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SUBREGIONAL ASSESSMENT REPORTS

Part I: **UNEP/MAP MED POL SUB REPORTS**

Part II: **UNEP/MAP SPA/RAC SUB REPORTS**

Part III: **UNEP/MAP BP/RAC SUB REPORTS**

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UNEP/MAP – MED POL

Sub-regional assessment of the Status of Marine and Coastal Ecosystems and of Pressures to the Marine and Coastal Environment

Eastern Mediterranean Sea

3 June 2010

Contents

1. Introduction

The Sub-Regional Assessments, including the present one, were prepared by MED POL and sub-regional experts in the framework of the UNEP/MAP's road map for the gradual application of the Ecosystem Approach for the management of human activities in the Mediterranean Sea.

The Ecosystem Approach (ECAP) has been introduced aiming at improving the way human activities are managed for the protection of the marine environment. Following the World Summit on Sustainable Development, the ECAP has been adopted by many International Conventions and Regional Seas Organizations. The Contracting Parties to the Barcelona Convention have adopted it in January 2008 at their Almeria meeting. The proposals to that meeting were developed in the framework of a project (ECOMED) funded by the EC. In this context, any environmental policy should be developed in a way that secures an effective protection of the marine environment and that makes possible the continued provision of marine goods and services for the wealth of the population. The application of the ECAP has the potential to help reach a balance between the requirements of human activities and the conservation of the marine environment. Its adoption and gradual implementation within the framework of the Mediterranean Action Plan (Barcelona Convention) will give new impetus to the preparation of more integrated and holistic policies by the Convention, including the impact of human activities on the marine environment.

To ensure the sustainability of the exploitation of marine goods and services in the Mediterranean Sea, it is important that the ECAP and its related conservation and management measures be applied not only to areas under the jurisdiction of States, but also to the habitats and ecosystems located beyond the national jurisdiction. As a consequence, the implementation of the Ecosystem Approach is not only a task for the Convention and its subsidiary bodies, but also and mainly for its Parties.

The project aims among others, at promoting and enhancing the implementation of the road map for the application of the ecosystem approach to the management of human activities. The road map requires that an assessment of the ecological status and of pressures and impacts is undertaken in four different regions of the Mediterranean, identified on the basis of bio-geographic and oceanographic considerations. The present report is a contribution to such a project with reference to the Eastern Mediterranean Sea.

The assessment is mainly based on:

- Reports prepared in the framework of MED POL by the relevant Contracting Parties (Egypt, Greece, Israel, Lebanon, Syria and Turkey) which include the national Diagnostic Analysis (NDA) on various environmental issues and pressures and the national Baseline Budget (NBB) of emissions and releases of selected pollutants within each respective country;
- Basin-Wide Assessment Reports on selected environmental issues prepared in the framework of MAP;

- A range of other publications which are relevant for the purpose of the present review.

The report will first present a synoptic review of the more relevant features of the physic-chemical and biotic parameters of the coastal and marine ecosystems with the area under review. It will then identify and assess priority issues arising from pressures and impacts related to contamination, dumping activities, nutrient and organic matter enrichment and other factors in this area. Whenever possible, it will assess the availability and reliability of the data on which the assessment is based, identifying any gaps which need to be addressed in the future.

2. Physical and chemical characteristics

2.1 Topography, bathymetry and nature of the seabed

The East Mediterranean Sea constitutes the last remnant of the Mesozoic-Cenozoic oceanic basin of Tethys, which is now almost totally consumed as a result of the long-term plate convergence between Eurasia and Africa. The morphology of the East Mediterranean seafloor relates both to the early history of formation of the deep basins and the recent geodynamic interactions between interfering microplates.

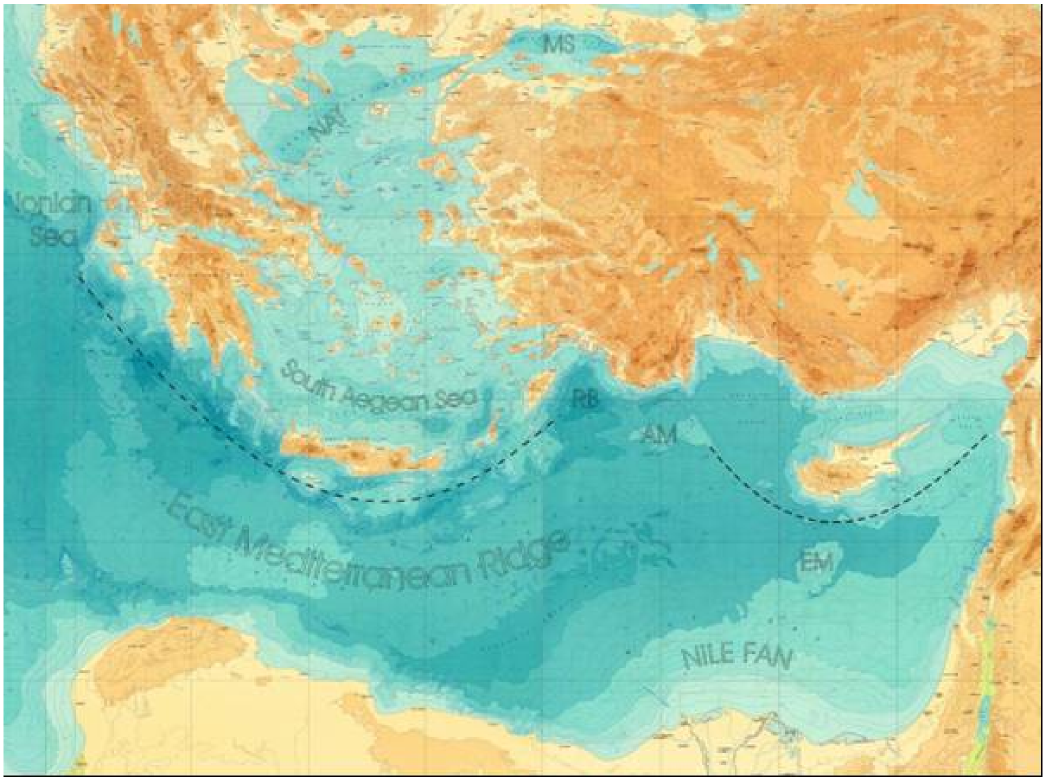


Figure 1. Morphology of Aegean –Levantine Basin

From southwest Peloponnesus to south of Crete and Rhodes, it is characterized by a 1500 km long and 200–250 km wide, arc-shaped, sedimentary wedge / accretionary prism, known as the **East Mediterranean Ridge** (Heezen and Ewing, 1963; Emery et al., 1966). It results from the relatively rapid convergence between Eurasian and African continents, the subsequent subduction of the oceanic crust along the Hellenic Island Arc underneath the overriding Aegean microplate and the deformation of its sedimentary cover, which is responsible for the cobblestone relief of the ridge (Le Pichon et al., 1995; Dewey and Sengoer, 1979; Kreemer and Chamot-Rooke, 2004; McClusky et al., 2000; Reillinger et al., 1997). Mobilisation and diapirism of the Messinian salt layer underlying the 6-7 km thick sedimentary pile of the ridge as well as fluidisation of deep mud layers result to mobilisation and circulation of mud, fluids and gases through fault zones and the formation of numerous mud volcanoes associated with brine lakes and possibly with gas hydrates.

The deep trenches north of the Mediterranean Ridge, known as Hellenic Arc and Trench System, represent the morphological expression of transpressional fault-zones, like the Herodotus and Matapan trenches to the west and the Strabo and Pliny trenches to the east. Maximum depth of 5100m has been observed in the Oinousses Deep, southwest of Peloponese. Numerous canyons and deep valleys originate from the shelf off mainland Greece and the Ionian and South Aegean Islands. Of particular interest is the seafloor topography of the West and East Cretan straits, which are characterized by complex morphology with narrow canyon running between steep sloped ridges. The Hellenic Arc terminates eastward at the Rhodes basin, a 4000-4500m deep relatively young basin east of Rhodes island, characterized by thin sedimentary cover.

Adjacently to the eastern side of the deep Rhodes basin the Anaximander Mountains are rising to minimum depth of about 1500m. They represent a continental block, tectonically separated from Anatolia, composed of alpine rocks (Woodside and others 1997, 1998). The Anaximander Mountains are the only site in the Mediterranean Sea where gas hydrates have been sampled (Lykousis et al., 2004). Their formation is related to the active mud volcanoes which occur on the shallow parts of the Mountains.

A second arc-shaped feature, the Cyprus Arc, initiates at the Anaximander Mountains and comprises the Florence Rise, the Cyprus margin, Larnaka and West Taurus ridges, to finally stretch towards the Levantine coast off Syria. Eratosthenes Seamount, located south of the Cyprus Arc, is a striking positive morphological feature of the Levantine seafloor. It has been interpreted as a continental block of the African plate which is already involved in underthrusting beneath the Cyprus Arc.

The Nile Fan, covering the Egyptian passive margin over more than 100000 km^2, which corresponds to a fairly thick sedimentary wedge, resulting from successive terrigenous inputs delivered by the Nile River since at least 5 million years before present (Dolson, Boucher, & Shann, 2000; Salem, 1976). Extensive mass movements and widespread cold seeping phenomena (mud volcanoes, pockmarks etc) characterize particularly the deeper, western sector of the fan (Loncke et al., 2004)

2.2. Salinity, Temperature, Circulation, Currents

The Mediterranean Sea consists of two major interacting sub-basins, the western and eastern Mediterranean, connected by the Straits of Sicily with sill depth ~1000m. The Ionian, Levantine, Adriatic and Aegean are the sub basins in the eastern part which communicates with the Black Sea through the Strait of Dardanelles.

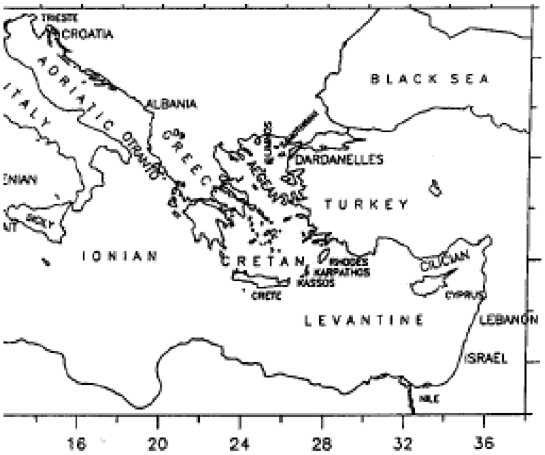


Figure 2: Major basins of the Eastern Mediterranean. Source: Reprinted from Robinson et al 2001

On the largest scales of interest, i.e. interannual and basin-wide scales, the circulation of the Mediterranean is determined by its exchanges of water and heat with the atmosphere through the sea surface and the water and salt with the adjacent seas through the Straits. The thermohaline circulation of the Mediterranean, which reflects the largest scale motion, is forced by the buoyancy exchanges and is driven by its negative heat and freshwater budgets (Theoharis, 2008) and the wind stress forcing (Tsimplis et al 2006)

A general north-south gradient in the net heat flux is apparent, from a net heat loss in the northern half of the basin to a gain in the southern half. The gradient primarily reflects a reduction in the shortwave flux with increasing latitude and strong wind driven latent heat loss in the Aegean Sea. In winter, the heat loss is the major factor contributing to the deep water formation. Significant interannual variations in the winter heat loss are known to occur, the prime example being the severe winters of the early 1990s which have been linked to the Eastern Mediterranean Transient (Theocharis et al., 1999; Josey, 2003),

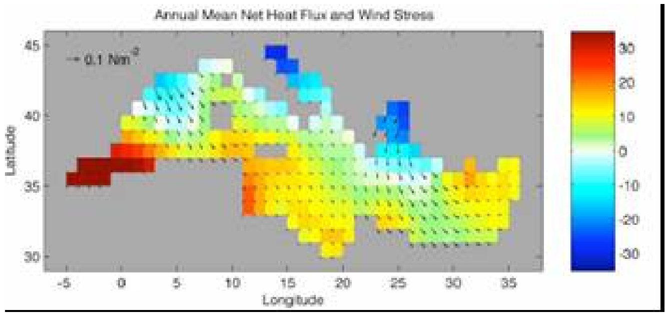


Figure 3: Climatological annual mean fields based on the SOC climatology for the net heat flux and the wind stress. Climatological annual mean net heat flux (colours Wm-2) and wind stress (arrows). Source: Reprinted from Josey et al., 1999

The physical characteristics (T and S) of the waters in eastern Mediterranean are summarised in Table x1. Satellite derived maps describing the mean spatial T and S variability are shown in figure 4 whereas figure 5 provides satellite snapshots of T across the basin in May 2010 (top) and December 2009 (bottom)

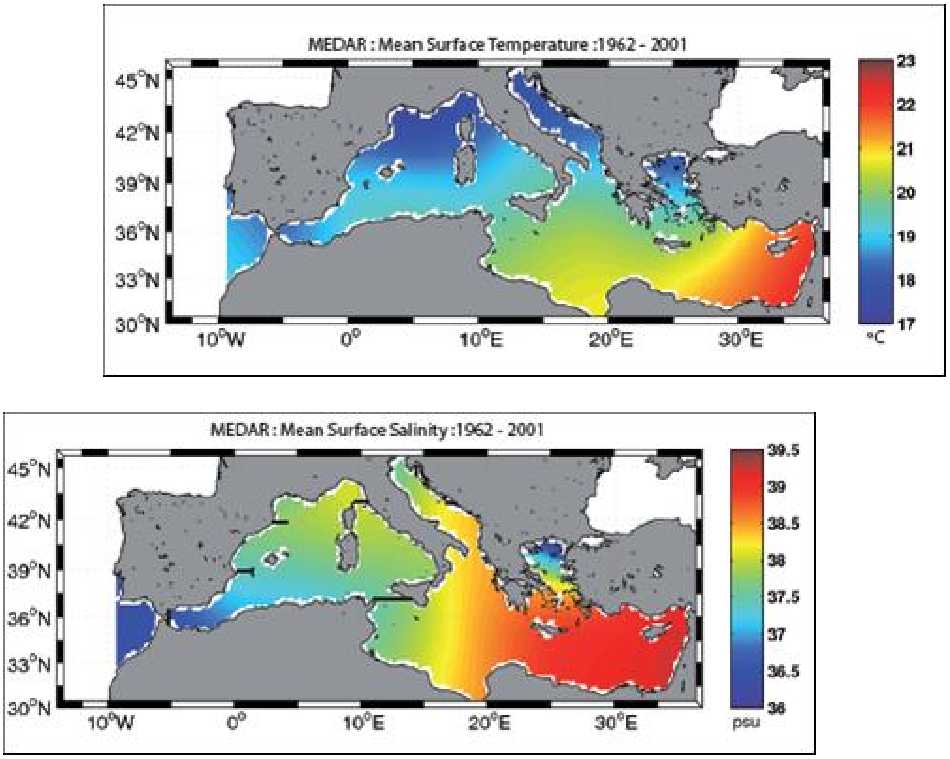


Figure 4: MEDAR Mean surface Temperature (top) and salinity (bottom) 1962 -2001. Source: Reprinted from Vidal-Vijande (2008)

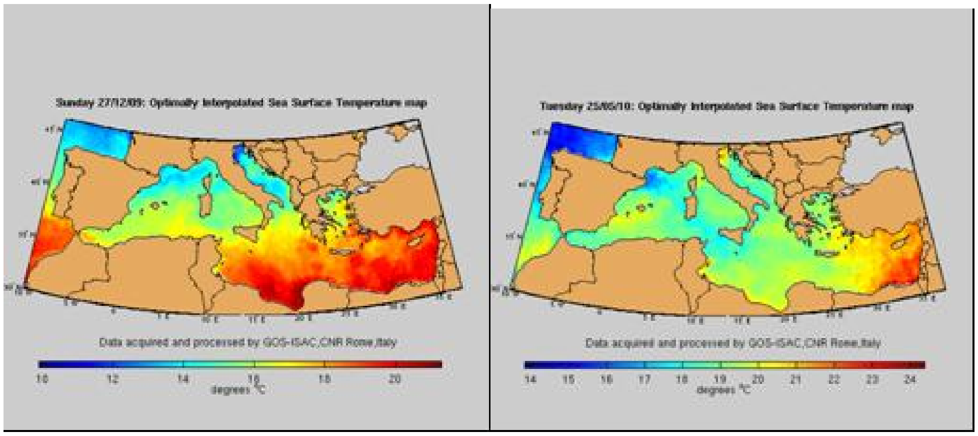


Figure 5. Satellite snapshots of T across the basin in May 2010 (top) and December 2009 (bottom). **Source:** HCMR Poseidon System. http://www.poseidon.hcmr.gr

Table1. Mean surface temperature (winter-summer) values and salinity in the surface and intermediate (200–1 000 m) layers of the basins in the eastern Mediterranean Sea Source: EEA, 2002

	Temperature °C		Salinity	
Sea area	Surface	Layer from 200 to 1000 m	Surface	Layer from 200 to 1000 m
Straits of Crete and south Aegean	16–24	14.9	38.7	38.8
Levantine	16–26	14.9	39	38.9

The general circulation consists of a number of sub-basin-scale gyres and eddies interconnected and interleaved by current jets and filaments. Variabilities include: the shape, position and strength of permanent gyres; the meander pattern, bifurcation structure and strength of permanent currents; and the occurrence of transient and aperiodic eddies and jets (Robinson et al 1991). The inherent seasonal and inter-annual flow variability impinges on the coastal regions and strongly influences the local dynamic of currents (EEA, 1999).

Schematically, the Mediterranean Sea can be considered as comprising three main water masses all of which of major importance in the eastern Mediterranean sub-basin (Figure 6) :

- the Atlantic Water, found in the surface layer, having a thickness of 150-200 m and characterised by a salinity of 36.2 psu near Gibraltar to 38.6 psu in the Levantine basin;

- the Levantine Intermediate Water (the main water body of the Mediterranean) formed in the Levantine basin, from the overlying Levantine Surface Water (LSW) lying in depth between 200-500 m, and characterised by temperatures of 13-15.5°C and salinity of 38.4-39.1 psu;

- the Mediterranean Deep Water formed in both the western and eastern basins; the Western Mediterranean Deep Water (WMDW) is characterised by a temperature of 12.7°C and a salinity of 38.4 psu while the Eastern Mediterranean Deep Water (EMDW) is characterised by a temperature of 13.6°C and a salinity of 38.7 psu.

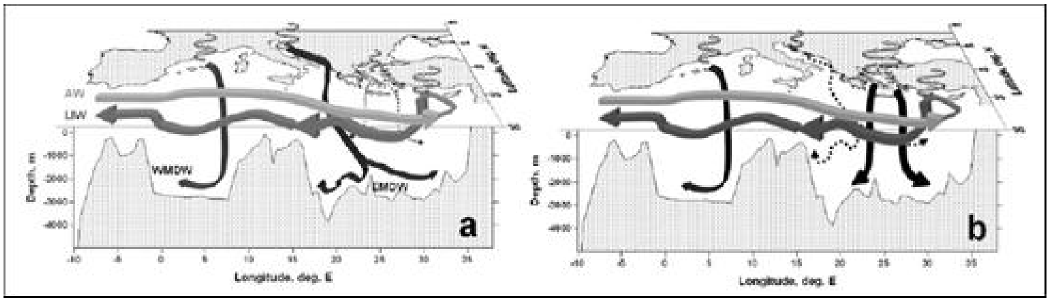


Figure 6. The thermohaline cells of the Mediterranean Sea before the EMT (a) and after the EMT (b). Source: From Tsimplis et al., 2006

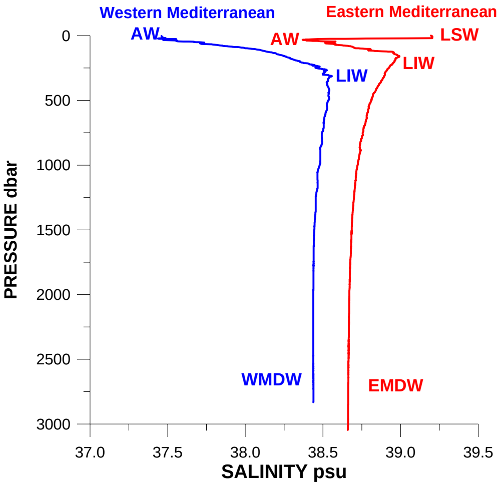


Figure 7. Vertical profile of water bodies throught he Mediterranan

The northwest Levantine Basin is the main source of the Levantine Intermediate Water (LIW), while the Adriatic Sea is basic site of Eastern Mediterranean Deep Water (EMDW). the North and South Aegean Sea, is also an important source which under the synergy of extreme meteorological and favourable hydrological conditions become more effective and may considerably influence the thermohaline circulation in medium or longer term. LIW is considered the most important component of the large scale circulation and dynamics because it spreads throughout most of the Basin and affects the background stratification at the other major deep water formation areas (Adriatic and Aegean). It is also the main constituent (80%) of the high-salinity Mediterranean Water that is exported to the Atlantic Ocean (Lascaratos et al., 1999). Another loop connects the Mediterranean with the Black Sea. In this case, the Aegean Sea acts as an intermediate machine that modifies the received LIW and exports it to the Black Sea via the Marmara Sea

Sub-regional eddies and local current systems have also been identified: the mid-Mediterranean jet which is an intensification of the Atlantic-Ionian Stream in the Levantine basin; the Rhodes and Ierapetra gyres; and the Mersa-Matruh and Shikmona gyres (Figure 8)

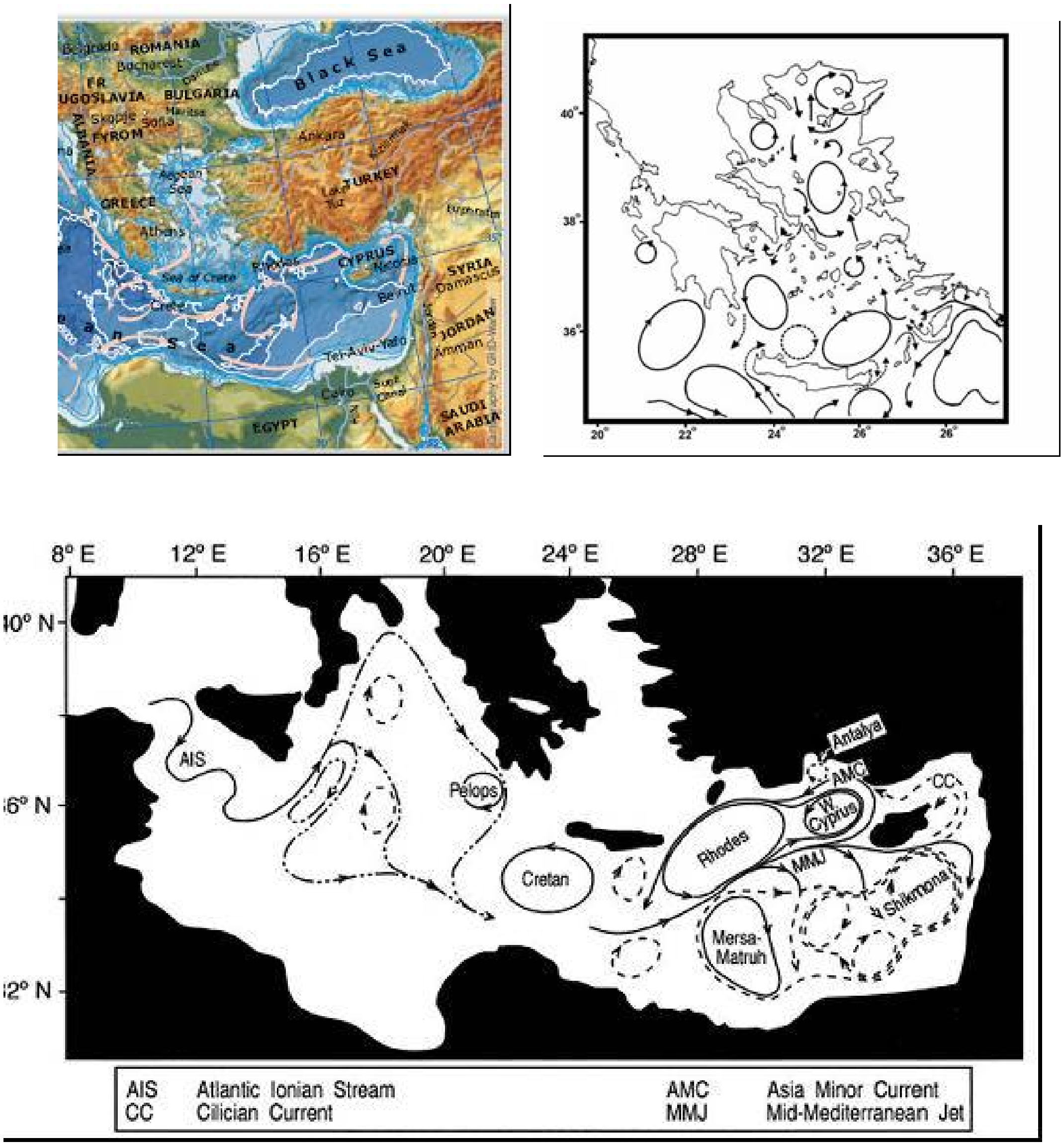


Figure 8: Schematic upper general circulation in Eastern Mediterraena. Source**:** Reprinted from EEA, 2002 (top left), Lykousis et al., 2002 (top right) and Malanotte-Rizzoli et al, 1997 (bottom)

Although the inflow of water from the Black Sea to the Mediterranean is about 2 orders of magnitude smaller than the inflow of Atlantic water, the large salinity difference between the Black Sea and Mediterranean of ~18 psu, makes the role of the Black Sea outflow significant at least for the Aegean Sea. This inflowing Black Sea water occupies the surface layers in the north Aegean Sea where it is thought to have a controlling function on the vertical stability and mixing (Zervakis et al, 2004).

Variations of the Black Sea water outflow may affect the thermohaline circulation in the North Aegean; reductions of ~100 km^3/yr are quite plausible, which are equivalent to changes in evaporation of 0.2 m/yr over the Aegean Sea (Stanev and Peneva, 2002). By contrast, an increase of the transport of Black Sea water into the Mediterranean Sea could block or at least decrease the rates of any deep water formation taking place in the north Aegean Sea (Zervakis et al, 2004).

It is only recently that the role of the Aegean Sea as a deep water formation area has been conclusively demonstrated (Roether et al., 1996). In late 80s-early 90s, abrupt significant consecutive changes, increase in salinity (1987-1992) and drop in temperature (1992-1994), caused continuous increase of density and massive deep water formation in the1999, that altered the thermohaline circulation of the eastern Mediterranean (Figure 6a,b) (Robinson et al., 2001; Roether et al., 1996) with consequences also for the distribution of other environmental parameters (Klein et al., 1999). This major event, unique in the oceanography of the Mediterranean since the beginning of the 20th century, evolved within the last 18 years and was called the "Eastern Mediterranean Transient" (EMT). The engine of the conveyor belt was up to 1987 the convective cell of the Southern Adriatic, while in early 90s the active convection region shifted to the Aegean. The Aegean became the new more effective source than the Adriatic, since it produced not only denser water, namely the Cretan Deep Water (CDW), but also in large volumes (Theocharis et al, 1999). During the EMT period, both open-ocean and shelf processes were the responsible mechanisms for the deep-water formation in the Aegean. The signal of this change has passed the Sicily Strait and has been felt in the western Basin. The event has gradually decayed since 1995 indicating its transitional nature (Theocharis et al., 2002). This abrupt change has been mainly attributed to important meteorological anomalies (extended reduced rainfalls, change in wind patterns, exceptionally consecutive cold winters) in the eastern Mediterranean and to changes of circulation patterns (routes of the AW and LIW) and to the reduced Black Sea Water outflow (Malanotte-Rizzoli et al., 1999; Theocharis et al., 1999; Zervakis et al., 2004). The relationship between the heat loss and large scale atmospheric patterns (e.g. NAO) was also investigated. These episodic changes have been superimposed onto the long-term trends observed in the Mediterranean (Boscolo and Bryden 2001). It is worth mentioning that palaeoceanographic information has certified the large sensitivity of the Aegean Sea to climatic variability. Additionally during the EMT period a new intermediate water was generated in the Cretan Sea, namely the Cretan Intermediate Water (CIW), that replaced the LIW within the western region of the Eastern Mediterranean (Ionian Sea). This salty water fed the Adriatic during the following years, supporting the reactivation of the previous long term dominance of the Adriatic (Theocharis, 2008)

In conclusion, the Mediterranean is not in a steady state and is potentially very sensitive to changes in atmospheric forcing (Tsimplis et al., 2006).

2.3. Riverine fluxes

Rivers are important sources of freshwater and nutrients for the Mediterranean (Ludwig et al 2009). Freshwater inputs alone can influence the marine ecosystems functioning through their control on the general water circulation in the Mediterranean Sea (e.g. Skliris et al., 2007).

Estimates of total riverine freshwater flux into the Mediterranean and Black Sea have been established in a recent work (Ludwig et al 2009) Table 2. In the eastern Mediterranean a decreasing trend has been established for the Aegean (AEG) and the Southern Levantine (SLE); for the North Levantine Sea (NLS) no significant trends could be detected. Discharge reductions were frequent in the rivers of the eastern Mediterranean when the records extend to recent years rather than stopping in the eighties. This is in agreement with Skoulidikis and Gritzalis (1998) who reported that many Greek rivers reduced to up to half of their original discharge.

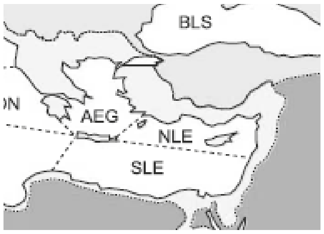
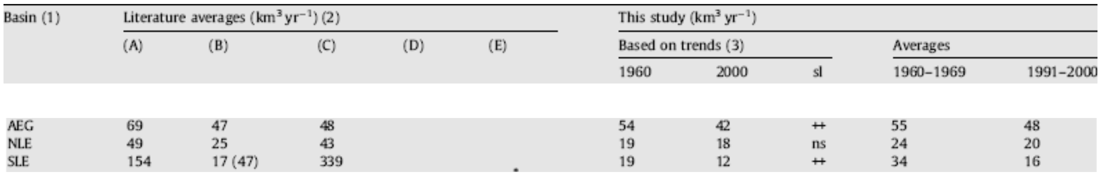


Figure 9: Drainage basins of the Eastern Mediterranean

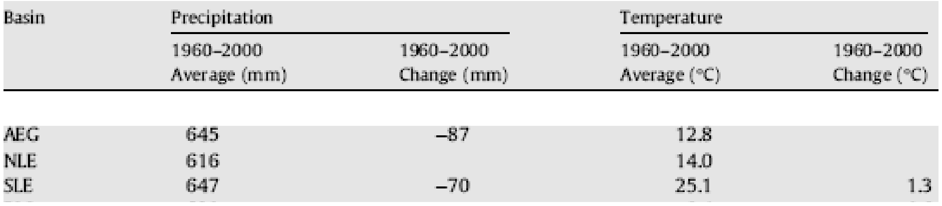
Table 2. Average freshwater fluxes to the Mediterranean and the Black Sea. Source: reprinted from Ludwig et al. 2009



Basin (1)	Literature averages (km³ yr⁻¹) (2)					This study (km³ yr⁻¹)				
	(A)	(B)	(C)	(D)	(E)	Based on trends (3)			Averages	
						1960	2000	sl	1960–1969	1991–2000
AEG	69	47	48			54	42	++	55	48
NLE	49	25	43			19	18	ns	24	20
SLE	154	17 (47)	339			19	12	++	34	16

According to Ludwig et al. (2009), the patchiness of the discharge records makes it difficult to extrapolate the detected changes to larger spatial and temporal scales unless the records are compared to the general evolution of climate. Results of trend analyses on hydroclimatic parameters in the eastern Mediterranean revealed a precipitation decrease with reductions in the Aegean Sea (-13%), and the South-Levantine Sea (-10%) following the general Mediterranean precipitation trend. On the other hand the drainage basins of the Aegean and North-Levantine seas have experienced a decrease in temperature in contrast to the strongly increasing temperatures of the entire basin (Table 3).

Table 3. Trend analyses on hydroclimatic parameters in the eastern Mediterranean Source: reprinted from Ludwig et al. 2009



Basin	Precipitation		Temperature	
	1960–2000 Average (mm)	1960–2000 Change (mm)	1960–2000 Average (°C)	1960–2000 Change (°C)
AEG	645	–87	12.8	
NLE	616		14.0	
SLE	647	–70	25.1	1.3

The application of an appropriate model to the entire drainage basin allowed a realistic valuation of the impact of climate forcing on the river freshwater fluxes to the sea (Ludwig et al., 209). The work suggested that climate change alone could have provoked a water discharge reduction of more than 20% over the entire Mediterranean Strongest reductions appear for the Alboran (-64%), Southwestern (-31%), Southern-Levantine (-25%), Aegean (-24%) and Adriatic (-17%) seas. Such reduction in only 40 years are highly remarkable (Ludwig et al., 2009). This underlines why the Mediterranean region was identified as one of the most prominent ‘‘hot-spots” in future climate change projections (Giorgi, 2006).

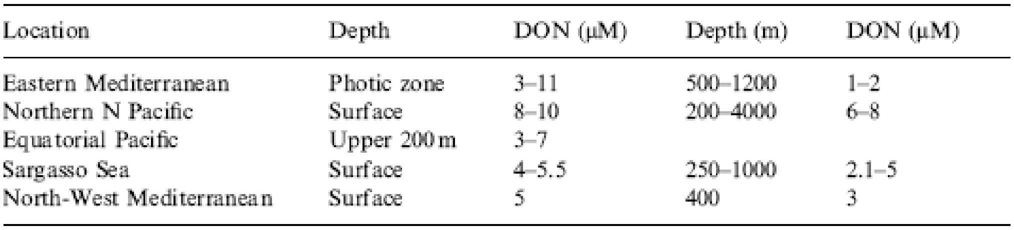
These reductions in river flow may have hydrological implications affecting the circulation in the basin. Skliris et al. (2007) demonstrated by modelling that reductions in the riverine freshwater inputs can cause greater deep water formation rates in the Mediterranean Sea. Our data show that during 1985–1994the river discharges to the Aegean Sea were suddenly reduced by more than 30% compared to the previous years (1960–1984). This may have contributed to higher salinities in the surface waters, favouring the formation of deep waters and the onset of the Eastern Mediterranean Transient.

2.4 Nutrients

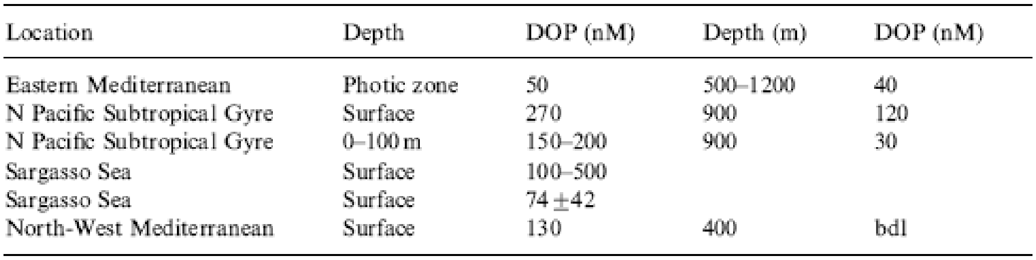
2.4.1 Nutrients spatial and temporal trends

The Mediterranean Sea is oligotrophic and thus chlorophyll and nutrient concentrations are lower than in the other regional seas. The Eastern Mediterranean Sea is an extreme oligotrophic environment (Krom et al., 2003; 2005) Table 4, whose ultra-oligotrophic status is reflected in the exceptional water clarity low concentrations of nutrients, extremely low values for all phytoplankton related variables, including chlorophyll a, primary production and cell abundance dominance of small-size phytoplankton and outstandingly low bacterial abundance and production (Psarra et al., 2005 and references therein); this extreme ‘‘poverty’’ has also been verified by satellite imagery of sea-surface chlorophylls and derived primary production (Bosc et al., 2004) (table 5, figures 10,11,12). Primary productivity in the eastern Mediterranean (and particular in the Levantine basin) has been shown to be phosphorus limited (Krom et al., 1991) or co-limited as recently verified (Krom et al 2005, Law et al., 2005, Psarra et al 2005, Pitta et al 2005, Zohary et al, 2005).

Table 4: Concentration of DOC (top), DON (middle) and measured by High Temperature Oxidation and DOPUV measured by UV photooxidation in the eastern Mediterranean (Levantine), compared to values determined in other subtropical oligotrophic regions of the world’s oceans. Source: Reprinted from Krom et al 2005



Location	Depth	DON (µM)	Depth (m)	DON (µM)
Eastern Mediterranean	Photic zone	3–11	500–1200	1–2
Northern N Pacific	Surface	8–10	200–4000	6–8
Equatorial Pacific	Upper 200 m	3–7		
Sargasso Sea	Surface	4–5.5	250–1000	2.1–5
North-West Mediterranean	Surface	5	400	3



Location	Depth	DOP (nM)	Depth (m)	DOP (nM)
Eastern Mediterranean	Photic zone	50	500–1200	40
N Pacific Subtropical Gyre	Surface	270	900	120
N Pacific Subtropical Gyre	0–100 m	150–200	900	30
Sargasso Sea	Surface	100–500		
Sargasso Sea	Surface	74 ± 42		
North-West Mediterranean	Surface	130	400	bdl

Satellite snapshots and maps of averages (seasonal and/or multi annual) are available that can be used to monitor algal blooms and primary production on a long term basis in order to detect modifications in the biogeochemical equilibrium and assist in monitoring the onset and impacts of eutrophication (Figures 10,11, 12). However no long time series exist of field data to acquire a trend of nutrient enrichment and eutrophication.

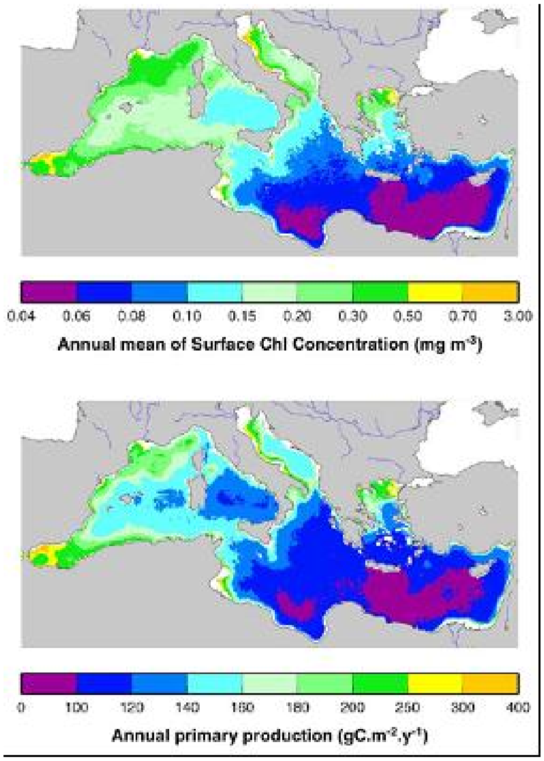


Figure 10: Maps of annual averages of (top) surface algal biomass and (bottom) primary production, computed over the period September 1997 to December 2001. Bosc et al 2004

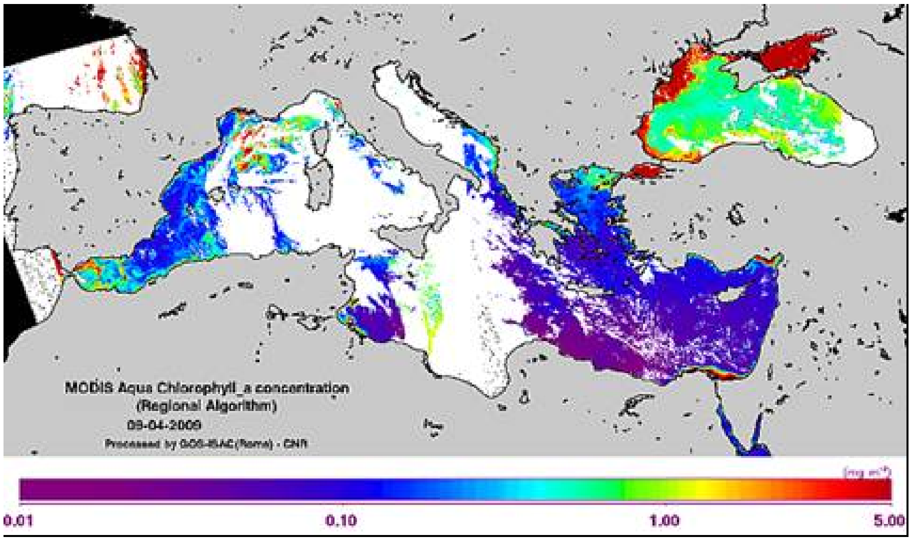
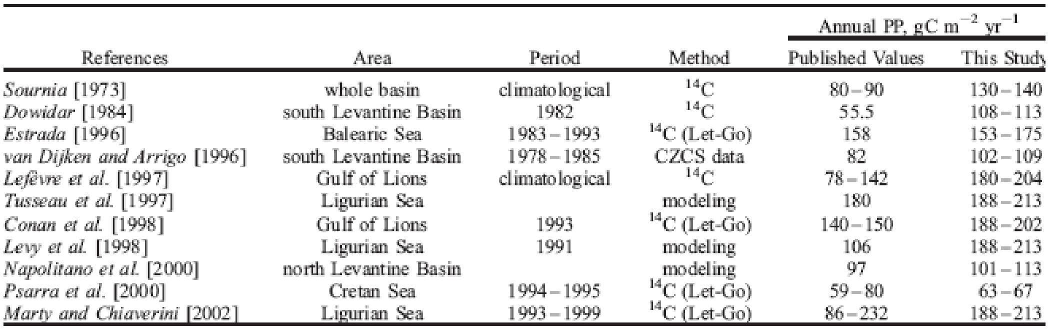


Figure 11: MODIS Aqua Chloroplyll-a concentration (regional algorithm), 9/4/2009 Source: HCMR Poseidon System

Daily MODIS Aqua Chloroplyll-a images over Meditarranean are downloaded from GOS-ISAC, CNR, Rome Italy. The data processing for Chloroplyll-a concentration is based on regional algorithms. More information can be found at http://gos.ifa.rm.cnr.it.

Table 5**:** Published Values of Annual Primary Production (in g C m^{-2} yr^{-1}) for Various Regions of the Mediterranean compared to SeaWiFS Data over the Period 1998–2001). Source**:** Reprinted from Bosc et al 2004



References	Area	Period	Method	Annual PP, gC m^{-2} yr^{-1}	
				Published Values	This Study
Sournia [1973]	whole basin	climatological	^{14}C	80 – 90	130 – 140
Dowidar [1984]	south Levantine Basin	1982	^{14}C	55.5	108 – 113
Estrada [1996]	Balearic Sea	1983 – 1993	^{14}C (Let-Go)	158	153 – 175
van Dijken and Arrigo [1996]	south Levantine Basin	1978 – 1985	CZCS data	82	102 – 109
Lefèvre et al. [1997]	Gulf of Lions	climatological	^{14}C	78 – 142	180 – 204
Tusseau et al. [1997]	Ligurian Sea		modeling	180	188 – 213
Conan et al. [1998]	Gulf of Lions	1993	^{14}C (Let-Go)	140 – 150	188 – 202
Levy et al. [1998]	Ligurian Sea	1991	modeling	106	188 – 213
Napolitano et al. [2000]	north Levantine Basin		modeling	97	101 – 113
Psarra et al. [2000]	Cretan Sea	1994 – 1995	^{14}C (Let-Go)	59 – 80	63 – 67
Marty and Chiaverini [2002]	Ligurian Sea	1993 – 1999	^{14}C (Let-Go)	86 – 232	188 – 213

The general spatial and temporal trends of algal blooms and primary production can be summarised by the main findings of Bosc et al (2004) when analysing SeaWiFS data. All the subregions in this basin are characterized by low chl-a concentrations all around the year (e.g. 0.03 to 0.3 mg m^{-3} for spatial averages), the lowest concentrations being observed in the Levantine Basin (with the exception of waters at the boundary of the Nile plume). A marked seasonal cycle is observed in the various regions, with a decrease of the algal biomass by a factor up to 3–4 from winter to summer (e.g. for the Levantine Basin, from 0.12 to 0.03 mg m_3 on average, Bosc et al 2004), and large interannual variation (e.g in 200-2001 the largest decrease is observed for the Aegean Sea (-14%), and the North Levantine Basin (-11%) as depicted in the satellite image analysis in figures 12 and 13. Seasonal and interannual variations are also present in primary production where surface biomass in most provinces decreases significantly from winter to summer and as a result, primary production exhibits a weakly marked maximum over summer.

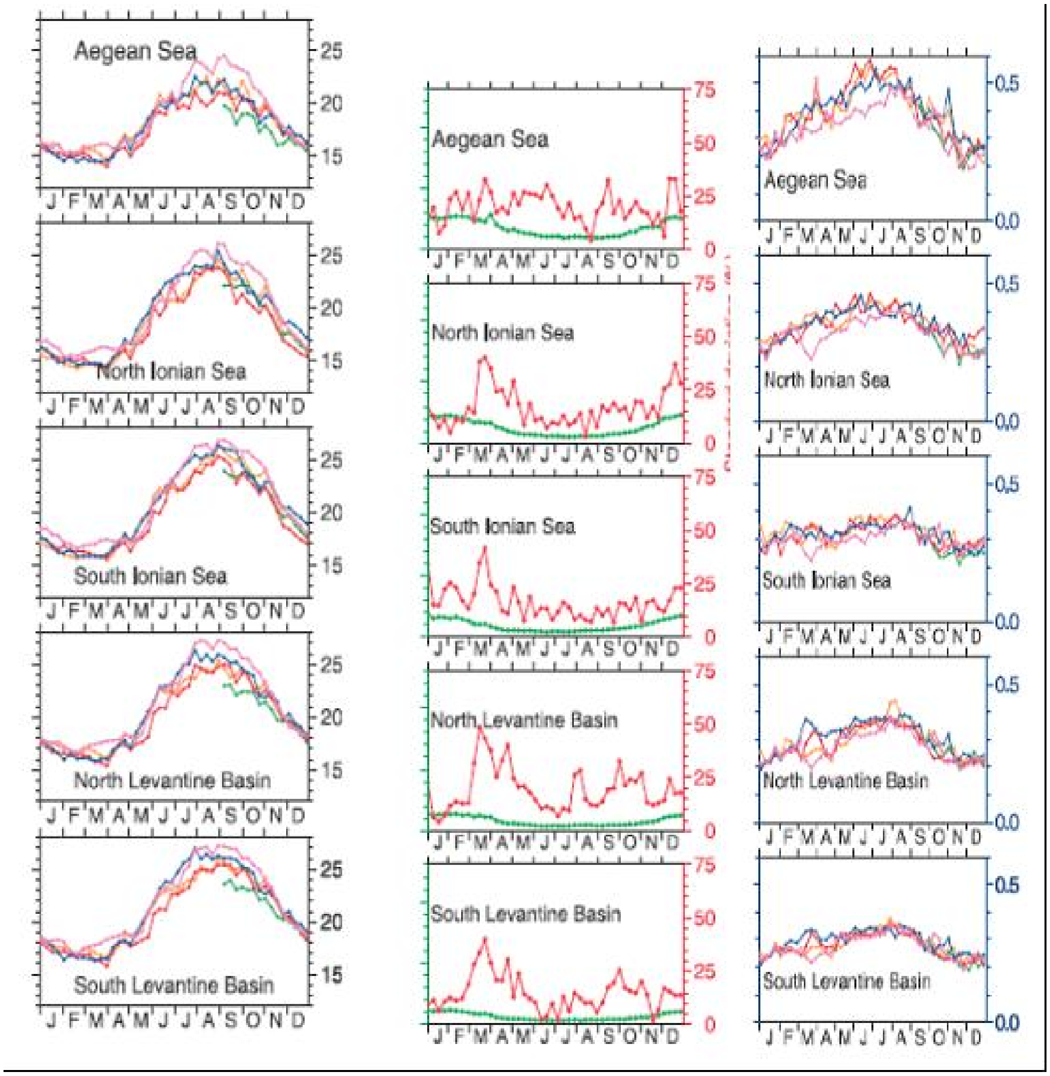


Figure 12: Weekly values (over the period September 1997 to December 2001) of the average temperature of the productive layer (left), eight-day averages of the chlorophyll concentrations derived from SeaWiFS data averaged over the different years (green lines, in mg m^{-3}; left scales), (centre) and eight-day averages of the primary production (in gC m^{-2} d^{-1}), and averaged over the whole basin and the various regions. Source: Bosc et al 2004

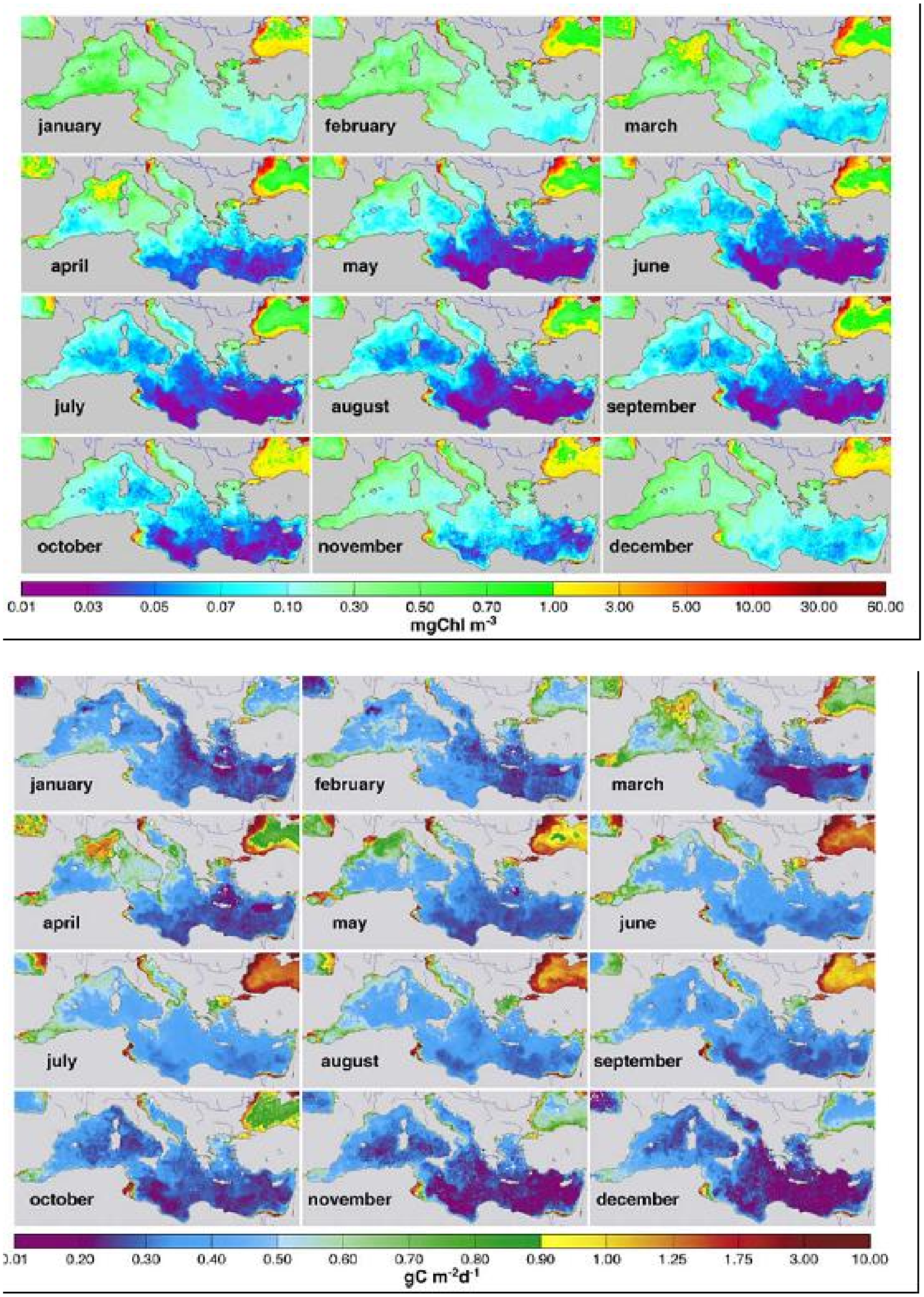


Figure 13 Monthly chlorophyll maps derived from SeaWiFS data (reprocessing #4), after correction using the regional algorithm, (top) and primary production (bottom) for the year 1999. Source: Reprinted from Bosc et al 2004

In recent assessments of Chlorophyll and nutrients in transitional, coastal and marine waters along EU 27 countries (EEA CSI 021and CSI 023 respectively, 2009) in 2005 high oxidised nitrogen concentrations were observed at single stations in Cyprus and Greece in Eastern Mediterranean; Greece also exhibited high concentrations of orthophosphate (Figure 14). Only Greece has submitted long enough time series to perform a trend analysis which shows that oxidized nitrogen concentrations are increasing at 4% of the stations, decreasing at 1% of the stations, and no statistically significant trend can be detected at the remaining 95% of stations. No statistically significant trend could be detected for orthophosphate. As for chlorophyll (investigating eutrophication in European waters) high concentrations were observed at single stations in the Gulf of Orfani in Greece (Figure 15); however as not long enough time series exist to detect any statistically significant trend.

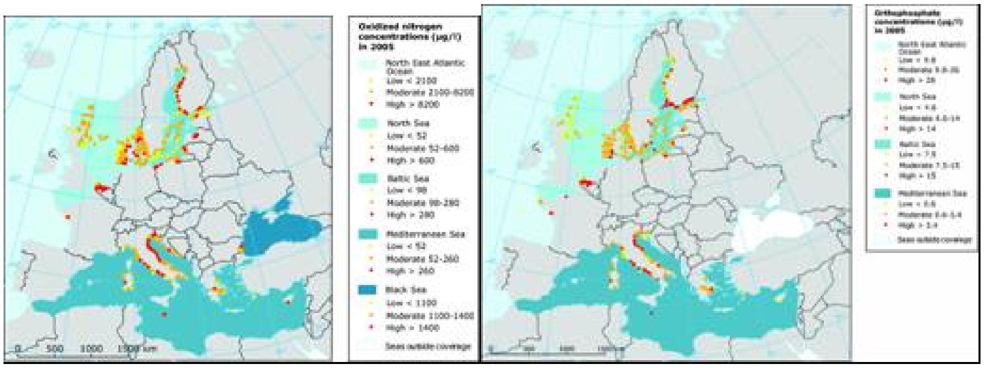


Figure 14 Map of orthophosphate (left) and winter oxidized nitrogen (right) concentrations observed in 2005. Source: EEA, CSI 023, 2009

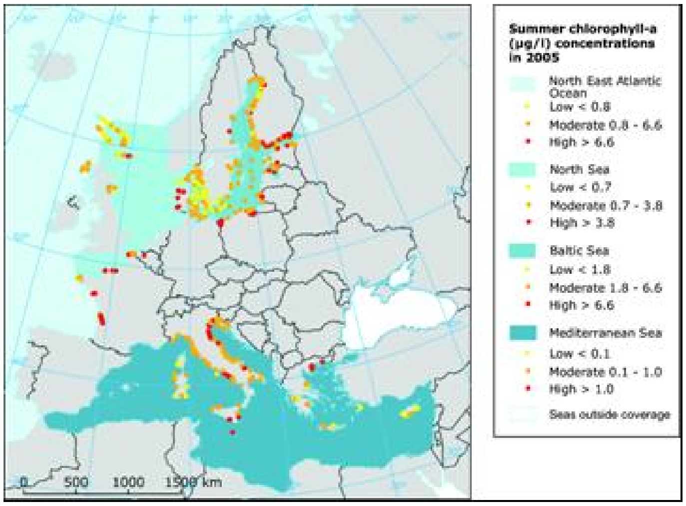


Figure 15: Map of summer chlorophyll-a concentrations observed in 2005 . Source: EEA, CSI 021, 2009

Chlorophyll variations in surface waters, in general revealed that the highest levels correspond to the areas close to river deltas or those off large urban agglomerations The main spatial features, detected include the general gradient in algal biomass from north to south and from west to east of the Eastern Basin, the ‘‘ultra-oligotrophic cores’’ of the south Levantine Basin (corresponding to the Mersa-Matruh and Shikmona Gyres, the Nile plume, the north-south gradient in algal biomass in the Aegean Sea, attributed to the combined effects of river inputs, northerly winter and signal from the nutrient reach Black Sea waters. Hot spots can also be identified (see part 3.1 Nutrient and organic enrichment).

2.4.2 Nutrients and rivers

The reduction of the river freshwater discharge suggested by Ludwig et al (2009) could imply a reduction of the associated fluxes of many nutrients which could be particularly important for an oligotrophic system like the Mediterranean Sea. However this was not the case. According to Ludwig et al (2009) although analysis results indicated that nitrogen pollution was not a major problem in Mediterranean rivers and was usually dominated by diffuse sources, in particular agriculture, which is characterized in southern Europe by less intensive cultivation practices (figure 16 depicts the evolution of N fertilisers and the load drained particularly in the Aegean Sea) and that no clear regional pattern could be neither observed for Phosphorus whose pollution is normally dominated by point sources, such as urban waste waters, the evolution of river fluxes of nutrients exhibits increasing nitrogen and phosphorus fluxes, enhanced via anthropogenic activities in the drainage basins.

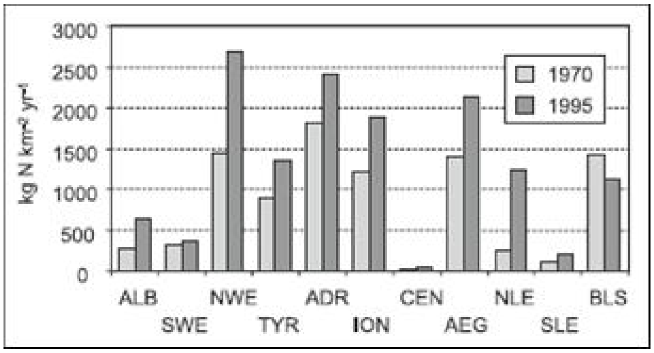
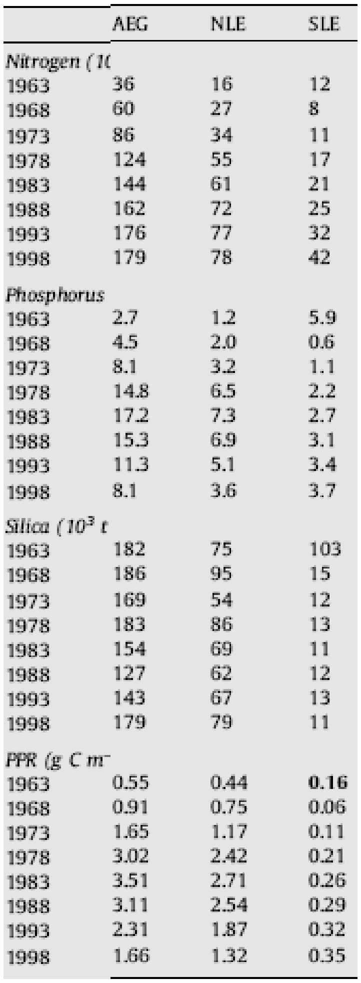


Figure 16: Fertilizer use in the different drainage basins of the Mediterranean and Black Seas in 1975 and 1995. Source: Ludwig et al 2009

However, the anthropogenic nutrients did not follow exactly the same trends. Efforts undertaken to mitigate point source pollutions in the 1980s and 1990s had an immediate impact on the phosphorus loads; after a dramatic increase in the 1960s and 1970s, phosphorus rapidly declined to early 1960s levels. The pattern is somehow different for nitrogen, mainly released via diffuse sources such as fertilizers. Nitrogen followed more or less a continuous increase over the study period, before starting to decrease only recently in the whole basin but not so in the eastern basin (Ludwig et al, 2009). With regard to the situation in 1960 (Table 6), Mediterranean and Black Sea rivers are nowadays characterized by a strong excess of nitrogen over phosphorus and silica. Interestingly Gross primary production sustained by rivers (PPR) represents only less than 2% of the gross production (PP) in the Mediterranean; possible ecological impacts of the changing river inputs should therefore be visible only in productive coastal areas (Ludwig et al, 2009).



	AEG	NLE	SLE
Nitrogen (1			
1963	36	16	12
1968	60	27	8
1973	86	34	11
1978	124	55	17
1983	144	61	21
1988	162	72	25
1993	176	77	32
1998	179	78	42
Phosphorus			
1963	2.7	1.2	5.9
1968	4.5	2.0	0.6
1973	8.1	3.2	1.1
1978	14.8	6.5	2.2
1983	17.2	7.3	2.7
1988	15.3	6.9	3.1
1993	11.3	5.1	3.4
1998	8.1	3.6	3.7
Silica (10^3 t			
1963	182	75	103
1968	186	95	15
1973	169	54	12
1978	183	86	13
1983	154	69	11
1988	127	62	12
1993	143	67	13
1998	179	79	11
PPR (g C m			
1963	0.55	0.44	**0.16**
1968	0.91	0.75	0.06
1973	1.65	1.17	0.11
1978	3.02	2.42	0.21
1983	3.51	2.71	0.26
1988	3.11	2.54	0.29
1993	2.31	1.87	0.32
1998	1.66	1.32	0.35

Table 6: Riverine nutrient budgets for the Eastern Mediterranean

Nitrogen (10^3 t N yr^{-1}), Phosphorus (10^3 t P yr^{-1}), Silica (10^3 t Si yr^{-1}) PPR (g C m^{-2} yr^{-1}PPR= Potential marine primary production supported by rivers. The values were calculated according to the limiting nutrient in the river loads (P = normal, N = bold) and averaged for 5 years time slices. Source: reprinted from Ludwig et al, 2009.

3.4.3. Atmospheric deposition

Finally, atmospheric deposition data tend to be regarded as not consistent to support reliable calculations for Eastern Mediterranean (UNEP/MAP 2007b). Some information exists for wet deposition fluxes of inorganic nutrients (PO4-, NO3-, NO2, NH4+) at sites along the Mediterranean coast of Israel, which were made as part of a long-term study (MEDPOL Phase II and III monitoring activities, Herut et al., 1999, Herut, 2005). Herut (2005) has reported on dry atmospheric deposition of N and P in SE Mediterranean focusing on the role of Sahara dust in enhancing primary production.

2.5. Sedimentology

The basin sediments of the eastern Mediterranean Sea are muddy with high carbonate contend due to the biogenic particles originated from the phytoplanktonic production of the system. Deep-water ventilation changes, on longer time scales, are witnessed in the sedimentary record of the eastern Mediterranean Sea, by the presence of sapropels. These dark organic-rich layers are found throughout the eastern Mediterranean Sea.

The precise mechanisms leading to this unusual past accumulation of organic matter in the Mediterranean Sea are still a matter of debate (Anagnostou pers. comm.). Their formation is related to a slow-down of deepwater ventilation attributed in most cases, to changes into much wetter climatic conditions. For the sapropel formation the stagnation/anoxia theory has been proposed, which suggests that, during times of excessive freshwater influx into the Mediterranean Sea, the water column became strongly stratified, preventing vertical mixing and oxygen supply to the bottom waters. This procedure contributed to the preservation of higher percentage of the total organic carbon (TOC) and to the sapropel formation with >2–5% total organic carbon. The sapropel formation seems to be also associated with increases in export productivity and increase in the flux of organic matter.

Aegean Sea, which shows very complicated seafloor morphology, is chosen as a case study area, to present the main sedimentological characteristics with emphasis on coastal areas based on Karageorgis et al, 2005 and Sakellariou et al 2005.

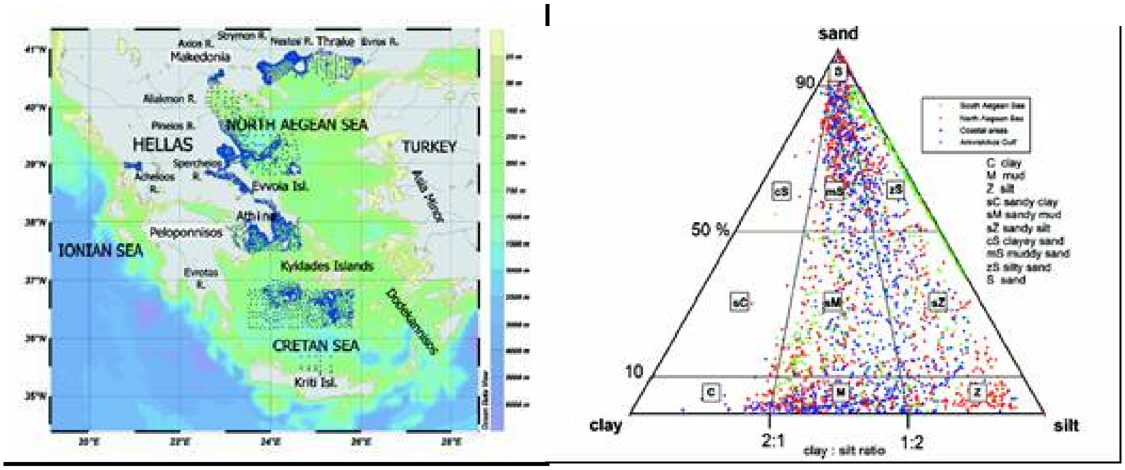
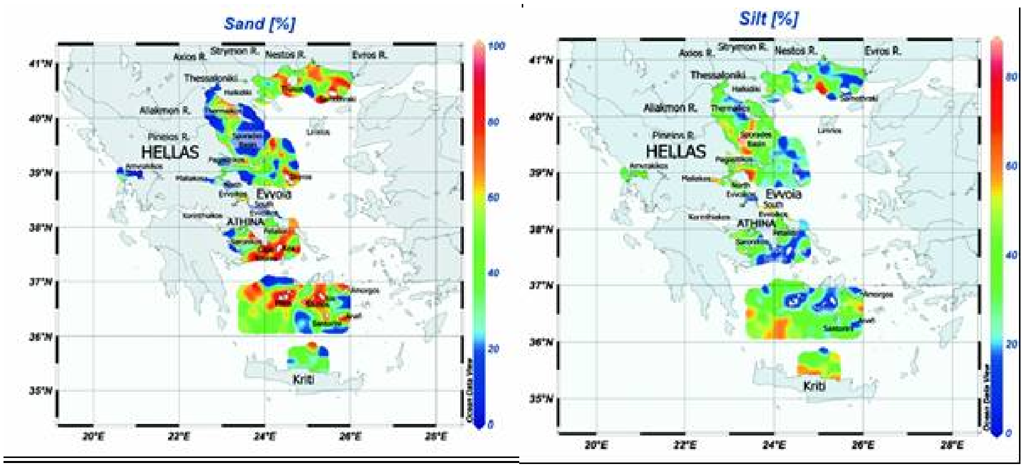


Figure 17: Locations of surface sediment sampling stations (blue dots)[left], Sand-silt-clay ternary diagram of surface sediments from the Hellenic Seas. Source: Reprinted from SoHelMe, 2005

The results of all the sedimentological data are presented in the ternary diagram of the Figure 17 and the spatial distribution of the sand, silt, clay and carbonate content in the maps in Figure 18.



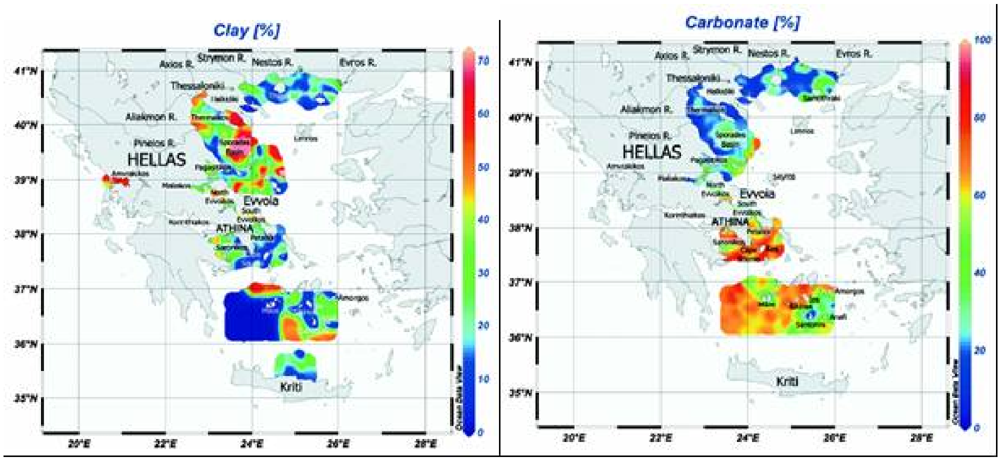


Figure 18: Spatial distribution map of dry weight percentage of sand, silt, clay and carbonate content in sediments of the Hellenic Seas. Source: Reprinted from SoHelMe, 2005

North Aegean Sea:

Sand and silt are the major constituents of the sediments, with a minor amount of clay and, therefore, these sediments are classified as sands, muddy sands, muds and silts Sand is the predominant sediment fraction in the continental shelf and upper slope of the north Aegean Sea. The sediments of the north Aegean Sea are generally characterized by low carbonate content (<20%). In the continental shelf (water depth <130 m) and upper slope area (water depth 130-300 m) carbonate content is generally <20%, however, some elevated values appear around the islands of the area. In coastal areas and semi-enclosed gulfs, sediments are generally muddy sands and muds. The carbonate content varies from values <40% in values up to 70%.

South Aegean Sea:

Sediments collected from the south Aegean Sea cover the southern part of the Kyklades Islands, the northern part of the Cretan Sea and a part of the central offshore sector north of Kriti Island. The sediments of this region are mainly composed of sand and silt, and minor clay content. They are classified mainly as sandy muds and muddy sands. Sediments around the islands are characterised by high sand content (>80%), with the volcanoclastic component predominating around Milos and Santorini and the biogenic component in the rest of the area. Offshore sand decreases to smaller contents. The silt content is up to 70%, the higher values are observed mainly in the Cretan Sea. The clay content is also up to 60%. The carbonate content exhibits high values (60 to >80%) in the areas where the biogeniccomponent predominates in the sand fraction.

3. Pressures and impacts

3.1. Pollution sources

Although most big cities in the eastern Mediterranean operate wastewater treatment plants for a part of their population, there is still an important part of the population of this area, which is not connected to a wastewater treatment facility (Table 7 (UNEP/MAP-Plan Bleu 2009).

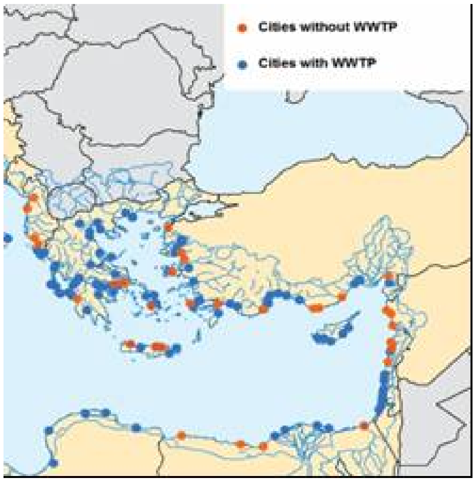
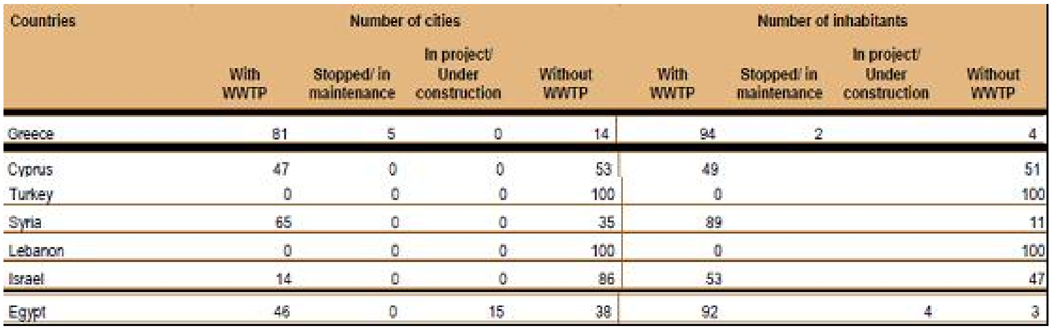


Figure 19: Localisation of waste water treatment plants on the coast of Aegean – Levantine. Source: UNEP/MAP-Plan Bleu, 2009.

Table 7: % of Waste Water Treatment Plants in Aegean-Levantine coastal cities Source: UNEP/MAP-Plan Bleu 2009

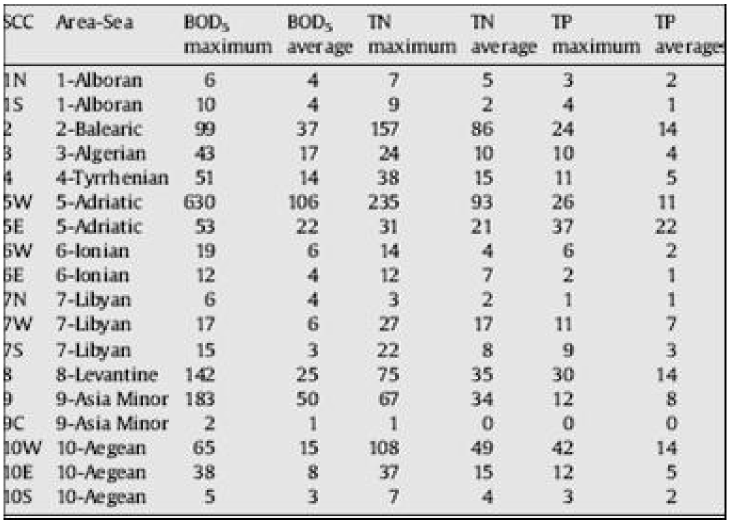


Countries	Number of cities				Number of inhabitants			
	With WWTP	Stopped/ in maintenance	In project/ Under construction	Without WWTP	With WWTP	Stopped/ in maintenance	In project/ Under construction	Without WWTP
Greece	81	5	0	14	94	2		4
Cyprus	47	0	0	53	49			51
Turkey	0	0	0	100	0			100
Syria	65	0	0	35	89			11
Lebanon	0	0	0	100	0			100
Israel	14	0	0	86	53			47
Egypt	46	0	15	38	92		4	3

Notes: WWTP = Waste Water Treatment Plants; This table do not include the cities discharging into rivers

Stamou and Kamizoulis (2009) using UNEP/WHO, 1999 and UNEP/MAP, 2000 and 2004 data estimated the BOD_5, TN and TP loads for the present conditions discharged to the 18 typical Surface Coastal Currents (SCCs) of the Mediterranean (Table 8). Areas 8-Levantine, 9-Asia Minor, 10W-Aegean appear to be the most enriched in BOD_5, Total N and total P in the sub-region.

Table 8 Calculated average and maximum concentration values (mg/l) in the 18 Surface Coastal Currents (SCCs) for the existing conditions. Source: Reprinted from Stamou and Kamizoulis, 2009



SCC	Area-Sea	BOD_5 maximum	BOD_5 average	TN maximum	TN average	TP maximum	TP average
1N	1-Alboran	6	4	7	5	3	2
1S	1-Alboran	10	4	9	2	4	1
2	2-Balearic	99	37	157	86	24	14
3	3-Algerian	43	17	24	10	10	4
4	4-Tyrrhenian	51	14	38	15	11	5
5W	5-Adriatic	630	106	235	93	26	11
5E	5-Adriatic	53	22	31	21	37	22
6W	6-Ionian	19	6	14	4	6	2
6E	6-Ionian	12	4	12	7	2	1
7N	7-Libyan	6	4	3	2	1	1
7W	7-Libyan	17	6	27	17	11	7
7S	7-Libyan	15	3	22	8	9	3
8	8-Levantine	142	25	75	35	30	14
9	9-Asia Minor	183	50	67	34	12	8
9C	9-Asia Minor	2	1	1	0	0	0
10W	10-Aegean	65	15	108	49	42	14
10E	10-Aegean	38	8	37	15	12	5
10S	10-Aegean	5	3	7	4	3	2

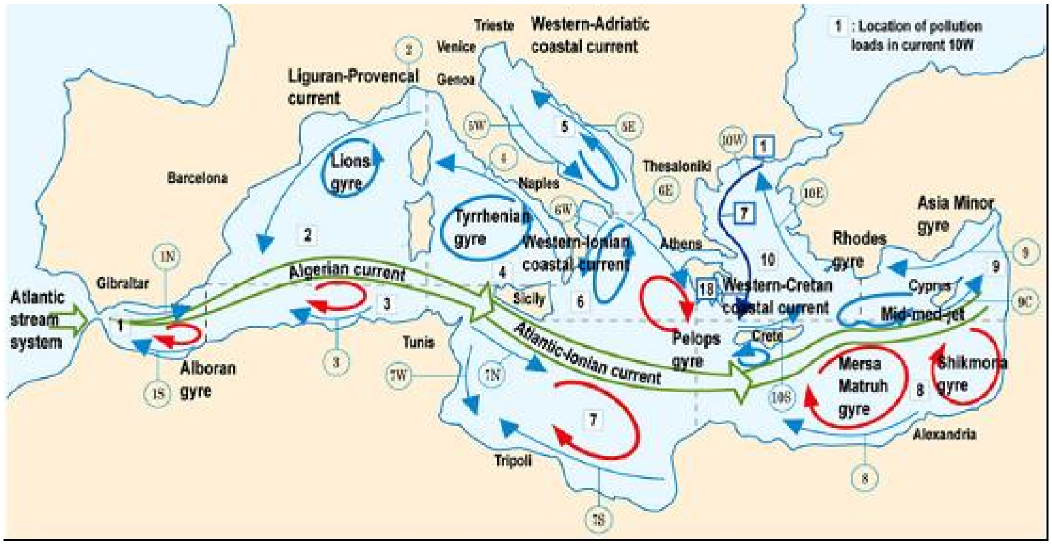


Figure 20: The 10 areas of the Mediterranean Sea and the 18 coastal currents (SCCs). Source: Reprinted from Stamou and Kamizoulis, 2009

The status of waste water treatment in Aegean-Levantine countries as reported to UNEP/MAP/MED POL/WHO, 2004 and 2008s is described below and provides more information than the factor of the presence/absence of WWTP in action

Cyprus

Cyprus is the only country were all wastewater produced is treated and is reused, thus there is no disposal of sewage into the sea for cities >10000 inhabitants (permanent population 330,300). For the 106,958 inhabitants (populating twenty-four coastal cities with population between 2,000 and 10,000), eight cities are served by a main sewage treatment plant or individual treatment systems (UNEP/MAP/MED POL/WHO, 2004 and 2008).

Egypt

Of the 5,161,000 inhabitants (in cities > 10000 inhabitants) in 2003), 50% were served by wastewater treatment plant. However, Alexandria seems to produce large quantities of primary treated wastewater (74% of the population is served by wastewater treatment plant) and the remaining cities are subjected to secondary treatment). There was no direct discharge of treated sewage into the sea. Regarding the untreated sewage there was no adequate information on either quantities or way of discharge (UNEP/MAP/MED POL/WHO, 2004). In the 12 coastal cities (population between 2,000 and 10,000) with a resident population of 65,458 inhabitants, only two operated wastewater treatment plants. Treated wastewater discharge was led into the sea by canals. Regarding the untreated sewage is disposed in the soil, possibly in desert (UNEP/MAP/MED POL/WHO, 2008).

Greece

According to the 2003 information, 7.2 million people inhabited 63 areas each with population greater than 10,000 that are located close to the coastline. More than 60% of the population is located to the greatest Athens area (capital of Greece) and Thessaloniki. Only 10% of the wastewater produced is untreated and the treated wastewater in most cases this is disposed after secondary treatment trough submarine outfalls or in some cases trough rivers or streams to the sea (UNEP/MAP/MED POL/WHO, 2004).

According to UNEP/MAP/MED POL/WHO, 2008, 764,580 peopled resided in hundred and seventy eight areas with population between 2,000 and 10,000 inhabitants that are located close to the coastline and approximately 31% of the total number of the cities were served by a WWTP, 42% did not have treatment facilities while a significant percentage of 23% will be served by a treatment system (plants under construction/projected). Treated wastewater, 61,322 m^3/ day, was discharged mainly to the aquatic environment (through a submarine outfall - 36% of the cases - or directly into the sea – 55% of the cases-). Untreated sewage was reported not to be directly discharged to the marine environment since in all cases raw sewage from households is collected to septic tanks.

Israel

All 3,640,000 habitants in the nine cities with population more than 10000 were served by respective wastewater treatment plants, (seven operate secondary treatment and two operate primary treatment (UNEP/MAP/MED POL/WHO, 2004). All the 8 coastal cities (population between 2000-10000) with a resident population of 44,982 inhabitants were served by respective wastewater treatment plants, which in all of the cases provided secondary treatment, while only one coastal city out of eight was served at about 50% by a plant and uses septic tanks for the rest 50% (UNEP/MAP/MED POL/WHO, 2008). In both categories there was no discharge of untreated wastewater while treated wastewater was mainly reused.

Lebanon

Available information for Lebanon refers to only cities (locations) which gather a population over 10,000 residents. Wastewater facilities served 32% of the population of 2,256,000 persons in large coastal cities (only one of the seven cities, Beirut, was served by a primary wastewater treatment plan), while sewage system network serves the remaining 68%. The total wastewater produced was in the order of 300,000 m^3/d 70% of which was untreated and discharged raw in the marine environment (UNEP/MAP/MED POL/WHO, 2004). In the 2008 report data involved thirteen coastal localities with a total population of 5,675,000 inhabitants, in three of which the population was served by a treatment plant. The degree of wastewater treatment was primary for 15% of the total number of cases and secondary for the rest 85% (UNEP/MAP/MED POL/WHO, 2008).

Syria

All the population in the seven coastal cities larger than 1000 inhabitants (607,635 people) was served by network and probably by individual autonomous wastewater services such as septic tanks or other similar devices. The total amount of untreated wastewater discharged mainly to the sea through small submarine outfalls, was to the order of 60,000 m^3/d (UNEP/MAP/MED POL/WHO, 2004). Fifty-three smaller coastal cities with a total resident population of 205,776 inhabitants exist and none was served by WWTPs. The total amount of untreated wastewater discharge reached the 30,656 m^3/ day totally into the marine environment (UNEP/MAP/MED POL/WHO, 2008).

Turkey

A total of 41 large coastal cities were reported and 62% of the population was having wastewater treatment facilities (19 wastewater treatment plants serve about 3 million habitants). The reported quantity of treated wastewater (about 721,000 m3/day) was discharged in most cases through submarine outfalls to the sea, whereas untreated wastewater was mainly directly discharged to the sea (UNEP/MAP/MED POL/WHO, 2004). A total of a hundred and ninety two smaller (population between 2000-1000) coastal cities were reported with a permanent population of 878,242 residents; 81% of the total number of the cities were not served by a treatment plant. Of the treated wastewater (about 45,042 m3/day) 23% was discharged to the sea (for the rest there was no available information, same as to the fate of untreated wastewater (about 44,244 m3/day)) according to UNEP/MAP/MED POL/WHO (2008).

3.2. Levels of contaminants in the marine environment

3.2.1 Trace metals

Draft analysis of representative trace metals in the sediment and biota in the eastern part of Aegean – Levantine by MEDPOL (2009a) despite lack of data in some of the countries (notably Syria and Lebanon in general and from Greece and Cyprus in the case of sediments) revealed patterns of anthropogenic source of these trace metals originating from point and diffuse land-based sources providing useful information on the identification of hotspots in the area although not fully comprehensive.

In the maps that follow the concentrations of trace metals in sediment and biota are depicted providing useful information on the identification of some hotspots in the area.

Table 9. Trace metals in sediments and biota in the Aegean – Levantine . Median (and range) values (µg g^{-1} dw) Source: MEDPOL, 2009a

	Cd	**Total-Hg**	**Pb**	**Zn**	**Cu**
Sediments	0.11 (0.01-8.47)	0.16 (0.00-5.18)	5.9 (0.03-132.3)	26.8 (0.07-1505)	11.2 (0.31-198
Mytilus galloprovinciallis	0.36 (0.05-5.27)	0.06 (0.01-0.63	2.09 (0.84-5.97)	68 (6.7-325)	5.90 (1.01-36.1)

Note: 1.Sediments values include only data from Egypt, Israel and Turkey
2. Trace metal in biota include data from Cyprus, Greece, Israel and Turkey.

Trace metals - sediments

The analysis of representative trace metals in the sediment in the eastern part of Aegean – Levantine by MEDPOL (2009a) revealed values in sediments that in general, are in the lower range than those reported in previous assessments (derived from MEDPOL I and II).

Table 10: Mean and median concentrations of trace metals in sediments ($\mu g\ g^{-1}$ dw) by country. Source**:** MEDPOL, 2009a

	Cd		**HgT**		**Pb**		**Zn**		**Cu**	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Egypt	0.19	0.22	0.24	0.25	2.26	0.61	20.13	18.45	6.22	5.09
Israel	0.37	0.08	0.25	0.10	9.81	4.10	36.46	11.55	12.12	2.3
Turkey	0.30	0.13	0.22	0.16	33.13	19.1	108.31	79.83	41.54	31.9

In Greece monitoring of metals in sediment based on Greek MEDPOL (HCMR) data, revealed a pollution gradient across the Greek coastal areas indicating different pollution fingerprints in different areas (SoHeLME, 2005). However the moderate coverage in temporal terms does not allow for the determination of apparent trends (Kaberi, pers. comm.). The temporal and spatial coverage of trace metals in Greek Seas are presented in figures 21 and 22 and table 10.

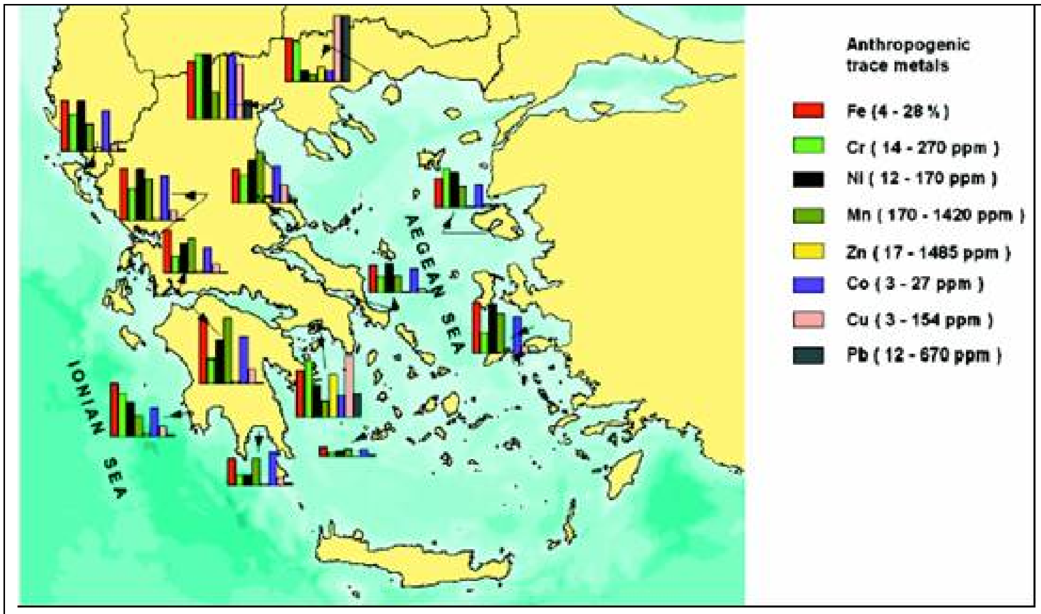


Figure 21: Heavy metals distribution as estimated from measurements of the anthropogenic component (mean values over the year). Source: Reprinted from SoHelMe, 2005

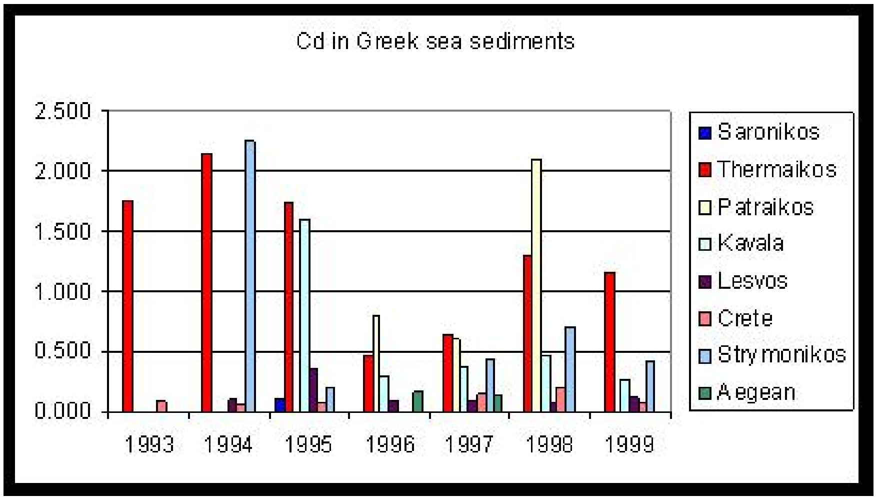


Figure 22: Trends of Heavy metals (Cd µg/g) in sea sediments across the Greek seas.Source: HCMR data base - MEDPOL data (courtesy of Kaberi, E.)

Trace metals - biota

Trace metal analysis in biota is more comprehensive as it encompasses almost all countries in the area (except Lebanon and Syria) exhibited low values in general for the area in the case of *Mytilus galloprovinciallis*. Analysis in *Mullus barbatus* appeared uniform metal bioaccumulation through the area but certain stations from Greece and Turkey exhibited the higher levels of Cd and Cu. In general the accumulation was found higher in mussels than in fish with reported values, excluding the hotspots, of the same order of magnitude than those obtained during the MEDPOL I and II. (MEDPOL, 2009a).

Table 11: Mean concentrations of trace metals in bivalves and benthic fish by country. Source: MEDPOL 2009a

	Mytilus galloprovinciallis					*Mullus barbatus*				
	Cd	HgT	Pb	Zn	Cu	Cd	HgT	Pb	Zn	Cu
Cyprus						0.06	0.34	0.54	34.19	1.74
Greece	0.77	1.13	1.03	150.48	8.22	2.27	0.66	0.43	55.9	2.28
Israel*	1.87	0.28		123.84	10.26	0.57	0.33		24.46	2.43
Turkey	0.59	0.05	3.97	54.90	6.37	0.11	0.13		14.28	15.73

*values correspond to *Mactra corallina*

3.2.2. Chlorinated hydrocarbons

Organochlorines [PCBs (polychlorinated biphenyls), DDTs (dichloro-diphenyl-trichlopo-ethane), HCHs (hexacholohexanes, of which γ- HCH Lindane is the most infamous representative) and HCB (hexachloro-benzene)] are highly toxic persistent and bioaccumulative compounds

Chlorinated hydrocarbons in sediment

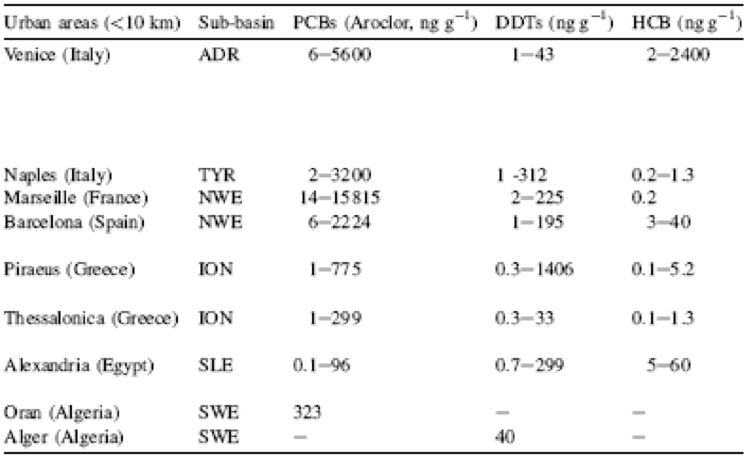
The levels of selected persistent organic pollutants, namely polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroetane and its degradation products (DDTs) and hexachlorobenzene (HCB), in Mediterranean sediments (1971 to 2005) along with their main drivers and pressures has been by assessed by Gomez-Gutierrez et al (2007); gaps were also identified. This study only included Greece and Egypt from the Aegean-Levantine countries identifying a major gap in sediment analysis in the area. Large cities have been identified as critical sources of hazardous substances pollution, since most of the "hot spots" are located in their neighbouring sediments (Alexandria and Port Said in Egypt and Athens and Thessaloniki in Greece) Table 12. Also, high concentrations of hazardous substances are found in sediments located in river mouths and estuaries of major Mediterranean rivers (Nile) and lagoons (lake Manzala, Egypt) figure 25.

When trying to identify the relative importance of the drivers and pressures, it was seen that maximum values for PCBs and DDTs throughout the Mediterranean were found in the Nile river mouth, ranging from 53 to 1500 ng g^{-1} for PCBs (Aroclor) and from 29 to 826 ng g^{-1} for DDTs (El-Dib and Badawy, 1985; Abd-Allah et al., 1992)

In the Aegean Sea, high concentrations of the target compounds were found in the Saronikos Gulf, close to Piraeus and in the Thermaikos Gulf, near to Thessalonica (Greece). The highest values available for the area of Piraeus correspond to the 1970s probably reflecting the state of contamination when these products were still in production and usage in the region (Dexter and Pavlou, 1973. However, a recent study showed also high concentrations for both PCBs and DDTs (Hatzianestis and Botsou, 2005). Furthermore, based on the DDT/DDE ratio, authors indicate that recent disposal of DDT is probably occurring in the area. In addition to this, concentrations recently reported in the commercial harbour of Piraeus also showed elevated levels (up to 76 ng g^{-1} of DDTs and 927 ng g^{-1} of Aroclor) (Galanopoulou et al., 2005).

In the Southeastern part of the Mediterranean basin, sediments off the city of Alexandria showed high levels of pollution. The coast of Alexandria and especially the semi-enclosed bays (Abu-Quir and El-Max bays) are subject to the discharge of untreated agricultural and industrial wastes from major urban centres as well as to the diffuse agricultural runoff. In fact, two main disposal outfalls discharge industrial, agricultural and domestic wastes directly into the Mediterranean Sea through these two bays (Abd-Allah and Abbas, 1994). Based on recent data analysis, PCBs, DDTs and HCB are compounds of concern in the area (Barakat, 2004).

Table 12: Ranges of PCBs, DDTs and HCB concentrations in sediments within an area of 10 km from the principal Mediterranean urban centres (>100,000 inhabitants). Source: Reprinted from Gomez-Gutierrez et al, 2007.



Urban areas (<10 km)	Sub-basin	PCBs (Aroclor, ng g^{-1})	DDTs (ng g^{-1})	HCB (ng g^{-1})
Venice (Italy)	ADR	6–5600	1–43	2–2400
Naples (Italy)	TYR	2–3200	1 -312	0.2–1.3
Marseille (France)	NWE	14–15815	2–225	0.2
Barcelona (Spain)	NWE	6–2224	1–195	3–40
Piraeus (Greece)	ION	1–775	0.3–1406	0.1–5.2
Thessalonica (Greece)	ION	1–299	0.3–33	0.1–1.3
Alexandria (Egypt)	SLE	0.1–96	0.7–299	5–60
Oran (Algeria)	SWE	323	–	–
Alger (Algeria)	SWE	–	40	–

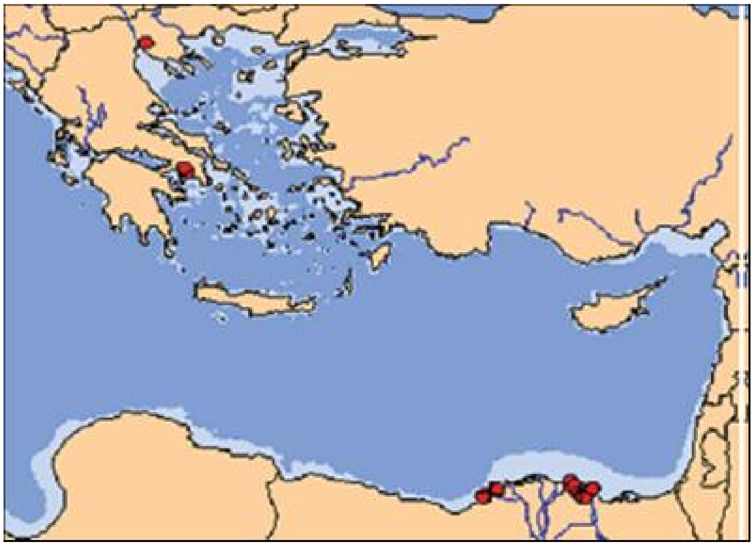


Figure 23: Identified 'hot spots' for the concentrations of PCBs, DDTs and HCB 4 in the Mediterranean surficial sediments Source: Reprinted from Gomez-Gutierrez et al (2007)

Chlorinated pesticides in biota

Chlorinated pesticides have been extensively analyzed in Mediterranean biota since the inception of MEDPOL (UNEP, 1990). However, it has been only since the last decade that they have been continually monitored, and data gathered in the MEDPOL

Database and in the case of Aegean-Levantine spatial analysis is limited to Cyprus (fish) and Turkey (mussels and fish) as shown in tables 13 and 14. In the latest assessment concentrations of aldrin, dieldrin, endrin, lindane and hexachlorobenzene in *Mytilus galloprovincialis across the Mediterraenan* were in the low ng g^{-1} range with the exception of some stations from Turkey where concentrations of DDTs were one order of magnitude higher. (MEDPOL 2009a).

Table 13: Chlorinated compounds in *Mytilus galloprovincialis* in Turkey Median (and range) values (ng g^{-1}dw). Source: MEDPOL 2009a

	Σ DDTs	Lindane	CB138	CB153	Σ7CBs
Mytilus galloprovinciallis	17.44 (6.02-440)		0.21 (0.01-20.6)	0.33 (0.02-32.4)	1.13 (0.07-110)

Table 14: Mean concentrations of OCPs in *Mullus barbatus* (ng g-1 dw) in Cyprus and Turkey. Source: MEDPOL 2009a

	DDTs	ALD	DIE	END	HCB	LIN
Cyprus	27.29	0.45	1.55	0.82	3.77	1.77
Turkey	137.74	8.94	7.34		3.82	

PCBs in biota

Data on *Mullus barbatus* and *Mytilus galloprovincialis* in the latest MEDPOL analysis is limited to Cyprus and Turkey (table 14 and 15). The values can be considered in the low range, taking into account the higher accumulation capacity of fish with respect to mussels (MEDPOL, 2009a).

Table 16: Mean concentrations of PCB congeners in *Mytilus galloprovincialis* (ng g-1 dw). Source: MEDPOL 2009a.

	CB28		**CB52**		**CB101**		**CB118**		**CB138**		**CB153**		**CB180**		**CB7**	
	MG	MB	MG	MB	MG	MB	MG	MB	MG	MB	MG	MB	MG	MB	MG	MB
Turkey	0.04	0.03	2.78	2.34	2.78	2.34	0.60	0.51	4.97	4.19	7.81	6.59	7.5	6.32	26.47	22.33
Cyprus		6.06		2.79		21.58				9.28		9.14		11.06		29.49

Case study: Organochlorines in Greek costal and marine environment

In Greek coastal sediments the contamination of organochlorines is regarded SoHelME , 2005). Only sporadic data exist and almost zero time series despite the fact that the compounds were under the Greek MEDPOL program. A pollution gradient has been detected which also differentiates among the impact of pollutants in sediments. PCBs and DDTs revealed low to moderate contamination (Thermaikos Gulf: PCB:0.5± 0.6 ngg^{-1}dw, DDTs ±1.3 2.1 ngg^{-1}dw) and heavy contamination (Elefsis bay PCB:29.2± 11.6 ngg^{-1}dw, DDTs 4.1±2.5 ngg^{-1}dw; ports of Peraias PCB:68.9± 05.7 ngg^{-1}dw, DDTs 54.8±4.8 ngg^{-1}dw and Thessaloniki PCB:88.5 ngg^{-1}dw, DDTs 22.8 ngg^{-1}dw), areas under urban and industrial stress in contrast to DDT which revealed higher contamination in areas with agricultural activities (SoHeLME , 2005, MPI – Greece, 2006)

Organochlorine concentrations accumulated in biota destined for human consumption, (based on Monitoring programmes exist (mainly Greek MEDPOL) determining the levels of pollutants in filter feeding organisms (mussels) and commercial fish species (red mullets and bogue)) are regarded low and below the standard human health limits (SoHelME, 2005). The spatial analysis of the organochlorine bioaccumulation in biota across the Greek coastal environment is presented in figure 24.

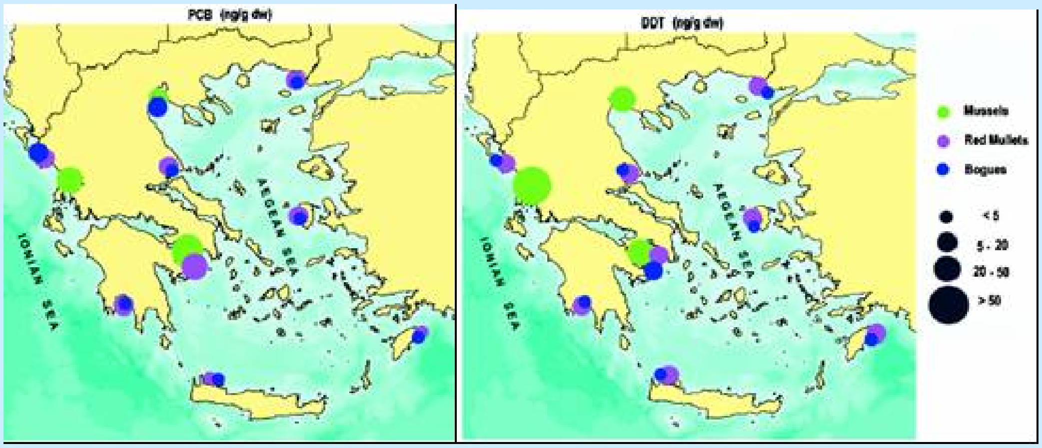


Figure 24: PCBs (left) and DDTs (right) concentrations in mussels and fishes (ng/g ww) in Greek seas. Source: Reprinted from SoHelME)

The analysis provided evidence of a contamination gradient when mussels were used as an indicator. Two areas were identified as sources of heavy metals into biota: a PCB pollution area (Saronikos Gulf - industrial and urban effluents) and a DDT contaminated area (Amvrakikos Gulf – agricultural effluents). On the other hand spatial analysis of bioaccumulation in fish revealed a homogeneous pattern indicating no point sources of pollution (SoHelME, 2005).

Temporal trends are also available (mainly as a result of the Greek MEDPOL programme) providing useful trends. These trends in mussels indicate no reduction of pollutant levels despite the ban indicating continuous inputs into the coastal environment; similarly temporal trend in fish revealed no pattern of reduction (SoHelME, 2005)

3.2.3 PAHs

Marine transport is one of the main sources of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbon (PAH) pollution in the Mediterranean Sea. It is estimated that about 220 000 vessels of more than 100 tonnes each cross the Mediterranean each year discharging 250 000 tonnes of oil. This discharge is the result of shipping operations (such as deballasting, tank washing, dry-docking, fuel and discharge oil, etc.) and takes place in an area which since 1973 has been declared as a 'Special Sea Area' by the MARPOL 73/78 convention, i.e. where oily discharges are virtually prohibited. The PAH input varies according to the type of oil discharged and its range is estimated at between 0.3 and 1,000 tonnes annually (UNEP Chemicals, 2002). Illicit vessel discharges can be detected through the interpretation of ERS SAR (Synthetic Aperture Radar) satellite images (figure 26 and 27). In addition 80,000 tonnes of oil have been spilled in the Mediterranean Sea and its immediate approaches because of shipping accidents (taking into account accidents resulting in releases of more than 700 tonnes, figure 27). Finally incidents at oil terminals and routine discharges from land-based installations have been estimated at 120,000 tonnes/year (EEA, 2006).

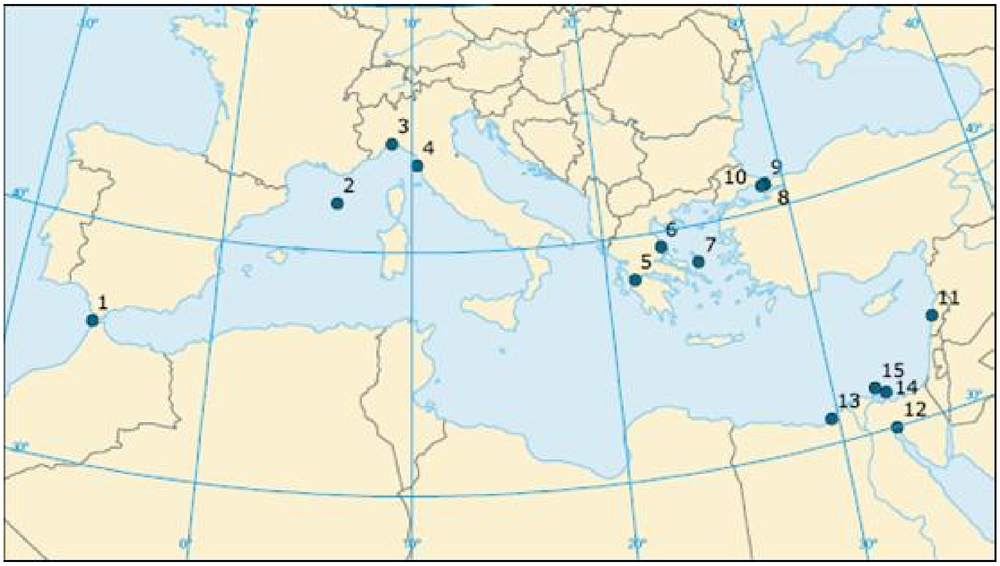


Figure 25: Location of Major tanker oil spills (> 700 tonnes) 1990–2005 Source: Reprinted from EEA 2006

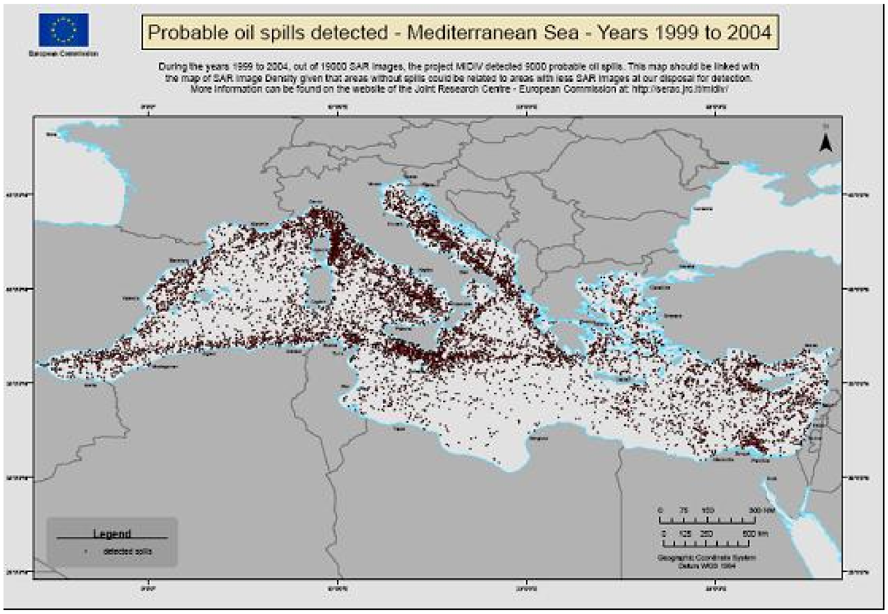


Figure 26. Oils spills detected across the Mediterranean

Source: JRC, http://serac.jrc.it/med/1999_to_2004_oilspills.pdf

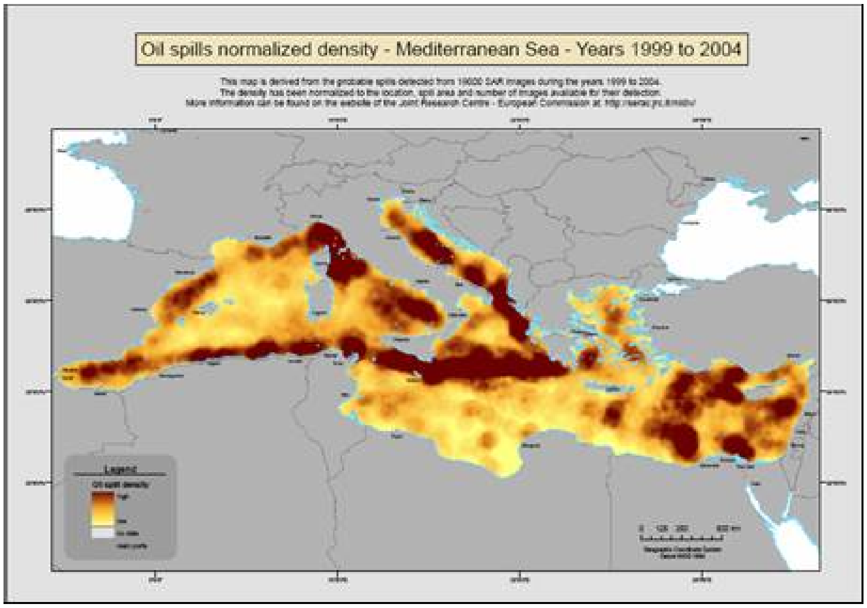


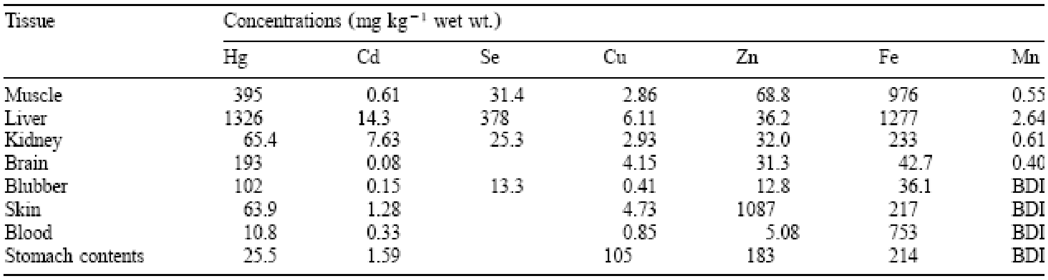
Figure 27. Oils spills density across the Mediterranean, 1999-2004. Source: JRC http://serac.jrc.it/med/1999_to_2004_oilspill_density.pdf

3.2.4. Hazardous substances in higher biota

a) Trace metals

Very little is known about heavy metal concentrations in tissues of cetaceans inhabiting the Eastern Mediterranean. A stranding of Risso's dolphin (Grampus griseus) on the Mediterranean coast of Israel revealed high concentrations of trace metals (Hg, Cd, Zn, Fe and Se) while Cu and Mn concentrations were naturally low (figure 39). No connection was found between the high concentrations of trace metals in the internal organs and the cause of death and it was assumed that the high concentrations were a result of the high trophic level of this species, its diet and its advanced age. Anthropogenic influence could not be assessed due to the sparse database of trace metals for this species, in particular knowledge of the natural levels (Shoham-Fridera et al 2002).

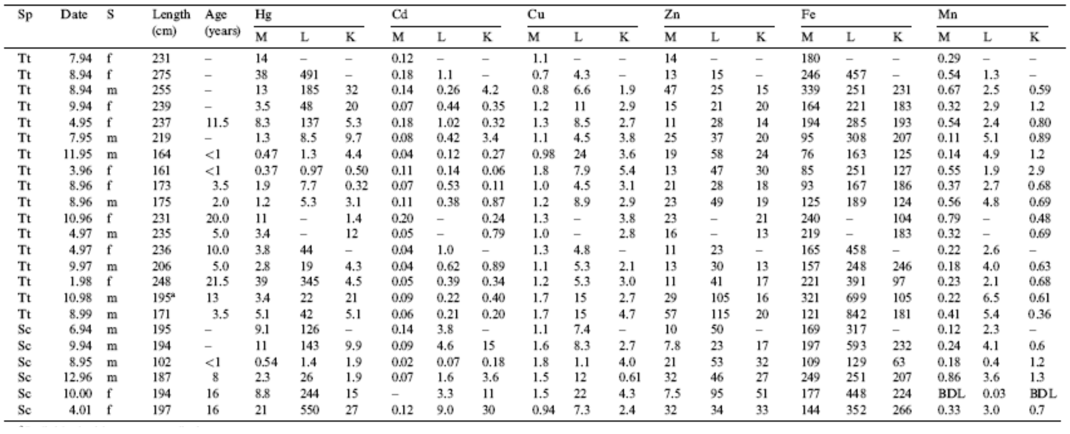
Table 17. Concentrations of trace metals in various tissues of the *Grampus griseus* specimen stranded in Israel. Source: Reprinted from Shoham-Fridera et al 2002



Tissue	Concentrations (mg kg^{-1} wet wt.)						
	Hg	Cd	Se	Cu	Zn	Fe	Mn
Muscle	395	0.61	31.4	2.86	68.8	976	0.55
Liver	1326	14.3	378	6.11	36.2	1277	2.64
Kidney	65.4	7.63	25.3	2.93	32.0	233	0.61
Brain	193	0.08		4.15	31.3	42.7	0.40
Blubber	102	0.15	13.3	0.41	12.8	36.1	BDI
Skin	63.9	1.28		4.73	1087	217	BDI
Blood	10.8	0.33		0.85	5.08	753	BDI
Stomach contents	25.5	1.59		105	183	214	BDI

Examination of heavy metal content in 61 bottlenose dolphins and 8 striped dolphins stranded in Israel from1993 - 2001, (the first large series ever reported with the scope of metals and tissues tested) allowed only qualitative comparisons with findings from other part in Mediterranean observations. It seemed that that mercury levels tend to be similar while cadmium levels (at least in muscle and liver) are lower in the western Mediterranean locations in the case of bottle nose dolphins while striped dolphin resemble the Tyrrhenian–Ligurian population in their mercury levels but could be distinct in having higher cadmium and zinc concentrations in muscle and skin (Roditi-Elasar et al 2003).

Table 18: Heavy metal concentrations (µg/g WW) in key tissues of bottlenose (Tt) and striped (Sc) dolphins from the Mediterranean coast of Israel. Source: Reprinted from Roditi-Elasar et al 2003



Sp	Date	S	Length (cm)	Age (years)	Hg			Cd			Cu			Zn			Fe			Mn		
					M	L	K	M	L	K	M	L	K	M	L	K	M	L	K	M	L	K
Tt	7.94	f	231	–	14	–	–	0.12	–	–	1.1	–	–	14	–	–	180	–	–	0.29	–	–
Tt	8.94	f	275	–	38	491	–	0.18	1.1	–	0.7	4.3	–	13	15	–	246	457	–	0.54	1.3	–
Tt	8.94	m	255	–	13	185	32	0.14	0.26	4.2	0.8	6.6	1.9	47	25	15	339	251	231	0.67	2.5	0.59
Tt	9.94	f	239	–	3.5	48	20	0.07	0.44	0.35	1.2	11	2.9	15	21	20	164	221	183	0.32	2.9	1.2
Tt	4.95	f	237	11.5	8.3	137	5.3	0.18	1.02	0.32	1.3	8.5	2.7	11	28	14	194	285	193	0.54	2.4	0.80
Tt	7.95	m	219	–	1.3	8.5	9.7	0.08	0.42	3.4	1.1	4.5	3.8	25	37	20	95	308	207	0.11	5.1	0.89
Tt	11.95	m	164	<1	0.47	1.3	4.4	0.04	0.12	0.27	0.98	24	3.6	19	58	24	76	163	125	0.14	4.9	1.2
Tt	3.96	f	161	<1	0.37	0.97	0.50	0.11	0.14	0.06	1.8	7.9	5.4	13	47	30	85	251	127	0.55	1.9	2.9
Tt	8.96	f	173	3.5	1.9	7.7	0.32	0.07	0.53	0.11	1.0	4.5	3.1	21	28	18	93	167	186	0.37	2.7	0.68
Tt	8.96	m	175	2.0	1.2	5.3	3.1	0.11	0.38	0.87	1.2	8.9	2.9	23	49	19	125	189	124	0.56	4.8	0.69
Tt	10.96	f	231	20.0	11	–	1.4	0.20	–	0.24	1.3	–	3.8	23	–	21	240	–	104	0.79	–	0.48
Tt	4.97	m	235	5.0	3.4	–	12	0.05	–	0.79	1.0	–	2.8	16	–	13	219	–	183	0.32	–	0.69
Tt	4.97	f	236	10.0	3.8	44	–	0.04	1.0	–	1.3	4.8	–	11	23	–	165	458	–	0.22	2.6	–
Tt	9.97	m	206	5.0	2.8	19	4.3	0.04	0.62	0.89	1.1	5.3	2.1	13	30	13	157	248	246	0.18	4.0	0.63
Tt	1.98	f	248	21.5	39	345	4.5	0.05	0.39	0.34	1.2	5.3	3.0	11	41	17	221	391	97	0.23	2.1	0.68
Tt	10.98	m	195[a]	13	3.4	22	21	0.09	0.22	0.40	1.7	15	2.7	29	105	16	321	699	105	0.22	6.5	0.61
Tt	8.99	m	171	3.5	5.1	42	5.1	0.06	0.21	0.20	1.7	15	4.7	57	115	20	121	842	181	0.41	5.4	0.36
Sc	6.94	m	195	–	9.1	126	–	0.14	3.8	–	1.1	7.4	–	10	50	–	169	317	–	0.12	2.3	–
Sc	9.94	m	194	–	11	143	9.9	0.09	4.6	15	1.6	8.3	2.7	7.8	23	17	197	593	232	0.24	4.1	0.6
Sc	8.95	m	102	<1	0.54	1.4	1.9	0.02	0.07	0.18	1.8	1.1	4.0	21	53	32	109	129	63	0.18	0.4	1.2
Sc	12.96	m	187	8	2.3	26	1.9	0.07	1.6	3.6	1.5	12	0.61	32	46	27	249	251	207	0.86	3.6	1.3
Sc	10.00	f	194	16	8.8	244	15	–	3.3	11	1.5	22	4.3	7.5	95	51	177	448	224	BDL	0.03	BDL
Sc	4.01	f	197	16	21	550	27	0.12	9.0	30	0.94	7.3	2.4	32	34	33	144	352	266	0.33	3.0	0.7

Concentrations of heavy metals (Hg, Cd and Pb) were determined in internal organs and nest contents of green turtles *Chelonia mydas* and loggerhead turtles *Caretta caretta* from northern Cyprus. Concentrations of mercury in liver tissue were higher in loggerhead turtles (median 2.41 µg g^{-1} dry weight) than in green turtles (0.55 µg g^{-1} dry weight). Data suggested cadmium concentrations to be highest in kidney tissue of loggerhead turtles (median 30.50 µg g^{-1} dry weight) but in liver tissue of green turtles (median 5.89 µg g^{-1} dry weight). Concentrations of lead in internal tissues were often below analytical detection limits in both species, but when measurable, tended to be higher in loggerhead turtle. These findings suggested that metal levels in both green and loggerhead turtles are not likely to be high enough to affect the health of these endangered species (the only exception to this might be relatively high lead concentrations in loggerhead turtle hatchlings, and perhaps also green turtle hatchling (Godley et al 1999).

These data from Cyprus are comparable with those encountered in specimens in other parts of the Mediterranean Sea e.g. Adriatic (Storelli et al 2009) and Murcia Spain (Jerez, 2010) confirming the homogeneity of the area comprising the southeastern basin of the Mediterranean Sea from an ecological point of view.

Concentrations of heavy metals measured in tissues of common bottlenose dolphins, collected along the Israeli Mediterranean coast during 2004–2006, ranged as follows: 0.01–123 mg kg^{-1} wet weight for Hg, <0.04–1.3 for Cd, 1–30 for Cu, 0.3–4 for Mn, 19–517 for Fe, 4.3–68 for Zn and 2.4–48 for Ni. These concentrations were similar to those found in specimens collected during previous years in the region, suggesting stability over time in the HM levels of the basin's food-web ((Shoham-Frider et al 2009).

b) Chlorinated hydrocarbons

Cetaceans and seals, top predators in the marine environment, have a reduced capacity to metabolize hydrophobic persistent chemicals compared to birds and land mammals. They accumulate high levels of these compounds up the food web and are most exposed to their toxic effects and therefore, they were suggested as potential bio-indicators for organochlorine contamination of the marine environment. ΣDDT and PCBs concentrations in tissues of common bottlenose dolphins, collected along the Israeli Mediterranean coast during 2004–2006, were highest in the blubber, with a wide concentration range of 0.92–142 and 0.05–7.9 mg kg^{-1} wet weight, respectively. Blubber PCBs values were an order of magnitude lower than in tissues of this and other delphinid species in the Western Mediterranean. Relatively high DDE/ΣDDT percentage (85–96%) was discovered, which fitted the general trend of increase in the last 20 years in the Mediterranean Sea, indicating the progressive degradation of the remnant DDT and the absence of new inputs. These findinds were in accordance to the ones reported from Greece for *Stenella coeruleoalba* (ΣDDT 15.4, DDE/Σ DDT 0.77 (mg kg_1 wet weight)) from Georgakopoulou-Gregoriadou et al. (1995).

Concentrations of individual chlorobiphenyls (CBs) and organochlorine pesticides (OCPs) in marine turtle tissues collected from the Mediterranean (Cyprus, Greece) and European Atlantic waters (Scotland) between 1994 and 1996 are described. ΣCB concentrations were highest in adipose tissue and ranged from 775 to 893, 39 to 261 and 47 to 178 mg/kg wet wt in loggerhead (*Caretta carretta*), green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles, respectively.

The measured concentrations of contaminants in marine turtles from Mediterranean were similar to those determined in the same species elsewhere in the Atlantic, and were considerably lower than the concentrations shown to cause deleterious effects in freshwater turtles (Mckenzie et al, 1999).

Blubber from Mediterranean monk seals (*Monachus monachus*) from the Western Sahara coast (Atlantic), sampled during 1996– 1999, and from the Greek coast), sampled during 1995–1999, was analyzed for organochlorine pollutants (OCs). Significant differences in concentrations and pollutant patterns were found between populations. Thus, Mediterranean individuals presented significantly higher levels of HCB (hexachlorobenzene), tPCB, and DDTs concentrations andDDE/tDDTand tDDT/tPCB ratios than their counterparts from the Atlantic. Moreover, the relative proportion of different congeners in relation to the total PCB load (congener/tPCB) was also different between the two areas indicating a predominance of industrial inputs over those associated with agriculture in Atlantic as opposed to Mediterranean seal population, where a proportionally higher contribution of pollutants of agricultural origin was suggested (Borrell et al 2007).

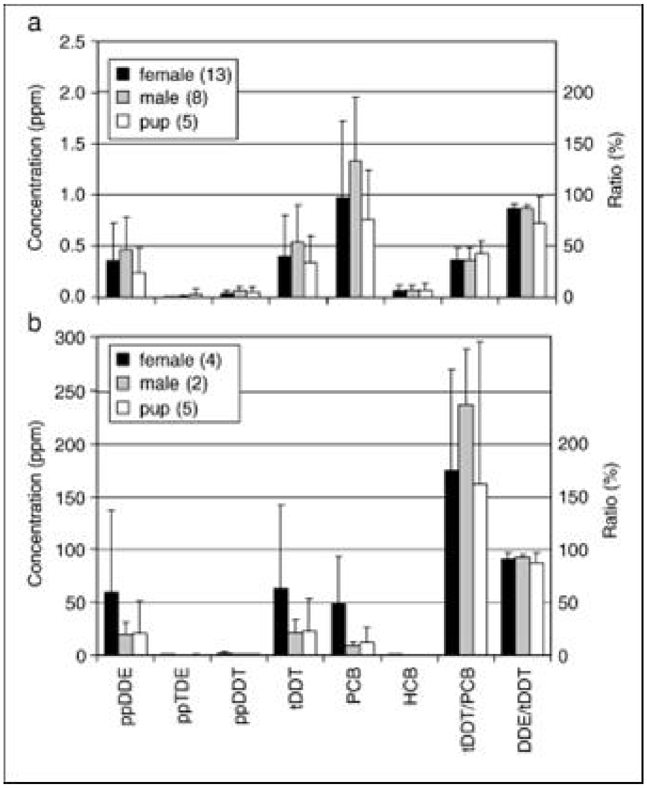


Figure 28: Comparison of organochlorine concentrations and ratios (mean±SD) between sexes and reproductive stages in Mediterranean monk seals fromWestern Sahara (a), and from Greece (b). Differences between females, males and pups were not statistically significant (pN0.05) in each region. Source: Reprinted from Borrell et al 2007

3.2.5 Radionuclides

The eastern Mediterranean is characterised as on of the regions of high natural radioactivity (Henriksen, and Maillie, 2003). On the other hand Mediterranean as a whole is characterised by low levels of anthropogenic radionuclides compared to the world's oceans (IAEA, 2005).

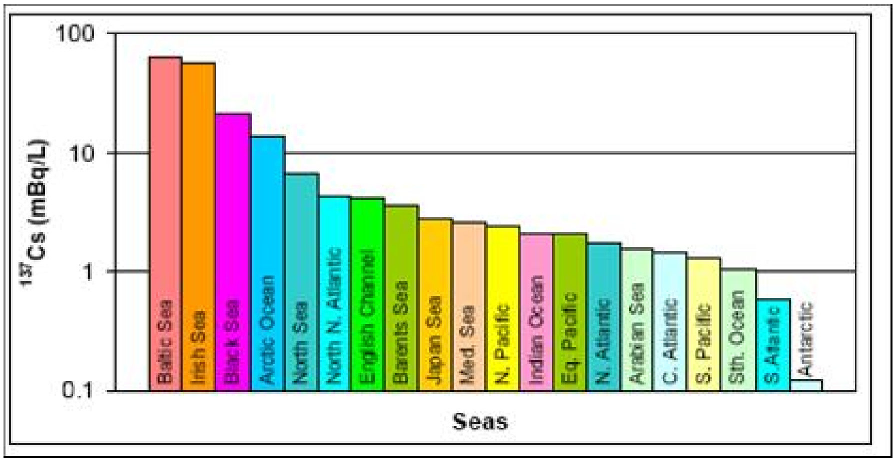


Figure 29.^{137}Cs in the world's oceans and seas (adjusted to 01.01.2000). Source: Reprinted from IAEA 2005

According to IAEA (2005) the major source of anthropogenic radionuclides to the Mediterranean Sea is the global fallout (atmospheric weapons testing and accidents i.e. Chernobyl in 1986). The input deriving from the nuclear industry is very small compared to other sources.

Fallout from atmospheric weapons testing in the early sixties accounted to 12 PBq of ^{137}Cs and 0.19 PBq of ^{239,240}Pu) [UNEP MAP 1992, Holm et al 1988, Papucci at al 1995] whereas fallout from the Chernobyl accident contributed significantly to the total input of caesium isotopes; 3 to 5 PBq of ^{137}Cs were deposited after the accident, mainly in the eastern and northern parts of the basin. An additional input of Chernobyl radionuclides came through the Black Sea (0.3 PBq of ^{137}Cs) [Egorov et al 1999]. For the Aegean in particular the total amount of ^{137}Cs deposited at its surface in May 1986 was estimated by Kritidis and Florou (1990) to be 800 TBq. Egorov et al.(1994) the predicted ^{137}Cs outflow from the Black Sea to the Aegean Sea to be of approximately 250 TBq.

No time series stations have been established in the Mediterranean Sea for anthropogenic radionuclide concentrations and only few scattered data have been published on radionuclide vertical distribution in the Eastern Mediterranean. The eastern Mediterranean has been studied in detail, also in relation to the so-called "deep water transient", the change in circulation of the deep and intermediate water that made the basin of interest in the 1990s.

Before the Chernobyl accident there were no significant differences in surface ^{137}Cs concentrations in the different basins of the Mediterranean Sea with eastern basin exhibiting the lowest values (mean 4.2 ± 0.3 Bq/m3) in 1977 (compared to 4.4 ± 0.7 Bq/m^3 in the SW Mediterranean and in the Tyrrhenian Sea, and 4.8 ± 1.8 Bq/m^3 in the NW Mediterranean, Adriatic and Ionian Seas) [Fukai et al 1980]. The vertical profiles obtained by Fukai et al. (1980) in 1977 for the Ionian and Levantine Basins showed ^{137}Cs concentrations decreasing from the surface values of 4.4±0.2 to 0.4 mBqrl at the depth of 2000 m, with no differences below 1000 m. Data obtained in the Aegean Sea in 1984 by Florou (1992) showed the same trend, but with lower surface concentrations (2.9±0.8 mBqrl). In both cases, subsurface maxima were found at depths of 50-100 m, usually attributed to vertical water movements.

An analysis of radionuclide data (1995 and1996–97) discussed the distribution in relation to water circulation and to the input of Chernobyl radionuclides (Papucci and Delfanti 1996). In this work surface concentration of ^{137}Cs ranged between 3.3 and 4.0 Bq/m3. The vertical profiles showed relative maxima in recent intermediate and deep water, also characterized by an increase in dissolved oxygen concentration exhibiting a linear increase with depth (similar to that of the western Mediterranean). In the vertical profiles, relative maxima were observed in the intermediate (4 mBqr/l) and deep waters (2.5 mBqr/l) formed after the Chernobyl accident (figure 31). Papucci and Delfanti 1996 continued their analysis demonstrating that starting from the winter 1986-1987, the Chernobyl-related ^{137}Cs, deposited onto the surface of the eastern Mediterranean, has been transferred to intermediate and deep layers by convective movements. As shown by IAEA (1991) part of it has rapidly left the Eastern Mediterranean in association with the intermediate water leaving the basin; ^{137}Cs concentrations in the surface water of the Ionian and Levantine basins, 9 years after the Chernobyl accident, are very similar to the values characterising the whole Mediterranean Sea in the early 1980s, but the vertical distribution of this radionuclide shows significant changes with respect to the past.

The intermediate and deep waters formed in the Levantine Basin and in the Adriatic and Aegean Seas in recent years show enhanced 137Cs concentrations, due to convection processes that have efficiently transferred the contamination due to the Chernobyl accident from surface to depth (Papucci and Delfanti 1996).The 1997 profile shows a decrease in 137Cs concentration both in the Levantine intermediate water and in the eastern Mediterranean deep water with respect to 1996. The decrease in Levantine intermediate water is likely due to seasonal interannual variability, while the changes in the deep layer are related to the spreading westward into the Ionian of the new Aegean dense water (IAEA, 2005).

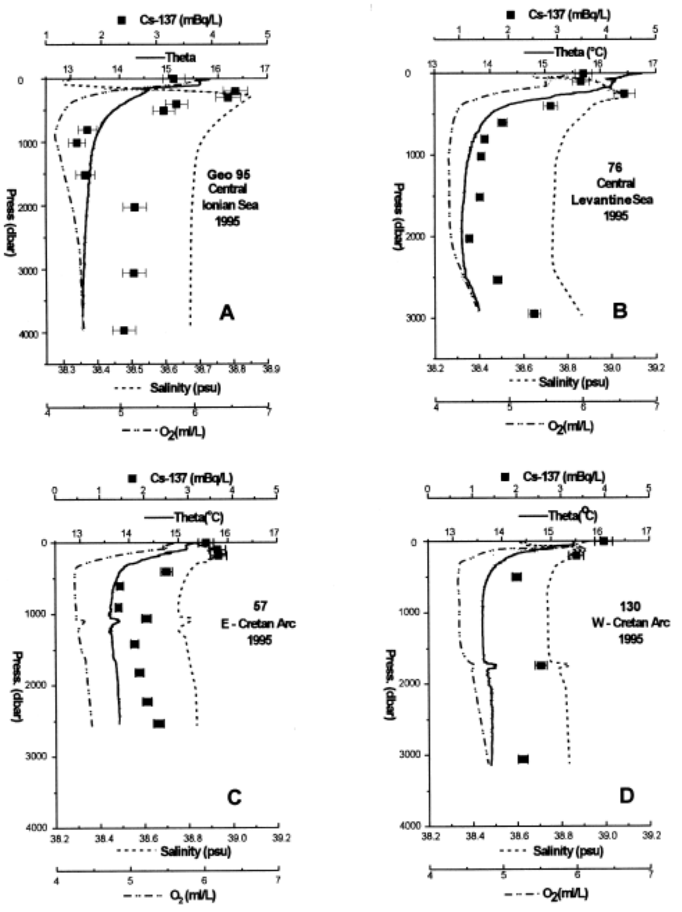


Figure 30: Salinity, Temperature, O_2 , ^{137}Cs vertical profiles, 1995. A: Geo 95-Central Ionian Sea; B: St. 76-Central Levantine Sea; C: St. 57E-Cretan Arc; D: St. 130-W Cretan Arc. Source: Reprinted from Papucci and Delfanti 1996

Since 1986, the radiological status of the Aegean Sea has also changed. During 1986 the average deposition of ^{137}Cs from the fallout was estimated to be approximately 4 kBqm^{-2}, whereas the respective value for the Ionian Sea was considerably lower, 2.5 kBqm^{-2} (Florou and Kritidis, 1994). After 2000, the radiological status of the Greek marine environment was characterized by higher values in the North Aegean Sea (mean ^{137}Cs activity concentration 13.3±1.3 Bqm^{-3}) and decreasing ones in the Southern Aegean (with a mean a value of 5 Bqm^{-3}) (Florou et al., 2006)

Evangeliou et al (2009) calculated trends of the ^{137}Cs in the Aegean. In 2005 the activity concentrations of ^{137}Cs for the surface and bottom layer of the North-Eastern Aegean Sea varied from 5.1±0.5 to 7.1 ±0.2 Bqm^{-3} and from 2.8 ±0.4 to 4.3 ±0.3 Bqm^{-3}, respectively; in 2006 the surface and bottom layer activity concentrations differed considerably and ranged, respectively, between 8.7 ±0.2 and 12.6±0.2 Bqm^{-3} and 3.4±0.3 and 3.7±0.4 Bqm^{-3} (Figure 31).

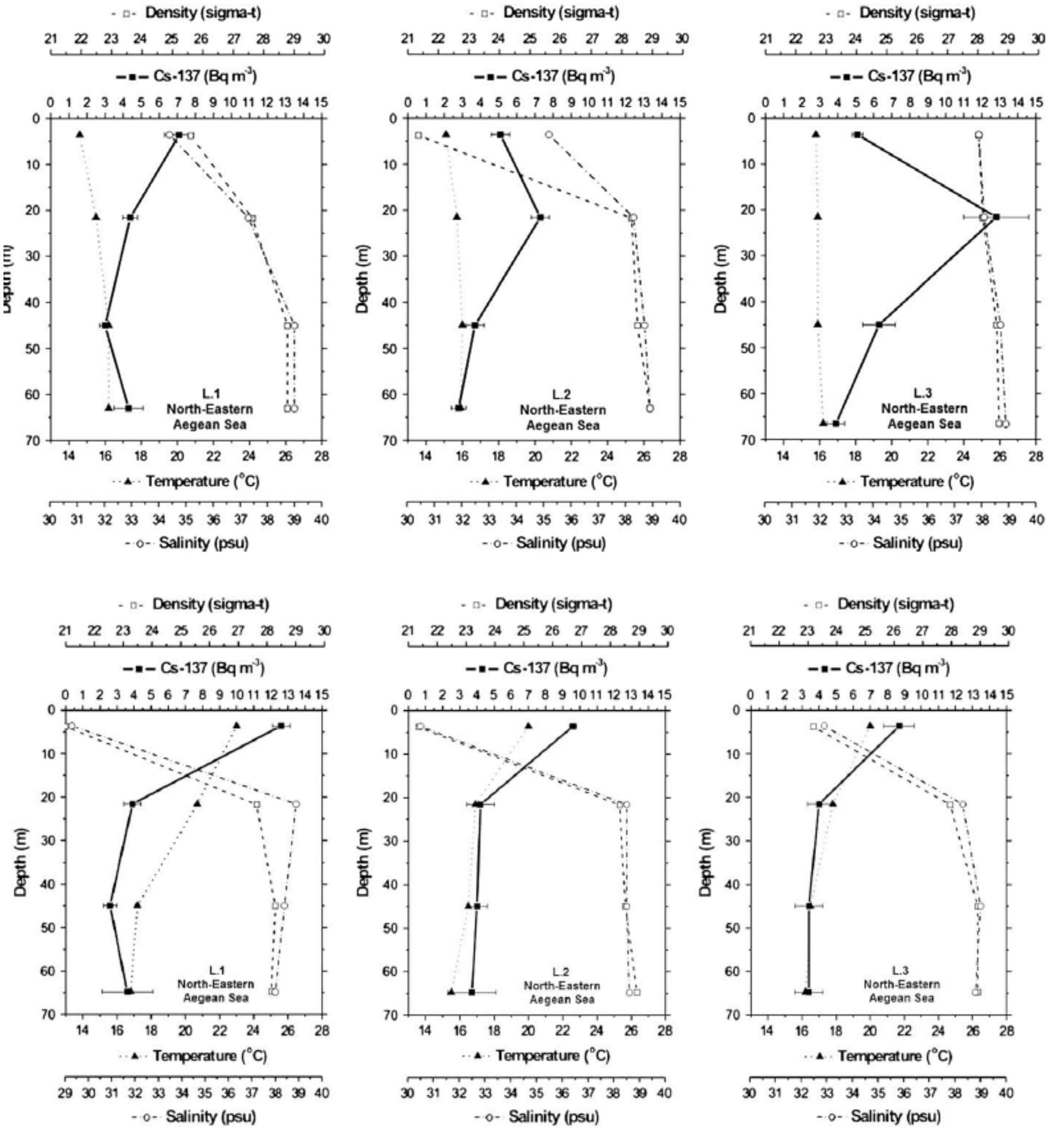


Figure 31: Vertical distribution of salinity, density, temperature and 137Cs activity concentration in the North-Eastern Aegean Sea on December 2005 (top) and June 2006 (bottom) .Source**:** Reprinted from Evangeliou et al 2009

These values compared to those found during December 2005 indicate higher activity concentrations in surface waters in the summer, following the increase of temperature, as expected, whereas the ones found at the bottom layer were similar or lower than those found in winter. These figures are higher than those reported in Ionian Sea (the activity concentrations of ^{137}Cs in the Gulf of Patras ranged between 1.2 and 6.7 Bqm–^{3}). In the same work it was demonstrated that the vertical profiles in the North-Eastern Aegean Sea followed the same pattern, with higher concentrations in the upper layer (0– 20 m depth) and lower ones in greater depths. This phenomenon was attributed to the Black Sea water outflows that mainly affect the surface layer of the study area. Considering the spatial distribution of 137Cs in the Greek marine environment (integrated ^{137}Cs levels on the inventory basis), higher values were found in the North-Eastern Aegean Sea than in the central part of the Gulf of Patras confirming that the Black Sea waters are the main source of ^{137}Cs in the Greek marine environment (Evangeliou et al 2009). In general, ^{137}Cs concentrations obtained from this study were comparable to those recorded in the literature for other parts of the Mediterranean. In comparison to those reported previously for the Greek marine environment, these values are considerably lower, similar to those of the pre-Chernobyl period.

3.3. Nutrient enrichment and eutrophication

As described before, the main spatial features of chlorophyll-a and nutrient analysis, include the general gradient in algal biomass from north to south and from west to east of the Eastern Basin, the ‘‘ultra-oligotrophic cores’’ of the south Levantine Basin (corresponding to the Mersa-Matruh and Shikmona Gyres, the Nile plume, the north-south gradient in algal biomass in the Aegean Sea, attributed to the combined effects of river inputs, northerly winter and signal from the nutrient reach Black Sea waters.

Hot spots of nutrients and organic matter releases has been identified by UNEP/MAP at the NW Aegean (Thermaikos Gulf - rivers and the sewage from the city of Thessaloniki), at rivers’ mouths in the North Aegean, at the coastal area of Izmir in NE Aegean (Izmir bay), at Lebanon and Israel coast in the SE Mediterranean and in the coastal zone in front of Alexandria area and in the Nile delta system (UNEP/MAP-Plan Bleu, 2009) (Figure 32).

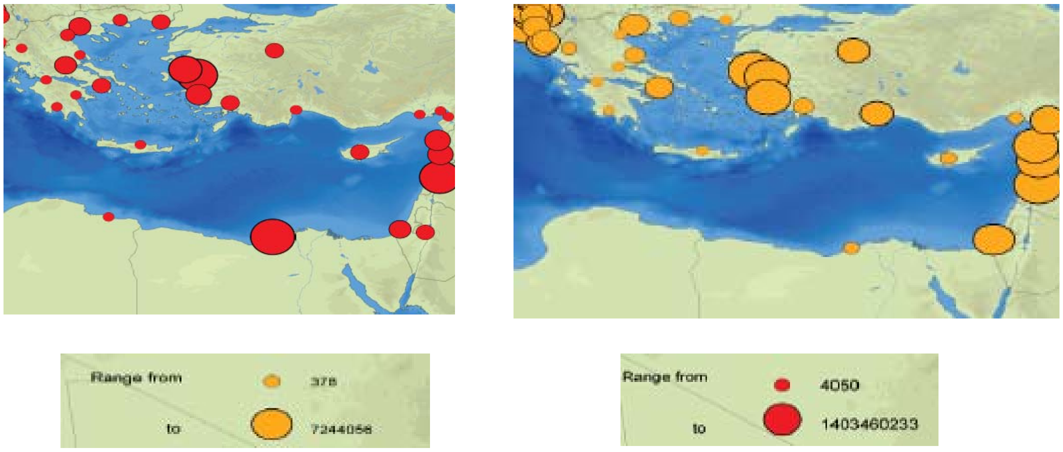


Figure 32: Industrial Total Nitrogen (left) and BOD (right) releases from point sources. Source: MED POL NBB, reprinted from UNEP/MAP-Plan Bleu 2009

To have a larger picture of the eutrophication phenomena, remote sensing is an important technique for monitoring eutrophication complementary to field work. CZCS, SeaWiFS, MODIS and MERIS images have been used extensively for studies of water colour. However they require a significant corrective functions but the use of algorithms has resulted in reliable results which should be treated with care. Automatic buoys have also been recommended as supplementary techniques for monitoring eutrophication in the framework of the MED POL medium/long term strategy (UNEP/MAP 2007b).

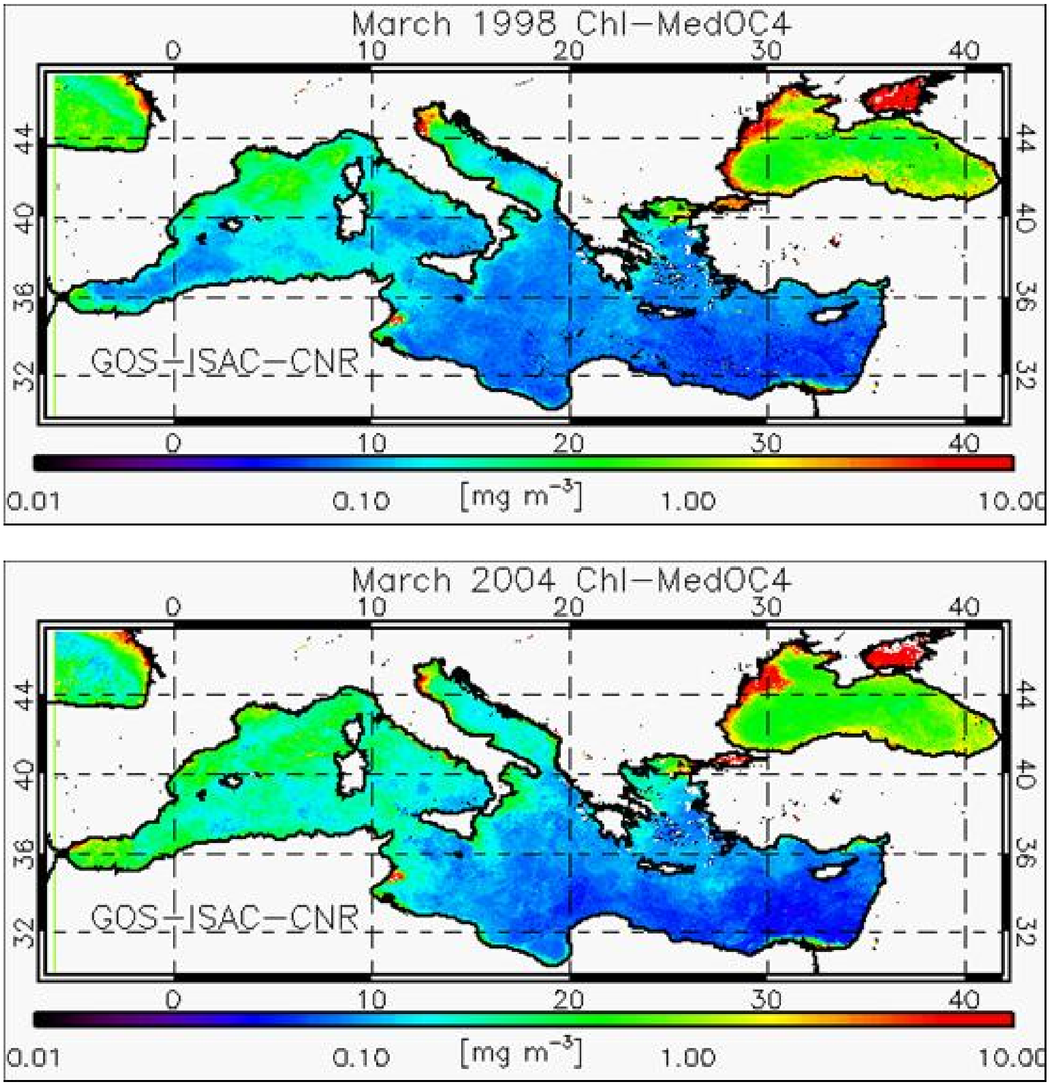


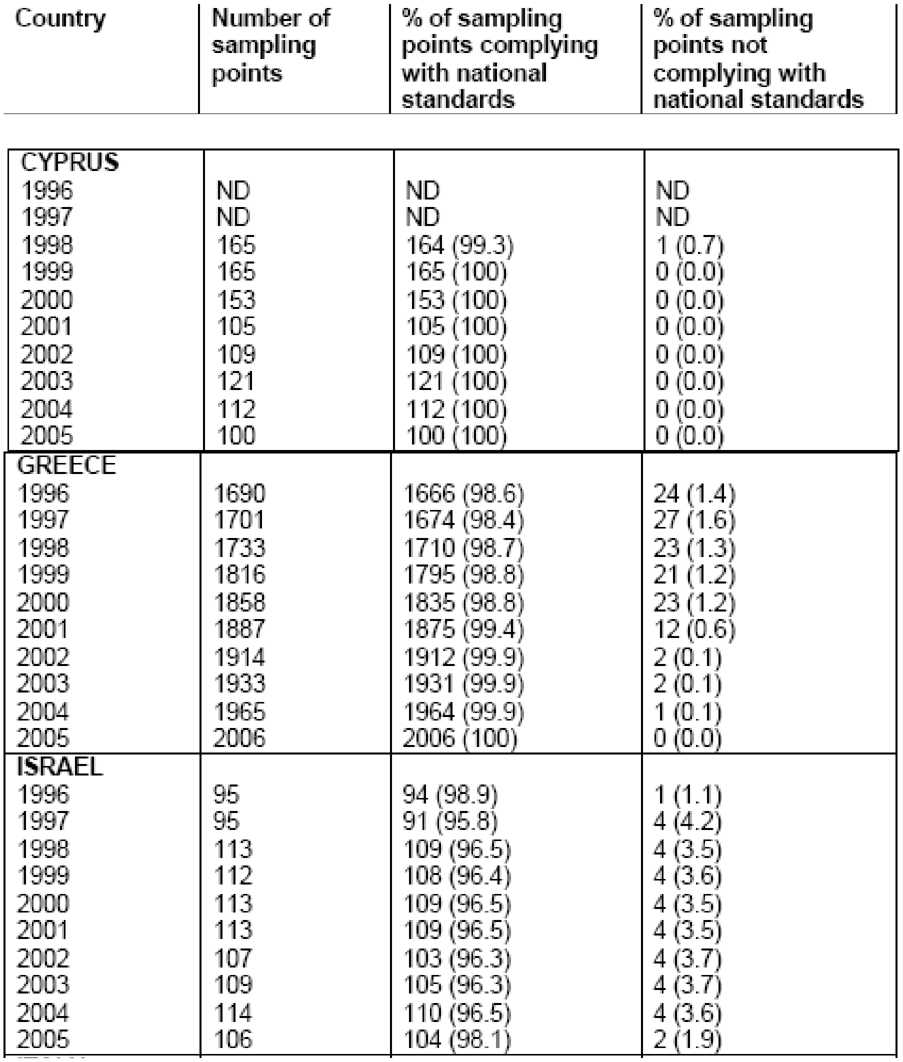
Figure 33: Maps derived from SeaWiFS satellite images showing monthly mean concentrations from October 1997 to December 2004. Source: Volpe *et al.,* 2005

3.4. Microbial pathogens

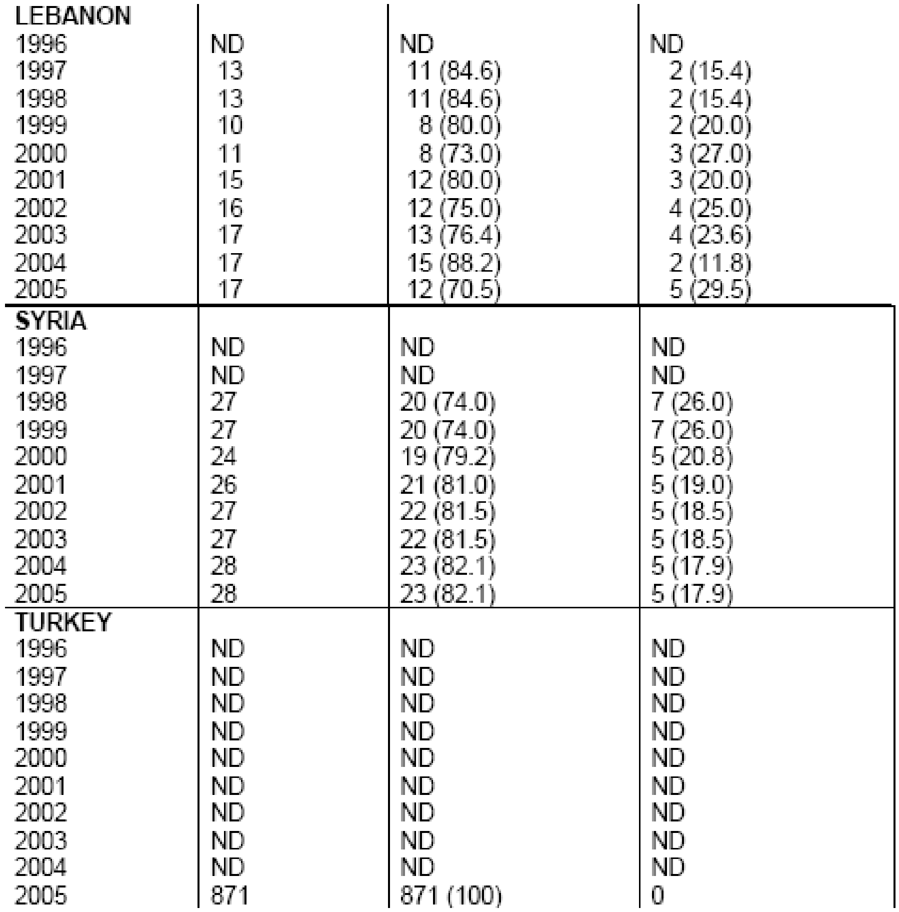
During the period 1996-2005, there has been a near stagnation at a high level in the percentage of bathing waters conforming to national standards (from 92.3% to 92.8%), with fluctuations during the period. A slight improvement is seen between 2004 and 2005. It should be noted that data only refers to waters that are officially monitored and there may be a number of bathing areas which are used for recreation that are not monitored.(UNEP MAP Plan Bleu, 2009). The report concluded that although there is no real trend evident during the sampling period it can be seen that, 50% of the countries submitting data for 2005 achieved over 90% compliance with national standards for bathing water quality, and that Cyprus, Greece, and Turkey all achieved 100% compliance with their national standards by 2005.

All Eastern Mediterranean countries have legislation and microbiological quality criteria and standards for bathing waters. EU countries are bound by the relevant EU Directives, while the Mediterranean non-EU countries by their common Guidelines.

Table 21: bathing water quality across Eastern Mediterranean Source: Reprinted from UNEP/MAP-MED POL/WHO, 2010



Country	Number of sampling points	% of sampling points complying with national standards	% of sampling points not complying with national standards
CYPRUS			
1996	ND	ND	ND
1997	ND	ND	ND
1998	165	164 (99.3)	1 (0.7)
1999	165	165 (100)	0 (0.0)
2000	153	153 (100)	0 (0.0)
2001	105	105 (100)	0 (0.0)
2002	109	109 (100)	0 (0.0)
2003	121	121 (100)	0 (0.0)
2004	112	112 (100)	0 (0.0)
2005	100	100 (100)	0 (0.0)
GREECE			
1996	1690	1666 (98.6)	24 (1.4)
1997	1701	1674 (98.4)	27 (1.6)
1998	1733	1710 (98.7)	23 (1.3)
1999	1816	1795 (98.8)	21 (1.2)
2000	1858	1835 (98.8)	23 (1.2)
2001	1887	1875 (99.4)	12 (0.6)
2002	1914	1912 (99.9)	2 (0.1)
2003	1933	1931 (99.9)	2 (0.1)
2004	1965	1964 (99.9)	1 (0.1)
2005	2006	2006 (100)	0 (0.0)
ISRAEL			
1996	95	94 (98.9)	1 (1.1)
1997	95	91 (95.8)	4 (4.2)
1998	113	109 (96.5)	4 (3.5)
1999	112	108 (96.4)	4 (3.6)
2000	113	109 (96.5)	4 (3.5)
2001	113	109 (96.5)	4 (3.5)
2002	107	103 (96.3)	4 (3.7)
2003	109	105 (96.3)	4 (3.7)
2004	114	110 (96.5)	4 (3.6)
2005	106	104 (98.1)	2 (1.9)



LEBANON			
1996	ND	ND	ND
1997	13	11 (84.6)	2 (15.4)
1998	13	11 (84.6)	2 (15.4)
1999	10	8 (80.0)	2 (20.0)
2000	11	8 (73.0)	3 (27.0)
2001	15	12 (80.0)	3 (20.0)
2002	16	12 (75.0)	4 (25.0)
2003	17	13 (76.4)	4 (23.6)
2004	17	15 (88.2)	2 (11.8)
2005	17	12 (70.5)	5 (29.5)
SYRIA			
1996	ND	ND	ND
1997	ND	ND	ND
1998	27	20 (74.0)	7 (26.0)
1999	27	20 (74.0)	7 (26.0)
2000	24	19 (79.2)	5 (20.8)
2001	26	21 (81.0)	5 (19.0)
2002	27	22 (81.5)	5 (18.5)
2003	27	22 (81.5)	5 (18.5)
2004	28	23 (82.1)	5 (17.9)
2005	28	23 (82.1)	5 (17.9)
TURKEY			
1996	ND	ND	ND
1997	ND	ND	ND
1998	ND	ND	ND
1999	ND	ND	ND
2000	ND	ND	ND
2001	ND	ND	ND
2002	ND	ND	ND
2003	ND	ND	ND
2004	ND	ND	ND
2005	871	871 (100)	0

3.5. Dumping

Relatively little is known about the disturbance caused by the disposal of industrial solid wastes or dredging dumping on marine benthic communities.

Studies in Greek waters demonstrated effects of tailings comparable to those of organic pollution. Dumping of coarse metalliferous wastes, at about 75 m depth had mostly indirect effects on the benthic fauna, through changing the particle size composition of the sediment and increasing the instability of the environment (Nicolaidou et al 1989). Continuous monitoring of the area and long assessment over a period of over 10 years verified this classical model of variation of community parameters along a gradient of increasing stress as for organic pollution; the observed spatial and temporal variations of the macrozoobenthic communities under the pressure of solid waste discharge were mostly attributed to the physical effects of the discharge such as turbidity and the mechanical effects of sedimented and resuspended tailings. Direct effects on the community structure, as comparison with reference site showed, include decline in species diversity and species richness (Simboura et al, 2007).

Along similar lines studies conducted off the coast of Israel comparing two deep sea dump sites (receiving gypsum acidic wastes from a single source (36000tyr^{-1}) and coal fly ash dumping site (approximately 1.25 million tons dumped between 1989 and 1995) respectively) and at a deep sea control area in the southeastern over the 1988-1995 period showed some significant differences between metal contents in the samples from the three sites but no systematic trend or consistency. Rank score analysis based on metal contents of the fauna gave the lowest sum of scores to the control site, indicating probable effect of the disposal operations (Kress et al 1998)

3.6. Marine Litter

Marine litter remains a key aspect of transboundary issues tantalising the Mediterranean since the Sea is a sensitive ecosystem lying amid a densely populated and highly industrialized region, with intense coastal and shipping activities. A recent bibliographical study conducted by MED POL on the phenomenon in the Mediterranean concluded that, between 2002 and 2006, the situation had hardly changed.

The studies of marine debris in the Mediterranean so far have focused on beaches, floating debris and the seabed of the continental shelf or the deep sea. In most of the studies that investigated marine debris on the seabed, debris was collected by trawls (Katsanevakis and Katsarou 2004). Similarly in the eastern Mediterranean studies have been performed by means of trawling and only one has focused on the distribution of underwater marine debris in coastal areas (shallow (<25 m) by diving. Most studies of benthic litter describe its composition and origin (i.e. plastic, metal, fishing gear), calculate its concentrations for each type, estimate its density on the seabed, and identify their sources (broadly categorized into land and marine origin (vessel and fishing based). Table 22 presents the main findings of the studies conducted in the eastern Mediterranean with emphasis in Greek waters.

Table 22. Densities and proportion of significant litter types among benthic marine litter in eastern Mediterranean

Sea	Depth range	gear	Item/1000m^2	Plastic	Metal	other	Source
Eastern Mediterranean transect (17 hauls)	194-4614	trawling	0-8.5 Mean 2.4	36	9	44 Paint chips	Galil et al 1995
W. Greece (2 Gulfs 2 hauls)	80-360	trawling	0.089-0.240	79-83	7.5-8.5	8-13	Stefatos et al., 1999
59 coastal sites, Greece	0-25	diving	0-251, Mean 14.9	55.5%	25.7%	5.2% rubber	Katsanevakis and Katsarou, 2004
W & S Greece (54 hauls, 5 regions)	15-320	trawling	0.072-0.437 Mean 0.165	55.9	16.8	9.2 fishing gear	Koutsodendris et al 2008

The conclusion drawn by UNEP (2005) on the incomparability of the studies becomes evident however general remarks can be drawn

Katsanevakis and Katsarou (2004) concluded that in shallow coastal Greek areas marine debris density is much greater than debris concentration estimated by other studies in the Mediterranean continental shelfs or on the deep seafloor, with the exception of some accumulation zones in the open sea (described in detail in Galgani *et al.*, 2000). Furthermore greater abundance of marine debris was found in bays than in open areas. Results from Koutsodendris et al 2008 support the argument and suggested that a large volume of the litter that enters the marine system is concentrated to shallow coastal areas and only a small percentage reaches deeper waters

Comparing the findings from the deeper parts, Stefatos et al (1999) concluded that the debris concentration on the seafloor of the western Greek gulfs is comparable with the debris concentration found on the seafloor in the eastern Mediterranean (as described by Galil et al 1995); the comparison of the Greek gulfs to the sites in western Mediterranean by Koutsodendris et al (2008) revealed that three of them show moderate litter pollution (<150 Item/km^2), which is comparable to most sites around the world, whereas Patras Gulf shows significant litter pollution (150-500 Item/km^2), which is comparable to the Adriatic Sea, East Corsica, Bay of Biscay, and Gulf of Lions (as described by Galgani et al., 2000) Sea attributed to the proximity of study sites with metropolitan areas.

Plastics dominated the composition of seafloor debris in all case with the exception of the eastern Mediterranean transect (table 24). The percentage of plastic items from the Greek sites is close to the 60± 80% of plastic components reported to constitute the litter on beaches of 13 Mediterranean beaches (in Spain, Italy, Turkey, Cyprus and Israel) (Gabrielides *et al.*, 1991) with almost all worldwide other studies

Both Koutsodendris et al (2008) and Stefatos et al (1999) remarked that land-based debris provided the majority of the total litter items followed by vessel-based and fishery-based sources (69%, 26% and 5% respectively in the four gulfs investigated by Koutsodendris et al (2008) despite the fact that some of the site were fishing areas . Again these findings are in accordance with the Gabrielides et al. (1991) report of low percentage (2.8%) of fishing gear on the Mediterranean beaches. UNEP/MAP-Plan Bleu (2009) has quantified the origin of marine litter in the Mediterranean attributing it to coastal urban centres (generated by direct disposal of domestic waste, tourism infrastructure waste, flows from landfills and rivers); figure 34.

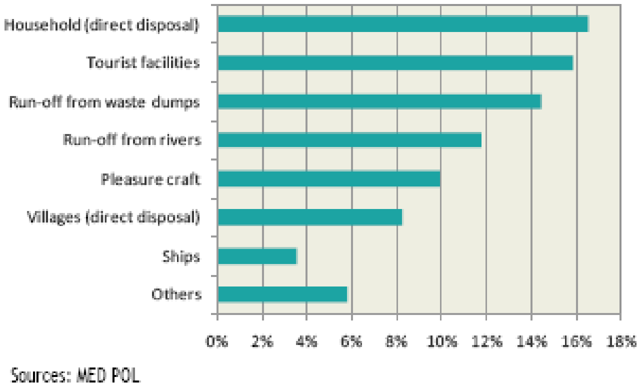


Figure 34 Origin of marine litters in the Mediterranean. Source: reprinted from UNEP/MAP – Plan Bleu, 2009

National, regional and international NGOs are active in Mediterranean beach cleaning campaigns. The International Coastal Cleanup (ICC) observes that, in the Mediterranean, the heavy fraction (big household appliances) is on the decrease1 and that the average weight of waste found in the sea has dropped from 511 g to 258 g. As regards the light fraction, the number of plastic bags, caps and plastic bottles is also on the decrease; the share of plastic found in the sea dominates and composes 75% of collected items. The analysis of the data available indicates that coastal and recreation activities account for 52% of the waste found on beaches (UNEP/MAP-Plan Bleu (2009).

4. Overall assessment

Pollution in eastern Mediterranean (Aegean and Levantine) has been manifested mainly through the impacts of hazardous substances and eutrophication. Marine pollution from cities, the industry and tourist resorts, is large but localised. The presence of macro-waste on beaches and in the high seas has a considerable impact (UNEP/MAP-Plan Bleu 2009), but has not been quantified.

The Aegean-Levanine Seas experience a decreasing trend in riverine fluxes. A decreasing trend has been established for the Aegean (AEG) and the Southenn Levantine (SLE) wheras no trend could be detected for the North Levantine Sea (NLS). Trend and model analyses on hydroclimatic parameters revealed also a precipitation decrease with reductions in the Aegean Sea (-13%), and the South-Levantine Sea (-10%) following the general Mediterranean precipitation trend and increases of the dry spell length. On the other hand the drainage basins of the Aegean and North-Levantine seas have experienced a decrease in temperature in contrast to the strongly increasing temperatures of the entire basin.

The Eastern Mediterranean Sea is an extreme oligotrophic environment with Phosphorus limited primary productivity. All the sub-regions in this basin are characterized by low chl-a concentrations all around the year, the lowest concentrations being observed in the Levantine Basin (with the exception of waters at the boundary of the Nile plume). No temporal trends could be detected A marked seasonal cycle is observed in the various regions, with a decrease of the algal biomass from winter to summer along with large inter-annual variations. Seasonal and inter-annual variations are also present in primary production. Spatial chlorophyll variations in surface waters, in general revealed that the highest levels correspond to the areas close to river deltas or those off large urban agglomerations The main spatial features, detected include a general gradient in algal biomass from north to south and from west to east of the Eastern Basin, the ‘‘ultra-oligotrophic cores’’ of the south Levantine Basin (corresponding to the Mersa-Matruh and Shikmona Gyres, the Nile plume, the north-south gradient in algal biomass in the Aegean Sea, attributed to the combined effects of river inputs, northerly winter and signal from the nutrient reach Black Sea waters.

River fluxes have resulted in increasing trends of nutrient fluxes in to the marine environment enhanced via anthropogenic activities in the drainage basins (despite the decrease of riverine flow) of nutrients into the sea for both N and P. However there is a mark difference: nitrogen has been on a steady increase, whereas Phosphorus has recently started a decreasing trend.

Large cities have been identified as critical sources of hazardous substances pollution, since most of the “hot spots” are located in their neighbouring sediments (Alexandria and Port Said in Egypt and Athens and Thessaloniki in Greece). Also, high concentrations of hazardous substances were found in sediments located in river mouths and estuaries of major Mediterranean rivers (Nile) and lagoons (lake Manzala, Egypt). Pollution from heavy metals appears to be somewhat decreasing, as their content in sea water remains low and even the situation seems to be improving. Similarly concentrations of chemicals (DDT, PCBs) are also decreasing, but in some cases concentrations still remain relatively elevated. Hazardous substances trend revealed decreases more evident in the case of DDTs probably due to a more efficient regulation of this chemical. PAHs are studied to a limited extend both spatially and temporally; and the same can be concluded for anthropogenic radionuclide concentrations. However these limited studies on the latter revealed a ^{137}Cs concentrations decreasing from the surface to bottom in Greek waters and from east to west as well as through time reaching levels similar to those of the pre-Chernobyl period highlighting the effect of Black Sea water in the radioactivity of the area.

Investigation of a small number of studies of the bioaccumulation hazardous substances on the high trophic level (cetaceans, and turtles) suggested that levels were similar to those in other parts of the Mediterranean and not high enough to have likely affected the health of these endangered species. In contrast seals presented significantly higher levels of organochlorines than their counterparts from the Atlantic indicating a predominance of pollutants of agricultural origin in eastern Mediterranean.

Regarding nutrient and organic matter enrichment hot spots can be identified; eutrophication from nutritional substances has been increasing for 20 years; however it is limited to local areas. In Greece, the NW Aegean with Thermaikos Gulf (rivers and the sewage from the city of Thessaloniki), as well as rivers' mouths in the North Aegean, and Saronikos bay off the city of Athens, consist the most seriously eutrophied areas. In Turkey the Sea of Marmara and Bosphorus Straits are presenting serious eutrophication phenomena, and some coastal areas in NE Aegean (Izmir bay). In the SE Mediterranean a few cases of eutrophication are recorded in Lebanon port areas, Israel, coasts. Finally in Egypt, ports in Alexandria area and in the Nile delta system are frequently encountering eutrophication phenomena.

Litter posses a serious threat for the integrity of coastal and marine environment. Although here are publications that are excellent sources of data, these studies were based on short-term surveys and geographically limited observations and, in addition, they were not conducted according to any standard methodology. Even so existing data support the argument that a large volume of the litter that enters the marine system is concentrated to shallow coastal areas and only a small percentage reaches deeper waters and that plastic is the main litter on the sea bed.

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UNEP/MAP – MED POL

Sub-regional assessment of the Status of Marine and Coastal Ecosystems and of Pressures to the Marine and Coastal Environment

Ionian and Central Mediterranean

31 May 2010

Contents

1. Introduction

The Sub-Regional Assessments, including the present one, were prepared by MED POL and subregional experts in the framework of the UNEP/MAP's road map for the gradual application of the Ecosystem Approach for the management of human activities in the Mediterranean Sea.

The Ecosystem Approach (ECAP) has been introduced aiming at improving the way human activities are managed for the protection of the marine environment. Following the World Summit on Sustainable Development, the ECAP has been adopted by many International Conventions and Regional Seas Organizations. The Contracting Parties to the Barcelona Convention have adopted it in January 2008 at their Almeria meeting. The proposals to that meeting were developed in the framework of a project (ECOMED) funded by the EC. In this context, any environmental policy should be developed in a way that secures an effective protection of the marine environment and that makes possible the continued provision of marine goods and services for the wealth of the population. The application of the ECAP has the potential to help reach a balance between the requirements of human activities and the conservation of the marine environment. Its adoption and gradual implementation within the framework of the Mediterranean Action Plan (Barcelona Convention) will give new impetus to the preparation of more integrated and holistic policies by the Convention, including the impact of human activities on the marine environment.

To ensure the sustainability of the exploitation of marine goods and services in the Mediterranean Sea, it is important that the ECAP and its related conservation and management measures be applied not only to areas under the jurisdiction of States, but also to the habitats and ecosystems located beyond the national jurisdiction. As a consequence, the implementation of the Ecosystem Approach is not only a task for the Convention and its subsidiary bodies, but also and mainly for its Parties.

The project's aims among others, at promoting and enhancing the implementation of the road map for the application of the ecosystem approach to the management of human activities. The road map requires that an assessment of the ecological status and of pressures and impacts is undertaken in four different regions of the Mediterranean, identified on the basis of bio-geographic and oceanographic considerations. The present report is a contribution to such a project with reference to the Ionian and Central Mediterranean.

The assessment is mainly based on:

- Reports prepared in the framework of MED POL by the relevant Contracting Parties (Italy, Greece, Malta, Tunisia and Libya) which include the national Diagnostic Analysis (NDA) on various environmental issues and pressures and the national Baseline Budget (NBB) of emissions and releases of selected pollutants within each respective country;
- Basin-Wide Assessment Reports on selected environmental issues prepared in the framework of MAP;
- A range of other publications which are relevant for the purpose of the present review.

The report will first present a synoptic review of the more relevant features of the physic-chemical and biotic parameters of the coastal and marine ecosystems with the area under review. It will then identify and assess priority issues arising from pressures and impacts related to contamination, dumping activities, nutrient and organic matter enrichment and other factors in this area. Whenever possible, it will assess the availability and reliability of the data on which the assessment is based, identifying any gaps which need to be addressed in the future.

2. Area under Review

2.1 Geographical features

The area under review (Figure 1) in the present study is that of Cluster B, which incorporates the Ionian Sea and the Central Mediterranean. The countries involved include the parts of Greece and the parts of Italy within the Ioniana Sea, Malta, Libyan Arab Jamahiriya (henceforth referred to as Libya) and Tunisia.

Figure 1: Area under review in present study, showing major coastal cities, location of hot spots (red circles) and locations of major environmental concerns (blue circles).

The Ionian Sea is bounded by southern Italy including Calabria, Sicily and the Salento peninsula to the west, and by southern tip of Albania, and a large number of the Greek Ionian islands, including Corfu, Zante, Kephalonia, Ithaka, and Lefkas to the east. The Central Mediterranean extends from the southern margin of the Ionian to the coastlines of Libya and Tunisia.

Often being a political hotspot, the maritime jurisdiction of the area is not necessarily accepted by all member states. However according to one interpretation, the area includes the territorial waters of the five states, the historical bay of the Gulf of Sirte and that of Taranto, three fishing zones for Malta, Tunisia and Libya, while the rest of the area is either an ecological protection zone or an area of high seas.

The area under review includes one of the most seismic areas in the world.

The approximate length of coastline involved has been estimated to amount to 5700 km which represents 12% of the total Mediterranean coastline. The total surface area of marine waters amounts to approximately 800,000 km^2, which again represents 32% of the total surface of the Mediterranean Sea.

2.2 Bathymetry, hydrodynamic and other features

Figure 2 shows the general marine bathymetric of the area.

Evidently, the bathymetry of the area under review is highly variable, with the western half being much shallower, generally up to 1000 m deep, than the eastern half, which can extend up to 3000m deep and more. This eastern half includes the deepest part of the Mediterranean (5267m) which is south-west of Pylos Greece, forming part of the Hellenic Trench. The western half forms the relatively shallow submarine ridge (sill) between Sicily and Tunisia, which divides the Mediterranean in two main basins. The eastern ridge has maximum depth of about 540m connecting the Sicilian Channel with the Ionian Basin. The western sill is divided in the large Adventure Bank and the Nameless Bank. These large sill systems are separated by the narrow shelf in the central part. The shape of slope is extremely irregular, incised by many canyons, trenches and steep slopes.

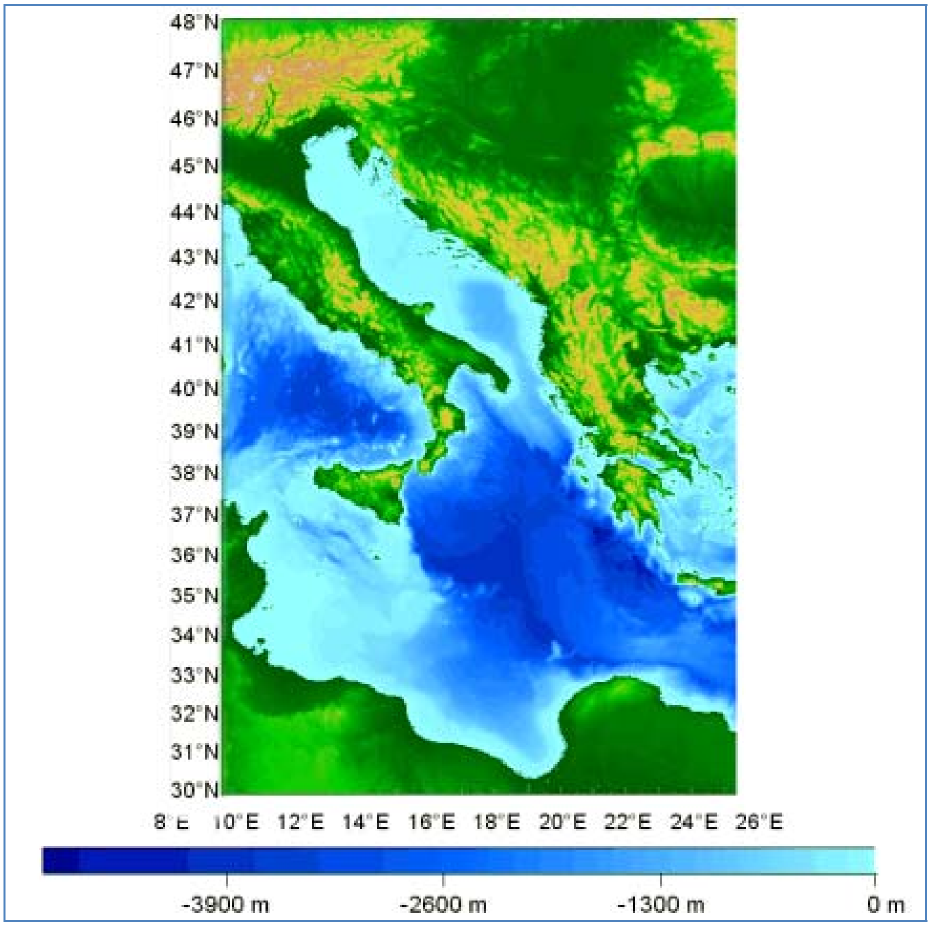


Figure 2. Marine bathymetry of the area under review.

The Maltese Archipelago is located on the outermost limit of the Sicilian continental shelf.

The hydrodynamics of the area (as in other Mediterranean areas) are determined by water exchanges through the various straits, by wind forcing and by buoyancy flux at surface due to evaporation, river inputs and heat fluxes. The slow Mediterranean thermohaline basin-scale circulation leads to the formation of a two water masses consisting of less saline Modified Atlantic Water flowing towards the East at surface and a deeper more saline Levantine Intermediate Water flowing in the opposite direction. This flow occurs at an average depth of 280m.

At surface the Atlantic-Ionian Stream (AIS) meanders its way towards the East for most of the year. As it reaches the deeper waters it moves northward forming the so-called Ionian Shelf Break Vortex (Drago and Sorgente, 1998, Robinson, et al., 2001).

Modified Atlantic Water is carried along with the AIS across the area under review moving towards the South-East and re-circulating in part on the Tunisian and Libyan continental shelf areas.

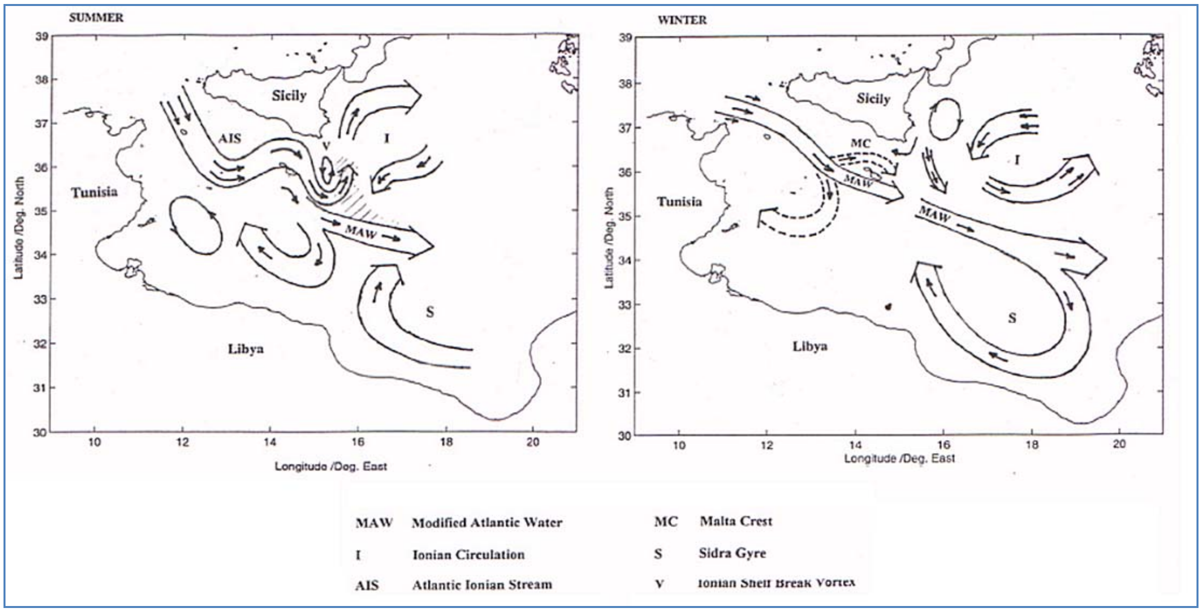


Figure 3: Surface currents in the Central Mediterranean *(From Drago and Sorgente, 1998)*

The surface currents in the Ionian Sea generally follow a counter-clockwise course: they flow towards the north parallel to the Greek coast and then turn west and south along the Italian coast. In general this current is not very strong though it can be stronger in straits or close to islands.

A recent review of surface circulation in the Central Mediterranean (Poulain and Zambianchi, 2007), based on data of satellite-tracked drifters for 1990-99, provides a broad quantitative description of the central Mediterranean surface circulation. The emergent view is that the dynamics of the channel at large, including the Tunisian shelf and the area south of Malta, sometimes exhibit unexpected characteristics of the surface velocity field, sometimes stagnant or even directed the opposite way with respect to the currents flowing further to the north. Furthermore the seasonal character of the surface circulation in the area as well as the effect of wind forcing was found to be well evident. It was found that when winds blow from the northwestern sector (like the Mistral) the surface eastward transport in the Sicily Channel is enhanced. In contrast, for opposing wind conditions (blowing from the southeastern sector), the transport trough the Channel is significantly reduced. The quasi-Lagrangian nature of the drifters also allowed for an estimation of auto-covariance, the horizontal diffusivity and the integral time and space scales. In the Sicilian Channel, diffusivities and scales ranging in 1-5 × $10^7 cm^2 s^{-1}$, 1-2 days and 10-30km were found, respectively. All these hydrodynamic features are highly relevant to determine the fate of contaminants in the area. In general the tides in the area under review are weak, at about 10-50 cm.

Surface sea temperatures and salinity patterns in the open waters are mainly influenced by seasonal circulation patterns and coastal upwelling. Upwelling events are often evident in the Straits of Otranto and off Sicily as well as off the Tunisian and Libyan coasts. Along the Sicilian coast upwelling is governed by the south-eastward winds and by the inertia of the isopycnal domes of the Atlantic Ionic Stream meanders and cyclonic vortices that can extend its influence far offshore due to the configuration of the circulation. Furthermore, relatively sharp transitions in SST along the east-west axis of the area under review are often evident especially during certain parts of the year, due to sub-basin hydrodynamic changes. In the coastal regions, SST exhibit wider diurnal and seasonal fluctuations due to the shallow waters.

Marullo et al., (2006) have used archived data of the Pathfinder-AVHRR SST for the period 1985 to 2005 to produce climatological synoptic maps such as that presented in Figure 4.

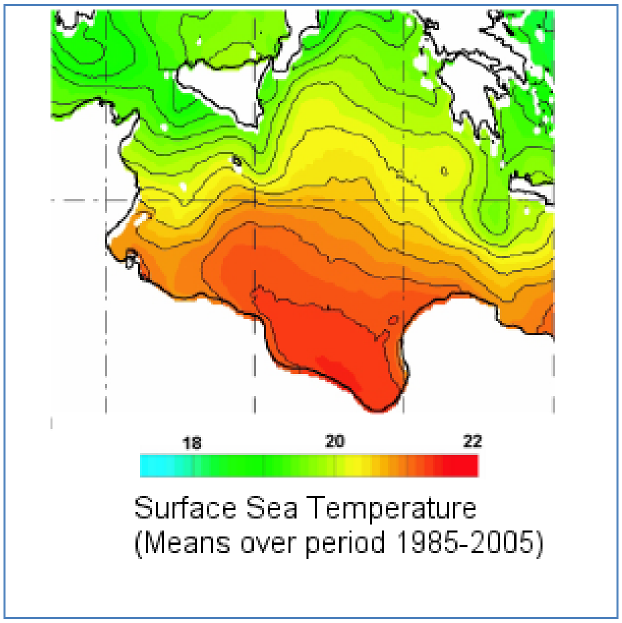


Figure 4: Sea surface temperatures for the area under review as estimated by Marullo et al., 2006. For further details see text.

The transitional nature of the area along the North-South Axis in terms of SST is clearly visible in this figure.

According to the review by Ludwig et al., (2009), the annual average rate of precipitation over the period 1960 to 2000 has been estimated to be 552 mm for the whole Mediterranean basin, 784 mm for the Ionian area and 79 mm for the southern Central Mediterranean. This clearly shows that the uneven availability of water in the area under review, with its European half having an average precipitation rate above the Mediterranean average, and its African half being one of the driest areas of the whole basin. Furthermore trend analysis suggests that climate in the Mediterranean clearly evolved towards dryer conditions.

The same authors indicate that the mean recorded air temperatures in the Mediterranean show an upward trend. The only exceptions are the drainage basins of the Ionian, Aegean and North-Levantine seas, where the trends are statistically not significant.

2.3 Nutrients and primary productivity

Like in other oligotrophic marine areas, the Mediterranean, including the area under review is characterized by generally pronounced thermal stratification of the water column, which delimits (1) a warm surface mixed layer with high light intensity but depleted in nutrients and (2) a sub-superficial layer with low light levels and more nutrients. The depth where the dissolved nitrate concentration approaches zero (nitracline) is around 75 m in the Ionian Sea, during the stratified period. The same nitracline is found at about 10m depth at the Alboran Sea, and can reach more than 150 m in the Levantine basin of the Mediterranean Sea. This is one of the features of this area which well exhibits its transitional nature between the two basins.

As expected, these low nutrient conditions have a direct and great impact on the level of primary productivity in the area. In fact a decrease in integrated primary production, particulate carbon export and nutrient availability towards the eastern side of the Mediterranean Sea is observed, while integrated chlorophyll a remained constant. Integrated primary production normally reach 300 mg C m^{-2} d^{-1} in the Ionian basin, which is again found to be intermediate between the value generally recorded for the western basin (approx. 500 mg C m^{-2} d^{-1}) and that recorded in the Levantine basin, which is 150 mg C m^{-2} d^{-1} and which is considered as a limit for primary production rates under strong oligotrophic conditions (Moutin and Raimbault, 2002). The highest levels of productivity occur along the coasts, near major cities, and at river estuaries.

It is generally believed that in the Mediterranean, photosynthetic production is limited by phosphate availability. Dissolved inorganic phosphate concentrations in the upper photic zone are known to decrease from west to east reaching levels well below 1 nM (Moutin and Raimbault, 2002). Nonetheless in some places where nitrates or even silicates are low, they are also known to be major limiting factors for primary productivity.

Pacciaroni and Crispi (2007), evaluated the relative importance of nitrogen and phosphorus, as external loads, on Mediterranean biogeochemical cycles. Biomass concentrations were analysed considering the steady state response of the three-dimensional ECHYM model to three nitrogen and phosphorus atmospheric depositions, considered as continuous in time. The distributions of nutrients within the biochemical compartments were analysed, highlighting, inside the Mediterranean oligotrophic environment, the role played by ultraplankton, the smaller phytoplankton compartment. The authors review how the oligotrophy of the Mediterranean Sea is explainable as a response to the negative thermohaline circulation. The inverse estuarine circulation of the whole basin determines a negative budget for nutrients at the Gibraltar Strait, since there, nutrient-poor surface water is imported from the Atlantic Ocean and relatively nutrient-rich intermediate water is exported. Thus the detailed three-dimensional hydrodynamics of the entire basin, coupled to the main biogeochemical dynamics, must be taken into account to resolve the Mediterranean ecosystem variability. Furthermore, phytoplankton growth depends on the above-mentioned nutrient conditions. Chlorophyll concentrations remain high in the upper layer and coincide with nutrient depletion. The nutrient-depleted surface layer is separated from a layer of abundant nutrients, at some distance below the euphotic depth, by a nutricline, layer in which nutrient concentrations increase rapidly with depth. Therefore, depending on light intensity at the surface and the turbidity of the water, the displacements of nutricline and pycnocline determine abundance and productivity of phytoplankton.

Zooplankton is typically concentrated within the euphotic zone, but because of sinking and diel vertical migration of some species into and outside from the euphotic zone, organic matter is supplied and various types of zooplankton can be found at deeper layers. This depth range can displace the grazers from the near surface lighted waters where the phytoplankton grows, to deeper environments. Therefore, understanding the mechanisms of Mediterranean ecosystems is connected to physical, chemical and biological aspects of the photic and aphotic zones.

The authors estimated through the application of models the yearly averaged Chl:C ratio for ultra- plankton in the whole Mediterranean basin. The western side of the Mediterranean Sea shows the greatest values, 0.018, in the Gulf of Lions and in the south of Sardinia. The lower Chl:C ratio is detected in the extreme eastern basin with about 0.008. They also estimated the Chl:C ratio for netplankton, giving values about halved than those for ultra-plankton. For the Ionion and Central Mediterranean, the values for Chl:C for ultra-plankton ranged from 0.01 to 0.04 (Figure 5), while for netplankton, the rations varied from 0.004 to 0.009. The higher values tended to be located in the western half of the area under review and in particular along the Tunisian coastline.

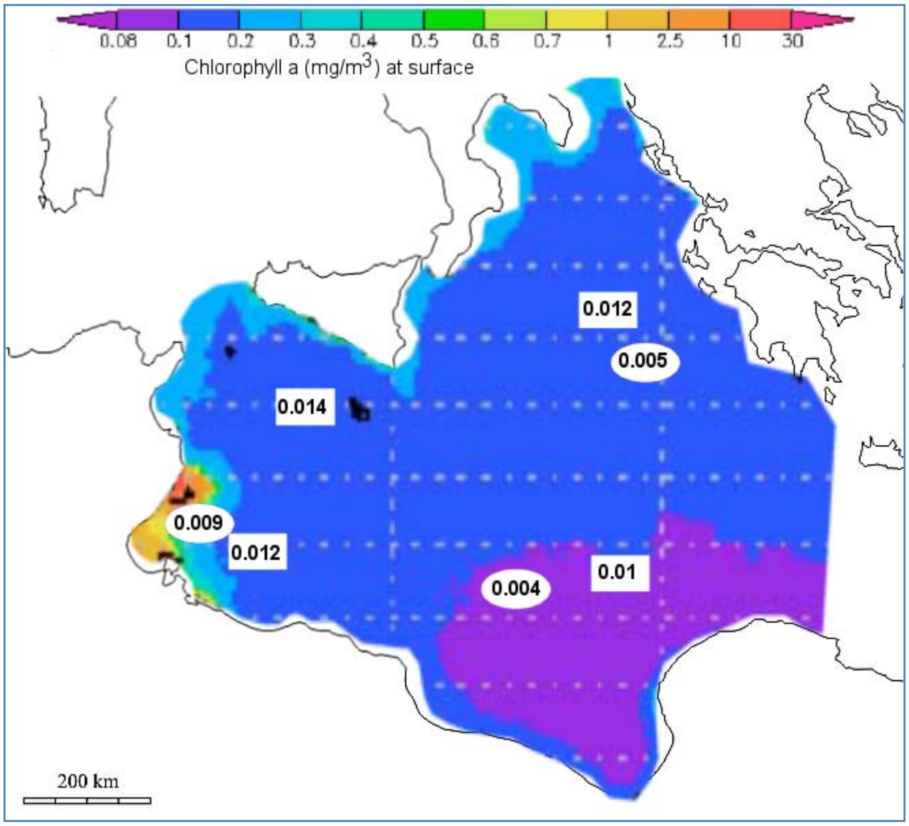


Figure 5: Geographical distribution of the more relevant bio-productivity parameters in the area under review. The false colour contour map shows the distribution of chlorophyll a (mg m^{-3} at surface, as estimated using remote sensing images from a*nalyses and visualizations produced with the Giovanni online data system, developed and maintained by the NASA GES DISC, as quoted and reproduced by Cruzado, 2009. The chlorophyll a levels are means averaged between August 2002 and December 2008. The values inserted in rectangles show annual chlorophyll to carbon ratios relative to ultraplankton, and those inserted in eclipses show the same ratios relative to net plankton. These ratios have been estimated by* Pacciaroni and Crispi (2007), as described in text.

The annual modelled upper layer chlorophyll means generally show the Alboran basin exhibiting the highest chlorophyll with respect to the whole basin, values reach about 0.8 mg Chl $m^{-3.}$ In the south and central Ionian and in the far Eastern Mediterranean, values are generally well below 0.05 mg Chl m^{-3} (Figure 5). These models also show near-surface chlorophyll signals above background northwest and south of Sicily. Unfortunately such models did not cover many coastal zones of southern Mediterranean and Libya.

The same models were also used to estimate vertical profiles (up to 200m depths) of chlorophyll distribution along selected transects of the Mediterranean, one running from the Gulf of Gabes towards the East. The result suggest a deep chlorophyll maximum of 0.2 mg Chl m^{-3} at 100 to 40 m depths starting within the Gulf of Gabes, and extending along the Gulf of Sirte with values of 0.15 mg Chl m^{-3}

As regards the atmospheric nutrient deposition in the different Mediterranean areas, the authors estimated values ranging from 9.9 to 10.4 x 10-8 umol N dm^{-3} s^{-1} for nitrates and 1 to 2.9 umol P dm^{-3} s^{-1} for phosphates within the Central Mediterranean. These values are intermediate between those for the Western and Eastern basins.

Figure 6 shows the distribution of particulate carbon in February 2010 as visualized and analyzed by the Giovanni online data system, developed and maintained by the NASA GES DISC. In spite of its limited temporal extent (representing the situation in a single month), this figure in general collaborates the features of bio-productivity in the area under review as have been identified in the above account.

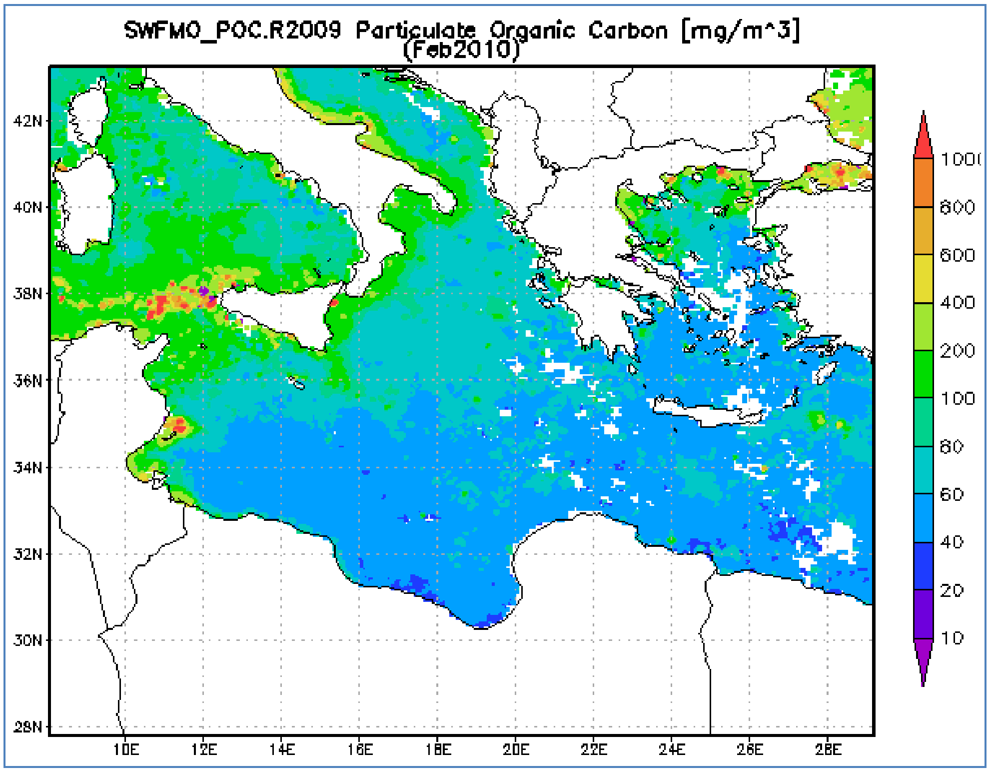


Figure 6: Particulate Organic Carbon as recorded in February 2010. *Analyses and visualization were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.*

2.4 The coastline, demography and pressures

As already indicated above, the area under review comprises approximately 5700 km of coastline which represents 12.4% of the total Mediterranean coastline. The physical and topographic coastline features in the area vary greatly, from the relatively long sandy beaches of Libya to the undulating Ionian coastline of Greece. Unlike the rest of the Mediterranean basin, mountains are not particularly evident in this area, except for Mount Etna in Sicily. Relatively significant alluvial plains are found in Tunisia, being associated with the Medjerda River discharging in the Gulf of Utica and forming the crucially important wetlands associated with Ghar el Melh lagoon. Wetlands of unique beauty may also be found along the Greek coastline such as the Gialova lagoon at Pylos, Messinias.

According to one estimate (UNEP/MAP/MEDPOL, 2005), in 2000, the combined Mediterranean coastal population was greater than 150 million. According to the same estimate, the coastal population in the North was expected to remain relatively stable, whereas the coastal population in the South is projected to increase by approximately 30 million people in 25 years. Currently there are great disparities in coastal population densities among the riparian states, with more than 1,000/km^2 in the Nile Delta and less than 20/km^2 along coastal Libya. The southern rim of the Mediterranean now contains more than 50 percent of the total population and this percentage is expected to grow to 75 percent by 2025. These projected demographic changes in the region will have significant effects on the Mediterranean environment, as demand for natural resources will dramatically increase in the south. Population densities are much greater in coastal than in non-coastal areas, especially in the southern parts of the Mediterranean.

With respect to the area under review, an estimated 8.6 million inhabitants reside in a total of 27 coastal urban centres or areas. Of these, Tripoli is the biggest urban centre with 1.06 million inhabitants, with Tunis being the second largest with 0.72 million inhabitants, and Benghazi being the third largest with 0.67 million inhabitants. On the European side, the biggest coastal urban area is that of Taranto with 0.58 million and then Reggio Calabria with 0.57 million. This evidently shows that the urban concentrations with the highest populations are located on the African coastline in the area under review. On the Ionian Greek coastline, Patra is the biggest urban centre with 0.22 million inhabitants. Figure 7 shows the location of these urban centres together with the relative levels of populations residing in such centres.

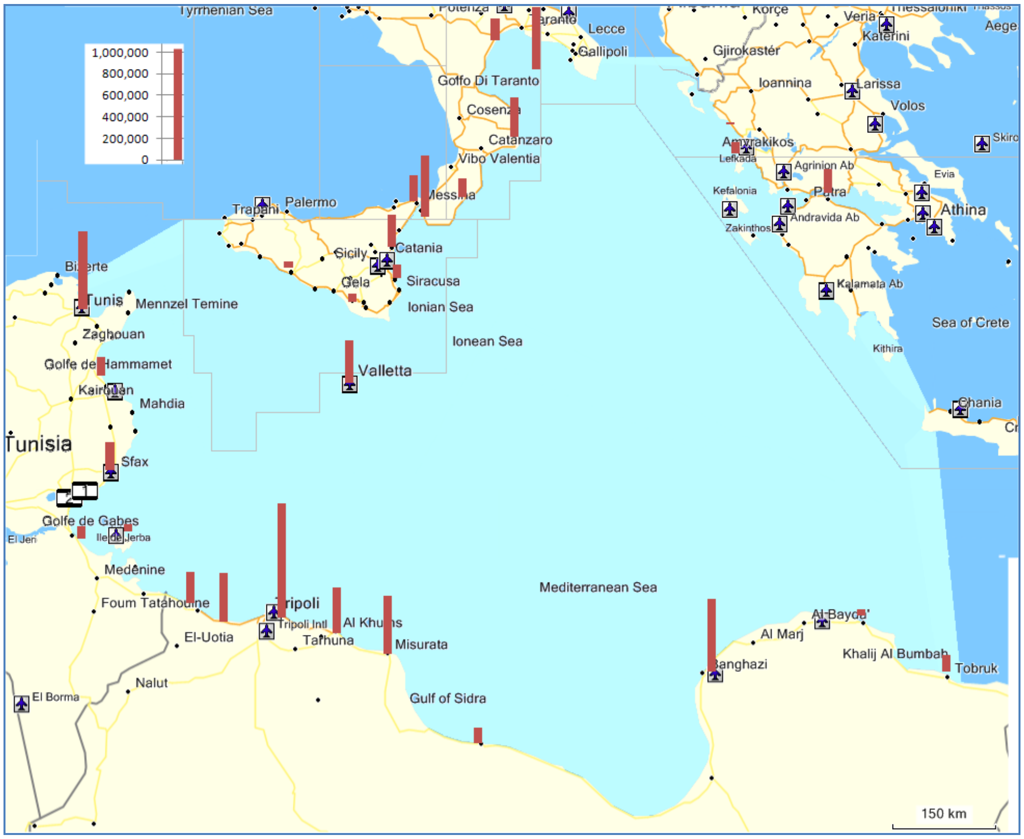


Figure 7: Location of major urban centres with relative population levels in the area under review.

A list of pollution hotspots and locations of areas of major environmental concern for the various Mediterranean countries has been complied on the basis of national diagnostic analysis submitted to the Mediterranean Action Plan (MAP). Such list includes a total of 138 hotspots and 69 areas of major environmental concern. 15% (22) of such hotspots and 14% (10) of areas of major environmental concern are located within the area under review. The locations of such areas are indicated in Figure 1.

2.5 River inputs and runoffs

Terrestrial inputs including runoff and river discharges have a direct influence on the coastal and marine systems and therefore on the quality status. The degree of such an impact may be at least partly gauged by the ratio between the surface area of the terrestrial watershed to that of the marine basin into which such discharges are emptied. For the whole Mediterranean basin, this ratio amount to 0.55 (CIESM, 2006). The various sub -basins within the Mediterranean have different ratios. For example the greatest value for such a ratio is that for the Central Mediterranean (1.87), while that for the Ionian Sea is the smallest (0.37). This implies that the Central Mediterranean and in particular, the shallow coastal waters along the African coastline would be expected to come under great influence of the terrestrial watershed (drainage basin), which is particularly large for Libya. On the other hand, since the rate of precipitation in the area is low, then the rates of discharges would be low. In fact, according to Ludwig et al., (2003) the estimated rate of freshwater inputs in the Ionian Sea in 1995 was estimated to be 25 km^3 per year, while that for the Central Mediterranean may be less than 5 km^3 per year. Grenon and Batisse (1989) report the average annual runoff flows from different river basins within the Mediterranean from different sub-regions. While such runoff volumes would be expected to vary significantly from year to year depending on precipitation and other factors, it is evident that the area under review would be expected to receive approximately only 10% of the total annual runoff reaching the whole Mediterranean basin. Considering that this area is approximately 32% of the total surface of the Mediterranean, it may be expected that such area is not unduly directly influenced by such runoff when compared to other sub-regions within the Mediterranean. Furthermore, the greatest impact that may be expected from such runoff on coastal and marine water status would be in the Ionian part and along the coastlines of Italy and Greece, which would receive more than 95% of such runoff for the area.

Evidently, the manner and degree to which such land-based natural discharges effect the coastal and marine environment also depends on a large degree on the various anthropogenic pressures and activities on land. This includes forest cutting and grazing, leading to increased erosion, intensive agriculture as well as animal husbandry, damming and irrigation, as well as coastal urbanization.

In a recent report by Ludwig, et al., 2009, river inputs of nutrients in the Mediterranean were reviewed. According to such estimates, the annual amounts of nitrogen, phosphorus and silica reaching the Ionian and Central Mediterranean from rivers in 1998, amounted to 63,000 tonnes N, 2,900 tonnes P and 59,000 tonnes Si, respectively. When compared to the same estimates for the whole Mediterranean, these inputs of N, P, and Si amount to 5 to 6% of the total amounts reaching the whole basin. The same report includes estimates of the amount of fertilizers (nitrogen) applied in the different drainage basins around the Mediterranean. For 1995 it was estimated that the amount of fertilizers (N) applied in the drainage basins for the Ionian and Central Mediterranean waters amounted to 1,900 kg N /km^2/year. This amounted to 15% of the application rates for the whole Mediterranean basin.. Evidently, when viewed at the sub-region basin scale, river inputs may not be considered as a significant pressure on coastal and marine quality status for the area under review. The same may not be true to localized inshore areas in immediate vicinity of major river discharges.

3. Pressures and Impacts

This section will review the pressures and impacts in the area under review of contamination by marine waters, sediments and biota by hazardous substances such as trace metals, petroleum hydrocarbons, antifouling agents, and other priority substances. The assessment is based on:

- A background document prepared by UNEP/MAP (2008) which represents an overview of the priority substances globally and regionally within the Mediterranean;
- A draft review prepared in the framework of MED POL Monitoring Programme (2009) on hazardous substances in the Mediterranean, based on an assessment of the MEDPOL database;
- The Emission Inventories from industrial sources (National Baseline Budget – NBB) and the National Diagnosis Analysis (NDA) of Greece, Italy, Malta, Libya and Tunisia prepared in the framework of MED POL;
- Data for individual industrial entities as reported in the European Pollutant Emission Register (EPER/PRTR).
- Other published or unpublished literature, whenever available.

As remarked by other authors, the availability of verifiable data on levels of contaminants in the area is quite limited and unevenly distributed geographically.

3.1. Emissions of pollutants

3.1.1. Urban sources

According to EEA (2006) all five states within the area under review consider the marine discharge of urban wastewaters as a priority environmental issue. Such effluents often include excessive loads of nutrients and of organic matter which lead to a deterioration in the water and sediment quality status and therefore of the eutrophic status of inshore waters, as well as pathogens and a whole range of hazardous chemicals, which are potential risks to human health. These issues may seriously affect the quality of life in the coastal areas, and therefore have economic implications to coastal development and tourism.

The permanent population along the coastal areas of the Ionian and Central Mediterranean is in the order of 8.6 million inhabitants residing in about 27 coastal urban centres or conglomerations. The demographic features of the area have already been reviewed above. Furthermore, due to the intense tourism activities in the area, this population may be doubled during the summer peak months. Though no regionally based data of tourist's arrivals were available for the present report, a rough calculation from the available published data may indicate that the number of tourist arrivals may reach from 15 to 20 million visitors per year.

As part of the pollution reduction component of the Euro MED Initiative Horizon 2020, LDK-ECO S.A. Environmental Consultants (2006) reviewed the pressures arising from urban wastewaters in a range of South Mediterranean countries, including Libya and Tunisia. While past infrastructure projects have extensively taken place on urban wastewater sanitation in Libya, the report refers to defects in pumping stations and wastewater treatment plants, and improper connection with run-off ditches and open channels, resulting in lack of proper treatment of urban effluents. At least up to 2006, rehabilitation of the treatment plants was required for the largest two cities Tripoli and Benghazi, as well as Janzur, Dernah, Khums, Tobruk and Sabrata. Maintenance of civil and mechanical works and connection of sewage pumping sanitation were needed for a number of wastewater treatment plants. The report also refers to large amounts of run-off water from urban areas find their way to the sea through special outlets, as in Tripoli, or through natural valleys and watercourses, as in Khums, Al Qarabulli, Tajura, and Sirt Cities.

In the case of Tunisia, the LDK-ECO S.A. report (2006) states that wastewater services were very well developed. However up till 2006, some large cities required an extension of their sewage network (Ariana and Ben Arous in Tunis area, Mahdia, Sfax, Gabes and Djerba), where the connection rate is below 85%. Furthermore because of the fast growth of the urban population, some treatment plants cannot cope with the rapidly increasing flow of effluents. For example, although the greater Tunis area operated a sewage treatment plant, the rapid population growth has resulted to a treatment capacity deficit of 60,000 m^3 per day. It is quite likely that this state of affairs had improved since 2006.

As part of the present assessment, an attempt has been made to estimate the approximate volume of domestic wastewaters produced in the region, and of this how much receives treatment. Although available data are insufficient in some cases, nonetheless some estimates were possible on the basis of reported number of residents in these areas, Furthermore, according to various EU online databases, for the whole Italy it has been reported that than 60% of its urbane wastewaters, currently receiving some kind of treatment. Based on this information, as well as on the data provided by the NDA reports for the other countries, it was estimated that the approximate total volume of urban wastewaters generated in the area under review would be 765 million m^3 per year. At least 40% of this remains untreated and a significant amount is bound to reach the marine environment. Figure 8 shows such assessment graphically.

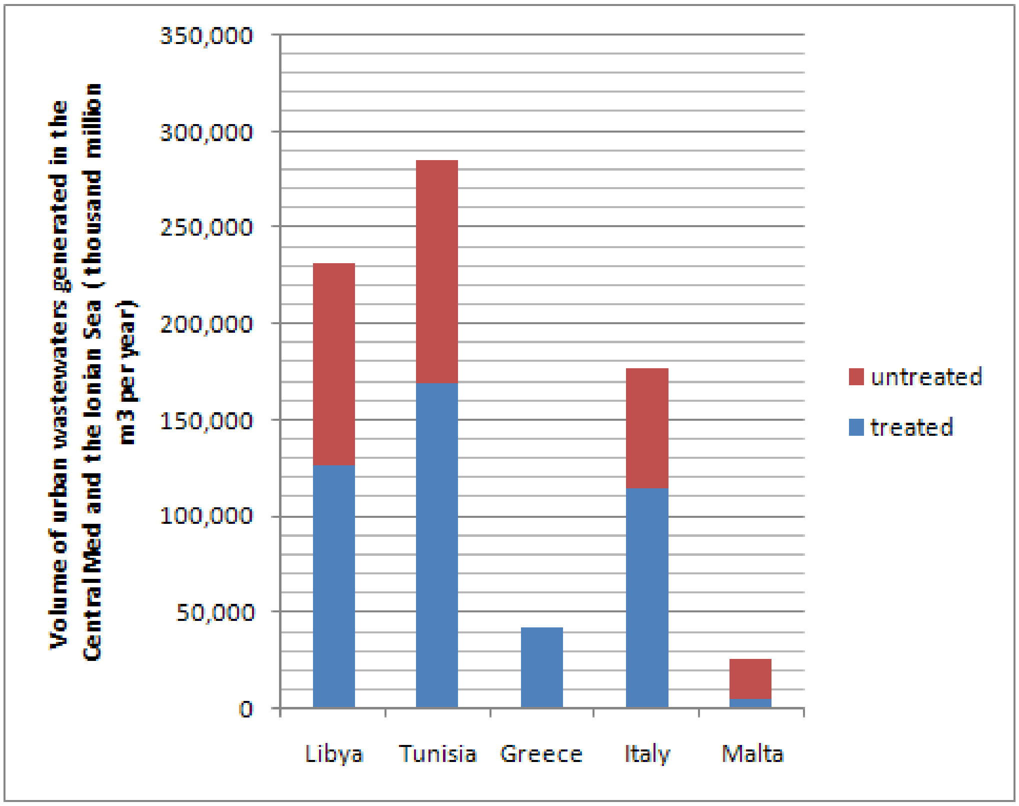


Figure 8: Volume of urban wastewaters (million *1000 m3 per year) by the various regions bordering the Ionian and Central Mediterranean.

This assessment shows that, most of the untreated sewage is being discharged along the North African coast of the area under review. Furthermore the efficiency of wastewater treatment plans may not always be as that desired.. This problem must be compounded by the rapid urban sprawling along the southern coastline of this area.

These discharges of urban wastewaters especially if left untreated are bound to significantly increase the nutrient and organic content loads of coastal waters especially in the vicinity of outfalls. Figure 9 shows an estimation of such annual loadings in the area under review, based on two scenarios: the best base scenario whereby the reported proportions of wastewater treatments in the respective (when given) are indeed applicable, and the worst case scenario, whereby none of the wastewaters receive any treatment. Evidently the real current status is difficult to determine but must lie somewhere in between these two extremes. The same figure also shows the annual loadings arising from industrial sources as have already been identified in a previous section above.

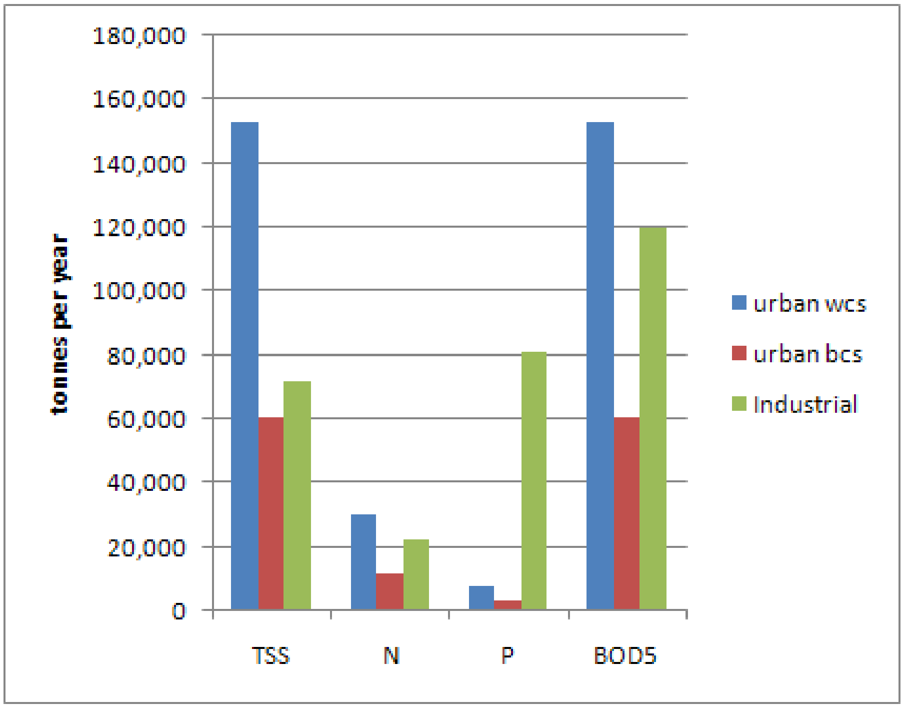


Figure 9: Annual releases of nutrients, total suspended solids and organics (in terms of BOD5) into the area under review as arising from two scenarios for urban wastewaters wcs= worst case scenario; bcs= best case scenario; for details see text), and from industrial wastewaters.

One pertinent feature which becomes well evident from these considerations is the fact that industrial effluents are comparable as pressures on water quality to urban effluents. Indeed for the case of phosphorus, industrial effluents far exceed urban effluents in importance.

3.1.2 Industrial sources

UNEP/MAP (2008) had reported the total load of some selected pollutants as reported by all Mediterranean countries by sector. The data suggest that when compared to releases over the whole Mediterranean, the annual rates of release of a number of important pollutants in the area under review are not significant. This particularly applies to mercury, phenols, lead, chromium and possibly nickel. On the other hand releases of polyaromatic hydrocarbons in this area are significantly higher than those that would be expected, probably related to the increased shipping traffic in the Central Mediterranean.

The most important sources of releases of marine contaminants in the Mediterranean, has been recently reviewed by UNEP/MAP (2008) and UNEP/MAP-Plan Bleu (2009). As pointed out by the latter report, data transmission of NBB by the various states within the Mediterranean presents gaps. This is particularly so for the Central Mediterranean since the data on industrial releases from the southern Mediterranean states accounted to only 11% of the whole data set received by the UNEP/MAP unit.

Based on the emissions reported to MED POL, in the Central Mediterranean area manufacture of metals and oil refining and oil/fuel related operations assume bigger importance as sources of pollution, than production of energy. As expected (due to the level of water scarcity as has already been identified in the previous sections), the industrial sector of desalination also features quite prominently. Also aquaculture appears to be a sector of emerging importance.

Figure 10 shows the relative importance of releases (% loads) of trace metals from the various identified industrial sectors in Italy (releases into the Ionian sea only), Libya and Malta.

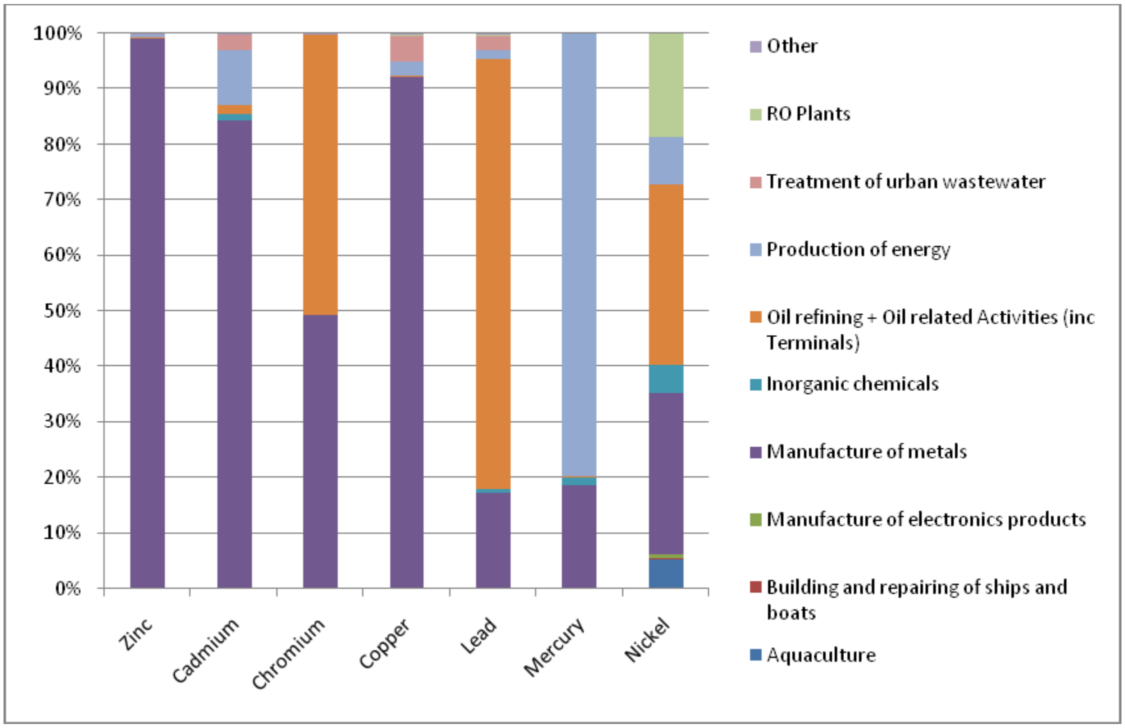


Figure 10: The relative importance of various sectors for the release in the marine environment of various trace metals (based on data from Italy-Ionian, Malta and Libya)

As would be expected, most of the metals released in the area arise mainly from the manufacture of metals as well as from oil refining and oil/fuel related activities. Mercury is mainly released from production of energy, unlike for the rest of the Mediterranean, where is mainly released from manufacture of fertilizers (UNEP/MAP, 2008).

Figure 11 shows the relative importance of releases (% loads) of various other main contaminants from the various identified industrial sectors in Italy (releases into the Ionian sea only), Libya and Malta.

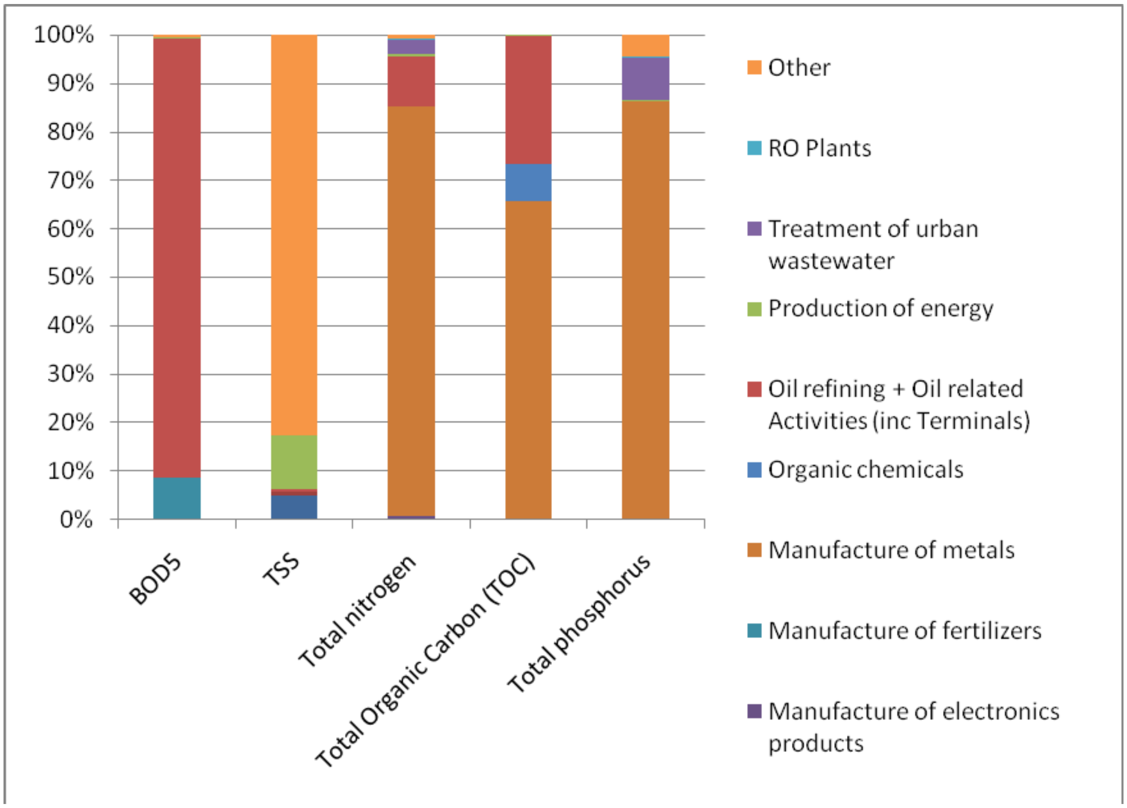


Figure 11: The relative importance of various sectors for the release in the marine environment of BOD5, TSS, TOC and total Nitrogen and Phosphorus (based on data from Italy-Ionian, Malta and Libya)

Again manufacture of metals features prominent for the release of a number of contaminants. This may not necessarily be representative for the whole area under review. Furthermore, UNEP/MAP (2008) shows this industrial sector to be only relatively important for the release of total nitrogen, for the rest of the Mediterranean.

For the area under review, the available data suggest that the oil sector is the main industrial sector responsible for BOD5 release. According to UNEP/MAP (2008), this is also a main feature found for the rest of the Mediterranean (along with food packaging, and farming of animals).

3.1.3. Agriculture and other runoff

Agriculture has been reported to be the largest non-point contributor of pollutants to the Mediterranean (UNEP/MAP, 2001). One of the main drainage basins dominated by agricultural land is located in Sicily (online EU database: reports.eea.europa.eu). Agriculture as a non-point source of pollution in the Mediterranean has been commented upon by UNEP/MAP/MEDPOL, 2005, and will not be repeated here.

Agriculture is a main economic sector in the area under review. In fact it has been cited as the main consumer of fresh water resources within the Mediterranean (64% for the whole basin, UNEP/MAP-Plan Bleu, 2009). For Tunisia, Libya and Greece, irrigation for the agricultural sector accounted for approximately 80% for water demand over the period 2005-2007). Coastal agriculture is a common feature for the area under review (especially for Tunisia and Libya), and in view of the need to increase produce with limited land availability, the application of natural and artificial fertilizers (apart from pesticides) must be quite intense in several localities. Rain runoff from the drainage basin containing such agricultural lands is most likely to be an additional source of nutrients and organic loadings in coastal waters. This may be less important in countries like Libya where the rate of annual precipitation is quite limited. It may be much more important along the Ionian coastline.

Agriculture in Tunisia makes a considerable contribution to the country's GDP. The industry is faced with problems of water availability, desertification and soil erosion. Coastal agriculture in particular is characterised by fairly advanced technologies, including considerable use of inorganic fertilisers and increasingly generalised phytosanitary treatment. To a certain extent this contributes to the pollution of seawater (UNEP/MAP- Plan Bleu, 2001). The development of intensive irrigated agriculture has led to the overexploitation of ground water; the response has been to design recharge programmes in order to maintain the agricultural activities necessary to the region.

Agriculture in Malta is not an important contributor to the country's GDP. Nonetheless it has an important role in landscape conservation. One of the main environmental pressures arising from current agricultural practices on the island, is the release of excessive nutrients (particularly nitrates) in the fresh water aquifer resources. Several studies also indicate that specific coastal areas such as Marsascala, and Xlendi are particularly sensitive to increased nutrient loadings from agricultural run-offs.

Eighty per cent of Libya's agriculture is located in coastal areas. A major environmental concern here is the depletion of groundwater as a result of overuse in agriculture, causing salinisation due to sea-water penetration into the coastal aquifers.

An EEA report (2009) recently assessed the nitrogen loadings/emissions over the member states of the EU. Agriculture and transport were given as the main sources of nitrogen pollution. When this pollution exceeds certain levels ('critical load'), it is damaging to biodiversity through eutrophication, etc... Across the EU-25, approximately 47 % of (semi-) natural ecosystem areas were subject to nutrient nitrogen deposition leading to eutrophication in 2004. The extent to which critical loads are exceeded varied significantly across Europe. For the Ionian Italian and Greek coastal areas, the report indicates exceedances along most of the coastline especially in Greece.

3.2 Levels of Contaminants in the Marine Environment

The following assessment of levels of contaminants in the marine waters, sediments and biota in the Ionian and Central Mediterranean is mainly based on UNEP/MAP (2008) and UNEP/MAP - MED POL (2009a). Both reports noted that the main problem to be taken into consideration was unequal geographical distribution of the available data. For the area under review, this was missing from Malta and Libya. In the following account and whenever possible, the area assessment will also include available data from Malta (both published and unpublished).

3.2.1 Trace metals

Most of the data are available on five metals, namely: cadmium, mercury, lead, zinc and copper. UNEP/MAP-MED POL (2009) produced synoptic figures of the distribution of mean concentrations of trace metals as found in coastal marine sediments and in marine bivalves, in the Mediterranean (Table 2).

Table 1: Trace metals in sediments and biota: median (and range) values (µg g^{-1} dw) (UNEP/MAP-MED POL 2009a)

Central Mediterranean	**Cd**	**Total-Hg**	**Pb**	**Zn**	**Cu**
Sediments	0.53 (0.38-0.65)	0.05 (0.01-6.00)	4.3 (0.33-50.4)	34.4 (0.05-176)	5.14 (0.29-52.9)

Mytilus galloprovincialis	0.44 (0.13-3.40)	0.18 (0.01-7.00)	0.81 (0.07-5.36)	87 (11.6-565)	9.32 (1.36-70.5)

As indicated by UNEP/MAP (2008), elevated levels of mercury in marine sediments are more often found in the immediate vicinity of industrialized or heavily urbanized coasts. For example, mercury levels in the Gulf of Taranto range from 40 to 410 ng g^{-1} dw in sediments near the coast and 70 ng g^{-1} dw in sediments offshore, in the centre of the gulf. An extensive study in the Strait of Sicily revealed that mercury levels ranged from 50 to 70 ng g^{-1} dw, with samples registering higher contents with maxima up to 202 ng g^{-1} dw . Similarly, sediments of the Strait of Otranto reached 78 ng g^{-1} dw.

Mercury levels in marine offshore sediments as recorded in the Ionian Sea were generally found to be comparable to those from other Mediterranean areas (around 50 ng g^{-1} dw). Di Leonardo et al., (2006) have shown occasional high levels of mercury in the Strait of Sicily.

More recently some additional data is available for trace metals in sediments from Malta, Lampedusa and to a lesser extent from Linosa. The most elevated levels of such contaminants in sediments were associated with the main sewage outfall in Malta. This currently discharges 80% of the total liquid wastes (domestic and industrial wastes) generated in Malta, untreated in the marine environment.

Of the four trace metals assessed, zinc levels were generally higher, probably due to natural factors. For the case of mercury in marine sediments in Malta, Lampedusa and Linosa, levels were relatively low, except for some outlier maxima reported in the immediate vicinity of the main outfall in Malta (Figure 12)

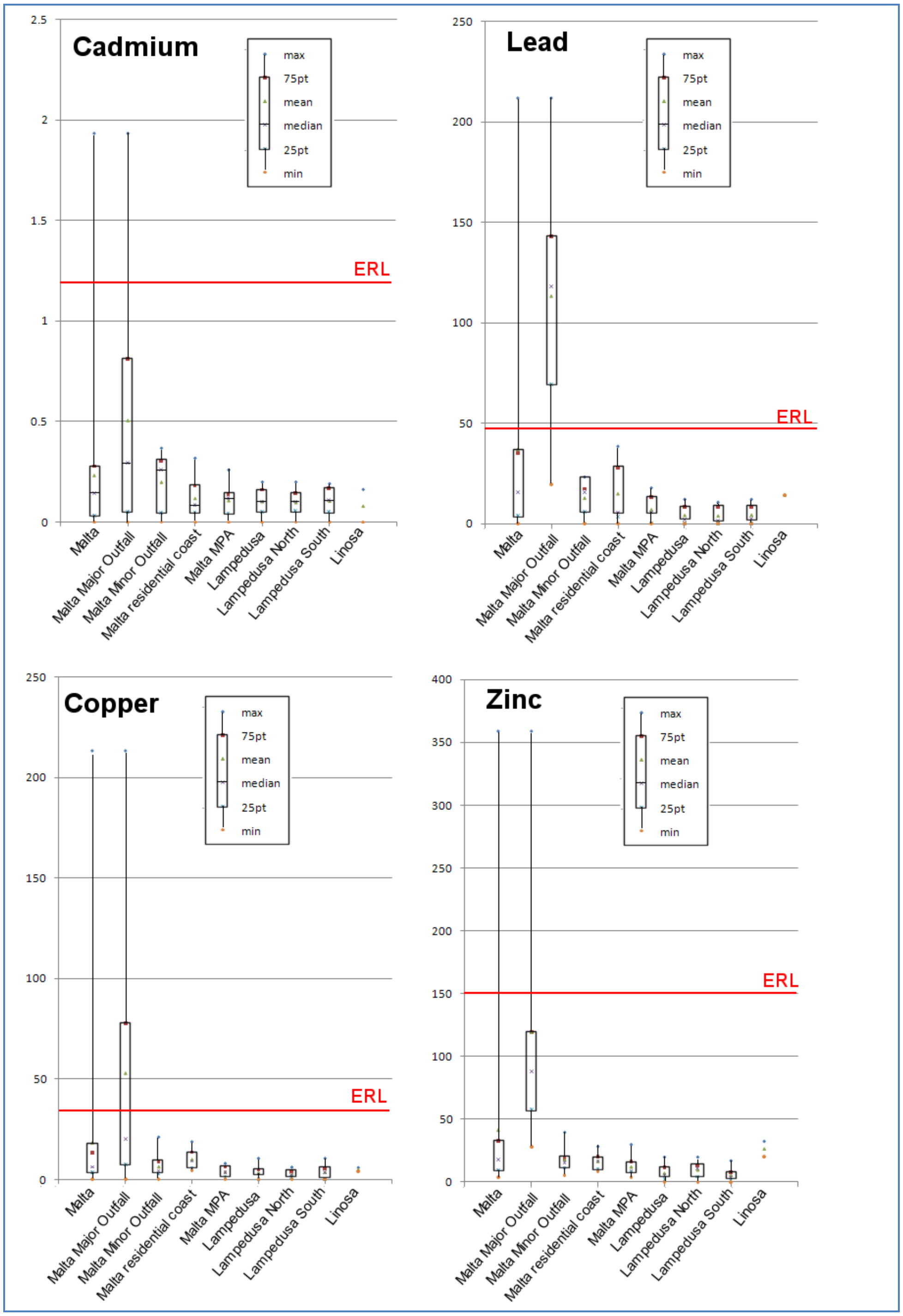
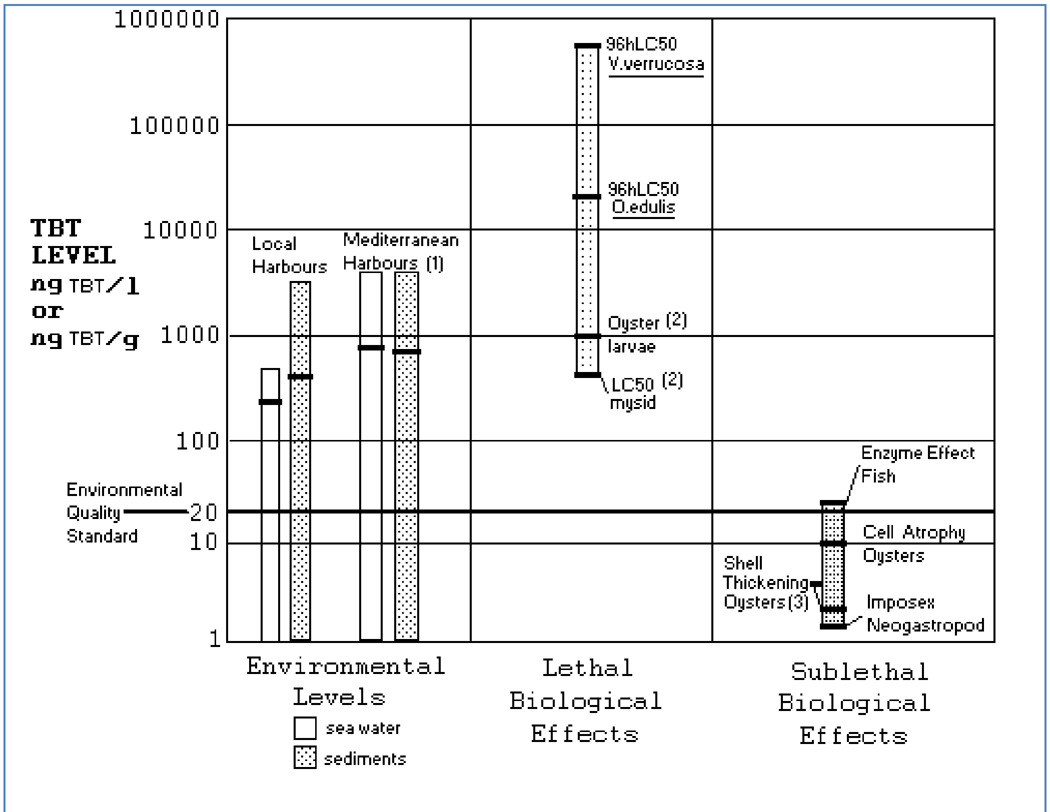


Figure 12: Levels of trace metals in superficial marine sediments (µg g^{-1} dw) in three islands in the Central Mediterranean: Malta, Lampedusa and Linosa, as well as in specific localities within these islands.

Organotins have been used for a wide range of applications, generally related to their biocide effects. One of the best known is tributyltin (TBT) which has until recently been used as an antifouling agent for ships and boats (amongst other applications). TBT is one of the most potent biocides which may reach the marine environment and as such warrants a more detailed look at the available data. UNEP/MAP (2008) reviewed much of the available data on organotins in general and more specifically on TBT. Such review has shown that much of the data available for the Mediterranean comes from the western basin (especially Spain) and Egypt. For the Central Mediterranean, Axiak et al., (2000), reported that the two main sources of marine contamination by TBT in Malta were the ship-repairing dockyards and marinas. It was found that in bulk seawater, TBT values ranged from below the detection limit of 5 ng Sn L^{-1} to 300 ng Sn L^{-1}; in sediments deriving from the most polluted areas, TBT concentrations as high as 1500 ng Sn g^{-1} dw were measured as seen from Figure 13. At TBT levels found in local harbours, several biological responses were observed, including significant reduction in Mixed Function Oxidase enzyme system activities of fish; digestive cell atrophy in the oyster *Ostrea edulis*; and induction of imposex in the snail *Hexaplex trunculus*. The latter two responses are evident at TBT concentrations below the environmental quality standard (20 ng Sn L^{-1}).

Imposex monitoring in Lampedusa and Linosa during 2006-2007 (Axiak, et al., in press) have shown that recent TBT contamination in both islands which have to date been considered as relatively pristine areas, is significant. There is also evidence that the occurrence of such imposex has increased significantly since 1996 (as reported by Terlizzi et al., 1998, and so has the impact on the populations of this species. The most likely source of pollution by TBT in both islands is the relatively high maritime activities during summer. Through imposex monitoring, it is evident that levels of TBT are or at least until very recently were widespread found in the Ionian, the Central Mediterranean and elsewhere.



1= from Gabrielides et al. 1990. 2 = from Huggett et al. 1992. 3 = from Waldock et al. 1987

Figure 13: Summary of environmental levels of TBT as monitored in 1996-1998 (ranges and means) and their biological impact. Source: Axiak et al., 2000.

3.2.2 Halogenated hydrocarbons

According to MED POL data, (UNEP/MAP-MED POL 2009a) the Central Mediterranean and Ionian Sea were relatively free of hotspots of chlorinated hydrocarbons in marine bivalves, at least according to the present availability of data. Also lower median levels were estimated for total DDTs, and for Lindane in the bivalve *Mytilus* as reported in the area under review, when compared to median levels in other Mediterranean sub-regions.

Table 2: Chlorinated compounds in Mytilus galloprovincialis. Median (and range) values (ng g^{-1} dw)

Central Mediterranean	**Σ DDTs**	**Lindane**	**CB138**	**CB153**	**Σ7CBs**
Mytilus galloprovincialis	10.24 (0.40-26.0)	0.11 (0.1-1.40)	5.00 (0.30-23.0)	4.27 (0.70-38.0)	

UNEP (2002) made an assessment of toxic and persistent organic compounds including halogenated hydrocarbons. The report concluded that apart from areas of intense local contamination, compounds of regional concern are PCBs, DDT, HCHs, and HCB, amongst others. Other compounds, e.g., phthalates, alkylphenols and PBDE/PBBs, are suspected to be ubiquitous but data were lacking.

Few spatial and long-term temporal trend monitoring of fish, mussels and seabird eggs have been carried out in the Northern Mediterranean. A general decline of DDTs has been reported for marine biota along the Mediterranean coast of France and Italy, and from the Adriatic Sea between 1970's and 1990's, which is consistent with the regulatory restrictions on production and use of this compound. PCBs, in general, do not exhibit such clear trend. No such conclusions could be reached for the area under review, due to limited availability of data.

UNEP/MAP (2008) reviewed the levels of various forms of halogenated hydrocarbons within the Mediterranean, including DDTs and other halogenated pesticides, chlorinated paraffins, perfluorinated compounds, brominated flame retardants, dioxins and furans, as well as polychlorobyphenyls. In this review, a number of case studies (often of an ad hoc nature, rather than resulting from long-term monitoring) are reviewed. Few case studies which fall within the area under review were identified. These are as follows:

Ranges of reported levels of PCB levels in the fish *Dicentratus labrax* and of *Thunnus thynnus* in the Strait of Messina, were in general comparable to those of other regions, though sometimes higher. The same applies to levels of DDT (though wide ranges in such levels have been often recorded)

Levels of dioxins and furans (polychlorinated dibenzo-p-dioxins, and dibenzonfurans) in the shrimp *Aristeus antennatus*, during 2001 as measured in the western and eastern

Ionian Sea were generally lower or comparable to those measured along the Catalan and Balearic coastal waters.

Recent results from ‘mussel watch’ experiments as well as chemical monitoring in sediments, in Lampedusa, Linosa and Malta (Scarpato et al., in preparation) suggest that except in the immediate vicinity of the main sewage outfall in Malta, the levels of PCBs, chlorinated pesticides and other halogenated hydrocarbons are low and often below detection limit.

Most of these halogenated hydrocarbons often reach the marine environment through river discharges, coastal runoff (especially from agricultural land for pesticides) as well as sewage outfalls (especially when industrial wastewaters are discharged into public sewers. The above account suggests that though levels of such contaminants may be high in the immediate vicinity of likely sources (as identified above), such as along heavily industrialized coastal areas along the Ionian and Sicilian Italian coast, from an area-wide perspective, the area under review is relatively free of contamination hot-spots.

A geographical trend in contamination was also found for striped dolphin in the Mediterranean basin: PCB and DDT levels decreased from the north-west (Ligurian Sea) to the south-east (Ionian Sea). Fossi et al., 2004, investigated the bioaccumulation of a range of contaminants in specimens of striped dolphin collected from various regions within the Mediterranean.

3.2.3 Polyaromatic Hydrocarbons and Petroleum related Hydrocarbons

Polyaromatic hydrocarbons (PAHs) are often related to crude oil, and petroleum fuels and products. Though there is a range of potential land-based sources of such marine contaminants, the most evident are maritime traffic and the chronic (from normal operations) and accidental releases of oils and other fuels, oil refineries and oil/fuel terminals, as well as atmospheric fallout from point and diffuse land-based sources. Industrial solvents and degreasers may also be considered as significant sources of such hydrocarbons.

PAHs are often associated with superficial marine sediments, especially in harbours and near coastal industrial complexes. UNEP/MAP (2008), while reviewing PAHs in marine sediments from several Mediterranean localities, indicated that such levels as measured in Sfax coastal region and in Bizerte lagoon, Tunisia, are in general comparable or lower than those from other regions. Furthermore, PAHs as measured in limpets collected from various Sicilian coastlines were again comparable or lower than PAHs as measured in a whole range of other biota, elsewhere. Levels of PAHs in superficial sediments from Lampedusa, Linosa and Malta were in general very low and often below detection limits, except in the immediate vicinity of Malta's major sewage oufall. Evidently, the validity of such 'snapshot' data to an assessment of a region-wide assessment of levels of pollution is limited.

Nonetheless there is evidence to suggest that levels of petroleum hydrocarbons in the vicinity of oil refineries and oil terminals located within the area under review are often significantly high. For example, Zrafi-Nouira et al., (2008 a,b) reported on the concentrations, spatial distribution and chemical profiles of petrogenic PAHs in the coastal area of Jarzouna, Bizerte in Tunisia, which is one of the major oil refineries in the area. Total hydrocarbon levels ranged between 46 and 76 mg L^{-1} in seawater samples and between 28 and 102 mg L^{-1} in water extracts. The sites nearest to the oil refinery were found to be chronically contaminated by total petroleum hydrocarbons based on aliphatic biomarkers. PAH contamination is generally much more pyrolytic than petrogenic. The same research group showed that Total Hydrocarbon (TH) concentrations ranged from 602 ± 7.638 µg g^{-1} in superficial sediments to 1270 ± 2.176 µg g^{-1} in deeper sediments. The results suggest that the deeper the sediment, the higher the level of total hydrocarbon found. The sedimentary Non Aromatic Hydrocarbon (NAH) and Aromatic Hydrocarbon (AH) concentrations ranged from 66.22 ± 1.516 to 211.82 ± 10.670 µg g^{-1} for NAH, and from 13.84 ± 0.180 to 115.60 ± 2.479 µg g^{-1} for AH. The high variability of these concentrations was associated with the location of the sediment collection sites. Aliphatic biomarker analysis revealed petroleum contamination close to the refinery rejection site, and biogenic sources further away.

Zaghden et al., (2005) also reported significantly high levels of non-aromatic hydrocarbons in superficial marine sediments from Sfax, Tunisia, with ranges from 310 to 1406 µg g^{-1} dw. The same authors suggest that such status is due to the marine discharge of untreated industrial effluents. Similar situations must be found in the vicinity of other refineries in Libya and Sicily. Cardellicchio, et al., (2007) analyzed for a range of marine contaminants in surface sediments from various stations in the Mar Piccolo of Taranto. Total PAH concentrations ranged from 380 to 12,750 µg kg^{-1} d.w., these levels being considered as higher than those found in others marine coastal areas of the Mediterranean Sea. For PAHs, low molecular weight/high molecular weight, phenanthrene/anthracene and fluoranthene/pyrene ratio were used for discriminating between pyrolitic and petroleum origin. Results showed that PAHs were mainly of pyrolitic origin.

Hydrocarbon analysis in superficial sediments within harbour areas and elsewhere in Malta have been carried out over the past 2 decades (Axiak, in preparation). Such analysis have been undertaken using UV-spectrofluorimetry and therefore are not sufficiently detailed to identify individual PAHs. Nonetheless the results indicate that levels in harbours may sometimes exceed 100 ug (Chrysene Equivalents) g^{-1} dw especially near intense shipping activities and near a tanker reception facility.

Furthermore, Bouloubassi et al., (2006) showed that deep and open waters in the Mediterranean appear to act as a significant PAH sink. The group collected one year time series of sinking particles at two depths and analysed for PAH. Average total PAH concentrations were 593+/-284 ng g^{-1} at 250 m and 551 +/- 198 ng g^{-1} at 2850 m. Total PAH fluxes averaged 73 +/- 58 ng m^{-2} d^{-1} at 250 m and 53 +/- 39 ng m^{-2} d^{-1} at 2850 m. The authors concluded that contamination levels and thus, exposure of marine organisms to PAH are comparable in surface and deep waters. Furthermore PAH temporal patterns showed noticeable seasonality. This is partly due to varying levels of specific components such as the winter increase of pyrolytic PAH. Downward transport processes and the nature of sinking particles also impact on PAH fluxes, as inferred during periods of increasing productivity. Different phase-associations and interactions with particulate organic carbon for low-MW fossil PAH and high-MW pyrolytic PAH influence their downward transport efficiency.

Bianchi et al., (2004), reviewed several data on persistent toxic contaminants in various environmental phases at Augusta-Priolo and Gela, Sicily (both sites of important oil refineries and petrochemical operations). These include a range of heavy metals, PCBs as well as PAHs. The group concluded that a high birth prevalence of hypospadias and other human congenital anomalies from the two areas are related to such levels of pollution.

3.2.4 Visible oil slicks and tar

Small to medium size oil slicks and floating pelagic and coastal tar are unfortunately a common feature in surface waters of the area under review. Golik et al., (1988) reported on a monitoring survey of 101 stations in the Mediterranean Sea in August–September, 1987, where floating tar samples were collected, using neuston nets. The authors concluded that the Gulf of Sirte where the mean tar content was recorded at 6859 µg m^{-2} . The area with the next polluted levels was found to be in the far eastern basin with mean values being at least 75% less. The least polluted areas were the western Mediterranean, 236 µg m^{-2}, and the northern Ionian Sea as far east as halfway between Crete and Cyprus with mean tar concentration of 150 µg m^{-2}

No recent data on the densities of tar balls within the Gulf of Sirte are available. It is to be noted that for the four main Libyan oil terminals in the region (Tripoli, Misurata, Khoms and Zawia), no waste reception facilities are available except for the one in Tripoli, which according to REMPEC lacks 'adequate and organized reception and treatment facilities for oily waste' (REMPEC, 2005).

The presence of oil slicks is also well documented in the area under review. According to the EC Joint Research Centre/IPSC (2006). the area between Sicily and Malta is a pollution hotspot regarding oil spills in the Mediterranean Sea. The same conclusion has been reached by a recent review by Heber, 2009. The author explains how since 2008, the European Maritime Safety Agency has been providing Member States with snapshots of their monitoring zone, allowing potential oil spills to be spotted. In 2007-2008, REMPEC in collaboration with the European Space Agency under the MARCOAST project circulated identical images on an experimental basis for Morocco, Algeria and Tunisia. From 240 images received, 454 potential cases of discharge were spotted.

Oil spill density maps derived from satellite imagery for the whole Mediterranean have been produced by various authors (e.g. Tarchi et al., 2006; Ferraro et al., 2007). Figure 14 shows one example. In general, these reviews are indicative of the following conclusions:

- Offshore areas, often beyond territorial waters are often exposed to high levels of oil spill incidents. This suggests that such spills arise from illegal and deliberate releases in high seas.

- For the area under review, most of the oil spills are often located along the major East-West maritime traffic lane along the Sicilian Channel, and especially between Malta and Sicily, as well as on the Ionian stretch between Sicily and the Peloponnese peninsula. Considerable oil spills are also present along the Ionian waters off western Greece and in the Straits of Otranto. These latter spills most likely arise from the considerable maritime traffic leading into and away from the Adriatic.

- The Gulf of Sirte and the Tunisian waters are often depicted as have relatively low levels of oil spills. This may be due to the relatively low number of images available for analysis from this area.

- Ferraro *et al*. (2007) noted that the number of spills more evident during the summer months.

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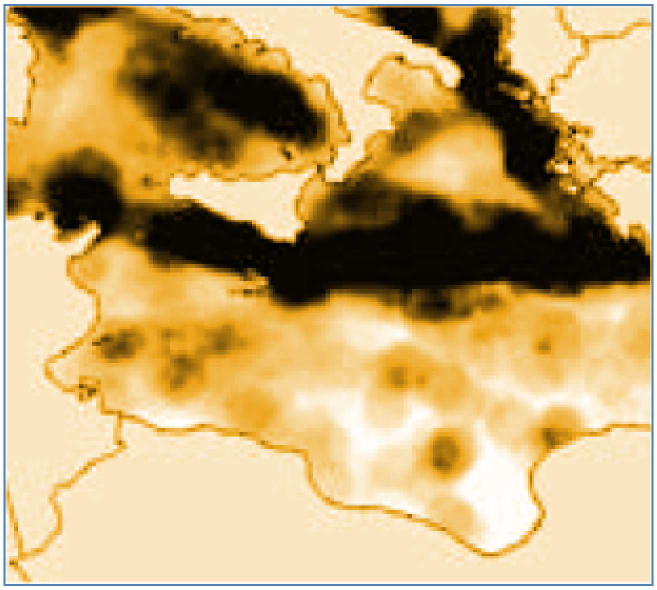

Figure 14: Oil spill density (darkest areas shows highest density of spills) in the Central Mediterranean and the Ionian Sea over the period 1999–2004. From Tarchi *et al.*, 2006.

3.2.5 Radionuclides

The main point source of radionuclides releases into the marine environment would be operational or active nuclear reactors used for energy generation and/or research. At present, the area under review is relatively free from such sources. Of the four nuclear power stations and two research reactors which have been or were at any one time in operation since the early 1960s in Italy, none are located along the shoreline of the area under review. The nuclear research reactor of Tajura in Libya (located approximately 17 km from the Mediterranean coastline), is the main focal point of the countries relatively small nuclear programme mainly focused for the research in water desalination. The only research reactor (10 MW) in Greece is located at the Demokritos National Centre for Scientific Research, Athens, but it is no more in operation. There are also no operational reactors in Tunisia or Malta.

It is likely however that the current situation may change since there are plans for an expansion in the nuclear programmes of some countries. For example, Tunisia may be installing two nuclear power plants within a 10 year period. Each one of these is projected at producing 900-1000 MW. The central authorities in Italy have announced plans for the construction of 3 to 4 nuclear power plants (and possibly more). Sicily has been mentioned as one of the potential locations for such reactors. Such reactors produce highly radioactive wastes, and in general it is agreed that an acceptable disposal route for this waste have yet to be identified. The approximate annual generation rate of spent radioactive fuel arising from the current European sources range from 2000 to 4000 tonnes of heavy metals (OECD, 2007),

No data on the levels of possible nucleotides in Italy were available. In the case of Greece, the NDA reported that the activities that could cause the pollution of waters with radioactive substances are limited and connected to research programmes of Institutes and thus, there is low probability of pollution. Several surface waters are monitored but data have not been made available by the respective authorities. The NDA reports for Libya refer to the potential sources of radionuclides (these being research centres and hospitals) but do not provide any information on levels. The situation is the same for Tunisia.

Other potential sources of radioactive substances apart from fuel processing plants, include hospitals, clinics and scientific laboratories utilizing radioisotopes for medical and scientific purposes, as well as coal-fired power plants. Trace quantities of uranium in coal, range from less than 1 ppm in some samples to around 10 ppm in others. Generally, the amount of thorium contained in coal is about 2.5 times greater than the amount of uranium. For a large number of coal samples, the average values of uranium and thorium content have been determined to be 1.3 ppm and 3.2 ppm, respectively. The average radioactivity per tonne of coal is 17,100 millicuries/4,000,000 t, or 0.00427 millicuries/t. Several coal-fired power plants are or were until recently in operation in the area. For example in Malta, the Marsa Power Station had been running on coal in the early 1990s. Vella and Axiak (2002) had estimated that from this power plant alone, when it was running on coal, as much as 1.3 t of uranium and 3 t of thorium could have been released annually. The authors had concluded that probable the period of coal firing in Malta has resulted in the most significant background radioactive contamination of the local immediate environment throughout recent history. Other coal or lignite power plants are found in Greece and Italy.

In general, it is usually thought that radioactive contamination within the Mediterranean is not a problem of major concern. According to the EEA (2006) the overall total inventory of radionuclides in the Mediterranean Sea is declining. The levels of ^{137}Cs and ^{239,240} Pu in surface waters show decreasing trends. In marine organisms used for human consumption, ^{137} Cs concentrations are very low (less than

1 Bq/kg). It is in fact quite likely that the single most important major anthropogenic release of radioactivity for the whole basin was the Chernobyl accident apart from past nuclear weapon testing. The Ionian and Central Mediterranean were not particularly affected by such events.

Nonetheless, there is very little data available on actual levels of radionuclides in the area under review. Furthermore, whatever data is available is highly fragmentary in temporal as well as spatial extent, so as not to allow an assessment of the relevant risks of contamination on a basin-wide scale. One of the most recently reported monitoring programmes was that for ^{137}Cs in *Mytilus galloprovincialis* (Mediterranean Mussel Watch) from 60 coastal stations from the Mediterranean and the Black Sea. The measured ^{137}Cs levels were found to be very low (usually < 1 Bq kg(-1) wet wt) ^{137}Cs activity, though concentrations in the North Aegean Sea were up to two orders of magnitude higher than those in the western and other Mediterranean areas. The authors concluded that such effects, far from representing a threat to human populations or the environment, reflect a persistent signature of the Chernobyl fallout in this area.

Illicit sinking of ships carrying radioactive wastes has been suspected to have happened in various locations in the Mediterranean, particularly in the area under review (Mukerjee, 2010). These highly hazardous wastes may include mercury, cobalt, selenium and thallium as well as ^{137} Cs. Though as yet unconfirmed, such risks would constitute a long-term and significant pressure for this area.

Florou, et al., (2001, 2003) reported on the levels of ^{137} Cs in a number of locations within the Mediterranean. The study concluded that the highest levels were in the North Aegean Sea, being reduced towards the southern part, and more so in the Central Mediterranean. The horizontal distribution of this particular radionuclide in the Ionian and other seas, were found to be very similar to those measured before the Chernobyl accident. The authors reported that the levels of ^{137} Cs detected till April 1986 were due to worldwide fallout and varied between 2.3-2.9 Bq m" ^{3} from the southern to the northern part of the Aegean Sea. The respective values elsewhere including within the Gulf of Sirte were lower.

Shenber et al., (2001, 2002) reported on the radioactivity levels in the Gulf of Sirte. Average activity concentrations in surface air of ^{7}Be and ^{137}Cs were found to be 1920 and 2.1 mu Bq m ^{3}, respectively, ^{137}Cs activity concentration in surface soil was found to be 450 m Bq kg $^{-1}$. The results suggested that the concentration factor in the fish, *Scina cirrhosa* was calculated to be 132 and the ingestion dose 19 nSv per year.

One of the most recent publications reporting on radionuclides in the area under review is that by Evangeliou et al., (2009). The authors reported on ^{137}Cs levels in the water column of the Gulf of Patras, as well as in the North-Eastern Aegean Sea over the period 2004-2006. Within the Gulf of Patras, the activity concentrations of ^{137}Cs ranged between 1.2 and 6.7 Bq m^{-3}. The estimated inventories of ^{137}Cs for this gulf ranged 0.25 ± 0.03-0.79 ± 0.03 kBq m^{-2}.

3.3. Nutrients and eutrophication

UNEP/MAP-Plan Bleu, 2009, includes an assessment of the relative importance of different sources of releases for nutrients, organic matter and total suspended solids in the Mediterranean. Such assessment was based on the NBB received from different Mediterranean countries. The assessment concluded that for nitrogen (N), the largest emitters are urban waste water treatment (31%), livestock farming (19%) and metal industry (11%); for phosphorous, the manufacture of fertilizers accounts for the majority of phosphorus emissions (63%), followed by the livestock farming (20%) and urban waste water treatment (8%).

In the present section, attention will be focused on the relative importance of difference sources within the Ionian and Central Mediterranean. UNEP/MAP-Plan Bleu, 2009, presented an assessment of the geographical distribution of point sources of BOD5 and Total N (Industrial sources) as based on the individual countries' emission inventories (NBB). Using this information, an attempt was made to identify the percentage of releases of such contaminants as arising from the area under review on the basis of the graphical information as reported by UNEP/MAP-Plan Bleu, 2009. The result is presented in Figure 15.

In spite of the inherent limitations of the available data, this suggests that the releases of total nitrogen (from industrial point sources) as well as of organic matter (in terms of BOD5) from the area under review is lower than similar releases from other regions (taking into account that the area covers 32% of the total surface of the whole basin).

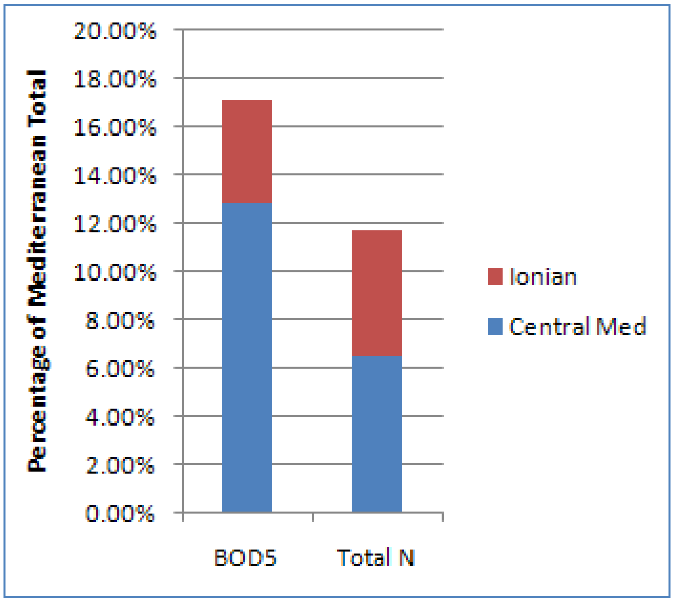

Figure 15: Percentage releases from industrial point sources, of BOD5 and of total nitrogen as reported by UNEP/MAP-Plan Bleu, (2009) in the area under review as compared to releases in the whole Mediterranean.

Increased nutrient loads and localized enrichment by organic materials, may be expected to lead to eutrophic conditions as well as possible to harmful algal blooms. The following section will review our current knowledge of such risks to the area under review.

A recent MED POL draft assessment (UNEP/MAP – MED POL 2009b) commented that although in open water of the Central Mediterranean Sea there is no evidence of eutrophication, nonetheless a number of coastal and estuarine areas are regularly exposed to such risks, due to localized enrichment by nutrients and organic material.

For the Greek Ionian waters, eutrophic conditions have been reported in the semi-enclosed Amvrakikos Gulf, mainly due to agricultural runoff and effluents. Furthermore high levels of nutrients (e.g. nitrate maxima of >100 µg-at L^{-1}) and phosphate levels in excess of background levels were often recorded in the Gulf of Patras. On the other hand the Greek Ionian coastal waters are generally oligotrophic, except in the immediate vicinity of river discharges (which carry mainly agricultural runoffs).

In Tunisia available data indicate eutrophic conditions of the coastal lagoon of the Lagoon of Tunis, where various cases of dystrophic events have been reported, including fish mortalities due to anoxic conditions and blooms of toxic algae. In the

Northern Ionian Sea, including the Sicilian Channel only minor levels of increased nutrients have been recorded (as evidenced through chlorophyll levels). Libyan waters are mostly affected in the immediate vicinity of the large cities such as Tripoli and Benghasi. In the case of Tunisia, the levels of chlorophyll in the Gulf of Gabes were found to be relatively high, this being probably due to natural conditions. Incidence of mild eutrophic conditions in Maltese waters is restricted to harbour areas (such as the innermost part of Grand Harbour) and marinas (eg. Msida marina), as well as to creeks exposed to significant agricultural and other runoffs, such as Marsascala (Axiak, 2004).

In Italy, only one area is reported a sensitive to eutrophication, in the southernmost regions, this being Castellamare del Golfo, in Sicily, which is not strictly within the area under review.

Localized enrichment by nutrients and organic matter may often lead to increased primary productivity and eventually also to algal blooms. These phenomena may or may not be associated with eutrophic conditions. Though some of such blooms are often due to natural conditions, others are at least partly due to anthropogenic releases.

Such increased algal phenomena are often easily detectable from space. Figure 16 shows a series of satellite images (http://www.eosnap.com/). Image A, shows the southern coastal waters of Calabria and Basilicata flanked by a large algal bloom with distinctive gyres. Image B, shows a massive long-shore algal bloom covering all of the southern coastline of Sicily. The eastern part of the bloom extends into large swirls which penetrate the Central Mediterranean and reaching to the East of Malta. Likewise, image C shows swirling patches of an algal bloom along the eastern coastal waters of Tunisia extending into the Gulf of Gabes. It is likely that these massive bloom phenomena are mostly due to natural hypertrophic events linked with local upwellings and other factors. Nonetheless, these images clearly show the geographical extent of such blooms, which may then be augmented through anthropogenic induced hyper-productivity especially in the vicinity of river estuaries (often carrying agricultural runoffs) and sewage or industrial discharges.

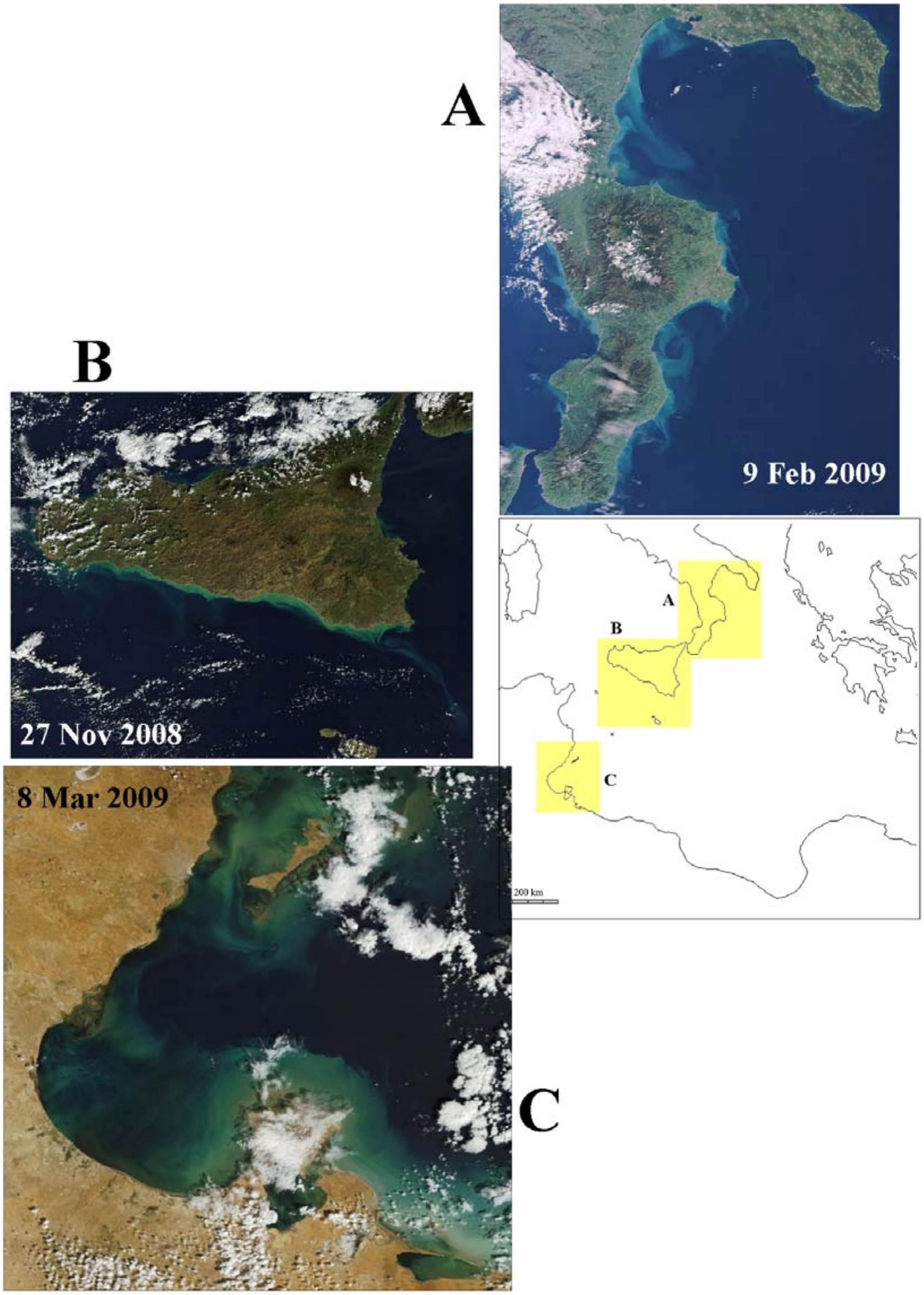

Figure 16: Satellite images of various locations in the Ionian and Central Mediterranean showing evidence of massive algal blooms along coastal and offshore waters (2008-2009). Source: http://www.eosnap.com/

Barale et al., (2008) had used SeaWiFS data acquired over the period 1998 to 2003 to identify algal blooming patterns in the Mediterranean. In general the recurrent, increasing blooms at the various hotspots, appearing in the chlorophyll anomalies, have been described as localized phenomena, linked to either air–sea interactions in pelagic domain or increased nutrient availability and low water renewal in coastal areas. The latter kind of anomalous blooms would be related to the anthropogenic impact on coastal sites or to the combination of specific geographical and meteorological conditions (e.g. enclosed bays during summer, when hydrodynamic forcing is low). This would suggest that noxious, or harmful, blooms — known to have occurred in the areas and periods considered — are predominantly local phenomena, with little or no connection to regional events.

This study generally shows that the Ionian and Central Mediterranean follow the same patterns of activity and trends as the rest of the basin with regard to developments of algal blooms. However very high anomalies (absolute values of chlorophyll equal or exceeding 10 mg m^{-3}) were seen to recur in the Gulf of Gabes.

Figure 17 show the distribution of events of eutrophication and of harmful algal blooms in the Ionian and Central Mediterranean.

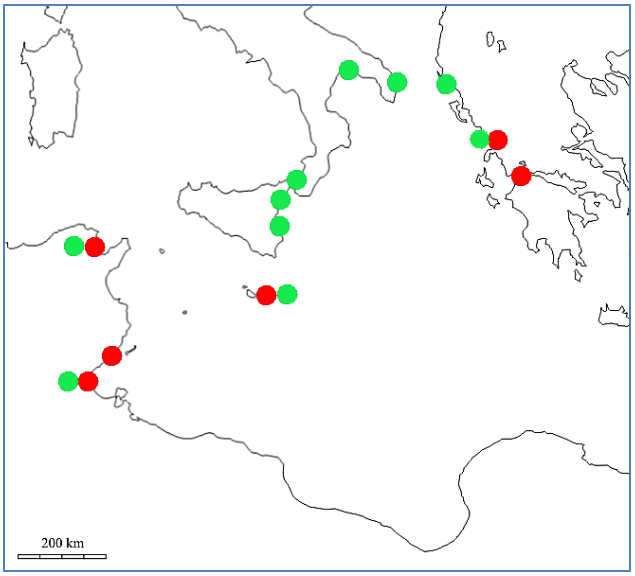

Figure 17: Locations of reported cases of eutrophication (red circles) and of harmful algal bloom events (green circles) in the area under review. *(Sources: EEA, 2006;* *http://www.bentoxnet.it, and others as quoted in text)*

Apart from the coastal waters of Libya, it seems that the pressures possibly leading to such phenomena are evenly distributed throughout the coastline of the area, though in the case of harmful algal blooms, they seem to arise more frequently along the Italian coastline. Nonetheless this may be an artefact of data availability. In fact no data is available about such phenomena from Libyan waters.

3.4 Dumping activities

UNEP/MAP/MEDPOL, 2005 had reviewed the main sources of dumping wastes reaching the Mediterranean Sea. Most of this dumped material originates from the direct disposal from household waste, with releases from touristic facilities and run-off from waste dumps being also significantly important. Dumping of mine tailings is particularly important due to the often hazardous nature of such wastes. Deliberate dumping of oily bilge wastes from ships has already been reviewed in previous sections of the present report.

Voluntary dumping or loss of fishing gear may also be considered of importance, especially in this area under review which is often exposed to intense fishing practices. This may often lead to ghost fishing whose ecological and economic impacts may be considerable.

The NAP for Greece states that the disposal of solid wastes and sludge to the aquatic environment is prohibited. However, the degree of compliance with such regulations is not assessed. In the case of Malta, Axiak et al., (2002) reports that considerable amounts of excavation wastes and dredged spoils are dumped at sea off the Grand Harbour, Valletta. For 2001 alone, approximately 177,000 tonnes of material were deposited at this official spoil ground. This practice has been ongoing ever since.

The NAP for Libya refers to the fact that the disposal of solid waste often presents problems for ‘all coastal towns’. Furthermore, ‘rains may cause these wastes to be driven to the seashore and hence may go further back along the coast’. In Tunisia the, discharge of industrial by-products such as phosphogypsum (10,000 -12,000 tonnes per day) into the Gulf of Gabes (e.g. near Sfax, Ghannouch) constitutes a threat to the coastal marine environment and the ecological impact of such releases is significant. Guillaumont et al., (1995) had earlier on reported on a pollution impact study in the Gulf of Gabes in 1995, with particular reference to phosphogypsum discharge. The group indicated that 50 million tonnes of this material had been discharged near Gabes city since 1975. Analysis of remote sensing data indicated major ecological changes in the Gabes Gulf to the west of the Gneiss-Djerba sill. *Posidonia* meadows that covered most part of the Gulf were by then restricted to some areas upwards of 10m depth.

Under hydrodynamic processes, bare sediments could be easily re-suspended. Light reaching the bottom was reduced, inducing a shift from bottom primary production to a planktonic one.

As regards marine disposal of dredging from coastal engineering works, very little detailed information was available from the relevant countries' NDA reports. Nonetheless, due to the intense urbanization as well as mass tourism developments along the most of the coastline of the area under review, it is likely that this type of impact is significant. The NDA report for Malta gives some details about such activities, especially related to development of marinas. The report states that over the period 1998-2002, the estimated coastline of mainland Malta had been increased by 5% as a result of such engineering works. The ecological impacts of such works were also briefly outlined and these included reduction in the transparency of the water column, regression of *Posidonia* meadows and other related benthic changes. It was calculated that over a period of 1996-2002, approximately 4870 tonnes of TSS had been released in the coastal waters arising from five major coastal engineering works and dredging. It is quite likely that the same phenomenon has been occurring along many coastal areas especially in Tunisia, Libya and the Ionian coast of Greece which have been exposed to intense tourism activities.

Badalamenti et al., (2006) report on impact studies of dredging works associated with a methane pipeline between Sicily and Tunisia (1981-93). This development involved considerable trenching at Capo Feto (Sicily) which resulted in significant impacts on *Posidonia oceanica* meadows The mortality rate decreased with distance from the trench at all depth ranges, showing that the plants close to the excavation suffered a higher level of disturbance. Turnover and annual gross shoot recruitment rate were higher in the shallow portion of the meadow than in the deep range. Forecast of future meadow development close to the trench indicates that, if present conditions are maintained, shoot density will be reduced by 50% over the next 6 to 17 yrs.

Sea reclamation by disposal of solid waste in inshore waters, has often been proposed as one management option for solid inert waste. Sandy beach reclamations and replenishment programmes are also known from Malta.

3.5. Marine Litter

Though not being classified along with hazardous substances, marine litter often pose significant risks to marine life. Some of the most frequently documents risks are those related to marine turtles and cetaceans, as well as to the smothering effects of bottom sea litter on benthic communities. Furthermore, besides representing an aesthetic problem in several coastal areas, marine litter is known to lead to economic impacts due to damages to small water crafts. The NDA country reports for the area under review do not give sufficient details on this environmental issue, so only a brief outline of the potential problem within the area, may be included here.

Unpublished work from Malta (O'Neil, 2003) reported on the levels of beach stranded litter in four local sites in 2002. The same sites had been investigated in 1992. The study showed that the mean mass litter densities on the various beaches ranged from 622 to 40 g m^{-2}, with plastic being the most abundant component. The reported beach litter densities of a decade before were of the same order of magnitude. This had been explained by assuming that the level of stranded marine litter at these sites has reached a dynamic maximum (dependent on a balance between rates of stranding and rate of release back into the water phase due to currents) which may not be exceeded. Compared to other beaches within the Mediterranean, the reported values of beach stranded marine litter were quite high.

UNEP, 2009, quotes studies undertaken by the University of Patras in collaboration with volunteer fishermen in four major gulfs along the western coast of Greece. A total of 3,318 items of marine litter were collected from an overall area of 20 km^2 and reaching depths of 300 m. The results showed that the major sources of the collected litter were from land-based activities while the predominant items were composed of plastic (56 percent). The most impacted area was that of the Gulf of Patras with a recorded number of items ranging between 188 and 437 per km2.

UNEP, 2009, gives the most recent overview of this problem within the Mediterranean and elsewhere. During the period from February to April 2008, 14 reports were received from ships within the Mediterranean recording the incidence and densities of marine litter in surface waters. In total, observations of 1,947 km of Mediterranean Sea resulted in the recording of 500.8 kg of marine litter. Observations were carried out mainly in the eastern Mediterranean (Aegean Sea, Libyan Sea and Eastern Mediterranean Levantine Sea), in the Alboran Sea between Spain and Morocco and in the Adriatic Sea. Again. plastic items were most numerous.

Marine litter released from ships and water craft amount to only 5% of litter at sea. This was attributed to the fact that all vessels above 400 tons or carrying more than 15 persons are obliged to implement garbage management plans in accordance with international maritime law. It is also true that the situation concerning the availability of reception facilities in the major Mediterranean ports has also improved in recent years. The status of ‘Special Area’ of MARPOL Annex V for the Mediterranean has taken effect as from the 1 May 2009. Subsequently disposal of plastics, and other litter is now prohibited into the Mediterranean Sea. Furthermore, Italy, Greece, Malta and Tunisia have confirmed that they have adequate port reception facilities for garbage disposal in the area.

The same report states that 52% of marine litter in the Mediterranean originates from shoreline and recreational activities. This is mainly due to the inadequate solid waste management practices of several countries within the region. This fact has been highlighted in Section 3.3 of the present report.

Marine litter from ‘shoreline and recreational activities’ is also highly related to the tourism industry. Given the importance of tourism industry in the area under review, there is little doubt that a substantial amount of marine litter originates from the tourism industry, even here. This will evidently be much dependent on the level of solid waste management at the localities mostly exposed to intense tourist influxes, especially in summer. In fact UNEP/MAP-Plan Bleu, 2009, cited MEDPOL sources indicating that tourist facilities may generate up to 16% of coastal marine litter.

3.6. Microbial Pathogens

UNEP/MAP-MED POL/WHO (2008), has carried out a basin-wide assessment of the state of microbial pollution in the Mediterranean Sea. The report gives a review of the potential sources of pathogens on coastal waters and sediments, as well as the various bacteriological standards for bathing waters in different EU and non-EU countries, and details will not be repeated here. The same report indicates that for Greece, by 2005, all of the 2006 sampling points were complying with the national standards. For Italy, by 2005, only 6.2% of the 4919 stations sampled failed to comply with the national (EU) standards. In the case of Malta, by 2005, all 87 stations sampled complied with EU standards.

In the case of Libya, it may be noted that the number of stations sampled was quite low (30) compared to the length of coastline. Of these 30 stations, 10% failed to comply with the national standards. For Tunisia, out of a total of 506 stations sampled in 2007, 10% failed to comply with the national standards.

3.7. Maritime activities

While maritime activities within the Mediterranean have always been a characteristic and essential element of human presence, according Abdulla and Linden (2008), between 1985 and 2001, a 77% increase was recorded in the volume of ship cargo loaded and unloaded in Mediterranean ports. An estimated total of 200,000 commercial ships cross the Mediterranean Sea annually and approximately 30% of international sea-borne volume originates from or is directed towards the 300 ports in the Mediterranean Sea. These values are expected to grow three or four fold in the next 20 years. This growth is due mainly to ship traffic and to an increase in the size of ships. Considering that the Central Mediterranean is the main traffic-way between the East and West Mediterranean, and the Ionian Sea is the gateway to and from the Adriatic, it is not surprising to conclude that the area under review is exposed to more than its fair share of such pressures as arising from such maritime activities.

REMPEC (2008) has recently reviewed the maritime traffic in the region.
In 2006 around 10,000, mainly large, vessels transited the area en-route between non Mediterranean ports. Merchant vessels operating within and through the Mediterranean are getting larger and carrying more bulky cargo. Vessels transiting the Mediterranean average 50,000 DWT and are, on average, over three times larger than those operating within the Mediterranean. Overall vessel activity within the Mediterranean has been rising steadily over the past 10 years and is projected to increase by a further 18 per cent over the next 10 years. Transits through the Mediterranean are expected to rise by 23 per cent. Chemical tanker and container vessels will show the highest rates of growth in respect of port callings within the Mediterranean over the next ten years whilst increases in transits will be most pronounced in the product and crude tanker sector.

The top 20 ports within the Mediterranean account for 37 per cent of all Mediterranean calls and 43 per cent of DWT capacity. With a few exceptions most of the top ports are located in the western Mediterranean.

With respect to the Ionian and Central Mediterranean, the main ports are Patras and Corinth in Greece, Gioia Tauro and Augusta in Italy, the Grand Harbour and Marsaxlokk in Malta, the Port of Tunis in Tunisia, and the ports of Tripoli, Misurata and Bardia in Libya. Since 1997, Gioia Tauro has been one of the focal points of development in the container trade in the region. Gioia Tauro and Augusta feature as two of the main Mediterranean ports which receive the largest vessels, while the Grand Harbour, Malta is one of the regional ports with the smallest size ranges of calling vessels. Figure 18 shows the main maritime traffic routes for the region in 2006. In addition, one major traffic route for container ships (in excess of 190 transits per year) passes along the Sicilian Channel. When this figure is compared to Figure 14, it becomes evident that the main cause of the reported spills in along these lanes are due to illegal releases of bilge oils and other ‘operational losses’, rather than due to any accidental releases from ships.

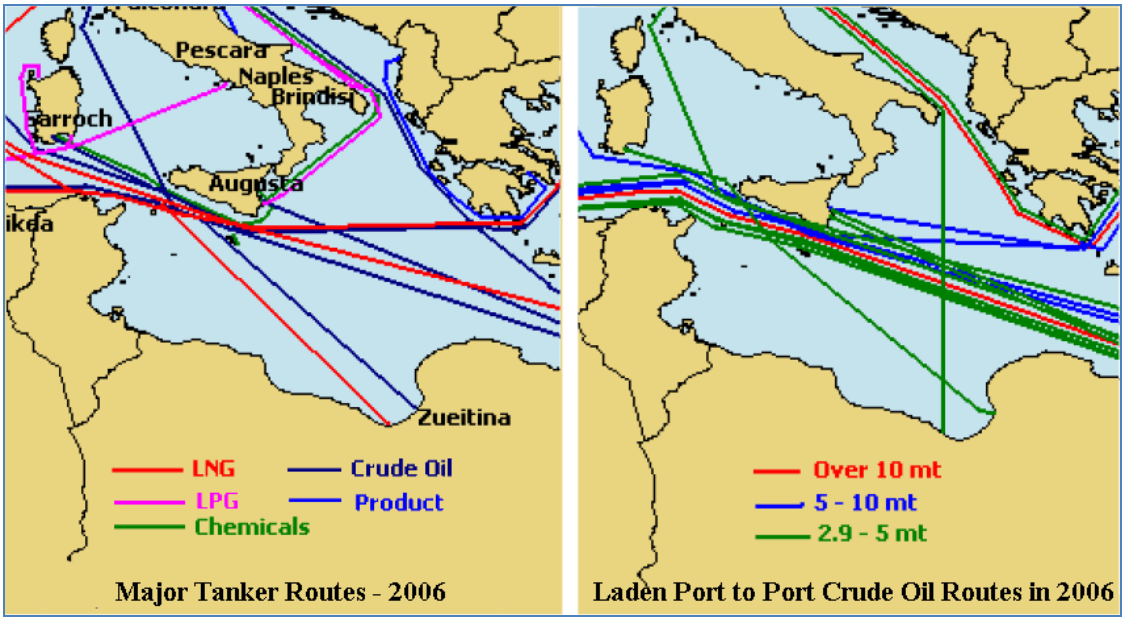

Figure 18: Main maritime routes in 2006 according to Lloyd's Marine Intelligence Unit, as reported by REMPEC (2008).

In 2006 crude oil loaded at Mediterranean ports amounted to 220 million tonnes. If we include the main oil loading port of Skikda, in Algeria, which is close to Tunisia, then the total weight of crude oil loaded in ports within the area under review amounts to 55.9 million tones, which is 25% of the Mediterranean total. In fact, crude oil and LNG trades are concentrated around a relatively small population of load and discharge ports and routes in the western and central Mediterranean.

Crude oil shipments from Novorossiysk to Mediterranean destinations and from Sidi Kerir to both Mediterranean destinations and ports west of Gibraltar as well as exports from the Persian Gulf through the Mediterranean via Suez dominate the major traffic lines. In the LNG sector North African exports to other Mediterranean destinations predominate.

The average age of vessels calling at ports in the eastern Mediterranean is significantly higher than at western and central Mediterranean ports. For example, the average age of vessels calling Valletta, Malta is over 20 years compared to less than 14 years at the western Mediterranean ports. This point is highly relevant when assessing the risk of casualty in the region.

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UNEP/MAP – MED POL

Sub-regional assessment of the Status of Marine and Coastal Ecosystems and of Pressures to the Marine and Coastal Environment

Western Mediterranean

31 May 2010

Contents

1. Introduction

The Sub-Regional Assessments, including the present one, were prepared by MED POL and subregional experts in the framework of the UNEP/MAP's road map for the gradual application of the Ecosystem Approach for the management of human activities in the Mediterranean Sea.

The Ecosystem Approach (ECAP) has been introduced aiming at improving the way human activities are managed for the protection of the marine environment. Following the World Summit on Sustainable Development, the ECAP has been adopted by many International Conventions and Regional Seas Organizations. The Contracting Parties to the Barcelona Convention have adopted it in January 2008 at their Almeria meeting. The proposals to that meeting were developed in the framework of a project (ECOMED) funded by the EC. In this context, any environmental policy should be developed in a way that secures an effective protection of the marine environment and that makes possible the continued provision of marine goods and services for the wealth of the population. The application of the ECAP has the potential to help reach a balance between the requirements of human activities and the conservation of the marine environment. Its adoption and gradual implementation within the framework of the Mediterranean Action Plan (Barcelona Convention) will give new impetus to the preparation of more integrated and holistic policies by the Convention, including the impact of human activities on the marine environment.

To ensure the sustainability of the exploitation of marine goods and services in the Mediterranean Sea, it is important that the ECAP and its related conservation and management measures be applied not only to areas under the jurisdiction of States, but also to the habitats and ecosystems located beyond the national jurisdiction. As a consequence, the implementation of the Ecosystem Approach is not only a task for the Convention and its subsidiary bodies, but also and mainly for its Parties.

The project's aims among others, at promoting and enhancing the implementation of the road map for the application of the ecosystem approach to the management of human activities. The road map requires that an assessment of the ecological status and of pressures and impacts is undertaken in four different regions of the Mediterranean, identified on the basis of bio-geographic and oceanographic considerations. The present report is a contribution to such a project with reference to the Western Mediterranean.

The assessment is mainly based on:

- Reports prepared in the framework of MED POL by the relevant Contracting Parties (Algeria, France, Italy, Monaco and Morocco) which include the national Diagnostic Analysis (NDA) on various environmental issues and pressures and the national Baseline Budget (NBB) of emissions and releases of selected pollutants within each respective country;
- Basin-Wide Assessment Reports on selected environmental issues often prepared in the framework of MAP;
- A range of other publications which are relevant for the purpose of the present review.

The report will first present a synoptic review of the more relevant features of the physic-chemical and biotic parameters of the coastal and marine ecosystems with the area under review. It will then identify and assess priority issues arising from pressures and impacts related to contamination, dumping activities, nutrient and organic matter enrichment and other factors in this area. Whenever possible, it will assess the availability and reliability of the data on which the assessment is based, identifying any gaps which need to be addressed in the future.

2. Area under Review

2.1. Bathymetry, salinity and hydrodynamics

a) Bathymetry

The Western Mediterranean Sea can be divided into four main morphological units (Rehault et al, 1984). *The bathyal plain,* surrounded by the 2700 m isobath, lies in the deepest central part of the basin with a maximum depth (up to 2850 m) reached southwest of Corsica, in the Sardo--Balearic plain . The tops of some buried salt domes occur as knolls, 50 to 100 m high, dotting the flat Ligurian and Algerian bathyal plains. *The continental rise and the deep-sea fans* (between 2000 and 2700 m) are widely developed in the northern part of the basin, where there are three main gravitative sedimentary bodies. The Rhone deep-sea fan, including numerous elementary lobes, has the largest extension with a deep-sea channel and lateral branches as collector. In the Ligurian Sea, sedimentary supplies from the Var and Roya rivers and other canyons build up a coalescent deep-sea fan. Finally, the main part of the Valencia Gulf, deeper than 1000 m, belongs to the continental-rise geomorphological province. The Ebro canyon and numerous smaller submarine cut the continental slope and merge in a complex coalescent fan, including numerous juxtaposed sedimentary bodies. Elongated salt ridges and walls are observed, trending NE--SW or NW--SE (Liguro--Provencal Basin), N--S (southern Gulf of Lion) and E--W (Algerian Basin). Compared to the Provencal or Catalan rises, the Corsican, Sardinian, Balearic and Algerian rises are still very narrow. This dissymmetry of the basin is a consequence of a different sedimentary supply from the two borderlands of the Mediterranean: Northward, continental rise and deep-sea fan are fed by the sedimentary influx carried out by such large European rivers as Roya, Var, Rhone and Ebro; rivers are however minor in Corsica, Sardinia, the Balearic Islands and Algeria, and consequently margins are starved.

Except off the Gulf of Lion, western Sardinia, the southern Menorca promontory and the Ibiza Plateau, continental shelf and slope are narrow in the whole Western Mediterranean Basin. Most continental shelves are Pliocene and Quaternary small progradational prisms, built up on Messinian erosional surfaces, But the Rhone and Ebro rivers feed a wide and thick prograded platform in the Gulf of Lion and the Valencia Gulf. The depth of the shelf break is variable: off Provence, Corsica, the Balearic Islands and Algeria, it is no more than 100 to 125 m deep. It is deeper off Tuscany (130--150 m) and reaches 200 to 235 m depth off western Sardinia .As shown by recent computerized bathymetry (*http://www.ifremer.fr/caraibes*), the slope is steep (6 ° up to 10°), rocky or overlapped by a thin sedimentary sheet, and split into successive steps. When the coast is mountainous (Provence, Ligurian Alps, Corsica, Algeria, South Balearic Islands), the slope is locally more than15°.

Around the Mediterranean Basin, numerous submarine canyons cut the continental slope, and some deep incisions reach the pre-Pliocene sedimentary layers and, sometimes, the ante-Mesozoic basement. They are derived from the messinian crisis leading to lower sea levels, 5 to 6 millions years ago (Bache et al., 2009; Garcia-Castellanos et al., 2009).

The Alboran Sea must be described separately. The western Algerian Basin is delimited by the 2000-m isobaths. The Alboran Basin can be divided into three morphological units including the middle part, the Alboran ridge, bounded by the 1000 m isobaths, trends NE--SW, that separates two basins, respectively 1500 m (to the north) and 1100 m (to the south) deep.

Southward and northward, the wide Moroccan and Spanish Plateaus (1000 m) are seaward extensions of the African and Iberian borderlands. Eastward, depth gently decreases from 1000 m to the shore. Resting upon oceanic crust, the sedimentary column is very thick (up to 7 km) and can be divided into three a detrital lower formation, an evaporitic middle one and a turbiditic upper one.

The Western Mediterranean Basin is surrounded by the Alpine system. The creation of this almost continuous folded belt is connected with the converging motion of the European and African plates since the Cretaceous, and this convergence is also probably the driving force for the generation of such marginal basins as the Western Mediterranean. The bases of some continental slopes are outlined by a large negative gravity anomaly. North of Algeria, the negative anomaly is correlated with a southward dipping of the Messinian layers and oceanic basement, suggesting a reactivated subduction (Kheroubi et al, 2009). The basin margins along the Ligurian Alps, Corsica and the Apennines have been uplifted since the Late Miocene as the Sierra Nevada and the Savona Basin (Rehault 1984). Vertical faults occur along some margins assumed to be the result of rejuvenation of the Oligocene--Miocene normal faults. Unusually precipitous slopes off Provence, the Western Alps, the Spanish and Balearic Islands and off Algeria and northwest Corsica suggest a recent margin shortening. According to these data, Western Mediterranean margins are undergoing a compressional stress between the European plate and the African plate moving north-westward or north-north-westward and could become active in the future.

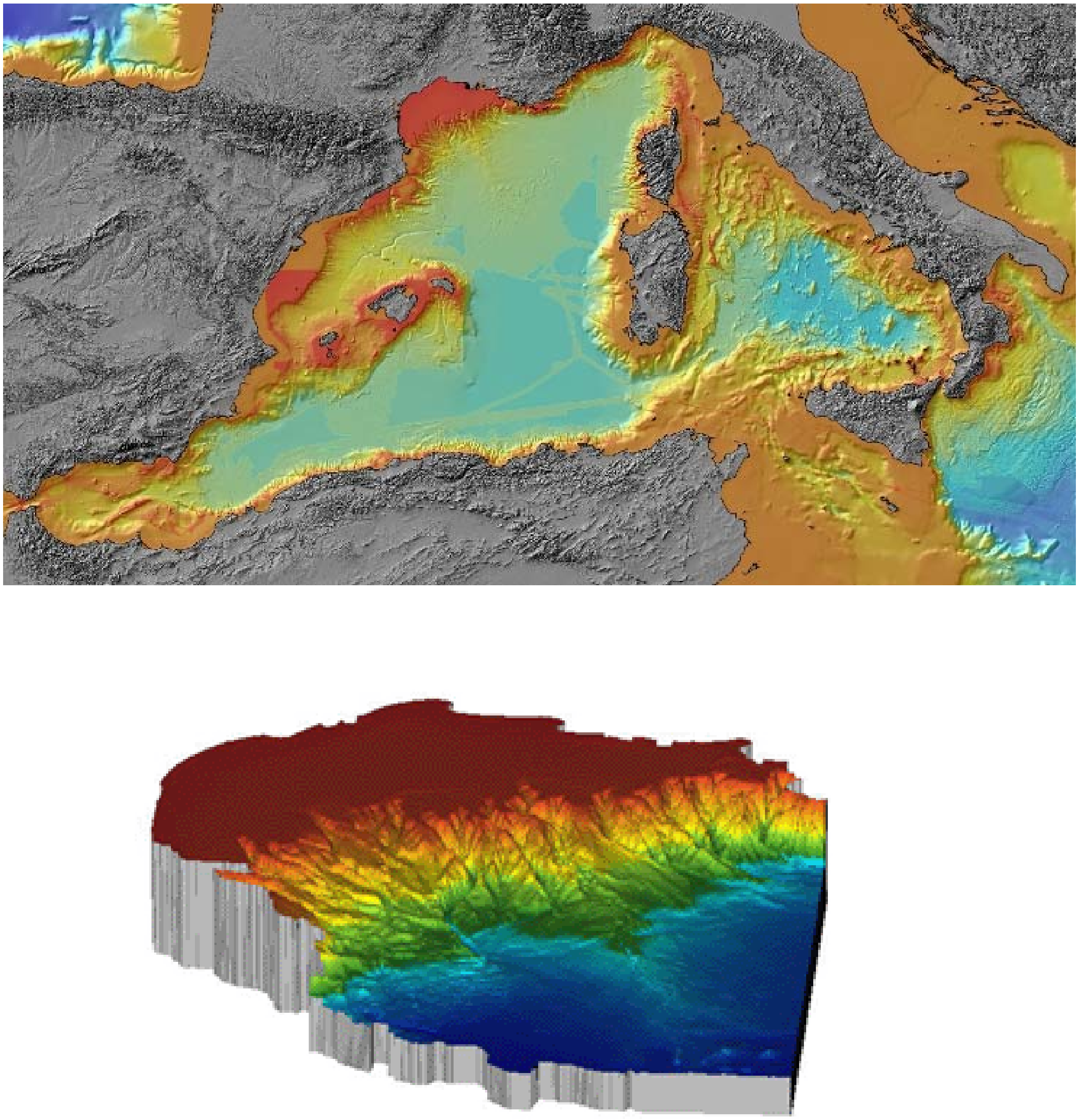

Figure 1 : Bathymetry of the western basin of the Mediterranean sea (from Geosciences Azur, IFREMER, CIESM, 2008) and sea beam data from surrounding countries) and details from the gulf of lion (http://www.ifremer.fr/caraibes/)

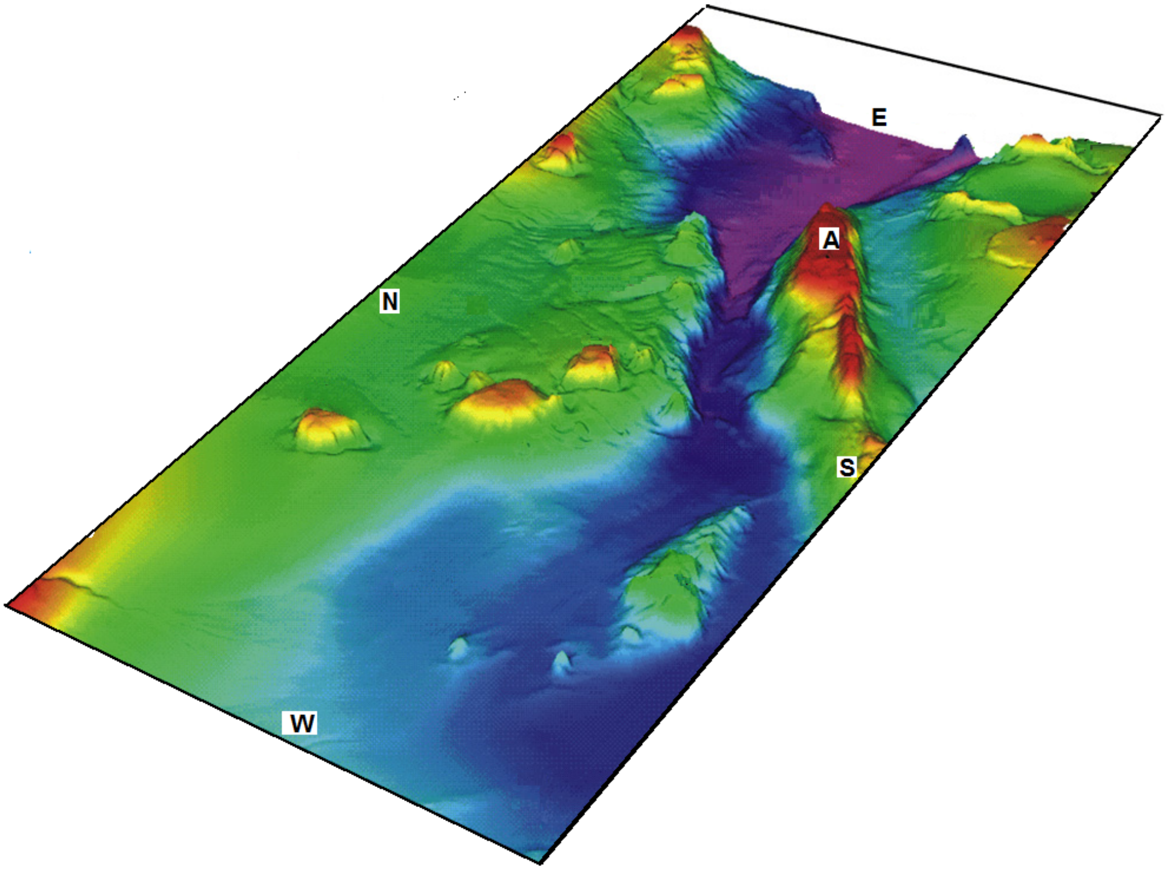

Figure 2 : 3-D diagram of Albora´n Basin compiled from multibeam data (view looking southwest). After Munoz et al.(2008.) A:Alboran island.

Nevertheless, subduction is lacking west of the Calabrian arc, and in this area, the shortening resulting from converging motion must be absorbed by regional deformation. Then The tectonic and volcanic events in the more recent Thyrrenean basin has given a rough abyssal plain when sedimentary events led to a flat abyssal plain in the older basin between Algeria and Provence.

b) Sedimentology

The continental shelf is fragmented and discontinuous. Extremely small, it disappears along coastal mountains and develops off the coast near major rivers including the Rhone, Ebro, and Tevere etc... In the large gulfs (Gulf of Lions) or bays (Algiers, Algeciras, Tunis etc.). Sedimentation is of dual origins, biogenic from planktonic or benthic organisms and terrigenous from river sediments (fine, coarse). The latter is most important. Distribution of terrigenous sediments on the sea floor is made on a bathymetric gradient or a gradient of silt from the coast to sea with a characteristic succession of sedimentary facies: fine sand, silty fine sands, sandy muds and true vases. The fine sand silt and sandy muds are transition sediments enabling changes from coastal fine sand to pure vases offshore. In capes around bays and gulfs of the African coast, sea floor is rough (very coarse sand, gravel). Then the following distribution of sedimentary facies is a general model for southern shores. The fine sands are located in shallow waters where they form a narrow coastal strip. Vases are sometimes pure and occupy almost the entire continental shelf (Gulf of Al-Hoceima, Bay of Arzew, Bou Ismail, Gulf of Bejaia, Skikda, Bay of Tunis), while the absence of river and oueds (Bay of Oran) promotes coarse sands and gravels. Direct inputs of sediments influenced by tectonic movements have been described for the occidental basin. They act as important sources of natural trace metals and complete other sources from bio-geochemical cycles (Rajar et al., 2008). The distinction between these two sources is difficult. Contributions linked to tectonics are important in volcanic areas and around geothermal sources such as the southern Tyrrhenean. These contributions explain important natural levels of metals around some islands (Aeolians, Sardinia, Palmarola). The presence of mines located upstream of rivers or streams in the basin (Almaden, Spain, Monte Amiata in Tuscany) is also a source of enriched sediments (UNEP-MAP, 1996).

Natural resuspension of sediments is dominated by waves of short duration down to 40m depth. The coastal winds (Mistral, Tramontana on the north shore and Sirocco in the south) have no effect on the resuspension but control the dispersion of turbid waters seaward. This natural phenomenon allows a release of nutrients trapped in sediment pore waters. The effects of bottom trawling are very comparable to localized severe storms, and affect resuspension of fine sediments from the continental shelves (50 m to 200 m depth) where effects of waves and currents are negligible. At the scale of the fishing fleet from the Gulf of Lions, The resuspended volume of sediment (5 million tons, # 3% of storm inputs) is equivalent to particles inputs from the Rhone (Ferre et al., 2008). Then, the resuspended nutrients are in quantities several orders of magnitude larger than those from natural fluxes and bioturbation. They must then be considered for the evaluation of biogeochemical cycles.

On the south shores, atmospheric particles from the Sahara-Sahel Corridor (Western Sahara, Algeria, Chad and Niger) are natural sources of aluminium and iron and most trace metals, and contain elevated levels of anthropogenic molecules (Zn, Pb, Cd) or chemicals leached after abrasion of natural rocks (chrome, nickel). All the coasts of southern basin are concerned (Castillo et al., 2007). In some areas such as Annaba (Algeria), the particle flux and atmospheric winds are responsible for air intakes of lead, chromium, manganese, nickel, cadmium and cobalt associated with the presence of industrial activities (Khoja ali et al, 2008).

Behaviour of particles at sea has become an important process for sediment budget evaluation. Although this process is not sufficient to completely explain the space and time variations of observed particle fluxes, especially at depth, particle exchange across the margins and fluxes, variable annually, in canyons are largely resulting of the effect of the general current and by dense water formation in winter rather than variations in the sources of matter (Guarracino et al., 2006). Smaller aggregates are more abundant in coastal waters, as a result of continental input, cross-slope export, and re-suspension along the slope. With a relative proportion of large cells increased with the magnitude of the upward velocity, mesoscale vertical motion controls directly the size structure of phytoplankton in the ocean. CTD-video packages experiments demonstrated that large particulate matter spatial heterogeneity generated by the upper layer mesoscale hydrodynamics extends into deeper layers and may significantly contribute to the biogeochemical cycling between the upper and meso-pelagic layers (Gorsky et al., 2002). The layers that contain very high concentrations of small aggregates are observed from surface down to 1000 m, and extend from the continental slope to the fronts (Stemann et al., 2008). Even if the particles are derived from the atmosphere or internally produced by biological processes, their transference from the upper to the deeper ocean is controlled by the stabilization of the water column and the distribution of the water masses. Concentrations of sediments and large aggregates are highest in and under frontal zones probably as a result of physical coagulation, and/or biological transformations with limited cross-slope transport. This processes, which takes place in sub-mesoscale zones (5–10 km wide) are widely distributed amongst the occidental basin and have consequences for the transport of continental particles to the ocean's interior.

A budget evaluation of particulate organic carbon (POC) fluxes carried out in the deep part of NW basin (Ziga et al. 2008) demonstrated the low Particulate organic carbon input in both Thyrrenean deep waters and Algero Balearic basin mainly related to the spreading of dense cold water along the whole basins that supplied Particles at depths higher than 2000 m. The size structure of phytoplankton may also depend more directly on hydrodynamic forces than on the source of available nitrogen (Rodriguez et al., 2001) and drifting sediment trap measurements showed highly variable fluxes of planktonic and terrigeneous lipids at 200 m in the NW Mediterranean and pulses to be depending on the intensity of particle dry weight, plankton and aggregation processes (Mejanelle and Dachs, 2009).

c) Hydrodynamics

The Western Mediterranean sea has a negative water budget: the loss in the atmosphere by evaporation is larger than the gains by precipitation, runoffs from the main rivers and input from the Black Sea. Since the basin is limited by the shallow Gibraltar and Sicily Straits, the warm surface inflow of Atlantic water transformed into dense Mediterranean waters remains mostly trapped in deeper areas.

The general circulation (residual currents) has been extensively studied during last decades. The experiments MEDIPROD (1986-1987), PRIMO-0 (1990-1991) in the channels of Corsica and the Balearic Islands, PRIMO-1 (1998-1999) in the channel of Tunisia and Sardinia, the experiments THETIS-MAST-2, ALGIERS and ELISA-MAST-3 and historical series helped to give a consistent pattern of movement. Since the 2000s, the development of models and their validation has clarified the mechanisms of the general circulation and developed particularly in the southern basin, and remains valid in its general scheme (Millot, 1999).

A large thermo haline cell encompasses the whole Mediterranean and is mainly driven by the water deficit and by the heat fluxes, compensated by the exchanges through the Gibraltar Strait. The formation and subsequent spreading of the intermediate water, together with the inflow of the Atlantic Water through the Gibraltar strait, contributes to this thermohaline circulation. While progressing eastwards, Atlantic water gets progressively denser before being transformed into dense water along the North African coasts (Bethoux et al., 2002, Gasparini et al., 2005). The contribution of the water formed in the Eastern basin (the Levantine Intermediate Water) is also essential to the formation of deep water in Western basin through the Sicilian-Tunisian channel. Deep circulations in the two main sub-basins, separated by the Sicilian Straits, are decoupled and are composed by two minor thermohaline cells forced by events of dense water formation occurring in the Gulf of Lions for the western Mediterranean. Favourable hydrographic conditions cause bottom and intermediate waters formation, which in Mediterranean occurs where strong winds and cyclonic structures are recurrently observed. The Levantine Intermediate water in the eastern Mediterranean is characterized by maximum in salinity and in temperature and represents the most important player of the Mediterranean thermohaline circulation and is in fact the principal component of the eastern Mediterranean waters flowing in the Western basin through Sicilian Channel. In addition, it represents the main component of the Mediterranean outflow at Gibraltar which is essentially driven by the difference of density between both sides of the strait. Northern winds and permanent circulation force the formation of the deep water, which takes place in the Gulf of Lions during the wintertime. The characteristics (density, temperature and salinity) of the deep waters are determined by the long time accumulation of the dense waters formed during successive winters up to a level above the sills. Upon exiting the Gibraltar strait, the outflow of Mediterranean water (saltier) dives along the slope in the Atlantic Ocean with a flow rate 10 to 20 times larger than the Mediterranean inputs, and affects the deep layer and thermohaline circulation in the Atlantic Ocean. The volumes of water exchanged at Gibraltar are mainly fixed by local conditions near the strait.

Besides the main thermohaline circulation, several local features characterize the Mediterranean circulation, such as gyres and fronts. The Atlantic Water is present almost everywhere in the basin. It forms two anticyclonic gyres in the Alboran sea, constrained by the bathymetry, and then bifurcates around the Sardinia Island in two different branches, One into the Tyrrhenian Sea as the source of the large-scale cyclonic circulation occurring in the north-western Mediterranean. The other crosses the Sicilian Channel and penetrates in the Ionian Sea. The water from the Tyrrhenian produces a large cyclonic circulation in the western Mediterranean, with the central gyre between the Balearic Islands and the Sardinia being the region of deep water convection. Principal feature is the strong current (the Liguro-Provencal Current), which leaves the Italian coast and moves south-westward along the continental margins, and an intense front spanning from the Balearic Islands to the Sardinia.

Atlantic water inflow in the Alboran Sea or the Northern Current in the Ligurian Sea, exhibit vertical motions that induce significant exchanges of properties between the surface layer and the deeper layers. These vertical motions have an important role on heterogeneous nutrient inputs in the mixed layer and affect the distribution of marine aggregates.

In the southern part, the Algerian currents are unstable and generate (50-100 km) eddies with vertical extents to the bottom at around 3000m and lifetimes in the months-year range. Eddies usually propagate eastward along the continental slope at few km/day. They can detach and drift in the open basin. This intense mesoscale activity is responsible for the dispatching of water masses at surface, intermediate and deep levels. In the northern parts, the mesoscale current has a clear seasonal signal and is associated to deep water formation. During wintertime the current is stronger and faster. Eddies generate significant upwelling and subduction. Along the continental slope, currents follow submarine canyons producing topographically-controlled up- and down-wellings which affect the cross-slope transfers of particulate and biogenic matter. This process can be enhanced by concomitant storms that flush the shelf water or hinder by intense freshwater discharge (Ulses et al., 2008). Shelf regions are affected by river plume dynamics, wind-driven meso-scale circulation and dense water transport that control the exchanges of water and biogeochemical elements from the enriched coastal areas to the interior of the basin. Freshwater discharges from large rivers (e.g., Rhône, Po) produce highly stratified buoyant flows sometimes beyond the shelf. Finally, altimetric measurements have shown that the sea surface height has changed for the last decade over the Mediterranean basin. The improvement of the sensors that monitor the Mediterranean region at higher temporal resolution has made possible the observation of these changes, which could be related to climate change

Interactions between different constraints affecting the current such as ocean-atmosphere interactions (Korres et al., 2000), the formation of deep water, the influence of topography (Beranger et al., 2005) implies high-resolution models. In recent years, the improvement of methods enabled to characterize seasonal variations (Bethoux et al., 2002), the formation and variability of gyres (Testor et al. 2005; Demirov and Pinardi, 2007, Hu et al, 2009). More recently, models were made available to the scientific community. Systems such as the "Mediterranean Forecasting System (MFS) using a 5-7 km resolution was demonstrated to be sufficiently accurate to study the variability of mesoscale gyres. The altimetry has also demonstrated the importance of varying forces on currents. Despite the properties of the geoid, which must be considered, this approach is very useful to characterize the variability of gyres (Vigo et al., 2005, Pascual et al. 2007; Aldeanueva-Criado et al., 2008). A high resolution (3-4 km) and a comparison with altimeter data enabled estimation of mean currents during a 12 years period with a permanent atmospheric forcing (Jordi and Wang, 2009). This model reproduces most of the major currents and eddies and confirms the importance of meso-scale. The Mediterranean ocean forecasting system (MFS) has started operational activities in January 2000. Presently it produces daily analyses and 10-days forecasts of currents and temperature and salinity fields for the entire Mediterranean at approximately 10 km resolution. At INGV, weekly forecasts Bulletins are disseminated through the MFS (http://www.bo.ingv.it). Confirmed by observations particularly since the development of VHF radar images, drifting buoys followed more recently by gliders (Molcar et al., 2009; Rubio et al., 2009; Ruiz et al.2009) and largely modelled with improved resolution, the general pattern of the circulation was confirmed.

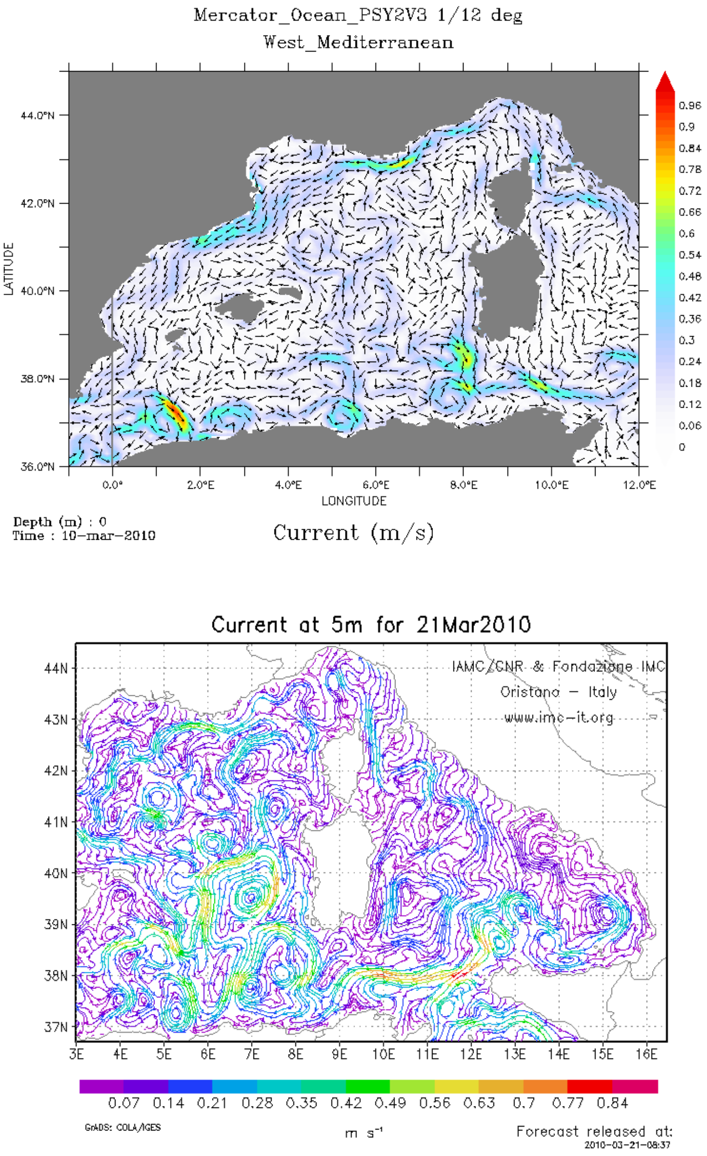

Figure 3: Large scale General circulation in the occidental Mediterranean basin on March 10th (Mercator, http://www.mercator-ocean.fr/) and March 21st (http://www.cnr.it/sitocnr/home.html)

MOON (http://www.moon-oceanforecasting.eu/), the coordinating body of the EuroGOOS Mediterranean Task Team, has also developed an operational and pre-operational systems at national, regional and global scales (MFSTEP, MERCATOR, ADRICOSM, POSEIDON, CYCOFOS, ESEOO,etc..) that is interesting the Mediterranean sea, promoting the development and optimisation of the scientific base, the technology and the information system for operational oceanography and promote the GOOS (http://www.ioc-goos.org/) goals at regional level for the benefits of the Mediterranean Countries. Besides international or European, (http://pelagos.oc.phys.uoa.gr/mfstep/, http://oceancolour.jrc.ec.europa.eu/data_portal, http://www.ocean-modeling.org/, http://oceanservice.noaa.gov/), national (http://www.lamma.rete.toscana.it,) or team projects (Santinelli et al., 2008; Schroeder et al., 2009, Ruiz et al., 2009, Hu et al., 2009) have been evaluated and demonstrated the feasibility of near real time forecasts at sub-regional/shelf scale and sometimes higher resolutions (1.5 – 3.5 km) . Detailed models have been also proposed for important areas such as Alboran sea (Beranger et al., 2005), gulf of Lion (Lerrede et al., 2007) and Sicily-Tunisian channel (Ismail et al., 2007) including bays or areas closed to large towns and the southern part of the basin (Brahim et al. 2009). They also enable the interpretation of local events such as predictions of oil, litter of jellyfishes transport (Jorda et al., 2007).

Rivers are important sources of freshwater and nutrients for the Mediterranean sea. A reconstruction of the spatial and temporal variability of these inputs since the early 1960s, based on available data on water discharge, nutrient concentrations and climatic parameters was performed recently (Ludwig et al., 2009). Results demonstrated rivers suffer from a significant reduction in freshwater discharge, estimated to be at least about 20% between 1960 and 2000. Recent climate change and dam construction may have reduced discharge even further. Rivers do play a particular role in sustaining the marine productivity in the Mediterranean Sea. The latter is a semi-enclosed ocean basin and does have a high value of drainage area to surface area compared to the open ocean. The importance of the strong connection to the river inputs is related to the oligotrophic character of the Mediterranean Sea. Because exports of nutrients to the Atlantic Ocean, they are lost for the basin internal primary production. Zones of High productivity are therefore mainly restricted to the coastal waters in the vicinity of major freshwater inputs, as this is shown by satellite images on chlorophyll concentrations in surface waters (Bosc et al., 2004).

Estimates of total riverine freshwater flux into the Mediterranean have been established through inventories of major rivers, mapping of average runoff depths, modelling or country-based inventories of water resources. Most of them vary around 400– 450 km3 yr-1 for the Mediterranean.

Precise quantification of the reduction is complicated by the fact that the evolution is also superimposed by the cyclicity of humid and dry periods. Long-term series of precipitation and discharge (e.g., in the Rhone rivers) show that in the northern part of the Mediterranean, this cyclicity occurs in intervals of about 20 years (Zanchettin et al., 2008). A decrease of the total freshwater discharge of 80–100 km3 yr-1 by rivers is therefore a realistic estimate for the last 40–50 years in the whole Mediterranean sea. The results of analyses reveal strong negative trends for half to two third of the Mediterranean rivers and no significant trends could be detected for the others. Strongest negative trends appear for rivers that were affected by the construction of dams, such as the Ebro River in Spain and the Moulouya River in Morocco. The Rhone River does not follow the general trend. Its water discharge remains about constant as affected by the non Mediterranean climate in the northern part of the basin.

Both climate monitoring and modelling studies revealed a general trend toward drier and warmer conditions, which already started in the last century, and which is supposed to worsen even further in the future (Giordi and Lionello, 2008). Strong repercussions for riverine water discharges can be expected and changes in Mediterranean riverine inputs are therefore potential drivers for long-term changes in the marine ecosystems. For drainage basins of the Western basin, there is a highly significant negative trend for precipitation with an average decrease by about 11%.

The decrease is particularly important for the Alboran Sea (34%). Also the South-western Sea seems to be affected by a precipitation decrease. Temperature, on the other hand, strongly increased. Lespinas (2008) reported an average temperature increase of about 1.5 °C for the period 1965–2004 in a regional study on the coastal river basins in the Gulf of Lions. Although annual precipitation remained approximately constant, they showed that water discharge decreased in this region, mainly by a temperature related reduction of the basin internal water storage in the snow, soil and groundwater reservoirs.

Also reservoirs can reduce the natural water discharge of rivers, in particular when they allow water extraction for irrigation of the fields. The Ebro River in Spain is a typical example where damming was continuously developed for agricultural purposes. This river counts nowadays about more than 130 dams in its basin and the strong and continuous reduction of its water discharge is commonly attributed to anthropogenic water use (Ludwig et al., 2009). Another interesting example is the Moulouya River in the drainage basin of the Alboran Sea. Here, climate induced water stress was great in this Mediterranean region and a major dam (Mohamed V) was constructed in 1967 (Snoussi et al., 2002). The predicted runoff decrease of this river (72%) is almost fully reproduced by trend analyses and observed discharge before and after the dam construction suggests that water extraction may have reduced the river discharge by about 20%.

Table 1: Discharge trends in some Mediterranean rivers from occidental basin (after Ludwig et al., 2009 from Medhycos data server, 2001; Global River Discharge database RivDIS and french national Hydro database, Hydro, 2006)

River	Country	Station Area (km2)	Period Mean	Q (m3 s_1)
Rhône	France	Beaucaire 95,590	1960 1999	1721.0 (a)
Aude	France	Moussan 4956	1965 1997	43.8 (c)
Herault	France	Agde 2577	1966 2004	40.3 _52.6 (c)
Var	France	Malaussene 1830	960 2005	37.7 _24.5 (c)
Tet	France	Perpignan 1357	1971 2004	10.4 (c)
Orb	France	Beziers 1323	1966 2004	26.9 _19.6 (c)
Ebro	Spain	Tortosa 84,230	1960 1999	416.0 _63.5 (a)
Jucar	Spain	Alcala del Jucar 10,785	1975 1999	12.7 _72.9 (a)
Moulouya	Morocco	Dar el Caid 24,422	1960 1988	21.1 _71.5 (b)
Medjerdah	Tunisia	Ghardimaou 1490	1960 1995	3.9 (b)
Tevere	Italy	Ripetta 16,500	1960 1997	216.8 _36.3 (a)
Arno	Italy	San Giovanni 8190	1960 1995	83.6 _24.5 (a)

The north-westerly winds (Mistral, Tramontana) overlooking the north shore of the western basin of the Mediterranean influence the currents generated in the northern basin. Although of secondary influence to the whole basin, the upwelling generated by these North West winds and currents cause complex physical phenomena that promote the redistribution of dissolved elements, particles and nepheloids and the recovery of nutrients to water surface. This mixing causes the homogenisation of the water, including mixing with waters of large rivers such as in the Rhone delta and Ebro estuary. The arid period from 1990 to 2000, the significant decrease in water inflows, the trapping of sediments in dams are the mains reasons for the decrease in the flow of materials from rivers. Studies by the National Agency of Water Resources (ANRH) of Algeria have clearly highlighted the link between sediment yield and discharge rates. These are linked to periods of flooding. The volumes of sediment trapped in dams located in coastal areas deprive beaches of solid particles inflows. This is illustrated by the case of oueds representative of the North African coast.

Strong gradients for many physical and chemical parameters are occurring in estuaries (Chapman and Wang, 2001) and affect the quantity and composition of dissolved organic matter and colloidal particles, which play an important role in the transfer of contaminants and their transformation as the ionic strength and precipitation phenomena are affecting the bio availability of contaminants. Due to salinity gradients, stratification of water is common, causing density currents whose depends on the topology in the case of the Rhone and the Ebro rivers. The time series analysis of climate, currents and particulate matters fluxes (Durrieu de Maderon et al., 1999) showed that the particles transported to the bottom could be linked to sediment exchanges between the continental margin and greater depths rather than only atmospheric inputs or transportation from major rivers. In this case, the vertical oscillations of flow on the continental slope govern much of the contributions to the bottom and undergo significant seasonal variations due to fluctuations in vertical temperature. The Var River flowing at Nice has been largely studied for the transport of sediments. Besides currents from the general flow, isopicnal currents related to differences in salinity (Mulder et al., 2001 a & b; Gervais et al, 2003) have been demonstrated in this area. These currents are likely to support a very important contribution of transport in the deep adjacent canyon up to distances of more that one hundred kilometers to reach distal lobes. Under these conditions, transport of contaminants associated with sediment particles into the abyssal plains must be considered. Finally, the contributions related to accidental flooding or storms are linked to exceptional climatic events. They affect sediment transport in rivers, including small ones (Gremare et al. 2003). In this case, a significant contribution of sediment but also dissolved substances or contaminants is taken up by the local hydrodynamic and contributes to coasts and canyons enrichment. The role of waves and currents driven by onshore and off-shore wind regimes has been determined as dominant mechanisms for the dispersal of river plumes, resuspension of shelf sediment, and off-shelf sediment export (Canals et al., 2006, Palanques et al., 2008). Secular accumulation rates and grain-size patterns reveal distinct sedimentary facies on the shelf adjacent to Rhône river, including prodeltaic and mid-shelf depocenters of fine sediments with most (90%) of the river sediment discharge trapped on the shelf. In situ observations combined with 3D modelling to quantify the suspended sediment transport in the Gulf of Lions revealed (Ulses et al, 2008) that most of the particulate matter delivered by the Rhone was entrapped on the prodelta, and that marine storms played a crucial role on the sediment dispersal on the shelf and the off-shelf export. Erosion is controlled by waves on the inner shelf and by energetic currents on the outer shelf. Sediment deposition takes place in the middle part of the shelf, between 50 and 100 m depth. Resuspended sediments and river-borne particles are transported to the south-western end of the shelf by a cyclonic circulation induced by these onshore winds and exported towards the Catalan shelf and into the Cap de Creus Canyon which incises the slope close to the shore. Export taking place mostly during marine storms was estimated to reach 9.1 Mt during in 2003-2004.

Observations from a submarine canyon on the Gulf of Lions margin demonstrated that these flows can also be triggered by dense shelf water cascading, a type of current that is driven solely and seasonally by seawater density contrast. It not only transports large amounts of water and sediment but also reshapes submarine canyon floors and rapidly affects the deep-sea environment. One study measured the resuspension particulate matter in these areas. From the evaluation of particulate flow, sedimentation rates and different terms of inputs (rivers, atmosphere, primary production) and output (degradation in the water column and at the interface water-sediment), a first assessment of particulate organic carbon fluxes has been established. This assessment indicates that less than 10% of the particulate material brought to the Gulf of Lions is exported to the North Mediterranean basin.

d) Salinity and temperature

Climatically, the Mediterranean is characterised by warm temperatures, winter-dominated rainfall, dry summers and a profusion of microclimates due to local environmental conditions (Ludwig et al., 2003). Mean annual temperature follows a marked north to- south gradient to which local orographic effects are superimposed. Lowest average temperatures of <5°C are found in the higher parts of the Alps, whereas temperatures of >20 °C are typical for southern part. Mean annual precipitation has a general decreasing north-to-south gradient. Annual precipitation values of 1500–2000mmyr-1 and more exist in the alpine and Pyrenean headwater regions of the Rhone and the Ebro rivers.

The strong summer–winter rainfall contrast is the major characteristic of the Mediterranean climate. This contrast increases from north to south and from west to east (Ludwig et al., 2003). Precipitation mainly occurs during winter and autumn, and often less than 10% of the annual precipitation falls during summer. High precipitation during autumn is typical for the coasts of Spain, France and Italy. The Rhône and Ebro rivers alone account for more than 20 % of Mediterranean riverine inputs.

Altimetric measurements have shown that the sea surface height has changed for the last decade over the Mediterranean basin. Over the past 25 years the rate of increase in sea surface temperature in all European seas has been about 10 times faster than the average rate of increase during the past century. In the Mediterranean, the warming occurs three times faster than the global average over the past 25 years. Deep waters in the Western basin have also been evolving slowly since 1970 with increasing temperature and salinity (Rixen et al., 2005), whereas the SST has increased in annual mean by about 1°C in 30 years, mainly due to warmer wintertime temperature. Also, the dense water formed in winter on the continental shelf of the Gulf of Lions could contribute significantly to the modification of the characteristics of the western deep waters.

Hydrological processes are largely variable both in time and space due to the high variability of rainfall regime, the influence of topography and the spatial distribution of soil and land use. The temporal variability of precipitation within and between years is one of the specific characteristics of this climate characterised by a succession of dry and flash-flood periods that locally affect salinity.

The improvement of sensors has made possible the observation of these changes, which could be related to climate or to natural variability associated to the Noth Atlantic oscillation. Actually temperature and salinity are monitored on regular basis and data from various sensors are available online (see for examples GMES project, http://www.gmes.info/index.php; MOON project, http://www.moon-oceanforecasting.eu/) and from database at both regional or sub regional scale including participants from all countries surrounding the western basin (MEDAR project, http://www.ifremer.fr/medar/ ; http://medar.ieo.es/).

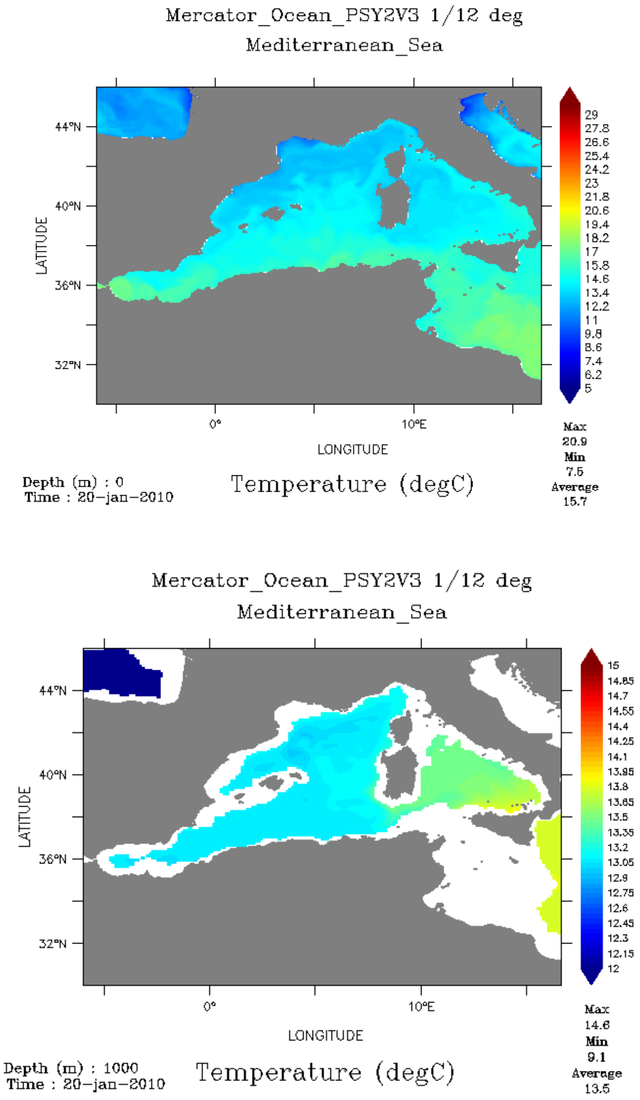

Figure 4: Examples of temperature measurements at the occidental basin scale (http://bulletin.mercator-ocean.fr/)

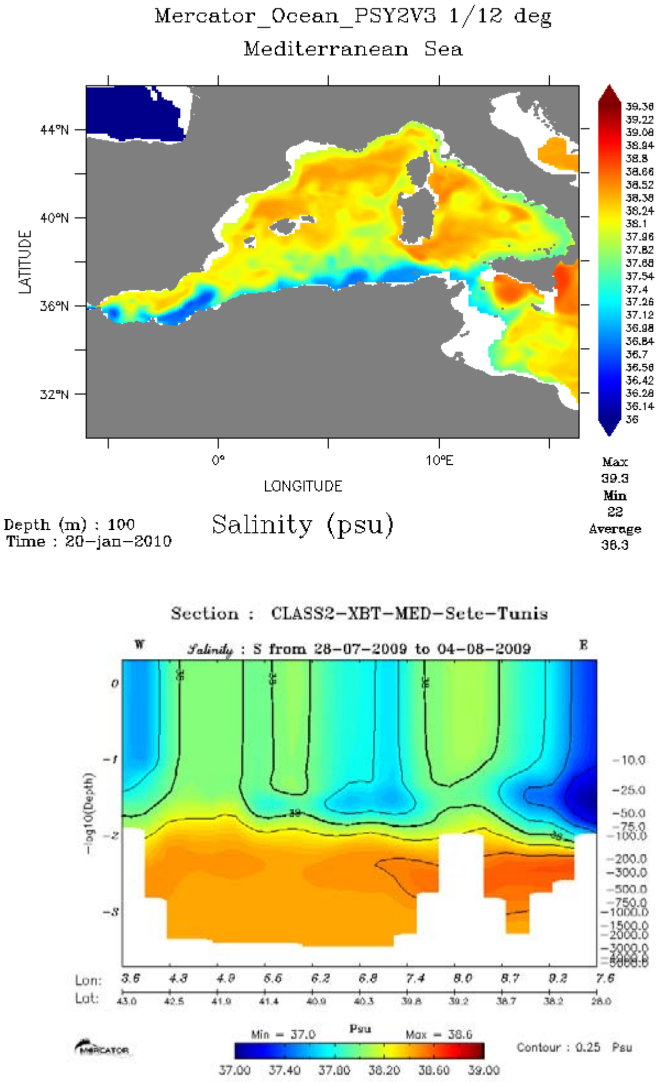

Figure 5: Surface Salinity of the occidental basin scale (20/01/2010) and salinity profile along a Sete – Tunis transect (mean values for the period from 28/07 - 04/08/2009, http://bulletin.mercator-ocean.fr/)

2.2. Nutrients and primary productivity

The Mediterranean basin is characterised by a reduced biomass of phytoplankton, which causes a high water clarity and deep penetration of light in the water column. The richest waters in the western basin are located on the north shore. Inversely, the offshore waters are generally oligotrophic, except in cases of deep nutrient-rich upwelling. Biogeochemical models has enabled the evaluation of nutrients stock exchanges in the Mediterranean and demonstrated the differences between East and West. The ecosystem behaviour simulation in relation to rivers or atmospheric inputs and exchange between different basins has shown (Crispi and Pacciaronia, 2009) that the nitrogen balance in the intermediate layers of depth beyond 180 m and the chlorophyll balance in the euphotic layer are typical of a west-east gradient of primary production. The reason for the oligotrophy of the Mediterranean is then explained as a response to the exiguity of nutrient inputs and to the negative thermohaline circulation, with the precise biogeochemical mechanism, which controls oligotrophy, being the biological pump. The Mediterranean geochemical cycling of nutrients depends on the inflow and outflow with the Atlantic Ocean, influencing the deep-water convection, the atmospheric inputs, which modify the upper layer concentrations in terms of the different oligoelements and the inflow of freshwater by the main rivers prevalently affecting coastal areas. Schroeder et al (2010) recently confirmed the role of the eastern basin as a source of nutrients for the western basin, and showed the significant evolution of the geochemical footprints of the deep water masses of the western basin due to recent formation of new deep waters. These four facts determine an oligotrophic ecosystem with anomalous nutrient ratio with respect to the ratio in the world Ocean, described by Redfield.

According to UNEP (EEA 1999) there are numerous factors governing the transfer of nutrients. The total nitrogen (N) is largely rejected by urban wastewater treatment(31%), livestock (19%) and metals industry (11%), while fertilizer production represents the majority of emissions of total phosphorus (P) (63%), followed by livestock (20%) and urban wastewater treatment (8%). These factors illustrate how a small group of industries is responsible for the main emissions/discharges of nutrients and transportation to the sea in the Mediterranean region. It appears that large cities also play an important role in the contributions to organic matter and nutrients inputs.

The origin of nutrients is largely due to the presence of rivers. In the western Mediterranean, all water systems are small apart the Rhone and the Ebro rivers, which have influence areas at sea of 96 000 and 84 000 km2 respectively. They received more attention because of their importance for the geochemical budgets at larger scales, and more or less complete reconstructions of their nitrate and phosphate fluxes during the last 40 years. These large rivers have also the advantage that their basins integrate the variety of human activities at regional scales, making them more representatives for the general evolutions than smaller river basins. Nitrate fluxes in the Rhone and Ebro rivers increased steadily from the beginning of the 1970s up to the 1990s, before they remained approximately constant, or even decreased during recent years.

The inputs of nutrients are however important in small rivers too collecting rich effluents in large quantities. This is the case in most north African oueds (Djemai & Mesbah, 2008) but also in rivers of the north shores where after heavy rains following dry periods, metals, nitrates and organic carbon reach concentrations that could affect biological populations (Nicolau et al, 2006). Fluxes of nitrogen (N) were strongly enhanced by anthropogenic sources during last decades when Phosphorous only increased up to the 1980–1990s, and then rapidly dropped down to about the initial values of the 1960s limiting primary production (Ludwig et al. 2009) .Silica (Si), strongly controlled by water discharge, was decreased during the same period and has become a limiting element for siliceous primary producers such as diatoms, since the early 1980s. However, Gross primary production sustained by rivers (PPR) represents only less than 2% of the gross production in the Mediterranean. Possible ecological impacts of the changing river inputs should therefore be visible only in productive coastal areas, such as the Gulf of Lions, where Primary production can reach more than two thirds of primary production.

Nitrogen, phosphorus and silica exist in rivers in various dissolved, particulate, organic and inorganic forms. When considering the proportions of specific nutrient forms in more densely populated regions, such as the Mediterranean, the dissolved forms and especially nitrates are the dominant forms in the total nitrogen (TN) fluxes when other DIN species (NO2- and NH4+) are only abundant when rivers suffer from organic pollution reducing the oxygen levels. For phosphorus, however, the particulate forms cannot be neglected and monitoring programs often also determine the total phosphorus (dissolved and particulate P species) content in rivers that is also dependent on suspended solids. Then, although phosphate is not necessarily the dominant P form, average values might be more suitable for an assessment of phosphorus enrichment in rivers.

Table 2: Average nitrate and phosphate levels in Mediterranean and Black Sea rivers

River	Country	av. N–NO3 (Period) (mg l_1)	av. P–PO4 Q (period) (mg l_1)	Flux–NO3 (kg N km2 yr_1)	Flux–PO4 (kg P km2 yr_1)
Arno	Italy	2.39 (01–05)	0.149 (01–05)	255	609 38
Aude	France	1.51 (00–05)	0.107 (00–05)	290	437 31
Ebro	Spain	2.39 (00–05)	0.065 (00–03)	110	263 7
Herault	France	0.58 (00, 06)	0.023 (00--06)	590	340 13
Jucar	Spain	4.01 (00–05)	0.080 (05)	58	233 5
Llobregat	Spain	2.19 (01–04)		95	208
Rhone	France	1.44 (00–05)	0.050 (00–05)	564	812 28
Tevere	Ialy	2.10 (03–04)		446	937
Turia	Spain	3.22 (00–05)	0.235 (05)	42	135 10

Average concentrations were taken from EEA (2007) and Ludwig et al (2009).

Monitoring of water quality parameters in rivers has been developed at national levels but only for recent years these data became widely available. For European rivers, many of them are now centralised in the Waterbase database at the European Environmental Agency (EEA, 2007), allowing the nitrate and phosphate levels in western European countries to be quantified. African countries are not considered in this database, which can bias the general picture.

For nitrate, data (Table 2) demonstrated relative moderate specific fluxes in river basins, indicating that nitrogen pollution is still low compared to what is commonly reported for the large European rivers further to the north, such as the Seine and Rhine rivers. Phosphorus pollution is normally dominated by point sources, such as urban waste waters. The north to south decreasing trend that is typical for nitrate in Europe is overprinted for phosphate by an upstream to downstream increase, following the distribution of population densities. Phosphate levels reported in scientific studies are often clearly lower but observations mostly refer to scientific studies that were limited in time (Ludwig et al., 2003), making it difficult to catch the long-term evolutions.

Phenomena of eutrophication in freshwaters and coastal waters are not only depending on the degree of anthropogenic nutrient enrichment, but also on the relative nutrient composition. In particular the unbalance of nitrogen and phosphorus with respect to silica seems to play a crucial role, as it can provoke a shift in primary production from diatoms to non-siliceous algae, often harmful for the ecological equilibrium.

The Mediterranean has a pivot position between the temperate and subtropical climates, and temperatures are generally higher than in the pure temperate climate further to the north. Consequently, Billen and Garnier (2007) found higher Si values in Mediterranean rivers compared to temperate climate using however a general approach that cannot account for the influence of other controlling factors, such as the nature of the weathered rock types in the drainage basins and anthropogenic factors that can modify the natural riverine

Silica loads. When eutrophication conditions are favourable for diatom growth, silica retention can also occur in large rivers (Sferratore et al., 2006).

Several modelling approaches have been published in order to predict the spatial variability of DIN fluxes on the basis of economic and demographic input data (e.g., fertilizer spreads). The NEWS-DIN model of Dumont et al. (2005) (after adjusting and recalibrating it for rivers) shows that particulate river loads are spatially more variable than dissolved loads.

Budgets strongly depend on the estimates of the nutrient levels in the incoming Atlantic waters. These budgets should also include the nutrient inputs from other sources such as wastewaters of coastal cities that are directly discharged into the sea (UNEP/ WHO, 1999) and recent data on European rivers, showing that the strong reduction of anthropogenic P continues and probably will in the near future. A prospective scenario corresponding to the application of the European Water Framework Directive (WFD, 2000) may involve a 90% abatement of phosphorus from all urban wastewater inputs by 2015. This means that the phosphorus levels in the Mediterranean could fall below the 1960 levels. However, statistical modelling applied to a large number of historical nutrient data to assess the significance of human perturbations in the Mediterranean Sea (Karafistan et al., 2002) does not indicate any particular trend in time for the last 30 years. Average horizontal space distributions of the phosphate data over the whole Mediterranean clearly demonstrated oligotrophy was mainly affecting the Levantin basin. Results from the 3D modelling also revealed that natural variability is very important when compared to that the anthropogenic influence to the nutrient distribution and nutrient uptake might be responsible for the anomalous Redfield-ratios (N/P > 25) observed in the upwelling areas of the north-western basin

Besides rivers, the main sources of nutrients are soil erosion and excess nutrients from over-fertilization and livestock. Among the first areas of drainage, soil erosion and nutrient loss in the Mediterranean, 3 are located in the western basin (Sicily, Sardinia, Spain; EEA / UNEP 1999). More locally, intensive marine aquaculture, although undeveloped in open seas and mainly located on the north, largely participate in waters inputs of organic matter and nutrients (Doglioli et al., 2004). In the area influenced by the plume of the Rhone, the organic enrichment and quantities Phaeopigments suggest an organic matter of detrital and terrestrial origin. (Alliot et al.2003). In some areas not influenced by river inputs, the marine origin of nutrients and organic matter is important (Di Leonardi et al. 2009).

In 25 years, nitrate concentrations in the waters of the Ebro (Spain), which has a basin of 85,566 km2, increased in 46% of the 65 sampled sites in parallel of increase of agricultural activities (R2 = 82, Lassaletta et al. 2009). At the estuary, the Ebro is highly stratified and shows a positive balance of nitrogen and phosphorus inputs due to its superficial layer of fresh water, the presence of dissolved and particulate compounds, the reduction of uptake by phytoplankton due to a decrease in chlorophyll in the estuary, the high turbidity and to a lesser extent, the effects of sewage. The annual burden is among the highest in the Mediterranean for nitrates and silicates (# 10 000 tons) while the phosphorus is released at relatively low concentrations (approximately 200 t year-1) even above needs (Falco et al. 2010). By comparison, the total load of inorganic nitrogen and phosphorus is respectively 77,500 and 2,500 tonnes for the Rhone but with a higher flow.

In the sediments at the mouths of rivers, the levels of nutrients are decreasing regularly (Denis and Grenz, 2003). If the levels of nitrites and silicates are variables, nitrate, phosphorus and silicate are respectively 5%, 7% and 28% of nutrient requirements for the primary production of the continental shelf. Under these conditions, sediments act as a reservoir that plays an important role in the biogeochemical cycles of the Gulf of Lions, mainly for inorganic phosphorus.

Table 3: Comparison of intakes of nutrients in the Gulf of Lion. (DIN, DIP and DSi: Total nitrogen, phosphorus and dissolved silicates) (After Denis and Grenz, 2010)

	RHONE (Kt y-1)	NW CURRENT	SHELF SEDIMENTS	CONSUMPTION (kty-1)
DIN	99.9-104.3	75 (nitrates)	14.1	299
DIP	2.7-3	6	2.9	41
Dsi	135-139	nd	165	600

According to national assessments measuring inputs of nutrients on the Algerian coast, the transfer of nutrients from the terrestrial system to the marine system is concerning agricultural areas, including intensive farming of coastal lowlands (Annaba, Mitidja Algerian Sahel, Mostaganem area) or 'use of nitrogenous and phosphates fertilizers that have multiplied inputs to the coast (UNEP/MAP, 2003). Levels of nutrients in Mitidja indicate peaks of 200 mg / liter of nitrate (standard 50 mg / l). On the hills of the Sahel and other coastal areas (Skikda, plain, Saf Saf Mostaganem) nitrate is made by runoff and transferred directly to the sea. In the Gulfs of Arzew and Algiers, the distribution pattern of organic carbon shows sedimentation in middle of bays and nearby ports. These maxima are related to increasing population and industrial activities (Buscail et al., 1998). Nutrient concentrations in sediment are higher in harbours than those measured in the vicinity and correlated to levels of organic pollutants. Djijell, Algiers and Annaba are the most affected. In some areas with a continental influence, high levels of nutrients (14.9 micromol N-N03 L-1, 2.04 micromol L-P04 L-1, 11.3 mg Chl AL-1) can be observed (Freha et al, 2007). in the Oued Aissi water basin, situated in the South-East of Tizi-Ouzou, significant surface and underground water resources are generated by irregular precipitations (annual average pluviometry = 910 mm). Following the increase in population, the industrial development and the increased use of fertilizers, concentrations of pollution parameters like ammonium (0.8 mg/l), the nitrites (0.095 mg/l), phosphorus (0.408 mg/l) and the ferrous-iron (0.326 mg/l) arise in concentrations higher than the standards of quality of water surface (Mohammed and Mohamed, 2008).

In Morocco, only one important site, Oued Martil estuary, where urban and industrial wastes are discharged, is affected by excessive levels of nutrients with maximum nitrate concentrations ranging from 400 to 500 µg/l.

The Spanish coast is characterized both by natural enrichment due to upwelling and an induced eutrophication caused by human discharge. The high productivity of the Alboran Sea appears to be related to the upwelling generated by the anticyclonic circulation generated by the flow of Atlantic waters entering the Mediterranean through the Gibraltar strait. 0ther areas affected by nutrients appear to be coastal areas close to Valencia and the Ebro delta. As monitored by concentrations of nutrients, Localised events of eutrophication in the Mediterranean coasts of Spain have been reported in several cases (UNEP-MAP, 2008). Finally, the bay of Tunis is an enclosed gulf where the urban areas around the Lac de Tunis have caused serious nutrients inputs.

In Italy, nutrients are mainly related to effluent discharges from urban agglomerations (Foce Torrente Lerone, Marinella - Foce Magra, Napoli) and only in a few cases from inputs of rivers (Sarno, Arno, tevere).

The remineralization of organic matter, measured by the kinetics of total organic carbon or dissolved is recognized as an important source of inorganic nutrients in coastal systems. It increases the production of endogenous nutrients. However recycling of nutrients causes a significant limitation in certain areas because of low supplies. Whether in offshore waters or in coastal areas in winter, levels of certain nutrients, including phosphates may limit primary production. An experimental and numerical study of the spatial distribution of aerosols over the western Mediterranean basin (Salameh et al. 2007) showed the influence of northerly winds (Mistral and Tramontana) in the Rhone valley and the Gulf of Lion. The transport of natural and anthropogenic aerosols at sea may affect the whole north-western basin. These winds are responsible for the transport of particles containing ammonium nitrates and sulphate in an advective pattern from the northern region of Fos / Berre / Marseille to North Africa and Italy. They are also influencing and generating currents in the northern basin. Although of secondary influence in the Mediterranean, the upwellings generated by these persistent north-west winds and currents cause complex physical phenomena that promote the redistribution of dissolved and particulate elements and the recovery of nutrients to surface waters. This mixing causes the homogenization of the water, mixing with waters from large rivers in the delta of the Rhone and near the estuary of the Ebro and changes in concentration of chlorophyll in the sea surface as described since for many years (El Sayed et al., 1994).

Due to oligotrophy, phytoplankton biomass as chl-a, generally displays low values (less than 0.2 μg chl-a l -1) over large areas, with a modest late winter increase. A large bloom (up to 3 μg chl-a l -1) throughout the late winter and early spring is only observed in the NW area (Siokou-Frangou et al., 2009). Relatively high biomass peaks are also recorded in fronts and cyclonic gyres. A deep chlorophyll maximum is a permanent feature for the whole basin (except during the late winter mixing). It progressively deepens from the Alboran sea (30 m) to the west. Primary production reveals a similar west-east decreasing trend and ranges from 59 to 150 g C m-2 (in situ measurements). Overall the basin is largely dominated by small-size autotrophs, microheterotrophs and egg-carrying copepod species. The phytoplankton and the microbial (autotrophic, heterotrophic and probably diazotrophic) reveal a considerable diversity and variability over spatial and temporal scales.

Satellite imagery type "broad scope" or "low spatial resolution" or "high time resolution" provides access to certain environmental parameters of sea surface, which can monitor large areas but is usually associated with a rather low spatial resolution of about a kilometre at most a few hundred meters. This is largely compensated by a high temporal resolution of about 1 to 3 days, which allows to effectively monitoring the highly dynamic phenomena at the ocean surface.

The data from sensors such as MODIS (Moderate Resolution Imaging Spectro-radiometer, 1km resolution, field width 2350 km, repetition: 1 to 2 days) or MERIS (Medium Resolution Imaging Spectro-radiometer 1km resolution, field width 1150 km, Repeatability: 2 to 3 days) allows, after image processing, to obtain information on the concentration of surface chlorophyll a (chl-a, an indicator of the trophic richness of the medium) and suspended solids (TSS, transfers terrigenous or resuspension of particles), the temperature of surface water (SST - Sea Surface Temperature, global warming) and finally transparency .

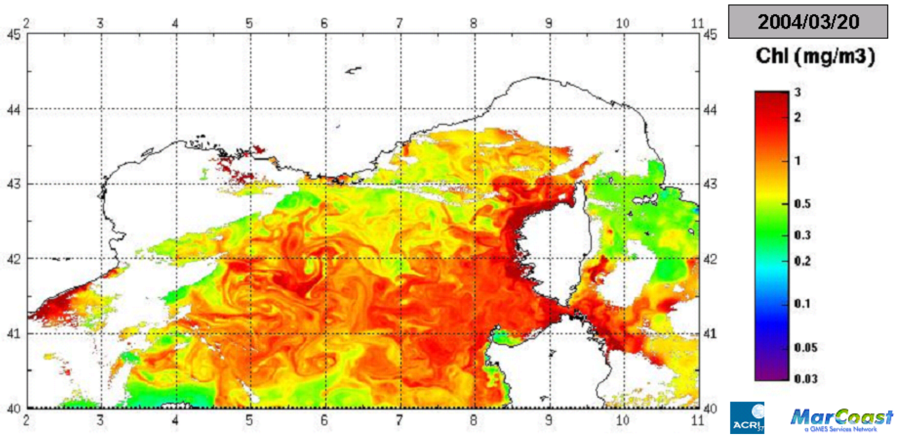

Figure 6: example of calculation of chl-a derived from MERIS (March 20, 2004) for the northern Western Basin (MARCOAST).

This approach, coupled with the use of models allows a systematic coverage in time and space of bodies of water. It will eventually dispose of evidence of very thorough comparison between the northern and southern basin. Satellites allow regular monitoring ocean but only for the near- sea surface parameters and at limited temporal frequencies. In contrast, in situ data collection is almost always much more sparse and irregular in spatial coverage. Technologies, such as autonomous platforms, can routinely provide observations at higher temporal and spatial scales than before, and while this has greatly increased our monitoring capabilities, it has also revealed new challenges for practical utilization of data and for understanding the dynamics of smaller scales. On the prediction side, increasing resolution is not enough as initial and boundary conditions uncertainties as well as physical and numerical approximations impose severe limitations in forecast skills (Rixen et al. 2009). Resolution of these problems have recently led to an emergence of innovative data assimilation and stochastic and statistical modelling techniques that attempt to optimise use of the available data and models to produce more accurate assessments and predictions.

3. Pressures and Impacts

3.1 Emission of pollutants from urban-industrial sources

The North-western basin of the Mediterranean is affected by intense human activities that can cause chemical contamination, degradation and risk of serious harm in the marine and coastal areas (EEA, 1999). The coast is particularly affected because of maritime traffic, absence of tides, the importance of the maritime routes and the oil related industries present all around the basin. Urbanization has experienced significant growth particularly along the coastal strip, to serve the population for permanent and temporary, with related changes in the quality of the environment. Highly developed industrial countries in the North are mainly affected with a striking contrast with non-urbanized areas of the south shores. In the future, coastal areas should be facing even greater pressure and a multi-disciplinary approach should be adopted in studies of distribution and flows of chemical contaminants, since the behaviour, futures and balances of anthropogenic compounds are influenced by the dynamics of major biogeochemical cycles (Cossa et al. 2009). The evaluation of national plans and reports on "hot spots" and the identification of sources of pollution enable to understand the nature and levels of chemical contamination along the coasts of the western basin of the Mediterranean.

For Italy (UNEP/MAP, NDA Italy, 2005), even with objectives of reduction of almost total input by 2025 and the closure of landfills, the most consistent sources remains linked to industries and urbanization in Genoa, La Spezia, Livorno-Rosignano, Piombino, Bagnoli-Napoli and Palermo. Sources are varied but still responsible for contributions of major pollutants (metals, hydrocarbons, PCBs and insecticides). In some areas, some pollutants are more specific such as metals in SW Sardinia, hydrocarbons and nutrients in Porto Torres, Chromium at Cogoleto Stopani (Genoa) or nitrogen oxides in Piombino. Similarly the Italian rivers of the western basin (Arno, Tevere, Salento rivers) are described as sources of organic matter but also pollutants. National sensitive areas (Orbetello) are also affected although mostly related to transitional waters.

Because the principality of Monaco has developed a rational management of waste, recovery of industrial and wastewater treatment including specific processes, it is not an area heavily affected by pollution (UNEP/MAP.NAP Monaco, 2005).

In the case of France (UNEP/MAP, NAP France, 2006), defined sources of pollution and "hots spots" are primarily located in the south-eastern coast of the French Mediterranean. They cover the cities of Marseilles-Fos (municipal waste, industrial inputs, and port activity), Toulon (military and commercial harbour) and in a lesser extent, the area of Cannes-Nice (highly urbanized area, light industry, marinas). Sources of specific contaminants sources such as the industrial waste from Gardanne immersed deep in the Cassidaigne canyon (metals) and to a lesser extent asbestos-residues dumped in the past in the western part of Cap Corsica (Galgani et al., 2006) must also be considered. The Rhone and smaller rivers such as Var and Argens (Frejus) have significant inputs of contaminants. Finally areas of high sensitivity are also concerning the transition waters such as many coastal lagoons, but also nurseries in the Gulf of Lions.

Spain has identified 7 key priority areas in terms of pollution and two sensitive spots in the western basin (UNEP/MAP, NAP Spain, 2005). These are the port of Barcelona and the Llobregat in Catalonia, Tarragona –Vila seca coastal zone, the region of Castellon, Carthagena-Valle Escombreras- Port man (port operations, mining), Carboneras-Villaricos (province of Almeria, desalinisation plant, industrial and urban effluents), the region of Motril (iron mining) and the bay of Algeciras (petrochemical industries). Sensitive areas are represented by the Mar Menor lagoon and Ebro estuary, the latter being the most consistent in terms of contributions to pollution of coastline.

In Morocco, with a reduced population, an average low rainfall (300 - 500 mm / year), 14 oueds with only 2 having impacted coastal areas of more than 1 000 km2, sources of marine pollution are limited to urban (Tangier-Tetouan, Al Hoceima, Nador / Melilla) and industrial (Tangier-Tetouan, Nador, Oujda) areas. Chemical and paper pulps in the west and steel and food industry in the east are the main sources of heavy metals. Discharges of sewage are the main sources of water pollution, also through the coastal oueds (oueds Moghogha, Martil, Lihoudi) enriched in Nickel, Arsenic, Chromium and Mercury. Cities have only basic infrastructure and reduced treatment (Nador, Al Hoceima) and wastewaters and stormwaters are discharged directly into the marine environment. There is no landfill and leaching often transport pollutants to the (Al Hoceima). The development of intensive agriculture and disinfection involve the consumption of significant quantities of pesticides. Old Pesticide stocks are limited to few tonnes in the west. In recent years, Moroccan beaches have been subjected to tourism. Because of the proximity of the Straits of Gibraltar and nearby waterways, maritime transport can have significant impacts on the coast and its resources including risks related transportation of hazardous materials or oil spills. Then, the city of Tangier and its industrial activities should be considered as a major source of pollutants that may affect the western basin. The elimination of old stocks of pesticides, improved control pollution levels, the rationalized program for effluents treatment and the recent collection of used oils are the main actual actions to improve the quality of coastal waters (Lahbabi and Anouar, 2005).

In Algeria (UNEP/MAP, Algeria NDA, 2003), the most affected coastal areas by the water pollution and detritus, are those adjacent to major cities (Algiers, Oran, Annaba) or neighbouring large industrial harbours (Ghazaouet, Mostaganem, Arzew, Bejaia, Skikda). These areas are impacted by several sources of pollution including Discharges with organic pollution (Algiers, Annaba, Oran, Mostaganem, Skikda), oil terminals and refineries chemical near industrial harbours (metals, hydrocarbons, nitrogens compounds, cyanides, pesticides and detergents), discharges from power plants (Marsat, El Hadjadj, Algiers, Cape Djinet), agriculture run offs (Central plain and Annaba), Mostly untreated Wastewaters and solid wastes, industrial and domestic, a special problem in metropolitan coastal areas and in adjacent oueds.

With Urban inputs, industrial and petrochemical related activities and characterized by an important river system (oueds Medjerda, Meliane, Elbey, Bézirk, El Abid), the Bay of Tunis is the most affected area in northern Tunisia (Baouendi, 2005) and undergoes a strong anthropogenic pressure (Sammari, 2010). This heterogeneous structure (lagoons, bays, estuaries) and to a lesser extent, the Bizerte lagoon, remain potential source of contaminants.

Atmospheric deposition is a main route of entry of anthropogenic inputs of trace metals accumulated in recent sediments from the sea, while the lateral advection, currents and sediment gravity flows is proposed to reflect pre-industrial concentrations of metals (Martin et al, 2009). Similarly, the geochemical behavior may be very different as Pb and Cu remains in the sediments while Zn is advected. In coastal areas, atmospheric inputs are largely superseded by fluvial deposits when they are present (Roussiez et al., 2006). Given the particular importance of atmospheric transport of air-water exchange and circulation, offshore waters are also a source of concern for chemical contamination, especially through the processes of trophic transfer and bioaccumulation. The knowledge of concentrations, inflow and exit behaviour in water and sediments and toxicological impacts on ecosystems are highly variable, depending on the contaminant groups studied. For many countries, no detailed information is available on quantities of hazardous substances from point sources (industry and urban centers). In general, there is a lack of adequate data and data interpretation also passes through an understanding of geochemical cycles. As an example, the overall balance of mercury in the Mediterranean has been assessed by Rajar et al. (2008) with input from the bottom of 120 kmol / year. This includes direct inputs of sediment from the tectonic movements and the natural leaching of mercury. The distinction between these two sources is difficult. The contributions related to tectonic sources are important in volcanic and geothermal sources near as southern Tyrrhenean Sea. These contributions explain natural important levels in some islands of the basin. The presence of mines located upstream of rivers or streams in the basin (Almaden in

Spain, Monte Amiata, Tuscany) Explains also flows to the sea which can be evaluated over the entire Mediterranean at 610 kmol / year compared to 4 to and kmol / year for other sources (UNEP-MAP, 1996).

3.2 Levels of Contaminants in the Marine Environment

A significant amount of information exists on the distribution of chemicals, both from research projects and monitoring. However, often data are available from local studies, resulting to significant gaps in geographical coverage or/and in emerging contaminants such as dioxins, alkyl phenols. In addition, lack of standardized methods in these surveys makes it difficult to compare and use data from different sources in a regional assessment in order to draw conclusions about the spatial and temporal trends.

3.2.1. Trace metals

The deposition of trace metals is dominated by atmospheric inputs (Migon et al., 2005), which are characterized by a signature of European origin, both natural and anthropogenic. In the Mediterranean, Saharan dust signatures are superimposed on this natural background signature. The spatial variability of atmospheric deposition, however, seems low, despite the variability of weather and climate (rainfall, wind speed, the efficiency of the aerosol scan). The influence of major rivers is higher in coastal regions and the primary source of metal particles on some continental shelves. For example, in the Gulf of Lions, Radakovich et al. (2008) have shown that air flow is less than 5% of the total (atmosphere + rivers) flows of particles of Cr, Co, Ni, Cu and Pb, 17% Zn and 35% for the Cd. In the Northwest basin, important metal inputs could be related to floods and natural disasters (up to 80% of contributions in certain coastal areas). The partition between dissolved and particulate phases in the surface layer strongly determines then the behaviour of trace metals and their involvement in biogeochemical cycles (Cossa et al. 2009). Little is known about the absorption of contaminants in the first trophic levels (plankton and benthos) and how they behave in cycles. Bacteria seem to play an important role in the bioaccumulation and the metal enrichment of the first trophic level, both pelagic and benthic. During photosynthesis, phytoplankton assimilates nutrients and trace metals in the proportions following a Redfield ratio evaluated as: C: N: P: = 106:16:1. This ratio is approximate and may vary by region. The seasonality of phytoplankton blooms is responsible for large variations in metal concentrations and therefore on vertical profiles of nutrients. In case of high metal concentrations, their assimilation by organisms may be limited by their solubility or toxicity. In addition, the involvement of trace metals in the process of absorption depends on factors such as the redox speciation, complexation with organic ligands and photochemical reactions. The transfer of trace metals in the food chain to higher marine organisms has been demonstrated, including dolphins and whales. The concentrations of trace metals in the stomachs of whales suggest that the food source is responsible for a significant proportion of metal contamination. During the 1970s, several articles have highlighted the high levels of mercury in fish Mediterranean. More recent work has confirmed the accumulation of methyl mercury in the hake in the Gulf of Lion, related in part to bioaccumulation from the food chain, especially phytoplankton and bacterioplankton (Harmelin-Vivien et al. Submitted) (http://www.ifremer.fr/medicis/EN/projets/merlumed.html). Concentrations of 0.1 to 1.4 mg Hg kg-1 with maxima of 4 mg kg-1 were evaluated in Sharks and tuna (UNEP-MAP, 1996; Storelli et al., 2006). On the whole, trophic transfer could account for an export of 1 .2 million tonnes per year. Fertilizers production represents the main source of lead and mercury, while cement industry, energy and metal processing produce emissions of mercury. Chromium in water is mainly rejected by oil refineries, followed by the fertilizer industry and the tanning. Finally, air emissions of nickel are originating from power plants. In the case of ports, the analysis of sediment cores clearly demonstrates the recent origin of metals in sediments. (Di Leonardi et al. 2009).

Data of contaminants in water and sediments are not widespread in North Western Mediterranean. Analysis of MEDPOl evaluations revealed significant concentrations of cadmium and copper on the coast of Morocco (Nador) and mercury lead in the northern Ligurian Sea. The recent development of passive sensors (Gonzales et al. 2005 & 2007; Schintu et al., 2008) enabled the evaluation of metals in waters of the western basin (Table 7). The results show significant levels in the mining, industrial and urban areas.

Table 4: Concentrations of dissolved metals (ng / l) in seawater as measured by DGT (CDGT) in various locations from the North west Mediterranean. (After Gonzales et al. 2005 & 2007; Schintu et al., 2008).

	Ag	Cd	Cr	Cu
Marseille(France)	0.5 - 0.8	2 - 8	70 - 280	5 - 170
Toulon (France)	5 - 9	4 - 30	22 - 208	67 - 530
Canari (North Corsica)	5 - 12	5 - 16	55 - 418	110 - 362
Rosignano (Italy)	4 - 6	4 - 8	599 - 633	138 - 149
Porto Torres (NW Sardinia)	3 - 37	3 - 13	243 - 368	85 - 452
Casaletta (SW Sardinia)		10 - 35		9 - 38

Mussels and mullets were the most extensively studied organisms in the basin through numerous case studies. Recently, Posidonia was proven as a suitable species in the Mediterranean context (Lafabrie et al., 2007). Then occasional work with various species (limpet, worms etc.) and meiofauna (nematodes, foraminifera) appropriately measured contamination in harbours (Moreno et al., 2009, Rumolo et al., 2009). In mussels' tissues, the maxima levels of metals are generally found in priority sites pollution (EEA, 2006). Cadmium is found in significant amounts (> 10 mg / kg) in the site El Portus (Spain), in the Bay of Naples and the south west coast of France. Average levels remain high also in the islands (northern Sardinia and Sicily) but probably related to a tectonic related natural background. Lead is mainly located in Italy, especially in areas around Lazio and the Gulf of Genoa. The levels of copper are very important along the Italian coast of Sardinia and while Zinc is located in Naples, Palermo and to a lesser extent in the Gulf of Genoa. A significant difference was observed for mercury between the eastern part of the North West basin, along Italian coast, with low concentrations and those found in the western part along Spain.

Table 5: Trace metals in mussels (*Mytilus galloprovincialis*) from the North West basin of the Mediterranean sea

	PB	CD	CU	CR	Hg	Ni	Zn

Balearic islands	0.8-6.7	0.14-1.59	5.9-58.3	0.7-14.8	0.13-2.21	0.7-35.2	48.9-316.7	Gomes-Giuterrez et al, 2008
South Spain	0.5-12.2	0.2-12.5	2.6-11.85	-	0.05-1.80	-	86-423	Benedicto et al.,2008
Spain native (mean)	7.59	0.99	-	-	0.19	-	-	UNEP, 2007
Italy	1.47-3.9	0.66-2.43	6.6-16.40	-	0.3-0.47		90.13-234	Corsi et al, 2002
Italy native(mean)	3.56	0.88	12.51	-	0.30	-	159.5	Medpol database
Sardinia Transplanted	0.07-0.33	1.07-2.01	-	-	0.07-0.33	0.6-1.1	-	Andral et al.2010
Tunisia native (mean)	0.95	0.33	-	-	0.22	-	-	Medpol database
France native	0.1-34.6	0.03-2.62	2.3-29.6	0.30-3.38	0.02-1.24	-	123.3(mean)	www.ifremer.fr
France native (mean)	2.14	0.88	7.97	-	0.14	-	105.5	Medpol database
Alboran sea caged	0.6-6.29	1.10-2.11	-	-	0.06-0.15	0.636-2.72	-	Andral et al., 2010
Tyrrhenean caged	0.66-3.06	0.86-2.05	-	-	0.07-0.22	0.123-3.20	-	Andral et al., 2010
North west caged	0.69-2.79	0.94-1.97	-	-	0.07-1.23	0.63-1.85	-	Andral et al., 2010
Naples/Bagnoli	21-1288	0.01-4.70	6-165	4-43	0.01-2.90	3.4-181.3	111-2525	Romano et al,2008
Morocco (Perna perna) (2)	-	<1	-	-	0.05-3.6	-	180-390	Benaoui et al.,2004
Corsica (10)	0.9-1.2	0.89-1.23	-	-	0.07-1.1	0.6- 1	-	Andral et al.2010
Noth Tunisia transplanted(7)	1-1.3	1.28-2.48	-	-	0.1-0.14	1.4-3.4	-	Andral et al.2010
Algeria Transplanted (8)	0.8-1.5	0.87-1.97	-	-	0.08-0.14	0.6-3.1	-	Andral et al.2010
Morocco transplanted (4)	0.6-1.6	1.05-1.42	-	-	0;04-0.08	0.7-2.7	-	Andral et al.2010
Sicily transplanted (11)	0.9-1.2	1.33-2.89	-	-	0.10-0.23	1.1-1.4	-	Andral et al.2010

The analysis of metal contamination in 134 stations of mussels transplanted along the coast northwest of the basin enabled recently to specify the levels of contamination in areas of 20-30 meters depths (Andral et al, 2010; Benedicto et al, in preparation). The results confirm previous data on natural mussel: Two main sites in Sardinia and Portoscuso El Portús in Spain, close to major industrial and mining areas are characterized by high levels of lead, mercury and cadmium. Portoscuso, in Sardinia is also a risk area for the Environment (Mitis et al, 2005). Recent studies have reported high concentrations of metals in sediments and transplanted mussels (Schintu et al, 2009). The site El Portus, near the hot spot Cartagena (UNEP, 2003), is under the influence of a naval base, an industrial complex and former Portman Mining. Other authors have reported high levels of cadmium and mercury in the seagrass *Posidonia oceanica* (Sanchiz et al, 2000). In Tunisia, the Gulf of Tunis is the most affected by metals due to inflows of the city, trade with the lagoon, the river flows Medjerda and its atmospheric inputs. In Algeria, discharges are responsible for main inputs. The maximum levels of Hg and Ni are in Skikda, Annaba, Oran and Algiers and mercury was found in Algiers as described previously (Taleb et al., 2007; Soualili, 2008).

On the coast of Morocco, the importance of lead has been confirmed in Nador (Benaoui et al., 2004). On the French coast, the Huveaune (Pb and Hg) is considered a major source of pollution in the Gulf of Marseilles (Sauzade et al., 2007). Similarly, the former factory of asbestos located in the Western Cape Corsica is responsible for inputs of contaminants associated with metals such as chromium, cobalt or nickel (Galgani et al, 2006, Lafabrie et al. 2009). Three sites are affected by metals on the coast of Spain in addition to the area of Cartagena. The mouth of the Llobregat, responsible for massive inputs of lead in the Barcelona area, the Bay of Algeciras with high concentrations of cadmium and the bay of Valencia affected by Nickel also confirms previous data (Palanques et al, 2008; Benedicto et al, 2005).

Beside Portoscuso, Palermo, Genoa and Livorno-Cornigliano-Rosignano are the sites most affected the Italian coast of North West Basin by metals, including cadmium and nickel (Tranchina et al, 2008; Lafabrie et al., 2007). In addition to these sites, Zinola, Oristano (Cucco et al, 2006; Magni et al, 2006), Piombino (Bocchetti et al, 2008) showed significant concentrations of metals in various organisms.

Rivers and streams promote metal inputs. The Tevere, the Rhone, the Ebro River and smaller rivers as Gapeau (France) or the Zhor area are responsible of inputs of industrial (Andral et al. 2004) or natural origin (Bouzenoune and Remoum, 2008). Runoffs on polluted urban areas may also have major impacts on the environmental geochemistry of some coastal areas like Portman or Porto Ferraio on the island of Elba (Marín-Guirao et al, 2005; Benedicto et al, 2008). In these areas, resuspension is possible during storms in addition to natural leaching of soils and other geochemical origin. In the case of Islands (Balearic, Palmarola, Aeolians), inputs naturally associated with geological substrates seem the most likely source of trace metals.

In general, comparisons of concentrations with sites outside the Mediterranean basin (Andral et al., 2010) show levels of contamination of the same order of magnitude. The comparison of data with values under European legislation demonstrates levels of metals did not exceed existing limits, except for mercury in organisms from the Gulf of Portoscuso. Related to processes of bioaccumulation and biomagnification, these compounds can reach dangerous levels, particularly in top predators, including marine mammals.

3.2.2 Clorinated hydrocarbons

Available data indicate that contaminants are not uniformly distributed throughout the Region. For example, concentrations of total DDT in sediments range from <0.25 to 885 ng / g and PCBs from 1.3 to 7274 ng / g, higher levels corresponding to the "hot spots" areas near outfalls wastewater of major cities and at the mouths of large rivers (eg Rhône). Levels up to 400 mg / g fresh weight of DDT and 1400 mg / g wet weight of PCBs were found in the fat of marine mammals (dolphins), far greater than the equivalent data in the Atlantic. Some geographical areas are in situations of concern. These include estuaries (Rhône, Ebro), bays and gulfs (Fos Sea, Bay of Algiers and Tunis, Genoa, Naples, Algeciras) and areas affected by the landfill.

In general, the highest concentrations of chlorinated hydrocarbons are found in port areas, due to limited water exchanges and intense urban and industrial activities. Direct discharges, runoff (Tolosa et al. 1995) or deposition of dredging (Alzieu, 2000) are also very important locally. Consequently, the concentrations found in the catchment areas of towns and rivers are above levels found in continental shelves. Temporarily absence of water in some rivers is a concentration factor. In estuaries, because of strong gradients in many physical and chemical parameters, the quantities and composition of dissolved organic matter, and colloidal particle play an important role in the transfer of contaminants and their transformation. Stratification of water is common due to salinity gradients causing density currents that depend, in such large rivers as the Rhone and the Ebro, on the topology. The behaviour of contaminants (PCBs, organochlorine pesticides, etc - Gomez-Gutierrez et al.2006) was demonstrated to be related to intrinsic chemical properties such as the ionic strength and precipitation phenomena, affecting the bioavailability. For example, the contributions of organic contaminants in the Ebro, monthly measurements between 2002 and 2003, Give concentrations of 0.4 a 19.5 ng L-1 for organochlorine compounds (dissolved and particulate) with an average of 8.9 ng l-1 for PCBS and from 0-to 170 ng l-1 for polar pesticides with an average of 82 ng l-1 for Atrazine. The quantities estimated annual inputs of 167 and 1258 kg respectively for the organochlorine pesticides and polar pesticides. DDTS were related to occasional contributions of suspended particles while the products of agriculture are related to seasonal use.

Table 6 : Distribution of organic contaminants in the North west basin of the Mediterranean sea, Data from Mytilos experiment (Andral et al 2010, Scarpato et al., 2010; Galgani et al., 2010, Benedicto et al., 2010). Minima-maxima / mean (std dev)

	DDTs μg/kg	PCBs μg/kg	PAHs μg/kg	Dioxins ng/kg
ALBORAN	1.07-7.51	1.83-18.74	43.06(17.08)	0.386 (0.003)
	3.68(2.07)	8.82(4.42)	25-84.6	0.384-0.388
SW	1.65-10.21	6.31-51.13	46.77(14.43)	0.534 (0.276)
	3.18(1.95)	11.43 (10.4)	25-79.6	0.375-1.02
TYRHENEAN SEA	1.19-15.33	4.07-91.48	48.31(14.13)	0.653 (0.306)
	3.95(2.58)	15.22(16.07)	25.4-80.4	0.399-1.49
NW	0.38-15.44	3.12-103.52	45.9(18.35)	0.698 (0.540)
	4.42(3.50)	17.12(19.23)	21.9-105.5	0.325-2.667

From the MED POL database, it was shown concentrations of aldrin, dieldrin, endrin, hexachlorobenzene, lindane, as measured in wild *Mytilus galloprovincialis*, are low in the North West Basin. Concentrations of DDT are higher, especially the degradation products as p, p'-DDE. The recent inputs, although not excluded, are not probable in this part of the Mediterranean. Analysis of pesticides concentrations in 122 stations of transplanted mussels (Scarpato et al, 2010) showed low concentrations of some pesticides such as lindane (HCH) and no detectable gamma-HCH. In regard to the DDTS pp'-DDE is the most represented with n average 80% of metabolites.

A comprehensive study was undertaken (Giuterrez et al. 2006) in order to evaluate the toxicity and risks associated with organic contaminants such as PCBs, DDTS and HCB in marine sediments. The effects were assessed using the levels of contaminants and by adopting existing guidelines for ecotoxicological information on persistent organic pollutants (POPs) in sediments of the Mediterranean. The results allowed the identification of problems in the vicinity of industrial and urban sites, as in major Mediterranean rivers mouths. Harbours of Imperia, Viareggio, Piombino, urban areas of Marseille, Toulon, Barcelona, Genoa and Nice and pro deltas under the influence of the Rhone and Ebro are affected by POPs pesticides and particularly the family DDTS with the associated risks (SIDIMAR, 2005; Giuterrez et al., 2007).

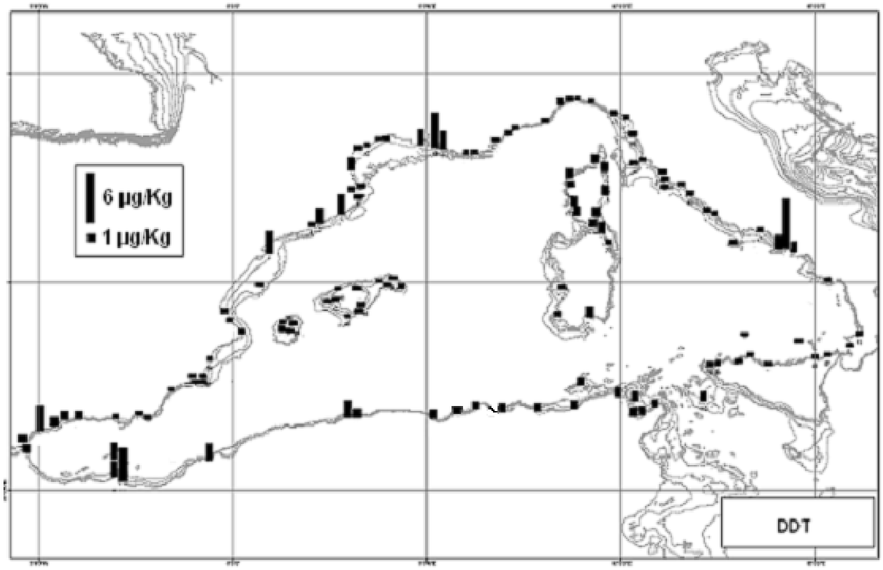

Figure 7: Levels of DDTs in Mytilus galloprovincialis transplanted in occidental basin of the Mediterranean (after Scarpato et al., 2010)

These contributions are related to increases in particulate matter associated with runoffs, resuspension of sediments and the seasonality of use of agrochemicals. In mussels kept in cages in areas at depths of 20 meters, the distribution profiles of DDTS are identical to those of wild mussels: High levels in Marseille (16.6 mg / kg), Barcelona / Llobregat (16.2 mg / kg), at the mouth of the Rhone and the Ebro, in the Gulf of Naples (15.3 mg / kg), in Algiers (10.9 mg / kg). The analysis of the concentrations of total PCBs or from BC 153 to MEDPOL data reveals a low number of data on marine organisms from the south shore. In the northern basin, the baseline levels are high and the sites most affected are the areas of Barcelona, Marseille (up to

1500 ng / g dry weight) and the Bay of Genoa. Ratios CB138 / 153 are somewhat variable. Recently, techniques for transplanting mussels have solved the problem of lack of samples of the natural environment, control factors such as exposure time and depth and stage of sexual maturity. In this context, the project Mytilos (Andral et al, 2010, Scarpato et al, 2010, Galgani et al, 2010) dedicated to the North Western basin of the Mediterranean provides an important basis of data and provides the scientific and technical services for large monitoring programs. These data refer to 122 sampling stations covering a period of monitoring all of 3 years (2004-2006).

The PCB congeners 31, 52, 156 and 180 are present at low concentrations and in industrial areas or urban. The PCB 153 and 138 show maximum levels of accumulation along the French coast, particularly at Marseilles and his emissary (respectively 42.3 mg / kg and 27.6 mg / kg) and to a lesser extent al mouth of the Rhone

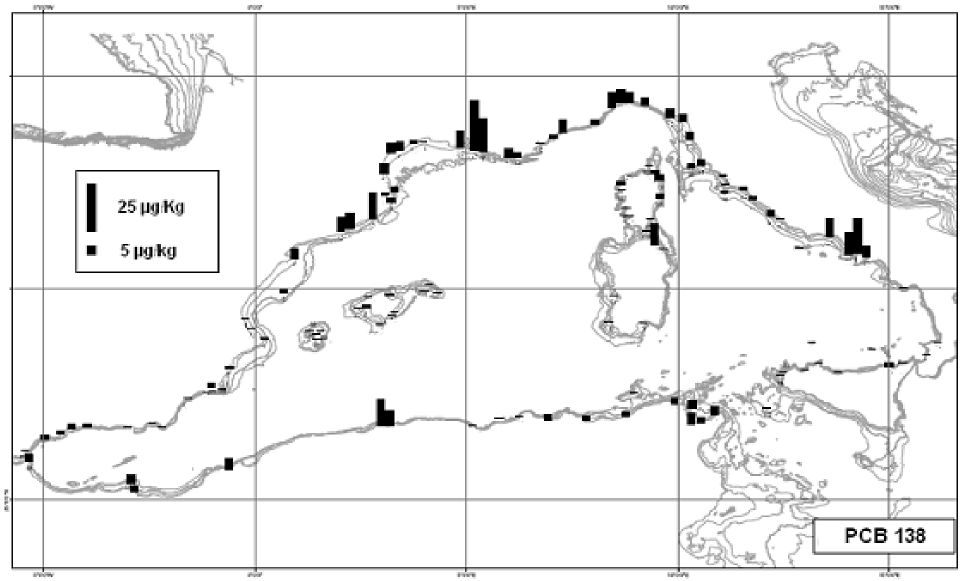

Figure 8: Levels of PCB138 in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Scarpato etal., 2010)

Concentrations are also important along the Italian coast, in Napoli (28.0 mg / kg and 19.0 mg / kg) and Bagnoli (16.0 and 12.0 mg / kg), in Sardinia at La Maddalena (PCB 153: 26.0 mg / kg, PCB 138: 12.0 mg / kg), at the Llobregat mouth (18.1 and 14.4 mg / kg) and in Barcelona (11.0 and 8.2 mg / kg).

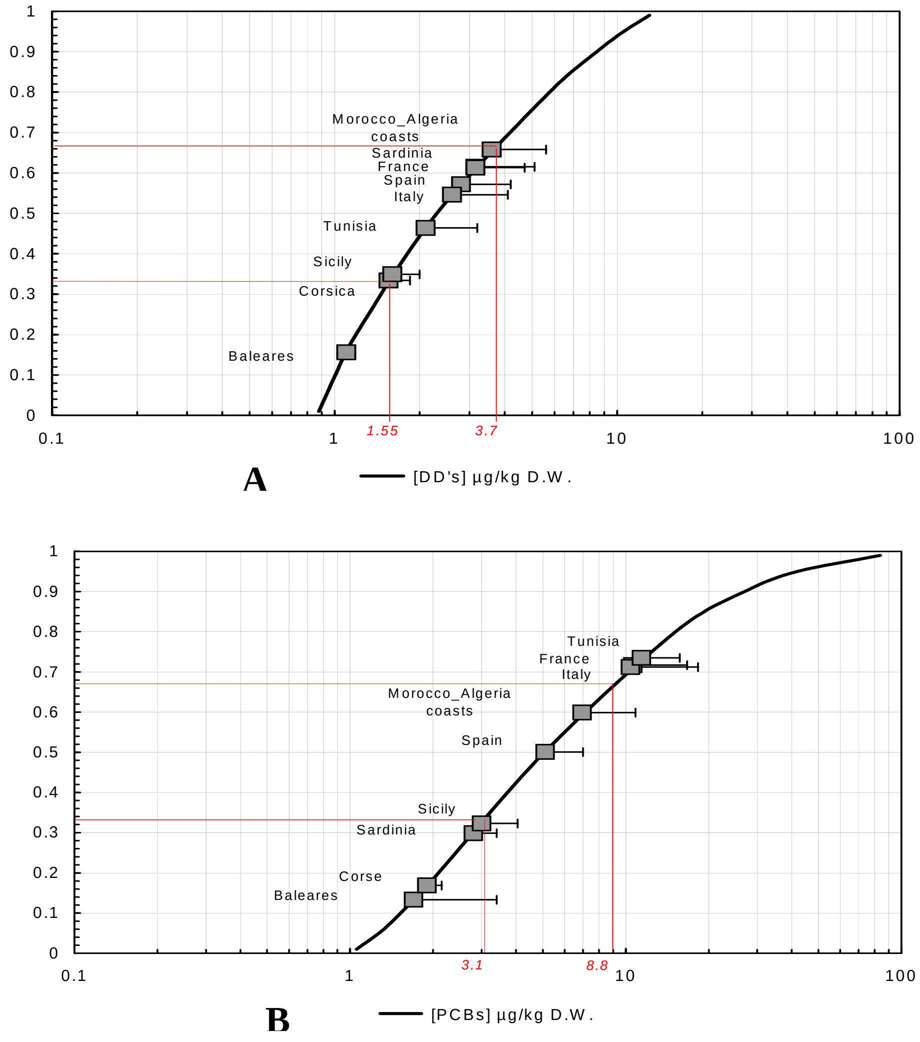

Figure 9: Classification of different areas of the basin of the North Western Mediterranean based on measurements of DDTs and PCBs in 122 stations (Algorithm of Johnson, Scarpato et al., 2010)

In southern Mediterranean, significant values for PCB 153 and 138 (20.5 and 14.1 mg / kg) were demonstrated in Algiers. All other sites have values not exceeding 10 mg / kg. PCBs 101 and 118 are only rarely found along the western shores of the Mediterranean. Marseille presents the highest concentrations (16.3 mg / kg and 8.4 mg / kg) of PCB 101 and 118. Then, the Ebro estuary, Barcelona, Besos and Llobregat, gulf of Napoli, Livorno, Nice are above detection limits when Algiers is the only site in South Mediterranean coast with detectable levels. The situation is similar to the mono ortho PCB 105 and 28 trichlorobiphenyl detected at low levels in Livorno, Genoa, Zinola, La Maddalena, and in major cities of the basin such as Marseilles, Naples, Barcelona to the north shore. PCB 28 was detectable only in the Bay of Algiers.

Environmental contamination by PCDD/Fs is of great concern, due to their long-range atmospheric transport, persistency, incorporation in sediment, accumulation in biota and biomagnification along food chains and toxicity for wildlife and humans (Gomara et al., 2005). The United Nations Environment Programme has published national inventories of PCDD/F emissions to air in Western Europe (UNEP, 1999) and identified large sources that could affect the occidental basin of the Mediterranean sea. In the case of France, emissions have decreased by 88% since 1990. Little data is available on the marine environment contamination In a study along the french coasts (Munschy et al., 2008), PCDD/F isomeric composition showed a fairly homogeneous distribution pattern dominated by 2,3,7,8- TCDF and OCDD, typical for mussels but enabling locally to characterise inputs. At a larger scale, analysis of dioxins in mussels *Mytilus galloprovincialis* in 33 stations from the whole occidental basin (Andral et al., submitted) indicates a median value of # 0.7 ng/kg (TEQ, toxic equivalent). The highest value was recorded in Marseille (2.66 ng/kg) with significant inputs. On the basin scale, the distribution of dioxins was similar to the one of PCBs, with highest values at Barcelona, la Maddalena (Sardinia), Algiers and Napoli but also in Toulon (Munschy et al, 2008) when Corsica and Northern Africa were the areas with lower concentrations.

Table 7. Minimum and maximum concentrations of PCDD/Fs in native mussels from various coastal locations in Europe (including this study), Asia, North America and Oceania (After Munschy et al., 2008)

Area	period	min	max	References
Mediterranean coast	1995–2005	0.05	184.4	Munschy et al. (2008)
Spain, Italy, France	2004–2006	0.02	1.57	Caixach et al. (2007)
Spain (Market)	1995–2003	0.09	1.89	Gomara et al. (2005)
Spain (Catalonia)	1999	1.19	5.59	Abad et al. (2002)
Spain (Catalonia)	2000	0.49	1.39	Eljarrat et al. (2002)
France	1999–2000	0.2	3.15	Abarnou and Fraisse (2002)
France	2004-2006	0.07	2.62	Andral et al.(2010)

3.2.3. Polyaromatic Hydrocarbons (PAHs)

The west Mediterranean has been described as affected by PAHs contaminations, especially in sediments (Mille et al., 2007; Martínez-Lladó et al., 2007), water (Bouloubassi et al., 2006), in marine organisms (Piccardo et al. 2001; Andral et al., 2004, Galgani et al, 2010) and by measurement of biological effects (Burgeot et al . 1996; Minier et al, 2006; Box et al, 2007, Martínez-Gómez et al., 2008).

The main sources of PAHs in the region are related to oil transportation, with high traffic areas (Strait of Gibraltar, the Messine strait, Sicily channel) and major ports (Algegiras, Valencia, Barcelona, Fos / Sea-Marseille, Genoa, Livorno, Porto Torres, Naples, Palermo, Naples, Tunis, Algiers, Nador) while river inputs do not contribute largely to inputs. In addition to land based sources, direct seawater discharges are important for PAHs because of the intense shipping transportation of oil (UNEP, 2002). Then, transfer to deeper waters has been demonstrated (Bouloubassi et al. 2006). In open western Mediterranean sea, average total PAH fluxes through sinking particles were 73 ± 58 ng m2 d-1 at 250 m and 53 ± 39 ng m2 d-1 at 2850 m. Thus, exposure of marine organisms to PAH are comparable in surface and deep waters but variable along the year due to specific components such as the winter increase of pyrolytic PAH and periods of increasing productivity.

The formation of oil slicks by accidental release of oil and petroleum products begin to be evaluated quantitatively (ref) by aerial surveillance and satellite imaging, and will enable a precise evaluation of associated risks. Evaluation of oil contamination in transplanted mussels (Galgani et al, 2010) showed the total levels of PAHs ranges from 20.0 to 105.5 mg / kg dry weight. Higher values were observed around areas of known contamination, including the major cities but also some industrial areas as described previously (UNEP / MED POL, 1999) with Marseille, Genoa Area, Naples, Palermo (Di Leonardo et al., 2009), Tunis, Algiers and Nador as the most contaminated areas.

Average levels by country are homogeneous with the exception of Algeria, which has low levels. The profiles of individual PAHs are very different stations. The North of Sardinia is characterized by PAH of low molecular weight characteristics of industrial sources (Piccardo 2001). Phenanthrene, anthracene, Dibenzo [a, h] anthracene, the Acenaphtylene, benzo [a] anthracene, benzo [b] fluoranthene, benzo [k] fluoranthene, indene [1,2,3-cd] pyrene and indene [1,2,3-c, d]) pyrene rarely exceed the limits of detection. Acenaphthene presents higher values in the northern part of the basin (11 - 25 mg / kg) around the mouth of Ebro, from Montpellier to Marseille and from Genoa to Imperia. A maximum of 2.7 mg kg (Algiers) was found on the African coast. Anthracene was detected in 21% of the stations. Naphthalene and fluoranthene are distributed with the same pattern. For naphthalene, the highest values (32-42 mg / kg) were obtained in Marseille, Porto Torres and Nador.

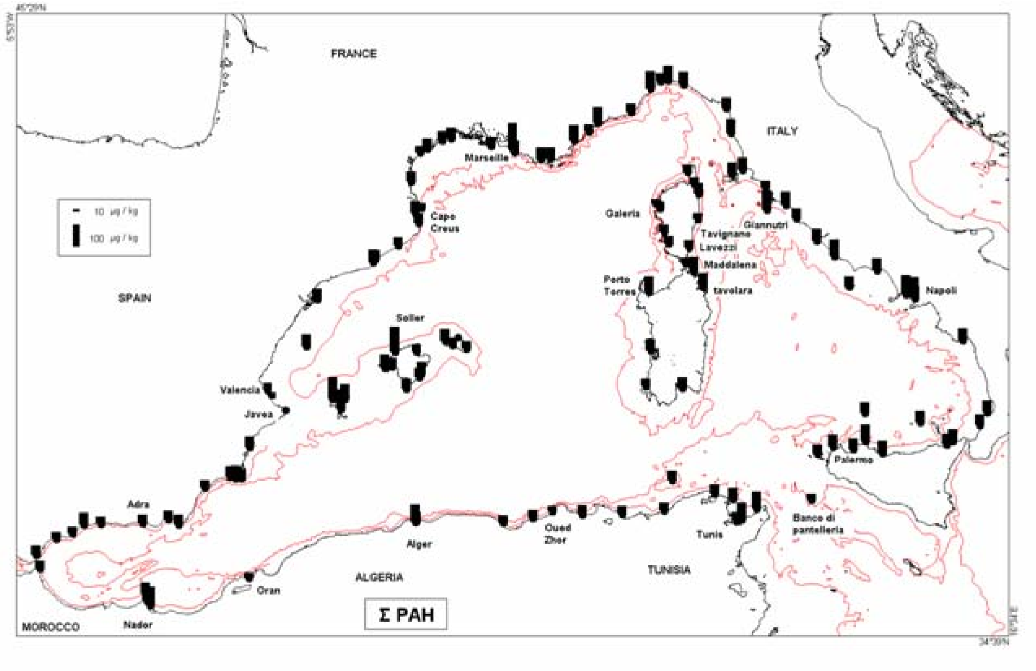

Figure 10: Levels of total PAHs in *Mytilus galloprovincialis* transplanted in occidental basin of the Mediterranean (after Galgani et al., 2010)

Consistent with previous data, the calculation of molecular ratios (Piccardo et al, 2001, Mille et al., 2007, Galgani et al.2010) demonstrated the pyrolytic origin (from industrial combustion) in most sites, with the exception of La Maddalena (Sardinia), Naples and Ebro, where PAHs are characterized as petrogenic (from oil origin).

3.2.4. TBT

Due to its widespread use as an antifouling agent in boat paints, TBT is a common contaminant of marine ecosystems exceeding acute and chronic toxicity levels. TBT is the most significant pesticide in marine waters due to its toxic, persistent, bioaccumulative and endocrine disruptive characteristics. Despite optimistic forecasts by various scientists after regulatory measures were taken in the 1980s and a total interdiction since 2008, coastal tributyltin (TBT) contamination is still a major problem and has been detected in a number of environmental samples. TBT concentrations are usually high in commercial harbours with large ships, including ferries, as the probable cause of high contamination but also in marinas. The studies concerning the occidental basin shows that contamination is however not limited to harbour areas, but extends along the coast, including protected areas where Contamination as high as 7 ng TBT l-1 has been measured (Michel et al., 2001) and deep sea waters as shown on a transect across the ligurian current (Michel and Averty, 1999).

Once released from antifouling paints, TBT is rapidly absorbed by bacteria and algae or adsorbed onto suspended particles in the water (Luan et al., 2006) and incorporated into the tissues of filter-feeding zooplankton, grazing invertebrates, and, then in higher organisms where it accumulates (Borghi and Porte, 2002). TBT may under favourable conditions degrade within days to weeks through successive dealkylation to produce dibutyltin (DBT), monobutyltin (MBT), and ultimately inorganic tin, becoming progressively less toxic in the process.

Concentrations of BTs in the recent sediments obtained from a large number of coastal stations in Spain demonstrated that Northern Mediterranean Sea marinas and harbours are more polluted than sampling sites of the Southern Mediterranean Sea (Diez et al., 2002). In Corsica (Michel et al, 2001), Contamination was also high in waters from marinas (53 – 189 ng l-1) and quite comparable to that of large commercial harbours such as Marseille, Nice or Toulon (38 – 239 ng l-1) or harbours from catalan coasts (7.4 to 60.5 ng TBT g-1). In the 1980s, much higher contaminations have been reported, reaching 3600 ng l-1 in marinas located in the Northern Tyrrhenean (Bacci and Gaggi, 1989) and ranging, in 1990, from 2 to 833 ng l-1 in French harbour and marinas (Diez et al, 2002) confirming the contamination decrease, even with an excessive current levels (Antizar-Ladislao, 2008). In a similar study, Diez and Bayona (2009) measured organotin concentrations in sediments with values ranging from 124 ng g-1dry wt in Tarragona ports and marinas from Spanish Western Mediterranean coast to 3144ng g-1dry wt in Barcelona.

TBT has been demonstrated to cause impairments in growth, development, reproduction and survival of many marine species. Of particular concern has been the decline of marine molluscs in costal areas due to imposex (review in Antizar-Ladislao, 2008). Although there is a wide amount of information available on toxicity of TBT, field observations are still relatively scarce. Measurements indicate lower concentrations than sediments and/or water and not many differences within areas in the occidental basin, accumulation being more related to distance from the local sources (Sole et al., 1998). An imposex survey for three neogastropods species was conducted at five sites along the northern Mediterranean coasts of Morocco. Rates of occurrence and degree of imposex were more important in harbours sites than in the seaside stations where only sporadic and small boats are used in traditional fishing activities (Lemghich & Benajiba, 2007) as in smaller marinas along the mediterranean coasts of Spain (Sole et al. 1998), Italy (Terlizzi et al, 1998), France (Alzieu, 2000) and after Transplantation experiments in northern Tunisia (Lahbib et al., 2008).

Table 8 : Butyltin compounds in biological tissues (ng Sn g $^{-1}$ DW) unless indicated otherwise). After Diez et al., 2002; Diez and Tolosa, 2009

Location	Date	Species	MBT	DBT	TBT
NW Mediterranean, Spain	1996	Deep sea fish	1.–54	4.0–67	1.0–52
SW coast, Spain	1993–1994	Oyster	28.1±12.6	59.3±21.3	269±96
SW coast Spain	1999	H. trunculus	<DL- 63	<DL- 85	<DL- 48
NW coast Sicily	1999–2000	H. trunculus	1 –167	1 –316	1 –91
NW coast Spain	2005	Oyster	0.4–12.9	7.6–441	74–193
NW coast Spain	2005	Mussel	52.8–96.1	20.2–25.7	52.8–96

BT: monobutyltin; DBT: dibutyltin; TBT: tributyltin; DL: Detection Limit.

3.2.5. Emerging contaminants

With the improvement and development of analytical techniques, identification and quantification of a large number of organic compounds not previously detected in the marine environment has increased dramatically in recent years. Molecules such as PBDEs, alkyl phenols, new pesticides or phenyl-ureas, veterinary medicines and pharmaceuticals, biocides bactericides and phthalates have been identified. These molecules could be of concern because of their persistence, toxicity and bioaccumulation properties. In the case of sea-surface microlayer concentrations up to 177 mg l-1 phthalates were demonstrated in the Tyrrhenian Sea (Cincinelli et al. 2009. They are believed to be ubiquitous but data are lacking on their occurrence in the Mediterranean.

Surfactants, used in industrial processes as well as household, have one of the biggest production rates. In Mediterranean cities, Linear Alkyl sulphonates are the main surfactant employed (Blasco et al., 2010). Concentrations up to 50µg/l were found in water and 2mg/kg sediments in Spain. Other surfactants have been recorded in Hotspots from the spanish Mediterranean coasts, including nonylphenols (NP) and Nonylphenols ethoxylates (NPEO, approximately 80% of the total worldwide production) with concentrations ranging from 0,6 to 1 mg/kg. In a study performed along the Italian coasts (Ferrara et al., 2008), nonylphenols (NPs) and their respective ethoxylates were found in all samples from various species in Livorno, Fiumicino and Salerno. Mullets and sea breams generally showed high values of total alkylphenols (APs) and alkylphenol ethoxylates (APEOs) (44–55 ng g-1 and 27–525 ng g-1) with a maximum concentrations in shrimps from Fiumicino (1255 ng g-1). Tuna also exhibited very high concentrations of total alkylphenolic compounds (889 ng g-1). Seafood from Fiumicino fishing area, which is under the influence of the River Tiber, showed a degree of contamination of at least one order of magnitude higher than the other two sites. NPs and OPs are toxic to aquatic organisms (algae, invertebrates, fish and mammals) at concentrations even of few g l^{-1}. These substances are also recognized as endocrine disrupters.

Pharmaceuticals are considered as emerging contaminants in the environment. They were demonstrated in effluents of Spanish Wastewaters Treatment plants where it represents a continuous input to coastal waters (Gomez-Gutierrez et al., 2007). According to many investigations they do not cause acute toxic effects in organisms when released in the environment. However, a report recently demonstrated that carbamazepine (CBZ), at concentrations found in the environment, affects the Mediterranean mussel by acting on specific biochemical pathways that are evolutionarily conserved (Martin-Diaz et al., 2009). Highly diluted at sea, their analysis in seawater and marine organisms is delicate. Measurement by passive diffusion techniques showed that in the northern basin caffeine concentrations range from 8 to 33 ng/l and CBZ concentrations from below detection to few the ng/l.

The recent use of new methods such as passive sensors for organic compounds (Arditsoglouet al., 2008; Togola & Budzinski, 2007; Gonzales, 2007) demonstrated that Diuron, Isoproturon, Simazine, Atrazine and Irgarol are the herbicides most frequently found, mostly at trace levels except in very confined areas such as bays and coastal lagoons. Besides the antifouling Irgarol, these molecules have an agricultural or urban origin but remain in all cases below non effects concentrations as set t by the Water Framework Directive.

Although the contaminants are usually found at coastal waters, they also might be detected in certain areas of the continental shelf and adjacent canyons. This is particularly important in NW Mediterranean Sea where the continental shelf is very narrow and the number of coastal canyons important. However, this kind of pollution is not well studies yet. On a global scale and in the context of the management and protection of environmental quality from terrestrial inputs, it is necessary to take into account the different compartments of a continuum watershed-coastal strip, canyons and continental slope - abyssal plain and the characteristics of the deep-sea environment. Occasional discharges during floods may play an important role in transporting sediment to continental shelf and through the canyons to the deep sea plains (Bourrin et al., 2008). Furthermore, industrial solid wastes (such as red mud residues from aluminium manufacturing) are deposited on the continental shelf (Galgani et al., 2006; Dauvin, 2010) and may also be transported, together with other sedimementary deposits, to deeper marine areas carried by turbidity currents. Along deep river beds (Var, Rhône, Ebro), which sometimes cover long distances of several tens of kilometres (Mulder et al, 2003), hyperpycnal flows are transporting particulate matter to the deep-sea floor. These flows are characterized by sudden increase of current velocity and downward particle fluxes that can reach up to 600 g m^{-2} d^{-1} of particles and 3.1 g m^{-2} d^{-1} in terms of organic carbon. Canyons are active for material transport and supply of organic matter and probably contaminants to deep sea (Khripounoff et a., 2009). These violent turbidity currents are common in the western basin due to reduced adjacent shelves that facilitates the supply and transport of sediment. For example, significant increases in levels of trace metals were detected in sediment cores in the upper canyon of Blanes (Palanques et al., 2008). The metal enrichment occurred during the 20th century are correlated with periods of increased population and industrial activities in the adjacent region. Deeper in the canyon at 1370 m depth, no metal enrichment was detected, probably due to the dispersion of particles and dilution with uncontaminated sediment. However, studies in deed sea sediments show that in some areas of Mediterranean, contamination does not affect just the coastal and continental shelf, but also the side of the continental slope sediments, transported through submarine canyons. On the bathyal plain, the isotopic signatures of industrial discharges have shown transport of contaminants in the direction of the general circulation over distances of several hundred miles.

3.2.6. Biological effects

A number of toxic effects in marine mammals, seabirds, fish and invertebrates have been associated with exposure to chemical pollutants. The observed abnormalities vary from molecular to ecosystem changes and from reversible to permanent alterations. Such effects have been thought to have contributed to population level impacts including reproductive failure and outbreaks of disease.

Biological effects of pollution are elements of major importance for the assessment of environmental quality. Estimated toxicities for different categories of sampling sites revealed harbours and Rivers as the main sources of POPs when Coastal lagoons and urban influenced areas are less effective (Gomez-Gutierrez et al., 2007).

The effects of pollution can be measured at different levels of biological organization, from the molecular to the community level. Biomarkers are cellular, biochemical, molecular, or physiological changes that are measured in cells, body fluids, tissues, or organs within an organism and are indicative of xenobiotic exposure and/or effect. Biomarkers response range from general to specific contamination and are most of the time used as early warning signals of environmental disturbance (Walker et al., 2006). They have been therefore incorporated into environmental monitoring programs including MED POL/ UNEP Mediterranean Biomonitoring Program (UNEP-MAP, 2006; Viarengo et al., 2007). Both EU water framework and Marine strategy directives pointed out the importance of biological monitoring for the determination of

In the Mediterranean, because they are ubiquitous and easy to collect, Mussels (*Mytilus galloprovincialis*) and mullets (*Mullus barbatus*) are the most commonly used sentinel organisms in biomonitoring studies (Lionetto et al. 2003,Minier et al 2006; Viarengo et al., 2007; box et al, 2007; Bocchetti et al. 2008, Zorita et al., 2008) but some other species such as gobies (Corsi et al., 2003) are useful in very coastal waters. Beside non-specific biomarkers at cellular or molecular levels, most studies were dedicated to indicators such as Ethoxuresorufin deethylase (EROD), metallothionnein and Acetylcholinesterase respectively related to the presence of aromatic rings (e.g. PAHs, dioxins etc..), trace metals and organophosphorous or carbamates compounds. Few experiments were performed at the occidental basin scale (Burgeot et al., 1996) and data on coasts of north Africa are scarce (Banni et al., 2007 & 2009) but confirm biological effects of contaminants in the same pattern than for the northern part of the basin. Most of the results demonstrated effects of contaminants in fishes of mussels around industrials harbours and large towns but also showed, even with relevant data, the difficulties of using native fish as sentinels (Zorita et al., 2008). More recently, biomarkers of oxidative stress and multixenobiotic resistance related proteins were considered but large scale monitoring was recommended on regular basis only for lysozome stability and ACHE (Variengo et al., 2007)

3.3.7. Radionuclides

The anthropogenic radionuclides present in the marine environment can be sorted into two groups: Radionuclides which could have possible radiological impacts, e.g.

90Sr, 137Cs, 238Pu, 239Pu, 240Pu and 241Am, and radionuclides such as 3H, 14C, 99Tc and 129I which have mainly been used as radioactive tracers to study marine processes. Within the framework of national and international programs IAEA technical cooperation, projects, CIESM /GIRMED/musselwach programs), the levels and related sources of anthropogenic radioactivity namely global fallout, nuclear test sites, reprocessing plants, dumping of radioactive wastes and nuclear accidents have been evaluated. (Nouredin et Baggoura, 1997; Radakovitch et al, 1999; Livingstone et al., 2000; Pujol et al, 2000; Lee et al., 2006; Nourredin et al., 2006; Thebault et al, 2008; Reguigui,2010). The distribution of anthropogenic radionuclides in the south-western (SW) Mediterranean Sea was investigated indicating that the accumulated inventories of 239,240Pu, 241Am, 137Cs and 90Sr are lower than those found in the NW Mediterranean, and also lower than the global fallout deposition in these latitudes (Lee et al., 2006). In the southern part of the western Mediterranean Sea, maximum activity was found at 1000m in the Sicily Channel and at 250 m along Algerian coasts. 137Cs was increased from west to east (1.69±0.11 to 3.3±0.2 Bq/m3, Nourredin et al., 2006) and activity gradually decreased with depth. However, higher values were observed at the bottom layers in the Sardinia and Sicily Channels probably due to Levantine Intermediate Water (LIW), carrying higher concentrations due to the Chernobyl accident. Along the Algerian coasts, artificial radioactivity in 1990's was expected to come from nuclear-testing fallout (Nouredin et Baggoura, 1996) but recent measurements of 238Pu/239,240Pu activity ratios indicate that plutonium in the SW Mediterranean is of global fallout origin (Lee et al. 2006). The 241Am/239,240Pu activity ratios are much lower than that of global fallout due to the enhanced scavenging of 241Am from the water column.

The Chernobyl nuclear accident in April 1986 was the largest nuclear accident to occur so far and had significant impacts on both the terrestrial and marine environments. For the Mediterranean Sea, the main contribution from Chernobyl was from atmospheric deposition, with an estimated deposition at 2.8 PBq of 137Cs, mainly in the Aegean Sea (Livingston et al., 2000).

Among the accidents of aircraft carrying nuclear weapons, a crash which occurred in January 1966 near Palomares, Spain, on the south-eastern Mediterranean coast should be mentioned. The debris from the two nuclear weapons carried by the aircraft was distributed over the land. Although 10 cm of soil was removed during cleaning operations, heavy rains transported Pu and Am to the Mediterranean continental shelf. The Pu inventory estimated from sediment cores collected on the continental shelf was about 1.4 TBq.

37Cs and 239+240Pu have been measured in the sediments of various part of the Mediterranean Sea, including deep basins, where they were found in the uppermost centimetres of the sediment (Garcia Orellana et al., 2009). A radiological characterisation of surface waters of the Ebro River, carried out during November 1994, demonstrated that the geological setting, large cities, agricultural areas and dams influenced the occurrence of natural radionuclides. However, contamination from nuclear power plants located along the river was not detected (Pujol et al., 2000).

Maximum accumulation rates, estimated using the 210Pb dating method or the evolution of the 137Cs/134Cs activity ratio with depth in the sediment from the Rhone submarine delta demonstrated a rapid decrease in the river mouth seawards in relation to the spreading of surface and bottom nepheloid layers. Mixing and diffusion processes were evidenced by 137Cs that penetrated to greater depths than expected from the 210Pb derived accumulation rates. The 137Cs inventory over the studied area (480 km2) was estimated to be 19·6 TBq in 1990 (Rakanovitch et al., 2000), of which more than 40% was found in the prodelta (30 km2), in the vicinity of the river mouth. Not only Chernobyl and weapons test fallout in this region were incriminated but also in a lesser extent discharges by nuclear installations on the Rhone. Due to a new treatment process applied to the liquid effluents, a decrease of two orders of magnitude in the industrial plutonium discharged into the River Rhone has been registered from 1991 to 2000 (Eyrolle et al., 2004). The river sediment compartment could represent a significant delayed-source term of plutonium on the scale of the Rhone watershed as river Sediments have been also demonstrated to scavenge elements transported by advection or diffusion on the shelf.

Recently (Thebault et al., 2008), the first distribution map of 137Cs was published at the scale of the entire Mediterranean and Black Seas. 137Cs activity in the Black Sea and North Aegean Sea were up to two orders of magnitude higher than those in the western Mediterranean Basin where activity ranged from 0.01 to 0.077 Bq kg_1 wet wt, Algeria being less affected than other countries (Table). Such effects, far from representing a threat to human populations or the environment, reflected a persistent signature of the Chernobyl fallout in this area.

Table 9: 137Cs activity (Bq kg_1 wet wt) in mussels (*Mytilus galloprovincialis*) from the occidental basin of the Mediterranean sea (After Thebault et al., 2008)

Country	Station number	min	max
Algeria	7	0.007(oran)	0.011(Annaba)
France	8	0.01(bonifacio)	0.03(Faraman)
Italy	5	<0.01	0.05
Morocco	4	0.016	0.040(nador)
Spain	9	0.010	0.077(malaga)

3.2.8. General pollution trends

Information on contamination trends in the Mediterranean Sea by PCBs, DDTs and HCB mainly deal with discontinued local studies or hot spot situations. Moreover, significant geographical data gaps exist, particularly in the South and South-eastern basins. These limitations, together with the lack of standardised methodologies, make it difficult to use and compare data in a regional context, and assess as well as conclude on temporal trends. More over, analysis requires a sufficiently large time span of data (<10yr) for evidencing and assessing significant variations. There are few areas to fulfil the requirements of a temporal trend assessment, and the situation is even less satisfactory in the case of DDTs and PCBs. Consequently, the trend analysis is focused on mussels, through simple linear regressions, to gain a general insight into the available information.

Data on trace metals for samples of *Mytilus galloprovinciallis* collected in 21 stations along the period 1979-2006 within the French monitoring system (RNO, http://www.ifremer.fr) clearly show a general decline of concentrations during this time span. Also, analysis of concentrations of metals in sediments from the gulf of Tunis (Cd, Pb, Hg, Cu, Zn, Fe) performed in 1999, 2003 and 2010 demonstrated the metals remains in the same range for the last 12 years except Cadmium that was decreased more than 10 fold. Cadmium decrease was also found in Mytilus galloprovincialis, in Tunisian stations during the period 2001-2008.

The decrease in concentrations of banned or restricted persistent organohalogen contaminants such as PCBs and PCDD/Fs in environmental media such as biota or sediment has been observed both in Europe and on a global scale (Gomara et al., 2005). This trend is related to the severe restriction or phasing out of these compounds and more efficient control of emissions. The data collected as part of national monitoring programs show a downward trend usually observed in the concentrations of chemicals which use has been banned for decades (DDT, PCBs, Lindane etc.), although in some cases the concentrations may remain relatively high.

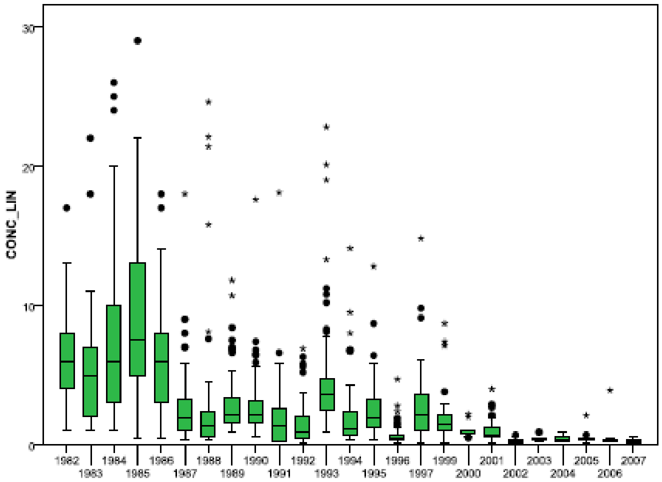

Figure 11: Temporal trends of lindane (ng g-1 dw) in *Mytilus galloprovinciallis* from the French monitoring network in Mediterranean stations (www.ifremer.fr)

Gomez - Giuterrez et al. (2007) has also concluded that a decreasing trend at the whole Mediterranean scale, more evident for DDTs than for PCBs (Figure 12).

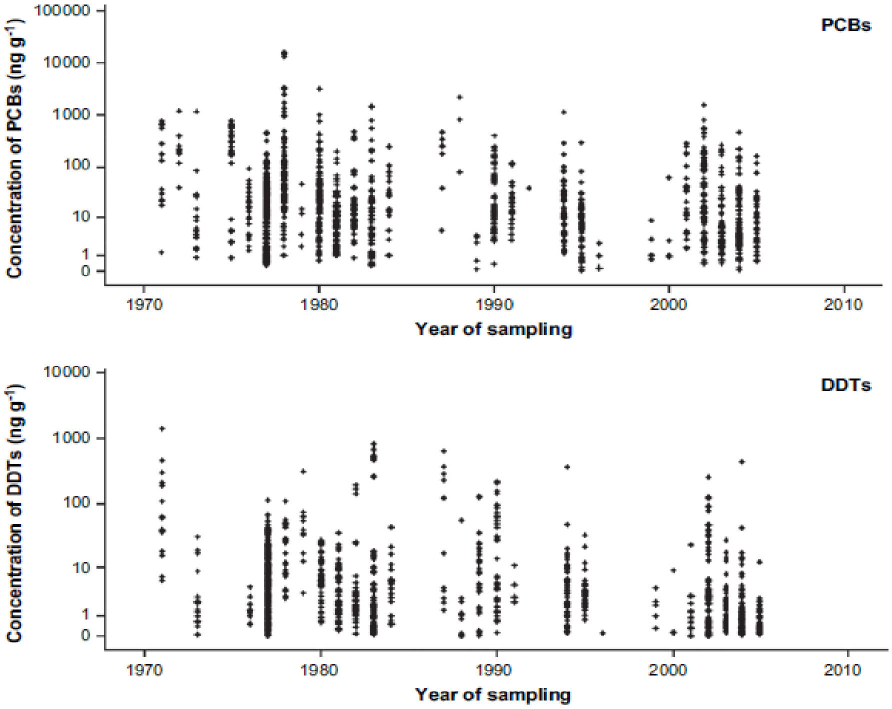

Figure 12: Concentrations of PCBs (Aroclor eq.), and DDTs in Mediterranean sediments with respect to the year of sampling (Gomez-Gutiérrez et al., 2007)

Similar trends were observed in the French monitoring network of coastal pollution using bivalves as sentinel organisms. In general, it was found that during the period 1979-1998 the decreasing trends were in the order ΣDDT > HCHs > PCBs

In the North of the basin, total DDT concentrations in mussels *Mytillus galloprovincialis*, decreased from 18-668 ng / g wet weight (mean 146 ng / g) in 1973-1974 to 4-126 ng / g (mean 26 ng / g) in 1988-1989. More recently, an analysis of concentrations of DDT in the fatty parts of bottlenose dolphins conducted between 1978 and 2002 different points on the coast of western basin showed that concentrations were divided by 23.7 during this period (Borrell and Aguilar, 2007).

Rigorous measures have been taken in Europe in the last 25 years to reduce PCDD/F emissions, leading to a sharp decrease after 1980. Then, in archived marine mussels collected between 1981 and 2005 from selected mediterranean sites along French coasts, the time trend study showed a pronounced decrease in PCDD/F concentrations over the 24-year period at most sites except the town of Toulon (Munschy et al., 2008).

Similar trends were also observed for PAH concentrations in mussels from French (ROCCH/RNO, http://www.ifremer.fr) National monitoring program. From the database, the average concentrations in mussels PAH16 in the French Mediterranean coasts decreased from 157 ng / g DW in 1994 to 73 ng / g DW in 2006. On the Italian coast (SIDIMAR, national monitoring program of Italy), the concentration levels are extremely variable and no clear trend could be observed

3.3. Eutrophication

Eutrophication is defined as a process led by the enrichment of waters by nutrients, especially compounds of nitrogen and / or phosphorus, resulting in increased growth of primary production and biomass of algae, changes in the balance of organisms and degradation of water quality including a decrease in oxygen concentrations. The medium may then, in extreme cases, become hypoxic and anoxic and favor the emergence of reducing compounds. The main disadvantages of eutrophication are the loss of biodiversity and water quality as a resource. Consequently, it has negative effects on tourism and fishing (Ferreira et al, 2010)

The Mediterranean basin is characterized by low production of raw materials and a reduced biomass of phytoplankton. With a few exceptions, all river systems discharging in the Mediterranean Sea are small. The most eutrophic waters in the western basin are located on the north shore, at the mouth of the rivers Rhone and Ebro. They have catchment's areas extending to 96,000 and 84,000 km^2 respectively. The total estimated loads are about 304,000 ton/year N and 22,000 ton/year P. Both nitrogen and phosphorus are deposited in water and soil in different forms: nitrogen as ammonia which has evaporated from animal manure, and as NOx coming from combustion of fossil fuels, i.e. power plants and transportation; phosphorus as dust, falling leaves and bird faeces. The highly productive areas are located near river deltas or large urban agglomerations while offshore waters are generally oligotrophic. In the Mediterranean, the main drivers related to eutrophication in the marine and coastal environment are urbanization in coastal areas, tourism, agriculture, industry and the influence of aquaculture and fisheries. Tourism could also be a strong pressure related to eutrophication.

The Mediterranean Sea has long been known as having an abnormality in the relationship between the two compounds are the major nutrients nitrate and phosphate (Garcia et al., 2006). Indeed, while these compounds are distributed in the world ocean in a ratio close to the value 16 / 1, said Redfield ratio, the ratio nitrate / phosphate in deep waters of the Mediterranean is higher than 20:1 in the western basin and 25:1 in the eastern basin. While nitrate is considered the limiting factor of productivity in most oceans, the deficit of phosphate Mediterranean waters, has led some authors to consider this as the nutritional factor limiting primary production in this region. This is particularly true in some confined environments, where the contribution of excess nitrogen from the atmosphere would lead to long-term phosphorus deficiency.

On the Algerian coast, the transfer of nutrients occurs from the terrestrial to the marine system trough the oueds runoff transferred directly to the sea and port areas (Djijell, Algiers and Annaba) or some adjacent bays (Arzew and the bay of Algiers). In these areas, the concentrations of nutrients in sediments are higher than those measured in the vicinity and correlated levels of organic pollutants. Under these conditions, blooms, almost Permanent (Freha et al, 2007), can be observed in the terrigenous stations masking seasonal variations. Annaba Bay, receiving continental runoff, is characterized as highly fertile with low salinity and low transparency. Also the high nutrients and chlorophyll-a concentrations indicate eutrophication together with occasional blooms of Pseudo-nitzschia sp.

In France, total N, total P, ammonium, turbidity as impact criteria such as phytoplankton (chlorophyll-a, phaeophytin-a, phytoplankton population), macrophytes, macrofauna, and dissolved oxygen are monitored on a regular basis (IFREMER, http://www.ifremer.fr). Data for eutrophication assessment are derived from the Data base QUADRIGE and the monitoring projects REPHY, RNO, REBENT, RSL, RLC and remote sensing or *in situ* instruments (http://www.ifremer.fr). Only two areas are really eutrophic but related to coastal lagoons (Palavas complex and Or lagoon). Enrichment and eutrophication events have been however found in other lagoons and coastal areas along the gulf of Lion and some bays, which clearly demonstrate the important contribution of the Rhône and smaller adjacent rivers. Dinoflagellate blooms have been demonstrated regularly (UNEP-MAP, 2007).

In Morocco data used for eutrophication assessment were obtained through the National institute of Fisheries Research (INRH), the MED POL programme coastal water monitoring and remote sensing authority. Only one important site, Oued Martil estuary, where urban and industrial wastes are discharged, was characterized as at risk to become eutrophic the maximum nitrate concentrations recorded ranged between 400-500 µg/l. The studies performed in the Nador lagoon showed also that certain areas present problems of eutrophication.

The Spanish coast is characterized both by natural enrichment due to upwelling and an induced eutrophication caused by human discharge. The high productivity of the Alboran Sea appears to be related to the upwelling generated by the anticyclonic circulation generated by the flow of Atlantic waters entering the Mediterranean through the Gibraltar strait. Other eutrophicated areas were found close to Valencia and the Ebro delta, where dinoflagellates blooms were developed.

In Italy, historical data for eutrophication assessment are available from 2001 to 2006 indicating that manifestations of eutrophication depends on the hydrology, hydrodynamics and morphology of the areas concerned. In the Ligurian Sea and the Tyrrhenian Sea, the phenomena are episodic and generally not widespread, with secondary effects (hypoxia/anoxia in the bottom waters) being of little significance. Eutrophication causing conditions arise to a large extent from the effects of effluent discharges from urban agglomerations and only in a few cases from inputs of rivers. Only episodic but serious eutrophication events occur in the western coast of Italy. For Ligurian Sea, two sites have been identified as eutrophic. Foce Torrente Lerone with urban wastewater discharges and organic inputs from industries and Genova harbor and Marinella - Foce Magra with pollution from the harbour area of La Spezia, including discharges of domestic and industrial wastes and organic inputs from aquaculture activities. Discharges of domestic and industrial wastes from the highly polluted Sarno River as well as discharges from agriculture activities, nutrient, industrials and organic inputs from the harbour of Napoli are the main sources of eutrophication in the bay of Napoli. Nutrient (P and N) inputs from agriculture and urban wastewater discharges transported by Tevere River are responsible for eutrophication events at the Tevere estuary. Finally , nutrients transported by the Arno river, which are due to agricultural activities and urban wastewater discharges from Firenze and Pisa account for the eutrophication of the Arno estuary and adjacent areas.

Remote sensing from airplanes and satellites offers the opportunity to detect large-scale changes in the biological properties of the Mediterranean (e.g. use of colour data), to detect changes in coastal areas and to detect and monitor accidental pollution (EEA/UNEP, 1999). The long-term record of ocean colour data provided by the SeaWiFS mission is an important asset for monitoring and research activities conducted on primary production and to study the major characteristics of temporal variability associated with optical properties across the Mediterranean Sea (Vandeprotte et al. 2010).

Satellite images of the Mediterranean able to show the chlorophyll variations in surface waters, revealed that the highest levels correspond to the areas close to river deltas or those off large urban agglomerations. Conversely, the open seawaters of the Mediterranean are generally close to oligotrophy or even ultra-oligotrophy except for cases caused by the upwelling of deep waters rich in nutrients. An analysis of Chlorophyll a images (UNEP-MAP, 2007) derived from SeaWiFS satellite images (MOON MERSEA) and also from recent analysis of these images (Blasco et al., 2010) confirmed Mediterranean is extremely oligotrophic. However, the algorithms used for chl-a evaluations are originally and generally designed for oceanic waters and it can lead to large uncertainties in rivers or coastal areas due to the presence of dissolved organic matter and suspended particulate matter.

The gulf of Lion and Ebro area were confirmed to be the most affected area. The southern coastal waters of Italy are oligotrophic with a few exceptions as the Gulf of Naples due to sewage.

Although of limited use in coastal areas due to the limited resolution models and interference with terrestrial signals, analysis of satellite data over several years allows, by statistical methods will enable to take into account seasonal variations, long term monitoring and large scale evaluations (Ferreira et al., 2010) and the elaboration of indexes and seasonal parameters related to eutrophication and measured over time (Figure 13) and classify bodies of water

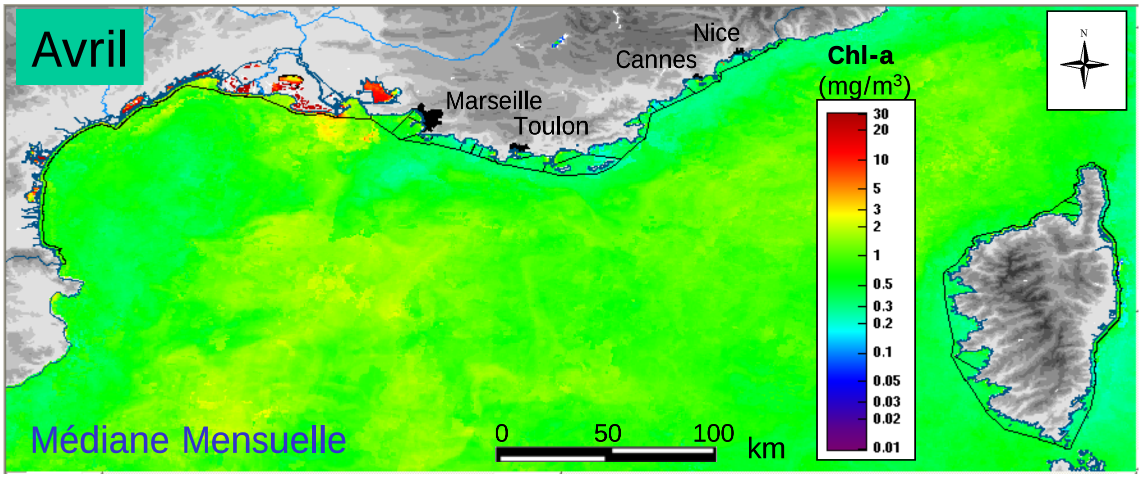

Figure 13: the median monthly Chl-A for the month of April 2003, 2004 and 2005 in the area north of the western basin of the Mediterranean

With the integration of data from satellites (SeaWiFS, MERIS, MODIS etc) coupled to physical – biogeochemical 2D/ 3D models, it has been possible to test predictions of episodes of enrichment and eutrophication at a local scale (Fontana et al., 2009) and to monitor the state of coastal waters for years after effluent treatment (Blasco et al., 2010). In confined areas subjected to specific hydrodynamic conditions and intermittent injections of nutrients, these models yield consistent estimates of surface chlorophyll, primary production and therefore valuable informations for the management of eutrophication issues.

3.4 Dumping activities

To control dumping dedicated management tools are in use in most of the large harbours of the Western Mediterranean: Ecoports (www.ecoports.com) in Genoa, Livorno and Civitavecchia, management schemes (Valencia, Bejaia, Alger, Nador, Tunis, Napoli) including the reduction of treatment plants numbers to limit affected areas (Marseille), recolonisation experiments and monitoring of impacts. However, dumping (wastes, dredging, and industrial dumping) remains important, in the million tons range, around the Mediterranean harbours.

As examples of sites affected by dumping, controlled industrial inputs such as aluminium mineral residues (red muds) in the Cassidaigne canyon (France, 330 m, Galgani et al, 2005; Dauvin 2010) and ancient asbestos factory in Cape Corsica affected by leaching of metals enriched sediments (Galgani et al, 2006; Lafabrie et al., 2009) enabled to evaluate biological effects of minerals dumping. Besides national and local regulations have controlled the process and engage programs for reducing inputs or recovery of sites. In the case of Cassidaigne, about 20 millions tons were affecting the adjacent canyon mainly through mechanical effects when 11 millions tons asbestos containing minerals dumped during a 30 years period along the coastlines was demonstrated to affect chemically the surrounding area after 40 years.

Dumping of mine tailings into Portman Bay (SE Spain) during the 20th century was also monitored to evaluate the state and temporal trends of the residual metal contamination (Benedicto et al., 2010). Concentrations of Hg, Cd, Pb, Cu, Zn, and As in wild mussels (*Mytilus galloprovincialis*) were studied over the period 1991-2005 indicating significant downward trends in the concentrations of Hg, Cu, Pb, and Zn that remains higher reference concentrations established for the coast of Murcia and the Spanish Mediterranean littoral. This site is still one of the areas most heavily contaminated by Pb and Cd along the Mediterranean coast of the occidental basin 15 years after the cessation of mining activities.

3.5. Litter

Littering is a growing problem, which includes aesthetic degradation but also a number of potentially harmful implications including the transport of persistent organic pollutants, the release of toxic compounds (including medicines), the entanglement of larger marine organisms and the mortality of many marine species, including marine mammals, sea birds and turtles after ingestion of litter (Katsanevakis, 2008).

General strategies to investigate seabed litter are similar to methodology for benthic ecology and place more emphasis on the abundance and nature (e.g. bags, bottles, pieces of plastics) of items rather than their mass. Interpretation of trends is made difficult because the ageing of plastics at depth is not well researched and the accumulation of plastics on the seabed began long before specific scientific investigations started in the 1990s.Litter are mainly made of plastic (60-90% in western Mediterranean) and among the variety of human activities that contribute to the pattern of marine debris in shallow coastal areas, fishing activities of the coastal fleet seem to be of great importance (Katsanevakis 2008). Litter washed ashore on the coastline is one of the most obvious signs of marine litter pollution and is present in all countries around the western basin of the Mediterranean as densities on the sea floor were found the highest along European coasts (Galgani et al., 2000). Beaches litter as assessed more often by volunteers and there was no permanent program of monitoring before Marine strategy frame directive will implement it in the northern part of the basin. Numerous studies have been undertaken at local scale for both evaluation and cleaning. On 32 beaches on the Balearic Islands (Martinez-Ribes et al., 2005), contamination expressed as item abundance was double in summer that in the low season and showed a heterogeneous nature associated with beach use. Plastics related to personal hygiene/medical items were predominant in wintertime (67%). In both seasons, litter characteristics suggested a strong relationship with local land-based origins. While beach users were the main source of summer debris, low tourist season litter was primarily attributed to drainage and outfall systems.

UNEP produced guidelines on surveying litter on coastlines in 2009, which deal comprehensively with the methods available to assess litter on the coast. Evaluations at sea have been undertaken at sub regional scale including floating litter (Aliani et al. 2003) and litter on the sea floor (Galgani et al., 2000) and deep sea floor (Galgani et al., 1996). It appears that outsides of bays and around towns or water masses fronts, floating litter have uniform distribution at sea. They however accumulate on deep sea floor after sinking and transportation through general circulation along the coasts in canyons where densities around large towns were found up to 1500 items per hectare in the northern part of the basin.

The accumulation of plastics in coastal canyons may also be related to strong currents occurring in the upper part of canyons, which decrease rapidly in deeper areas resulting from increased confinement. Accordingly, debris distribution seems to be more temporally stable. An inevitable effect of this is the presence of greater amounts of debris in deeper shelf waters than in coastal waters (Galgani *et al*., 1996, 2000). Investigations using submersibles at depths beyond the continental shelf have revealed substantial quantities of debris. Estimates for the longevity of plastics are variable but are believed to be in the range of hundreds or even thousands of years depending on the physical and chemical properties of the polymer, but this is likely to be greatly increased at depth, where oxygen concentrations are low and light is absent. We know little about trends in accumulation of debris in the deep sea as studies are rare, but the data we have indicate considerable variability. Abundance remained stable in the Gulf of Lion, France during a 15 years period (1994-2009).

Among the most problematic marine litter is derelict or discarded fishing gear, which may continue to fish for years, a process that has been termed ‘ghost’ fishing. Entangled animals may get killed by drowning, suffocation, or strangulation.

Many marine species such as marine mammals, seabirds, marine turtles, fish and invertebrates have been reported to ingest marine debris especially plastics. All cetacean from the Mediterranean sea, all species of marine turtles, more than 111 species of seabirds worldwide (including some in the Mediterranean) and many species of fish have been reported to ingest marine debris (Katsanevakis, 2008)

There is considerable concern about the accumulation of microscopic pieces of plastic (microplastic) as plastics are progressively fragmenting in the environment. Plastic particles as small as 1.6μm have been detected in the marine environment and it seems likely that items of debris exist into the nanoparticle scale.

A recently completed global survey confirmed that polyethylene, polyvinyl chloride and polypropylene fragments are now present on shorelines worldwide (Barnes et al., 2009). However, through laboratory simulations of natural conditions it becomes apparent that marine litter is not a significant source of metals (Cd, Pb, Cu and Zn) through its role may not be considered as negligible at local level (Chalkiadaki et al., 2002).

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UNEP/MAP – MED POL

Sub-regional assessment of the Status of Marine and Coastal Ecosystems and of Pressures to the Marine and Coastal Environment

Adriatic Sea

31 May 2010

Contents

1. Introduction

The Sub-Regional Assessments, including the present one, were prepared by MED POL and subregional experts in the framework of the UNEP/MAP's road map for the gradual application of the Ecosystem Approach for the management of human activities in the Mediterranean Sea.

The Ecosystem Approach (ECAP) has been introduced aiming at improving the way human activities are managed for the protection of the marine environment. Following the World Summit on Sustainable Development, the ECAP has been adopted by many International Conventions and Regional Seas Organizations. The Contracting Parties to the Barcelona Convention have adopted it in January 2008 at their Almeria meeting. The proposals to that meeting were developed in the framework of a project (ECOMED) funded by the EC. In this context, any environmental policy should be developed in a way that secures an effective protection of the marine environment and that makes possible the continued provision of marine goods and services for the wealth of the population. The application of the ECAP has the potential to help reach a balance between the requirements of human activities and the conservation of the marine environment. Its adoption and gradual implementation within the framework of the Mediterranean Action Plan (Barcelona Convention) will give new impetus to the preparation of more integrated and holistic policies by the Convention, including the impact of human activities on the marine environment.

To ensure the sustainability of the exploitation of marine goods and services in the Mediterranean Sea, it is important that the ECAP and its related conservation and management measures be applied not only to areas under the jurisdiction of States, but also to the habitats and ecosystems located beyond the national jurisdiction. As a consequence, the implementation of the Ecosystem Approach is not only a task for the Convention and its subsidiary bodies, but also and mainly for its Parties.

The project aims among others, at promoting and enhancing the implementation of the road map for the application of the ecosystem approach to the management of human activities. The road map requires that an assessment of the ecological status and of pressures and impacts is undertaken in four different regions of the Mediterranean, identified on the basis of bio-geographic and oceanographic considerations. The present report is a contribution to such a project with reference to the Adriatic Sea.

The assessment is mainly based on:

- Reports prepared in the framework of MED POL by the relevant Contracting Parties (Albania, Bosnia & Herzegovina, Croatia, Italy, Montenegro and Slovenia) which include the national Diagnostic Analysis (NDA) on various environmental issues and pressures and the national Baseline Budget (NBB) of emissions and releases of selected pollutants within each respective country;
- Basin-Wide Assessment Reports on selected environmental issues prepared in the framework of MAP;
- A range of other publications which are relevant for the purpose of the present review.

The report will first present a synoptic review of the more relevant features of the physic-chemical and biotic parameters of the coastal and marine ecosystems with the area under review. It will then identify and assess priority issues arising from pressures and impacts related to contamination, dumping activities, nutrient and organic matter enrichment and other factors in this area. Whenever possible, it will assess the availability and reliability of the data on which the assessment is based, identifying any gaps which need to be addressed in the future.

2. Physical and chemical characteristics

2.1. Area under Review

The Adriatic Sea is a semi-enclosed basin within the northernmost part of the Mediterranean Sea. It has a surface area of 138600 km^2 and a volume of 35000 km^3. It extends northwest from 40° to 45° 45' N., with the length of about 800 km and width of about 200 km. The Strait of Otranto, which connects the southern part of the Adriatic Sea with the Ionian Sea, is 72 km wide and 780m deep, which allows for extensive water exchange between the two basins. The Adriatic Sea is characterised by an extended continental shelf in the Northern and Central part while the continental slope is mostly found in the Southern part where the maximum depth of 1223 m is reached. The sea basin is surrounded by Dinarides on the East, Alps on the North and Apennines on the West. The largest country in the Adriatic basin is Italy, followed by Albania, Croatia, Bosnia and Herzegovina, Montenegro and Slovenia (Figure 1).

Figure. 1 Adriatic Sea

The Adriatic Sea receives large amounts of fresh water from numerous rivers. The largest is the river Po, which contributes to 46, 5% of all the freshwater input. Most of the riverine input is in the north- west side (72%), while only 27% of fresh water comes from the Eastern side. The biggest river in the South-Eastern Adriatic area is Drin, bringing 10% of annual freshwater input. Rivers provide important inputs of low-salinity waters and land-drained materials from the land. (Cushman-Roisin et al., 2001, Vollenweider et al., 1992)

Albania's coast is about 429 km long, the northern part belonging to Adriatic basin, while the southern part belongs to Ionian coast. Albania has a population of 3.100.000 people[1], with approximately 58% of population living in the coastal zone. The Adriatic coast, with a total length of about 259 km, is low-lying alluvial plain 4-50 km wide. The low coast is interrupted at a number of locations by hills at a right angle to the coast forming capes. These divide the coast into a number of closed physiographic units of varying sizes. Several small deltas and coastal lagoons, formed by nine rivers are in the Adriatic part of the coastline. Shoreline shows dynamic changes in the vicinity of the river mouths of the deltas, which are still kept in a natural state. In the case of the Darci River, however, the old delta is undergoing severe erosion at the river mouth as the sediment input to the coast has almost completely ceased. (NDA Albania, 2003)

The coast of Bosnia and Herzegovina is 25 km long. Only 24, 3% of the countries' hydro-geographical network drains in the Adriatic Sea, while 75, 7% belongs to the Blacks Sea (Sava River) catchment area. Main rivers are Neretva, Trebišnjica and Cetina river catchment areas. Population density in the Mediterranean region of the country is 33 capita per square kilometre. The largest city in the coastal area is Neum, with population of 4 300 inhabitants. (NDA Bosnia and Herzegovina, 2003)

The Croatian Adriatic mainland coast length is 1777 km coast. Entire coast is divided on Istria, Hrvatsko Primorje and Dalmatian area. Dalmatian coastline area is the longest, extending from Premuda near Zadar to the Kobili promontory south of Dubrovnik. Within this zone there are 4324.5 km of shoreline of which 74% are island shoreline. Croatia has a permanent coastal population of 1 000 000 which increases considerably during the summer because of tourism. The larger coastal towns are Split, Rijeka, Zadar, Pula, Sibenik and Dubrovnik. Dalmatian area makes up two thirds of the total Adriatic coastline and island shoreline length. Within the Main

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[1] http://earthtrends.wri.org/text/population-health/country-profile-2.html

rivers outflows in Croatian coastline are Zrmanja, Krka, Cetina rivers. (NDA Croatia, 2003)

Italy's coastline stretches 7 500 km and the whole territory is located in drainage basins flowing into the Mediterranean Sea. Several rivers drain into the Adriatic Sea (Po, Piave, Adige and Reno). Some of the larger cities are Trieste, Venice, Ancona and Brindisi. The Po River, on the NW side of the Adriatic, together with other important rivers draining the southern divide of the Alps (Reno, Adige, Brenta, Piave, Isonzo, etc.) NAP Italy (2005).

The Mediterranean coast of Montenegro has a population of approximately 150.000 and a total length of 293 km. The major towns are: Bar, Herceg Novi, Kotor, Ulcinj, Budva and Tivat. The summer population of these towns increases because of tourism.

Slovenian coastline has the length of 46 km. It hosts approximately 80 000 people who mainly reside in the towns of Koper, Izola and Piran. Main rivers in Slovene coastal are Rizana, Badasevica and Dragonja. Adriatic Sea catchment part in Slovenia is 3 842,25 km^2 large. This represents 19% of the country area. 81% of Slovene hydro-geographical network drains in the Black Sea (Danube catchment). 240 000 inhabitants live in the Slovene part of Adriatic catchment area, representing 12% of entire population. (NDA Slovenia, 2003)

2.2. Topography, bathymetry and nature of seabed

The Northern part of the Adriatic is very shallow, with depth increasing slowly southwards, reaching 270 m in the Middle Adriatic and Jabuka Pits (Pomo Depressions). The Palagruža pit (Pelagosa Sill) links Mid-Adriatic with much deeper south Adriatic Pi, reaching maximum depth slightly over 1200 m. Further south the bottom rises to 780 m in the Otranto Sill, which links Adriatic and Ionian Sea (Figure 3).

The western coastline is relatively smooth, without any islands and with a gentle shelf, while eastern part is characterised by many islands and irregular bottom increasing steeply in the offshore direction. There are 1246 islands in the Adriatic Sea, of which only 69 are inhabited.

(http://www.absoluteastronomy.com/topics/List_of_islands_in_the_Adriatic).

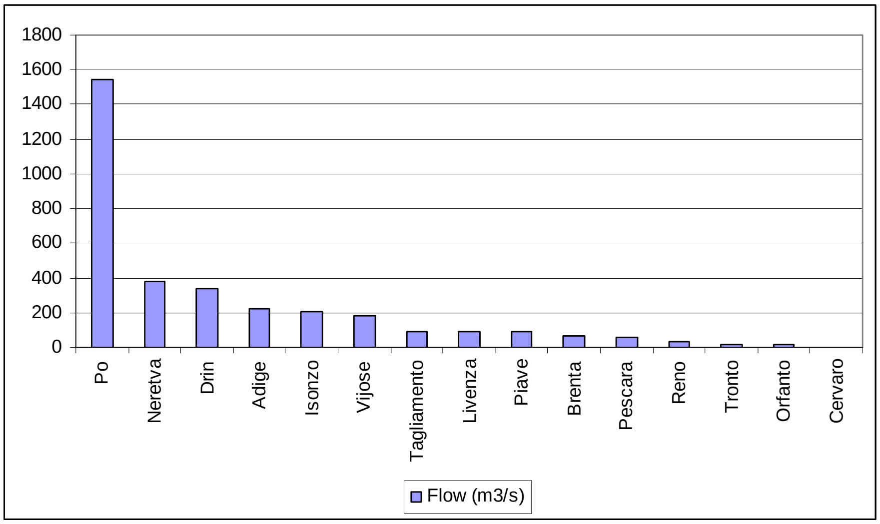


Figure 2. Freshwater inflow from Adriatic rivers (data from Socal et al., 2008)

The difference between east and western part is emphasised by high mountain chain (the Dinaric Alps) in the east vs. much smoother land surface in the Italian side, where the Apennine Mountains are more distant from the coast. The Dinaric Alps strongly influence the wind field and strengthen the land-sea temperature differences. (Cushman-Roisin et al., 2001).

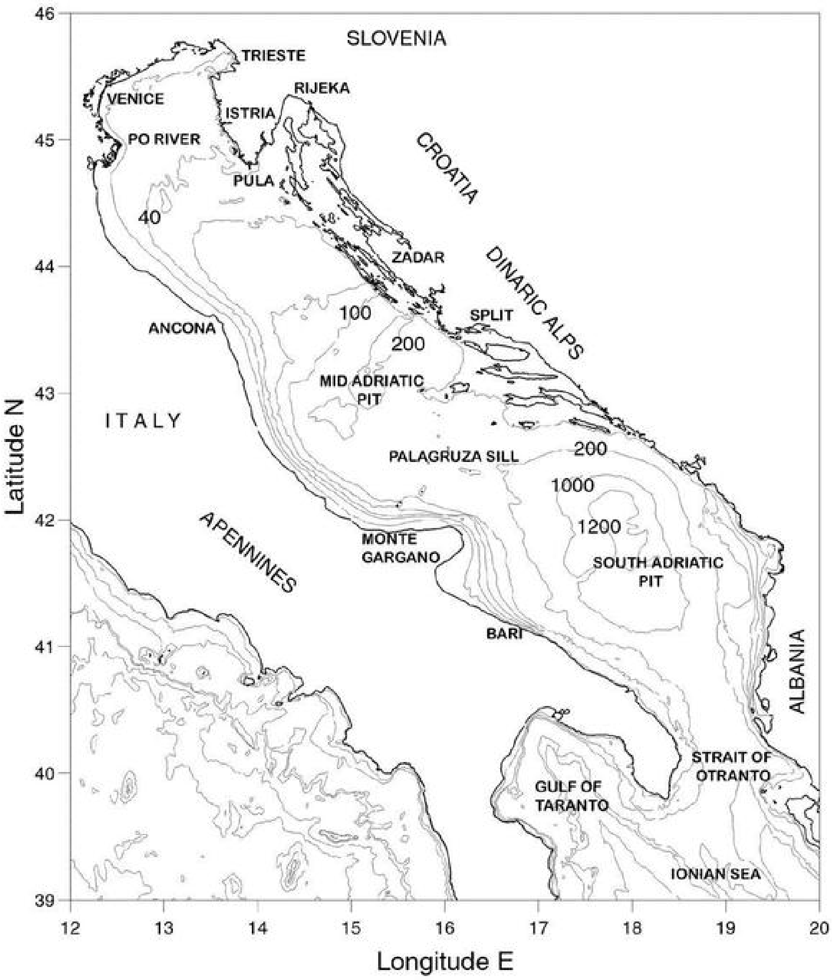


Figure 3. Adriatic Sea coastline and topography. (from Cushman-Roisin et tal., 2001) The eastern coast is generally high and rocky, whereas the western coast is low and mostly sandy.

Figure 4. Coast in Croatia (left), Italian coast (right)

2.3. Salinity, temperature and hydrodynamics

2.3.1. Salinity

Inflow of fresh water by precipitation and river runoff exceeds evaporation in the Adriatic basin. Freshwater inflow decreases water salinity, while the influx of saline Mediterranean waters through the Strait of Otranto increases it. The open waters in the southern part of Adriatic basin have salinity between 38.4 – 38.9. Salinity is lower and more variable in the northern part and in coastal zones (average 37-38‰), while it can fall under 35‰ in the summer (Cushman – Roisin et al., 2001). Long term measurements of salinity in the coastal and open waters in the middle and southern basins have shown historical increase of salinity, suggesting the reduction of freshwater supply caused due to Aswan Dam on the Nile River (Zore-Armanda et al., 1991). Variability of other climatic factors, such as changes in precipitation and increase of evaporation may also contribute to fluctuations in salinity. (Grezio and Pinardi, 2006)

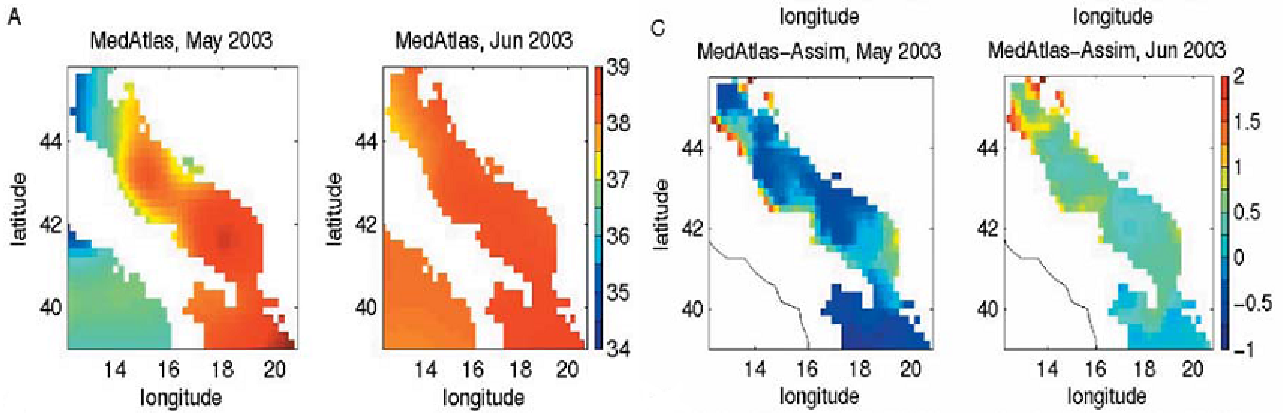


Fig. 5 Monthly mean salinity at 5 m depth (in psu) for May and June: A: MedAtlas climatological months for May and June, B: salinity AF for May and June 2003 (Grezio and Pinardi, 2006)

2.3.2. Temperature regime and Sea Surface Temperature (SST)

The annual surface temperature range is 18°C in the South and 25°C in the North. The extremes of the surface temperature range from 3°C to 29°C respectively. Adriatic is a temperate warm sea, since even temperatures of the deepest layers are mostly warmer than 10°C. The termocline occurs at 10-30m during warmer seasons. (Cushman et al., 2001).

The Northern Adriatic exhibits substantial fluctuations, possibly linked to the cycle of winter cooling and summer warming in the relatively shallow sub-basin. The North Western section shows larger fluctuations than the North Eastern one, with lower winter SST, probably due to the freshwater inflow from the Po River delta. The Southern Adriatic exhibits less variability, possibly influenced by the periodic water exchanges with the Ionian Sea. The South Eastern section shows somewhat larger fluctuations than the South Western one, with higher winter SST, probably due to the inflow of warmer waters from the south. The two Central sections reveal patterns similar to the ones of the whole basin. The observed temperature patterns appear to follow the classical Adriatic cyclonic circulation scheme (Barale et al., 2004).

From a long-term time data (1981-1999), which were processed to estimate Sea Surface Temperature (SST) values, an apparent general warming trend of sea surface can be recognized in Adriatic basin. The linear fit to the seasonal cycles suggests an increase of about 2°C in 20 years, essentially due to a steady rise of summer values.

A general north-south temperature gradient can be found during winter, the Northern sections being colder than the Southern ones. An east-west gradient also appears, the Western sections being warmer then their Eastern ones. (Figure 7)

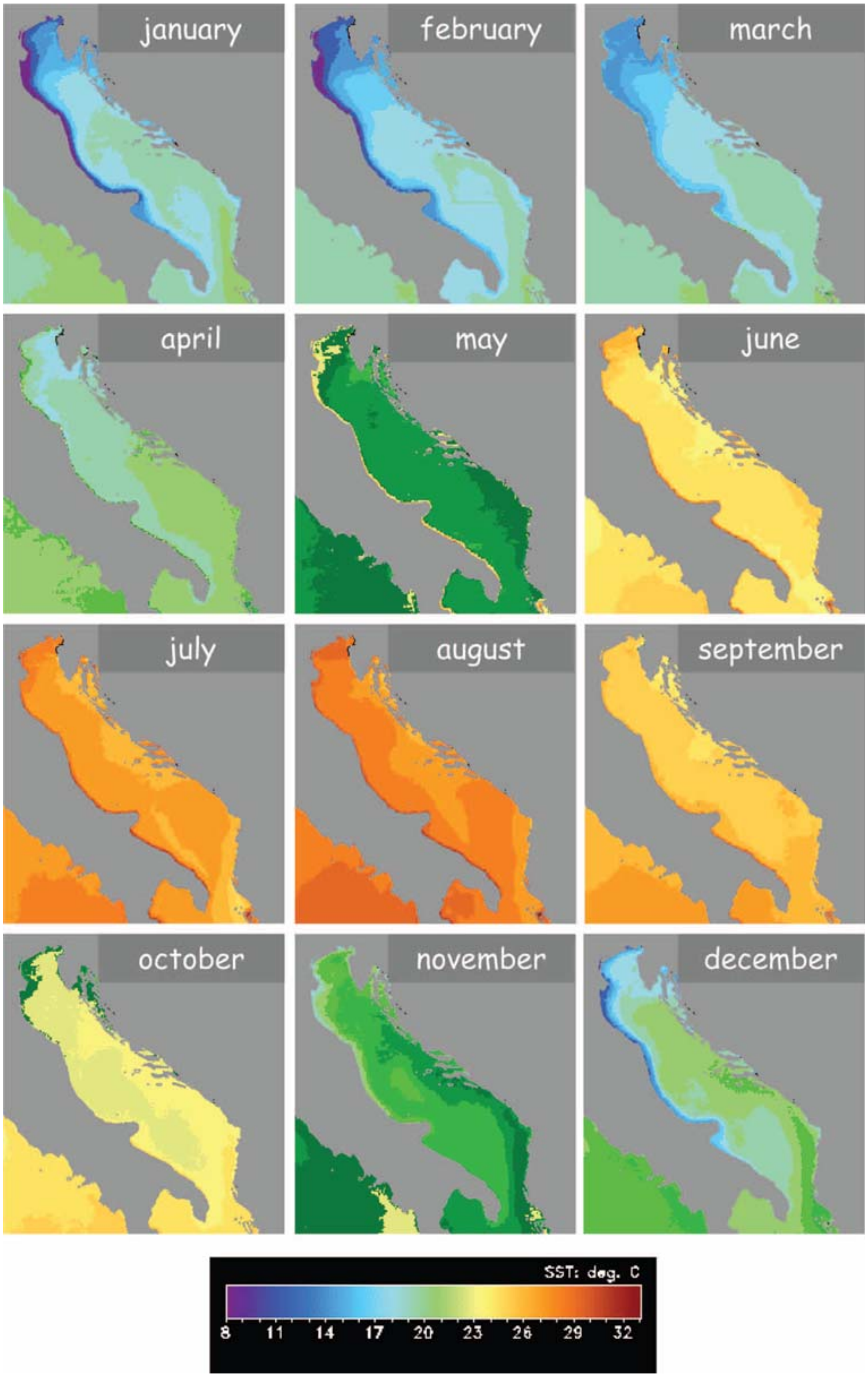


Figure 6: Sea surface temperature (SST) in the central Mediterranean Sea, derived from AVHRR data. Monthly averages for the period 1981–1999. (Barale et al., 2004)

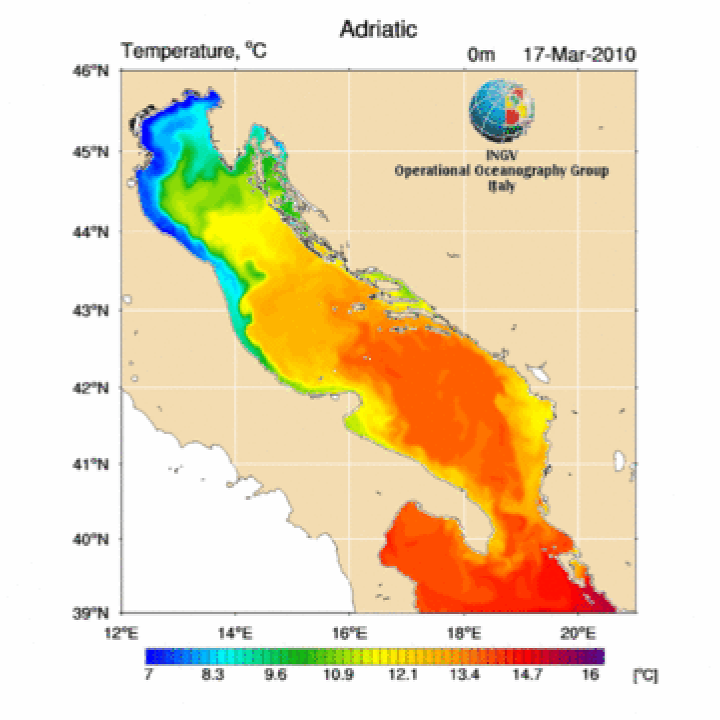


Figure 7: SST in March 2010 (From: http://gnoo.bo.ingv.it/afs/external/domani_T.gif)

2.3.3 Water-mass properties

The Adriatic Sea is composed of three regional basins (North, Central and South), differing in latitude, bathymetry, physiography and biogeochemical features. Three types of water masses were identified in Adriatic by Zore – Armanda (1963), distinguished according to temperature (T, °C), salinity (S) and density (σ_t in kg/m^3) the following three regions:

- Northern Adriatic Dense Water (NadDW: T=11, S=38,5 and σ_t = 29,52 kg/m^3);
- Mid-Adriatic Dense Waters (MadDW: T=12, S=38,2 and σ_t = 29,09 kg/m^3);
- South-Adriatic Dense Waters, called also Deep Waters (ADW: T=13, S=3,6 and σ_t = 29,20 kg/m^3), which are expected to have higher salinity by 2010 due to the salinity increase in the middle and southern parts of Adriatic;

The fourth water type is the Mediterranean Levantine Intermediate Water (LIW), formed in the Levantine Basin, which enters the Adriatic through the Strait of Otranto. The intensity of water exchange rate between the Adriatic and Ionian Sea is influenced by the variability of air pressure field, which varies considerably from year to year.

The variable impact of the Mediterranean water also influences primary and secondary production (Cushman-Roisin et al., 2001).

The Modified Levantine Intermediate Water, which enters the Adriatic Sea through the Otranto Strait recirculates within the central basin. However, part of the southern salty waters flows northward till the Gulf of Trieste, turning west and forming a cyclonic gyre in the Northern Adriatic. Northern Adriatic Dense Water is generated locally in winter, when water temperature drops below 12°C. These cold and saline waters sink and flow southward along the western Adriatic side close to the bottom until they reach the Ionian Sea through the Otranto Strait (Artegiani et al. 1997a; Russo et al. 2005). A main frontal system, mostly visible in winter, divides the coastal from the offshore waters, the latter containing the freshwater contributions of the Po and other minor rivers, showing a partial thermohaline stratification. The offshore waters in the eastern part of the basin are not influenced by continental inputs and are generally characterised by a lower degree of winter stratification. In the NAS the prevailing winds, 'bora' (NE) and 'scirocco' (SE), trigger modifications of hydrological properties by altering the stratification and the vertical stability regimes and by changing the physical features of the basin in general (Cushman et al., 2001). This is reflected in the biogeochemical properties of the basin as well as biomass and the structure of the pelagic phytoplankton community (Mauri et al. 2007). The spatial and temporal extension of seasonal stratification, characterised by variable pycnoclines, also shows a strong interannual variability in intensity and duration (Socal et al., 2008).

Three regions of relatively homogeneous vertical water mass properties (climatological water masses) were identified: (i) the northern Adriatic Sea, from the 100 m isobath to the northernmost corner of the basin; (ii) the middle Adriatic containing the Pomo Depressions, more than 250 m deep; and (iii) the southern Adriatic starting approximately from the Pelagosa sill to the Otranto Channel. At the surface the winter general circulation is composed only of NAd and SAd current segments and the flow field is very different from all other seasons (Figure 8). The general circulation is dominated by temperature and salinity compensation effects, which give no resulting density signal. Barotropic, wind-induced transport and circulation are probably major components of the general circulation during winter (Artegiani et al., 1997b).

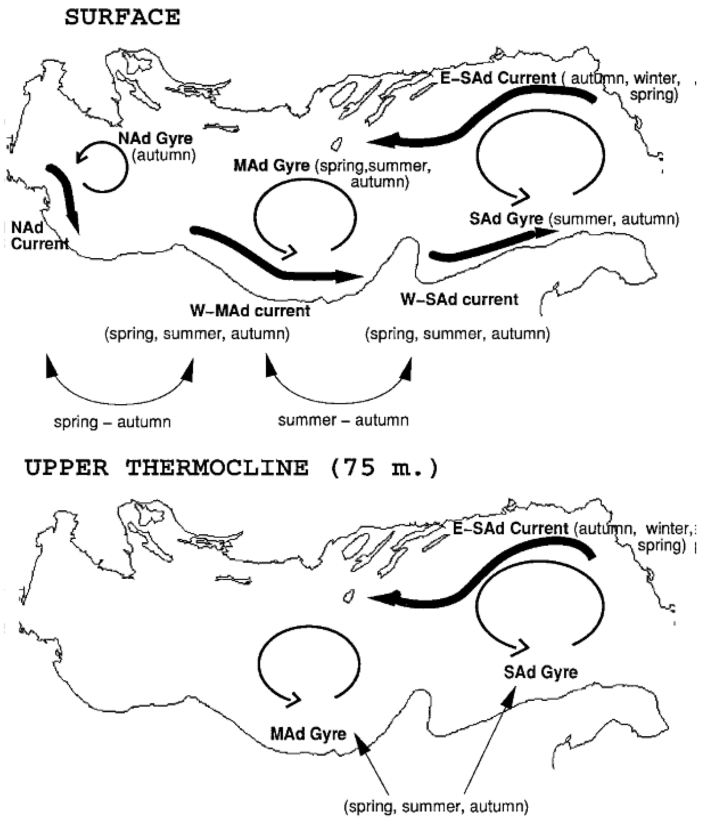


Figure 8. Schematics of the Adriatic Sea baroclinic circulation (Artegiani et al, 1997b)

The spring–summer surface flow field is characterized by the appearance of western current segments (W-MAd, W-SAd currents) and the two major cyclonic gyres of the Adriatic circulation. The seasonal vertical stratification in the basin triggers the appearance at the surface of gyres and boundary intensifications, more generally of eddies and jets, probably a result of baroclinic/barotrophic nonlinear instabilities in the basin. During summer the smallest spatial scales occur and the E-SAd current weakens. The autumn conditions are characterized by maximum spatial coherence in the general circulation structure. There are three cyclonic gyres, a continuous western Adriatic boundary current, connected between the three subbasins, and an intense SAd current. In autumn there is a maximum MLIW entrance and spreading from Otranto, causing maximum warming of the subsurface layers of the northern Adriatic. The aggregation of the general circulation into large-scale structures could be due both to the stabilization of the water column and to the structure of the external forcing of the circulation. The Otranto inflow of MLIW could be a substantial part of that external forcing. The wind driving during autumn also consists of a south-easterly wind, called ‘‘scirocco,’’ which in turn could reinforce the inflow of water at Otranto. At the depth of the seasonal thermocline (75 m) the presence of the E-Sad current and the SAd gyre was identified. The MAd gyre is not evident at this depth during winter as is the case for the surface flow field. The spring–summer flow field is again characterized by smaller spatial scales than in the other two seasons (*Artegiani et al., 1997b)*.

The deep waters of the Adriatic can be separated into two categories: the first, clearly formed in the northern Adriatic region, cool and relatively fresh, found in the northern and middle Adriatic, and the second of much higher temperature and salinity, in the southern Adriatic. Vertical mixing between water masses is an extremely powerful dynamical process in the basin, especially as an explanation of the modification of NAdDW into MAdDW. (Artegiani et al., 1997a)

2.3.4. Currents and upwelling

Western and North-Western Adriatic basin

The western side of the Adriatic basin is a site of intense current segments, which are disconnected in the three sub basins (northern, middle, and southern) in spring and summer. The autumn conditions show an overall cyclonic circulation with the intensification of three cyclonic gyres in the sub basins. The forcing of the general circulation has three major components, perhaps equally important for the overall Adriatic dynamical engine. The first component is river runoff, characterized by the low salinity waters derived mainly from the Po and Albanian Rivers. The Po forcing produces compensation of temperature and salinity gradients horizontally and is an important component of the buoyancy budget in the overall basin. The second component is the wind and heat forcing at the surface, which produce deep-water masses in the northern and southern Adriatic and forces the circulation to be seasonal. The third component is the Otranto Channel forcing, which inputs heat and salt in the circulation as a restoring mechanism for the northern heat losses and water gains. (*Artegiani et al., 1997b)*

Gulf of Trieste is limited in size (20kmx20 km) and shallow (24 m) part of Northern Adriatic, but it plays an important role in the circulation of the entire Northern Adriatic Sea. In general, circulation of the Gulf is driven by wind stress (particularly bora), buoyancy fluxes and general circulation of the Adriatic Sea, together with tides and seiches (Bogunović and Malačič, 2009). The Isonzo River is the largest freshwater inflow in the Gulf of Trieste (average of 204 m3/s according to Raichich, 1994). Dynamics of the Gulf is largely impacted by the Isonzo freshwater input, since its waters flow into the southern part of the Gulf. In all seasons there is a general inflow into the Gulf of Trieste at its lower, deeper part. This inflow makes a cyclonic turn cantered in the southern part during average winter conditions. This turn is enhanced during spring and closes in an elongated cyclonic gyre during average summer conditions. In spring and summer, the cyclonic gyre is coupled with an anticyclonic gyre near the closed eastern part of the gulf. A "dome"-like density profile across the gulf's axis in the inner part of the gulf above the bottom appears with this circulation during spring and summer. In climatic autumn there is a smaller anticyclonic gyre on its southern side. Near the sea surface there is an outflow during winter, which is driven by the dominant "bora" wind blowing along the gulf's axis. This outflow, however, is detached from the southern coastline to the right, and crosses the gulf diagonally, merging with the belt of freshwater outflow along the northern coastline. This is shown to be a consequence of the balance between the pressure gradient force caused by elevation piled up in the direction out of the gulf, the Coriolis force, and vertical friction between layers near the sea surface. During the stratified season the surface of the gulf is occupied by an anticyclonic gyre due to the inertial plume of the Isonzo River. (Malacic and Petelin, 2009)

Eastern Adriatic

Unlike the Western Adriatic, the eastern part is replete with islands and headlands, among which the water depths can reach 100 m. Due to complicated geographical features every bay and channel tends to have specific oceanographic characteristics. The wind is an important forcing mechanism and is modulated seasonally. Alongshore winds and offshore winds are stronger in winter than in the summer due to changing state of atmosphere above the Adriatic. The strongest winds in Adriatic are bora and sirocco, which are accompanied by different weather patterns. Bora winds come with high air pressure, low sea and air temperature, almost cloudless sky, low humidity and no precipitation, while sirocco winds are accompanied by low air pressure, high sea and air temperatures, large amounts of clouds, high humidity and heavy precipitation. Freshwater discharges are smaller then along the Italian coast, amounting altogether to 900m3/s. 59% of freshwater input is due to rivers, 31% due to underground seepage, spring water (6%) and land runoff (4%).

Upwelling events, associated to the prevailing NW winds, is frequent along the Croatian coast during summer months (Cushman-Roisin et al., 2001).

Albanian Shelf

The Albanian coast is a narrow shelf area, north of the Strait of Otranto, with smooth bathymetry and with circulation features determined by waters from Ionian Sea. The total discharge of Albanian rivers reaches 1000 m3/s. The influence of freshwater inflow is felt also far downstream the Croatian coast.

North-eastern wind generates also very intense coastal upwelling along the Albanian shoreline due to the sudden change of the coastline orientation. Bora winds induce an undercurrent at intermediate depths near the Albanian shelf break and weaken the Levantine Intermediate Water flow into the Adriatic Sea. (Cushman-Roisin et al., 2001)

2.3.5. Case study: Coastal inundation in the Adriatic

In the Adriatic Sea, the sea level alteration due to storm surges is highly related to the tide's amplitude, which is usually higher than in the rest of the Mediterranean, especially in the northern Adriatic. Astronomical forcing produces an almost complete "cooscillation" with the Mediterranean, where the continuous driving from the southern inlet is much more important than the negligible local direct forcing from the moon and sun. Additionally, the southeast winds (Sirocco) raise the sea level, especially in the North Adriatic, where a long-lasting Sirocco and low air pressure can also raise the water level up to 1 m. Wind influence is less important in the South Adriatic, where the air pressure influence is dominant giving rise to sea level changes of up to 30 cm (Tsimplis et al., 1995; Bondesan et al., 1995; Leder,1988).

Low-elevation coastal areas and their populations are at risk during and after the appearance of a storm surge event. The sea level rise due to storm surge events was examined for the period 2000–2004 and potential inundation zones were then identified using a 90-m horizontal resolution digital elevation model. Based on the combination of the risk level determination of an area and the calculation of sea level alteration the major 'risky' coastal regions were identified (1) (Krestenitis et al., 2010).

Table 1. Potential inundation areas in km2 and the respective coastline length (km) and density population of each area (persons / km2) (From Krestenitis et al., 2010).

	Potential inundation area (km2)	Front length (km)	Population density n (persons / km2)
Venice Lagoon	6300	288	n>500
Neretva Delta	200	16	100>n>25
Gulf of Manfredonia	200	63	100>n>50

Venice Lagoon is the area of the highest risk is, due to the largest potential inundation area and highest population density.

2.4. Sedimentology

Geophysical investigations in western Adriatic indicate that the top of the limestone series, underlying the clayey and sandy deposits of the Pliocene and the Quaternary has a very uneven topography. Its greatest depths (4–6 km) are found a) between Ravenna and Rimini, b) between San Benedetto and Pescara, and c) below the Albanian shelf. Recent sands are mainly limited to the littoral zone; pleistocene sand, originally supplied by rivers, covers the greater part of the deeper shelf. Between these zones a terrace-shaped pro-littoral mud belt is present, where the bulk of the recent terrigenous mud is deposited. The maximum rate of accumulation in this belt is probably about 4 1/2 mm per year.

The remaining part of the recent mud is transported in the sea water as floccules of such small size that they remain suspended over the deeper zones of the shelf. Most of it is deposited in the basins of the Central Adriatic (maximum accumulation rate for the Holocene on the average circa 1/2 mm per year) and in the bathyal basin in the southeast. The deepest area of the latter basin is formed by an almost horizontal plain (circa 1218 m deep). The longest core from this plain (240 cm of Holocene and 400 cm of late Pleistocene) is composed for roughly 61% of turbidity material, 5% of volcanic ash (coarser than fine silt), 0,2% of organic carbonate remains (coarser than silt) and 34% of normal terrigenous mud. The ash falls were limited to the central and south-eastern parts of the Adriatic. (van Straaten, 1970).

The Po River, draining a catchment of about 75,000 km^2, is the main sediment entry point. The Apennine Rivers, draining smaller catchments characterised by very high sediment yield, act altogether as some sort of a linear source. The Adriatic prodelta deposit is up to 30 m thick along a shore-parallel belt from the Po to the area south of the Gargano Promontory, and is characterised by subaqueous progradational geometry. Prograding sigmoids reflect fluctuations in sediment supply, climatic/anthropic impacts in catchment areas, and basinal energy regime. Fluctuations in sediment flux to the basin result in diagnostic geometries within the Adriatic prodelta wedge and can be quantified by establishing chronological constraints from sediment cores. (Vollenweider et al., 1992; Boldrin, et al., 2005).

Figure 10 shows the spring runoff of sediments, billowing from the shore into the Adriatic Sea as a consequence of spring rain showers and melting snow in the Apennine Mountains as well as river sediment transport.

Figure 9: Map of sedimentation process along the western Adriatic coast (http://upload.wikimedia.org/wikipedia/commons/a/a3/Spring_Runoff_in_the_Adriatic_Sea.jpg)

Case study: The Po River basin

The Po River has the largest inflow of fresh water in the Adriatic sea. Its basin is covering an area of 74 000 km2 (70 000 km2 in Italy, 4 000 km2 in Switzerland and France). The Po crosses the northern part of Italy for over 650 km and discharges its water into the Northern Adriatic Sea at an average 1 470 m3/s. Its delta, covering about 380 km2, is regarded as one of the most complex estuarine systems in Europe.

The Po area is a strategic region for the Italian economy, with significant agriculture, livestock, industry and tourism. Each year about 27.9 billion m3 of water are withdrawn, 5.1 billion of which are for industry, 0.6 billion for agriculture and 2.2 billion from wells for domestic and commercial use. The two main urban and industrial agglomerations are the municipalities of Milan and Turin. The population density is about 232 inhabitants/ km2 for the whole basin. Some 37% of Italy's industry is located in the basin, employing 47% of the workforce and accounting for 48% of the total national electricity consumption. There are some 280 power plants (269 hydroelectric, 11 thermal power).

The principal farming areas in the Po catchment cover 45% of the basin's total area, 50% of which is irrigated. Most of the agricultural land in the Po valley is arable land, drained by artificial ditches, and irrigated during summer. The major crops that are grown are wheat, maize, fodder, barley, sugar beets and rice. The agricultural sector is an important consumer of water, resulting in a high level of water wastage due to infiltration and discharge. The main environmental problems are related to chemical and organic fertilizer input, and to the use of pesticides. Nutrient concentrations have decreased in the last decade, as new sewage networks and wastewater treatment plants were constructed. http://www.grid.unep.ch/product/publication/freshwater_europe/po.php)

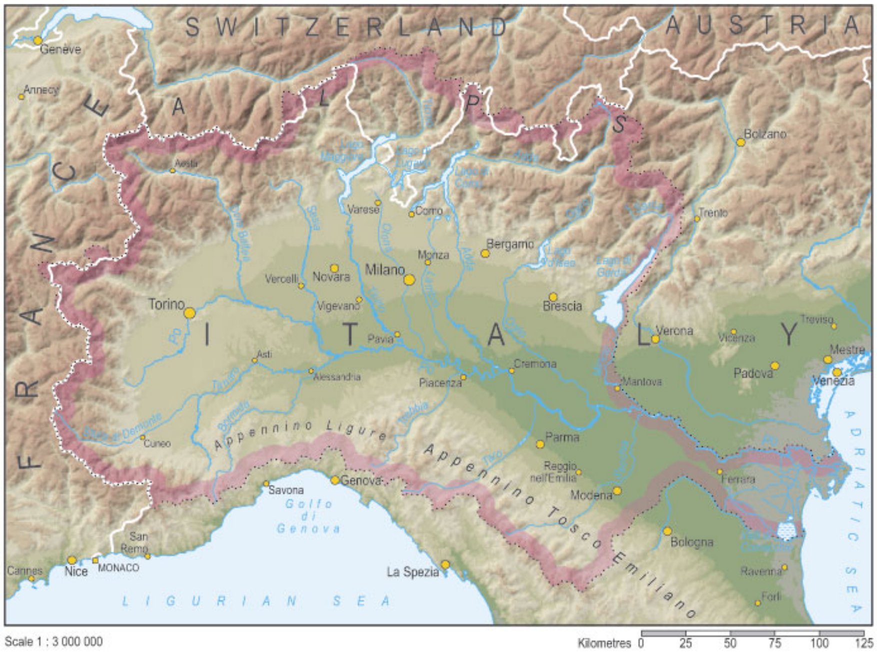


Figure 10: Po river basin (Italy)

Nutrients inflow from agriculture

The most extensive nutrient comes mostly from the extensive freshwater inflow of nutrient reach waters from Po river (de Wit, 2002). In the early 1990s the estimated average contribution of agriculture to the total nutrient load was 43-49% (Rhine), 28-58% (Elbe), and 47-57 % (Po) for N and 13-21% (Rhine), 11-16% (Elbe), and 22-25 % (Po) for P. The reduction of the fertiliser consumption and the increase of crop yields resulted in a slight (Rhine and Po basins) and a drastic (Elbe basin) reduction of the agricultural surplus of N and (especially) P between 1985 and 1995. However, this reduction has not (yet) resulted in a similar reduction of the agricultural inputs to the river network. The results of this study suggest that the EU Nitrates Directive may not be stringent enough to substantially reduce the river N and P load in the nearby future (2015-2020). The principal solution of agricultural nutrient pollution in Europe is a large-scale change towards agricultural systems where the input (manure and fertilisers) is balanced with the requirements of the crops (output). (de Wit et al., 2002).

Variations in sedimentation rate

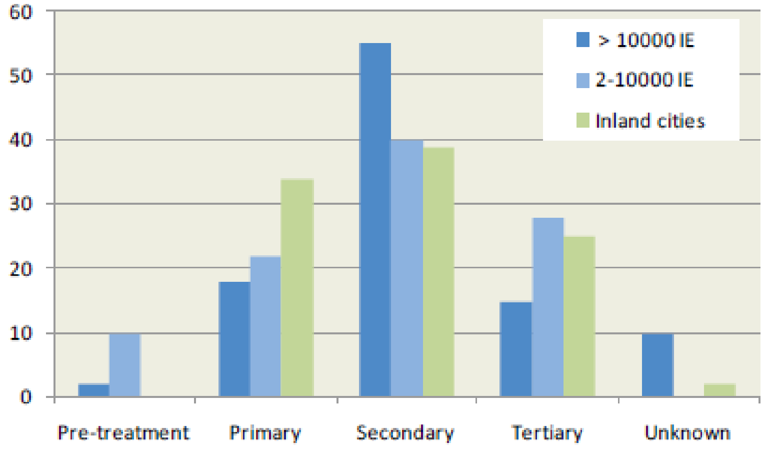
The research of Barmawidjaja (1995) shows the historical impacts of Po River on the Northern Adriatic Sea ecosystem. First substantial changes are related to variations in sedimentation rate due to changes in natural course of the Po River (canals, dikes) as well as deforestation started already between 1800 and1840. The association of existing vegetation started to change and decreased substantially. Since 1900 the trend of nutrification started to increase and became strongly eutrophicated until 1930's. Faunal changes from 1960's indicate seasonal anoxia episodes. (Barmawidjaja, 1995).

3. Pressures ressures and impacts Resulting from Contamination by Hazardous Substances

3.1. Pollution sources

3.1.1. Urban effluents

The average rate of urban population with access to a sanitation system in Adriatic basin is around 96%, although not all collected wastewater is appropriately treated. In average in the Mediterranean, the rate of wastewater collected and treated by public sanitation ranges from 7% to 90%. On a regional scale, 40% of municipalities with over 2,000 inhabitants (673 cities out of 1699) are not served by wastewater treatment plants. The most common treatment level is secondary treatment, used in 55% of the coastal cities with over 10 000 inhabitants. Tertiary treatment is not extensively used, albeit proportionally more in small cities: 28% and 25% for non coastal cities and 15% in large coastal cities (Figure).



Note : IE = Inhabitant Equivalent

Source : MED POL

Figure 12: Degree of treatment process of waste water treatment plants in coastal and inland cities, 2004 (%) (From UNEP/MAP - Plane Bleu, 2009)

	>10.000 inhabitants **(UNEP/MAP/MED POL/WHO, 2004)**	**2.000-10.000 inhabitants** **(UNEP/MAP-MED POL/WHO, 2008)**
Albania	Four coastal cities were reported (the same reported in 2000) with a resident population	Three coastal cities were reported with a resident population of 17,200

	>10.000 inhabitants (UNEP/MAP/MED POL/WHO, 2004)	2.000-10.000 inhabitants (UNEP/MAP-MED POL/WHO, 2008)
	of 290,000 persons. New information was included mainly with respect to the population served by a sewerage network (about 38% of the total population), since three out of four cities are today served by collection systems. It should be stressed however, that there are no wastewater treatment facilities and thus the collected sewage is directly discharged into the sea untreated.	persons. Information regarding collection systems was not reported. It should be stressed, that there are no wastewater treatment facilities and thus the untreated wastewater is partly discharged into the seawater and cesspools.
Croatia	Ten coastal cities were reported with a resident population of 796,600 persons. Comparing the 2003 reported data to the respective information of the 2000 reporting period, one area was excluded (Susak), whereas area of Opatija-Lovran was added to the list of cities with population over 10,000. Furthermore, the cities of Split and Solin are currently served by a common wastewater treatment plant. With respect to the treatment provided, this is limited to primary treatment for the eight out of ten cities. The disposal of primary treated sewage is conducted through submarine outfalls in all cases, while untreated sewage is disposed into the aquatic environment by many small submarine outfalls.	Eighty-three coastal cities were reported with a resident population of 368,042 persons. According to the provided information forty two coastal cities are served by WWTPs while pre-treatment is applied for the forty one out of forty two cities. The disposal of primary treated sewage is conducted through submarine outfalls in almost all cases, while untreated sewage is disposed mainly into the aquatic environment by many small submarine outfalls.
Italy	The reported data involve a total of 120 cities with a resident population of about 8,000,000 persons, currently served, or projected to be served by 138 wastewater treatment plants. The total population served by wastewater treatment plants reaches a figure of 9,700,000 including the seasonal population. The operation of 138 operational treatment plants was reported, while 20 more plants are either under construction, projected or forecasted. Treatment of wastewater was distributed as follows: primary treatment 20 plants (14%);	The reported data involve a total of a hundred and seventeen cities, while cities with over 10,000 residents are excluded from the evaluation of the data. Total permanent population is about 652,231 persons. The total population served by wastewater treatment plants reaches a figure of 542,998, with 79% of the total cities are served by WWTPs, while 3% are under construction/ projection to be served.

	>10.000 inhabitants (UNEP/MAP/MED POL/WHO, 2004)	**2.000-10.000 inhabitants (UNEP/MAP-MED POL/WHO, 2008)**
	secondary treatment 54 plants (39%); tertiary treatment 18 plants (13%), and for the remaining 46 plants (33%), no information on the degree of treatment was available. No information was provided concerning the quantities of untreated wastewater and way of disposal. Regarding the year of construction of the plants, some of them started their operation as far back as in the early 30’s while the majority of the plants were constructed in the 70’s and 80’s.	Treatment of wastewater was distributed as follows: pre-treatment 2% primary treatment 77%; secondary treatment 18%; tertiary treatment 1%, and for the remaining 1% no information on the degree of treatment was available. The discharges of treated wastewater is about 73,550 m3/ day (for the respective population of 542,998 residents), while no information was provided concerning the way of disposal. The quantities of untreated wastewater and its way of disposal were not reported too.
Montenegro		The reported information involves a total of nine cities. Total permanent population is about 35,604 residents. It is noted that none of the reported cities is served by a WWTP, Whereas available information referred to municipalities and not to the cities (for the former population is much greater than 10,000 residents). The available information related to the cities concerns the way of untreated wastewater disposal, according to which it is led into the sea through submarine outfalls.
Slovenia	In Slovenia there are three coastal cities with a resident population of 76,000 persons. In two areas there are wastewater treatment plants that provided for primary treatment of 53% of the total population reported, which have both been upgraded to tertiary treatment in 2009. Treated wastewater is discharged into the sea (area of Koper) and through a submarine outfall (area of Piran).	Five coastal cities with permanent population greater than 2,000 and up to 10,000 residents were reported, with a total population of 18,045 inhabitants. 100% of the total cases are served by the WWTP's of Piran and Koper.

Overview of municipal wastewater treatment facilities, divided on coastal cities with population between 2000 and 10000 and coastal cities with population > 10000, is presented below.

Coastal cities with population between 2000 and 10000

Table 2: Permanent Population with or without wastewater treatment plant - coastal cities with population between 2000 and 10000

	WWTP	**No WWTP**	**Population (2000-1000)**
Albania	0	10200	10200
Croatia	196326	171716	368042
Montenegro	0	226655	226655
Italy	435988	129698	565686
Slovenia (2009)	18045	0	18045

Table 3: Degree of Wastewater Treatment - coastal cities with population between 2000 and 10000

	None	**Primary / mechanical**	**Secondary**	**Tertiary**
Albania	10200	0	0	0
Croatia	171716	188291	8035	0
Montenegro	226655	0	0	0
Italy	129698	409595	26393	0
Slovenia (2009)	0	0	0	18045

Coastal cities with population > 10000

Table 4: Permanent Population with or without wastewater treatment plant - coastal cities with population > 10000

	No WWTP	**WWTP**
Albania	278000	0
Croatia	528900	267700
Montenegro	0	0
Italy	140000	4818510
Slovenia (2009)	0	76000

Table 5: Degree of Wastewater Treatment - coastal cities with population >10000

	None	**Primary / mechanical**	**Secondary**	**Tertiary**
Albania	278000	0	0	0
Croatia	528900	267700	0	0
Montenegro	0	0	0	0
Italy	140000	277220	1059410	1537620
Slovenia (2009)	76000	0	0	76000

Comparison of quantities and degree of wastewater treatment in small and large coastal cities shows, that smaller cities have no- or primary treatment, while larger number of coastal population in big cities is connected to WWTP with primary or secondary treatment.

Table 6: Degree of Wastewater Treatment in coastal cities

	None	Primary / mechanical	Secondary	Tertiary	All together
Cities with population > 10000	946900	544920	1059410	1613620	4164850
Cities with population 2000 - 10000	538269	597886	34428	18045	1188628
Together	1485169	1142806	1093838	1631665	5353478
Share of coastal population	0,28	0,21	0,20	0,30	

28% of sewage emissions from coastal population in the Adriatic basin was not treted in 2004, while 21% of sewage only had primary treatment.

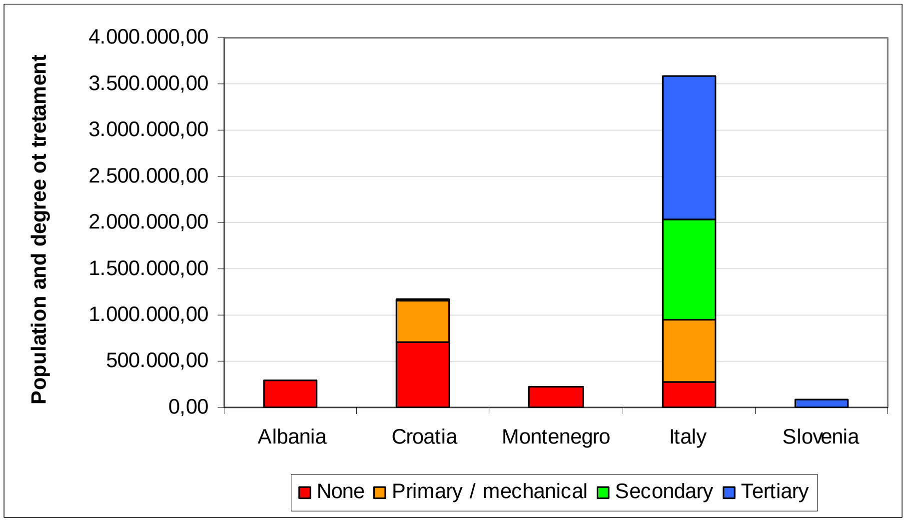


Figure 13: Population and degree of treatment by county

3.1.2. Industrial sources

Albania

After 1991, most large Albanian industries (e.g. mineral production and processing, pesticides, fertilisers, chemicals, plastics, paper, food and textiles) were closed down. This left stockpiles with obsolete hazardous substances as well as contaminated land.

Mercury contamination inland of the former chlor-alkali plant detected in an area of 20 ha around the factory at a soil depth of 1.5 m is problematic in Vlora district (mercury concentrations 5 000–60 000 mg/kg soil) as well as mercury in groundwater and coastal sediments of Vlora Bay (up to 2.33 mg/kg). Chlorinated hydrocarbons and other dangerous pollutants are found in the soil. (NDA Albania, 2003)

Bosnia and Herzegovina

The pollutants generated in the drainage basins of the major Bosnian rivers of Neretva (from the nearby towns of Konjic, Mostar, Caplinja, Ploce and Metcovic) and Trebisnjica (from the towns of Bileca and Neum) can be carried to the Adriatic Sea affecting its environment (Figure 3.3) (NDA Bosnia and Herzegovina, 2003). The area of concern is Mostar (population 130 000), where barrels of obsolete chemicals are left on both riverbanks. During the war (1992–1995), bombing destroyed electric power transformers leading to oil leakage and contamination of soil and water with PCBs.

Croatia

Major pollution problems occur in Kastela Bay (Split), where metals and organo-halogen compounds accumulated in the sediment due to the discharge of untreated urban and industrial wastewater. (NDA Croatia, 2003)

Italy

The river Po is a very important pollution vector in the area transporting urban and industrial wastewater as well as agricultural run-off from its drain-age basin to the Adriatic Sea, draining the entire northern part of most industrialised part of Italy.

Montenegro

The areas of concern are:

- Bar, due to industrial wastewater coming from food industry,
- Herceg Novi due to effluents from urban areas and industry (shipyard, harbour and food);
- Kotor: urban and industrial (metal, chemicals, petroleum storage and harbour);
- Ulcinj: urban and industrial (salt and harbour);
- Budva: urban and harbour;
- Tivat: urban and industrial (shipyard and harbour).

(NDA Montenegro, 2003)

Slovenia

Discharges of partly treated industrial wastewater and (NDA Slovenia, 2003), which contains heavy metals (Ni, Cr and Zn) are emitted in Koper bay. Tributyltin compounds are also still reaching high concentrations in sediments as well as in water column (national monitoring programme, 2008).

3.1.3. Oil pollution

The main sources of oil pollution in the marine environment include land-based activities (either discharging directly or through riverine inputs), maritime transport, both through accidental and deliberate discharges, atmospheric deposition (from military activities and commercial jet flights), coastal refineries and offshore installations (GESAMP, 2005; GESAMP 2007; Redondo et al., 2008). Marine transport is one of the main sources of petroleum hydrocarbon (oil) and polycyclic aromatic hydrocarbon (PAH) pollution in the Mediterranean Sea. (EEA, 2006)

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. The damage of oil spills is not restricted to the environment but also has socio-economic component. Oil spills in fishing (catching, spawning and feeding) or aquaculture areas or coastal locations which rely upon tourisms can be severely impacted. Fisheries may close and tourism decline with the associated loss of income and livelihoods. Even if there is little or no actual environmental damage the perception that an oil spill has affected the coastline can still have the same impact. (EEA, 2006)

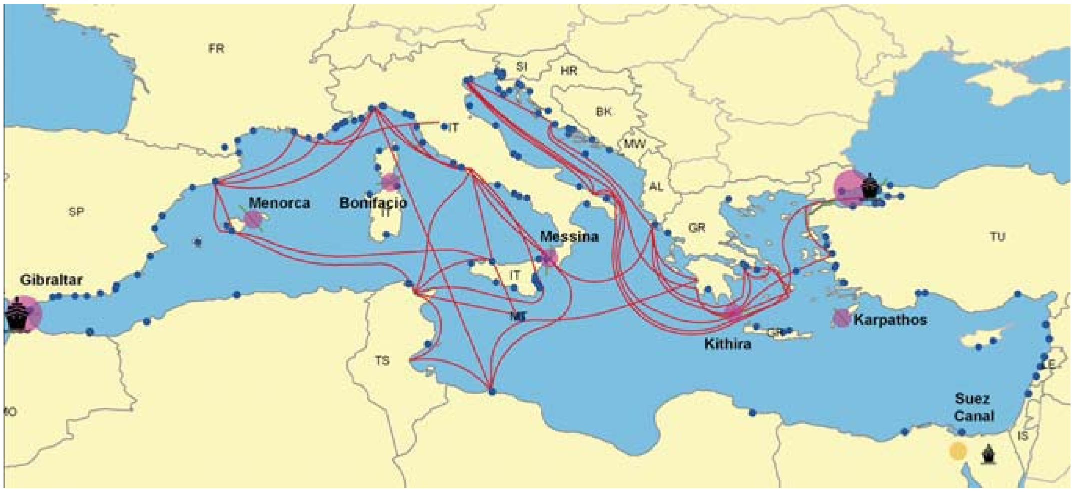


Figure 14: Ports and major shipping lanes

Shipping and oil slicks and spills

It is estimated that about 220 000 vessels of more than 100 tonnes each cross the Mediterranean each year discharging 250 000 tonnes of oil. This discharge is the result of shipping operations (such as deballasting, tank washing, dry-docking, fuel and discharge oil, etc.) and takes place in an area which since 1973 has been declared as a 'Special Sea Area' by the MARPOL 73/78 convention, i.e. where oily discharges are virtually prohibited. The PAH input varies according to the type of oil discharged and its range is estimated at between 0.3 and 1 000 tonnes annually (UNEP Chemicals, 2002).

Several approaches to assessment of oil spills quantities are widely used. Illicit vessel discharges can be detected through the interpretation of ERS SAR (Synthetic Aperture Radar) satellite images. Analysis shows that during the years 1999 to 2002 about 7000 oil spills were detected (Figure 1). According to the Regional Marine Pollution Emergency Centre in the Mediterranean (REMPEC) statistics, 82 accidents involving oil spills were recorded during the period January 1990 to January 1999 and the quantity of spilt oil was 22 150 tonnes (REMPEC, 2001). Incidents at oil terminals and routine discharges from land-based installations (estimated at 120 000 tonnes/year, (EEA, 2006)

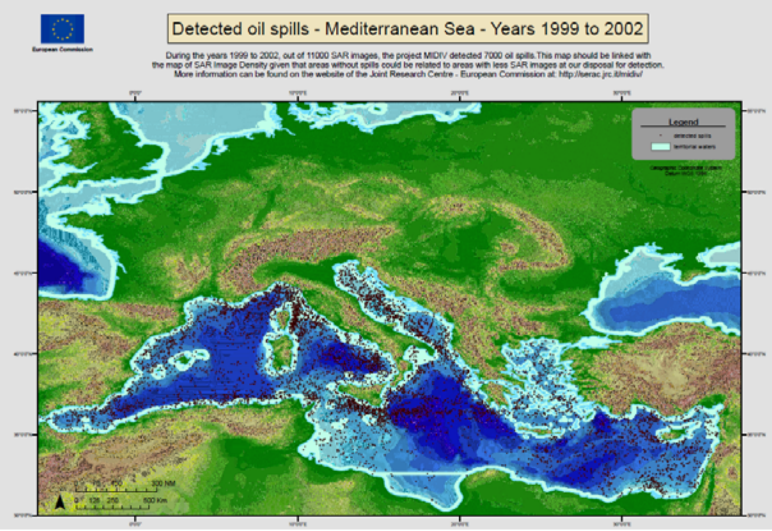


Figure 15: Detected oil spills 1996-2002 (More information can be found on the website of the Joint Research Centre - European Commission at: http://serac.jrc.it/midiv/)

The map below was derived from the spills detected from 11200 SAR images during the years 1999 to 2002. The density has been normalized to the location, spill area and number of images available for their detection (Figure 1).

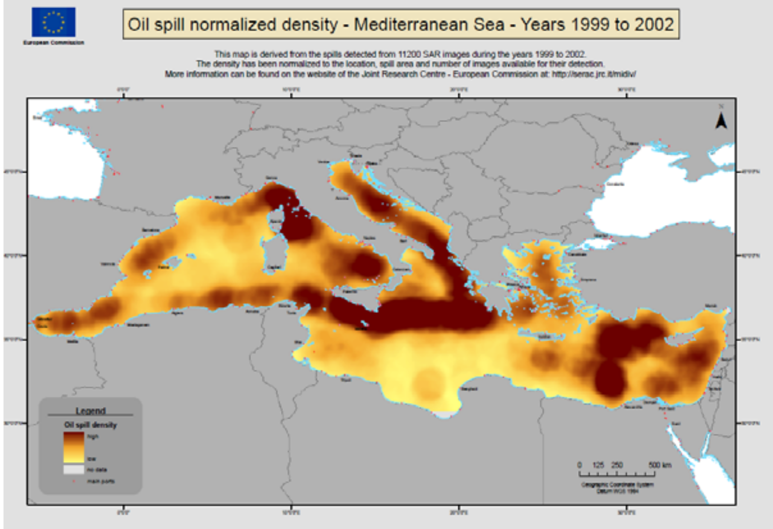


Figure 16: Oil spills normalised density 1999-2002 (http://serac.jrc.it/midiv/)

3.2. Levels of hazardous substances in the marine environment

3.2.1. Trace metals

Overall concentration ranges of Cd, total Hg, Pb, Zn and Cu in sediments and biota (*Mytilus galloprovincialis*) in Adriatic are presented in the table below. The individual analysis reveals the occurrence of some stations with high levels of Hg, Pb and Zn in Croatia. The accumulation in mussels follows a similar trend than for sediments Cd > HgT > Pb > Zn. (UNEP/MAP-MED POL, 2009)

Table 7: Median and range values for trace metals in sediments and biota (bivalves) in (µg g^{-1} dw)

Eco-region	**Cd**	**Total-Hg**	**Pb**	**Zn**	**Cu**
Adriatic (sediment)	0.21 (0.01-18.5)	0.10 (0.01-166.9)	9.5 (0.39-1033)	65.7 (5.0-980)	16.1 (1.39-122)
Adriatic (biota)	0.75 (0.03-2.73)	0.15 (0.01-8.45)	1.49 (0.07-67.5)	121 (5.7-467)	7.92 (0.51-81.6)

Kljakovic-Gaspic et al. (2007) monitored the Blue Mussel (*Mytilus galloprovincialis*) in the Mali Ston Bay, located on the eastern Adriatic coast, from 1998 to 2005. The content of trace metal concentrations in the edible tissue of mussels (averages Cd: 1.15 µg/g dw.; Hg: 0.15 µg/g dw.; Pb: 1.09 µg/g dw) fell in the range of values usually found in low to moderately contaminated marine coastal areas, although according to EU and WHO legislation and guidelines, consumption of the edible tissue of the mussels was not harmful for humans. Analysis of temporal trends during the 7 years of monitoring showed that metal concentrations had not changed over time) (UNEP/MAP-MED POL, 2009).

Similarly, a monitoring survey carried out during the 2001-2005 period in the Croatian coast using the blue mussel as an indicator species, determined that Pb and Hg were significantly elevated in the urban and industrial areas, while Cd was more uniformly distributed across the monitored sites, being also high in mussels from rural areas located far away from anthropogenic sources of pollution. The majority of values were yet below the maximum thresholds for fresh seafood. Again, metal concentrations had not changed during the five year-period (Kljakovic-Gaspic et al., 2007). (UNEP/MAP-MED POL, 2009)

Overview of data obtained by monitoring of cetacean species tissues shows that concentrations of mercury in liver found in species living in the Mediterranean are substantially higher than in species from the Pacific and Atlantic (Monaci et al., 1998, Capelli et al. 2008).

3.2.2. Chlorinated compounds

Concentrations of aldrin, dieldrin, endrin, lindane and hexachlorobenzene in *Mytilus galloprovincialis* are in the low ng g-1 range, with the exception of some stations from Albania. As shown in the Table 8, concentrations of DDTs were one order of magnitude higher, with p,p'-DDE being, in general, the predominant component, although recent inputs of DDT in some areas cannot be ruled out. Concentrations up to 9779 ng g^{-1} dw of total DDTs were found in mussels from the Albania coast, probably indicating the presence of stockpiles of DDT in the country, as well as of lindane.

Table 8: Chlorinated compounds in Mytilus galloprovinciallis - median (and range) values (ng g^{-1} dw)

Eco-region	**Σ DDTs**	**Lindane**	**CB138**	**CB153**	**Σ7CBs**
Adriatic	11.45 (0.01-9779)	0.24 (0.001-88.4)	6.67 (0.1-350)	5.00 (0.05-85.5)	96.6 (4.0-875)

Data for concentrations of DDT levels in sediments were published for river Po delta. Concentrations were in the range of between 0.3 – 1406 DDTs (ng/g dw), while background values 0.08 – 5 were determined for Mediterranean (Gómez- Gutiérrez et al. 2007).

PCBs content in sediments in Mediterranean according to overview (UNEP/MAP – MED POL, 2009) is ranging between 1-15815 ng/g dw (Aloclor eq.), while PCB levels in *Merluccius merluccius* from the Adriatic Sea have been shown to slightly decrease between 1993 and 2003 from 1,380 ng/g to 943 ng/g lipid weight (Storelli et al., 2004). The remaining levels are still high and the declining trend was not statistically significant. Such values are in accordance to the PCB concentrations in other fish species from the same region. Between the years 2000 and 2002, PCB in Scyliorhinus canicula from the South Adriatic reached high levels ranging from 500 up to 2,351 ng/g lipid weight. In the same line, specimens of Dicentrarchus labrax from the Strait of Messina sampled in 2004 reported elevated PCB levels ranging from 63,200 to 109,400 ng/g lipid weight. (UNEP/MAP-MED POL, 2009)

3.2.3. Polycyclic Aromatic Hydrocarbons

In general, PAH pollution in the Mediterranean is widespread detected in coastal areas, clearly influenced by urban and industrial emissions to air and water. Atmospheric inputs are the main source of pollution in the open sea. In sediments, research has been focused on ports, coastal lagoons, river mouths and coastal enclosures close to urban centres. Higher levels are usually detected in harbours, especially in Trieste (Table).

Table 9: Levels of PAHs in sediments (UNEP/MAP-MED POL, 2009)

Location	**∑PAH (ng/g dw)**	**Reference**
Trieste harbour, Italy	2340 - 64570	Adami et al. (2000)
Gulf of Trieste, Italy	25 - 604	Notar et al. (2001)
Rovijn coastal area, Croatia	32 - 13681	Bihari et al. (2006)
Gulf of Rijeka, Croatia	213 - 695	Bihari et al. (2007)

Maximum levels of PAHs in biota are usually lower than those reported in sediments. The highest levels (up to 46700 ng/g dw) have been detected for mussels and fish in the Egyptian coasts. According to referenced data, concentrations in the Adriatic do not exceed 1000 ng/g dw. (Table 10)

Table 10: Levels of PAHs in biota (mussels) (UNEP/MAP-MED POL, 2009)

Location	**Conc.(ng/g dw)**	**Survey year**	**Reference**
Gulf of Rijeka, Croatia	251-671	2004	Bihari et al.(2007)
Venice lagoon, Italy	56,5 - 527	2005	Nesto et al. (2007)
Adriatic Sea	110 - 245	2004	Nesto et al. (2007)

3.2.4. Organic tin

The widespread use of organotin compounds as stabilizers in the manufacture of polyvinylchloride, as biocides in agriculture, as a fungicidal component in wood preservation and as anti-fouling agents has provided several sources of entry for these compounds into aquatic and terrestrial environments, which are found in both estuarine and marine waters, sediments and biota. Much of the attention on the release of organotin compounds into the environment has focused on tributyltin (TBT), which has been widely used as a biocide in paints and coatings in marine antifouling applications. Antifouling products play an important role in the shipping industry and are of significant economic importance. Research evidence of the damage caused by organotin compoundss on the reproduction and growth of various marine organisms has prompted action by many countries to regulate or ban their use in antifouling products. TBT has been banned since the 1980s in antifouling paints for ships smaller than 25 m in many countries, including many European countries. TBT-based antifouling paints, however, are still used in developing countries, for example most Asian countries, and their use have also continued worldwide for most vessels longer than 25 m (Horiguchi 2000, Stewart 1996). Despite such restrictions, TBT persists in many areas at levels considered to be chronically toxic to the most susceptible organisms (Berto, et al., 2006). Recent uses of tributyltin beside as a biocide in anti-fouling paints are wood preservatives and a wide range of industrial applications including cooling water, pulp and paper mills, breweries, leather processing and textile mills (WHO).

TBT has been found to be a problem in the Adriatic, but trends are downwards (Nemanic *et al.* 2008). In the year 2000, organotin pollution was investigated in the Bay of Piran, Slovenia, at the northern extremity of the Adriatic Sea by speciation analysis of pentylated organotin compounds in water and mussels (*Mytilus galloprovincialis).* The highest concentrations of tributyltin (TBT) in marine water ranged from 500 to 630 ng L-I (as Sn) in summer and from 180 to 230 ng L-I (as Sn) in autumn. TBT concentration in mussels varied from 500 to 3500 ng g-I dry weight (d.w.) (as Sn) (Nermanic et al., 2002).

Notwithstanding the increasing efforts to outlaw the TBT in antifouling paints, there is evidence of a persistent contamination in the aquatic environment. Measurements in the southern Venice lagoon there still show high TBT and DBT contamination in waters and sediments due to the increase of dockyards, shipping, and fishing activities. Significant contamination of TBT and DBT in the scavenger gastropod, N. nitidus, at dockyards, harbours, and marinas testifies to the continuous, even if not massive, input of BTs in the southern part of the lagoon. The higher content of DBT than TBT in gastropods is probably due to the greater mobility of DBT than TBT in the aquatic systems. The persistance of BTs in sediments and their diffusion, through resuspension by storms and by the enhanced anthropogenic activities, could facilitate the mobilization of these contaminants and their transfer to invertebrates and fish. (Berto et al., 2007)

3.2.5. Dioxins and Furans

Concerning fish species, Bayarri et al. (2001) carried out a study regarding PCDD/Fs con-tent in anchovy (Fam. Engraulidae), mackerel (Fam. Scombridae) and red mullet (*Mullus barbatus*) from the Adriatic Sea. In general, PCDD and PCDFs contamination levels were found to be low, ranging from 0.33 to 0.50 pg/g ww PCDD and 0.71-1.53 pg/g PCDFs for anchovy, 0.32-0.53 pg/g ww PCDD and 2.49-3.38 pg/g ww PCDFs for mackerel and finally 0.29-0.60 pg/g ww PCDD and 0.99-1.49 pg/g ww PCDFs. As it can be observed, PCDFs analytical contributions were higher than those of PCDD. I-TEQ results were greater for those species at higher levels in the trophic web (mackerel > red mullet > anchovy), although the higher fat content of these species should also be taken in account for part of the greater fresh weight-based PCDD/Fs measured. Contamination levels fell within 0.23 and 1.07 pg TEQ/g ww in the aforesaid species. Moreover, PCDD/Fs in species from the northern area were in general greater than those from the central and southern areas. Thus, these species showed a trend towards higher contamination levels associated with areas showing increased anthropogenic impact (Bayarri et al., 2001).

3.2.6. Temporal trends of pollution

There are very few countries with more than five years of available data to fulfil the requirements of a temporal trend assessment. In general, the country median values do not exhibit clear trends for metals, with few exceptions. On the basis of recent MED POL monitoring data, concentrations of Cd in Slovenia appear to be decreasing during the last decade. In the case of Italy, the decreasing trends are observed in NW Adriatic, while slight increase is observed in NE Adriatic part. Trends of Hg concentrations do not specific tendencies, although concentrations seem to be increasing in Albania and NW Adriatic (Italy) since 2000. The median values of DDT in mussels from Croatia exhibit clear decreasing trends, as well as the outlier values in the latter. The only exception seems to be Albania which is recognized to keep stockpiles of obsolete chlorinated pesticides (UNEP Chemicals, 2002).

The EEA indicator (CSI040), where the Mediterranean mussel (*Mytilus galloprovincialis*) was used as the monitoring organism, revealed that in most cases low or moderate levels were found, in particular for HCB, cadmium, mercury, and, to a lesser degree, lead. However, high concentrations were found in PCBs and DDTs in 87 and 62% of the cases, respectively. Even though only 3% of the stations had high values for cadmium, there is a statistically general upward trend. The large number of high values and upward trends should be a strong warning sign that steps to safeguard the abatement process. (EEA, 2010)

Temporal trends of pollution based on Eionet data 1998-2005, prepared by EEA show, that concentrations of Hg in marine organisms are kept mostly at moderate concentrations in Northern, NE and NW part of the Adriatic Sea basin, while they are are high in one area in Dalmatia. Generally the concentrations are lower in the southern part of the basin. Concentrations of Cd in marine organisms in Adriatic Sea show low concentrations and no significant trend in northern and eastern coast and decreasing trend along the western coast (Figure 17) (EEA CSI 40, 2010)

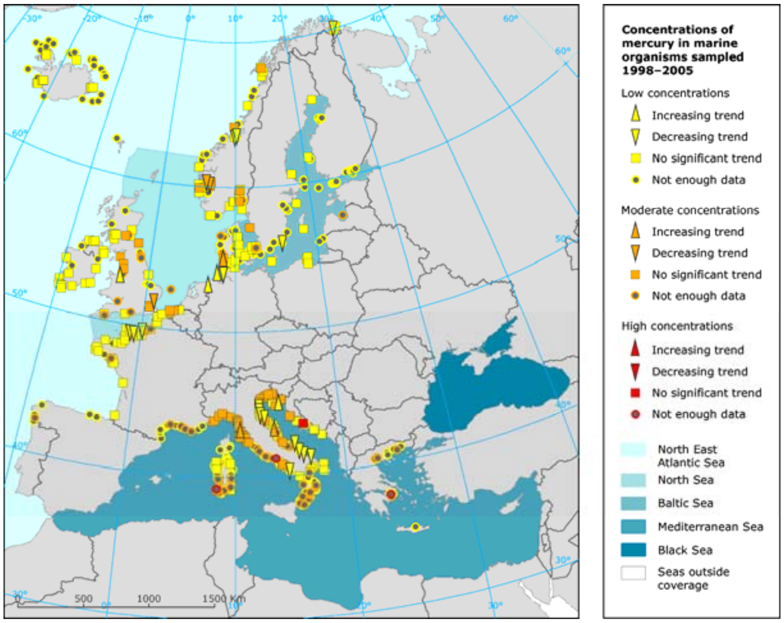


Figure 17: Temporal trends of mercury (Hg) based on Eionet data 1998-2005 (EEA CSI 40)

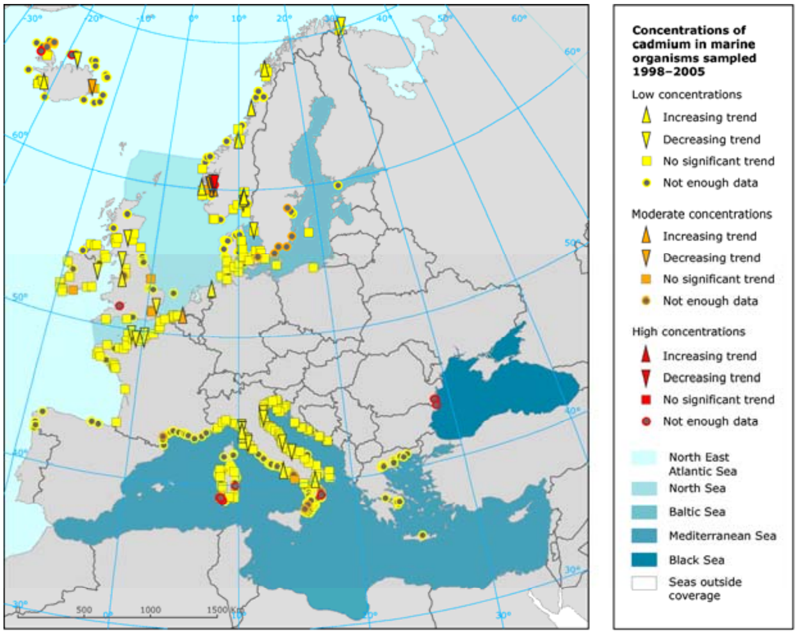


Figure 18: Temporal trends of cadmium (Cd) based on Eionet data 1998-2005 (EEA CSI 40)

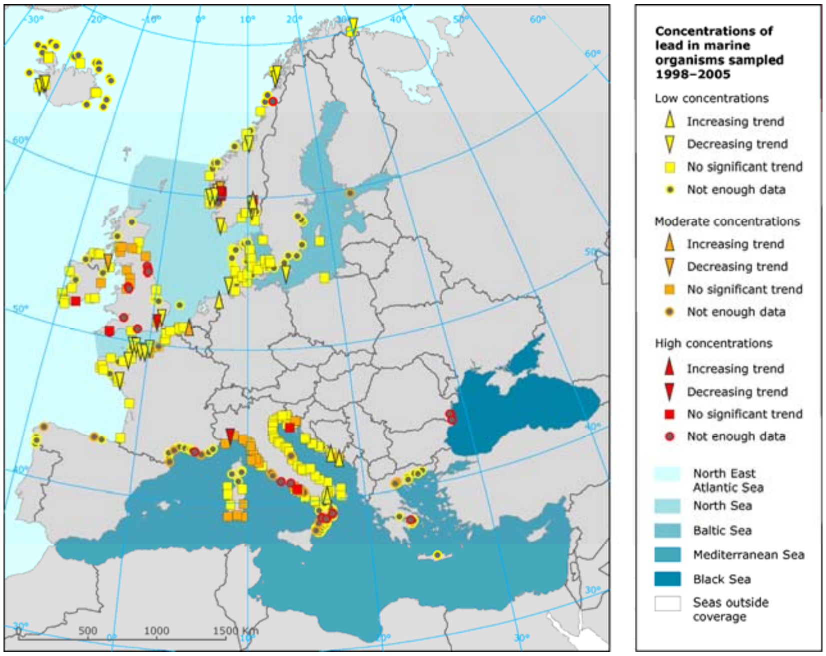


Figure 19: Temporal trends of lead (Pb) based on Eionet data 1998-2005

Concentrations of Pd in marine organisms show low concentrations in entire basin. There are three areas with moderate concentrations and one (Southern part of Istria) with high concentrations.

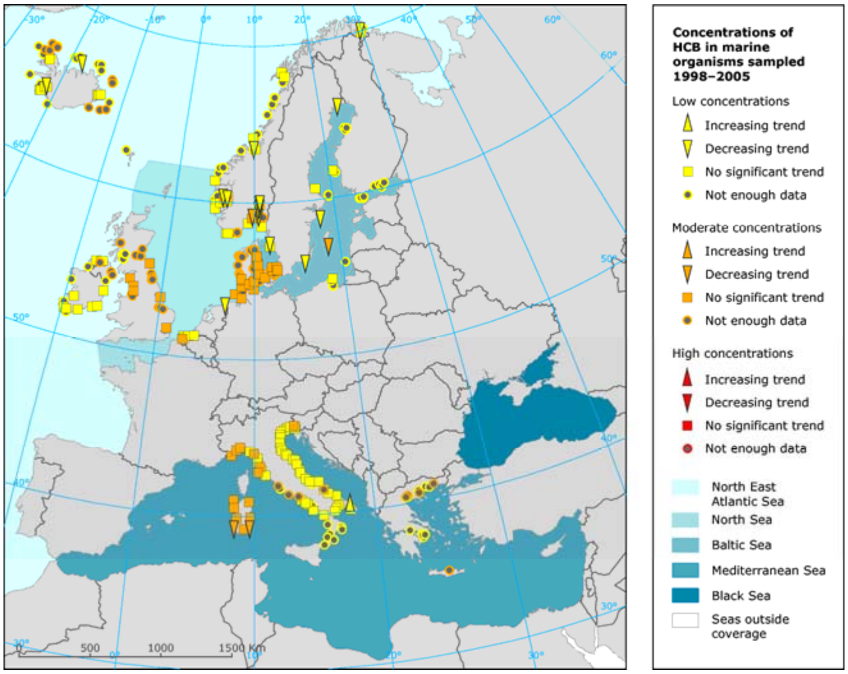


Figure 20: Temporal trends of HCB based on Eionet data 1998-2005 (EEA CSI 40)

For hexachlorobenzene (HCB), temporal trends of pollution in marine organisms based on Eionet data 1998-2005, show mostly low concentrations along the northern and eastern coast with two areas with moderate concentrations (Figure 20). PCB concentrations show the highest values of all substances reported in the CSI 40 (EEA). Concentrations are moderate along entire northern and western coast, with one area with high concentrations.

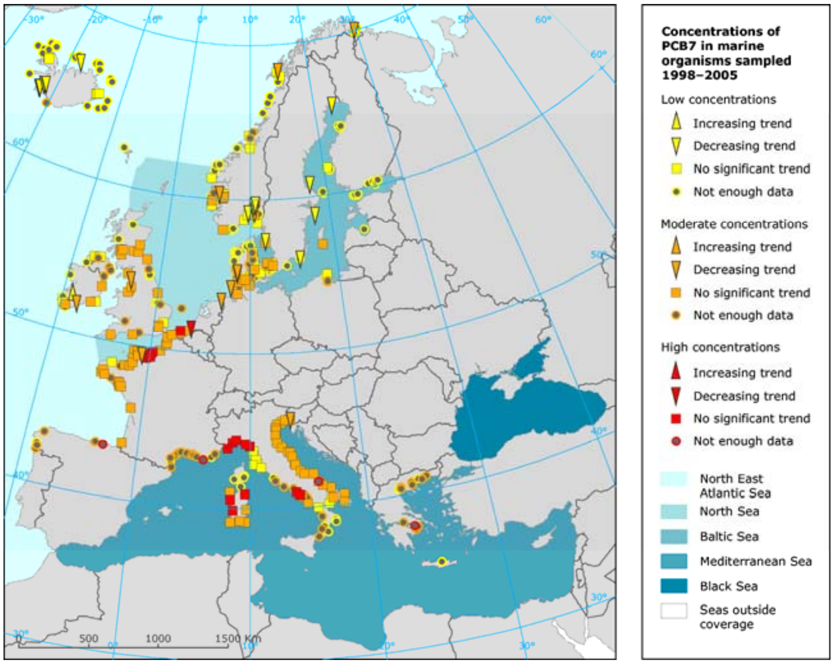


Figure 11: Temporal trends of PCB7 based on Eionet data 1998-2005 (EEA CSI 40)

Data on lindane are available for eastern part (Croatia). Concentrations are low and decreasing trend is shown in most of the area.

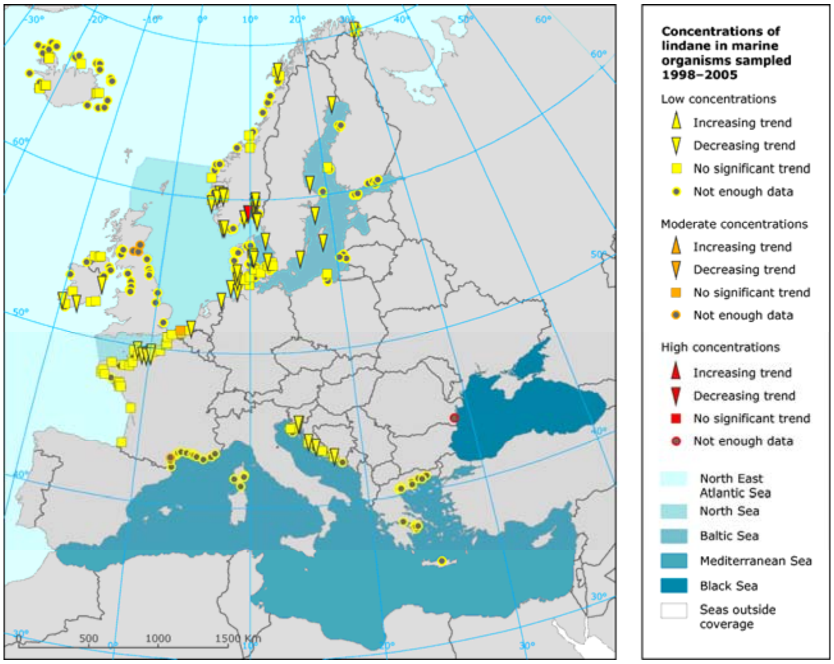


Figure 12: Temporal trends of lindane based on Eionet data 1998-2005 (EEA CSI 40)

3.3 Nutrients enrichment and eutrophication

2.3.1. N/P ratio

Research review, prepared by Guerzoni et al. (1999) suggests that despite of the early observations of P limitation, later work suggests that Mediterranean surface waters are nitrogen-limited. In fact, there is growing evidence that the Eastern MED is phosphorus-limited and that the Western MED is probably N-limited, or that limitation shifts from nitrogen to phosphorus and vice versa depending on the period of the year, or the area considered. The uniquely high levels of N/P ratios in the Mediterranean (20/27) compared with other open ocean averages (15) may reflect this situation, and are probably evidence of P limitation. (Guerzoni et al., 1999).

2.3.2. The Northern Adriatic

According to the MedPol reports (Legovic et al, 1990; UNEP/MAP-MED POL 2009), eutrophication of the northern Adriatic Sea was investigated since 1911 until 1982 using data on dissolved oxygen (DO). It was concluded that DO increased in the surface layer and decreased in the bottom layer in all seasons except during winter. DO changes were attributed to an increase of anthropogenic nutrient inflow starting from 1955-66. According to these observations, the North Adriatic ecosystem had changed towards a more eutrophic state leading to more frequent occurrence of significant episodes such as extensive phytoplankton blooms, extensive mucilage formations and mass mortality of benthic animals than before. The only remedy for decreasing the growth of primary production was to reduce the excessive rate of inflow of nutrients. Primary production, chlorophyll-a, dissolved oxygen near the bottom and measures of DO were parameters, measured regularly in affected areas while the benthic and demersal communities had been poorly investigated although massive mortalities of benthic organisms connected to oxygen depletion at the bottom have been reported.

Mortality of benthic community

In the shallow North Adriatic, the 1989 autumn offshore phytoplankton bloom was followed by a lack of oxygen in the bottom layers and a wide-scale mortality of sediment-living meio- and macrofauna (Zavodnik et al., 1990). In meiofauna an initial mortality of 80-95% was established: nematode populations were less affected than copepods and other taxa. The recovery "latent" period lasted about six months and, afterwards, a sharp increase in abundance occurred. From the macrofauna, some sponges, polychaetes, echinoderms and tunicates were almost totally exterminated but most of the actinians survived. The recovery of macrofaunal populations occurred stepwise but the process was faster in infauna than in sessile epifaunal assemblages.

Some bivalve and nematode species took advantage of the "free space" phenomenon observed at all stations surveyed. After two years of recovery the monitoring showed that at the macro- and meiofaunal levels, the communities studied were not yet stabilized.

Phytoplankton blooms and mucilage phenomena

In the research period 1989-1992, phytoplankton blooms occurred several times, in offshore and coastal north Adriatic areas. Mucous aggregates ("sea snow", "strings", "carpets") were assessed as a visual, i.e. secondary, effect of microphytic blooms. Mucous aggregations can be displaced by means of wind/waves and currents, and can be accumulated locally. Under special hydrographic and meteorological conditions, mucous aggregates can accumulate and deposit on the sea bottom, thus adversely affecting the benthic flora and fauna by smothering and/or provoking oxygen depletion in the bottom layer. In the area surveyed, bottom oxygen depletion was limited in space and time. Following the mass mortality of benthic organisms at one station in November 1989, biological anoxia was noted repeatedly in 1990 and 1991. It was noted that these events affected the population and community recovery process. (Zavodnik et al, 1994)

In the last two decades, a shift from red tides to mucilage phenomena was observed. This phenomenon is known to occur regularly for more than two centuries and was first recorded in 1729 (Vollenweider et al., 1995). Almost every year mucilage phenomena appears as marine snow or as dense cobweb, clouds, blankets, creamy/gelatinous layer (Precali et al., 2005). Mucus aggregates influence zooplankton temporal and spatial variability and can severely affect some species of fish which breed during the warm period of the year (Bochdansky and Herndl, 1995; Malej & Harris, 1993; Cabrini et al., 1992; Cataletto et al.,1996; Fonda Umani et al., 2005). When the mucilage sinks to the bottom, it physically covers the organisms living on the bottom or in the sediment and thus makes normal physiological processes impossible. Below the settled mucilage, total lack of oxygen occurs. The most destructive anoxia was recorded in September 1983 and lasted for two weeks, covering one third of the Gulf of Trieste (Stachowitsch, 1984,1986; Faganeli et al., 1985). In the affected area all the attached, partially attached and poorly mobile demersal animals died at that time. Recovery of the benthic system is not complete yet (Stachowitsch, 1991; Kollmann & Stachowitsch, 2001). Scientists are still not sure, how human activities affect the mucilage occurrence. New approach to the research of mucilage is being conducted with hypothesis that its occurrence is a consequence of the carbon cycle disruption (Gogek, 2008).

If hydrographical monitoring is too extended with regard to measuring periods, short term hypoxia cannot be checked and estimated in situ: its occurrence may be subsequently determined by the response of benthic fauna, at least at the meiofaunal level. Oxygen depletion provoked an unusual behaviour of individuals, gave rise to local displacement and disappearance of populations, and finally, a mass mortality causing an apparently complete extermination of particular species. Among the macrofauna, the most sensitive organisms to biological anoxia proved to be sponges, some polychaetes, echinoderms and tunicates, while actinians appeared to be the most resistant. Of the sediment living meiofaunal taxa, copepods were affected much more than nematodes. (Zavodnik et al, 1994).

The recovery of macrofaunal and meiofaunal populations was successful and most rapid in species whose reproductive period immediately followed the period of stress conditions. New invaders not characteristic of an autochthonous community can locally and temporarily achieve an ecologically important rank, thus influencing the recovery success of autochthonous species. After the two-year recovery period, the communities monitored at the macrofaunal and meiofaunal level, had not yet stabilized, possibly due to new invaders and other ecological disturbances which occured in this period. The recovery of soft bottom communities is a slow process which, because of the community instability, is very sensitive to interactions of biotic and abiotic environmental factors.

Critical areas

The Gulf of Trieste is known to have frequent algal blooms and hypoxia events. The first bloom has been described in 1954 from a coastal area close to the Po delta and was due to algal organism typical for transitional waters (Chromulina rosanofii and Oscillatoria tenuis). Monitoring shows, that such events are frequent in this area (Danovaro, 2003). The most affected areas are south of river Po and lagoons in N part of Adriatic (Giovanardi and Vollenweider, 2004). One of lagoons is the Lagoon of Venice, which is also a paradigmatic eutrophic lagoon system receiving urban, industrial and agricultural nutrient loads that have drastically changed parts of the original ecosystem with enhancement of seaweed growth and proliferation of anoxic areas. The North-western Adriatic coastline was most severely impacted by periodic anoxia events and frequent algal blooms, jelly fish invasions and mucilages.

2.3.3. The Central Adriatic, Kastela Bay

Studies were undertaken in order to gain better knowledge of the red tide phenomenon frequently recorded in the coastal waters of the Adriatic Sea (Marasovic, 1990). Long term observations in the most threatened areas were aimed at determining the circumstances preceding the red-tide phenomenon and which species caused it. Results showed a very high level of biological activity due to an increased eutrophication of Kastela Bay. In summer, due to poor vertical and horizontal circulation in parts of the water surface, stratification occurs with layers manifesting characteristics different from the rest of the bay. These phenomena seem to be responsible for the algal concentration, fostering the growth of monospecific blooms of those organisms showing certain competitive advantages in relation to the rest (*Gonyaulax poliedra*, *Olisthodiscus luteus*). In addition to a whole range of other competitive advantages, such as photoadaptation, resting cysts, temporary cysts and production of certain metabolites which enable them to exclude other organisms from the environment, these flagellated organisms are highly motile. Such intensive phytoplankton blooms eventually lead to their self-destruction. The resulting anoxia causes mass mortalities of other marine organisms.

A thorough consideration of these results leads to the conclusion that those regions constantly burdened with waste waters have sufficient quantities of micro and macro nutrients not to cause but, on the contrary, to enable and to support excessive phytoplankton blooms. In Kastela Bay, sea temperature in excess of 22 ºC, seem to trigger explosive development of certain populations mainly those with organisms (dinoflagellates) showing competitive advantages over other organisms thus developing monospecific blooms. When these blooms collapse, oxygen consumption takes place resulting on anoxic or quasi-anoxic states.

Some regions in the Central Adriatic have achieved such a high level of eutrophication that they can be described as hypertrophic. In order to rehabilitate such regions, it is essential to reduce the discharge of waste waters. However, since great quantities of micro- and macro-nutrients are deposited in the sediments, these areas will continue to exhibit a high level of eutrophication for a long time. The results obtained from these studies, combined with the results of physical, chemical and dynamic investigations should enable a more precise evaluation of the basin absorptive capacities i.e. to estimate the quantities of waste water that can be discharged without a significant disturbance of the ecological balance (Marasovic, 1990).

2.3.4. The Krka River salt wedge

With regard to the Krka River estuary, the exchange of freshwater and marine water in the stratified estuary varies with flux (Zutic and Legovic, 1990). During winter, the estimated renewal time of freshwater was from 6 to 20 days while during summer it was found to be around 80 days. The exchange time of marine water is about five times longer. The temperature maximum is located on the lower edge of the halocline where the highest temperature in the Adriatic has been recorded (31 ºC). Strong northerly wind induces a tilt of the brackish water layer and hence sudden mortality of marine shellfish culture located close to the halocline. The halocline is an accumulation interface of living and non-living organic particles and pollutants; a site of physico-chemical transformation of organic matter under the influence of salinity gradient; a site of intensive, mainly marine, primary production with a peak of dissolved oxygen concentration; a site of intensive decomposition processes; a barrier for oxygen transport to the marine layer.

The main source of silica and nitrogen is the Krka River itself. The dominant source of phosphorus in the upper estuary is sinking and decomposition of freshwater phytoplankton while in the lower estuary it is the anthropogenic inflow of the city and port of Šibenik. Only marine phytoplankton develops blooms in the estuary. In the upper estuary, blooms (such as *Gonyaulax polyedra*) are located below the halocline. Rarely in Prokljan Lake and regularly in the Šibenik area blooms appear above the halocline. Blooms in the upper estuary precede and are a primary cause of benthic hypoxia which induces massive mortality of benthic macrofauna including *Pecten jacobaeus*. Benthic hypoxia and massive mortality of benthic macrofauna was observed in two consecutive years. Growth of phytoplankton in the entire estuary was primarily phosphorus limited with the exception of the Šibenik area.

In general, the lowest O_2 concentrations were expected towards the waterfalls, in the salt wedge near the bottom, rather than in Prokljan Lake. To a smaller extent the hypoxia also appeared in front of Šibenik. A severe hypoxia may develop in Prokljan Lake during autumn, following a marine phytoplankton bloom. Decomposition drives the O_2 concentration values below 1 mg l^{-1} at depths greater than 10-15 m causing massive mortality of benthic macrofauna. The hypoxia persists until the river flow increases and the sea water on the bottom is renewed by compensatory flow with colder, oxygen richer water. A similar effect was found to happen in the lower Ebro River in Spain (Cruzado et al, 2002).

2.3.5. General overview

Assessment of nutrients concentrations and chlorophyll data, based on Eionet reportnet data (2005), show consistently, that largest problems with eutrophication are observed in the North-western part of Adriatic Sea, related to river Po input of nutrients. Time trends analysis shows that summer chlorophyll-a concentrations are increasing at 8% of the Italian stations, decreasing at 5% of the stations, and no statistically significant trend can be detected at the remaining 87% of stations.

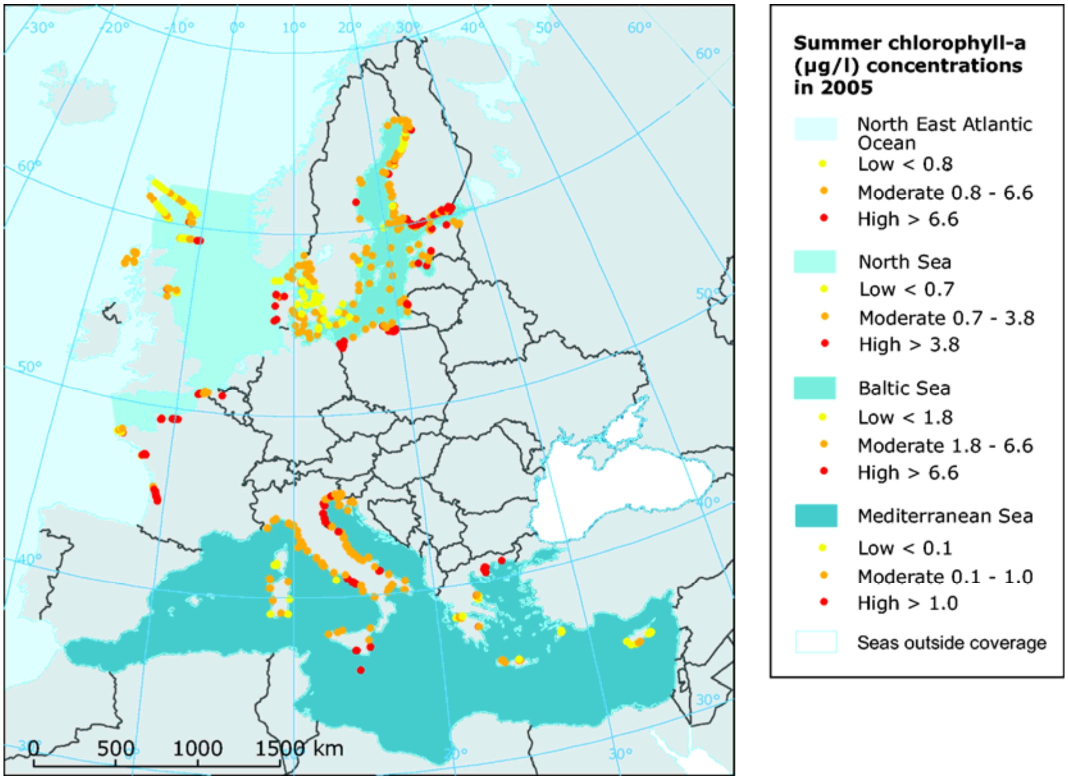


Figure 23: Map of summer chlorophyll-a concentrations observed in 2005 (CSI 021)
(Note: The low category on all maps refers to values within the lowest 20th percentile and the high category refers to values within the upper 20th percentile of concentrations in a regional sea.)

In 2005, the highest oxidized nitrogen concentrations were observed along the coast of Italy. In NW part of Adriatic the high concentrations can be attributed to inputs from the Po River. High concentrations were also observed at single stations in Croatia. Time trends analysis of data from Italy shows that oxidized nitrogen concentrations are increasing at 4% of the stations, decreasing at 1% of the stations, and no statistically significant trend can be detected at the remaining 95% of stations.

In 2005, the highest orthophosphate concentrations were observed along the coast of Italy. In the NW part of Adriatic the high concentrations can be attributed to inputs from the Po River. Time trend analysis shows that while orthophosphate concentrations are decreasing at 6% of the Italian stations, they are also increasing at 5 % of stations and no statistically significant trend can be detected at the remaining 89% of Italian stations.

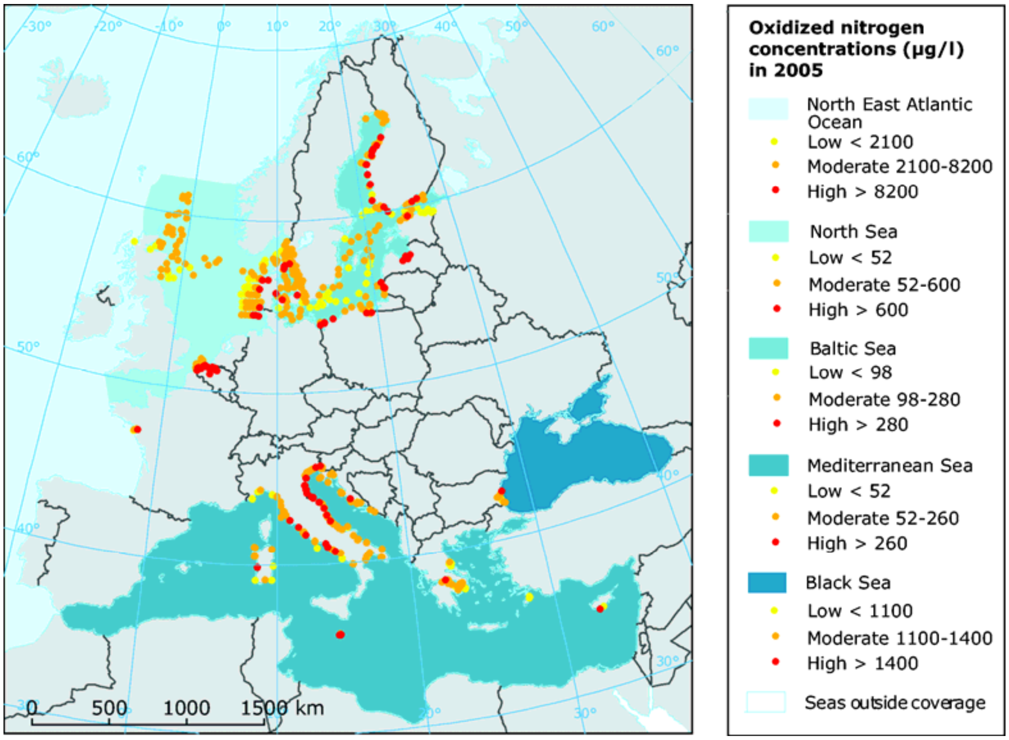


Figure 24: Map of winter oxidized nitrogen concentrations observed in 2005 (CSI 023)

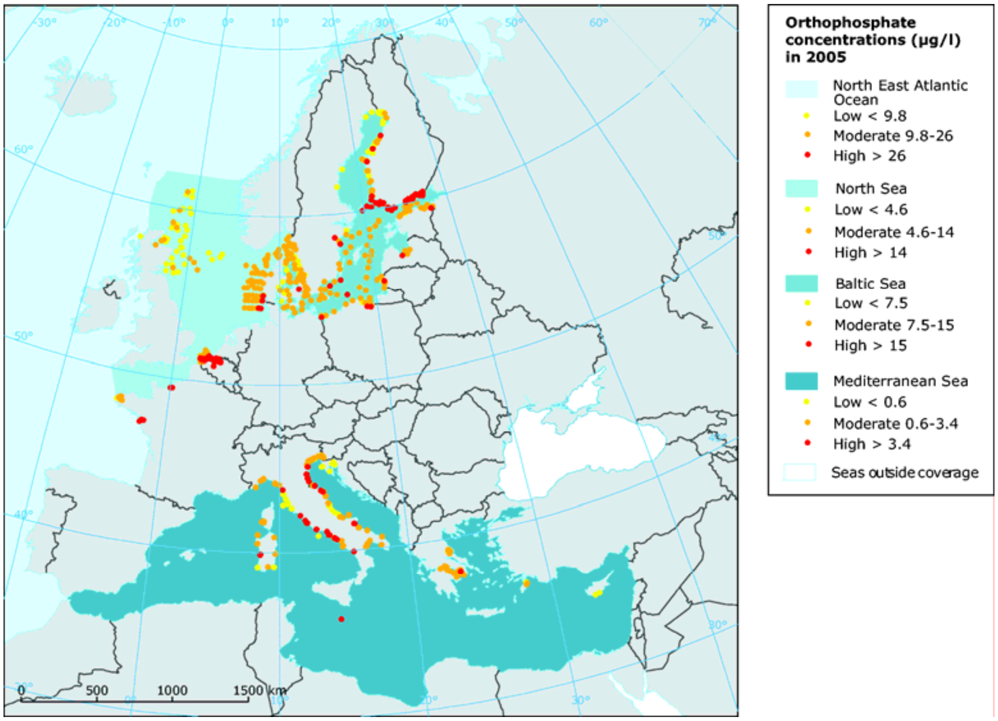


Figure 25: Map of winter orthophosphate concentrations observed in 2005 (CSI 023)

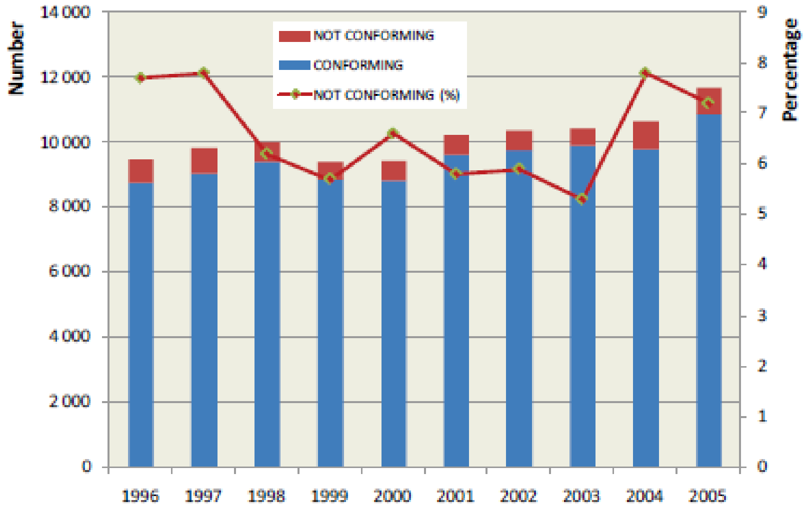
3.4 Microbial pollution

In both coastal and freshwaters the point sources of pollution that cause most health concern are those due to domestic sewage discharges. Diffuse outputs and catchments aggregates of such pollution sources are more difficult to predict. Risks to human health are related to recreational waters quality and to shellfish associated infections.

3.4.1. Quality of bathing waters in the Mediterranean

During the period 1996-2005, there has been a near stagnation in the percentage of bathing waters conforming to national standards (from 92.3% to 92.8%), with fluctuations during the period. Quality of those areas where monitoring takes place appears to have steadily increased until 2003 and then a slight worsening of quality are seen in 2004. A slight improvement is seen between 2004 and 2005. It should be noted that data only refer to waters that are officially monitored and that there may be a number of bathing areas which are used for recreation that are not monitored.

The positive trend for bathing water is also noticed in the number of sampling points, where samples were collected for analysis. In fact, following a minor decrease in 1999-2000, the number of sampling points was increased from 9,500 to 11,600 sampling points per year. The results confirm that every year more and more countries with an increasing number of sampling points implemented monitoring programmes.



Source: MED POL

Figure 26: Number and percentage of bathing water areas complying and non-complying with the national legislation per year, 1996–2005 (UNEP/MAP- Plan Bleu, 2009).

However, there is a geographical imbalance in the distribution of the sampling points, the northern and western parts of the region submitting data from a greater number of sampling points than the east and the south. (UNEP/MAP-Plan Bleu, 2009)

Case study – Trends in BW quality along Italian coastline

The results of the bathing water quality in Italy for the period 1990-2007 as reported in 2008 report and for the bathing season of 2008 are presented in the Figure 2. The graph shows:

- The percentage of bathing waters that comply with the guide values (class CG, blue line)
- The percentage of bathing waters that comply with the mandatory values (class CI, green line)
- The percentage of bathing waters that do not comply with the mandatory values (class NC, red line)
- The percentage of bathing waters that are banned (temporarily closed) or closed throughout the season (class B, grey line)

Italy reported 12 parameters under the Directive 76/160/EEC (1 Total coliforms, 2 Faecal coliforms, 3 Faecal streptococci, 4 Salmonella, 5 Entero viruses, 6 pH, 7 Colour, 8 Mineral oils, 9 Surface-active substances reacting with methylene blue, 10 Phenols (phenol indices), 11 Transparency, 12 Dissolved oxygen).

The bathing waters are classified in the following categories:

- Compliant with mandatory values of the Directive for the 5 parameters (class CI)
- Compliant with mandatory and more stringent guide values of the Directive for the 5 parameters (class CG)
- Not compliant with mandatory values of the Directive for the 5 parameters (class NC)
- Banned (temporarily closed) or closed throughout the season (class B)

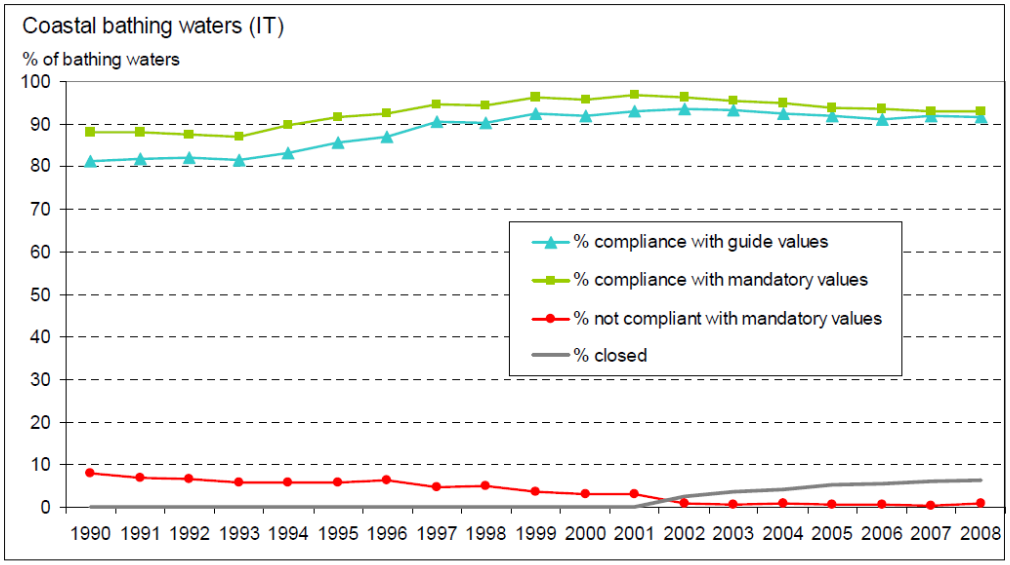


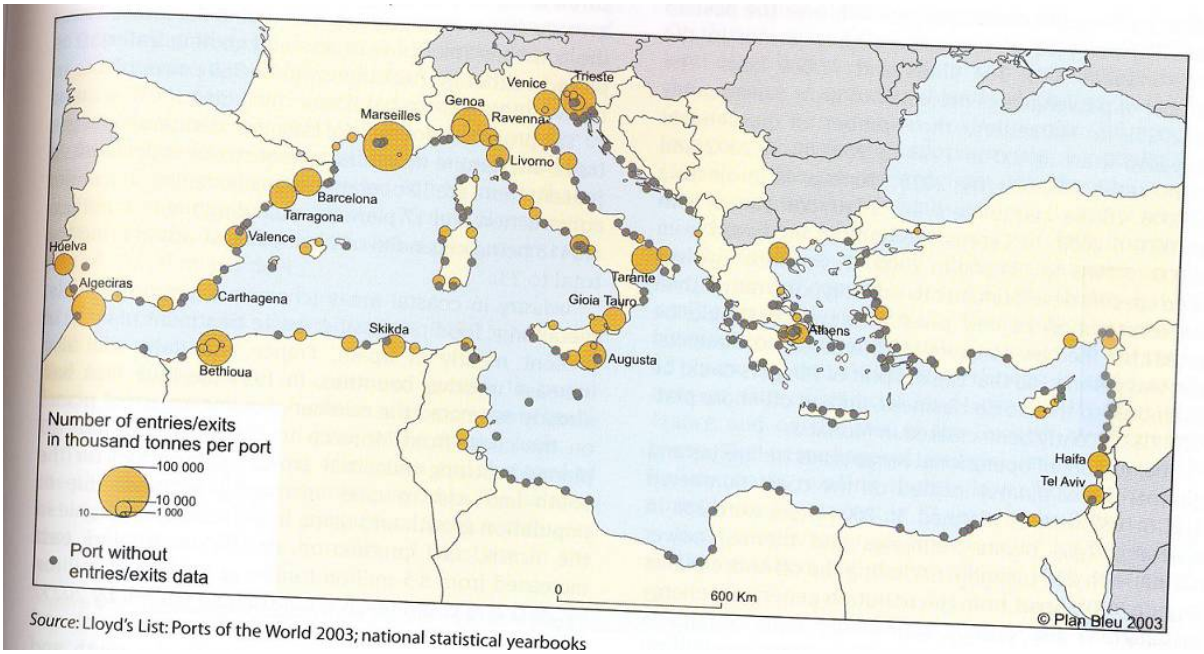
Figure 27: Results of bathing water quality in Italy from 1990 to 2008

Results show, that several non-compliant bathing waters were closed since 2002. As a result the number of non-compliant waters decreased.

(Source: http://ec.europa.eu/environment/water/water-bathing/report2009/IT_BWD%202008%20season.pdf)

3.5. Dredging and dumping

There are several large ports in the Northern Adriatic as well as in the Southern part, with regards to number of entries and exits. Intensive marine traffic and related port maintenance work are expected to have significant impacts on the marine environment, especially in the sensitive, shallow part of the Northern Adriatic.



Source: Lloyd's List: Ports of the World 2003; national statistical yearbooks

Figure 27: Ports in the Mediterranean: UNEP/MAP-Plan Bleu, 2009.

Accessibility of coastal ports, fishing harbours and navigable waterways is rarely naturally deep; therefore navigable depths must be maintained by repeated dredging. Every year, dredging operations result in hundreds of millions of cubic meters of sediment worldwide, which must be disposed of and managed in economically and environmentally sustainable ways (Van Dolah et al., 1984; Harvey et al., 1998). Dredging and disposal of dredged material is one of the most important problems of coastal zone management. (Simonini et al., 2005a)

Depending on their chemical and physical characteristics and the concentration of contaminants, dredged sediments may be disposed of in several ways: i.e. clean sediments with appropriate grain size may be used for beach nourishment, while contaminated sediments must be isolated and contained on land. However, for economic reasons, most dredged material is currently disposed of in appropriate off-shore disposal sites (Regoli et al., 2002; Cruz-Motta and Collins, 2004). In Italy the discharge of dredged material in appropriate off-shore disposal sites is permitted only if there is no established technical or economical possibility for their reutilization or settlement in land dumps (ICRAM, 2002; Simonini et al., 2005a)

Sediment disposal in open water may be more damaging to the benthic community than to any other part of the aquatic ecosystem because of the relative immobility of benthic organisms. Studies of dredge spoil dumping have demonstrated a range of impacts on soft-bottom benthos, ranging from large, long-term impacts to few or non-detectable effects (Harvey et al., 1998; Newell et al., 1998; Van Dolah et al., 1984; Roberts and Forrest, 1999; Smith and Rule, 2001; Simonini et al., 2005a). Where impacts were detected, these were primarily manifested by reductions in the diversity of communities at the receiving sites, compared to controls. Shifts in dominance patterns within the community may also occur, with a reduction in the abundance of some species and an increase in the abundance of opportunistic species (Harvey et al., 1998; Simonini et al., 2005a).

In some cases, studies have also demonstrated a shift in the trophic structure of the affected community. The type and severity of the impact of sediment disposal on benthic ecosystems varies, depending upon several factors:

3.3. chemical–physical characteristics and volume of sediment,
3.4. water depth, surface, sedimentary and hydrological regime of the dumping site,
3.5. time of the year and similarity of the sediment in dredged and disposal areas,
3.6. contamination of dredged material,
3.7. disposal method,
3.8. adaptation of organisms to the local sedimentary regime and structure and composition of benthic assemblages in the dumping site and nearby areas (review from Simonini et al., 2005a and references therein).

3.6. Marine litter

One of the transboundary impacts of waste released in the environment, related to waste dumping or inappropriate waste management is the phenomenon of marine litter. A recent bibliographical study conducted by MED POL on the phenomenon in the Mediterranean concluded that, between 2002 and 2006, the situation had hardly changed. Marine litter, found in the sea and on the coastline, originate mainly from coastal urban centres. These wastes are generated by direct disposal of domestic waste, tourism infrastructure waste, flows from landfills and rivers (Figure 33) and waste from maritime traffic. MED POL observes, in particular, that the management of solid waste in coastal areas is generally not covered by national environmental policies, but by health policies, and that there is generally no municipal policy of management of solid waste: municipal strategies being geared, above all, to meeting basic standards of public hygiene. For technical and economic reasons, it seems that the sea is still considered as the easiest waste disposal site and that, consequently, the disposal of solid waste into the sea is still common practice for small and medium size towns.

National, regional and international NGOs are active in Mediterranean beach cleaning campaigns. The International Coastal Cleanup (ICC) observes that, in the Mediterranean, the heavy fraction (big household appliances) is on the decrease1 and that the average weight of waste found in the sea has dropped from 511 g to 258 g. As regards the light fraction, the number of plastic bags, caps and plastic bottles is also on the decrease; the share of plastic found in the sea dominates and composes 75% of collected items. The analysis of the data available indicates that coastal and recreation activities account for 52% of the waste found on beaches. (UNEP/MAP-Plan Bleu, 2009)

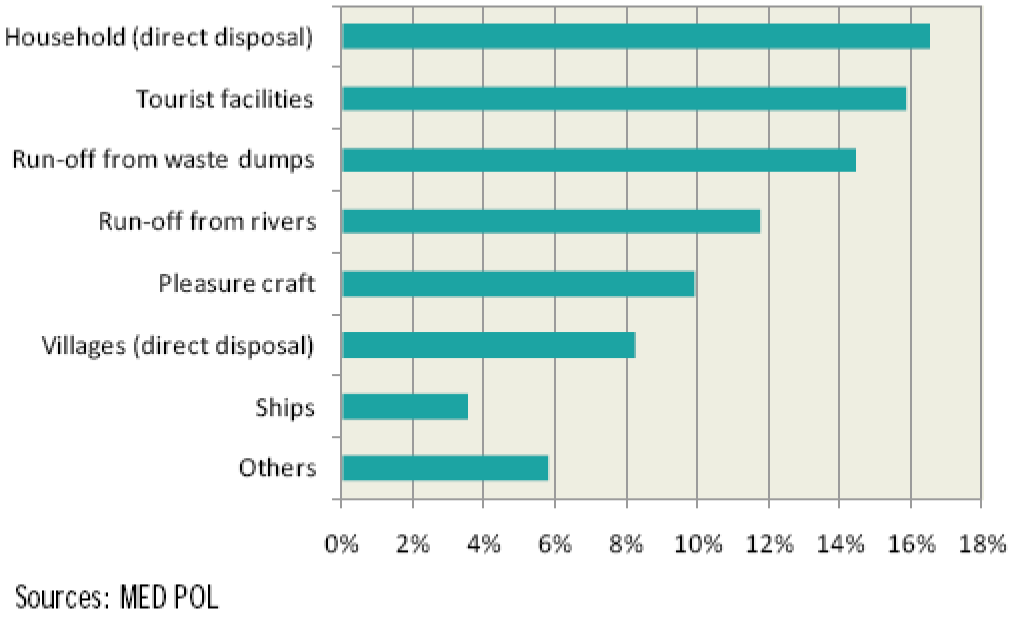


Figure 13: Origin of marine litter in the Mediterranean (UNEP/MAP-Plan Bleu, 2009)

There are no comparable data available on the regional level in the Mediterranean, but research conducted on benthic marine litter in four Greek Gulfs (Patras, Corinth, Echinades and Lakonikos) shows that mean distribution and weight densities of marine litter on the seafloor range between 72-437 pcs/km2. Three dominant litter sources were identified in assessment area: (i) land-based sources provide the majority (69%) of the total litter items followed by vessel-based (26%) and fishery-based (5%) sources. (Koutsodendris et al., 2008). It has been also estimated that over 13,000 pieces of plastic litter are floating on every square kilometre of ocean surface (UNEP, 2005).

A comparative study of the distribution and abundance of large items of marine litter on continental shelves of European Seas also shows that the sea floor is polluted with litter. Quantities of litter vary significantly among sub-regions, as presented in Table (Galgani et al. 2000).

Table 11: Abundance of litter on the seafloor – comparison of EU regional Seas (from Galgani et al., 2000)

Area	Abundance (items per km2)	Dominant type of debris or litter
Baltic Sea	126	Plastic fragments, plastic bags, plastic and glass bottles, metal and glass fragments, fishing gear
North Sea	156	
Celtic Sea	528	
Bay of Biscay	142	
North-western Mediterranean	1935	
Adriatic Sea	**378**	

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