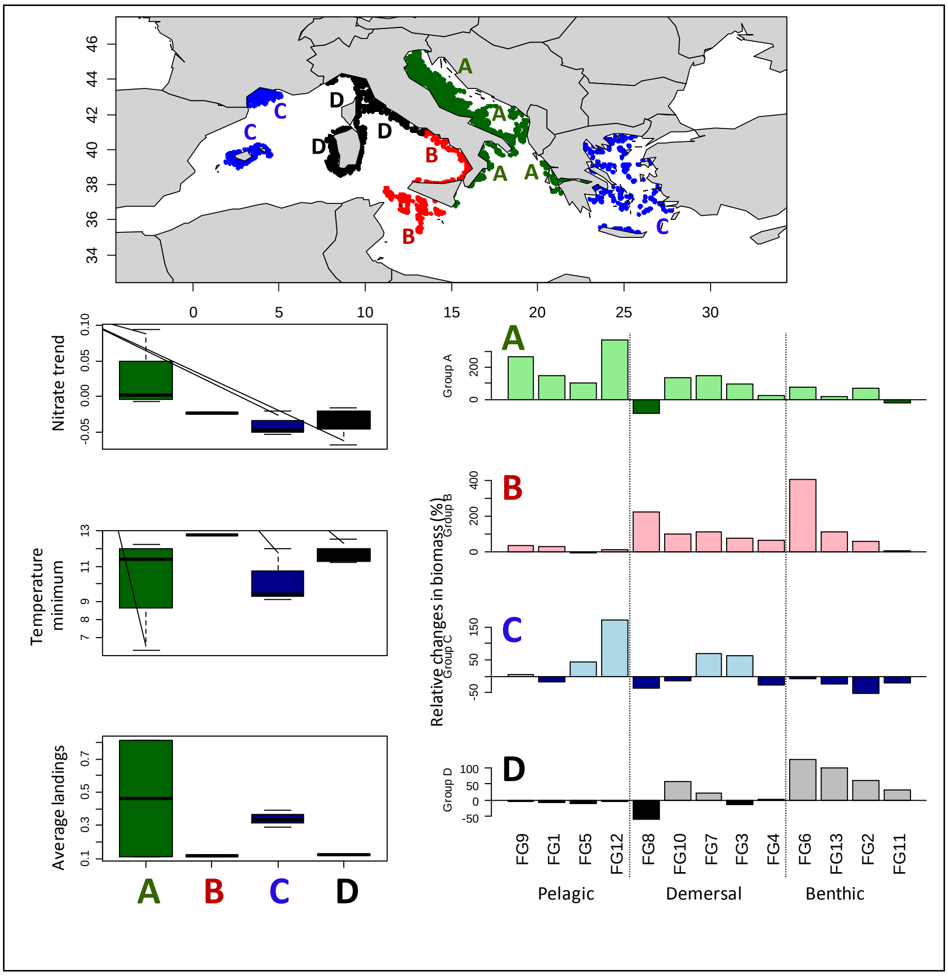


Figure 34: Groups of Mediterranean areas showing similar trends in the temporal evolution of their functional groups and main factors explaining these trends.

Group A (Adriatic and Ionian seas) displayed increasing nitrates, low minimum temperatures, and high FAO catches. Group C (enclosed bays and Balearic islands) was characterized by a decrease in nitrates, intermediate minimum temperatures and high FAO catches. The fourth group, group B (Tyrrhenian Sea and Sicily) were associated with intermediate increase in nitrates, high minimum temperature, and low FAO catches. Area group D (i.e. *Ligurian Sea and Sardinia)* was characterized by decreasing nitrate, high minimum temperatures, and relatively low FAO catches.

The results provides an objective way for grouping fish species into functional groups which is a first step towards a mechanistic understanding of Mediterranean marine food webs. It is also a contribution to the MSFD as it provides a method to define functional groups of species to assess food web indicators.

3.6 Impact of Non Indigenous Species on coastal ecosystems

The map below shows the areas concerned by the study on NIS. The results summarized below are given in details in deliverable D2.8 "Impact of Non Indigenous Species on coastal ecosystems in the Southern European Seas".

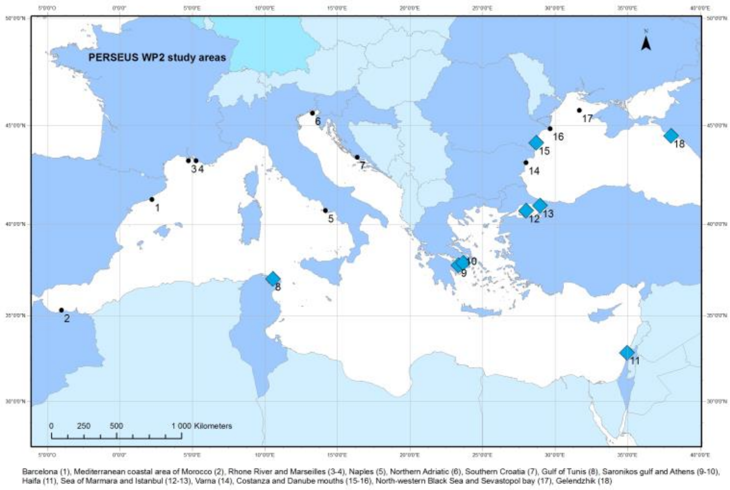


Figure 35: Selected areas for the study of the impact of NIS on coastal ecosystems

The main outcomes are:

- The rate of new introductions has been increasing at all study areas after 2000.
- Combination of pathways /vectors of introductions with rate of new introductions per study area, strongly suggests that climate change is the regulating factor for establishment of NIS (either introduced via the Suez Canal: Haifa, Gulf of Tunis) or ship transferred (Saronikos, Constanza, Gulf of Tunis).
- The ratio of NIS to native species (expressed as relative abundance of native and NIS), applied to the total biota was meaningful for Gelendzhik, showing an increasing impact with time in Gelendzhik Bay (closer to the port). An increasing trend in the quantitative contribution of polychaeta NIS was also observed in coastal waters of the Saronikos (closer to the port).
- The relative abundance of NIS to native species estimated in 2013 for the rocky reefs of Haifa Bay, reached 56% for Mollusca, and 23% for fish. Insignificant and decreasing was the contribution of NIS in Constanza ares, perhaps indicating an equilibrium of the ecosystem.

Western Mediterranean

<u>Tunis</u>

Among the new invaders, three fish species, namely the pufferfish (*Lagocephalus sceleratus*), the black-barred halfbeak (*Hemiramphus far*) and the brushtooth lizardfish (*Saurida Lessepsianus*) have reached the Gulf of Tunis. Further addition in the area is the occurrence of the mussel *Brachidontes pharaonis*, and the upside down jellyfish *Cassiopea andromeda*, both among the most invasive species in the Mediterranean.

Caulerpa taxifolia is in spreading in the Gulf of Tunis and presents a threat to indigenous species, in particular *Posidonia oceanica* that is in regression and becomes absent in some regions.

Eastern Mediterranean

<u>Saronikos</u>

Data on trends in new NIS in the Saronikos wider area exhibited an increasing trend with a maximum of 7 new species per year introduced in the 2005-2009 period.

The contribution of NIS to native species is increasing with time. In terms of species diversity the mean ratio ranged from 0 to 25% in 2012, while it was estimated from 0 to 15.5% in 2013. In terms of abundance the mean ratio of NIS/native increased from 4.5% in 2012 to 6.5% in 2013 . 25% of the NIS are classified as invasive. Yet, their impact to the native ecosystem has not been investigated yet. Regarding the alien macroalgae, their persistently low abundances, can hardly be considered a threat to the native macroalgal communities of the shallow infralittoral Saronikos coasts.

Haifa

The results clearly show that the reef system has *already* undergone considerable changes in the past century or so. This statement is based on three main facts:

1. Invasive species are highly dominant numerically in all assemblages (macroalgae, invertebrates and fish) examined.
2. Many native species, mostly invertebrates, that were once considered abundant are rare or absent. This is based on a literature survey of mollusks and some anecdotal data for urchins, but it might be true for other groups for which we have not even a qualitative description of their abundances in the past.
3. Overfishing is considerably reducing the abundance of many commercial fish, which are extremely rare in most areas except the shallow waters inside the Achziv-Rosh Hanikra reserve.

Black Sea

Constanza

1. The share of the non-indigenous benthic species *Anadara kagoshimensis* and *Mya arenaria* in the total benthic biomass and abundance was negligible.
2. The share of NIS did not exceeded 5-10% of the total number of species identified on each profile.

Gelendzhik

1. Twenty six out of a total of 229 species have been reported in the wider Gelendzhik port area, which brings the ratio of NIS to native species to 12.8%. The vast majority were reported In the last decade (2005-2014), and particularly in the 2004-2009 period when eleven non-indigenous phytoplankton species were recorded in the study area.

In summer 2014, the share of these two NIS made up 10-30% of total copepod abundance and 4-15% of total copepod biomass in the bay and coastal waters. So far, a possible impact of these species on the ecosystem is insignificant. The share of the non-indigenous benthic species *Anadara kagoshimensis* and *Rapana venosa* in the total benthic biomass and abundance was negligible for the exception of the shelf station due to the appearance of the large-sized species *Rapana venosa*.

The ratio of the invasive ctenophore *Mnemiopsis leidyi* permanently decreased from 90% of the total gelatinous top predator biomass in 1989-90 (their outburst) to 5-15% at the shelf off Gelendzhik in the last five years. In the first phase of the invasion, the outburst of *Mnemiopsis* abundance and biomass had a disastrous impact on the abundance and species composition of the Black Sea zooplankton led to the shrank or even disappearance of some species. Presently, the interannual variability in the *Mnemiopsis* population biomass did not cause any significant changes in abundance and species composition of mesozooplankton.

Despite the growing awareness of the problem, little is known about the mechanisms by which invasive alien species can impact the functioning of natural ecosystems.

3.7 Impact of chemical pollution on coastal ecosystems

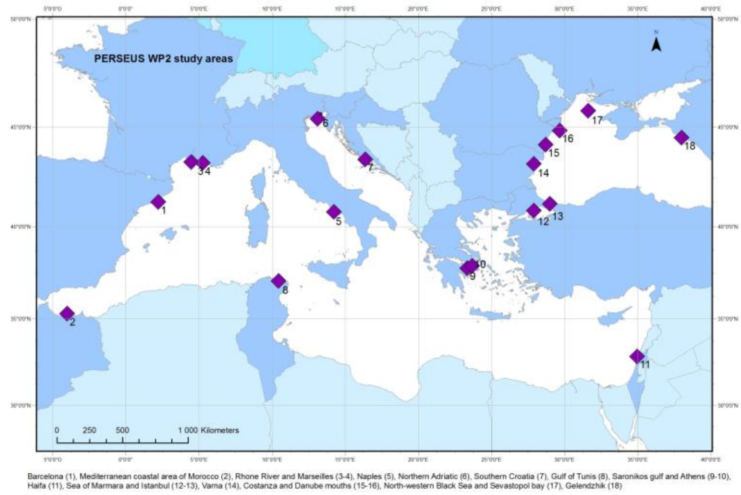


Figure 36: Selected areas for the study of the impact of chemical pollution on coastal ecosystems

The positive impact of the reduction of polluted waste water discharges and of the improvement of treatment plants in urban coastal cities is clearly visible on benthic communities under the direct influence of outfalls.

This result demonstrates that early policy measures (such as Water Framework Directive for European Countries) based on scientific evidence, maintain good environmental status and the efforts to reduce the discharges of untreated or poorly treated waste waters should be continued.

Contamination by chemical pollutants remains a significant environmental risk in the Mediterranean and Black Seas. The contaminants are subject to basin-wide transport, redistribution, bioaccumulation and biomagnification, and their pathways and key processes are now better known. Legacy pollutants as well as emerging pollutants are among the substances of concern. They are widespread, found in coastal areas and also in the open sea and deep sea environments.

Through literature studies, research cruises and field work in pilot areas PERSEUS study provide an assessment of several processes responsible for the pollution status in the Mediterranean and Black Seas and update information on contaminant levels and their background concentrations. The main conclusions can be summarized as following:

- High concentrations of contaminants are found in sediments, water and biota in the vicinity of hotspots such as large coastal cities, ports and industrial areas. However, like for nutrients the measures taken to improve wastewater treatment and better control of the release of chemicals in the environment have proved successful and led in several places to a decrease of chemical pollution. The evidence is also given that concentrations decrease rapidly from the hot spots toward the open sea;

- The screening of organic compounds in seawater samples in three coastal hot spots shows a large number of priority and emerging substances determined at wide range of concentrations;

- The contaminants in the biota reveal also distinct spatial patterns: the organic pollutants are found at much higher concentration in the vicinity of hot spots whereas trace metals distributions are more related to regional scale pressures and biogeochemical features;

- Differences between Mediterranean sub-regions are not significantly marked. However, a decreasing gradient of the concentrations from the north coast towards the southern coast can be clearly seen for several chemicals in the Mediterranean Sea;

- Concentrations measured for mercury, lead, cadmium, CB153 and fluoranthene in mussels and small pelagic fish (i.e. low trophic level species) from the coastal study sites remain below EC regulation concentrations for sea food.

Western Mediterranean

In Marseilles area, 2 sampling campaigns supplemented by a 3D modelling study showed that:

- Evidence of legacy and emerging organic chemical contaminants inputs associated to coastal cities "hot spots"
- In sea water concentrations showed very large ranges - wastewater outfalls and harbour areas vs. offshore stations. Dilution of chemicals from point source inputs occurred on small spatial scales.
- A large amount of contaminants is brought to the sea during floods
- High proportion of contaminants discharged in the bay are exported offshore after a few days, especially those adsorbed on fine and light particles (especially under Mistral wind forcing)
- Hydrophobic contaminants having an affinity for heavy particles tend to accumulate in sediments near outfalls
- The impact of a rainfall event on pelagic ecosystems could be compared to that of a strong Rhone River intrusion in spring, showing the potential influence of distant sources in an open bay like the bay of Marseille

Comparable concentrations of mercury in mussels and fish are observed in the various areas of the Mediterranean including the western sub-basin. The low variability between areas and between stations in the same area suggest that large scale factors – like atmospheric inputs or geochemical background - prevail on local ones in the contamination of biota by mercury.

For mercury and lead in biota, a decreasing gradient from north to south is clearly seen.

Remote reference stations show higher levels of cadmium in mussels than areas under strong anthropogenic pressure.

In spite of ban measures taken in the 80' for PCB, these organic pollutants can be found in biota especially in the vicinity of places having a long urban/industrial history. Concentrations found in remote areas are much lower. Like for PCB, PAH levels in biota are much higher in the coastal areas under high anthropogenic pressures.

The study of hydrophobic organic contaminant transfer in the low trophic level food webs showed:

- concentrations of CB 153 and BDE 47 in plankton generally higher in the eastern part of the Gulf of Lion (except in the largest plankton fraction - 1000-2000 µm), i.e. at the stations under direct influence of urban center of Marseille and of the Rhône River.
- the difficulty to differentiate the trophic relationship in the plankton. The biomagnification of PCBs over the range of plankton size classes was not demonstrated by the field studies.
- No apparent dilution effect with increasing plankton biomass
- Moderate but significant biomagnification with $\delta 15N$ signatures within plankton

- Significant biomagnification with δ15N between plankton and small pelagic fish

Adriatic Sea

The screening of legacy and emerging contaminants in seawater in the vicinity of Split showed - like in Marseilles - a wide range of concentrations as well as a rapid dilution away from the coast towards the Open Sea.

Significant cytotoxicity was detected in sediments from certain stations of the Adriatic (e.g. Split/Kastela Bay).

Like in the Western Med comparable concentrations of mercury in mussels and fish are observed in the Northern and central Adriatic Sea, suggesting the major influence of large scale factors. In the Northern Adriatic the high levels found are however attributed to the inputs of the Isonzo river which is known to be the main source of Hg in the Gulf of Trieste, due to the presence of the Idrija mining district in the Slovenian sector of its river drainage basin.

Levels of mercury in mesozooplankton observed in Kaštela Bay are comparable to the ones observed in the pollution hotspots of Northern Adriatic.

Eastern Mediterranean

In Saronikos gulf, tested biotic benthic indices demonstrated gradients of good-moderate-poor for most trace metals (Cu, Ni, Cr, V) and TOC and TN. Benthic indices are negatively correlated with the loads measured for most contaminants.

As in the Western Mediterranean, remote reference stations show higher levels of cadmium in mussels than areas under strong anthropogenic pressure, suggesting the major influence of large scale pressures. Like in the WMED, for mercury and lead in biota, a decreasing gradient from north to south is clearly seen.

For PCB and PAH levels in biota are much higher in the coastal areas under high anthropogenic pressures.

Black Sea

The screening of legacy and emerging contaminants in seawater performed in the Constanza area (in the same way as in Marseilles and Split) showed a wide range of concentrations and a rapid dilution away from the coast towards the Open Sea. The maximum concentrations are in the same magnitude than in the other both study areas.

Significant cytotoxicity was detected in sediments from the Black Sea, particularly in those collected from Constanta harbor, Danube mouths and Mangalia harbor/WWTP.

In Burgas Bay, significant negative correlations of biotic benthic indices (AMBI and BENTIX) with TOC and most metals in Zostera habitats (TOC, Zn,Cd,Mn,Ni,Fe, total metals plus Cu for Bentix) and most metals (Cu,Zn,Mn,Ni,Fe,total metals plus Pb for Bentix) was observed in sand.

Like in the Mediterranean, PCB and PAH levels in biota are much higher in the coastal areas under high anthropogenic pressures. Concentration of organic contaminants in biota are much higher in the Bosphorus Straits than in other areas.

3.8 Impact of litter on coastal ecosystems

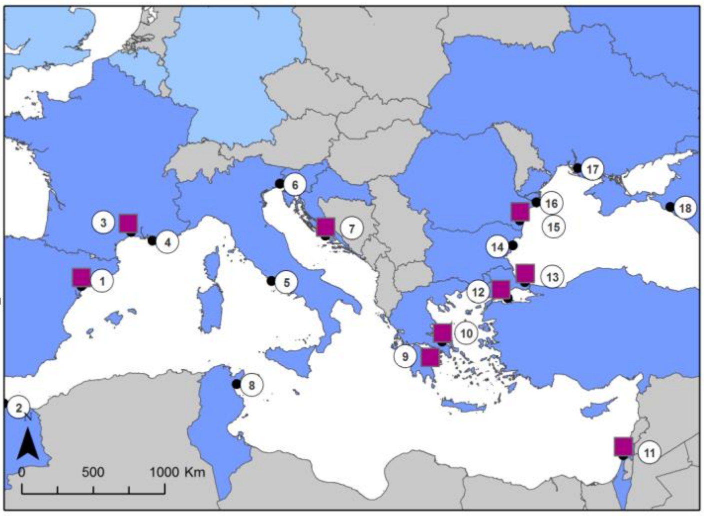


Figure 37: Selected areas for the study of the impact of litter on coastal ecosystems

In all areas, the majority of items were made of plastic often exceeding the global average of 75%. The largest part of all plastic items was bags, providing further support for the EU decision to reduce the use of plastic bags.

Floating debris have been observed everywhere with concentrations varying according to the methods.

Western Mediterranean

Plastic items were the most important items (81,6 %) of the litter collected in 2013 and 201' in the Gulf of Lions shelf. The largest concentrations were found in canyon floors at water depths exceeding 1000 m. Relatively little litter was identified in canyon walls.

The study of floating litter with an automatic camera system found that :

- Marine Litter constitutes the major part of floating items > 10 cm^2 in the Western Mediterranean Sea.
- Small size floating items smaller than 200 cm^2 contribute mostly to the object abundance and object surface area
- Concentrations of floating litter are variable, they ranged from 0 items/km^2 to 488 items/km^2.

In France, data obtained from microplastic sampling in sea water from cruises indicated a mean level of 110 000 items/km^2 with values ranging from 3000 to 715000 items/km^2.

Eastern Mediterranean

Bottom trawls surveys in several areas of the Greek coast revealed highly variable densities of marine litter. The highest density (over 3000 items/km^2) were found in Saronikos Gulf.

Data on Solid waste materials collected by bottom trawling along the Turkish Coasts of Northern to Mid Aegean Sea showed an high abundance in gulf areas (299,98 -211,75 items/km^2; 27,6-2,85 kg/km^2) but very low density (48 items/km^2 and 2,26 kg/km^2) in the open sea locations.

In samples from a Greek island (Kea island), plastic particles was found with an abundance up to 575 items m^{-2}. 70% of the particles was pre-production plastic pellets.

While assessing microplastics in fish stomachs from various pelagic & demersal fish species Greece and Cyprus in 2014, only 4 microparticles were counted on 172 samples from various species.

In Israel, sea surface microplastics collected in 2013 and 2015 at 16 stations along the coast showed presence of microplastic particles in all the net samples with a relatively high mean abundance of 7.68 particles per m^3.

Black Sea

Research surveys conducted with sampling trawl in Romania at depths ranging between 15 - 90 m showed that prevailing waste items (in mass) during hauls were metallic and petroleum products waste in solid or semi-liquid state or packaged in plastic bags and fabric. The largest amounts of metal, plastic and toxic waste (used petroleum products in solid state or semi-liquid) and readily degradable materials (plastics) were located in the areas around the ports and where is recorded a heavy naval traffic.

A survey carried out on the Romanian coast beaches found that 61.2 % of the litter items were plastics. Most waste localized and identified on land were represented by plastic packaging, paper, wood, glass etc., textile, medical waste, chemicals thrown by tourists on the beaches during the summer season and also abandoned in the sea by commercial and fishing vessels. Also, a considerable amount of waste is brought from the Danube, especially in seasons with heavy rains.

3.9 Impact of noise on coastal ecosystems

The data collected by PERSEUS of 3 study areas Barcelona (WMED), Saronikos Gulf (EMED) and Gelendzhik (BS) were not sufficient to draw conclusions on the level of the pressures and on the impact on the marine ecosystems.

The effort should first focus on the definition and the validation of standard protocols the acquisition of harmonized data making possible the assessment of the noise originating from various sources (geophysical, biological and anthropogenic sounds).

4 – Synthesis analysis on pressures and impacts

The following tables are an attempt to summarize for 4 sub-regions (WMED, Adriatic, EMED, Black Sea) the results of the impact of the coastal pressures which has been studied in PERSEUS. The classification of pressures given in the tables is based on expert judgement.

According to the following table, colour spots are used to scale the intensity of the impact for each class of pressures.

Table 2: Color scale and symbols used for representing pressure levels and trends in the SES

Intensity of impact	
(green circle)	No impact
(yellow circle)	Low impact
(orange circle)	Significant impact
(red circle)	High impact
(blue circle)	Impact not determined
Trend of pressure	
(green arrow)	Decreasing pressure
(grey arrow)	Stable pressure
(red arrow)	Increasing pressure

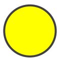
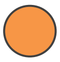
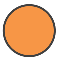
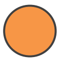
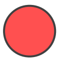
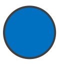
Western Mediterranean

Pressure	Intensity of impact	Trend	MSFD GES descript.	Impacted ecosystem component	Comments
Changes in riverine fluxes	🟡	→	D1, D3, D4, D7	Plankton communities and pelagic food webs	Climate change could severely affect riverine fluxes
Nutrients and organic enrichment	🟡	↘	D4, D5, D6	Plankton communities Benthic habitats including seagrass	Positive effects of WWTP and regulations (WFD, P in detergents) are visible. Local problems subsists due to untreated water discharges and Uncontrolled urban and tourism development may invert the trend
Introduction of contaminants/ hazardous substances	🟠	→	D8, D9	All components of the ecosystems. Top predators are especially contaminated through food web bioamplification process	Concentration decreases are locally observed but effort to be maintained on releases and emission reduction. Attention should be paid to new emerging substances Risk of pollution event due to increasing maritime traffic
Physical damages/loss of habitats	🟠	↗	D1, D6	Coastal benthic habitats	Urbanisation and tourism need to be better controlled in coastal areas Marine Protected Areas and marine spatial planning should be developed.
Extraction of species	🟠	→	D1, D3	Pelagic and benthic fish populations	Need to evaluate more fish stocks and improve taxonomic resolution of landings statistics. Fishery management need to take into account natural variability of ecosystems
NIS	🟠	↗	D1, D2	All biological components (pelagic, benthic)	Ecosystem and services should deal with the installation of tropical species in the whole basin. Impacts might be positive
Litter	🟠	↗	D10	Surface water, sea bottom (including deep sea), beaches	Effort to reduce release at sea required Public awareness need to be increased
Noise	🔵	↗	D11	Marine mammals + ?	Lack of knowledge on impact Straits particularly affected

Adriatic Sea

Pressure	Intensity of impact	Trend	MSFD GES descript.	Impacted ecosystem component	Comments
Changes in riverine fluxes			D1, D3, D4, D7	Plankton communities and pelagic food webs	Climate change could severely affect riverine fluxes
Nutrients and organic enrichment			D4, D5, D6	Plankton communities Benthic habitats including seagrass	Positive effects of WWTP and regulations (WFD, P in detergents) are visible. Local problems subsists due to untreated water discharges and Uncontrolled urban and tourism development may invert the trend
Introduction of contaminants/ hazardous substances			D8, D9	All components of the ecosystems. Top predators are especially contaminated through food web bioamplification process	Concentration decreases are locally observed but effort to be maintained on releases and emission reduction. Attention should be paid to new emerging substances Risk of pollution event due to oil and gas exploitation
Physical damages/loss of habitats			D1, D6	Coastal benthic habitats	Urbanisation and tourism need to be better controlled in coastal areas Marine Protected Areas and marine spatial planning should be developed.
Extraction of species			D1, D3	Pelagic and benthic fish populations	Need to evaluate more fish stocks and improve taxonomic resolution of landings statistics. Fishery management need to take into account natural variability of ecosystems
NIS			D1, D2	All biological components (pelagic, benthic)	Ecosystem and services should deal with the installation of tropical species in the whole basin. Impacts might be positive
Litter			D10	Surface water, sea bottom (including deep sea), beaches	Effort to reduce release at sea required Public awareness need to be increased
Noise			D11	Marine mammals + ?	Lack of knowledge on impact

Eastern Mediterranean

Pressure	Intensity of impact	Trend	MSFD GES descript.	Impacted ecosystem component	Comments
Changes in riverine fluxes			D1, D3, D4, D7	Plankton communities and pelagic food webs	Climate change could severely affect riverine fluxes
Nutrients and organic enrichment			D4, D5, D6	Plankton communities Benthic habitats including seagrass	Positive effects of WWTP and regulations (WFD, P in detergents) are visible. Local problems subsists due to untreated water discharges and Uncontrolled urban and tourism development may invert the trend
Introduction of contaminants/ hazardous substances			D8, D9	All components of the ecosystems. Top predators are especially contaminated through food web bioamplification process	Concentration decreases are locally observed but effort to be maintained on releases and emission reduction. Attention should be paid to new emerging substances Risk of pollution event due to increasing maritime traffic
Physical damages/loss of habitats			D1, D6	Coastal benthic habitats	Urbanisation and tourism need to be better controlled in coastal areas Marine Protected Areas and marine spatial planning should be developed.
Extraction of species			D1, D3	Pelagic and benthic fish populations	Need to evaluate more fish stocks and improve taxonomic resolution of landings statistics. Fishery management need to take into account natural variability of ecosystems
NIS			D1, D2	All biological components (pelagic, benthic)	Ecosystem and services should deal with the installation of tropical species in the whole basin. Impacts might be positive
Litter			D10	Surface water, sea bottom (including deep sea), beaches	Effort to reduce release at sea required Public awareness need to be increased
Noise			D11	Marine mammals + ?	Lack of knowledge on impact Straits particularly affected

Black Sea

Pressure	Intensity of impact	Trend	MSFD GES descript.	Impacted ecosystem component	Comments
Changes in riverine fluxes			D1, D3, D4, D7	Plankton communities and pelagic food webs	Climate change could severely affect riverine fluxes
Nutrients and organic enrichment			D4, D5, D6	Plankton communities Benthic habitats including seagrass	Positive effects of WWTP and regulations (WFD, P in detergents) are visible. Local problems subsists due to untreated water discharges and Uncontrolled urban and tourism development may invert the trend
Introduction of contaminants/ hazardous substances			D8, D9	All components of the ecosystems. Top predators are especially contaminated through food web bioamplification process	Concentration decreases are locally observed but effort to be maintained on releases and emission reduction. Attention should be paid to new emerging substances Risk of pollution event due to increasing maritime traffic and oil and gas industry
Physical damages/loss of habitats			D1, D6	Coastal benthic habitats	Urbanisation and tourism need to be better controlled in coastal areas Marine Protected Areas and marine spatial planning should be developed.
Extraction of species			D1, D3	Pelagic and benthic fish populations	Need to evaluate more fish stocks and improve taxonomic resolution of landings statistics. Fishery management need to take into account natural variability of ecosystems
NIS			D1, D2	All biological components (pelagic, benthic)	BS ecosystems has shown signs of recovery for several years, after a period of some fish stock collapse and massive invasive jellyfish blooms
Litter			D10	Surface water, sea bottom (including deep sea), beaches	Effort to reduce release at sea required Public awareness need to be increased
Noise			D11	Marine mammals + ?	Lack of knowledge on impact Straits particularly affected

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POLICY-ORIENTED MAPINE
ENVIRONMENTAL RESEARCH IN
THE SOUTHERN EUROPEAN SEAS