Pressures, processes and impacts on SES open waters ecosystems - Gap Analysis on data and knowledge

Deliverable Nr. 1.1

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CONTENTS

ANNEXES

21. Report of Alien Species Invasion into the Black Sea
22. Increase in Findings of Mediterranean Non-native Species in the Black Sea
23. Data integration and marine eco-regionalisation of the Mediterranean Sea

EXECUTIVE SUMMARY / ABSTRACT

Southern European Seas are analyzed for gaps on data and knowledge related to a list of key processes, pressures, and impacts. The Mediterranean Sea's hydro-meteorological variability is well-described using a combination of existing data bases and models; the availability and update of long time-series is stressed. The strait of Gibraltar and the Turkish straits are complex, extremely dynamic systems which were studied and modeled in past years. However, the biogeochemistry of the straits is still poorly understood. Targeted studies are required to gain knowledge on elemental fluxes, and their impact on biota; pollution appears to be an significant issue for the Turkish straits system. Maritime transport for SES poses threats to the environments due to accidental oil spills, and the invasion of alien species. Data availability is generally good, but completely lacking for marine litter and noise. Atmospheric inputs of N, P, and pollutants and the associated deposition processes have been recently studied, but there is a clear gap in the estimates of fluxes to the sea. Absence of data is more evident for the Black Sea. Fisheries in the Mediterranean are backed-up by 50-year-long time series, which demonstrate a decline of the mean trophic level of the Mediterranean, many commercial species exhibiting over-exploitation. Catches in the Black Sea are poorly documented; however substantial changes in the late 1980's have been recorded, as well as a transition to pelagic species dominance. Invasive alien species number almost 1000 in SES, but the Eastern Mediterranean is impacted more heavily. It is noteworthy that some IAS species are under exploitation. MSFD descriptors 1-8 and 10-11 are addressed to some extent in the reviews, with biodiversity (D1) attracting more interest. Overall, lack of data and long time series, and in many cases poorly constrained processes are the major gaps identified. Focused experiments within PERSEUS will contribute towards the improvement of the current situation.

SCOPE

PERSEUS Deliverable 1.1 addresses the description of South European Seas (SES) ecosystem state in respect to natural and human pressures. It comprises extensive reviews of five sub-tasks, which cover key-issues related to ecosystem components. The sixth sub-task is in a preparatory state, as reporting is scheduled for T32. The following synthesis constitutes an extended summary of the reviews, together with comments on the Marine Strategy Framework Directive (MSFD) Descriptors and/or indicators addressed, followed by the full versions of all reviews/contributions. Gaps in data and knowledge are identified in order to better-orient field studies within PERSEUS, as well as monitoring programs and future research. The structure of the Deliverable is a simple matrix of sub-tasks vs. regional seas, i.e. the Mediterranean and the Black Seas. D1.1 will be used by all partners engaged in field work in order to justify experiments planned, whereas the official approval will given during the forthcoming 'Umbrella Workshop'. Furthermore, D1.1 will contribute to the progress of WP5- Basin-wide promotion of MSFD principles and WP6- Adaptive policies and scenarios.

PRESSURES, PROCESSES AND IMPACTS ON SES OPEN WATERS ECOSYSTEMS - GAP ANALYSIS ON DATA AND KNOWLEDGE

WP1: Pressures and Impacts at Basin and Sub-basin Scale

Task 1.1: Analysis of pressures and processes and their impact on the ecosystems

Responsible: HCMR

Mediterranean Sea: brief description

The Mediterranean Sea is a semi-enclosed and evaporative ocean basin in which a wide range of oceanic processes and interactions of regional and global interest occur. It is connected to the Atlantic Ocean by the shallow Strait of Gibraltar and is composed of two basins of similar size, i.e. the Western and the Eastern Mediterranean Seas, separated by the shallow and narrow Strait of Sicily (Fig. 1). To the northeast it is also connected to the Black Sea through the Bosphorus channel. In the Strait of Gibraltar, at the surface, the comparatively fresher Atlantic water flows into the Mediterranean Sea to replace both the evaporated water and the denser, saltier Mediterranean water flowing out at depth into the Atlantic. Deep Mediterranean water is produced at different locations by intense air-sea interactions: in the Gulf of Lions (western Mediterranean), the Southern Adriatic, the northeast Levantine basin and the Aegean Sea in the eastern Mediterranean. The salty and dense outflow from the Mediterranean maintains a higher salinity in the North Atlantic than in the Pacific Ocean and may trigger the formation of North Atlantic deep water. The basin's circulation is characterized by the presence of sub-basin gyres, intense mesoscale variability and a strong seasonal signal. Interannual variability is also observed and most of it is directly related to interannual variability of atmospheric forcing. Moreover, it is characterized by extremely complex coastlines and topographical features, such as the Alpine, Apennine, Pyrenees and Balkan mountain chains, the Italian and Hellenic peninsulas and large islands.

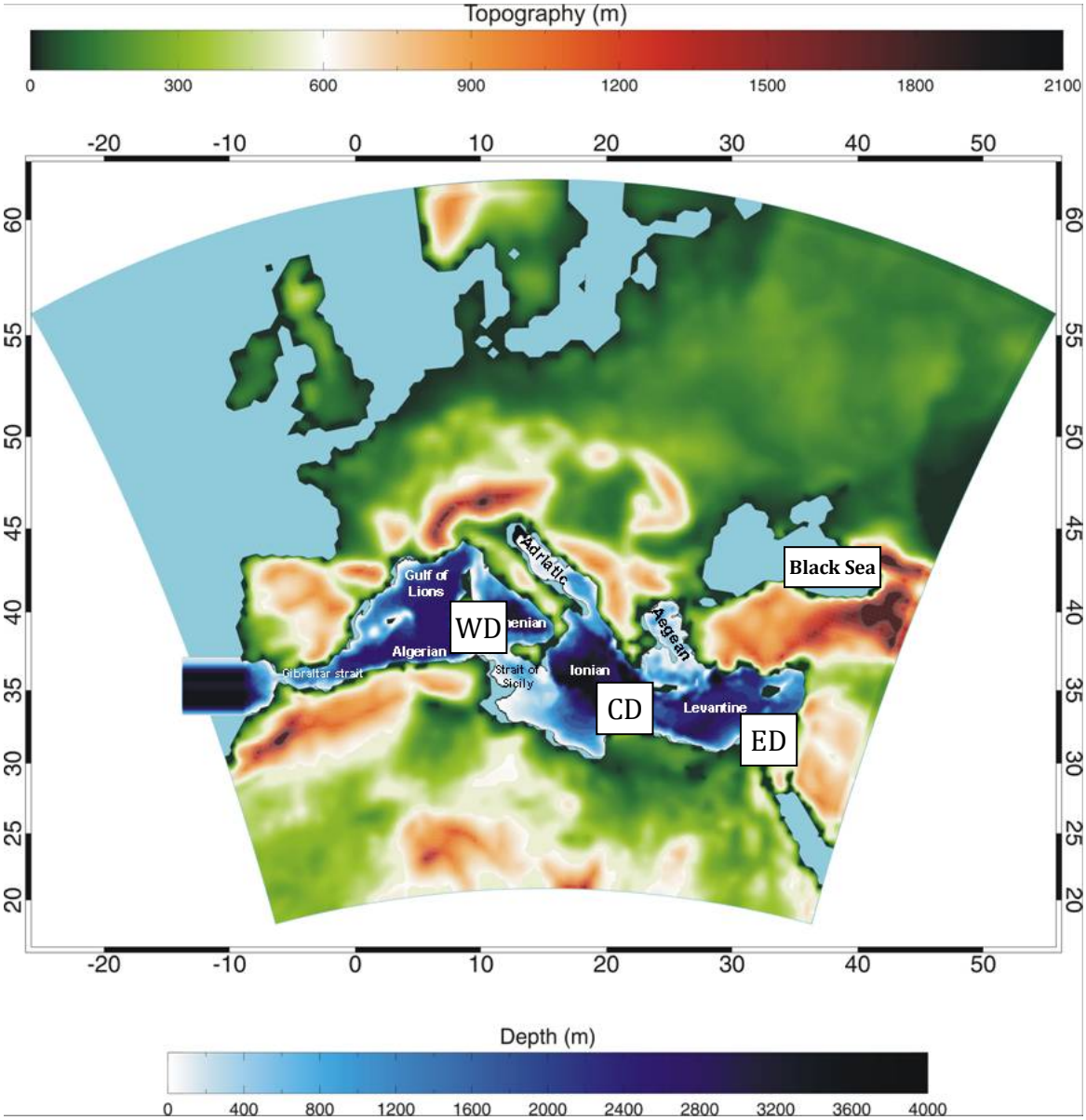

Figure 1. The Mediterranean Sea: topography and bathymetry. WD Western Mediterranean, CD Eastern Mediterranean, ED Eastern Mediterranean

Black Sea: brief description

The Black Sea (Fig. 2) is the most isolated sea in the World. It is connected to the World Oceans via the Mediterranean Sea through the Bosphorus, Dardanelle and Gibraltar straits and with the Sea of Azov in the northeast through the Kerch Strait. Due to a large catchment area compared to surface area the Black Sea is very vulnerable to pressure from land based human activity and its health is equally dependent from the coastal and non-coastal states of its basin. Eutrophication, pollution, and irresponsible fishing resulted in an overall decline of biological resources, the diversity of species and of the recreational values of the Black Sea.

The Black Sea has become a focus of research due to potential adverse effects of contaminated urban, industrial, and agricultural runoffs to the ecosystem. Over the last three decades, increased human activities have consequently increased the

inorganic nitrogen and phosphorus inputs to the Black Sea. Rivers and atmospheric deposition are expected to be the most important external sources of pollutants and nutrients to the Black Sea, however, their relative contribution has been poorly assessed.

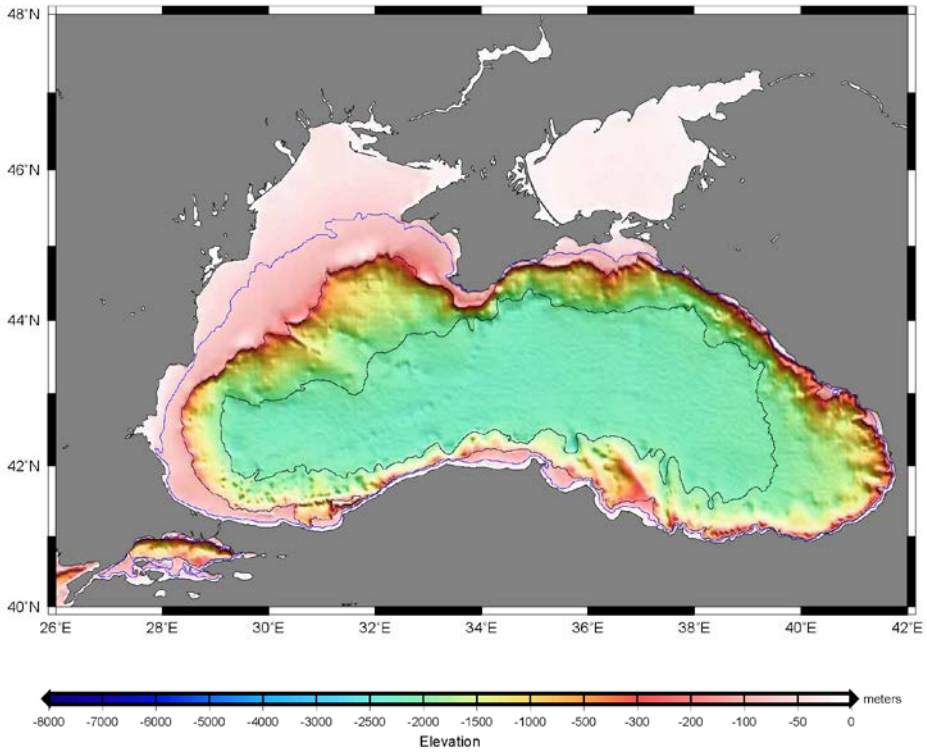

Figure 2. The Black Sea: bathymetry

Subtask 1.1.1. Hydro-meteorological variability

Responsible: ENEA

Participants: MHI

This subtask will provide detailed evaluation of variability of the physical parameters linked to ecosystem characterization. Parameters related to the hydrological cycle, water, heat and momentum fluxes for the Mediterranean and the Black Sea will be evaluated based upon observational data sets and coupled model simulations so as to provide an up-to-date information baseline.

Mediterranean Sea

Different sources of available information were used to determine the variability of the physical parameters linked to ecosystem characterization for the Mediterranean Sea covering the period 1961-2000. Gridded observational datasets and ocean-atmosphere coupled simulations were utilized in reproducing parameters related to the hydrological cycle, water, heat and momentum fluxes for the Mediterranean Sea. A high resolution coupled Atmosphere-Ocean Regional Climate Model (AORCM)

framework is an optimal tool providing accurate reconstruction of past, present climate as well as consistent future projections. The PROTHEUS system is composed of the RegCM3 atmospheric regional model and the MITgcm ocean model. This setup of existing information and modeling can help in quantifying the pressure and impacts relevant for the MSFD.

Descriptor 1: Biological diversity is maintained. Indicator: Hydrological condition (incl. water movement, temperature, salinity, clarity)

Data availability: high

Oceanic temperature and salinity

The marine habitat condition can be heavily affected by the oceanic currents, water temperature and salinity. Considering temperature averaged over the entire depth in the entire Mediterranean basin a clear trend is observed. This trend is observed below 600 m, reaching 0.009 °C year^{-1} between 1,000 and 2,000 m and 0.005 °C year^{-1} in the deepest layers, in the Western, Central, and Eastern Mediterranean. These values are higher than previous estimates.

Major water masses were identified in climatological vertical profiles of salinity. The Levantine Intermediate Water (LIW) layer in the Central and in the Eastern basin is well identified by the salinity maximum between 200 and 700 m, which in the EM exceeds 38.95.

Simulations show that there is a vertical homogenization of the water column, principally due to low SST, and high SSS in the EM, that gives rise to an enhancement of deep convection. However in the simulations taken into exam over the Adriatic basin a positive bias in salinity for the entire water column is observed that can affect the representation of deep circulation in the whole Central Mediterranean.

Descriptor 7: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems. Indicator: Extent of area affected by permanent alterations

Data availability: high

Water budget

The knowledge of the total freshwater budget of the Mediterranean basin, together with the behavior of the single components, is necessary to measure the changes in the hydrographical conditions of Mediterranean basin.

The temporal behavior of Water Budget integrated over the whole Mediterranean basin does not shows a clear trend over the period 1961-2000 even if we can identify two local maximum of freshwater loss, during late 80s and 90s, well defined in observational datasets as well as in numerical simulations. However, for some components of the water budget (i.e. river runoff and Black Sea inflow) only some estimates have been presented in the scientific literature.

Descriptor 8: Concentrations of contaminants are at levels not giving rise to pollution effects.

Surface momentum fluxes

The momentum fluxes (wind forcing) drive the transfer of mechanic energy between the atmosphere and the sea, driving the dynamic of the surface marine mixed layer. The three-dimensional oceanic currents can affect on the concentrations of contaminants. In WM the atmospheric forcing causes an eastward prevailing zonal surface current, stronger in the 1960s and the late 1970s. The meridional wind stress is mainly southward, with a maximum in the 1980s. In CM the zonal wind stress experiences a strong positive trend in the 1990s after a relative minimum at the end of 1980s. Over the considered sub-basin the zonal stress is positive, implying a prevailing eastward surface current. Also in this region the meridional component is on average negative (southward circulation), with a well detectable trend over stronger values. In EM the zonal stress is overall positive, while the meridional stresses are negative. The discrepancies observed between observations and model estimates can be attributed to the complex orography of the Aegean region due to the presence of several small islands that can be modify surface wind fields. The regional model needs a higher horizontal resolution to correctly reproduce those small scale features. Similar discrepancies were also observed over the Adriatic sub-basin.

Subtask 1.1.2. Exchange fluxes at straits

Responsible: METU

Participants: CSIC

Inter-basin exchange and mixing processes, strait pumps operating at the Atlantic-Mediterranean (Gibraltar Strait) and the Mediterranean-Black Sea (Turkish Straits System) transitions will be reviewed and evaluated to update existing information on the exchanges.

Strait of Gibraltar

The Strait of Gibraltar is the only dynamically relevant connection of the Mediterranean Sea with the World's Ocean. It is a narrow and shallow channel with an east–west orientation that possesses a minimum width of 14 km on the Tarifa Narrows (Fig. 3) and an average depth of about 600 m. Thirteen kilometers westward of the Tarifa Narrows lies the main bathymetric sill of the Strait, the Camarinal sill (CS), with a maximum depth of about 285 m. A second sill, the Espartel sill (ES) is situated 21 km west of the former and has a maximum depth of 358 m. The circulation in the Strait has been classically described as a two-layer system: a surface eastward Atlantic water inflow (AI) and a deep westward outflow of saltier (and denser) Mediterranean water (MOW).

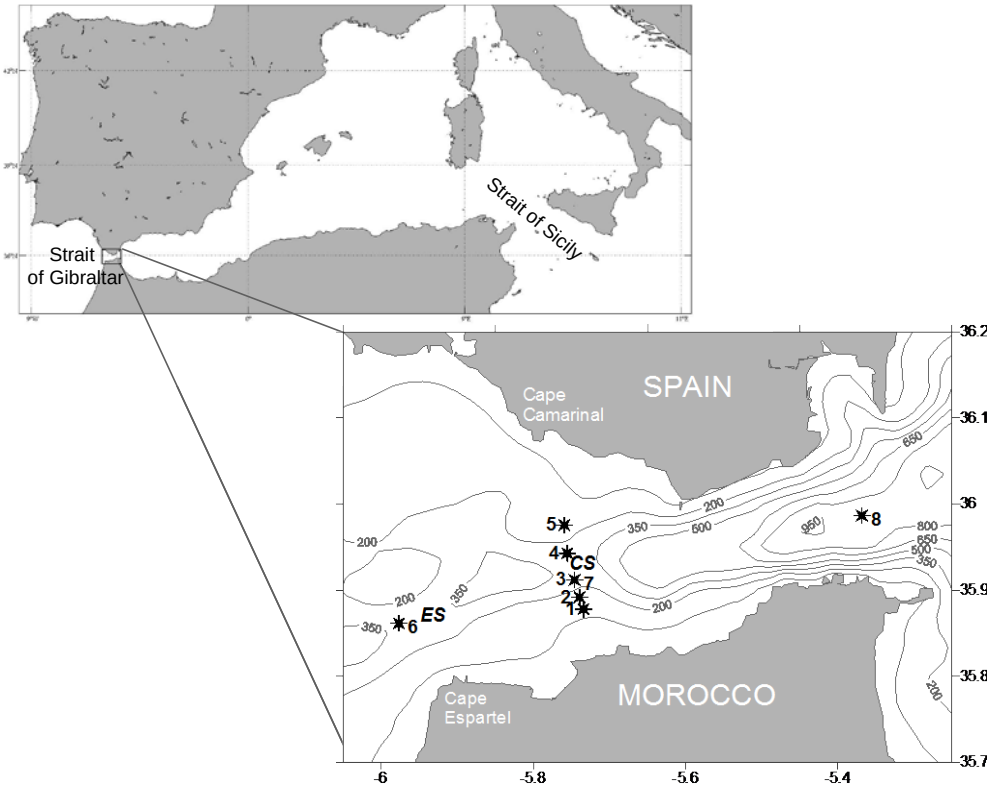

Figure 3. Location and bathymetry of the Strait of Gibraltar. CS and ES indicate the location of the sills of Camarinal and Espartel, respectively.

The inverse estuarine exchange can be approximated as a two-layer system with mean net transport of ~0.038±0.007 Sv (Sverdrups, 1 Sv=10^6 m^3 s^{-1}), equivalent to a net evaporation of 0.6 m y^{-1} in the Mediterranean, and where the AI transport is positive and the MOW transport negative. The complexity of the water circulation in the Strait of Gibraltar, particularly the strong tidal variability, complicates the assessments of the water fluxes through the channel, and the concomitant computation of exchange of substances. The import of different compounds, such as hydrocarbons, organic matter or anthropogenic CO_2, from the Atlantic to the Mediterranean has been well documented. In contrast, a reverse export of substances including alkalinity, inorganic carbon, and nutrients has been reported.

The exchange of waters carrying different concentration of substances through the Strait of Gibraltar has been regarded as the ultimate cause for the oligotrophy of the Mediterranean. It is traditionally assumed that the eastward flow of Atlantic nutrient-poor surface waters is compensated by the deep counter-current of Mediterranean nutrient-rich waters. Particularly, the ultra-oligotrophic conditions of the Eastern Mediterranean due to phosphate scarcity have been linked to the circulation patterns present in the straits of Sicily and Gibraltar. At the biogeochemical level, the main gap in the area deals with the transport of nutrients that takes place between the Mediterranean Sea and the Atlantic Ocean. Considering the eutrophication conditions expected to occur in certain areas of the Mediterranean as a consequence of global change, it is essential to accurately quantify the nutrient flux in the area. This knowledge will help to forecast the response of the whole basin to future human induced ecosystem perturbations.

The main descriptors affected by the exchange fluxes at the Strait of Gibraltar are the following:

Descriptor 1: Biological diversity is maintained. The biodiversity at both sides of the Strait is directly affected by the exchange fluxes.

Data availability: none to high

The occurrence of habitats depends of the unique hydrographic conditions that develop in the area, with their wide scales of variability (both temporal and spatial), that are tightly connected to the exchange between the Atlantic and Mediterranean waters.

Descriptor 3: Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

Data availability: none to medium

This descriptor is certainly affected as the main fishery in both adjacent sub-basins is the anchovy stock, whose nursery areas are environmentally controlled by the inter-basin exchange fluxes through the Strait of Gibraltar.

Descriptor 5: Human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.

Data availability: low to high

This descriptor is affected due to the biogeochemical fluxes that occur between the North Atlantic and the Mediterranean in the area. In fact, the Strait plays a fundamental role on the biogeochemistry of the Mediterranean due to the exchange of variables such as macronutrients or anthropogenic carbon.

Turkish Straits System

The Turkish Straits System (TSS) is a relatively small inland sea, like a large channel system, connecting the Black Sea to the Mediterranean Sea (Fig. 4). Thus it has a two-layer exchange flows carrying the Black Sea brackish waters to the Aegean basin of NE Mediterranean via surface lows in the Istanbul (Bosphorus) and Çanakkale (Dardanelles) Straits and the Sea of Marmara whilst the salty waters of Mediterranean flows into the Black Sea deep basin through the TSS undercurrents. Therefore, this channel system is of vital importance for both the Black Sea and Mediterranean Sea having distinctly different ecological properties. Two-layer flows established in the TSS have lead to the formation of distinct ecosystems in the TSS, Black Sea and NE Aegean Sea basin. The upper layer ecosystem of TSS is dominated by the Black Sea inflow. However, the increased population and industrial activities on the coastal zone of the Marmara Sea has introduced ample amount of inorganic and organic pollutants to the TSS after the 1960's.

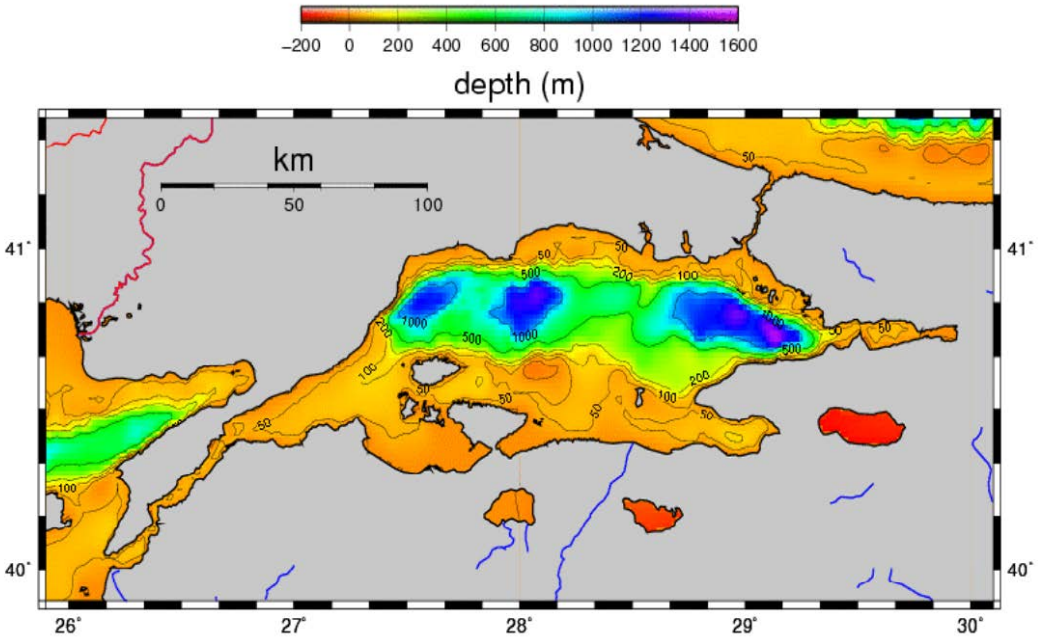

Figure 4. Location and bathymetry of the Marmara Sea.

No decadal trend has been observed in fresh water input to the Black Sea in recent decades and thus in the volume fluxes exchanged via the TSS. However, the increased loads of nutrients have significantly enhanced the total nutrient stocks in the

Marmara upper and lower layers. Limited chemical data in literature indicate important increases in the nutrient and organic matter loads exchanged in the TSS after the 1960's as well as the N/P/Si ratios in the exchanging waters through the TSS. Large amounts of organic matter, DIN and phosphorus have been introduced from the Black Sea to the TSS and NE Aegean basin as the Si load of the Black Sea surface flow has declined drastically. These changes in the chemical fluxes have naturally altered the nutrient ratios in the upper flow. These dramatic changes expectedly have modified dominant phytoplankton species in the TSS and adjacent seas; the chlorophyll *a* concentrations in the Marmara basin are 2-4 times higher than the Istanbul Strait. The increased loads of nutrients from the Black Sea into the Marmara and the NE Aegean Sea are dominated by dissolved and particulate forms of organic nutrients, exhibiting remarkable seasonal variations. Therefore, new systematic data sets from the upper layer of the Straits are needed to assess the impacts of different forms of N, P inputs to the target seas.

Primary production in the Sea of Marmara is controlled by the diatom and dinoflagellate blooms during the winter-spring and summer-late summer periods, respectively. Total primary production is equivalent to about 1.2 million tons of organic carbon, of which about 20-25% sinks down to the lower layer waters below the steep halocline and its major fraction (85-90%) is decomposed by aerobic bacteria in the water column and sediment-water interface, leading to the formation of suboxic/hypoxic conditions in the lower layer waters.

In the past, the Sea of Marmara provided a good income for fishery with up to 50 thousand tons of fish catch values annually. Due to two layer structure, there are at least two different groups of marine organisms in the water column in the Sea of Marmara. Long-term shoaling of the oxycline to the halocline depth has confined the oxygenated habitat of pelagic fish community, migrating fishes. Development of suboxic conditions in the lower layer has created a pressure on the demersal and benthic organisms and their habitats.

The descriptors affected by the exchange fluxes at the Turkish Straits System include the entire range of the eleven descriptors. Data availability is, as expected, highly variable, from none to high. Based on the gaps identified, the following issues have been suggested as priority axes for future research:

- The interactions between the Black Sea, Marmara and Aegean Sea need to be investigated as a long term study.
- Climate change and sea level rise issue also needs to be monitor.
- Alien species, their distribution and various impacts on marine life, human health, fisheries and tourism need to be further investigated.
- Commercial and non commercial fish stocks and their sustainable use need to be determined.
- Distribution, stranding and by-catch of marine mammals need to be investigated.
- Various pollution loads from the Black Sea to the Marmara Sea and vice versa also need to be investigated.

- Emissions of contaminants by ships also need to be monitored due to chemical composition of aerosol from ships is unknown can pose a threat to human health.
- A special mussel watch programme is needed for the monitoring of heavy metals and accumulation of the contaminants in mussels.

Subtask 1.1.3. Pollution from maritime transport and other activities

Responsible: UoP

Participants : HCMR

Identification of pressure patterns will be made and potential pollution effects related to oil spills due to shipping activities will be reviewed in the Black and in the Mediterranean Seas to provide an updated baseline on the pollutant effects arising from maritime transport.

Mediterranean Sea

The Mediterranean Sea is subjected to pollution by land- and sea-based sources. Pollution from land derives from urban, industrial and agricultural activities while the intense maritime traffic activities in the region are the major source of sea-based pollution. The semi enclosed Mediterranean Sea is particularly vulnerable to shipping associated impacts due to high-volume of shipping routes, long history of use, and sensitive shallow and deep-sea habitats. Here we present an updated overview of pressures and impacts by maritime traffic in the Mediterranean Sea with reference to their relevance to the Marine Strategy Framework Directive (MSFD) descriptors of Good Environmental Status (GES).

The Mediterranean Sea is amongst the world's busiest areas for maritime activity accounting for 15 per cent of global shipping activity by number of calls and 10 per cent by vessel deadweight tonnes (DWT). Vessel activity in the Mediterranean has been rising steadily over the last years; port callings in the Mediterranean have increased by 14 per cent and transits by 20 per cent between 1997 and 2006. There are 480 ports and terminals in the Mediterranean with recorded ship movements. Around 20 per cent of Mediterranean ports are in the Eastern Mediterranean east of Greece, compared with 80 per cent in the West and Central Mediterranean.

The Mediterranean Sea is the major route for transportation of crude oil from the oil fields in the Middle East and North Africa, and oil ports in the Black Sea towards the major consumption centres in Europe and also in North America. Approximately 18 per cent of global seaborne crude oil shipments take place within or through the Mediterranean. It is estimated that around 360 million tons of oil and refined products are transported along the Mediterranean Sea every year. The total oil input from ships into the Mediterranean Sea is estimated in the range of 100,000 – 150,000 tons/year. Cargo ships, fishing boats, leisure craft and naval vessels also contribute to operational pollution, though it is estimated that three-quarters of the shipping-derived petroleum hydrocarbons in the Mediterranean Sea result from the transport of crude oil and its refined products. Between 1977 and 2003, 470 accidents were recorded in the Mediterranean Sea, 376 of which involved oil, resulting in 304,700 tons of oil input into the Mediterranean Sea (Fig. 5). Some of the major accidental oil spills (> 5,000 tons) in the Mediterrannean Sea since 1970 are among the ten largest spills recorded worldwide. Although the number of accidents appears to increase since 1977, no major accidents occurred in the region since 1991.

Petroleum is a complex mixture of thousands of compounds, in which various hydrocarbons are the most abundant classes, usually accounting for >75% of the total oil composition. Monocyclic aromatic hydrocarbons (benzene, toluene, phenols), but particularly polycyclic aromatic hydrocarbons (PAHs), are possibly the contaminants

that have the most serious long-term environmental effects in water, sediment, and biota. Oil discharges from ships may result in the formation of tar. As the specific gravity of the tar is usually lower than that of seawater it normally floats on the surface and drifts by winds and currents eventually reaching the shoreline.

Ambient underwater noise levels have increased in the past 50 years mostly due to shipping activities. Over the past few decades the shipping contribution to ambient noise has increased by as much as 12 dB, coincident with a significant increase in the number, size and speeds of merchant ships. There appears to be a general lack of information on direct physical effects of vessels, namely anchoring, abrasion by ship hulls in shallow waters, propeller scarring, groundings, and disturbance of soft sediment bottoms during navigation, and shading. Air emissions from the maritime transport sector account for a significant portion of total emissions, affecting air quality and contributing to climate change and human health problems. Ship emissions to the atmosphere comprise ozone and aerosol precursors such as NOx, CO, volatile organic compounds (VOCs), SO_2 and the emissions of greenhouse gases.

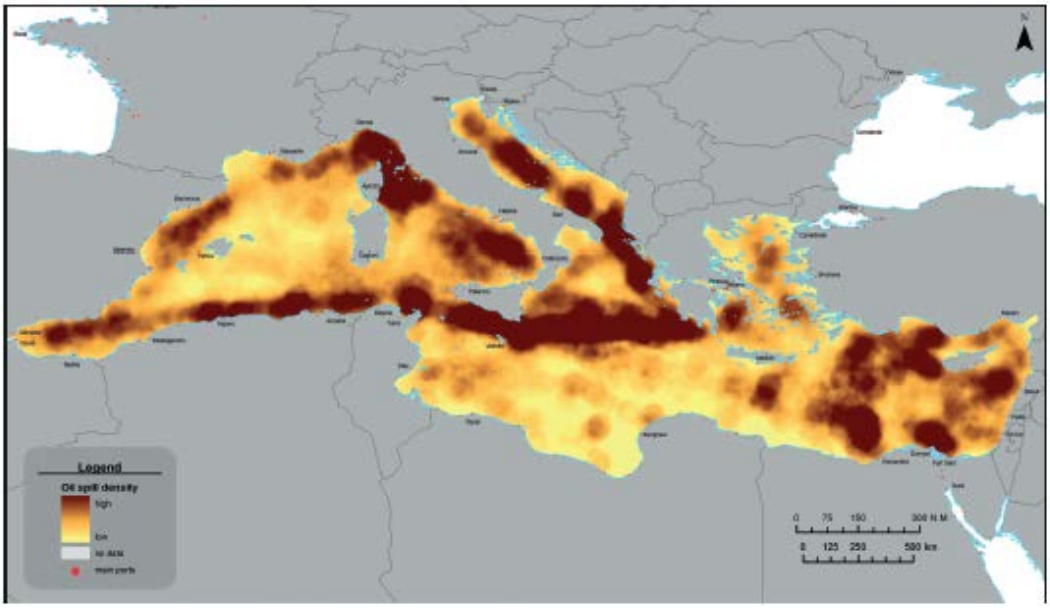

Figure 5. Oil spill density in the Mediterranean Sea for the period 1999-2004.

The intense shipping traffic in the Mediterranean Sea contributes to various threats to Mediterranean ecosystems including oil pollution and pollution by other hazardous chemicals such as antifouling biocides, marine litter, and introduction of alien species, physical impacts on biota and habitats, and noise pollution that are addressed by the MSFD. The most relevant MSFD descriptors of GES to maritime traffic impacts are D2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem, D8: Concentrations of contaminants are at levels not giving rise to pollution effects, D10: Properties and quantities of marine litter do not cause harm to the coastal and marine environment, and D11:Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

There is lot of information in the Mediterranean Sea on petroleum-related hydrocarbons (PAHs) and alien species introduction by shipping, limited data on

marine litter, while data on physical impacts of ships i.e. by anchoring, collisions etc and shipping noise pollution is very scarce. Overall, the majority of data with the exception of alien species introduction, concerns the North-western part of the Mediterranean Sea, while data in the Eastern-southern part is limited.

Black Sea

Most commonly associated with ship pollution are oil spills. While less frequent than the pollution that occurs from daily operations, oil spills have devastating effects. While being toxic to marine life, polycyclic aromatic hydrocarbons (PAHs), the components in crude oil, are very difficult to clean up, and last for years in the sediment and marine environment. Marine species constantly exposed to PAHs can exhibit developmental problems, susceptibility to disease, and abnormal reproductive cycles

For the years 2000, 2001, 2002 and 2004 approximately 1227 possible spills have been detected by remote sensing techniques. The analysis revealed an evident concentration of oil spills along the main maritime routes: Bosporus Strait–Odessa, Bosporus Strait–Novorossiysk and Bosporus Strait–Azov Sea (Fig. 6). Moreover a concentration of oil spills was detected in the area north of the Bosporus Strait and in the Marmora Sea.

More than 170 million people live in the Black Sea basin, and the sewage of 17 countries flows directly into the sea coastal waters without any prior rectification. The basic sources of the sea chemical contamination are large industrial cities, ports and also ships.

The emissions from ships engaged in international trade in the seas surrounding Europe - the Baltic, the North Sea, the north-eastern part of the Atlantic, the Mediterranean and the Black Sea - were estimated to have been 2.3 million tons of sulphur dioxide and 3.3 million tons of nitrogen oxides a year in 2000.

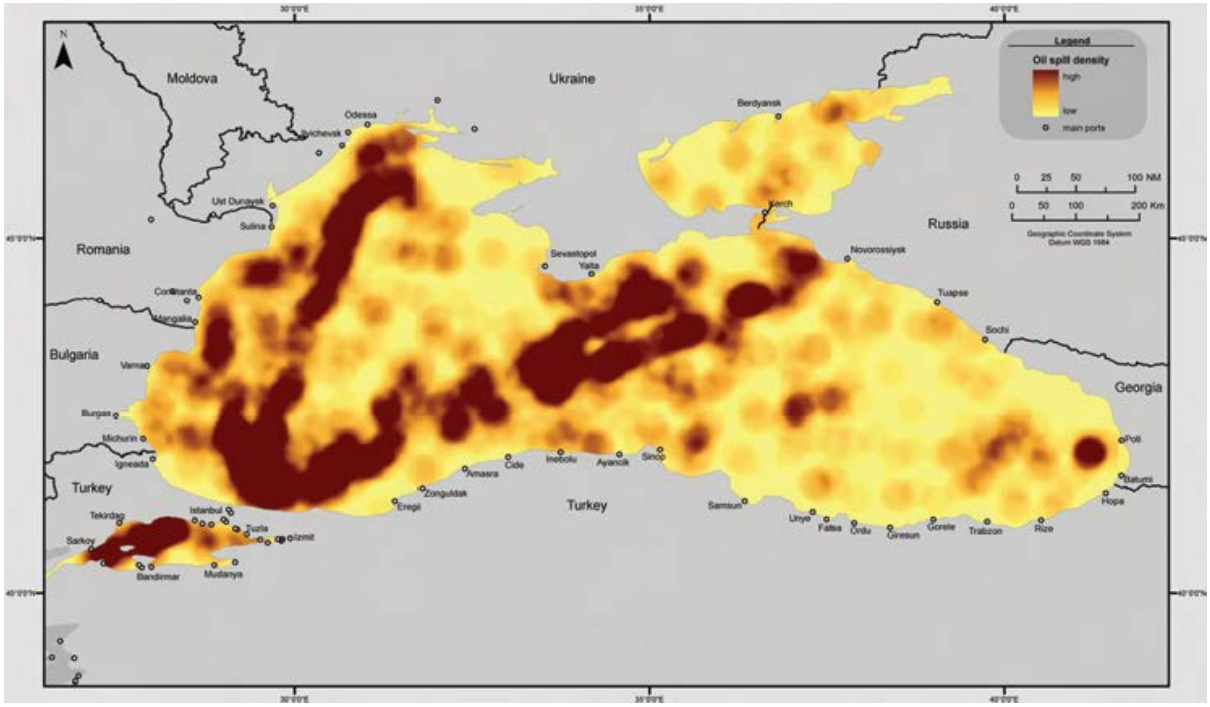

Figure 6. Oil spill density for the Black Sea for the years 2000, 2001, 2002 and 2004.

Several programmes have been set up to monitor and co-ordinate efforts in the Black Sea in the recent past. Unfortunately they seem to either "morph" into other initiatives or disappear completely. Instead of concentrating the data in one place they seem to be diluting the efforts and making it more difficult to answer simple straight forward questions such as "How much has the ship driven pollution changed (increased OR decreased) in the last 20/10/5/2/years?"

The plane answer is that we simply don't know. Ship generated pollution is decreasing for several reasons:

-Less ships and stricter controls on pollution and waste disposal. The amount of ships transiting the Istanbul Strait has decreased

-The Ministry of Transportation, Maritime Affairs and Communications provided the statistics on Ship traffic at Turkish States for the year of 2010. The number of the ships that passed through Istanbul Strait is 50,871; it has reduced by 1.1% when compared to the previous year's (2009) figures, which was 51,422.

The simple explanation for this is an increase in the gross tonnages of the ships involved.

Subtask 1.1.4. Atmospheric inputs

Responsible: UoC

Participants: IOLR, METU

Review the spatial and temporal variability of pollutants and nutrients (e.g N, P, trace metals etc.) for the Eastern and Western Mediterranean Seas, and the Black Sea, including ship emissions of gases (NOx and SOx), so as to provide a synthesis on atmospheric inputs.

Mediterranean Sea

The Mediterranean Sea has one of the most oligotrophic surface wasters in the world with Low Nutrient (dissolved inorganic nitrogen and phosphorous, DIN, DIP) and low chlorophyll. The average annual productivity (60–80 g C m^{-2} y^{-1}) in the Mediterranean Sea is half of the amount observed in the ultra-oligotrophic Sargasso Sea. The deep water of the East Mediterranean Sea has a uniquely high DIN/DIP ratio raging from 25 to 28, compared to the Western Mediterranean (22) and the "normal" oceanic Redfield ratio of 16. Studies have revealed the impact of inputs through atmospheric route on marine productivity, substantial fluxes of atmospheric macro and micro nutrients and even their dominance in some cases. These substances include mineral dust, plant residues, heavy metals, nitrogen species from combustion processes and a wide range of synthetic organic compounds from industrial and domestic sources.

The Mediterranean has one of the highest fluxes of aeolian dust because of its close proximity to the Sahara desert. Atmospheric inputs are an important source of nutrients (N and P) to the eastern basin in particular. Indeed the primary inputs of N and P to the eastern basin are from atmospheric deposition, accounting for 60–70% of the bioavailable N and 30–50% of the bioavailable P, of which dust is a major source. Atmospheric DIN input to the Western Mediterranean is of the same order of magnitude with riverine input, while in the Eastern Basin the deposition of DIN represents on average 60 to 70% of new production mainly via dry deposition.

The atmospheric deposition of metals over the whole Mediterranean is very poorly constrained and hinders a clear assessment of the extent to which atmospheric elements of various anthropogenic and natural origins affect its biogeochemistry. Available data show poor spatial representation, as most of the deposition data refer to the northwestern zone. Additionally, only a few present total deposition; also some data represent only one mode of deposition, either wet or dry, or only the dissolved fraction. In the case of total deposition, the large uncertainties in deposition velocities lead to poorly constrained fluxes. The representativeness of the fluxes to the open Mediterranean is also questionable as several data sets were obtained at sites which are under strong local influence of anthropogenic sources. Moreover, for elements whose fluxes have drastically changed following regulation (such as Pb), it is difficult to compare present values with the fluxes obtained more than ten years ago. By comparing atmospheric deposition fluxes of metals with data from sediment trap collectors, the significant role of the atmosphere as an external source of major and trace metals to the southern Black Sea has been demonstrated.

To address all those gaps an aerosol sampling network on existing stations will be used for the assessment of atmospheric fluxes (nutrients and metals) and related atmospheric and aerosol-seawater interaction processes. Finally, the role of

atmospheric deposition to the marine ecosystem will be simulated with a high resolution model, which is going to be improved by combining those field data.

MSFD descriptors affected by atmospheric deposition processes are D1, D5, and D8, where data availability is none to low.

Black Sea

The Black Sea is the most isolated sea in the World. It is connected to the World Oceans via the Mediterranean Sea through the Bosphorus, Dardanelle and Gibraltar straits and with the Sea of Azov in the northeast through the Kerch Strait. Due to a large catchment area compared to surface area the Black Sea is very vulnerable to pressure from land based human activity and its health is equally dependent from the coastal and non-coastal states of its basin. Eutrophication, pollution, and irresponsible fishing resulted in an overall decline of biological resources, the diversity of species and of the recreational values of the Black Sea. Over the last three decades, increased human activities have consequently increased the inorganic nitrogen and phosphorus inputs to the Black Sea. Rivers and atmospheric deposition are expected to be the most important external sources of pollutants and nutrients to the Black Sea however their relative contribution has been poorly assessed.

Concerning nutrients in the Black Sea, the majority of the studies focused on the role of rivers, whilst little attention was given to the role of atmospheric deposition, since there is absence of recent research on the atmospheric input of nutrients.

Atmospheric deposition of nutrients and metals is poorly known in the Black Sea. The proposed aerosol sampling network intends to cover that gap, in concert with aerosol measurements during the scheduled Black Sea EXperiment (BSex cruise).

Subtask 1.1.5. Biological pressures (fisheries and non-indigenous species)

Responsible: HCMR

Participants: CSIC, IEO, SIO-RAS, IO-BAS, METU

Existing data and information on overfishing, fishing down the food webs, by-catches and discards, and migratory species as well as trends of non-indigenous species and their environmental impact, in the Western and the Eastern Mediterranean Seas, Turkish Straits and Black Sea will be reviewed and then combined to provide a synthesis of biological pressures.

Mediterranean Sea-Fisheries

The Mediterranean Sea is a low productivity ecosystem, and certain parameters such as nutrient levels and chlorophyll concentrations decrease from west to east and from north to south. Phosphorous, rather than nitrogen, is the limiting nutrient. The highest levels of productivity occur along the coasts, near population centres and at river estuaries. The Mediterranean exhibits some of the most extreme oligotrophic waters in the world which has also a direct impact on fisheries productivity. In recent decades the Mediterranean ecosystems have been altered in many ways due to overexploitation of biological resources, direct habitat modification, introduction of exotic species, pollution and climate change. In relation to fisheries, the development of fishing technologies and the intense fishing effort aiming to meet increasing demands for fishery products is placing exhaustive pressure on resources, having both direct and indirect interactions with the different ecosystem components, thus affecting ecosystem structure and function. The mean trophic level of Mediterranean catches declined by about one trophic level during the last 50 years. As over-fishing reduces the populations of more valuable larger fish from higher trophic levels, such as piscivores, the landings of fish lower down the food web make up a larger proportion of the overall catch.

According to the MSFD Article 4 on Marine regions or sub regions, the Mediterranean Sea comprises the Geographical Sub-Areas (GSAs) 1 to 27, coinciding with the General Fisheries Commission of the Mediterranean (GFCM) management units (Fig. 7).

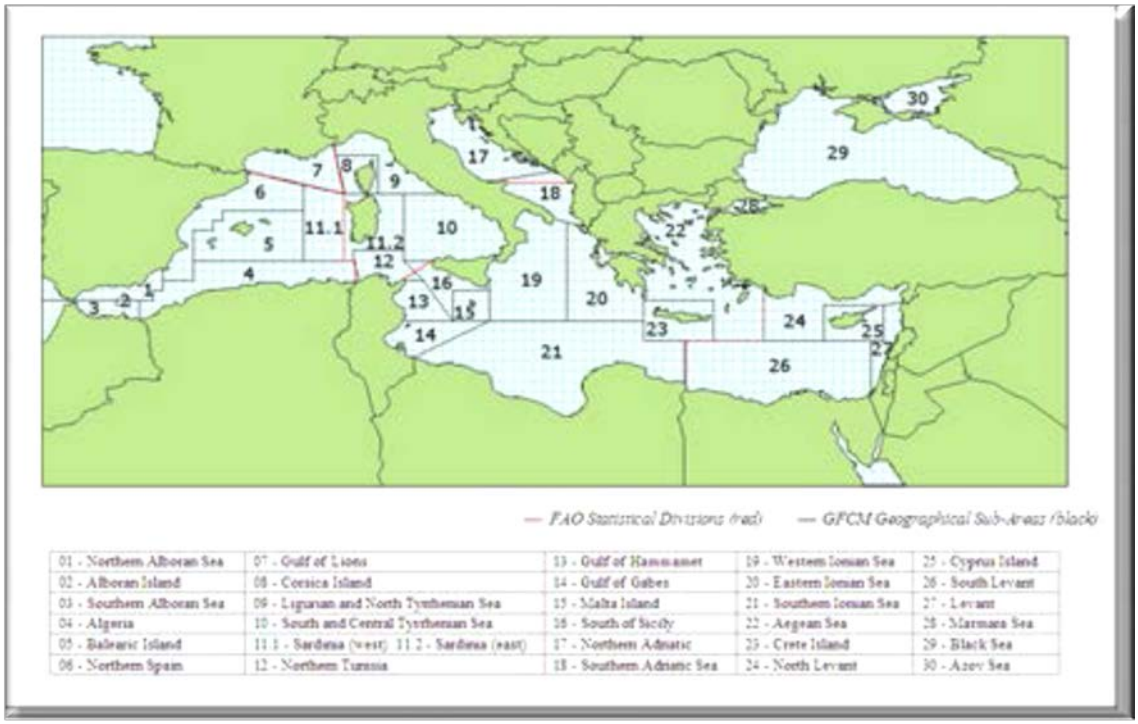

Figure 7. Mediterranean Geographical Sub-Areas according to the FAO General Fisheries Commission for the Mediterranean (Res. GFCM/33/2009/2).

A wide variety of fishing gears and practices is used in the Mediterranean, and fisheries are essentially multi-species in nature. Most of the activities are coastal but there are important fisheries off-shore such as the fisheries for large pelagic species (i.e. bluefin tuna and swordfish). The most important small pelagic species in the Mediterranean are mainly sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and round sardinella (*Sardinella aurita*) (Fig. 8). The trend of the small pelagics captures remains stable from 1980 onwards at little more than 400,000 tonnes; small pelagics as a whole do not show any particular trend, although the increase of round sardinella should be noted.

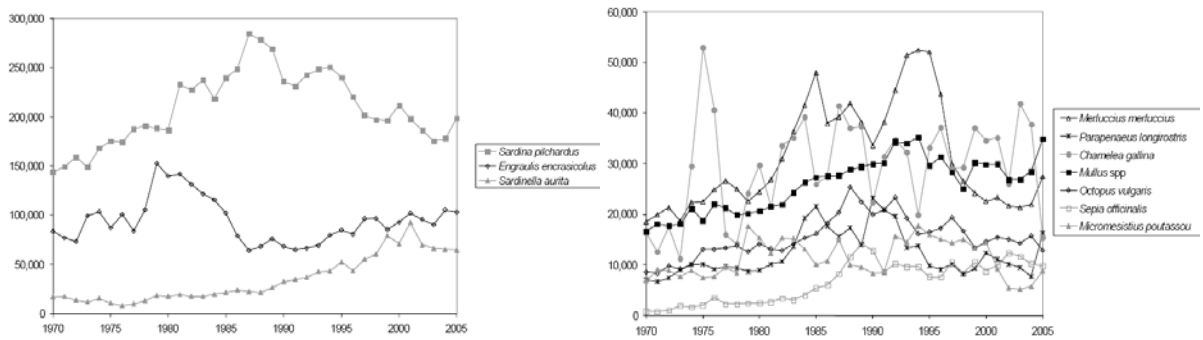

Figure 8. Captures in the Mediterranean (in tonnes).

Likewise, the most important species of demersal fisheries are: hake (*Merluccius merluccius),* bogue (*Boops boops*), deep-water rose shrimp (*Parapenaeus*

longirostris),striped venus (*Chamelea gallina*), red mullets (*Mullus barbatus* and *Mullus surmuletus*), grey mullets (mugilidae), Mediterranean mussel (*Mytilus galloprovincialis*), octopuses (*Octopus vulgaris* and other species) and cuttlefishes (*Sepia offininalis* and other Sepiidae and Sepiolidae), blue whiting (*Micromesistius poutassou*), anglerfishes (*Lophius* spp.), *Pagellus* spp., picarels (*Spicara* spp.) red shrimp (*Aristeus antennatus*) and Norway lobster (*Nephrops norvegicus*). Catch trends of some of the above species over the last decades are illustrated in Fig. 8.

Regarding large pelagics, although its percentage in the statistics is low, their economic as well the ecological impacts is of paramount importance in the Mediterranean. Bluefin tuna and swordfish are the most important large pelagic species in the Mediterranean. In both cases the growth of fisheries over the last decade has increased vulnerability of these stocks. The high exploitation rate is also reflected in progressive decreases in mean size and mean age at capture.

The information on the status of stocks in the Mediterranean concluded that some of the most commercial species are fully to over-exploited. Thus, hake *Merluccius merluccius* is over-exploited, *Mullus barbatus, Aristeus antennatus* and *Aristaeomorpha foliacea* are fully to over-exploited. It has also been reported that a number of target species including Atlantic bluefin tuna (*Thunnus thynnus)*, swordfish (*Xiphias gladius)*, european anchovy (*Engraulis encrasicolus,)* and pink shrimp *(Parapenaeus longirostris)*, are also over-exploited.

Concerning the EU countries the number of species for which stock assessments are available is very poor compared to the number of species that compose each fishery, while the status of most of the species assessed is described as overfished.

The data coming from the non-EU countries are few and scarce due to many problems. For example, a systematic data collection system covering the entire national coastlines in some countries needs to be implemented, while there is a lack of a routine system for the collection of biological data. A standardized data collection system must be set-up in the overall region, ideally among all the countries in the area and following a fleet based sampling approach for length frequency data.

Black Sea and Marmara-Fisheries

According to the MSFD Article 4 on Marine regions or sub regions, the Marmara Sea lies within GSA 28, whereas the Black Sea in GSA 29 (Fig. 7).

It should be noted that information pertinent to Black Sea fisheries is derived from Turkey. The Turkish Straits System (TSS) plays a vital role for the fish migration. The continuity of the fish migration and the prevention of its interruption by an unusual/unnatural impact/effect are important for the ecosystem's health and economic point of view.

Pelagic species dominate marine landings in the Sea of Marmara, particularly anchovy, pilchard, horse mackerel, sprat, bluefish and whiting. Around 60-70% of the total landings are anchovy. In Turkey, total fishery production was 623,191 tonnes, and 8.3% of the total production was obtained from the Sea of Marmara (Fig. 9).

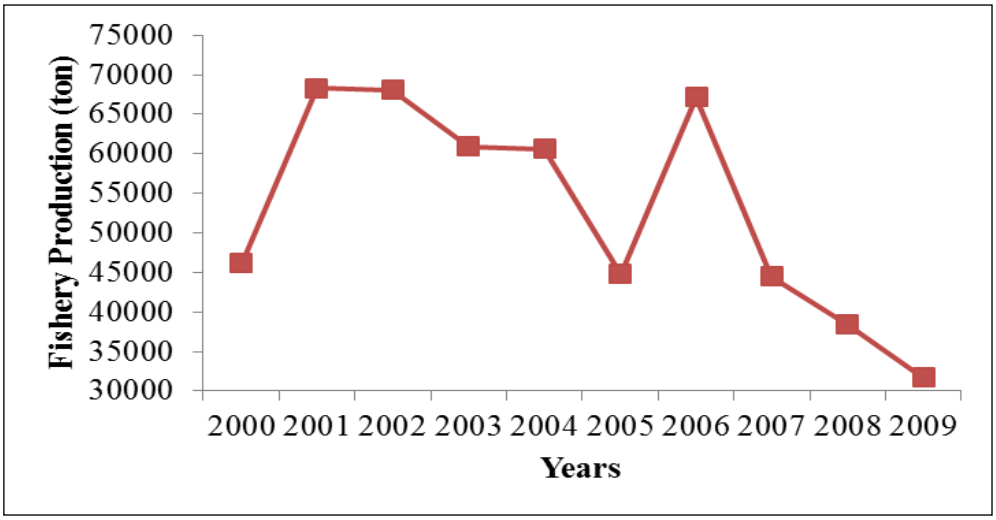

Figure 9. Fish production from the Sea of Marmara from 2000 to 2009.

The Black Sea, due to its very narrow continental shelf; very thin oxygenated upper layer and eutrophic nature, favors pelagic fishes. This is reflected in the catch composition of the landings, in which small pelagic fish forms more than 90% of the total catch. The landing figure fluctuates dramatically, particularly after the collapse experienced in 1989's. There are several contradicting arguments concerning the collapse. Whatever the reason was, it is clear that the Black Sea is in a new state different than that of 1980s with more pronounced pelagic species dominancy.

One of the main problems in the Black Sea region is the lack of comprehensive information on fishing activity, catch quantities and composition and how they affect the current state of fish stocks. Consequently, reports on the annual catch quantities and composition are produced with serious gaps and the analysis of fish stocks current state are far from high level of accuracy. What is more, the communication between responsible authorities needs improvement, while the data exchange at the regional level is not yet systematic and regular.

Descriptor 1: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions.

Data availability: none to medium (Mediterranean Sea and Black Sea)

Descriptor 3: Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

Data availability: none to medium (Mediterranean Sea and Black Sea)

Mediterranean & Black Sea-Non indigenous species

The number of introduced species in the Mediterranean outnumbers that of other European Seas and shows no sign of decline. By 2010 it was estimated that one new species is entering the Mediterranean every 1.5 weeks, listing a total of 955 alien species. Alien species regulations are of major importance in the new generation of EU political actions covering major maritime strategic objectives, such as the Marine Strategy Framework Directive (MSFD) (2008/56/EC), the European Strategy for Marine and Maritime Research (COM (2008) 534). Trends in introduction rates: the indicator is defined as number of new introduced marine alien species per decade since 1950 (Fig. 10).

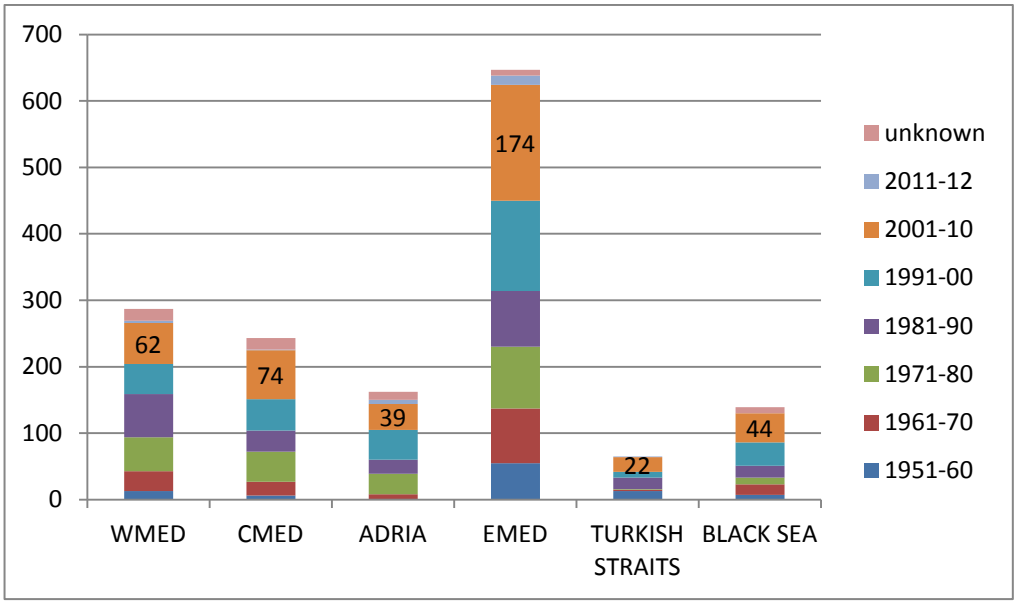

Figure 10. Trends in introduction rate of marine alien species in the Mediterranean and Black Sea

In the Mediterranean as a whole the majority of alien species are macrophytes, molluscan, crustaceans and fishes. The first three groups exhibit a similar distribution patter, while fish dominate in the CMED. In the Black Sea, the majority of Invasive Alien Species (IAS) belong to crustacean and macrophyta. By definition, all introduced species have an impact on biodiversity (Descriptor 1). In all MSFD areas the introduced species in most cases increase biodiversity without having major unwanted economic or ecological impacts. However, in many cases they become invasive (IAS=Invasive Alien Species) and they may detrimentally affect the socioeconomic values of an area by impacting on fisheries & aquaculture, health & sanitation, and infrastructure & building.

A total of 100 species are locally invasive or merely present in the EMED, 65 in the CMED, 49 in the Adriatic and 53 in the WMED (Figure 11). In the Black Sea 26 species are classified as IAS, while 20 IAS are present in the Turkish straits (some introduced from the EMED, some from the Black Sea. In addition to documented impacts on biodiversity, 22 of these invasive species, belonging to decapods, mollusks, and fish, have turned to be beneficial to man and be commercially exploited in several countries.

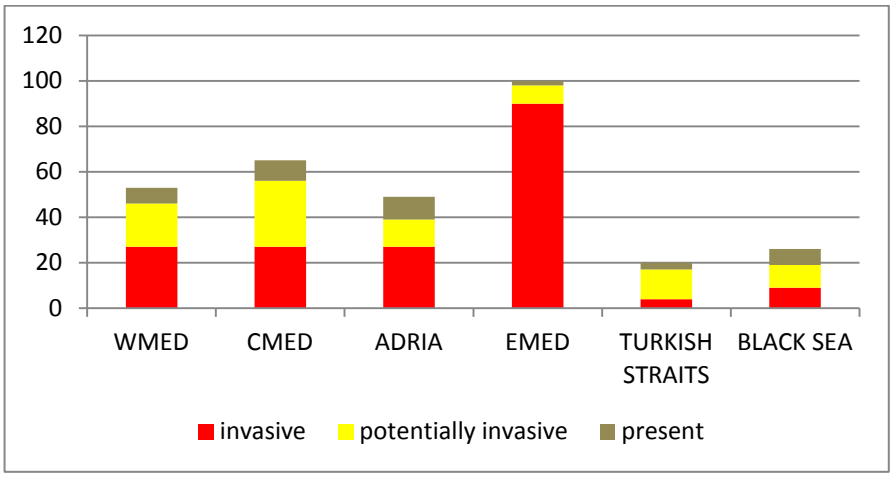

Figure 11. Overview of IAS distribution in MSFD areas

Lagocephalus sceleratus, one of the recent most rapidly expanding Lessepsians, has caused a real alert throughout the whole eastern Mediterranean, becoming the main subject of discussion in national and international meetings for the effect of NIS since 2005, due to its potential risk for human health and the extended damages it caused to fishing gears and catches of inshore fisheries particularly in Lebanon and Cyprus.

Particularly in the southeastern Mediterranean Lessepsian species introduced through the Suez canal, compose 40-70% of trawl catches at depths <100 m, including mainly venomous and non-commercial species at depths <30 m, as indicated by the still limited published quantitative information on the effect of NIS in fisheries.

As opposed to the Eastern Mediterranean, alien species do not feature prominently in fisheries resources within the Central Mediterranean, Adriatic Sea or western Mediterranean.

In the Turkish Straits, as well as in the Black Sea the top IAS Impacting Fisheries and Fish Stocks are the comb jelly *Mnemiopsis leidyi,* and the sea snail, *Rapana venosa.*

Due to the high population density of *R. venosa* along the Marmara coasts, oysters and mussels have been exterminated from these areas where the bivalve harvesting used to be commercially important. Between 1999 and 2007, a total of 1,444 tons of *Rapana* were caught in the Marmara Sea (Fig. 12).

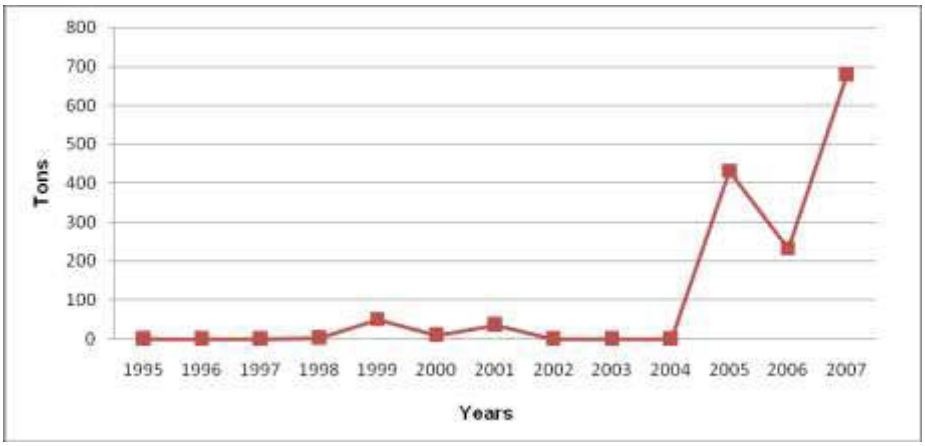

Figure 12. Catch of *Rapana venosa* in the Sea of Marmara from 1995 to 2007

Mnemiopsis leydi, is blamed for the decline of stocks of most of commercial fish in all countries of former Soviet Union, Bulgaria and Romania. However, after the arrival of its predator *Beroe ovata* the ecosystem began to recover. In particular, small pelagic fish stocks in Turkish area, showed signs of recovery.

Descriptor 2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

[except from the south-eastern Mediterranean where Lessepsian species introduced through the Suez canal, dominate demersal fish biomass down to 100 m depth, as indicated by the still limited published fisheries data]

Data availability: None to medium

Subtask 1.1.6. Data integration and marine eco-regionalisation

Responsible: UPMC (LOV)

A Geographic Information System (GIS) based on the integration and processing of existing data will be used to define ecoregions (homogeneous regions with predictable environmental and species assemblages properties that differ from one region to another) and to map ecosystem features as well as potential pressures (vulnerability to environmental, natural and anthropogenic changes) at basin scale.

Mediterranean eco-regionalisation

In recent decades, it has been found useful to partition the pelagic environment using the concept of ecoregionalisation within each partition it is assumed that environmental conditions and or species association are distinguishable and unique at global scale. Indeed, each partition of the ocean that has been proposed aimed to delineate the main oceanographical or marine ecological patterns and discontinuities to provide a geographical framework of marine ecosystems or biogeochemical units for ecological studies or management purposes. In recent years, the increasing amount of observations on both environmental conditions and biological composition of the ocean provided by remote sensing and the constant effort of oceanographic institutes (oceanographic cruises, development of remote or *in situ* time series) have enabled us to monitor and investigate marine ecosystems at a daily and fine-scale resolution.

The massive amount of observations available at multi trophic levels gathered from global datasets and provided by others subtasks of PEURSEUS enable us to investigate on the ecosystemic spatial division of the Mediterranean Sea and the impact of anthropogenic pressures on each identified partition. Here, based on new biogeographical methodologies developed over the last decade a two level division of the Mediterranean Sea will be investigated. The first level of partition, named biogeochemical regions, aims at delineating the characteristic oceanographical and biogeochemical features of the Mediterranean Sea and hence, identified the main biotopes (unique range of environmental parameters) of this basin. The second level of partition, named ecoregion, subdivided the biogeochemical regions according to biotic features of the Mediterranean Sea. Indeed, based on a multi trophic level database, characteristic species association will be retrieved. This second level of division will thus be used as a geographical framework to identify ecosystems that have been altered by human activities (i.e. pollution, fishery, invasive species).

Finally, based on the multi trophic database gathered from this study, a Gap analysis was performed. Result show that several component of Mediterranean marine ecosystems suffered from a lack of observation. This gap in our knowledge was mainly retrieved for benthic organisms, low trophic level pelagic species (bacteria and phytoplankton group) and for quantified indices of human activity.

ANNEXES I-XXIII


PERSEUS
POLICY-ORIENTED MARINE
ENVIRONMENTAL RESEARCH IN
THE SOUTHERN EUROPEAN SEAS


SEVENTH FRAMEWORK
PROGRAMME