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POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

Baseline analysis of pressures, processes and impacts on Mediterranean and Black Sea ecosystems

Deliverable Nr. 1.3

SEVENTH FRAMEWORK PROGRAMME

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CONTENTS

Executive summary / Abstract

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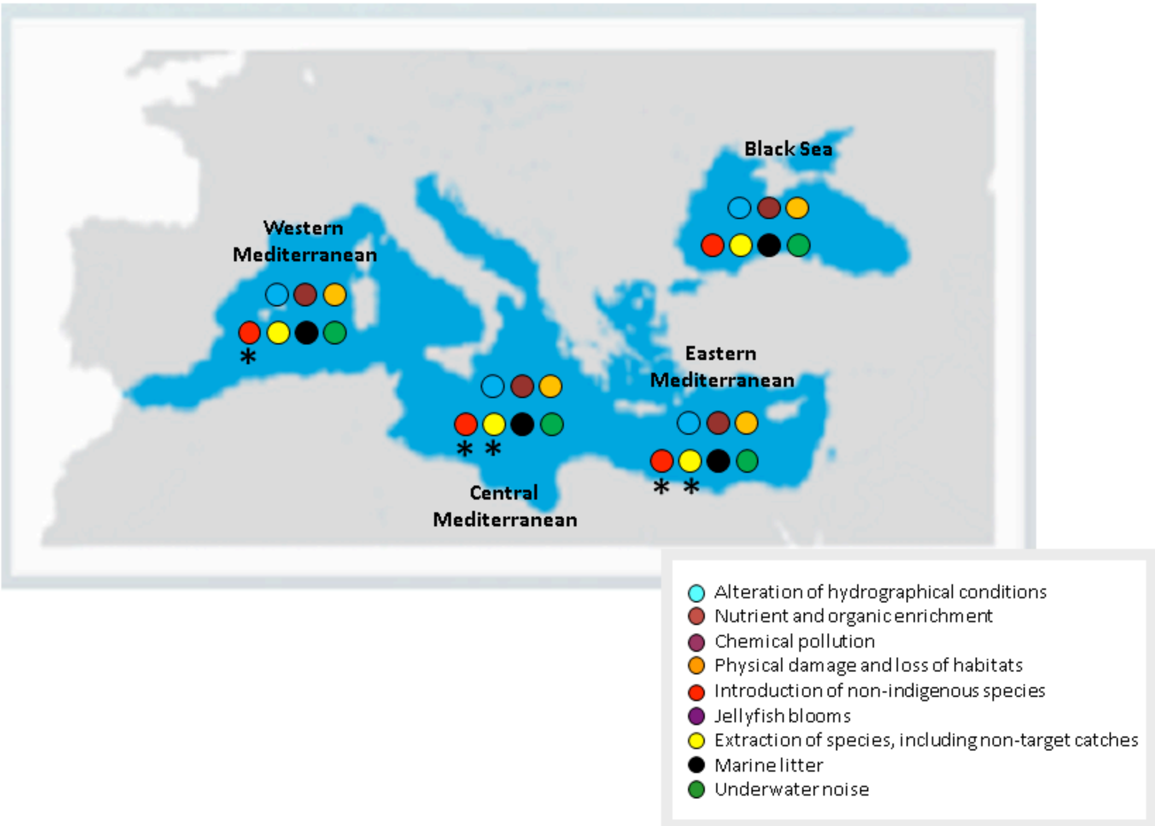
This report addresses the description of Southern European Seas (SES) ecosystem state in respect to natural and human pressures. The main risks identified in the basins of Southern European Seas are depicted for the main sub-basins. They cover most of the descriptors of he Marine Strategy Framework Directive (MSFD). For each of them, the most relevant natural processes, the main anthropogenic pressures, and the impacts (and potential interactions) on open-sea ecosystems are outlined, and their relevance for each sub-basin is presented based on existing knowledge and expert judgment. The growing evidence of multiple pressures acting on open-sea and deep-sea habitats, together with the scarce availability of data on impacts, call for urgent studies dedicated to assessing their effect on ecosystems. Some risks (*) were further investigated to formulate environmental targets, thresholds, and assessment methods for GES.



Scope

The following report summarizes the results of an baseline analysis of pressures, processes, and impacts for the different sub-basins of the SES. This deliverable follows the D1.1, which analyzed gaps on data and knowledge related to a list of key processes, pressures, and impacts, and thus oriented the field studies undertaken within PERSEUS in selected regions. This deliverable presents distinctly the main natural and anthropogenic pressures possibly impacting ecosystems in open sea (>200m). Furthermore, it will contribute to the progress of WP5- Basin-wide promotion of MSFD principles and WP6- Adaptive policies and scenarios.

1. Baseline analysis of pressures, processes and impacts on Mediterranean and Black Sea ecosystems

The Mediterranean and the Black seas are regional, semi-enclosed seas receiving significant natural and anthropogenic pressures, with direct effects on ecosystem functioning, goods and services. Deliverable 1.3 aims at the analysis of pressures and processes and their impact on the ecosystems based on existing information in the Mediterranean Sea and the Black Sea.

D1.3 is a synthetic document based on information previously collected and presented in D1.1 "Pressures, processes and impacts on SES open waters ecosystems - Gap analysis on data and knowledge: Preliminary report on pressures and processes in open waters and their impact on ecosystems in the SES". Additional information deriving from PERSEUS Umbrella Workshop and General Assembly discussions (22-25 January 2013, Barcelona, Spain) have been critically evaluated and embedded in the current document. During WP1, 2 & 6 Joint Meeting (6-7 March 2013, Marseilles, France), an initial screening of pressures/risks per basin/sub-basin was accomplished, which is listed in the next pages.

A thorough analysis of environmental processes and pressures exerted on the ecosystems is presented in a compact format, focusing on the identification of major risks for the Western, Central and Adriatic, and Eastern Mediterranean sub-basins, and the Black Sea. The ultimate goal is to set the top priorities for each sub-basin that need to be addressed in detail in WP6, i.e. socioeconomic analysis.

1.1. Alteration of hydrographical conditions

Main natural processes

The *thermohaline circulation* in the Mediterranean and Black seas is the main natural process controlling the ‘‘background’’ dispersal of water properties, sedimentary particles and associated chemicals at basin scale through time, thus involving the different sub-basins. It is closely connected and determined by the exchanges with the Atlantic Ocean through the Strait of Gibraltar. Mesoscale circulation patterns, shelf-slope exchanges and atmosphere-driven seasonal overturning (i.e., dense water formation) at specific locations further modify the distribution of sedimentary and chemical loads (in particular carbon) and rule the vertical exchanges between the surface and the deep layers. Therefore, physical processes operating at sub-basin and local scales play a pivotal role in the functioning of the Mediterranean and Black seas. These processes display a large spectrum of spatial and temporal scales leading to impacts on the ecosystem dynamics (MERMEX Group, 2011). Time-dominant circulation patterns could be altered by changes in the characteristics of surface water (e.g., when it becomes saltier and warmer) and in the atmospheric forcing (e.g., when stronger winds become more frequent).

Main anthropogenic pressures

Human-induced *seawater warming* and *dissolution of atmospheric* CO_2 in the surface water and reaction with the water molecules (H_2O) to form carbonic acid (H_2CO_3) have been recognized to increase the rate of acidification of the Mediterranean. While direct effects of water temperature increase (acute and chronic) have received some attention in recent years, with many documented on-going impacts such as massive mortality events, local extinctions, migrations and species replacement, much less is known with respect to indirect effects of warming (e.g. favoring the action of pathogens) and the disruptive impact of acidification on calcareous skeleton growth, food chains, community dynamics, biodiversity and ecosystem structure and function.

Impacts (and potential interactions) on open-sea ecosystems

The thermohaline circulation, and the mixed layer evolution through winter mixing and dense water formation thereby directly affects the distribution and the seasonal cycle of phytoplankton that, in turn, determines the trophic inputs to secondary and upper-levels. Modifications of the water budgets of the straits could substantially alter the exchanges of nutrients with the Atlantic, between the eastern and western basins, and with the Black Sea directly impacting the absolute and relative concentrations (i.e., Redfield ratios) of the deep nutrient reservoirs. Modifications of the coastal and open sea dense water formation magnitudes, driven by the atmospheric forcing have relevant repercussions for the vertical redistribution of nutrients and carbon in the water column, and could affect the magnitude and occurrence of the phytoplankton blooms.

The phytoplankton will respond to alteration of the circulation patterns through changes in physiological properties, growth and division rates, and/or modification of their succession pattern in the community, all of which are processes affecting the primary productivity rate. The expected changes in biomass, seasonal cycle, vertical distribution (i.e., depth of the deep-chlorophyll maximum), as well as magnitude and occurrence of the annual peaks, could entirely reconfigure the functioning of the ecosystems at the basin scale. The basin could shift from its several contrasting trophic regimes toward a more intense oligotrophy (e.g., if blooming areas lose their capacity to accumulate nutrients during winter) or toward a diffused augmentation of primary production (e.g., if the enhanced wind forcing deepens the winter mixed layer). The first hypothesis would lead to increased dominance of small algal cells with large consequences for matter transfer into food webs. The second would favor the growth of large opportunistic species.

Furthermore, *acidification* is also expected to significantly affect primary production rates in the Mediterranean as well as the structure of the planktonic community, with most likely an alteration of the calcifying organisms, such as coccolithophorids, which are important planktonic primary producers in the Mediterranean (Barry *et al.*, 2011; Gattuso *et al.*, 2013). This shift will potentially affect the capacity of the surface waters to provide organic matter to higher trophic levels, directly affecting fisheries, and to the deep ocean, limiting the capacity of surface waters to pump atmospheric CO_2. Subsequent impacts on remineralization in the surface layer and organic matter export to the deeper layers is expected. Lastly, the functioning and efficiency of the microbial carbon pump, which is considered as a significant mechanism in carbon storage in the recalcitrant reservoir of dissolved organic carbon (Jiao *et al.*, 2010), is supposed to be altered by the ocean warming and change in carbon flux.

Assessment of risks by sub-basins.

Western Mediterranean - Clear warming trends of the intermediate and deep waters are related to the intensity of the winter mixing in the northern part of the western Mediterranean. Any alteration of the intensity of the winter mixing and the formation of dense water, both by open-sea convection and by shelf-water cascading, is believed to impact the budgets of biogenic elements and the structure of the pelagic and possibly deep benthic ecosystems. The hydrographical conditions in the southern part are tightly connected to the exchanges between the Atlantic and the Mediterranean waters at the

Gibraltar Strait. However, these exchanges also appear to be modulated by the formation of dense water in the northwestern Mediterranean (Schroeder *et al.*, 2013), thus giving insights into the functioning of the entire western basin.
Being aware of the impact of the dense water formation processes on the fishery of the highly valued deep-sea shrimp *Aristeus antennatus* (Company *et al.*, 2008), and with the aim of trying to ensure the long-term sustainability of this resource, the Spanish Government has recently approved (May 2013), in agreement with the Fishery Association of Girona, a pilot regulation that applies to the fishing grounds of Palamós harbor, in Catalonia (Boletín Oficial del Estado, 2013). If successful, it could be eventually extended to other fishing areas of the Spanish Mediterranean Sea and possibly beyond. The regulation includes closed seasons in late winter and early spring, which coincide with the presence of juveniles on the fishing grounds located at submarine canyon heads, and specific actions during the occurrence of major dense shelf water cascading events that lead to temporary fishery collapses. Following such an intense cascading events, the population recovers and a peak of the landings are recorded 3 to 5 years after, mainly composed of juvenile individuals (Company *et al.*, 2008). The former is a perfect illustration of the above-described interactions between natural processes, human activities and associated impacts.

Central Mediterranean - In the Central Mediterranean area (Ionian and Adriatic Seas), the two thermohaline cells of the Eastern Mediterranean interact, generating an important natural source of decadal variability for the entire Mediterranean. The mechanism of this recently discovered interaction is called Adriatic-Ionian Bimodal Oscillating System (BiOS) (Gacic *et al.*, 2010). The thermohaline properties of the Adriatic and Eastern Mediterranean deep waters, the salt distribution over the Eastern Mediterranean (Gacic *et al.*, 2011), the nutrient vertical distribution in the Ionian and the nutrient pool in the Adriatic (Civitarese *et al.*, 2010), and the possible perturbation of biodiversity and ecosystem structures in the Ionian and Adriatic Seas (Civitarese *et al.*, 2010), are interconnected through the BiOS. Alteration of the hydrological conditions affects the efficiency of the biological carbon pump and the rates of carbon sequestration. In the past there was evidence that besides export production also lateral advection modified the biological carbon pump as a consequence of the spreading of the Eastern Mediterranean Transient (EMT) in the Mediterranean.

Eastern Mediterranean - During the last century, a series of dams were built along the Nile and since the operation of the Aswan High Dam almost all the water and sediment discharge to the southeastern Mediterranean stopped. This changed completely the hydrological and biological regime in the southeastern Mediterranean.
Major changes in the thermohaline circulation of the Eastern Mediterranean have been recorded in the 1990s (Eastern Mediterranean Transient). The hydrographical conditions are severely affected by the Black Sea Water inflow and its variability. Dense water formation and cascading from the Aegean Sea is a major process regulating biogeochemical cycles. The extent of this process on the efficiency of the biological carbon pump has also been recognized in the intermediate and deep waters diffusion through their circulatory routes in the central Mediterranean. Local atmospheric conditions play an important role in those processes.

Black Sea - There is a net long-term positive trend of increasing river discharge and precipitation and of decreasing evaporation. Changes in fresh water and sediment riverine fluxes change salinity and level regimes, as well as transparency and suspended matter sedimentation, which entail changing of phytoplankton community structure and changes in food-potential for fish and other marine organisms. Changes in river sediments are directly related to coastal erosion problems.

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1.2. Chemical pollution

Main natural processes

Metals and hydrocarbons in the marine environment can be of natural origin. Natural metal enrichment can be due to hydrothermal activity, seeps, volcanism, local inland mineralogy and diagenetic processes in the sediments. Natural sources of hydrocarbons in the marine environment include terrestrial plant waxes, diagenetic transformation of biogenic precursors, marine phytoplankton and bacteria. Metals and hydrocarbons of natural origin enter coastal and open waters through atmospheric deposition and advections of coastal-sourced fresh waters (rivers and submarine ground waters).

Main anthropogenic pressures

Hazardous substances are introduced in the Mediterranean and the Black Sea from its shores (land-based sources) via discharge points, dumping grounds and surface run-off, or directly by activities at sea (sea-based sources) such as shipping, mining, and oil and gas exploration. Hazardous substances of anthropogenic origin also enter the coastal and open-sea environment through atmospheric deposition (UNEP/MAP/MED, 2011; MERMEX group, 2011).

Persistent Organic Pollutants (POPs). POPs include certain chlorinated pesticides and industrial chemicals such as polychlorinated biphenyls (PCBs), most of which have already been prohibited in Mediterranean countries. However, POPs can also be unintentionally released, mainly as a result of combustion processes or as by-products in some industrial processes (e.g. dioxins and furans, hexachlorobenzene, PCBs, or PAHs). Industrial and domestic-use POPs include brominated flame retardants (polybrominated diphenyl ethers, or PBDEs). POPs also include organotins, biocides formerly used in antifouling paints released by maritime traffic and boating.

Oil pollution and polycyclic aromatic hydrocarbons (PAHs). Maritime transport is a main source of petroleum hydrocarbon (oil) and PAH pollution in the Mediterranean Sea. Oil pollution occurs on routine ship operations including illegal ones, and accidental events. Routine ship operations pollute the sea with oil by tank washings, release of ballast water and discharges of bilge oil. It is estimated that approximately 0.1 % of the crude oil transported ends up deliberately dumped every year in the sea as the result of tank washing operations. Crude oil is composed of thousands of complex compounds of which PAHs are the most toxic. In some areas PAHs levels are higher in offshore waters than they are closer to land that is attributed to intensive ship traffic and direct discharges from ships offshore. PAHs are also introduced into the Mediterranean Sea by atmospheric particulates from the combustion of fossil fuel and incomplete combustion of biomass and solid waste. Atmospheric deposition is an important route for the introduction of hydrocarbons and contributes significantly to the introduction of PAHs in open-and deep sea areas.

Heavy metals. Atmospheric deposition, urban and industrial wastewaters, run-off from metal contaminated sites, rivers and submarine ground water discharges constitute major sources of toxic metals. Heavy metals from localized land-based sources may not only accumulate in the coastal zone but may also move into the deeper areas of the continental margin through advection, and even into the deep basin through downslope transfer processes. Atmospheric deposition is the main pathway for heavy metals to enter open-water regions (Theodosi *et al*., 2010, 2013; Heimbürger *et al*., 2010, 2011). Major natural mercury sources such as volcanic and hydrothermal activity have been outranked by anthropogenic emissions since industrial times with the top contributions being from fossil energy burning (in particular coal), chlor–alkali plants and mining activities (e.g. Idrjia mine, Slovenia). There is evidence that the mercury stock of the Mediterranean Sea has significantly increased since industrial times. The Black Sea, dominated by river inputs and characterized by its anoxic waters (>150 m depth), is known to contain exceptionally high mercury concentrations (4-10 times higher compared to the Mediterranean and other open ocean waters).

Impacts (and potential interactions) on open-sea ecosystems

There is growing evidences that some chemical contaminants (organic and inorganic) can be accumulated over long distances from the dumping sites in the deep marine system (Heimbürger *et al*., 2012; Salvado *et al*., 2012).

POPs are capable of long-range transport, they bioaccumulate in human and animal tissue, biomagnify along the marine food chain, and have potentially significant impacts on human health and the environment. POPs have been shown to disrupt the endocrine systems of a number of organisms. These chemicals have been reported to modify the reproductive systems of swordfish, which may constitute a threat to the survival of the species and there is also evidence for potential trans-generational effects in small cetaceans. Very high level of contamination by persistent organic pollutants (POPs) have been measured in tissues of the Mediterranean deep-sea shark Centroscymus coelolepis (Portuguese dogfish).

Oil discharges and spills to marine areas can have a significant impact on marine ecosystems. The consistency of oil can cause surface contamination and smothering of marine biota, and its chemical components can cause acute toxic effects and long-term accumulative impacts. Polycyclic aromatic hydrocarbons (PAHs) are amongst the most toxic persistent organic pollutants composing crude oil.

Metals entering the Mediterranean and Black Sea through air-sea exchange may accumulate along the food web, becoming concentrated in higher marine organisms, or they may adhere to particles and sink to the seafloor where they accumulate in the sediments (Heimbürger *et al*., 2012). Mercury is a contaminant of particular importance because of the direct exposure risk of Mediterranean surrounding populations and the associated socio-economic impacts (Sonke *et al*., 2013). Mercury biomagnifies along the marine trophic chain with a factor of $1x10^7$ (e.g. 1 mg of Hg dispersed in 10,000,000 L of seawater accumulates in 1 kg of top predator fish). In order to be biomagnified, inorganic mercury of natural and anthropogenic origin needs to be transformed into its neurotoxic companion methylmercury (Cossa *et al*., 2012). Bacteria are known to be capable of generating methylmercury from its inorganic precursor, yet the exact mechanism and location remains uncertain (Parks, 2013). The majority of humans in Mediterranean and Black Sea countries are exposed to toxic methylmercury via the consumption of marine fish. Mediterranean fish often contains higher methylmercury levels than Atlantic and is often above the upper legal levels for commercialization.

Assessment of risks by sub-basins.

Western Mediterranean - The Western Mediterranean Sea is under a strong influence of air masses from Northern and Central Europe that carry anthropogenic emissions. The heavy maritime traffic and associated potential accidents pose an important pollution threats, of heavy metals (Hg, Pb, Cd, etc.) and/or persistent organic pollutants (PAHs, PBDEs, PCB, etc.). The ranges of POP concentrations in the bathyal sharks collected in the Gulf of Lion are among the highest levels reported in Mediterranean biota.

Eastern Mediterranean - Chemical contaminants enter Mediterranean and Black Seas open waters through various pathways, the most dominant being atmospheric deposition, river inputs, submarine groundwater discharge, and maritime transport.

POPs in mussels and red mullet reported generally lower PCBs levels in the Eastern Basin, but medium to high levels of PCBs in red mullets from Cyprus and Turkey and high values, related to industrial and urban effluents, offshore from the Athens port of Piraeus. Concentrations of DDTs are quite low in the Eastern Mediterranean, although moderate concentrations of DDTs were present in Izmir Bay (Turkey), at three stations south of Cyprus, as well as in Saronikos, Thermaikos and Amvrakikos Gulf (Greece).

Regarding accidental oil spills, in the last decade a third of the total accidents in the Mediterranean Sea occurred in the Eastern Region. The Eastern Mediterranean Sea is under a strong influence of Saharan dust emissions and anthropogenic emissions from Northern and central Europe, though less pronounced than for the western Mediterranean.

Black Sea - River-derived nutrients causing intense eutrophication triggers anoxic events and mass mortality. Currently, N and P emissions are 1.5 fold higher than in the 1950s, in a decreasing trend after the economic recession. The Black Sea is also known to be under influence of Saharan dust inputs and anthropogenic emissions from Northern and central Europe. Generally metal concentrations are comparable to Mediterranean waters except mercury which is 4-10 times higher.

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1.3. Physical damage and loss of habitats

Main natural processes

Natural sediment transport processes are the main carriers of matter and energy from one ocean compartment to the other. The main force behind all these processes is simply gravity so that water masses, sedimentary particles and massive sediment volumes move downwards till they find the density equilibrium level or a place where they accumulate and rest. Natural sediment transport processes involve pasive background processes such as the pelagic and hemipelagic settling of particles and energetic near-bottom transport mechanisms such as storms, both in shallow waters due to winds and in deep-sea environments (i.e., benthic storms) due to enhanced currents, turbidity and other density flows, and a variety of landslides quickly shifting large volumes to lower altitude compartments. Near-bottom density flows and landslides are usually short lived (generally hours to weeks) and could be, therefore, qualified as events. Though some patterns (e.g. seasonal) may exist for some of these events, they are en general difficult to predict, in particular the ones occurring at very low frequencies (centuries to millennia or more), often involving large sediment volumes.

Submarine landslides commonly occur on the continental slope, where pre-conditioning factors (e.g. boundaries between sediment units of contrasting mechanical properties, seaward sloping layers or gas accumulation weakening the resistance of the sediment to fail) and triggers coexist. Earthquake shaking, volcanic activity, and overpressure due to rapid sediment accumulation or fluid flow are some of the main triggers leading to slope failure. Rockfalls, landslides entering the sea, fast moving cohesive large volume submarine landslides and explosive volcanism can be tsunamigenic too. Submarine landslides impact the seafloor morphology and the benthic (and nearby pelagic) habitats as they affect the seabed integrity in the removal, transport and final disposal areas. The effects of submarines landslides and also other mass wasting processes on benthic habitats are long lasting.

Climate change is strongly impacting the Mediterranean Sea and Black Sea ecosystems, both directly and indirectly. Verified direct impacts refer mostly to shallow waters, where episodes of sustained high temperatures have damaged entire benthic communities and killed key species, including long-lived structuring ones. The term “thermal shocks” has been often utilized to refer to those events. It seems that such shock may also ease the action of pathogens, thus resulting in further damage to the affected communities and species. It is a matter of debate if such events represent precursor signs for similar effects on deep-water communities. Indirect climate change effects adopt different forms. For instance, warming of the water masses in the Mediterranean and Black Sea eased the penetration of tropical invasive species, thus leading to the process now known as “tropicalization” of the Mediterranean. This effect is by far stronger in the Eastern Basin and the Black Sea than in the Western Basin. Another consequence is that the warming of the upper ocean layers leads to a stronger stratification, thus lowering the chances for intense winter mixing of the water column and oxygenation of the deep benthic habitats. Also, the formation of dense waters becomes more difficult with a warmer surface layer, which according to some scenarios may result in less frequent and less intense offshore convection and dense shelf water cascading, both essential processes for the sustaining of the deep benthic habitats. These processes, in addition, act as “natural cleaners” of the coastal and surface ocean as they carry pollutants and litter to the deep; subsequently, these processes are “dirt carriers” to the deep. Coastal storms are also highly relevant processes in the land-locked Mediterranean and Black seas that trigger density flows carrying sediments, organic carbon and possibly pollutants to the deep too. Most scenarios indicate that storminess will increase with the ongoing global warming and so will do their effects from the coastal areas (e.g. enhanced erosion) to the deep basin.

Main anthropogenic pressures

The main direct anthropogenic pressures over the open-sea ecosystems are bottom trawling, which is practiced on continental slopes down to 1000 m, offshore engineering works and installations, and maritime transport.

Bottom trawling affects the seafloor over large spatial areas smoothing the seabed original morphology, modifying and destroying marine soils (e.g. the surface sediments) where complex communities live, and generating sediment resuspension making near-bottom waters to become highly turbid during most of the time. Though some species, such as the deep-sea red shrimp *Aristeus antennatus*, seem to be adapted to this altered environment, it is detrimental for most of them, as illustrated by the shift and impoverishment in the composition of the catches from the earlier exploitation period of continental slope grounds to the present in the Western Mediterranean Sea. The repetitive character of bottom trawling over the same grounds and their high frequency (i.e. often daily or even twice a day on a given ground) adds to the impact of this fishing technique and prevents the recovery of benthic habitats. Bottom trawling has been often compared with clearcutting or ploughing on land, but clearcutting occurs at a decadal scale and ploughing is usually practiced one or two a year only.

Offshore engineering works and installations mostly include offshore oilrigs with seabed structures, pipelines and cables. While historically the Mediterranean and Black seas have not been prime provinces for offshore oil and gas exploration in the global context, explorations and drilling in both basins has increased recently, which translates into more jackups and floating rigs. Demand for deepwater drilling is also on the rise. Recent discoveries of large gas fields near Cyprus, as well as promising hydrocarbon exploration results in Greece outline the increasing anthropogenic pressures that the Mediterranean and Black seas will probably experience. Another activity that relates to the hydrocarbon industry is the usage of old hydrocarbon fields to re-inject gas in order to have strategic energy reservoirs. In the Castor field, off the Ebro Delta in Spain, this has lead to a succession of earthquakes with a magnitude up to 4.2 in the Richter scale on the 1st of October 2013. Seafloor conditioning is sometimes required for the installation of structures or pipeline lying on the seabed, which results in localized disturbance of benthic habitats. The direct impact of pipelines and cables is generally limited, as it occurs mainly during the laying operations (in particular, if trenching is required), while once the pipe or cable is installed the direct physical impact is restricted to a narrow corridor.

Maritime traffic affects both the high seas pelagic habitats and the benthic habitats, as shown by the accumulation of litter on the seabed along the main shipping routes, due to overboard waste dumping, including clinker from old coal powered vessels, paint chips, and plastic and metallic objects such as bags and cans, amongst many others. Maritime traffic has also been identified as one of the main entry routes for invasive species that are released, jointly with pollutants, during ballast water discharge, tank cleaning operations and spills. In addition, maritime traffic and associated activities are the main source of noise in the open sea, which is produced by the engines, echo sounders and during communications.

Scientific activities such as bottom sampling, trawling, drilling or in situ testing are also a source of disturbance though it is generally minor (i.e. very localized) unless accidents, such as the escape of drilling mud, occur.

Interactions between natural processes and the results or products of man-made activities should also deserve attention, as they could lead to extended and often unforeseen impacts. This is well illustrated by the carrying of chemicals and litter from coastal areas to the deep margin and basin due to storm-induced or dense shelf water cascading currents, and also by the multiple breaking of submarine communication cables due to landslides, as it occurred off Algeria in May 2003. Cable recovery and repairs led to subsequent localized deep-sea habitat disturbance.

Impacts (and potential interactions) on open-sea ecosystems

he increasing pressures upon the marine realm threaten marine ecosystems, especially seabed biotopes (Salomidi *et al*., 2012). Various geological features of the ocean depths are hotspots of diversity and are habitat of vulnerable fauna like cold corals; they include features like submarine canyons, seamounts and cold seeps, mud volcanoes, brine pools and hydrothermal vents.

The demersal fisheries practiced in the Mediterranean high seas may be summed up as follows: bottom trawling and long line. Fishing in the high seas is currently done over the entire continental shelf and some portions of continental slopes down to 1000 m depth. Bottom trawling in Mediterranean Sea at depths >1000 m was forbidden in 2005 in order to protect the vulnerable deep sea fauna. The use of bottom gear can cause a series of cascade effects on the ecosystem.

Bottom trawling can threaten the habitats of the continental margin and bathyal zone. A strong priority is to be given to bioconstructors and to coralligenous formations. These sessile benthic fauna has an important role as organisms that structure the habitats providing a refuge for many marine species (e.g. cold water coral reefs, deep sea sponges, crinoid beds), and represent the second most important hotspot of species biodiversity in the Mediterranean. Trawling can remove such large-bodied, long-lived macrobenthic species and also their natural habitat, which is the soft sediment layer forming the marine soil or uneven rocky outcrops, subsequently reducing biomass and biodiversity. Fishing disturbance may cause shifts in the benthic community structure that particularly affect mobile scavenging species, probably the most food-limited group in muddy seabed environments. Trawling is also responsible for changing grain size distribution and sediment texture and for destroying the natural seafloor morphology (Puig *et al*., 2012). Trawling fishing practices can also change the natural patterns of sediment suspended in the water, and the increased turbidity can extend deeper than the immediate fishing grounds, affecting further deep-sea ecosystems (Martín *et al*., 2013).

There are potential implications for the benthic and pelagic communities immediately impacted by the construction footprint and operation of offshore infrastructures (e.g., oil rigs). Offshore drilling operations create various forms of pollution that can have negative effects on marine habitats and organisms. These include drilling muds, brine wastes, deck runoff water and flow line and pipeline leaks. Accidental spills and blowouts are also a threat from offshore drilling operations (Neff *et al*., 1987). Deep sea drillings for gas and oil exploitations are increasing. Offshore drilling presents environmental challenges, both from the produced hydrocarbons and the materials used during the drilling operation. Offshore drilling presents environmental challenges, both from the produced hydrocarbons and the materials used during the drilling operation.

Assessment of risks by sub-basins.

Western Mediterranean – Deep sea bottom fisheries of Spain, Italy, Algeria and Tunisia, which are basically targeting Norway lobster (*Nephrops norvegicus*) or red shrimp (*Aristeus antennatus* and *Aristeomorpha foliacea*) on slopes down to a depth of 1000 m, alter the seafloor morphology, and also modify the physical properties of seafloor sediments, water–sediment chemical exchanges and sediment fluxes. The deep benthic communities are often extremely vulnerable to physical disturbance and the recovery after impacts of trawling might take a long time. Submarine canyon flanks, where fisheries activities tend tooccur, are places where cold-water coral reefs develop. These are important and ancient reservoirs of marine biodiversity and are essential nursery habitats for many commercially important fish species.

Central Mediterranean - Deep sea fisheries for shrimps take place also in Italian as well as international waters of the central Mediterranean Sea. In the deep Central Mediterranean Sea, few studies have examined the effects of bottom trawling on demersal resources and on sea-floor status (e.g. Pipitone *et al*., 2000; Dimech *et al*., 2008, 2010; Gristina *et al*., 2006; D'Onghia *et al*., 2005). Among these studies, only few works have been obtained on the comparison of the populations and communities in trawled and non-trawled sites based on detailed data on fishing effort. The deep-water trawl fishery for red shrimps can be considered as 'monospecific' (with either of the 2 red shrimp species being dominant in the catch) relative to the trawl fisheries on the continental shelf and upper slope. In the Strait of Sicily the biomass of the deep water resources were higher in the non-trawled sites comparing to the trawled ones (Dimech *et al*., 2010). Furthermore, the populations of *A. foliacea* and *Etmopterus spinax* did not show any differences in biomass between the trawled and non-trawled sites. This situation provides an opportunity to assess the ecological impacts of bottom trawling on demersal resources and to provide advice on how to manage the trawl fisheries in line with the ecosystem approach to fisheries management.

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1.4. Non-indigenous species

Major natural processes

Corridors (Suez Canal, Strait of Gibraltar, Turkish Straits Systems) are the main pathways of the introduction of non-indigenous species (NIS) in the Mediterranean and Black Sea (Zenetos *et al*., 2012; UNEP-MAP-RAC/SPA, 2012).

Climatically-induced warming of the oceanic water can enhance establishment of some introduced NIS and skews the real magnitude of the phenomenon attributed solely to anthropogenic intervention. Tropicalization of the Mediterranean results in the establishment of tropical species that were previously absent from the basin.

Major anthropogenic pressures

Shipping, via ballast water and transfer of organisms attached to ship hulls as fouling or fishing discards, plays a major role in the introduction of NIS. The contribution of shipping (ballasts water and fouling) has steadily increased reaching approximately 78 species in the 2010s. The current rate (based on the last decade) of ship-mediated NIS in the Mediterranean is one new species every ~six weeks. The number of NIS introduced via either the Suez Canal or shipping has tripled since the 1950s but the increasing pattern was not the same. For Lessepsian immigrants there was an abrupt increase in the 1960s which continued over the next decades and has remained steady during the last two decades, with an average of more than 70 introductions every 10 years. A decline in NIS was observed in the 1980s, which has been attributed to the closure of the Suez Canal between 1967 and 1975 that limited the number of vessels entering in the Mediterranean. Some international harbors, such as Port Said, Haifa, Iskenderun, Mersin, Alsancak and Peiraias, are hot spot sites for NIS establishment (Çinar *et al*., 2012; Young *et al*., 2007). NIS have also been introduced in a lesser extent via *aquaculture*, as *contaminants of imported species*, or by *aquarium trade*.

Impacts (and potential interactions) on open-sea ecosystems

Invasive fish can have significant ecological and economical impacts and cause profound damage to natural habitats. NIS mostly impact fisheries and aquaculture, health and sanitation. Once established in a new region, NIS may invade new areas adjacent to the occupied area by natural dispersal, e.g. via transport in water currents in the case of many seaweeds and phytoplankton. NIS may displace native organisms by preying on them or out-competing them for resources such as for food, space or both, causing a threatening or even an elimination of native species from certain areas. Occasionally NIS can reproduce with native species and produce hybrids, which will alter the genetic pool (a process called genetic pollution), which is an irreversible change. Some pests and parasites associated to introduced NIS can adversely affect native species

Assessment of risks by sub-basins.

Western Mediterranean - Several hundred non-indigenous species are estimated in the Western Mediterranean Sea, and 64 are considered as invasive or potentially invasive. The status of some species with an eastern Atlantic origin in the western Mediterranean is difficult to determine, because of the intense fishing and transport activities that represents a potential and continuous source of introduction of NIS, of the role of the Strait of Gibraltar that is a boundary more or less permeable to Atlantic species that naturally increase their distribution range, and also because there is a limited knowledge on the biodiversity from North African littoral.

Central Mediterranean - The Central Mediterranean is also affected by the increased number of NIS species. Maritime transport (ballast waters and fouling) are major vectors of introduction whereas dissemination of already invasive species in the eastern Mediterranean accounts for a large number of NIS. As opposed to other parts of the Mediterranean Sea, most notably the Eastern Mediterranean, alien species do not feature prominently in halieutic resources within the Central Mediterranean. A significant number of fish (more than 30) of Atlantic origin have made their first appearance in the Sicilo-Tunisian Strait after 1990, before spreading eastwards. This is attributed to range expansion favoured by the current circulation and climate change.

Eastern Mediterranean - The EMED is exposed to a massive introduction of NIS immigrating naturally through the Suez Canal. Shipping is still the main pathway of primary and secondary introduction. In addition, a warmer affinity of most species is evident, in relation to the increasing temperature in the Eastern Mediterranean in general.

Of the nearly thousand non-indigenous species (NIS) in the Mediterranean, the vast majority occur in the eastern Mediterranean (Aegean Sea, Sea of Marmara, South Turkey, Cyprus, Syria, Lebanon, Palestine Authority, Israel, and Egypt). Here, the NIS number has climbed to 775 species, as a result of the continuous influx of Indo-Pacific species found mainly along the Turkish and Israeli coasts. The introduced species belong mostly to invertebrates, marine plants and fishes. The rate of new introductions, estimated to be one new species every two weeks, is most evident in the eastern Mediterranean.

In the EMED sub region, the Levantine Sea ranks first in terms of NIS belonging to all groups, followed by the Aegean Sea. The areas more visited are Israel and Turkey with more than 400 alien species each.

Black Sea - The introduction of non-indigenous species has caused severe changes in the structure and functioning of benthic and pelagic ecosystems of the Black Sea in recent decades. The relatively low biodiversity of the basin, interconnected to its young age and its low salinity, make it particularly vulnerable and easy target for the invasion of many exotic species. Species like *Mnemiopsis leidyi* have turned out to be extremely harmful to the native flora and fauna in the Sea of Marmara and in the Black Sea. This species feeds on fish eggs and larvae, negatively affecting important commercial fish stocks, such as *Scomber scombrus, Sardina pilchardusor, Sprattus sprattus*. The gastropod *Rapana venosa*, one of the most invasive species worldwide, has invaded the Black Sea in 1982. Its rapid distribution and increased biomass has caused severe damage to narrow benthic ecosystems both direct (predation on bivalves) and indirect (fishing with dredges. On the other hand, this species gained an economic importance and was exported as Rapana meat to Japan (Ozturk, 2010). A new copepod species, *Oithona davisae* was discovered along the western coast of the Black Sea in 2009–2012. In the short period since its discovery off the Bulgarian Coast, *O. davisae* populations have increased to become one of the dominant zooplankters, contributing up to 63.5–70.5 % of total mesozooplankton numbers in the Varna Bay and adjacent open sea waters. (Mihneva & Stefanova, 2013).

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1.5. Over-fishing

Major natural processes

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. The waters of the Gulf of Lions, Adriatic, and the northern Aegean Sea often contain enhanced nutrient concentrations (MERMEX group, 2011). The low productivity of the rest of the sea is related to the *basin-wide circulation,* hot-dry and seasonal *climate* and low *land runoff* (Turley, 1999). In fact, the Mediterranean exhibits some of the most extreme oligotrophic waters in the world which has also a direct impact on fisheries productivity (Stergiou *et al*., 1997).

Compared to the Western Mediterranean (87% of the known forms of life), the Eastern Mediterranean is poorer with regards to species diversity (43% of the known forms of life), and nutrients. Interesting to note is the apparently different zones in the Eastern Mediterranean with regards to nutrients and species diversity. The most eastern part, i.e. the Levant basin, presents a lower species diversity than the Aegean and Southern Eastern Mediterranean.

Major anthropogenic pressures

Fisheries are multi-species and multi-gear in nature, while the fleet is characterized by large number of small and medium sized vessels. They can be divided into three main categories: small scale fisheries (mainly coastal and artisanal fisheries), trawling and seining. Most of the activities are coastal but there is important fisheries off-shore such as the fisheries for large pelagic species (i.e. bluefin tuna and swordfish). The majority of the fishing fleet in the region comprises boats smaller than 12 m in length, reflecting the high socio-economic importance of small-scale fisheries. Small pelagic fish constitute an important group with anchovy and sardine sharing the majority of landings among all species caught. Concerning demersal species, hake, red mullets and octopus are actually the most important representatives; however they are collected on the continental shelf. Regarding large pelagics, although its percentage in the statistics is low, their overall economic value; bluefin tuna and swordfish are the most important large pelagic species. The growth of fisheries over the last decade has increased vulnerability of these two stocks. The high exploitation rate is also reflected in progressive decreases in mean size and mean age at capture. In the case of open sea fisheries we will be focusing on the ones targeting *Thunnus thynnus*, *Xiphias gladius*, the deep sea shrimps (*Aristeus antennatus* and *Aristeomorpha foliacea*) existing on continental slopes and small pelagics (*Engraulis encrasicolous* & *Sardina pilchardus*).

Despite the progress held during the last decades, management measures are considered to be at an early stage of development, and in general they do not always comply with scientific advice. The primary management measure applied is effort limitation, regulating the characteristics and use of fishing gears. In addition, spatio-temporal closures have been adopted to protect, in part, certain species during their reproductive period. Other management tools in use include total allowable catches or quotas for large pelagics, minimal landing sizes, protected species and limits on the days at sea.

Impacts (and potential interactions) on open-sea ecosystems

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. A well-documented and increasing risk in the Mediterranean is that of “Fishing down the food web”, since according to FAO fisheries statistics, the mean trophic level of Mediterranean catches declined by about one trophic level during the last 50 years (Pauly *et al*., 1998). 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.

Populations of large sharks are declining and even threatened with extinction in the Mediterranean Sea because of overfishing, habitat degradation, and slow recovery rates.

The loss of sharks is a concern because they play crucial roles as predators in marine ecosystems (Ferretti *et al*., 2008).

Moreover, fishing is also having direct impacts on a number of by-catch species including some species of conservation concern such as chondrichthyans, sea turtles, sea birds and sea mammals (SAP-BIO, 2003; GFCM, 2004; Damalas and Vassilopoulou, 2011). In fact there is compelling evidence that by-catch and discards by Mediterranean fisheries, and particularly those produced by unselective trawling fleets are significant (Vassilopoulou *et al*., 2007). The effect on marine communities is twofold: at a single-species level, the population dynamics of a species are altered, and at the ecosystem level profound changes occur because of the disruption of food webs.

Assessment of impacts by sub-basins.

Given that the large pelagic species, such as tunas (*Thunnus thynnus*) and swordfish (*Xiphias gladius*) are highly migratory, the assessment for those species is always made on a Mediterranean-wide basis. Consequently, the analysis by sub-basin that follows is focusing on demersal and small pelagic species. Regarding the large pelagic species, bluefin tuna and swordfish are those considered more important in terms of commercial value. Bluefin tuna is rebuilding from an overexploited situation, while swordfish seems to be overexploited but the degree of overexploitation remains uncertain.

Western Mediterranean - Most fisheries in the area of study are multi-specific, targeting more than one species and including important by-catches of other species. In this sub region, one sardine stock (GSA 1) is in a sustainable condition considered overexploited and -three sardine stocks are fully exploited (GSAs 3, 6, 7). For anchovy, the four assessed stocks are considered to be overfished (GSAs 1, 6, 7, 9). Both red shrimps (*Aristeus antennatus*, *Aristaeomorpha foliacea*) constitute important deep-water trawl fisheries in the western Mediterranean. For blue and red shrimp, the following assessments have been made on the status of stocks. In 2002/3, stock assessments in the Northern Alboran Sea (GSA 1), Balearic Islands (GSA 5) and northern Spain (GSA 6) pointed at stocks being fully exploited (GFCM SCSA, 2003). In 2005/6, stocks in the Balearic Islands and northern Spain were still deemed to be fully exploited (GFCM SAC, 2006) and, in 2006/7, stocks in northern Spain were overexploited according to the stock assessment (GFCM SAC, 2008). On 2012 *A. antennatus* was also overfished in the Balearic Islands (GSA 5) and northern Spain (GSA 6) (GFCM SAC, 2012). Management advice given by SAC in relation to the blue and red shrimp has included the recommendation to reduce fishing effort by 10 percent (8 942 fishing days for a fleet of 130 vessels).

Central Mediterranean - According to the assessment (STECF 2013) the status of both achovy and sardine stocks is considered to be above the reference point. Both red shrimps (*Aristeus antennatus*, *Aristaeomorpha foliacea*) constitute important deep-water trawl fisheries in the Central Mediterranean. The fishery is very lucrative, due to the high commercial value of the product. The stock of *Aristeus antennatus* is overfished in the Ligurian and N, Tyrrhenian Seas (GSA 9). In the same area the stock of Nephrops norvegicus has been also considered as overfished. The giant red shrimp (*Aristaeomorpha foliacea*) stock in the Strait of Sicily is also in a overfishing status (GSA 15-16)..

Eastern Mediterranean - Based on the assessment (STECF, 2013) in this area the status of the anchovy stock is regarded to be below the reference point, whereas the status of the sardine stock is considered to be above the reference point, presenting an improving trend in the last years. *Aristaeomorpha foliacea* is more abundant than *Aristeus antennatus* in the E. Mediterranean, mainly in the south part of Turkey (GSA 24). The fishery of both decapods has not been developed in this area and many data concerning fishery and biology are missing. An assessment is required for the areas that have available data on the fishery of both shrimps and landing data could be collected where information is lacking.

Black Sea - In the Black Sea small pelagic fish forms more than 90% of the total catch. Overfishing synergetic effects superimposed on food web alterations have resulted in dramatic fluctuations of landings during the past 30 years.

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1.6. Marine litter

Major anthropogenic pressures

Marine litter can be any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. It consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea and on beaches, including such materials transported into the marine environment from land by rivers, draining or sewage systems or winds. Marine litter consists of plastics, wood, metals, glass, rubber, clothing or paper (Ryan *et al*., 2009; Galgani *et al*., 2010). The most abundant litter types are plastic, glass, metal and clinker. Lost or discarded fishing gears and paint chips are also commonly found (Galil *et al.*, 1995; Ramirez-Llodra *et al.*, 2013).

The composition and abundance of litter is linked to its origin. The main input comes from land-based sources: discharges and leakages from land, including both point and diffuse sources of litter, such as municipal landfills, untreated sewage discharges, coastal industries and coastal tourism. Other sources of marine litter include offshore activities, shipping vessels (including waste and lost cargo), fishing vessels (including lost or abandoned fishing gear), aquaculture and litter from boating. The shallow region, closer to the coast, generally shows a higher proportion of plastics than the deeper regions, which had a higher proportion of heavy litter that mostly originated from ships, especially under major shipping routes (Ramirez-Llodra *et al.*, 2013).

The water circulation is the major mechanism of floating debris dispersion which explains their ubiquitous presence at basin scales. Debris that reaches the seabed may already have been transported to a considerable distance, only sinking when weighed down by fouling. In the open sea, submarine canyons are apparently special locations for the accumulation of large debris (Galgani *et al*., 1996, 2010; Galil *et al*., 1995; Papatheodorou, 2011)

Debris are progressively fragmenting in the environment (Colton *et al.*, 1974; Thompson *et al.*, 2004). Microparticles, defined as fragments of litter smaller than 5 mm (Arthur *et al*., 2009). Microplastics accumulate in the marine environment due to their high prevalence and slow rate of chemical and biological degradation (Kaberi *et al*., 2013). Spillage of pre-production plastics, transported as pellets (<5 mm) and powders (<1 mm), also plays a part.

Impacts (and potential interactions) on open-sea ecosystems

Impacts of marine litter are manifold. Harm can consist of social (reduction in aesthetic value and public safety), economic (e.g. cost to tourism, damage to vessels, fishing gear and facilities, losses to fishery operations, cleaning costs), and environmental aspects (mortality or sub-lethal effects on plants and animals, release of chemical degradation products, facilitation of non-indigenous species transport, alteration of benthic community structure).

Plastic ingestion can have lethal effects, while entanglement can lead to physical damage, especially to sessile and fragile organisms such as corals and sponges. Furthermore, the slow degradation of plastics results in large quantities of small plastic particles down to micro-plastics, which accumulate in the deep-sea environment where they are directly ingested by deposit-feeders with yet unknown effects (Thompson *et al*., 2009; Wright *et al*., 2013).

Accumulations of litter (organic falls, plastics and metallic detritus) have the potential to affect seabed habitats in some localized areas, in particular in submarine canyons that act as natural traps. Marine litter impacts the marine ecosystems in place, by altering the substrate while creating new micro-habitats that can be colonized by allochthonous organisms. Microplastic particles may act as carriers of contaminants (PAHs, PCB's, metals, etc; Karapanagioti *et al*., 2011) and they can be ingested by marine organisms with consecutive effects (Wright *et al*., 2013). Litter weight is often equivalent, and even in some cases higher, to the total biomass of megafauna at the same location (Ramirez-Llodra *et al*., 2013).

Assessment of risks by sub-basins.

Western Mediterranean - Potential impacts of marine litter include damages to benthic habitats, injures and death of a wide variety of marine organisms, transporting of chemicals, invasive species and bacteria, and also economic harms to fisheries and tourism. Observations on the French and Spanish continental slopes showed that submarines canyons concentrate marine litter.

Central and Eastern Mediterranean - Observations on litter are very limited for the Central and Eastern Mediterranean. Sources of marine litter in the open sea are mainly related to shipping and transport of litter from the coastal areas. Increased densities of plastic pellets are found in Greek islands.

Black Sea - The solid waste production in the Black Sea coastal zone could be considered as one of the significant environmental pressures; however, the management of solid waste still leaves space for a lot of improvements.

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1.7. Noise

Major natural processes

The major natural processes which take place in the seas regarding underwater noise are related to the ambient noise generated by the biological and non-biological intermittent sources of noise (Urick, 1984). The first include the vocalizations of marine mammals, fish and certain crustaceans, while the second include sounds that are induced by precipitation, wind, currents and waves as well as acoustic events such as sub-sea volcanic eruptions, earthquakes and lightning strikes. Some of the intermittent sources of noise can reach quite high source levels of more than 200 dB re 1 μPa peak to peak (UKMMAS, 2010).

Major anthropogenic pressures

The most important sources of anthropogenic noise in the Mediterranean and Black Sea are maritime traffic, seismic surveys, military sonar, drilling operations, coastal construction works and underwater explosions as well as sonar's operation originating from military exercises (Adbulla and Linden, 2008).

Despite their small areas, the Mediterranean, and in a lesser extent the Black Sea, suffer from heavier maritime traffic than any other sea in the world. Although most of the traffic is along an east–west axis, there is a complex web of lanes in some areas, including important marine mammal habitats. The large number (several thousands) of large cargo vessels crossing the SES at any given moment, implies that silent areas may no longer exist in the different basins. The greatest level of vessel activity is concentrated around western and central Mediterranean ports.

During the last years, oil and gas activities have become another major anthropogenic pressure. Up to now, seismic surveys with powerful air gun arrays have covered hundreds of thousands of line kilometers. Subsea development, drilling and production, subsea pipelines and gas processing will be an added pressure to the marine ecosystem (Genesis Oil and Gas Consultants, 2011).

Impacts (and potential interactions) on open-sea ecosystems

Noise is increasingly being considered as a threat to marine mammals. A synthesis of the impacts of underwater noise in marine and coastal biodiversity and habitats can be found in UNEP/CBD/SBSTTA (2012). In general, underwater noise is a growing concern, especially as it affects the communication and behavior of marine mammals (especially beaked whales) and certain fishes. As stated in Abdulla and Linden (2008) and the references therein, noise pollution can cause marine mammals to abandon their habitat and/or alter their behavior by directly disturbing them or by masking their acoustic signals over large areas; loud sounds may directly affect their hearing abilities by producing either temporary or permanent hearing loss. All these effects may be critical for the survival of marine mammals. Some high-energy sound sources can have immediate impacts and even trigger mortality events, as recently evidenced by several dramatic and well-documented cases of atypical mass stranding of beaked whales, such as in Greece in 1996.

Unlike chemical pollution or litter, noise does not persist in the environment. Potential mitigation of those impacts can be implemented by reducing the amount of incidental underwater noise from shipping (see recommendation of IMO MEPC 57/INF.4 report on Shipping noise and marine mammals).

Assessment of risks by sub-basins.

Noise from maritime traffic represent probably a permanent and widely spread pressure over the Mediterranean and Black Sea sub regions, as background noise levels have intensified in the past decades mostly due to significant increase in the number, size, and speeds of merchants' ships. During the last years, oil and gas activities, and related seismic surveys, have become a major anthropogenic pressure in the Eastern Mediterranean.

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2. Synthesis: major impacts and suggested topics for socio-economic analysis

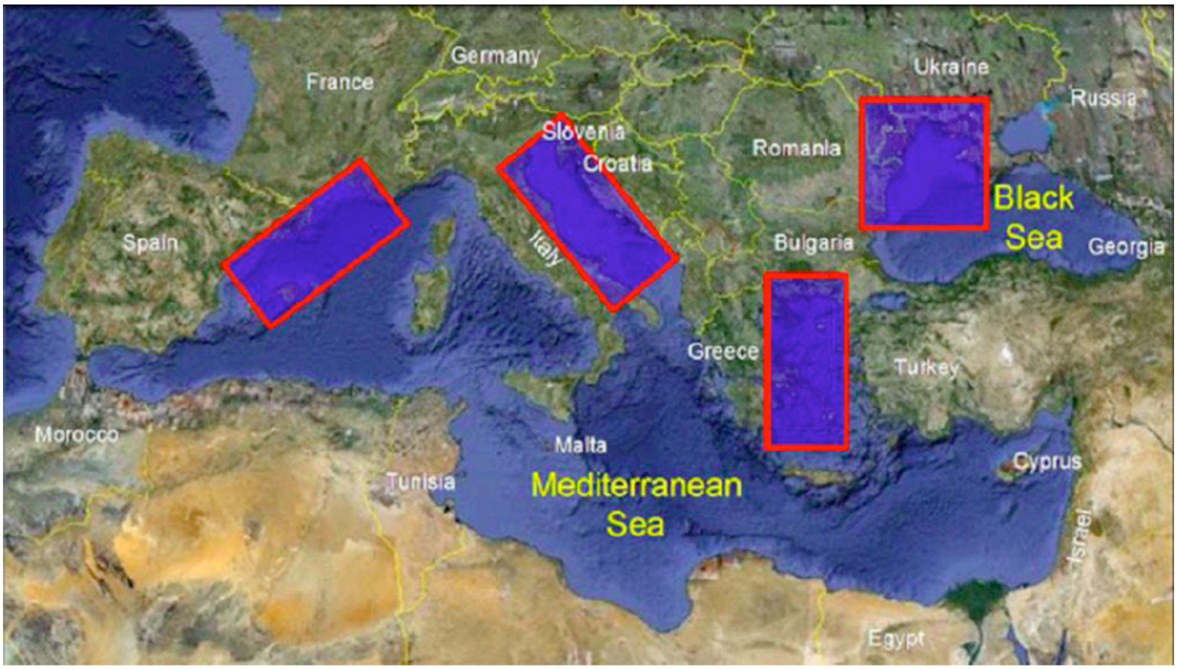
In line with the Umbrella Workshop and to prepare the implementation of the Adoptive Policy Framework (APF) in the WP6 Pilot cases, the main objective of D1.3 is to identify a preliminary list of risks of non-achievement of GES as a starting point of a selection process; the ultimate goal is to select the demonstrative issues which will be used to test and improve the APF. Further on, a specific objective is the identification of two to three risks for each WP6 Pilot Cases and to derive from them environmental targets and associated thresholds to develop future adaptive policies.

2.1 Environmental targets in open waters

A meeting between T1.2 & T2.2 participants that took place on the 16th of September 2013 and was coordinated by Plan Bleu, considered all relevant aspects and resulted in the formulation of lists of (1) top Environmental Targets and (2) potential risks induced by main human activities per WP6 pilot cases (Gulf of Lion in the northwestern Mediterranean, Adriatic in the central Mediterranean, Aegean in the eastern Mediterranean, and northwestern Black Sea). The following Table aggregates the top Environmental Targets that represent the most important issues for the MSFD implementation in the open Mediterranean and the Black Seas; the specific importance of each environmental target is not evaluated, therefore the list from 1 to 3 does not represent priorities.

Environmental Targets
• Reduction of releases of non-indigenous species by maritime transport and impacts on (open sea) marine ecosystems • Achieve sustainable stocks of commercially targeted exploited species (i.e., anchovy, sardine, tuna)

The four WP6 pilot cases are the northwestern Mediterranean, the Adriatic in the Central Mediterranean, the Aegean in the Eastern Mediterranean, and the northwestern Black Sea.



The following table aggregates the potential risks induced by main human activities per WP6 pilot cases

Cases	**Risks**	**Fisheries**	**Aquaculture**	**Maritime transport**	**Submarine cables**	**Offshore exploration**
Western Med.	PDLH NIS OF	PDLH OF	NIS	NIS	PDLH	PDLH
Eastern Med.	PDLH NIS OF	OF	NIS	NIS		PDLH
Black Sea	NIS OF	OF	NIS			

Legend:

PDLH	Physical damages and losses of habitats (D6)
NIS	Introduction of non-indigenous species (D2)
OF	Overfishing (D3)

These risks have been subject to discussion in order to derive environmental targets and thresholds. Consideration of combined issues and situations of interaction would represent added value for Perseus Project. Innovative policy design needs to tackle with interactions; however, little knowledge is available on the interacting patterns of both natural and human derived pressures, the first scientific objective of Perseus.

2.2 Non-Indigenous Species

Area

Northwestern Mediterranean (Gulf of Lion)

Selected Risk

NIS (Non-indigenous Species)

Environmental Target

Reduction of releases of non-indigenous species by maritime transport and aquaculture

Description

In the WMED, shipping remains the most prominent pathway of introductions and its lower proportion in the two last decades reflects the increase of other sources rather than a genuine decline (Zenetos *et al*., 2012). Shipping at large may include species introduced with fishing discards. The decades of 1970 to 2000 represent the heyday of introductions through aquaculture, both intentional and accidental (Verlaque, 2005; Mineur *et al*., 2007)

The rise of corridors as a pathway to the WMED in the last decade is a consequence of the slow but steady progress of species, which first arrived in the EMED through the Suez Canal to successively spread throughout the whole basin. Among the forerunners are the lessepsian bluespotted cornetfish *Fistularia commersonii* first sighted in 2007 in Corsica (Bodilis *et al*, 2011) and the rabbitfish *Siganus luridus*, caught in 2008 in Sausset-les-Pins, near Marseille (Daniel *et al*., 2009). At the same time, the effect of climate change is evidenced in the progressive immigration via Gibraltar of many tropical Atlantic fish (Francour and Bodilis, 2012).

Threshold value

Efforts to manage pathways should be reflected in the short and medium term in a declining trend of new introductions. A levelling off of the current increase in cumulative numbers of NIS, a reduction in their rate of establishment in new countries, and/or a shrinking distribution of these would be a signal that this target is addressed successfully.

Assessment method for monitoring

Trends in introduction and spread of species should be assessed. Rapid Assessment surveys in ports and marinas for target species among the most invasive on an annual basis (Johnson *et al*., 2001). Aquaculture sites should be regularly monitored. Monitoring of Marine Protected areas is expected to produce interesting results (Francour *et al*., 2010). Engagement of citizen scientists for conspicuous species such as fish is a valuable tool (Azzuro *et al*, 2013).

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Area

Central Mediterranean (Adriatic)

Selected Risk

NIS (Non-indigenous Species)

Environmental Target

Reduction of releases of non-indigenous species by maritime transport and aquaculture

Description

The Gulf of Venice, the Gulf of Trieste are among the most visited areas by NIS (*Occhipinti Ambogi*, 2000 ; Crocetta, 201; Lipej *et al.*, 2012). The majority of molluscs and macrophytes were introduced via aquaculture, whereas alien crustacean and polychaeta NIS were mostly related to the introduction by shipping.

Despite the Aquaculture Directive the number of NIS macroalgae keeps increasing (Sfriso *et al*, 2012). This holds true for Venice lagoon and the Mar Piccolo of Taranto (CMED) where important oyster, Manila clam and mussel plants are located. Many species of macroalgae are used for keeping the imported fish and molluscs fresh and at the end of the working day they are discharged: in Venice Lagoon the greater part of the NIS have been reported from canals adjacent to fish markets (Zenetos *et al*, 2012)..

Threshold value

Not possible to assess threshold values. The goal is no new invasions.

Assessment method for monitoring

Trends in introduction and spread of species should be assessed. Rapid Assessment surveys in ports and marinas for target species among the most invasive on an annual basis (Johnson *et al*., 2001). Engagement of citizen scientists for conscious species such as fish (Bodilis *et al*, 2013). This last tool has proven valuable in detecting many fish species in Croatian waters (Pecarevic *et al*., 2013).

Fish markets should be monitored.

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Area

Eastern Mediterranean (Aegean)

Selected Risk

NIS (Non-indigenous Species)

Environmental Target

Reduction of releases of non-indigenous species by maritime transport and aquaculture

Description

Despite the increase in aquaculture, alien species intentionally released in the wild and/or accidentally transported with them have declined in the last decades. The main threat remains navigation. Transport of alien species within the EMED, from the Levantine to the Aegean, is also facilitated with recreational boats. This vector needs to be monitored.

Threshold value

Not possible to be assessed. No new introductions is the goal.

Assessment method for monitoring

Trends in introduction and spread of species should be assessed. Rapid Assessment surveys in ports and marinas for target species among the most invasive on an annual basis (Johnson *et al*., 2001). Marine protected areas should be also monitored (Otero *et al*., 2013). Engagement of citizen scientists for conscious species such as fish (Bodilis *et al*, 2013; Zenetos *et al*, 2013)

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2.3 Over Fishing (Anchovy, Sardine)

Area

Central Mediterranean (Adriatic)

Selected Risk

OF (Over Fishing)

Environmental Target

Achieve sustainable stocks of commercially targeted exploited species (i.e., anchovy, sardine)

Description

The environmental target for small pelagic species (anchovy and sardine) is to maintain the exploitation rate E (E=F/Z; F: fishing mortality; Z: total mortality) below the empirical level of sustainability E<0.4 (Patterson 1992), and is regarded to be pressure-based.

Threshold value

E<0.4

Assessment method for monitoring

Anchovy:

The assessment is based on Integrated Catch at Age (ICA) analysis (STECF, 2013), using fishery independent acoustic surveys information as well as commercial catch at age data. According to the assessment, the status of the anchovy stock was above the reference point.

Sardine:

VPA (STECF 2012) and Integrated Catch Analysis (ICA) (STECF 2013) analyses have been used for sardine assessment in the Adriatic. The ICA has been performed from 1975 to 2011. Data used come from acoustic surveys and from the catch recorded for the fleets of Italy, Croatia and Slovenia. The biological data of the species were used to obtain the age distribution in the catches. According to the assessment, the status of the sardine stock was above the reference point, with an improving trend in the last years.

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Area

Eastern Mediterranean (Aegean)

Selected Risk

OF (Over Fishing)

Environmental Target

Achieve sustainable stocks of commercially targeted exploited species (i.e., anchovy, sardine)

Description

The environmental target for small pelagic species (anchovy and sardine) is to maintain the exploitation rate E (E=F/Z; F: fishing mortality; Z: total mortality; F is averaged over ages 1 to 3) below the empirical level of sustainability E<0.4 (Patterson 1992), and is regarded to be pressure-based.

Threshold value

E<0.4

Assessment method for monitoring

Anchovy:

The assessment is based on fishery independent surveys information as well as on Integrated Catch at Age (ICA) analysis model (SGMED, 2009). Specifically, acoustic surveys estimations (Machias *et al*., 2007) are used for Total Biomass estimates and Daily Egg Production Methodology (DEPM) surveys for the estimation of Spawning Stock Biomass (SSB), both applied at the same time. The application of ICA is based on commercial catch at age data (2000-2008) and as tuning indices the biomass estimates from acoustic surveys and the Daily Egg Production Method (DEPM) estimates are used. According to the assessment the status of the anchovy stock was bellow the reference point.

Sardine:

The assessment is based on fishery independent acoustic surveys information (Machias *et al*., 2007) as well as on Integrated Catch at Age (ICA) analysis (SGMED, 2009; Antonakakis *et al*., 2011) and Extended Survivors Analysis (XSA) (STECF 2012) models. Specifically, the acoustic surveys estimations are used for Total Biomass estimates. The applications of ICA and XSA are based on commercial catch at age data (2000-2008) and as tuning indices the biomass estimates from acoustic surveys are used. According to the assessment, the status of the sardine stock was above the reference point, with an improving trend in the last years.

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