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APPROACHES TO THE ASSESSMENT OF EUTROPHICATION IN MEDITERRANEAN COASTAL WATERS (FIRST DRAFT)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY **1**
1. INTRODUCTION **2**
2 OVERVIEW OF EUTROPHICATION ASPECTS IN THE MEDITERRANEAN ACCORDING TO THE DPSIR APPROACH **3**
A. Information from literature survey **3**
2.1 Drivers **3**
2.1.1 Population growth, urbanization, industrialization and tourism in coastal Mediterranean areas ***4***
2.1.2 Agriculture ***6***
2.1.3 Rivers ***6***
2.1.4 Aquaculture ***6***
2.2 Pressures **7**
2.2.1 Total nutrient loads ***7***
2.2.2 Atmospheric deposition ***8***
B. Information from countries **9**
3. OVERVIEW OF EUTROPHICATION MANIFESTATIONS IN THE MEDITERRANEAN **21**
3.1 Manifestastions of europhication **21**
3.1.1 Eutrophication in the Mediterranean ***21***
3.1.2 Historical review of eutrophication phenomena country by country ***23***
3.2 Results from Remote Sensing **36**
4. OVERVIEW OF EUTROPHICATION ACTIVITIES IN INTERNATIONAL POLICIES **38**
4.1 EU legislation and policies **39**
4.1.1 Water Framework Directive (2000/60/EC) **39**
4.1.2 Urban Waste Water Treatment Directive (91/271/EEC) **40**
4.1.3 Nitrates Directive (91/676/EEC) **41**
4.1.4 Habitats Directive (92/43/EEC) **41**
4.1.5 Shellfish Waters Directive (79/923/EEC) **42**
4.1.6 Bathing Water Directive (76/160/EEC) **42**
4.1.7 European Marine Strategy **45**
4.1.8 ICZM: Integrated Coastal Zone Management **45**
4.2 The EEA approach to eutrophication **45**
4.2.1 DPSIR: The Driving forces Pressure State Impact Response approach **45**
4.2.2. The eutrophication indicators selected by EEA ***47***
4.3 OSPAR **48**
4.4 HELCOM **50**
4.5 AMAP **51**
4.6 Bucharest Convention/Commission on the Protection of the Black Sea Against Pollution **51**
5. OVERVIEW OF EUTROPHICATION MONITORING STRATEGIES AND ASSESSMENT METHODS USED IN THE MEDITERRANEAN **51**
5.1 The MED POL adopted strategy for eutrophication monitoring and assessment **52**
5.2 Monitoring strategies applied for eutrophication studies by Mediterranean countries **53**
5.3 Assessment methods applied for eutrophication studies by Mediterranean countries **60**

6. ASSESSING THE TROPHIC STATUS IN THE MEDITERRANEAN USING THE TRIX INDEX 70
6.1 Background and scope of the work....70
6.2 Analytical data....71
6.3 Preliminary data screening and calculation of derived variables. 72
6.4 Analysis of the data. 74
6.4.1 First step: Cluster Analysis....74
6.4.2. Second step: Statistical analysis of the sample distributions (Johnson method). 75
6.4.3. Trophic classification 76
6.5 Results....76
6.6 Trophic Classification of Significant Mediterranean Coastal Areas based on TRIX Scale Criterion 79
6.7 Final comments 79
7. CONCLUSIONS AND RECOMMENDATIONS....80
7.1 Conclusions....80
7.2 Recommendations 83
LITERATURE CITED....84

EXECUTIVE SUMMARY

The document gives an overview of the present state of eutrophication in the Mediterranean Sea and analyses the responses from Mediterranean countries to a relevant questionnaire giving emphasis on the monitoring strategies and assessment methods used.

The information from the questionnaires complemented with a literature survey and the results from selected pilot eutrophication monitoring studies undertaken in the framework of the MED POL programme are used to present drivers and pressures related to eutrophication as well as eutrophication state and impact (DPSIR approach) in the Mediterranean by region or country. Remote sensing data are also used.

Most countries defined nutrient inputs and organic material from domestic sewage due to dense population coastal agglomerations and tourism, as the most important pressure in most sites. Other important pressures were riverine inputs as well as diffuse sources related to agriculture and animal husbandry, industrial activities, fish and shelfish farming and port activities.

The majority of Mediterranean countries use nutrients' concentrations (N, P) as eutrophication state parameters and chlorophyll-a concentrations, dissolved oxygen and in several cases toxic phytoplankton occurrence, toxins in shellfish tissues, mortality of organisms, N/P or even faecal coliforms as impact parameters.

Satellite images of the Mediterranean reveal that the highest levels of autotrophic biomass correspond to the areas close to river deltas or those off large urban agglomerations. The northern coastline presents most eutrophication hot spots, whereas open seawaters in the Eastern Mediterranean are extremely oligotrophic.

A presentation is also made of the various eutrophication policies, conceptual approaches and operational frameworks developed within international conventions covering the European region (OSPAR, HELCOM, etc) and EU directives such as the Water Framework Directive (WFD).

Mediterranean countries in most cases undertake classical monitoring activities. However, not all the countries monitor all parameters required by the MED POL strategy, though in several cases they monitor many more other parameters. The majority followed their national or other strategies. In a number of countries, national eutrophication assessment methods are performed, due to their obligations to EU directives or conventions. The TRIX index has already been used in some European countries for classification of trophic status, due to its simplicity of application.

The results of a TRIX analysis on eutrophication data from several Mediterranean countries are presented in order to evaluate the applicability of TRIX as an appropriate index of trophic status in the Mediterranean. It is concluded that TRIX is an index of the trophic status and that its use as an indicator has not yet been evaluated or established at the Mediterranean scale.

On the basis of the information received through the questionnaires, it was concluded that very few countries follow the MED POL monitoring strategy and that most countries prefer to follow their own monitoring strategies and assessment methods. Following this conclusion, the challenge for the MED POL and the countries is the harmonization of the monitoring strategies and assessment methods on a basin-wide scale. To this end, a specific proposal is made.

1. INTRODUCTION

The first MED POL assessment report on eutrophication was prepared by a group of experts on eutrophication (Prof. R.A. Vollenweider, National Water Research Institute, Burlington, Canada; Dr. A. Rinaldi, Laboratory "M.N. Daphne", Region of Emilia-Romagna, Italy; Prof. R. Viviani of the University of Bologna; and Professor E. Todini of the University of Bologna) and published as document UNEP(OCA)/MED WG.111/Inf.5 and as MTS 106 (UNEP/FAO/WHO, 1996). It describes the state of eutrophication in the Mediterranean Sea until the 1990s by addressing the main themes covered by this phenomenon, through an accurate analysis of the theoretical aspects as well as by describing the circumstances, effects and remedies to be applied.

The anthropogenic and natural origins of the various nutrient sources were defined and an estimation of the inputs into the Mediterranean was attempted. This estimation considers all sources: rivers, wastewaters from urban and industrial plants, agriculture, atmospheric precipitation and uncultivated land/forests. The phenomenon was recorded all around the Mediterranean Sea and this was apparent from the review of the publications from various countries. In many cases, the increased trophic level observed in coastal areas was creating problems of various kinds for the local inhabitants. However, the conclusion derived on the basis of the existing information at that time regarding eutrophication in Mediterranean Sea was that its main body would not be seriously threatened by eutrophication over the next few decades, although even larger basins as the Adriatic, Gulf of Lions and the northern Aegean Sea suffer from eutrophication problems.

Later, the EEA/UNEP (1999) report on the “State and pressures of the marine and coastal Mediterranean environment” pointed out, in the chapter by Izzo and Pagou regarding Mediterranean eutrophication, that the problem of eutrophication appeared to be limited in the Mediterranean. However, they suggest that considerable care must be given to the control of loads, in order to prevent deterioration of the water quality on a basin scale, the importance of nutrient limitation concept for the choice of appropriate measures and the influence of sediment resuspension and nutrient emissions to nutrient enrichment. Also they reviewed, updated and summarised the recorded eutrophication incidents and related side effects, though information was not always available, partly because of insufficient eutrophication monitoring throughout the basin. From that information, it was obvious that although the northern shores were most seriously affected by eutrophication, serious problems exist also in the south and the phenomenon should not be underestimated because the limited recorded events may be the result of the above-mentioned insufficient monitoring.

Finally, in a more recent EEA (2006) report on “Priority issues in the Mediterranean environment” it is stated again that eutrophication is still a major environmental problem in the coastal zone of Mediterranean. In fact 15 coastal countries had reported on facing eutrophication problems, among which 11 countries characterised these problems as medium (Albania, Algeria, Greece, France, Israel, Morocco, Gaza Strip, Slovenia, Spain, Syria and Tunisia) and 5 countries as important (Croatia, Egypt, Italy, Turkey).

On the basis of the above, it was considered pertinent to prepare another assessment of the situation. In order to collect information for the preparation of the report, a questionnaire was sent to all Mediterranean countries. It was also sent to individual scientists and institutes. Through the questionnaire an effort was made to collect information on the eutrophication status in these countries as well as on the monitoring and criteria and assessment methodologies used.

The information was used:

- to produce a list of designated sites as eutrophic or being at risk to become eutrophic (including pressures),

- to examine whether eutrophication assessments are made or planned by Mediterranean countries for their national coastal waters including estuaries and lagoons,

- to identify eutrophication assessment methodologies and criteria that have been used or planned to be used and

- to describe the monitoring/research activities each country undertakes to support the assessments.

The information collected through the questionnaires was supplemented by a literature survey. Finally, data analysis was done (as to TRIX analysis) in a parallel cooperation with the experts who have developed the index.

A document entitled “Eutrophication Assessment of Mediterranean Coastal Waters” was prepared by experts on eutrophication from the Institute of Oceanography of the Hellenic Centre for Marine Research (HCMR), while Dr Franco Giovanardi undertook the TRIX analysis and the MOON partners have provided satellite data. The first draft of this study was presented to a small meeting of experts for comments and suggestions. This MED POL Workshop on Eutrophication Assessment and Monitoring (Anavissos, Greece, 5-6 Februry 2007) concluded that the draft assessment document would better serve as a review of monitoring strategies and assessment methodologies used in the Mediterranean. On the basis of this document a specific proposal could be formulated for a common Mediterranean methodology.

Finally, it was agreed that TRIX is an index of the trophic status and that its use as an indicator has not yet been evaluated or established.

The original document was revised, on the basis of the recommendations of the workshop, and is presented here entitled “Approaches to the assessment of eutrophication in Mediterranean coastal waters (first draft)”. The Review Meeting on Monitoring activities is expected to comment on the contents of the document and put forward ideas for its improvement. At the same time it is expected to discuss the specific proposal for harmonization of the monitoring strategies and assessment methodologies used in the Mediterranean.

2 OVERVIEW OF EUTROPHICATION ASPECTS IN THE MEDITERRANEAN ACCORDING TO THE DPSIR APPROACH

A. Information from literature survey

2.1 Drivers

In the Mediterranean, the main sources of nitrogen are the run-off from agricultural land and atmospheric deposition. Most of the phosphorus comes from point sources, urban and industrial wastewaters raw or poorly treated. Also, cage culture fish farming often causes eutrophication problems at a local level. Therefore, 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.

2.1.1 Population growth, urbanization, industrialization and tourism in coastal Mediterranean areas

In the Mediterranean, the development of urban centres, agriculture and industry has been often geographically interdependent, therefore pollutants including nutrients which, in general, were collected and discharged by rivers to the sea, are concentrated along limited coastal areas, thus increasing their negative effects. Due to this reason, it is often difficult to discriminate between sewage and industrial/agricultural discharge and diffused pollution, which are characterized by synergistic effects.

The population of the coastal states of the Mediterranean was 246 million in 1960, and 380 million in 1990 (EEA/UNEP, 1999). In 2000 the countries bordering the Mediterranean Sea had a combined population of about 430 million people (UNEP(DEC)/MED WG.228/Inf.7, 2003 Table 1). A considerable part of the population lives directly on the coastal zone. Especially in the southern countries, population densities are much greater in coastal than in non-coastal areas. Coastal population densities range from more than 1000/km^2 in the Nile Delta to less than 20/km^2 along coastal Libya.

According to some projections, the population in the Mediterranean is expected to reach about 520 million in 2025 (Attané and Courbage, 2001) and is expected to reach approximately 600 million in the year 2050 and possibly as much as 700 million at the end of the 21st century (EEA/UNEP, 1999). It is expected that by the year 2025 about 75% of the population will be urban. The economic and environmental burden on cities, therefore, will increase substantially.

During the seventies most coastal Mediterranean areas were discharging untreated sewage to the sea and the rest after only minimal treatment. The worst affected were the northern Mediterranean coasts, which were subjected to higher anthropogenic pressure. For example the Riviera coast from the Ebro River in Spain across the French Riviera to the Italian Riviera and the Arno estuary were found to be the most polluted coasts (to take in consideration that these were investigated in detail). The Israeli and Greek coasts were found in similar conditions (Danovaro, 2003). Though a strong effort was carried out in Italy, France, Spain and later in Greece and some positive results are obvious the last 10 years (for example: HCMR, 2005; 2006), problems still remain due to smaller agglomerations, which may have only minimal sewage treatment or not at all (sometimes due even to aesthetic reasons), and which during summer become tourist hot spots. Also the actual functioning of the treatment plants, in general, is under question, since often are not active or have a reduced efficiency.

Industrial activity is another driver in Mediterranean. In the EEA report on the state and pressure of the marine and coastal Mediterranean environment (EEA, 1999), a description of the industrial activities in the Mediterranean region is presented.

Tourism as already mentioned, could also be a strong pressure related to eutrophication. In coastal cities the population usually increases during the tourist season. Within the framework of MED POL, information was collected from several projects fully and partially completed on the sewage discharged from the main Mediterranean coastal cities (WHO/UNEP, 1996; WHO/UNEP, 1997). Although the information is incomplete and fragmented and covered only 68 out of 86 cities with more than 100,000 inhabitants about 33% of the population did not had municipal sewage treatment. However all the Mediterranean cities discharge their effluents, treated or not, into the marine environment using appropriately or not sewage outfalls.

Table 1. Population density and development in the Mediterranean countries (Source: UNEP(DEC)/MED WG.228/Inf.7, 2003)

	POPULATION				DENSITY	
COUNTRY	AREA	2000	2025	TREND	TOTAL	MED/TOT*
	(km^2)	Thousand inhabitants		%	Inhab./km^2	
SPAIN	504,783	39,815	40,769	+ 2.4	78	2.13
FRANCE	547,026	59,412	64,177	+ 8.0	103	1.20
ITALY	301,277	57,456	53,925	- 6.1	190	1.04
MALTA	316	389	430	+ 10.5	1145	1.00
MONACO	2	34	41	+ 20.6	15000	1.00
SLOVENIA	20,251	1,965	2,029	+ 3.3	100	0.57
CROATIA	56,538	4,473	4,193	- 6.3	87	0.68
BOSNIA-HERZEGOVINA	51,129	3,972	4,324	+ 8.9	87	0.58
SERBIA-MONTENEGRO	102,000	10,856	12,217	+ 12.5	104	0.55
ALBANIA	28,748	3,114	3,820	+ 22.7	113	1.29
GREECE	131,944	10,558	10,393	- 1.6	78	1.18
TURKEY	779,452	65,627	87,303	+ 33.0	72	1.28
CYPRUS	9,251				54	1.00
SYRIA	185,180	15,936	24,003	+ 50.6	77	4.23
LEBANON	10,230	3,206	4,147	+ 29.4	293	1.88
ISRAEL	20,770	5,851	7,861	+ 34.4	263	2.98
PALESTINE	6,165	3,150	6,072	+ 92.8	365	6.33
EGYPT	997,739	66,007	94,895	+ 43.8	59	3.54
LIBYA	1,759,500	6,038	8,832	+ 46.3	3	8.28
TUNISIA	154,530	9,615	12,892	+ 34.1	57	2.37
ALGERIA	2,381,741	30,332	42,329	+39.6	10	22.21
MOROCCO	710,850	28,505	38,174	+ 33 9	37	2.39
TOTAL	**8,759,422**	**426,311**	**522,826**			

* ratio of the population density on the Mediterranean part of the country over that in the entire country.

2.1.2 Agriculture

Non-point pollution from agriculture is related to that part of the Mediterranean Sea that drains into the Mediterranean Basin. The basins draining into the Mediterranean cover a total of about 1.9 million km^2 not counting the upper Nile basin and include 24 countries (UNEP/MAP, 1997). As the Mediterranean basin is receiving waters from the Black Sea there is also a remarkable effect of the Black Sea in the Eastern Mediterranean, mainly the Aegean Sea. The fluvial input of Black Sea into the Mediterranean sea is 210 km^3/year and 20 tonnes of pollutants per km^3 are carried through by the movements of the water masses (UNEP(DEC)/MED WG.228/Inf.7, 2003).

Surface water eutrophication, one of the major impacts of continental runoff in coastal waters, is attributed to a combination of urban sewage (50%), industrial waste (25%) and 25% agricultural activities (Rossi et al., 1992). Fertilisers can be disposed into the marine environment through the rivers or a non-point pollution. As agricultural activities, a number of farm practices are considered such as land use, irrigation, cultivation, pasturs, dairy farming and aquaculture. Water runoff resuspends sediment and carried into the marine environment nitrogen, phosphorus, metals, pathogens, salts and trace elements (UNEP(DEC)/MED WG.228/Inf.7, 2003).

2.1.3 Rivers

Information regarding discharges via rivers is also fragmented since not all rivers that contribute significantly to pollution inputs in Mediterranean (about 80) are monitored for all parameters. According to EEA/UNEP (1999), though the information is not well documented, the water inputs to the Mediterranean have decreased dramatically over the last 40 years, not only for the Nile (probably more than 90%) but also for many other rivers (20-30% reduction) due to damming and irrigation. The nutrient levels found in Mediterranean rivers are about four times lower than in western European rivers. In all documented cases, nitrate levels are increasing; the trend for ammonia is variable depending on sewage collection and treatment. Phosphate may increase dramatically as in Greece, or steadily as in France, or decrease when restriction measures are imposed as in Italy (EEA/UNEP, 1999).

The available data on the average nutrient concentrations in the Mediterranean rivers are presented in UNEP(DEC)/MED WG.228/Inf.7 (2003). More than 30 rivers are documented for nitrate with average values.

2.1.4 Aquaculture

The aquaculture production in Mediterranean increased from 78,180 tonnes in 1984 to 248,460 tonnes in 1996 (freshwater aquaculture not considered) according to EEA/UNEP (1999) mainly due to the development of cage technologies as in Greece.

In many cases interaction with the surrounding environment and its capacity to absorb this interaction is neglected. Intensive fish farming results in the production of waste, which can stimulate and distort productivity and alter the biotic and abiotic characteristics of the water body (oxygen depletion, sedimentation with benthic enrichment, stimulation of anaerobic mineralization rates, hyper-nutrification and eutrophication) (Wu, 1995; Kaspar et al., 1988; Holby & Hall, 1991). Also the accumulation of uneaten food and faeces induces conditions favourable to blooms of algae (including toxic species, as in Svensen et al, 2005, Varkitzi et al., 2005, Reizopoulou et al., 2004; 2005, Strogylloudi et al., 2006, etc) and fungi.

Despite mass balance calculations that show a loss of up to 20 and 50% of the supplied P and N respectively, to the water column, the pelagic environment appears to be relatively unaffected (Danovaro, 2003). This is likely due to the fact that at most aquaculture sites all wastes are rapidly diluted. Nutrient regeneration, sediment anoxia and stimulation of anaerobic conditions at the expense of aerobic processes beneath cages can enhance water column production, but may have negative impact to benthic infauna and pelagic organisms which have part of their life cycle close to sediment.

2.2 Pressures

Hereinafter, some information is given regarding nutrient loads for Mediterranean, which correspond to the Pressures of the DPSIR approach. However, it must be noted that there is no complete source apportionment (EEA, 2005) due to the fact that the information from the Mediterranean countries was limited and scattered. Therefore, the presented data can only be considered as examples.

The Adriatic Sea, the Gulf of Lions and the northern Aegean Sea are areas with relatively higher mean nutrient concentrations, higher primary and secondary production and, sometimes, local algal blooms related sporadically to hypoxic or anoxic conditions and rarely to toxic algal blooms (EEA/UNEP 1999). As it is obvious this phenomenon is related to the loads these areas are receiving. Discharges of nitrogen and phosphorus to the Adriatic region are of the order of 270,000 and 24,000 t, respectively. The north Aegean Sea receives annually 180,000 t nitrogen and 11,000 t phosphorus from the Black Sea, which is comparable with the inputs from land-based sources to the northeast of the Mediterranean Sea (EEA/UNEP 1999).

With a few exceptions, all river systems discharging in the Mediterranean Sea are small. The Rhône, Ebro and Po have catchment's areas extending to 96,000, 84,000 and 69,000 km^2 respectively. The discharge of freshwater from the main rivers is about 260 km^3 per year, whereas net inflow from the Black Sea amounts to 163 km^3 per year (UNEP(DEC)/MED/WG.231/14, 2003), so Black Sea can considered as a major river discharging in Mediterranean.

Large river basins like those of the Nile, the Rhône and the Po are subjected to agricultural pressures. In EEA/UNEP (1999) a list of the 50 largest rivers flowing to the Mediterranean Sea is given with the mean annual water flow and for some of the rivers also the mean concentrations of nitrate, ammonium and phosphate were given (see Table 3.8 in EEA/UNEP, 1999). The total estimated loads are about 304,000 ton/year N and 22,000 ton/year P.

2.2.1 Total nutrient loads

In UNEP/FAO/WHO (1996) an estimation of the total load is made on the basis of population density, fertilizer use, land use and livestock populations for three different scenarios. The calculations revealed that the most likely actual total nitrogen load from land based sources would lie within the range of 1.5 to 2.5 million tons, and that for phosphorus between 0.15 and 0.25 million tons per year. More recently in the reports "Identification of priority pollution hot spots and sensitive areas in the Mediterranean" (UNEP/MAP, 1999) and "State and pressures of the marine and coastal Mediterranean environment" (EEA/UNEP, 1999) new calculations revealed an underestimate for phosphorous (Table 2 corresponds to Table 1 in UNEP(DEC)/MED/WG.231/14, 2003).

Marine aquaculture has shown a large expansion in production in a number of Mediterranean countries over recent decades, and increases from 1,693 metric tons in 1970 to 131,493 tons in 1999 (finfish only). Since marine intensive aquaculture is a relatively new sector in the Mediterranean and concerns mainly shellfish and some fish species, the impact is - according to EEA/UNEP (1999) - still rather limited and localised. Never the less the nitrogen load from marine fish farming, at least locally is a major nutrient source which can cause eutrophication effects (Table 2).

Table 2. Nutrient loads to the Mediterranean Sea from agriculture and aquaculture in t y^{-1}. (Source: Agriculture (EEA, 1999); mixed (domestic + industrial) UNEP/MAP, 1999; Aquaculture: data calculated from FAO database applying the formula used by Ackefors & Enell (1990). The relation between food and biomass is expressed by the Food Conversion Factor (FCR=kg of food/kg of living biomass), for which a mean value of 1.5:1 was applied for all countries**.)**

	P	**N**	**C**	**BOD**	**COD**
Agriculture	976,000	1,570,600	16,941,000		
Mixed	75,234	259,691		804,244	1,729,853
Aquaculture	394	8,678	38,225		

2.2.2 Atmospheric deposition

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.

According to EEA (2005) the annual deposition of oxidized nitrogen (NOx) is 1–10 kg/ha (EMEP), being highest in the centre of Western Europe around Germany and lowest in northern Scandinavia, where it may even be below 1 kg/ha. The deposition of ammonia nitrogen is of the same order of magnitude, and it is highest in regions with high livestock densities. For comparison, agriculturally intensive countries typically apply 40–70 kg/ha of nitrogen fertilizer as an average for the whole country. However, an estimation regarding southern Europe and Mediterranean is not given, probably due to lack of relevant consistent data and calculations.

The proportion that falls directly on the surface of inland or marine water is assessed separately in several source apportionments. It is often very small compared with other sources, but in lakes with a large surface area compared with the total catchment, or in coastal or marine waters, it may constitute a significant part of the total inputs. According to EEA (2005) atmospheric deposition constitutes about 25% of the total input to the Baltic Sea, about 10% of the input to Lake Peipsi, and about 3% of the input to the Bodensee.

The deposition of phosphorus is generally small and difficult to estimate. Previous estimates in Europe range from 0.05 to 0.50 kg/ha. For comparison, agriculturally intensive countries typically apply 8–13 kg/ha of phosphorus fertilizer as an average for the whole country.

However, some information exists for wet deposition fluxes of inorganic nutrients (PO_4^{3-}, NO_3^-, NO_2^-, NH_4^+) 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). The collected individual rainwater events represent 70-80% of the total annual precipitation. Recently, Herut (2005) in UNEP(DEC)/MED WG.282/Inf.3 (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.

Recently in the report UNEP(DEC)/MED WG.228/Inf.7 (2003) more information is given regarding N and P deposition in Mediterranean. It is characteristic that total NOx, NH_3 and total N emission in the Mediterranean region are 1,800, 2,300 and 4,200 kt N in 1999, so that

NH_3 and NOx accounted for 57% and 43% of total N emissions in the Mediterranean region. These emissions account for 14%, 36% and 24% of respective emissions in whole Europe indicating that the Mediterranean region is a significant contributor to the total European emissions, particularly for NH_3.

Table 3 below summarizes the estimated average wet, dry and leachable (soluble) inorganic N and P atmospheric fluxes over the SE Mediterranean based on long term measurements (Herut, 2005).

Table 3. Inorganic N and P atmospheric fluxes over the SE Mediterranean, (Source: Herut, 2005).

Nutrient **mmol m^{-2} yr^{-1}**	**Dry**	**Wet**	**Bioavailable**
N	50	20	~70
P	1	0.3	~0.7

B. Information from countries

Information for drivers and pressures/loads, state and impacts was also received from the questionnaires completed by countries and from the reports on the pilot monitoring programmes on eutrophication

- **Albania**

Sites: Albanian experts reported 7 sites as sensitive, thus being at risk to become eutrophic, namely: Drini bay, Rodoni bay, Karavasta bay, Ishmi estuary, Buna estuary, Drini estuary and Semani estuary.

Drivers/Pressures: In all these 7 sites the pressures defined were nutrient inputs (P and/or N) and organic matter inputs from diffuse sources. No report or any other more specific information was delivered regarding pressures and loads, nor if reference sites were assigned. They also reported in a second response to the questionnaire that they monitor in 7 sampling sites (5 in the Adriatic sea and 2 in the Ionian sea) without any more information on pressures, or if these sites are different or not from the previously reported.

State/Impact: The impact criteria used are chlorophyll-a concentrations, dissolved oxygen and nutrients; in some cases, hydrocarbon concentrations and HAB occurrences (as Rodoni bay). No other information is given regarding reference values or thresholds for these parameters.

- **Cyprus**

Sites: Cyprus reported 2 sites as type A2 (at risk to become eutrophic).

Drivers/Pressures: The coastal waters of Cyprus are classified as ultra-oligotrophic, since concentrations of nutrients are very low. Excess loading of nutrients from various anthropogenic activities, such as aquaculture, agriculture, sewage, etc. in this sensitive marine environment can cause a negative impact to the ecosystem, which may potentially lead to eutrophication. In the last 15 years, episodic eutrophication events with the proliferation of ephemeral macroalga *Cladophora spp*. were observed in the summer of 1990, 1991, 1998, 2004 & 2005 in both reported coastal sites, causing some nuisance problems. However, due to the sensitivity of the marine ecosystem in nutrient inputs, a monitoring programme related to eutrophication parameters is carried out.

a) *Site 1*: This site is located in the south region of Cyprus and is a popular touristic site. Within this area two aquaculture units are established: an offshore tuna ranching farm, which is located at about 35m depth and has a licence to produce 1,000 tons/yr and a fish farm, whose cages moored on the seabed at about 17m depth and has an annual production of 700 tons.

b) *Site 2*: This site is located in the east region of Cyprus and is adjacent to a touristic city. An aquaculture company, which includes an offshore fish farm and a hatchery, is situated in the area. The fish farm has a licence to produce 500 tons/yr seabream and seabass and its cages are moored at about 25-30m depth. The hatchery is an intensive land-based unit producing about 7,500,000 fry of the fish species seabream *Sparus auratus* and seabass *Dicentrarchus labrax* of about 1g weight.

State/Impact: Impact from nutrient inputs, in Cyprus coastal areas, is evident to the benthic ecosystem; therefore, impact criteria are the periodic occurrence and proliferation of the green macroalga *Cladophora spp*. and the compositional changes of rocky mediolittoral macroalgal communities. Regarding threshold values, these were not defined for the water column parameters (nutrients, chlorophyll, dissolved oxygen) since there are no significant changes in comparison to values from reference sites.

- **Egypt**

Sites: Four eutrophic sites were reported (El Mex, Abu Qir East, Port Said, Abu Qir Bay) and three sites at risk to become eutrophic (Alexandria eastern harbour, Rashid, Damietta), a lot less than those reported in UNEP/FAO/WHO (1996).

Drivers/Pressures: Cases of acute eutrophication in the Egyptian waters are reported mainly from the ports and coastal waters off Alexandria, and from the lagoons in the Nile delta for several decades (UNEP/FAO/WHO, 1996). Overall, eutrophication and the worsening of water quality (abnormal water colours, anoxia in bottom waters and production of hydrogen sulphide) in Egyptian coastal and brackish waters are caused by the combination of: (a) large inputs of fertilizing substances from urban, agricultural and industrial sources; (b) the long water residence times in the lagoons, partly due to physical barriers; (c) salinity stratification of the waters; (d) generally high water temperatures.

a) *El Mex:* El Mex is situated at the western part of Alexandria Area. El Mex receives water from the heavily polluted lake Maryut, into which many industries discharge their wastewater, and domestic sewage from residential areas.

b) *Abu Qir East*. It is an industrial area and receives also domestic sewage. The industries contribute markedly to the marine pollution by the discharge of hazardous effluents.

c) *Port Said*. Port Said is situated at the mouth of the Suez Canal. There are resort areas with bathing beaches. The major source of marine pollution is sewage discharged into Lake Manzala, which is connected to the Mediterranean Sea west of Port Said. Polluted water from the lake may be transported along the beaches of Port Said by the prevailing east-going currents. There is also a shipyard and a number of plants discharging wastewater. The seabed off Port Said is sandy. Along the coast there is a high abundance of *Donax* mussels that are exploited by fishermen. The abundance of *Donax* seems to increase in areas near sewage outlets (such as Alexandria, Rashid, Damietta and Port Said). *Donax* seem to be a suitable monitoring organism for toxic substances.

d) *Abu Qir Bay*. The Abu Qir Bay is also heavily polluted and there is an outlet at the Tabia pumping station. This outlet receives water from agricultural drains and wastewater from textile mills.

e) *Alexandria eastern Harbour*. Alexandria harbour is a fishing port and receives effluents from boats and domestic sewage. Also it receives an amount of discharges from shipyards.

f) *Rashid*. Rashid is a popular tourist city, mainly visited by Egyptians. There are many brick factories in the area and they use bunker oil. The marine waters off the Rosetta branch receive Nile water contaminated with hazardous industrial waste, domestic sewage, fertilisers and pesticides from agricultural activities. The water also contains wastewater from a pesticide plant at Kafr el Zaiyât in the Delta.

g) *Damietta*. This is the second branch of the Nile River. The major sources of marine pollution in the area are: water from the Damietta branch of the Nile contaminated with hazardous industrial waste, domestic sewage as well as fertilisers and pesticides from agricultural activities, domestic sewage from the residential and the resort areas and oil from ships. Tar balls on the beach at Ras el Bar were observed.

State/Impact: Parameters-indicators for state and impact of eutrophication in Egyptian coastal waters are nutrients and chlorophyll and dissolved oxygen concentrations respectively. Threshold values marking eutrophication for the above parameters are defined: for ammonium >2μmol l^{-1}, for nitrate >4μmol l^{-1}, for chlorophyll-a >1.99 μg l^{-1} and for dissolved oxygen <4mg l^{-1}.

- **France**

Sites: In the Mediterranean coastal area 2 lagune complexes were assigned as eutrophic sites: The Palavasians Lagoons and The Or lagoon.

Drivers/Pressures:

a) Etangs Palavasiens (The Palavasians Lagoons). It is a complex of seven lagoons (Ingril, Vic, Pierre-Blanche, Prevost, Arnel, Mejean-Perols and Grec), which extent in a length of 25 km behind the sand barrier from Frontignan to Palavas (Herault). These lagoons receive water inputs from the river basins (600 Km^2) of Lez and Mosson (east) and from the karstic area of Gardiole. Only two of the lagoons (Ingril and Prevost) have a direct and constant communication with the sea, through an outlet. The Rhône channel in Sête, which is going across the complex from east to west, has passages to every one of the lagoons and constitutes a real hydraulic way of communication for these enclosed lagoons. The observations performed in the riverine waters, the channels and the lagoons of the Palavasian complex confirmed the importance of the pollution state regarding N and P. This pollution has a domestic origin mainly, which clearly demonstrate the important contribution of river Lez. The Rhône canal in Sête enriches with N the lagoons surrounding it, and this influence diminishes towards the Ingril lagoon.

b) L'etang de l' Or (The Or lagoon), is a "huge" lagoon with a length of 11 km and a width of 3 km, bordering to the south with the Rhône canal in Sête, communicating with it through five passages. It has a surface of 410 km, which is occupied by 31 communities with a permanent population of 125,000 inhabitants. However, during summer the population reaches 250,000 inhabitants, due to the tourist development in Grande-Motte et de Carnon. The urban surface represents the 13% of the basin, which is mainly occupied by agricultural areas (>50% of the surface). The dominant cultures are vineyards, cereals, and fruits. In the last 25 years, continuous eutrophication processes have degraded seriously the Or lagoon.

In addition, a dominant population of polychaetes that construct calcareous tubes, whose development depends on eutrophication, are destroying the lagoon.

State/Impact: As state parameters they monitor parameters of the water column (total N, total P, ammonium, turbidity) and sediments. As impact criteria they refer to phytoplankton (chlorophyll-a, phaeophytin-a, phytoplankton population), macrophytes, macrofauna, and disolved oxygen for both eutrophic areas (Palavasians lagoons and the Or lagoon). Reference values and thresholds between classes for these parameters, in the framework of a eutrophication assessment scheme according to WFD classification, are provided (see chapter 5 and IFREMER, 2006).

- **Greece**

Sites: The trophic state of the open seawaters of the Eastern Ionian and Aegean Seas can be defined as oligotrophic (Friligos 1986a; Boussoulengas & Catsiki, 1989, Gotsis-Skretas *et al*., 1999; Siokou-Frangou *et al*., 2002; Ignatiades *et al*., 2002). Despite the above, eutrophication problems have been recognized in a number of coastal areas characterized as enclosed or semi-enclosed with poor water exchange, affected by urban and industrial waste-waters and/or nutrient inputs from rivers and agricultural activities (Pagou, 1990; Pagou & Ignatiades, 1988, 1990; Gotsis-Skretas, 1995).

The most disturbed Greek coastal areas, regarding anthropogenic nutrient enrichment, are the Saronikos and Thermaikos Gulfs situated in Central and Northern Aegean Sea, respectively, however other eutrophic or at risk to be eutrophic areas have been reported: Amvrakikos Gulf, Messolonghi lagoon, Pagassitikos Gulf, Gulf of Kavala, Gulf of Alexandroupoli, Araxos lagoon, Argolikos Gulf, Gulfs of Geras and Kalloni in Lesvos island.

Drivers/Pressures:

a) *Saronikos Gulf*: Saronikos Gulf (mean depth ~100m) was impacted by untreated sewage for more than 30 years from the metropolitan Athens (up to 3 million inhabitants during that period) discharged in the surface of its northern part, by a surface outfall (in Keratsini Bay). The industrial effluents from the Elefsis Bay (a shallow semi-enclosed area to the north of Saronikos Gulf) contributed also to the pollution of Saronikos. Elefsis Bay was the most industrialized area of Greece, where anoxic conditions near the bottom were recorded every summer. As from the summer of 1994, Saronikos Gulf receives the primary treated effluents (domestic and industrial) from the Psittalia Treatment Plant, through an outfall positioned at 60 m depth.

b) *Thermaikos Gulf*: The Inner Thermaikos Gulf (mean depth ~30 m) on the other hand and especially its northern part (Bay and Gulf of Thessaloniki) are the marine receptors of urban and industrial wastes from the city of Thessaloniki, along with agricultural effluents from the adjacent land, which includes drainage basins of rivers, streams and channels discharging in Thermaikos Gulf. At the same time in Inner Thermaikos Gulf several fishing practices and aquacultures (the most important aquaculture ground of Greece) exist together with recreational and touristic activities concentrated along its coastline. The western coast of the Inner Thermaikos Gulf is influenced by three major river estuaries (Axios, Loudias, Aliakmon). The riverine inflow of large amounts of freshwater enriched in nutrients (from agriculture run-off) and matter through these rivers determines significantly the trophic condition in the ecosystem. In fact, this inflow is the second most serious (after sewage) impact for the coastal environment of the Inner Thermaikos Gulf. However, from June 2000 a treatment plant with an outfall discharging at a depth of 25 m started operating in the northern part of Thermaikos including biological treatment of the influents. Load removal efficiency of the treatment plant has reached 90% for nitrogen and 50% for phosphorus.

c) *Amvrakikos Gulf*: This narrow-mouthed bay on the Ionian Sea coast is an important breeding area for fish and invertebrates of valuable species. From the eighties this area has shown signs of deterioration because of the excessive inputs of eutrophying substances, generally from sewage outfalls and agricultural effluents (Pagou, 1990). High levels of nutrients (silicates and nitrates in particular) are carried into the north of the lagoon by the Arachthos River (Friligos and Balopoulos, 1988).

d) *Lagoon of Messolonghi* (Gulf of Patraikos). Data obtained during 1983-84 (Friligos, 1986b) demonstrate that conditions of anoxia frequently occur in the northernmost part of the lagoon during the summer season. The nutrient concentrations are generally high, with the highest values in the area close to the town outfalls.

e) *Gulf of Pagassitikos*. High trophic levels are found in the northern area of the Bay of Volos. The nutrients come mainly from the city of Volos, rivers and industrial facilities.

f) *Gulf of Kavala*. Although the trophic levels are generally lower than in the other areas mentioned, sporadic algal blooms are recorded, thus the gulf may be at risk to be eutrophic due to anthrpogenic activities.

g) *Gulf of Alexandropoulis*: (Northeast of the Aegean). Receives nutrient inputs from the Evros River and agriculture.

h) *Araxos lagoon* (NW Pelloponesos, Patraikos Gulf). Breeding-feeding grounds for fish and shellfish, influenced by agricultural wastes, poor water circulation and overfishing.

i) *Argolikos Gulf:* Enclosed shallow gulf in E. Peloponessos, Central Aegean Sea, receiving sewage (treatment plant exists), agricultural and industrial effluents.

j) *Gulfs of Geras and Kalloni in Lesvos island*: Shallow enclosed bays receive agricultural wastes (point and diffuse sources) and sewage; fisheries activities, shellfish harvesting.

<u>State/Impact</u>: State parameters are iiinorganic nutrients in seawater. Chlorophyll-a concentrations, phytoplankton total population and group abundances, shift in dominant species, HAB occurrences, changes in N/P ratios, etc. are used as impact parameters. Reference values that coincide with background concentrations (as defined in oligotrophic coastal waters) have been assigned, whereas threshold values between trophic statuses also have been calculated and are currently in use. Reference values for chlorophyll-a are 0.1μg l^{-1}, for phytoplankton $6X10^3$ cells l^{-1}, nitrate 0.62μM, phosphate 0.07 μM and ammonia 0.55 μM (Ignatiades et al., 1992; Karydis, 1999).

a) *Saronikos Gulf*: (Data and results according to Pagou et al., 2002; 2005) Chlorophyll-a values are 2 to 10 times higher than reference values and phytoplankton abundance up to 100 times higher. For the Saronikos Gulf, eutrophication trends (20 years long time series) did not have a consistent character, since a different trend was detected for nutrients (eutrophication causative) when compared to chlorophyll (eutrophication result). Among nutrients, nitrates and recently phosphates revealed a clear increasing trend, whereas chlorophyll-a a more or less decreasing trend. The observed increasing trends of nutrients can be explained by the increase of the discharge volume. Probably, entry from the atmosphere should also be considered (Carpenter *et al*., 1998). On the other hand, no favourable relative concentration ratios in the sewage area (N/P, Si/N, Si/P) were observed, or even light limitation, since sewage is discharged at a greater depth than before 1994, should also be encountered. After 1995 dramatic changes occurred: no significant phytoplankton bloom have been reported and this can be attributed to the lowering of the trophic status of the most eutrophic areas (from eutrophic to high mesotrophic) due to the operation of the new waste treatment plants. However, according to recent data (1998-2004), minimum values (annual means) of N/P ratios (5-9) were found in areas near the sewage outfall in Saronikos Gulf after 1995. The ratio increases with distance from the outfall (14-18) and remains close to the theoretical value of 16 (Redfield ratio), due to the decrease of phosphates. Time series analysis of N/P ratio (1987-2004) showed a significant increasing trend in all areas except the one where the outfall discharges.

b) *Thermaikos Gulf*: (Data and results according to Pagou et al., 2002; 2006) Chlorophyll-a values are 10 to 40 times higher than reference concentrations. Trend analysis of nutrients and chlorophyll time series (from time series longer than 10 years) from the Thermaikos Gulf revealed also some important features. Nutrients and chlorophyll-a concentrations showed a general decreasing trend during the last years, according to the trend analysis performed in time series data from 1993 to 2000. These decreasing trends were often statistically significant.

On the other hand in the Thermaikos Gulf the frequent diatom blooms observed before 1996 changed to even noxious dinoflagellate blooms (as the toxic *Dinophysis acuminata*) that can be related to the very low N/P ratios recorded at the northern part of Inner Thermaikos gulf, the site where usually the exceptional blooms started.

- **Italy**

Sites: In Italy, episodic eutrophication events occur with the exception of NW Adriatic, where serious eutrophication is well documented. However, several eutrophic and reference sites have been reported in Liguria (3), Emilia Romagna (4), Marche (2), Veneto (2), Friuli-V Giulia (3), Campania (4), Toscana (2) and Lazio (2).

Drivers/Pressures:

Liguria. Though in general eutrophication is not an issue for Ligurian sea, two sites have been identified as eutrophic and one as reference site:

a) *Foce Torrente Lerone*. Pressures identified are urban wastewater discharges and organic inputs from industries (especially food industry). Pollution is also coming from the harbour area of Genova.

b) Marinella - Foce Magra. Pollution comes from the harbour area of La Spezia. Discharges of domestic and industrial wastes. Organic inputs from aquaculture activities. Dump areas.

c) Punta Mesco-Parco 5 Terre. Reference site

Emilia Romagna: Phenomena of eutrophication with distribution and persistence much greater than in any other case, that have occurred in other parts of the Mediterranean, have occurred and continue to occur in the coastal waters of Emilia-Romagna to the South of the Po delta from 1969 (Rinaldi and Montanari, 1988). For MED POL, 3 eutrophic sites and one reference site were identified.

a) *Lido Adriano*. Nutrient inputs from the Po River as well as from other coastal discharges

b) *Cesenatico*. Nutrient inputs from the Po River

c) *Porto Garibaldi*. Nutrient inputs from the Po River

d) *Cattolica*. Reference site

Marche: UNEP/FAO/WHO (1996) reported this area as oligotrophic. However, one eutrophic and one reference site have been reported.

a) *Foglia*. Nutrient inputs from Po river and Foglia river.

b) *Conero.* Reference site

Veneto: Severe eutrophication has been reported during the past decades (see UNEP/FAO/WHO, 1996).

a) *Porto Lido Nord (Cavallino).* Nutrient (P and N) and organic inputs from aquaculture. Human activities including tourism and densely populated coastline.

b) *Porto di Chioggia (Ca Roman).* Reference site

Friuli-V Giulia: Also part of the eutrophic N. Adriatic. Pressures here include aquaculture and other agricultural practices besides urban wastewater and industrial discharges. Two eutrophic sites and one reference site are reported.

a) *Duino-Baia di Panzano*. Organic inputs from aquaculture activities. Pollution coming from the harbour area of Monfalcone.

b) *Porto Nogaro*. Nutrient (P and N) inputs and organic from aquaculture and zootechny. Urban wastewater discharges. Pollution from industries (especially food and chemical industries).

c) *Miramare*. Reference site.

Campania: UNEP/FAO/WHO (1996) had reported serious deterioration of water quality from literature dated back to the 1980s.

a) *Foce del Sarno*. Discharges of domestic and industrial wastes from Sarno River (which is highly polluted) as well as discharges from agriculture activities.

b) *Napoli Piazza Vittoria*. Nutrient and organic inputs from under-sized, malfunctioning civil sewers (where these exist). Pollution coming from the harbour area of Napoli

c) *Portici Pietrarsa*. Nutrient and organic inputs from under-sized, malfunctioning civil sewers (where these exist). Pollution coming from the harbour area of Napoli

d) *Punta Licosa*. Reference site

Toscana:

a) *Fiume Morto*: Nutrients transported by the Arno river, which are due to agricultural activities. Urban wastewater discharges from Firenze and Pisa.

b) *Elba nord*. Reference site

Lazio:

a) *Fiumicino*. Nutrient (P and N) inputs from agriculture and zootechny transported by Tevere river. Urban wastewater discharges

b) *Zannone*. Reference site

In summary, Italy reported 14 eutrophic sites or being at risk to become eutrophic distributed in 8 regions, whereas a reference site was assigned in each region.

State/Impact: Information on parameters related to eutrophication is reported but no distinction is made between state or impact or supporting physicochemical parameters. So there is no information about criteria, thresholds or reference values regarding Italian coastal areas.

- **Lebanon**

Except for some eutrophic port areas where occasional blooms may occur, no eutrophic conditions are reported in the coastal waters of Lebanon. In general, these waters are oligotrophic, with limited seasonal fluctuations in autotrophic biomass featuring increases in spring and reductions in the hot season. However, in response to the questionnaire, three sites were identified as eutrophic (Antelias, Ramlet el Baida, Saida) and one reference site (Naqoura, Sud du Liban). No other information was given, especially regarding pressures.

- **Morocco**

Sites: One marine site was characterized as at risk to become eutrophic, Estuaire de Oued Martil a Tetouan, with reference site, Site de Kaa Srass. Also a eutrophic lagoon was reported, Lagune de Nador and reference site Cap de l'eau.

Drivers/Pressures:

a) *Estuaire de oued Martil*. This estuary is situated in the coastal zone of Tetouan. The Tetouan region is considered as a heavily populated that undergoes a very rapid evolution, higher of that of the whole Morocco. This development is accompanied by a parallel industrial. The urban and industrial wastes are discharged mainly in the estuary waters resulting in a negative impact for both the estuarine zone and the marine waters. The maximum nitrate concentrations recorded ranged between 400-500 μg/l. Also coliforms bacteria concentrations increased. According to most studies realized in the area, the Estuary of Martil is considered to be at risk of being eutrophic.

b) *Lagune de Nador.* The Nador lagoon is considered to be the largest lagoon of Morocco (11,500 hectares); it is situated to the littoral Mediterranean area in the NE part of the country (Morocco). It communicates with Mediterranean through a channel named 'Boukhana' which has a length of 24 km. The maximum depth of the lagoon in the central part is 7 to 8 m.

The urban development in the Nador area reached a population density of 120 inhabitants/km^2. The city developed according to a rapid and anarchic way. The industrial sector is also developed in the same way mainly consisting by a complex of steel industry. These activities contribute in a great proportion to the pollution of the lagoon through the urban and industrial wastes discharged to it.

The studies performed in the lagoon showed that certain areas of the lagoon present problems of eutrophication mostly in the edges of the lagoon (Beni Ansar and Kariat Arekman) and in the continental strip.

State/Impact: For Estuaire de oued Martil a Tetouan, the impact criteria are elevated counts of coliforms and increased concentration of nutrients (N, P). Coliforms counts must be lower than 6000 CF/100g of shellfish tissue.

For Lagune de Nador the impact parameters are occurrence of phytoplankton blooms (dinoflagellates), occurrence of toxic events (PSP, DSP), elevated counts of coliforms and increased concentration of nutrients (N, P). Thresholds, for PSP < 80µg toxin/100g shellfish tissue, for DSP negative).

- **Palestine**

Sites: Two sites were reported Wadi Gaza and Gaza Bay.

Drivers/Pressures:

a) The coastal area of *Wadi Gaza, Gaza Strip*. No pressures were reported; the area was characterized as eutrophic (A1).

b) *Gaza Bay*. No information regarding pressures, the area was characterized as at risk to become eutrophic

State/Impact: Disolved oxygen, salinity, pH, loss of marine fauna. No thresholds are defined.

- **Slovenia**

Sites: Slovenia reported 3 sites as eutrophic (Koper Bay, Rizana estuary and Seca Fish/Shellfish area) and 3 corresponding reference stations, located 3 miles offshore.

Drivers/Pressures: UNEP/FAO/WHO (1996) reported that in the Slovenian coastal area periodical near-anoxia or even anoxia (eg in 1983; Faganeli et al., 1985) events were related to the regional trophic state combined with the establishment of unusual oceanographic conditions (marked deep pycnocline, absence of "bura" wind), rather than to local sewage disposal influence (eg Malej, 1993).

The Gulf of Trieste (max depths 20-25 m), which extends to the coastal area of Slovenia, is the northernmost part of the Adriatic Sea with an approx. surface area of 600 km^2 and volume of about 9.5 km^3. The bays of Koper and Piran are the wide submerged valleys of the rivers Rižana and Dragonja, respectively. The hydrological characteristics of the Gulf of Trieste are influenced by inflowing Istrian waters of southern origin and freshwater inputs mainly from the Friuli Plain and the Karst. The general circulation pattern in the Gulf of Trieste is counter-clockwise and is modulated by local winds, tidal currents, density currents and inertial effects. Temperature ranges between 6-26^{o}C and thermal stratification is reported from May through September. Water column stability may be enhanced by density stratification due to differences in salinity (32 to 38.5 psu). Various economic activities have developed over roughly 80 % of Slovenia's coastline (Port of Koper, chemical and food industries, agricultural activities, tourism, marinas). The Bay of Koper is a small shallow bay (16 m), with fairly high sedimentation rates, and pollution loading (sewage).

a) *Koper bay:* It receives loads from rivers and Waste Water Treatment Plant of Koper, which discharge domestic and industrial wastes; is an enclosed coastal bay, shallow (< 20 m depth) with limited water recycling;

b) *Rizana estuary*: Receiving loads from WWTP Koper - discharge of domestic and industrial wastes; shallow and narrow estuary; small flow rate

c) *Seca fish/Shellfish area*

State/Impact: In their response to the questionnaire they refer to state/impact indicators: the chlorophyll-a concentration, nutrients, dissolved oxygen and Harmful Algal occurrences, without reference or threshold values.

However, Turk et al. (2005) give ranges of nutrients and phytoplankton parameters: Nitrate values range from 0.2 to 20.0 μmol/l. The highest value, up to 38 μmol/l, was recorded at a station in the middle of the Bay of Koper (Turk et al. - yearly reports of NMPSlovenia, Turk et al. 2001, Mozetič et al. 2005). Concentrations of orthophosphate are generally low and the highest are below 0.5 μmol/l. Enrichment experiments proved that phosphorous has been the primary limiting element for the growth of phytoplankton and bacterioplankton in the Gulf of Trieste (Cauwet et al. 1999, Fajon et al. 1999, Malej et al. 2003).

Mean water column chlorophyll-a is between 1.0 and 1.37 μg /l over the past 14 years (1989 – 2002) with chlorophyll *a* concentration variations from 0.2 to 8.8 μg Chl *a*/l. Although phytoplankton biomass increased gradually from 1993, it dropped below 1 μg/l again in 2000 and the years 2001 and 2002 did not differ significantly from the period 1989-1991.

From the above is obvious that rather moderate eutrophic phenomena occur in the study areas due to nitrate enrichment. In fact the most consistent eutrophication effects (Turk et al., 2006) are a shift in algal species composition and an increase in the frequency and intensity of nuisance algal blooms. Over the last 18 years, a shift from red tides to mucilage phenomena was observed. Almost every year mucilage phenomena appeared as marine snow and microflocs or as dense cobweb, clouds, blankets or creamy/gelatinous layer (Precali et al., 2005).

The presence of *Dinophysis spp.* was first recorded in 1984 (Fanuko et al., 1989), the next DSP outbreak in Slovenia was recorded in the autumn and winter of 1989 (Sedmak & Fanuko, 1991). The regular appearance of toxic dinoflagellates has been recorded over short time periods in the Gulf of Trieste (Honsell et al. 1992; 1996; Honsell, 1993; Mozetič et al. 1997, Cabrini et al., 1992). A longer series of data was evaluated for the period from 1995 to 2003 (Francé & Mozetič 2006), showing the seasonal distribution and inter-annual evaluation of the most recurrent *Dynophysis* species.

The other most frequent massive plankton events in the northern Adriatic, as well as in the Gulf of Trieste, were outbreaks of large jellyfish, which may have a significant impact on fisheries, tourism and the food web trophic structures (Malej, 2001).

Another serious manifestation of eutrophication is oxygen deficiency. Periods of oxygen depletion below the thermocline have been observed almost every year in the Gulf of Trieste (Faganeli et al., 1985; Stachowisch 1984; Herndl 1988; Malej et al. 1989; Stachowisch et al.1990; Fanuko & Turk, 1990, Malej and Malačič, 1995). In the last two decades, hypoxias have been occurring in the central part of the Gulf of Trieste in the late summer or in early autumn (August-October) (Malej and Malačič, 1995).

Finally regarding phytobenthos it must be mentioned that the polluted areas are limited to small local areas, but characterized by reduced associations or even a monoculture of *Enteromorphetum compressae* (Vukovič, 1982).

- **Spain**

<u>Sites:</u> Localised events of eutrophication in the Mediterranean coasts of Spain have reported in several cases (as example see literature cited in UNEP/FAO/WHO, 1996). In the framework of MED POL strategy for eutrophication, Spain nominated Laguna Coster del Mar Menor as eutrophic, in the Region de Murcia.

<u>Drivers/Pressures:</u> This lagoon is one of the largest lagoons in Europe and the largest in Spain. Pollution sources are sewage, ports, etc. Main pollutants are nutrients and especially nitrates resulting in eutrophication. No information was provided regarding estimation of nutrient loads.

State/Impact: However, there was not provided information regarding the state or impact parameters (concentrations of nutrients, chlorophyll, algal blooms, dissolved oxygen in the lagoon) they are using and the criteria and thresholds or reference values.

- **Syria**

Sites: The reported sites being at risk to become eutrophic are:

Drivers/Pressures:

1) *Port de Peche et de plaisance de Lattaquie*. A semi-enclosed site receiving nutrients and organic material.

2) *Port de commerce de Lattaquie*. A semi-enclosed site receiving nutrients and organic material.

3) *Sites where sewage outfalls discharge*. Nutrients and organic material loads.

4) *River Al-Kabire Al Chimali estuary*. Nutrients and organic material loads

5) *Other coastal estuaries in Syria*. Nutrients and organic material loads

A fixed reference site exists. According to available data a trend to become eutrophic is detected to all above-mentioned sites.

State/Impact: Nutrient concentrations are state indicators; impact indicators are elevated chlorophyll and decrease of dissolved oxygen concentrations. Regarding threshold values they did not define, since they do not have quite long time series of the relevant parameters in order to calculate with precision.

- **Tunisia**

Sites: One eutrophic marine site (Lac de Bizerte) and three marine sites at risk to become eutrophic (Golfe de Tunis, Golfe de Gabes, Estuaire Hergla) were reported with reference sites in Cotes de Sfax and Baie de Tunis. There were also reported three eutrophic lagoons (Lagune Bougrara, Lagune Ghar Elmehl, Lagune de Bizerte) and two lagoons at risk to become eutrophic (Lagune de Kheniss (Monastir), Lagune El Biban).

Drivers/Pressures:

Les côtes de Sfax: This area is heavily urbanized due to the city of Sfax and also is polluted by industries situated in the coast. Also is an area of important maritime traffic. The principal industrial activity is the phosphorus treatment and is implanted near the coast. The PO_4^{3-} concentrations in the marine environment are high (1.3 mg/l). During 1994, a spectacular phenomenon was recorded, massive deaths of fishes due to toxic phytoplankton species.

Baie de Tunis (Golfe de Tunis). The Gulf of Tunis is considered one of the most important of Mediterranean. It is an enclosed gulf where the urban agglomerations around the Lac de Tunis have caused a serious eutrophication. Several biological studies have been performed including the use of TRIX.

State/Impact: Different impact parameters/criteria and threshold values according to the water type are presented. Thus, for the eutrophic coastal marine sites regarding Golfe de Tunis the state/impact parameters are nutrients and occurrence of toxic algae, whereas threshold for chlorophyll is defined as range 3-6 mg m^{-3}. For Golfe de Gabes and the cotes de Sfax (reference site) nutrients, coloured waters due to cyanophytes permanent from 1988, occurrence of toxic phytoplankton and marine organisms kills, decrease of diversity and degradation of community, whereas thresholds are put on 5-9 mg m^{-3} for chlorophyll, 0.2-0.9 µM for orthophosphate and monitoring of occurrence of five toxic species. For Hergla estuaire, the Bougrara lagoon (thresholds: 0.3-0.5 µmol l^{-1} for nitrate and 1-1.2 µmol l^{-1} for phosphate) and the Ghar Elmelh lagoon (thresholds: 1.3-3.1 µmol l^{-1} for nitrate and 1-2 µmol l^{-1} for phosphate), impact parameter is defined the presence of toxic phytoplankton and marine organisms mortality. For the shellfish area in Lac de Bizerte impact indicator is the presence of toxic phytoplankton, whereas for Bizerte lagoon state/impact criteria are the nutrient concentrations, the presence of toxic phytoplankton and the mortality of marine organisms with thresholds defined at 6 g m^{-3} for dissolved oxygen, 12-32 g m^{-3} for nitrate, 10 mg m^{-3} for phosphate and 4-6.5 mg m^{-3} for chlorophyll.

- **Turkey**

Sites: Open marine waters of Turkey generally present conditions of oligotrophy; only in limited costal areas affected by the inputs of rivers, sewage outfalls or industrial effluents, conditions of eutrophication are reported.

Turkey reported Izmir bay and Mersin bay as affected (eutrophic) marine sites in Mediterranean, whereas reference sites are reported in offshore waters of the bays.

Drivers/Pressures:

a) *Izmir Bay*: Izmir Bay (western Turkey) is one of the great natural bays of the Mediterranean. The Bay divided into three zones: Inner (mean depth: 7m), Middle (mean depth: 16m) and Outer (mean depth: 49m) Bays according to the topographical, hydrological and ecological features of Izmir Bay. The main urban conurbation around the bay is the Izmir Metropolitan Municipality, covering 88,000 hectares and population of close to 3 million inhabitants. Izmir is an important industrial, commercial and cultural city center. The bay has a total surface area of over 500 km^2, water capacity of 11.5 billion m^3, a total length of 64 km and opens in the Aegean Sea. A 13 m deep sill, the Yenikale Strait, separates the Middle Bay from the Inner Bay. The Gediz River (area: 18,000 km^2 and average flow: 2.33×10^9 m^3), which flows to the Outer Bay, is the biggest river in the Izmir Bay. The Inner Bay is heavily polluted by nutrients and organic material.

b) *Mersin Bay*: The Mersin Bay is situated on the wide and shallow shelf zone of Levantine basin, NE Mediterranean Sea. Therefore the inner bay is isolated from the general circulation pattern of the NE Mediterranean basin as well as from effective exchange with open seawaters. The water column stratification of the bay is effected by local inputs of fresh water, and the intensity of vertical mixing caused by winds and surface heating/cooling. The currents in the inner part of the bay are essentially governed by the prevailing winds. The water column is well mixed during November through April. Thermal stratification begins in May and becomes well established in August-September. The nearshore waters of the bay receive large chemical loads from the major rivers and by direct discharges of municipal wastes (without treatment). Thus, the nearshore waters become very productive (eutrophic); the shallower zone of the bay is sensitive to eutrophication phenomena during the year. No long-term pollution data exist in the region. However, in 2005, a pilot project for eutrophication monitoring was conducted in the bay from May to November and 6 field surveys were all carried out during the daytime. Parameters for TRIX estimates were measured at 15 stations on 4 transects (13 nearshore stations, 2 reference stations). The TRIX values were in the range of 4.0-6.5 at the discharge point and the near shore zone.

State/Impact:

They have not defined which eutrophication related parameters and criteria are using (reference/threshold values) in their answers to the questionnaire. However, there was relevant information in the reports of the case studies for Mersin Bay.

a) *Izmir Bay*: Izmir bay is impacted by sewage and other eutrofying sources. A trend monitoring was performed and the distribution of inorganic nutrients and phytoplankton chlorophyll-a was investigated and N/P ratios were determined in Izmir Bay during 1996–2001 (Kontas et al., 2004). The average concentrations showed ranges of 0.01–0.19 and 0.01–10 μM for phosphate; 0.11–1.8 and 0.13–27 μM for (nitrate + nitrite)-nitrogen, 0.30–4.1 and 0.50–39 μM for silicate and 0.02–4.3 and 0.10–26 μg l^{-1} for chlorophyll-a in the outer and middle-inner bays, respectively. Nitrogen is the limiting element in the Izmir Bay. Phosphate, which originates from detergents, is an important source for eutrophication in the bay, especially in the inner bay. In early 2000, a Wastewater Treatment Plant (WTP) began to treat domestic and industrial wastes. This plant treats the wastes with about 60% capacity between 2000 and 2001. Although the capacity of wastewater plant is sufficient for removal of nitrogen from the wastes, it is inadequate for removal of phosphate. This is also in accordance with the decreasing N/P ratios observed during 2000–2001 (after WTP) in the middle-inner bays. Eutrophication of the inner bay is a serious problem throughout the year and red tide events are becoming more frequent (IMST, 1999).

b) *Mersin Bay*: An eutrophication monitoring pilot project in the Mersin Bay was carried out during 2005 in the framework of the MED POL programme. There were large inputs of nitrate from the rivers and ammonia from untreated domestic wastes of Mersin city. In the bay surface waters outside of the discharge zone, the concentrations of dissolved inorganic phosphorous and phosphate compounds were very low. The reference stations in the offshore zone (40-45m deep) were also very poor in both nitrate and phosphate. Naturally, BOD content of the bay waters increased markedly in the near shore zone, especially at the discharge point due to inputs of untreated wastewaters having very high concentrations of organic matter, nutrients and huge number of faecal coliforms. Chlorophyll-a concentrations were always high in the near shore zone, where the Secchi disc depth was consistently less than 3.0 meters. Water transparency was markedly high at the reference stations. There is an apparent eutrophication problem in the bay due to large inputs of nutrients and organic matter into the shallow zone having limited ventilation with open sea. However, the land-based pollution has not yet resulted in apparent oxygen deficiency in the bottom waters of the inner bay.

In summary, most countries use as eutrophication state parameters the nutrients concentrations (N, P) and in one case salinity and pH, whereas as impact parameters the chlorophyll-a concentrations, dissolved oxygen and in several cases toxic phytoplankton occurrence, toxins in shellfish tissues, mortality of organisms, N/P or even faecal coliforms, However, thresholds for these parameters were presented only from some of the countries, thus remaining unknown if they neglected to report or such values have not defined in all cases. Also no information is given on the methods the thresholds were calculated.

3. OVERVIEW OF EUTROPHICATION MANIFESTATIONS IN THE MEDITERRANEAN

3.1 Manifestastions of europhication

3.1.1 Eutrophication in the Mediterranean

Satellite images of the Mediterranean show the variations in chlorophyll in surface waters (Fig. 1) and reveal that the highest levels of autotrophic biomass 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 to ultra-oligotrophy (Béthoux, 1981; Cruzado et al., 1988; Krom et al., 1988; Innamorati et al., 1992; Turley et al., 2000;

Ignatiades et al., 2002) except for cases generally caused by the upwelling of deep waters rich in nutrients.

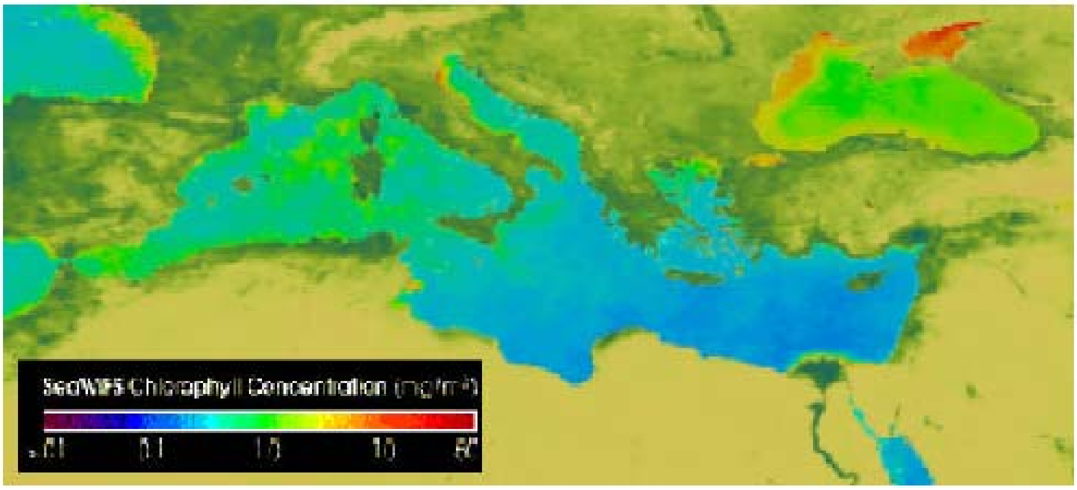


Fig. 1. Chlorophyll distribution in the Mediterranean Sea. Chlorophyll-a content has been estimated from SeaWifs satellite images over the period 1998-2000. (Source: UNEP(DEC/MED WG 228/Inf.7, 2003)

The most eutrophic waters in Mediterranean are more numerous along the northern coastline such as the Adriatic Sea (Solic et al., 1997), but areas, such as the Nile Delta are also eutrophic (Abdalla et al., 1995) and this problem has been increasing gradually over the last decades. The regions of high algal pigment concentrations, characteristic of eutrophic waters, are clearly visible from the satellite image in Fig.1. However, with expanding populations along the southern coastline of the Mediterranean there are increasingly more reports of eutrophication.

The manifestations of eutrophication due to the fertilizing substances produced by man are not the same in all cases and there is no linear relationship between cause and effect (Stirn, 1988). The degree of dilution, the hydrodynamics of the coastal systems, and seasonality are important parameters that may favour or prevent the formation of algal blooms and their secondary manifestations (hypoxia/anoxia of the waters near the seabed, bottom fauna kills and general deterioration of organoleptic qualities).

Over the last few decades, the Mediterranean ecosystem has experienced changes in biodiversity due to climatic and environmental change or to accidental inputs of exotic species. But the plankton community, which is the base of the food chain and remains only partly described, is also probably experiencing a drastic change. Observed changes in nutrient concentrations and ratios in the deep waters of the western Mediterranean, as well as differences between the eastern and western Mediterranean, suggest that shifts have occurred in the relative distribution of nutrients and therefore probably phytoplankton species over the whole sea. A shift from a diatom-dominated ecosystem to a non-siliceous one (as already observed in some coastal areas, with increasing algal blooms and eutrophication events) may involve the whole Mediterranean Sea and have consequences for fishery and tourism activities (Béthoux et al., 2002).

Figure 1 summarizes the most important sites of reported phenomena of eutrophication in coastal and lagoon areas. Although the northern shores are generally the most affected, the problem of eutrophication is also causing serious problems in the south. If forecasts are correct, the population of the North African states will rise to 208,000,000 in the year 2025 (Agnelli Foundation, 1991). Considering the almost total absence of environmental policies, eutrophication problems will scale up in the future.

3.1.2 Historical review of eutrophication phenomena country by country

The information presented below is based mainly on literature review.

- ***Albania* (Adriatic Sea and Ionian Sea)**

Four coastal cities were reported with a resident population of 290,000 persons. Though three out of the four cities are today served by collection systems with no wastewater treatment facilities and thus the collected sewage is directly discharged into the sea untreated (UNEP/MAP/WHO, 2004), reports regarding eutrophication do not exist.

- ***Algeria: (*Alboran and South-Western Mediterranean sub-basins*)***

Cases of eutrophication have been reported in a number of lagoons and in the port areas with heavy commercial traffic from the SW Mediterranean sub-basin. The western sector of 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, whereas the area shelters dense and weakly diversified phytoplankton populations resulting occasionally in blooms as with the diatom *Pseudo-nitzschia multiseries*, whereas elevated abundances of the toxic *Dinophysis caudata* have been also recorded (Ounissi & Frehi, 1999; Ounissi et al., 1998). The Lake of El-Mellah is affected by recurrent conditions of dystrophy and in summer of anoxia in the bottom waters (De Casabianca-Chassany et al., 1986; 1988). More recently, Samson-Kechacha and Touahria (1992) have observed the presence of potentially toxic species such as *Dinophysis acuminata* and others of the genus *Gonyaulax* and *Gymnodinium*. Conditions of environmental stress are mostly manifested in the most confined part of the lagoon, which receives direct input from rivers.

- ***Croatia* (Adriatic Sea)**

In the coastal areas of Croatia eutrophication manifestations have been recorded due to freshwater and sewage inputs. A total of 796,600 persons in 10 coastal cities are served mostly by primary wastewater treatment plants (8 out of the 10 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 (UNEP/MAP/WHO, 2004). Part of Kastela Bay in middle Adriatic Sea suffers from eutrophication which is closely related to an increase of anthropogenic nutrient loading and is regularly monitored since the 1960s, thus long time-series data of dissolved oxygen, nutrients, transparency, phytoplankton and heterotrophic plankton exist (Baric, 1992; Marasovic et al., 2005; Bojanic et al., 2006). The observed changes in the ecosystem include a decreasing N/P ratio (Baric, 1992), changes in the phytoplankton community from a markedly diatom type to a community of dinoflagelaltes and with a respective increase of primary production (Marasovic & Pucher-Petkovic, 1991; Marasovic et al., 2005). Another area that demonstrates eutrophication is the Krka estuary in Eastern Adriatic. The main source of silica and nitrogen is the Krka River. 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 Sibenik. Blooms of marine phytoplankton have been recorded in the estuary (icluding *Gonyaulax polyedra*) (Zutic & Legovic, 1994). High concentrations of POC, chlorophyll-a and phytoplankton were found in the lower reaches of the Krka estuary, adjacent to a source of anthropogenic eutrophication (Svensen et al., 2007). Gruz Bay (south-eastern Adriatic) was reported also as moderately eutrophicated (Vilicic et al., 1995), whereas an eutrophication gradient between the Po river delta (NE Italy) and Rovinj (Istria, Croatia) must also be reported (Radic et al., 2005).

- ***Cyprus* (North Levantine)**

Cyprus is located in the Eastern Mediterranean, which is not only ultra-oligotrophic, but is the largest oceanic ecosystem that is phosphate-limited (Woodward et al., 2006; Law et al., 2005). On the other hand Cyprus is the only Mediterranean country where all wastewater produced is treated and is reused, thus there is no disposal of sewage into the sea (UNE/MAPWHO, 2004). Therefore eutrophication seems not to be a problem for Cyprus. However, some considerations exist due to the possible effects intensive mariculture may have to the marine environment, as a result of nutrient release from the cages to the surrounding waters (Dalsgaard & Krause-Jensen, 2006) or sediments (Pusceddu et al., 2007) and the consequent stimulation of the pelagic primary production. The research performed has shown that so far this increase of biomass is unlikely to significantly alter ecosystem structure or functioning and would not considered as eutrophication under the EU definition. Only one case of algal bloom was recorded concerning a rather transient bloom of *Cladophora sp*. from 1988 to 1991 at Potamos, near a fish farm, when the bloom was ended (Anon, 1996). However monitoring changes in the nutrient status and biomass of primary producers should be undertaken on a large scale (FAO, 1997).

- ***Egypt* (South Levantine)**

Cases of acute eutrophication in the Egyptian waters are reported mainly for the ports and coastal waters off Alexandria, and from the lagoons in the Nile delta (though the Nile input was reduced by 90% in the last decades, Danovaro, 2003). Overall, eutrophication and the worsening of water quality (abnormal water colours, anoxia in bottom waters and production of hydrogen sulphide) in Egyptian coastal and brackish waters are caused by the combination of: (a) large inputs of fertilizing substances from urban, agricultural and industrial sources; (b) the long water residence times in the lagoons, partly due to physical barriers; (c) salinity stratification of the waters; (d) generally high water temperatures.

In the Eastern Harbour of Alexandria heavy algal blooms are the result of the excessive input of nutrients from the city of Alexandria, combined with the marked vertical stability of the basin (Halim et al., 1980; Labib & Ennet, 1997). Dowidar and Aboul-Kassim (1986) estimated mean chlorophyll-a at 23 mg/m^3 (June 1985). Zaghloul and Halim (1992) recorded red tides caused by the toxic dinoflagellate *Alexandrium minutum*, and anoxia in the bottom waters (Labib & Halim; 1995). Lately eutrophication phenomena have been reported from the western harbour as well (Dorgham, 1997; Dorgham et al., 2004; Gharib & Dorgham, 2000; 2003; Ismael & Dorgham, 2003).

Lagoons in the Nile delta. The lagoons are in part enclosed by reed belts (*Phragmites*), and in part covered by macrophytes (*Potamogeton* species; floating *Eichhornia*). They are important habitats for commercially valued fish. All lagoons receive the drainage waters from the extended irrigation systems that provide water to the highly developed agricultural areas of the Nile delta. These waters are then discharged into the Mediterranean. Since the '60s the inputs from the Nile have undergone drastic modification as a result of the High Dam construction. While the reduction in the quantities of solids carried down has affected the morphology of the delta area, the lower flow-rates have not only profoundly modified the hydrology and biology of the South-eastern Mediterranean, but also the lagoon areas. Further to the increase in fertilizer use and the rise in the human population of the delta area that has brought about an increase of nutrients, and a significant increase in primary productivity in the coastal sea-waters (GESAMP, 1988).

- ***France: North-western Mediterranean***

The French coast is mostly affected by the Rhône river discharge. A considerable number of coastal cities is recorded but in all cities there are wastewater treatment facilities that provide for secondary (62% of the plants) or primary (38% of the plants) treatment while there are only two areas (Roquebrune Cap Martin, Villefranche Sur Mer) with no wastewater treatment plant (UNEP/MAP/WHO, 2004).

Blooms of diatoms and dinoflagellates occur in favorable conditions. However the problem does not affect the French and Italian Riviera due to the cyclonic circulation from the Ligurian Sea (Danovaro, 2003). Some of the coastal lagoons in the Languedoc-Rossignol Region are also affected by eutrophication (Ménesguen, 1990; IFREMER, 2006). Harmful Algal Blooms is a recurrent event in this area also. *Dinophysis sacculus* was observed in the Mediterranean French coastal area. *Alexandrium catenella* and *A. tamarense* observed in the Thau lagoon and Mediterranean coasts (ICES, 2004).

Another eutrophication related phenomenon was the observed Dimethylsulfoniopropionate (DMSP) concentrations, as an example from October 1999 to September 2000 in a Mediterranean ecosystem (Little Bay of Toulon) submitted to eutrophication. DMSP was measured in the particulate material ($DMSP_p$), concentrations were relatively high, showing a strong temporal variability with maxima in February-March. The most elevated values were recorded in the 5-90 µm size class, and represented between 60% and 100% of the total $DMSP_p$. This fraction was mostly composed of Dinoflagellates whose biomass was significantly correlated with $DMSP_p$ concentrations (especially: *Ceratium furca, Dinophysis acuminata, Prorocentrum arcuatum* and also *Alexandrium minutum)*. The intracellular contents of DMSP were much higher in Dinoflagellates (124.9 plus or minus 5.7 mM) than in Diatoms (Jean et al., 2005).

- ***Greece* (Aegean and Ionian)**

Coastal Greek waters in bays and estuaries appear rather endangered, besides their general oligotrophic status. Eutrophication problems have been recognized in a number of Greek coastal areas, affected by urban and industrial wastewaters and/or nutrient inputs from rivers and agricultural activities (Pagou, 1990; 2005; Pagou & Ignatiades, 1988, 1990; Gotsis-Skretas, 1995; Karageorgis et al., 2005).

According to UNEP/MAP/WHO (2004), in Greece there are 63 areas with population greater than 10,000 that are located close to the coastline, with a total population of 7.2 million. More than 60% of the population is located to the greatest Athens area (capital of Greece) and Thessaloniki, which are situated in the most disturbed Greek coastal areas, regarding anthropogenic nutrient enrichment, Saronikos (Central Aegean Sea) and Thermaikos Gulfs (NW Aegean Sea). Both cities are served by wastewater treatment plant that can provide for biological treatment. In Thermaikos agricultural and river runoff are also major contributors to the gulf's eutrophication. According to the reported information only 10% of the wastewater produced is untreated, although it should be noted that untreated sewage is not directly discharged to the marine environment, since in most cases raw sewage from households is collected to septic tanks. With respect to treated wastewater in most cases this is disposed after secondary treatment through submarine outfalls or in some cases trough rivers or streams to the sea. The majority of wastewater treatment plants were constructed after 1990s.

A comparative study of Saronikos and Thermaikos gulfs (Moncheva et al., 2001) showed that in Thermaikos diatoms dominated even during summer, whereas spring blooms were due to diatom assemblages. On the other hand in Saronikos gulf, dinoflagellates, chrysophyceae and chlorophyceae species frequently outcompeted diatoms.

The numerical displacement of diatoms with other species in Saronikos, in relation to Thermaikos, was attributed to differences in the nature of nutrient loads and nutrient ratios. Higher dominance of the Si demanding diatoms in Thermaikos were more efficient in utilizing high nutrient levels (especially of Si) as mainly supplied by the rivers run-off. On the contrary, the sewage outfalls, rich in dissolved organic matter (a major source of eutrophication in Saronikos Gulf) stimulate the growth of mixotrophic microalgae.

However, after 1995, dramatic changes occurred in both areas. In Saronikos no significant phytoplankton blooms have been reported and this can be attributed to the lowering of the trophic status of the most eutrophic areas (from eutrophic to high mesotrophic) due to the operation of the new waste treatment plants.

A more interesting situation has been revealed in Thermaikos Gulf. The ΣN/P ratio values were lower than the Redfield ratio in all the examined areas, being lowest in the Bay and the northern part of the Gulf of Thessaloniki (most eutrophic areas due to sewage) and comparatively higher in the central area of the Inner Thermaikos Gulf near to the boundaries with the Aegean Sea.

In Thermaikos Gulf the frequent diatom blooms observed before 1996 changed to even noxious dinoflagellate blooms that can be related to the very low N/P ratios recorded at the northern part of Inner Thermaikos gulf, the site where usually the exceptional blooms have started (Karageorgis et al., 2005; Reizopoulou et al., 2007).

In the Aegean Sea coastal waters, red tide phenomena are sporadic and irregular. In the Saronikos Gulf, strong HAB events accompanied by fish death occurred during 1977-1983, as well as in 1987 and they were caused by the toxic dinoflagellate species *Gymnodinium breve* (Pagou & Ignatiades, 1990). Furthermore, a list of red tides phenomena (from early 80's to 1995), the blooming species (30 species) and their relation to anthropogenic eutrophication in Saronikos and Thermaikos gulfs was presented in Moncheva *et al*. (2001). A detailed review on the occurrence of mucilage phaenomena (associated with diatoms) in Greek coastal waters during 1982-1994 is given by Gotsis-Skretas (1995). Blue-green algae also were found to produce exceptional blooms in the Evvoikos Gulf during September 1999 (Metaxatos *et al.,* 2003). The toxic dinoflagellate species *Alexandrium minutum* proliferated during the period spring-summer of 2002 and 2003 over a wide geographic range along the north-south Aegean Sea coastline mostly at low concentrations (Gotsis-Skretas *et al*., 2002; 2003). In Thermaikos Gulf Dinoflagellates were the blooming species from 1996 and among them the toxic species *Dinophysis cf. acuminata*, a DSP causative, with substantial socio-economic impact in the area amounting to economic losses of ~3 million euros every year (Karageorgis et al., 2005; Pagou *et al*., 2004, 2006; Reizopoulou et al., 2007).

Other areas that have been reported to present eutrophicating conditions are: Pagassitikos Gulf, Alexandroupoli Gulf, Kavala gulf, Amvrakikos gulf, Kalloni and Geras Gulfs, Argolikos Gulf and lagoons as Pappas lagoon in W. Peloponissos, Vassova lagoon in Macedonian coast in Northern Greece, etc.

- ***Israel:*** **(South Levantine)**

The open waters of the southeastern Mediterranean where the Israeli shelf is situated are very low in nutrients, particularly if compared with those for other oceans. Thus the level of primary production in the waters overlying this continental shelf is very low, especially since the curtailment of the annual Nile River flood waters following of the Aswan High Dam in Egypt (Townsend et al., 1988).

Furthermore, the major coastal cities according to UNEP/MAP/WHO (2004), are served by respective wastewater treatment plants, which in most cases provide for secondary treatment. There is no discharge of untreated wastewater while treated wastewater is discharged to the sea through submarine outfalls (7%) or is reused (93%).

Therefore, serious eutrophication problems are not recorded in the literature.

- ***Italy*** **(North-Western, South-Western, Tyrrhenian, Adriatic, Ionian, Central)**

Manifestations of eutrophication occurring in the Italian seas depend on the hydrology, hydrodynamics and morphology of the areas concerned. In the Ligurian Sea, the Tyrrhenian Sea and the southern Adriatic, the phenomena are episodic and generally not widespread, with secondary effects (hypoxia/anoxia in the bottom waters) being of but 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. However, most coastal cities are currently served, or projected to be served by 138 wastewater treatment plants (UNEP/MAP/WHO, 2004). With the exception of lagoon areas (as Orbetello) the negligible damages caused by eutrophication occurring is due, in large part, to the hydrodynamic and morphological characteristics of these seas (Giovanardi & Volleweinder, 2004).

This is not the case throughout the northern Adriatic Sea, which is the most endangered area. Apart from receiving huge quantities of fertilizing substances, this part of the Adriatic is very shallow and has physical and hydrodynamic characteristics, which tend to segregate the nearshore and offshore systems for long periods; this is particularly noticeable in the area to the South of the Po delta, where, in the summer, water residence times may reach 40-50 days. Eutrophication under such conditions can be serious. The most affected areas on the Italian coast are along the Emilia-Romagna coasts, the lagoons, around Ravenna, the Gulf of Venice and the Gulf of Trieste.

The first bloom with green-red coloured water has been described in 1954 from a coastal area close to the Po delta and was due to algal organism typical of fresh-/mixo-aline waters (*Chromulina rosanofii* and *Oscillatoria tenuis*). From the constant monitoring of the Adriatic coasts it appears that such events are becoming more frequent (Danovaro, 2003). However, though increasing eutrophication and pollution do not appear to have a direct bearing on mucilage recurrence, it is the most serious manifestation of disturbance in the Adriatic. The phenomenon is known to occur for more than two centuries (Vollenweider et al., 1995).

Another result of eutrophication (partly) is that in the last 30 years, 41 alien species (13 algae, 27 invertebrates, 1 fish) have been recorded in the Northem Adriatic. Habitats of special interest for bioinvaders are the large semi-enclosed, brackish lagoons, particularly the Lagoon of Venice. The ecological features of the area suggest that it is subjected to considerable stress, both from natural causes (e.g. considerable freshwater runoft) and from human impact (eutrophication and pollution). These, in turn, facilitate the introduction, the establishment and the subsequent spread of non-indigenous species (Occhipinti-Amprogi, 2002; Bulleri et al., 2006).

- ***Lebanon* (North Levantine, Southern Levantine)**

The coastal area of Lebanon is also located in a very oligotrophic Mediterranean area. However, in seven major coastal cities reported with a resident population of 2,256,000 persons, nearly half of them coming from Beirut Greater Area, only one of the seven cities, (Beirut), is served by a primary wastewater treatment plant. Thus, wastewater facilities serve 32% of the population, while sewage system network serves the remaining 68%. From the produced sewage 70% is untreated and discharged raw in the marine environment, through small submarine outfalls (UNEP/MAP/WHO, 2004).

Nevertheless, literature regarding eutrophication is lacking or is very old and refers to Beirut coastal area (as in Hardy & Jubayli, 1976; Taslakian & Hardy, 1976). However the untreated domestic sewage resulted in extremely high concentrations of dissolved N and P, which promoted the development of phytoplankton abundances 8-10 times higher than background. Except for some eutrophic port areas, where occasional blooms may occur, no eutrophic conditions are reported in the coastal waters of Lebanon the recent period. The dinoflagellates present in this area belong mainly to the phytoplankton typical of the temperate Mediterranean areas. The presence of toxic species such as *Gonyaulax polyedra*, *Alexandrium minutum* and *Dinophysis spp.* is also recorded, without causing health problems, due to their very low abundances.

- ***Libya*** **(Central, South-Levantine)**

Existing literature from scientific journals is lacking information regarding eutrophication phenomena from the coastal area. However, according to UNEP/MAP/WHO (2004), 17 coastal cities exist with a resident population of 4,062,000 persons and with 16 wastewater treatment plants are currently in operation or under construction, while only one city is not served by a wastewater treatment plant.

- ***Malta*** **(Central sub-basin)**

No eutrophication incidents are reported in the literature. However, it must be noted that a very rapid development rate of finfish farming has been recorded for Malta, as with other Mediterranean countries more than 20 years ago (Stephanis & Divanach, 1993), whereas potentially toxic dinoflagellate species have been recorded in the Malta channel during a survey regarding Sicily waters (Giacobbe et al., 1995). Moreover, only one single wastewater treatment plant (tertiary), constructed in 1983 is in operation and provides services to a total of seven localities. The existing treatment plant serves approximately 55% of the population and the treated sewage produced is reused for agricultural purposes. However, untreated wastewaters are discharged through submarine outfalls into the sea from six coastal cities, which are served by different sewage networks. According to the reported information all sewage will be treated, by 2007, following the construction of sewage treatment plants for Malta South, Malta North and Gozo (UNEP/MAP/WHO, 2004). Therefore it is obvious that eutrophication monitoring in this area can be useful as being possibly at risk.

- ***Monaco*** **(North-Western Mediterranean sub-basin)**

According to literature review no eutrophication phenomena were recorded in the coastal area of Monaco. Regarding land-based discharges in Monaco, there is one single locality with a resident population of 35,000 persons that is served by a sewerage network together with a secondary treatment plant. The disposal of treated sewage is conducted trough a submarine outfall to the marine environment (UNEP/MAP/WHO, 2004).

- ***Morocco (Alboran)***

The Lagune de Nador is considered the largest lagoon in Morocco. The urban development was rapid and resulted in 120 inhabitants /km^2. The same with industry and aquacultures, therefore the lagoon is polluted. It must be noted that according to UNEP/MAP/WHO (2004) 12 coastal cities have been reported with a permanent population of 1,473,290 from which a small percentage (10%) is served by wastewater treatment facilities that provide for tertiary treatment. Two projects for new wastewater treatment plants that will serve the areas of Tetouan and Tanger are in progress. All wastewater produced (treated and untreated) is directly discharged into the sea.

- ***Palestine (Southern-Levantine sub-basin)***

According to literature review, no eutrophication phenomena were reported in the coastal area of Gaza Strip

- ***Serbia and Montenegro*** **(Adriatic)**

According to literature review no information was found about eutrophication phenomena in the coastal area of Serbia and Montenegro.

- ***Slovenia* (Adriatic)**

The Slovenian coastal area (Adriatic Sea) also suffers from eutrophication. In Slovenia there are three coastal cities with a resident population of 76,000 persons and in the two areas among them there are wastewater treatment plants that provide for primary treatment of the 53% of the total population reported. Treated wastewater is either directly discharged into the sea (area of Koper) or through a submarine outfall (area of Piran). The untreated wastewater is in most cases discharged through small outfalls into the sea (UNEP/MAP/WHO, 2004). Also the marine waters are influenced by transboundary pollution by the rivers discharge in Northern Adriatic.

Events resulting in visible water changes are linked mainly to highly stratified systems and the spring/summer period. In the Gulf of Trieste, there is an historical record of a *Noctiluca scintillans* bloom for November 1902 (Sellner and Fonda Umani, 1999). Over the last 18 years, a shift from red tides to mucilage phenomena was observed. Almost every year mucilage phenomena appeared as marine snow and microflocs or as dense cobweb, clouds, blankets, creamy/gelatinous layer (Precali et al., 2005). Large mucus aggregates influence microzooplankton and mesozooplankton temporal and spatial variability (Kršinić, 1995; Bochdansky and Herndl, 1995; Malej & Harris, 1993; Cabrini et al., 1992; Cataletto et al., 1996; Fonda Umani et al., 2005). Mucus aggregates can severely affect some species of fish which breed during the warm period of the year, for it is hard for the eggs to survive if caught in mucilage mass. 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. Filtering organisms (poriferans and tunicates) are severely affected, as are some other organisms such as coelenterates. Below the sedimented mucilage, total lack of oxygen occurs, which additionally affects the organisms living on the bottom, as they cannot escape the mucilage area.

Among various types of intoxication due to increase of some dinoflagellates and diatom species, three are of major concern in the Gulf of Trieste, as their causative organisms are commonly found in the northern Adriatic. First is diarrhetic shellfish poisoning (DSP) (by various dinoflagellate species of the genus *Dinophysis)*. Second, and more dangerous, is paralytic shellfish poisoning (PSP) which is caused by some dinoflagellate species of the genus *Alexandrium*. Recently (in 2006) analyses on the ASP (Amnesic shellfish poisoning) are carried out due to regular occurrence of some diatom species of the genus *Pseudo-nitzshia*. At shellfish farms on the Slovenian coast DSP occurs almost every year, and is the cause of the banning of the sale of shellfish. PSP and ASP however, has not been observed in this area thus far. Recently, there has been a growing interest in new toxin types such as the yessotoxins. They are produced by *Lingulodinium polyedrum* and *Gonyaulax grindleyi,* which are regularly found in the phytoplankton community of the Gulf of Trieste.

The other most frequent massive plankton events in the northern Adriatic were outbreaks of large jellyfish, which may have a significant impact on fisheries, tourism and the food web trophic structures (Malej, 2001).

Periods of oxygen depletion below the thermocline have been observed almost every year in the Gulf of Trieste (Faganeli et al., 1985; Stachowisch, 1984; Herndl, 1988; Malej et al., 1989; Stachowisch et al., 1990; Fanuko & Turk, 1990; Malej & Malačič, 1995). The most destructive anoxia was recorded in September 1983 (Stachowitsch, 1984,1986; Faganeli et al., 1985) and lasted for two weeks, covering one third of the Gulf. 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, 2004).

- ***Spain* (Alboran, North-Western, South- Western Mediterranean sub-basins)**

The Spanish coast is characterized both by natural enrichment due to upwelling and an induced eutrophication caused by human discharge. A total of 73 coastal cities were reported (UNEP/MAP/WHO, 2004) with a resident population of 6.4 million persons served by wastewater facilities (in 90% of the cases provide for secondary or tertiary treatment). With respect to the quantities of wastewater (treated and untreated) and way of discharge there was no available information.

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 (Tintore et al., 1988; Martinez et al., 1990; Ramirez et al., 2005). A large input of organic matter from urban effluents receives the Bay of Gadiz (SW Spain), a semi-enclosed coastal ecosystem, showing a progressive increase of both primary production and organic matter contents of sediments (Gomez-Parra & Forja, 1992). Highly eutrophicated areas appear to be coastal areas close to Valencia and the Ebro delta. A review of eutrophication phenomena along the Spanish coast, until the early 90s, can be found in UNEP/FAO/WHO (1996), with more severe manifestations the proliferation of toxic algae. Such phenomena continue up to day.

The Mar Menor, which is reported in the framework of the questionnaire produced for this report, is a lagoon threatened by several pressures and in the last decades detrimental impact on the natural community structure and dynamics have increased (Perez-Ruzafa, 2005). Nutrients and chlorophyll-a concentrations were analysed in 1997 and 2002-2003. During these periods, the dissolved inorganic nitrogen (DIN) increased whilst phosphate decreased significantly. These contrasting patterns depended upon the increased agricultural loading for DIN and were due to the implementation of the wastewater works for phosphates.

The nutrient runoff along the continental waters in the coastal zone of the North-Eastern Mediterranean induced by anthropogenic activities and/or consequent changes in nutrient ratios, can favour besides eutrophication the incidence of noxious algal blooms along the coast (Olivos Ortiz et al., 2002).

During 2003, DSP outbreaks caused by *Dinophysis* spp. constituted the main problem for shellfish exploitations in all regions on the Atlantic and the Mediterranean coasts of Spain. Toxic blooms of *Alexandrium minutum* are recurrent in Catalunya, between January and March reached maximum levels in May of 2**X**10^6 cell l^{-1} and 269 μg eq.STX **/** 100g (PSP) causing closure of natural banks of *Donax.* It must be noted that the coast of Catalan is an example of a heavily man-modified coast, with different sections of coast affected by different uses (recreational, urban and industrial). PSP outbreaks (2003) caused by *Gymnodinium catenatum* (up to 7X10^3 cell l^{-1}) that led to closures of clams, scallops and mussels harvesting were reported. In addition, during 2003 there were also closures due to DSP toxins in clams (*Callista chione* and *Donax trunculus*) associated with proliferations of *Dinophysis acuminata* (up to 26,000 cell l^{-1}) in August. Also icthyotoxic species as *Gyrodinium corsicum*, reached "red tide" levels (>10^6 cell l^{-1}) between May and June 2003. High biomass blooms of non-toxic species (*Gymnodinium impudicum, Alexandrium taylorii, Calyptrosphaera sphaeroidea)* occurred in the summer, causing social alarm and negatively affecting the tourist industry (Vila et al., 2001; Vila & Maso 2005; WG of Harmful Algal Bloom Dynamics, ICES 2004).

- ***Syria* (North Levantine sub-basin)**

According to UNEP/MAP/WHO (2004), all the population in coastal cities (population ~600,000-1,000,000 citizens) is served by network and probably by individual autonomous wastewater services, such as septic tanks or other similar devices. However, a considerable amount of untreated wastewater discharged mainly to the sea through small submarine outfalls. However no other information was found in literature regarding eutrophication.

- ***Tunisia* (Tyrrhenian and Central Mediterranean sub-basins*)***

Cases of eutrophication are reported mainly in the Lakes of Tunis and Ichkeul induced mainly by sewage. In general, a total of 36 treatment plants are currently in operation serving 22 coastal cities, while seven more wastewater treatment plants are expected to start their operation in the future (UNEP/MAP/WHO, 2004). Five plants were reported having tertiary treatment, whereas 30 plants (out of 36 which are in operation) provide for secondary treatment. According to the reported information and with respect to the wastewater discharge, 63% of the wastewater produced is treated and in most cases is directly disposed to the sea. The total quantity of untreated wastewater is also directly discharged to the sea.

The Institut National Agronomique de Tunisie conducts monitoring of harmful algae along the Tunisian coast. Research is focused particularly on the northern coasts of Tunisia. In the Bay of Tunis, phytoplankton samples were taken at monthly intervals between 1993-1995 and weekly during 2001. At other locations the sampling frequency is weekly or bi-monthly depending on the resources.

Investigations on phytoplankton in some Tunisian lagoons and coastal waters show that cell densities of the potentially harmful algae are very high in some of the lagoons studied, particularly those with enclosed areas. During 1995, in shellfish production areas, about 15 harmful algae associated with phycotoxins were observed e.g.. *Dinophysis* spp, *Prorocentrum lima* and *Alexandrium* spp. As an example, Lake of Tunis is a lagoon of 48.6 km^2 with an average depth of 1m. The only exchanges with the sea are the navigable canal (opening 500 m) and two other small channels (opening 40m), one close to the town of Kherredine. The lagoon receives the partially treated sewage of the city of Tunis (population of 1,000,000), which flows mainly into the northern part, while the southern section receives urban and industrial inputs (Stirn, 1968; Aubert and Aubert, 1986).

The high trophic state of the basin favours invasive proliferations of macroalgae and frequent, intense algal blooms of diatoms and dinoflagellates, *Gymnodinium sp.* and *Prorocentrum micans* (UNESCO, 1984).

Sixteen potentially harmful algal spp. have been observed among the 300 taxa in the Bay of Tunis although no toxic events have been recorded.

Belkhir et al. (1987) underline the presence of high nutrient values. Also anoxia and hydrogen sulphide caused widespread fish kills.

The trophic and physicochemical conditions of the Bou Grara lagoon (South of Tunisia) lead to monospecific blooms of *Gyrodinium* cf *aureolum* (*Gymnodinium* spp.) often associated with *Prorocentrum micans* and *P. minimum*. The first mass occurrence of *Gyrodinium* was recorded in 1991 and resulted in fish mortality.

- ***Turkey* (Aegean, North Levantine, Marmara Mediterranean sub-basins)**

Open marine waters of Turkey generally present conditions of oligotrophy; only in limited costal areas affected by the inputs of rivers, sewage outfalls or industrial effluents conditions of eutrophy are reported. Regarding sewage, 62% of the population is being reported as having wastewater treatment facilities (19 wastewater treatment plants serve about 3 million habitants). Treated wastewater is discharged in most cases through submarine outfalls to the sea, whereas untreated wastewater is mainly directly discharged to the sea (UNEP/MAP/WHO, 2004).

The innermost parts of the Bay of Izmir, referred to by many authors as seriously degraded bays (Balci et al., 1994) until the mid 1990s. Koray and Buyukisik (1988) reported a bloom of the dinoflagellate *Alexandrium minutum* (PSP toxins producer) that occurred in May 1983 in a zone particularly affected by large amounts of nutrients. The phenomenon was followed by anoxia in the bottom waters and bottom fauna kills.

The recurrent algal blooms in this area are due to algae that produce PSP-group toxins (Koray, 1990; Koray et al., 1992) amongst these *Alexandrium minutum*, *Gonyaulax poliedra* and *Gonyaulax spinifera*. Such algal blooms cause anoxia in the bottom waters. Koray (1988) and Koray and Buyukisik (1992) concluded that increases in autotrophic biomass are generally directly correlated with increases in phosphorus, nitrogen, light and temperature.

Recently nutrient and chlorophyll-a concentrations have been determined during 1996–2001 cruises in the Izmir Bay. Pollution in the outer bay is not significant, but eutrophication of the inner bay exists and might be spreading progressively to the outer part of the bay. Phosphate originating from detergents is an important source for the eutrophication, especially in the inner bay.

Another area in NE Levantine highly influenced by riverine inputs, domestic and industrial wastes is Mersin Bay. Eker & Kideys (2001) reported the colour of the sea was reddish brown on 5 April 1996 and noticed *Prorocentrum micans* bloom. Uysal et al. (2003) reported the presence of the dinoflagellate *Heterocapsa pygmaea* in bloom quantity for the first time in the Mersin Bay. Further, it was the only species of the family Heterocapsacea reported from Turkish Seas.

The Table 4 below summarises the Mediterranean coastal sites designated as eutrophic or as being at risk to become eutrophic and the related pressures to eutrophication.

Table 4. List of sites per Mediterranean country designated as eutrophic or as being at risk to become eutrophic and related pressures

COUNTRY	SITE	PRESSURE
Albania	1. Drini bay 2. Rodoni bay 3. Karavasta bay 4. Ishmi estuary 5. Buna estuary 6. Drini estuary 7. Semani estuary 8. Karavasta lagoon 9. Kune-Vaini lagoon 10. Patoku lagoon	Nutrient inputs, organic matter inputs from diffuse sources
Algeria	*No information received*	*No information received*
Croatia	*No information received*	*No information received*
Cyprus	site 1	Tuna ranching farm, fish farm
	site 2	Fish farm and hatchery

Egypt	1. El Mex	Freshwater inputs from lake Maryut (with industrial, domestic sewage)
	2. Abu Qir East	Industrial, domestic sewage
	3. Port Said	Sewage, shipyards
	4. Abu Qir bay	Agricultural discharges, textile mills
	5. Alexandria Eastern Harbour	Fishing port, domestic sewage, shipyards
	6. Rashid	Industrial sewage, domestic sewage, agricultural activities, pesticide plant
	7. Damietta	Industrial & domestic sewage, agricultural activities
France	1. Étangs Palavasiens (Ingril, Vic, Pierre-Blanche, Prévost, Arnel, Méjean-Pérols et Grec)	Domestic sewage
	2. Étang de l'Or	Tourism, agriculture
Greece	1. Saronikos Gulf	Domestic & industrial sewage
	2. Thermaikos Gulf	Domestic & industrial sewage, agriculture, tourism, aquacultres, riverine inputs
	3. Amvrakikos Gulf	Domestic and agricultural effluents
	4. Messolonghi lagoon	Domestic sewage, Breeding-feeding grounds for fish
	5. Pagassitikos Gulf	Domestic and industrial sewage, riverine inputs
	6. Gulf of Kavala	Domestic, industrial inputs
	7. Gulf of Alexandroupolis	Nutrients from Evros river, agriculture
	8. Araxos lagoon	Breeding-feeding grounds for fish, shellfish, overfishing, agricultural waste, poor circulation
	9. Argolikos Gulf	Domestic sewage, industrial and agricultural effluents
	10. Gulfs of Geras and Kalloni (Lesvos island)	Shallow enclosed bays, agricultural, domestic wastes, fisheries, shellfish harvesting
Israel	*No information received*	*No information received*

Italy	Liguria 1. Foce Torrente Lerone 2. Marinella-Foce Magra	 Urban, wastewater, food industry, harbour of Genova Harbour of La Spezia, domestic and industrial wastes
	Emilia Romagna 3. Lido Adriano 4. Cesenatico 5. Porto Garibaldi	 Nutrients inputs from Po river Nutrients inputs from Po river Nutrients inputs from Po river
	Marche 6. Foglia	 Nutrients inputs from Po riverand Foglia river
	Veneto 7. Porto Lido Nord	 Aquaculture, tourism, dense populated area
	Friuli-V Giulia 8. Duino-Baia di Panzano 9. Porto Nogaro	 Aquacultures, harbour of Monfalcone Aquaculture, domestic sewage, husbandry
	Campania 10. Foce del Samo 11. Napoli Piazza Vitoria 12. Portici Pietrarsa	 Domestic and industrial wastes from Samo river, agricultural activities Domestic sewage, harbour of Napoli Domestic sewage, harbour of Napoli
	Toscana 13. Fiume Morto	 Agricultural activities, domestic sewage
	Lazio 14. Fiumicino	 Agriculture, husbandry, domestic sewage
Lebanon	1. Antelias 2. Ramlet el Baida 3. Saida	*No information for pressures*

Libya	*No information received*	*No information received*
Malta	*No information received*	*No information received*
Monaco	*No information received*	*No information received*
Morroco	1. Estuaire de Oued Martil a Tetouan 2. Lagune de Nador	Dense populated, industries, fluvial inputs Dense populated, domestic and industrial wastes
Palestine	1. Wadi Gaza, Gaza Strip 2. Gaza Bay	*No information for pressure*
Serbia and Montenegro	*No information received*	*No information received*
Slovenia	1. Koper bay	Riverine nutrient loads, domestic wastes from Koper, industrial wastes
	2. Rizana estuary	Domestic and industrial wastes
	3. Seca	fish/shellfish area
Spain	1. laguna Coster del Mar Menor	Sewage, ports
Syria	1. Port de Peche et de plaisance de Lattaquie	Receives nutrients and organic material loads
	2. Port de commerce de Lattaquie	Receives nutrients and organic material loads
	3. sites where sewage outfalls discharge	Receive nutrients and organic material loads
	4. River Al-Kabire Al Chimali estuary	Receives nutrients and organic material loads
	5. coastal estuaries	Receive nutrients and organic material loads
Tunisia	1. Lac de Bizerte 2. Golfe de Tunis 3. Golfe de Gabes 4. Estuaire Hergla	

	5. Lagune Bougrara 6. Lagune Ghar Elmehl 7. Lagune de Bizerte 8. Lagune de Kheniss (Monastir) 9. Lagune El Biban	Domestic, industrial wastes
Turkey	1. Izmir bay	Industrial (food processing, tanneries, paint, chemicals, textile, petroleum refining) and domestic sewage
	2. Mersin bay	Isolated bay, freshwater inputs, riverine and domestic discharges

3.2 Results from Remote Sensing

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). Therefore, eutrophication can be an important aspect of these activities.

Remote sensing and automatic buoys are recommended among the supplementary techniques for monitoring eutrophication in the framework of the MED POL medium/long term strategy (Document UNEP(DEC)/MED/WG.231/14).

UNEP/FAO/WHO (1996) reported that 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 ultraoligotrophy (Béthoux, 1981; Cruzado *et al*., 1988; Krom *et al*., 1988; Innamorati *et al.,* 1992) except for cases caused by the upwelling of deep waters rich in nutrients.

Therefore, it is interesting to compare with more recent satellite images. A series of maps (Figures 2 and 3) of chlorophyll-like pigments concentrations in the Mediterranean Sea are shown below, corresponding to the spring blooming period (March) and the lowest productive one (August) for each year These maps are derived from SeaWiFS satellite images and show monthly mean concentrations from October 1997 to December 2004. These satellite images were provided for the needs of this report by the MERSEA project group in the framework of the MOON/UNEP cooperation (Volpe *et al.,* 2005).

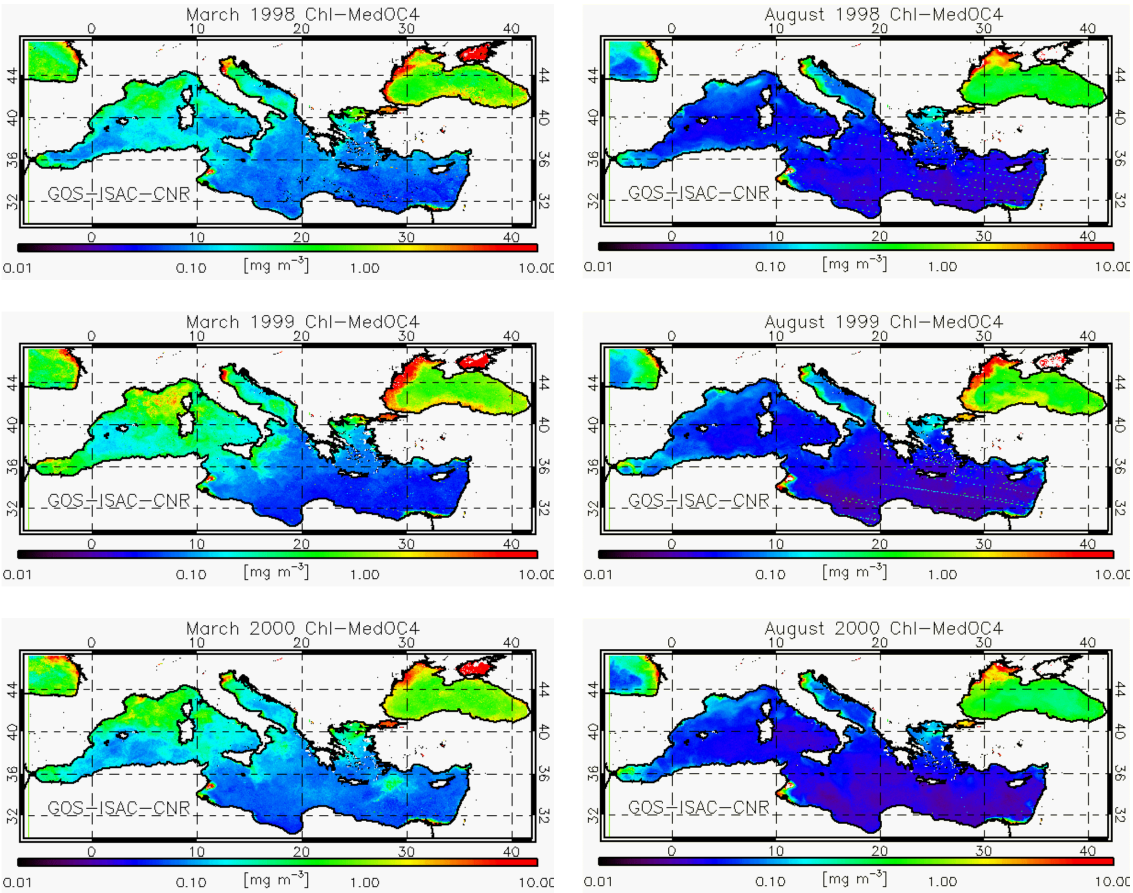
According to Volpe et al. (2005), one of the major objectives of MERSEA WP2 is to provide high quality satellite products for data assimilation and validation of global and regional models. This implies a carefully quality controlled dataset and accompanied with quantitative estimate of their error statistics.

In their report (Volpe et al., 2005) a detailed definition of the processing chain used to obtain the daily chlorophyll maps of the Mediterranean Sea is provided including the new Mediterranean Sea bio-optical algorithm, used to reprocess the SeaWiFS archive. Also they describe the whole processing procedure.

Throughout all the years (1997-2004) the NW part of Mediterranean remains the most productive area, whereas open seawaters in the E. Mediterranean are extremely oligotrophic.

The southern coastal waters of Italy are oligotrophic with a few exceptions as the Gulf of Naples due to sewage, whereas in NW Adriatic the serious eutrophication due to Po River influence. 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 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. In the SE Mediterranean a few cases are recorded in Lebanon port areas, Israel, coasts, In Egypt in ports in Alexandria area and in the Nile delta system. Finally a serious case is that of the Tunisisan coasts with the Lake of Tunis and Ickheul.

Finally regarding the satellite images it must be reminded, that since the chlorophyll OC4-V4 algorithm is originally designed for oceanic waters and it can lead to large uncertainities in river influenced due to the presence of dissolved organic matter and suspended particulate matter. Therefore the spatial gradients should be interpreted with caution, whereas also the temporal variability must be analysed accounting for the number of valid observations (cloudiness, etc).



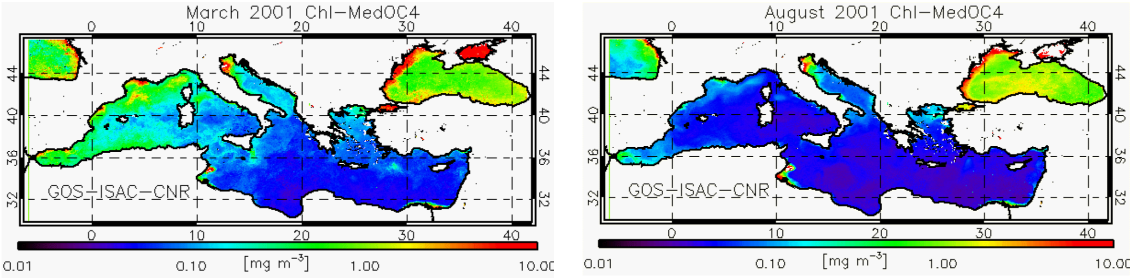


Fig. 2. Chlorophyll-like pigments concentrations in Mediterranean Sea, 1998-2001.

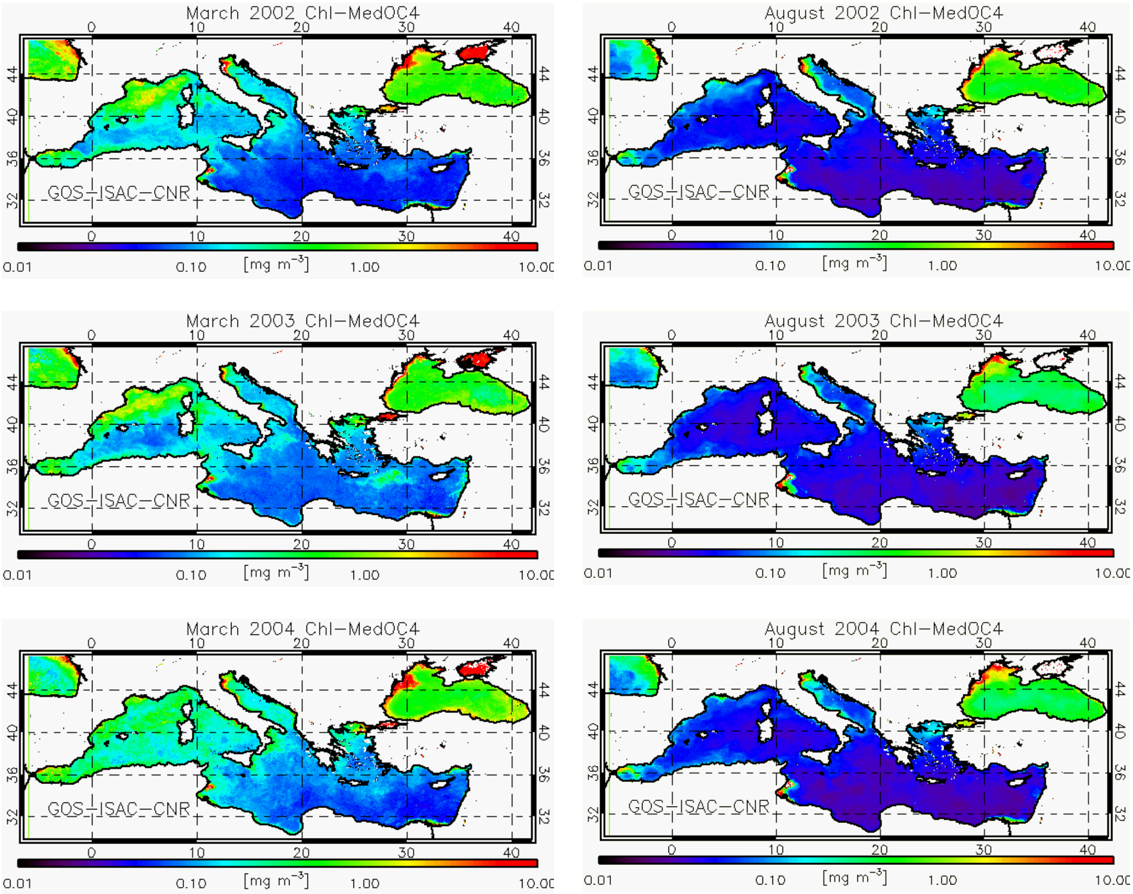


Fig. 3. Chlorophyll-like pigments concentrations in Mediterranean Sea, 2002-2004.

4. OVERVIEW OF EUTROPHICATION ACTIVITIES IN INTERNATIONAL POLICIES

Eutrophication is addressed in several EU policies and other international and regional conventions. Starting from the 1980s and 1990s, a number of international conventions addressed eutrophication in marine waters including OSPAR (in the North East Atlantic) and HELCOM (in the Baltic Sea).

This section considers and compares how eutrophication is understood, defined and assessed in European Community directives, policies and guidance documents. In addition, the understanding and the assessment of eutrophication in other regional bodies are presented, in particular in the international marine conventions OSPAR and HELCOM, due to the long-term established monitoring and assessment projects they realize.

4.1 EU legislation and policies

In the interim report (EC, 2005) "Towards a Guidance Document on Eutrophication assessment" a detailed and informative overview and common understanding of eutrophication in EC and international policies can be found. Here, in this document only a summary will be presented with the purpose of providing useful and synoptic information regarding the instruments that the EU Mediterranean countries have for eutrophication assessment and integrated management of nutrient enrichment of coastal areas. This information could be useful also for non-EU Mediterranean countries and in general for the MED POL programme.

4.1.1 Water Framework Directive (2000/60/EC)

Overview

The Water Framework Directive (WFD, 2000/60/EC) establishes an integrated and co-ordinated framework for the sustainable management of water, including prevention of deterioration of water bodies (lakes, rivers, coastal and transitional, groundwater), promotion of sustainable water use, and ensuring "enhanced protection and improvement of the aquatic environment". This last point requires that rivers, lakes, estuaries, coastal waters and groundwater achieve and/or maintain at least 'good status' by 2015. For surface waters this requires both Ecological Status and Chemical Status to be at least 'good'. Good status will be achieved by implementing a programme of measures as reported in River Basin Management Plans (Articles 11 and 13 in WFD), and based on the results of river basin characterisation. The WFD stipulates detailed procedures for its implementation including the classification and monitoring of water bodies.

Ecological status is derived from Ecological Quality Ratios (EQRs), which reflect the deviation of observed values from type-specific reference conditions. 'High', 'good', 'moderate', 'poor' and 'bad' Ecological Status have normative definitions (see Annex V of the WFD) based on the deviation, as a result of human activity, of quality elements from corresponding type-specific reference conditions. At good ecological status, the values of biological quality elements (communities of phytoplankton, plants, fish, macro-invertebrates etc.) should 'deviate only slightly from those normally associated with the surface water body type under undisturbed conditions' (Annex V 1.2 of the WFD). The boundary between good and moderate ecological status is crucial because it determines when restoration measures need to be taken. The values for the biological quality elements set by Member States for the 'high' – 'good' class boundary and the 'good' – 'moderate' class boundary are being compared as part of the intercalibration exercise (GIGs) the member states participate. European Mediterranean Member States participate in the MEDGIG exercise.

Requirements

The WFD requires Member States to classify the ecological status of surface water bodies into one of five ecological status classes; high, good, moderate, poor or bad ecological status (see Tables 5, 6 and 7). The ecological status of a water body is an expression of the quality of the structure and functioning of its aquatic ecosystem. The Directive provides qualitative definitions for each ecological status class and for each surface water category.

Nutrient enrichment is one of the many different anthropogenic pressures on water bodies that may affect their ecological status. As such, management measures may be required to control nutrient enrichment in order to achieve the objectives of the Directive. The sensitivity of water bodies to nutrient enrichment may vary depending on their physical characteristics and on the extent of other anthropogenic alterations to them.

For the purposes of monitoring water bodies at risk because of nutrient enrichment, Member States must monitor parameters indicative of the biological quality element, or elements, most sensitive to the effects of nutrient enrichment as well as the nutrients that are being discharged into the water body in significant quantities.

Conceptual framework

The WFD classifies water bodies in relation to type-specific reference conditions. This enforces the view of eutrophication as a process, where nutrient enrichment through human activities causes adverse changes in the aquatic environment, rather than as a particular level of productivity or trophic state.

The assessment of eutrophication is strongly implied in the classification of surface water bodies. The definition of good ecological status for the quality elements ‘Phytoplankton’ and ‘Macrophytes and Phytobenthos’ uses very similar wording as the definition of eutrophication used in the UWWT and Nitrates Directives and by OSPAR. Good status includes an absence of eutrophication problems.

Nutrients, as part of the physicochemical quality element, must be at a level to ensure the functioning of the ecosystem and the values specified for biological quality elements.

Methods for assessing eutrophication

Under the WFD, Ecological Status is assessed by using the quality elements. Many of these quality elements are traditionally used for assessing eutrophication, in particular ‘nutrient conditions’ as well as the ‘composition, abundance and biomass of phytoplankton and macrophytes’. At good Ecological Status biological quality elements should have only slight deviation from type-specific reference conditions. Corresponding values for nutrients necessary to support the achievement of good ecological status may be estimated from response curves based on knowledge of the relationships between nutrient concentrations and the biological quality elements (the dose-response relationship if applicable to all types of water bodies).

High nutrient concentrations without any corresponding biological impacts may not necessarily result in down grading Ecological Status. Thus assessments of eutrophication consistent with the WFD should primarily focus on the biological effects resulting from elevated nutrient levels, taking also into account possible effect of transboundary transport of nutrients. Measures to reduce nutrient loading may still be needed.

4.1.2 Urban Waste Water Treatment Directive (91/271/EEC)

The Urban Waste Water Treatment Directive (UWWT Directive) aims to protect the environment from adverse effects of urban wastewater discharges and direct discharges from certain (food processing) industries. It sets treatment levels on the basis of the agglomeration size and the sensitivity of waters receiving the discharges.

Article 2(11) of the UWWT Directive defines eutrophication as: “the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned”. It focuses more on changes in the aquatic environment rather than a particular state of productivity

Surface waters must be designated as Sensitive Areas (SA) if, inter alia, they are eutrophic or if they may become eutrophic in the near future if protective action is not taken. Discharges from agglomerations of >=10,000 (population equivalent) to Sensitive Areas require more stringent treatment for nitrogen and/or phosphorus. However, Member States do not have to identify Sensitive Areas if more stringent treatment is implemented over the whole of its territory (Article 5 (8)). The designation of Sensitive Areas needs to be reviewed at least every four years (Article 5 (6)), and for newly designated Sensitive Areas more stringent treatment, with nitrogen and/or phosphorus removal, must be in place within 7 years of their designation.

Sections of the UWWT Directive that particularly refer to eutrophication and surface water monitoring are: Article 2 (11) which defines eutrophication; Article 5 on the identification of Sensitive Areas and treatment requirements; and Annex II, which specifies criteria for identification of Sensitive Areas

The UWWT Directive does not specify any methods or guideline values for assessing eutrophication. Therefore Member States developed their own assessment systems and criteria, and this may consequently lead to different levels of protection of their water bodies. Several Member States have developed criteria based on the three elements in the definition: nutrient enrichment, algae or plant life growth and other undesirable effects (e.g. oxygen depletion).

4.1.3 Nitrates Directive (91/676/EEC)

The Nitrates Directive (91/676/EC) aims to reduce water pollution by nitrate from agricultural sources and to prevent such pollution occurring in the future. The Directive requires Member States to identify polluted waters and apply Action Programme measures (Annex III of the directive) within designated Nitrate Vulnerable Zones (NVZs) or throughout their whole territory.

Nitrate Vulnerable Zones cover all land draining to “polluted waters”, including natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or may become so in the near future if protective action is not taken. In order to designate and revise NVZs, the eutrophic state of surface freshwaters, estuaries and coastal waters needs to be reviewed and reported every four years (Article 6).

The Nitrates directive has the same definition of eutrophication as the UWWT Directive except that it only relates to nitrogen compounds.

The Nitrates Directive does not specify any methods or guideline values for assessing eutrophication, which has resulted in Member States developing their own assessment criteria, and may result in different levels of protection of their water bodies. However the European Commission has developed a monitoring guidance that includes some preliminary elements for setting eutrophication criteria.

4.1.4 Habitats Directive (92/43/EEC)

The Habitats Directive (92/43/EEC) requires Member States to designate Special Areas of Conservation (SACs) (Article 4.4) and Special Protection Areas (SPAs) (Articles 12 and 13) for habitats of plants and animals listed in Annexes I-IV of the directive. For the habitats and species of selected sites, measures must be implemented to maintain or restore to ‘a favourable condition’ (i.e. Favourable Conservation Status). The Conservation Status must be monitored for all habitats and species of Community interest, and this is not restricted to Natura 2000 sites. The monitoring of habitats can focus on ‘typical species’.

Although not explicitly mentioned in the Directive, the impact of point and diffuse pollution by nutrients on water quality is an important part of conservation status in aquatic habitats. The Habitats Directive does not specify any methods for assessing eutrophication. However, eutrophication is relevant to the Habitats Directive to the extent that it might affect protected species and habitats. Nutrient enrichment leading to eutrophication can have significant detrimental effects on specific aquatic species and habitats. For example, excessive growth of benthic algae from elevated phosphorus can threaten the habitat for the pearl mussel. More generally, changes in water quality can also help explain trends in biodiversity.

4.1.5 Shellfish Waters Directive (79/923/EEC)

The Shellfish Waters Directive aims to protect and improve shellfish waters in order to support shellfish life and growth and thus to improve the high quality of shellfish products for consumption. The Directive sets physical, chemical and microbiological water quality requirements that designated shellfish waters must either comply with or endeavour to meet. The Shellfish Water Directive will be repealed by the WFD by 2013.

The Shellfish Water Directive does not require an assessment of eutrophication per se, however Article 6 does require a number of parameters to be monitored to check the quality required for shellfish waters. Some of these parameters are relevant to assessments of eutrophication – in particular dissolved oxygen and saxitoxins (produced by dinoflagellates).

The Annex of the Shellfish Water Directive sets standards and monitoring frequencies for dissolved oxygen saturation and saxitoxin. These standards are set to protect shellfish beds and human health. They are absolute and apply regardless of whether the values reflect human induced impacts or naturally poor but undisturbed conditions.

4.1.6 Bathing Water Directive (76/160/EEC)

The Bathing Waters Directive (76/160/EEC) seeks to protect the environment and public health, by reducing the pollution of bathing waters and protecting such waters from further deterioration. Bathing waters are classified as all surface freshwater and seawater, where bathing is authorised by competent authorities of Member Sates and is not prohibited.

Physical, chemical and microbiological parameters applicable to bathing waters are set by the Directive and all necessary measures taken to ensure that the quality of the bathing water conforms to the limit values.

The Bathing Water Directive does not require a direct assessment of eutrophication. However, there is a requirement to monitor several parameters relevant to the assessment of eutrophication, i.e. transparency (fortnightly), dissolved oxygen, nitrates and phosphate when the quality of the water has deteriorated. Furthermore samples must be collected for ammonia and nitrogen (Kjeldahl) when there is a tendency towards eutrophication of the water (see Table 4). The Annex to the directive provides guideline values for transparency (2 meters), and dissolved oxygen (80 to 120 percent saturation). These parameters will not be included in the future amended version of this Directive.

Table 5 General overview of requirements of EC directives and regional conventions regarding eutrophication (Source: EC, 2005)

Directive /Policy	Requirement to assess eutrophication	Minimum monitoring requirements relevant to eutrophication
WFD	Implicit in classification of Ecological Status where nutrient enrichment affects biological and physico-chemical quality elements. Protected Area's support and upholds requirements of UWWTD and Nitrates Directive.	Phytoplankton (6 months), aquatic flora (3 yrs), macro-invertebrates (3 yrs), fish (3 yrs). Hydromorphological quality elements (Hydrology continuous - 1 month; others 6 years). Physicochemical quality elements (3 months).
UWWT Directive	In order to identify Sensitive Areas under Annex IIA (a) criteria (i.e. water bodies that are eutrophic or may become eutrophic in the near future).	Review of the existing Sensitive Areas and designation of new ones at least every 4 years (Article 5(6)).
Nitrates Directive	In order to identify polluted waters and designate their catchment area as Nitrate Vulnerable Zones.	Review the eutrophic state of surface water at least every 4 years.
Habitat Directive	If threatening protected habitats or species.	None
Shellfish Water Directive	No specific requirement to assess eutrophication.	DO (monthly) & algal toxins.
Bathing Water Directive	No specific requirement to assess eutrophication, but guideline and imperative values for transparency are explicitly related to eutrophication.	Transparency (fortnightly), pH, DO, nitrates & phosphate (when water quality has deteriorated. Ammonia & nitrogen (Kjeldahl) when there is a tendency towards eutrophication.
OSPAR Eutrophication Strategy	Explicit requirements for assessing the eutrophication status of waters in OSPAR maritime area using the OSPAR Common Procedure (in particular its Comprehensive procedure).	Monitoring of selected parameters for nutrient enrichment, direct effects, indirect effects and other possible effects according to the mandatory Eutrophication Monitoring ¨Programme (OSPAR 2005-4).
HELCOM	Explicit in quantifying and assessing emissions/discharges/losses and inputs to as well as concentrations and effects in the Baltic Sea [HELCOM Periodic Assessments of the Status of the Baltic Sea and PLCs (Air and Water)]	MONAS: Pollution Load Compilation (PLC Air and Water) Monitoring Programme (total nitrogen, nitrates, ammonia, orthophosphate and total phosphorus) and COMBINE (including total nitrogen, total phosphorus, DIN, DIP, Si, phytoplankton and zoobenthos species composition, abundance and biomass, Chl a, dissolved oxygen and Secchi depth).
Barcelona Convention-Strategic Action Programme(SAP) to address LBS	The SAP states Eutrophication as the result of input of nutrients from rivers and sewage into inshore waters such as lagoons, harbours, estuaries and coastal area which are adjacent to river mouths, so actions should be taken to reduce inputs of nutrients from Land Based Sources (LBS).	MED POL Eutrophication monitoring strategy (2003) – DIN, DIP, TP, Si, Chl A, Phytoplankton (total abundance, abundance of major groups, bloom dominance), Transparency, DO, T, S, pH

Table 6 The classification of water bodies not achieving the objective with regard to eutrophication under different directives and policies (overview) (Source: EC, 2005).

Directive/ Policy	Classification	Comments
WFD	Worse than good Ecological Status. (Deterioration in Ecological Status)	Water body is eutrophic if failure of eutrophication-related biological quality elements is due to nutrient enrichment, as compared to some other pressure. Covers all freshwaters and transitional waters and all coastal water that is on the landward side of a line that is 1 nautical mile seaward of the baseline from which the breadth of territorial waters is measured.
UWWT Directive	Sensitive Area	Sensitive Areas are water bodies (including freshwater bodies, estuaries and coastal waters) that are eutrophic or in the near future may become eutrophic if protective actions are not taken. Designation of Sensitive Area results in action regarding waste water treatment independent of the origin of the pollution (i.e. independently whether pollution comes from urban waste water discharges, or originates from agricultural-based sources, since both of them contribute to eutrophication)
Nitrates Directive	Polluted waters whose catchments require designation as Nitrate Vulnerable Zones.	NVZs must be established over the catchment of polluted waters, i.e. water bodies that are eutrophic or in the near future may become eutrophic if protective actions are not taken. Only applies to pollution by nitrogen from agricultural sources.
Habitats Directive	Non-favourable condition	If affecting protected habitats or species.
Shellfish Water Directive	No direct link	Might result in a shellfish water site failing water quality criteria.
OSPAR Common Procedure	Problem Area	Applies to the OSPAR Convention Waters (estuaries and marine waters). All anthropogenic nutrient sources and inputs are taken into account in assessing the eutrophication status.

Table 7 Comparison of assessment results under various policies for waters responding to nutrient enrichment (based on the assumption that the WFD classification is the starting point and that the different sources of pollution are relevant) (Source: EC, 2005)**.**

ASSESSMENT OF CURRENT STATUS				
Ecological Status	**WFD normative definition**	**UWWT Directive**	**Nitrate Directive**	**OSPAR**
High	Nearly undisturbed conditions	Non Eutrophic, designation of sensitive area is **not required**	Non Eutrophic, not a Polluted Water, designation of NVZ is **not required**	Non-Problem Area

Good	Slight change in composition, biomass	Non Eutrophic, designation of sensitive area is **not required**	Non Eutrophic, not a Polluted Water, designation of NVZ is **not required**	Non-Problem Area
Moderate	Moderate change in composition, biomass	Eutrophic or may become eutrophic in the near future, designation of sensitive area is **required**	Eutrophic or may become eutrophic in the near future, polluted water, designation of NVZ is **required**	Problem Area
Poor	Major change in biological communities.	Eutrophic, designation of sensitive area is **required**	Polluted water, designation of NVZ is **required**	Problem Area
Bad	Severe change in biological communities.	Eutrophic, designation of sensitive area is **required**	Polluted water, designation of NVZ is **required**	Problem Area

4.1.7 European Marine Strategy

The European Marine Strategy is developed under the 6th Environment Action Programme (6th EAP) with the overall aim to 'promote sustainable use of the seas and conserve marine ecosystems' (European Commission, 2002).

In some aspects European Marine Strategy, will be analogous to the WFD in a way that it will be based on an ecosystem-approach that will support a regional approach considering that problems are different in different seas or parts thereof. Although many of them originated from activities on land, it only deals with issues pertinent to the marine environment. Eutrophication will be addressed within the strategy as one of several priority issues. A common approach toward marine monitoring and assessment will be developed under the Strategy.

4.1.8 ICZM: Integrated Coastal Zone Management

The need for better management of coastal zones has led, in different degrees since the early 1970s, to political commitments and numerous measures. In some countries this has resulted in specific legislation and national strategies, regional management schemes, studies, inventories, and research. However, all these existing measures are not as effective as could be due to the lack of coordination between the many parties influencing the development of the coast (EEA/UNEP, 1999).

4.2 The EEA approach to eutrophication

4.2.1 DPSIR: The Driving forces Pressure State Impact Response approach

The DPSIR approach is the causal framework for describing the interactions between society and the environment adopted by the European Environment Agency: driving forces, pressures, states, impacts, responses (extension of the PSR model developed by OECD) (EEA, 1999, Technical report No 25, http://reports.eea.eu.int/TEC25/en).

The DPSIR framework (Fig. 4) is an approach to the system of indicators that are widely accepted for the marine environment and coastal zone to obtain:

- an information reporting system (structure for organising and reporting on monitoring data);

- a tool for communicating with policy-makers in particular, and also with the general public.

The DPSIR approach and its relation to environmental indicators is fully described in document UNEP(DEC)/MED WG.231/14, therefore here only an outline will be presented.

The definition of an indicator according to OECD (1993) is: "Indicator/parameter or a value derived from parameters, which points to, provides information about / describes the state of a phenomenon / environment / area and has further implications for the environment. The indicator is not necessarily an environmental parameter, but it could be the expression of a parameter or a pool of environmental parameters. A good indicator has to meet a set of criteria".

In relation to policy-making, environmental indicators are used for three major purposes:

i. to supply information on environmental problems, in order to enable policy-makers to assess their seriousness;

ii. to support policy development and priority setting, by identifying key factors that cause pressure on the environment;

iii to monitor the effects of policy responses.

In addition, environmental indicators may be used to raise public awareness on environmental issues. When selecting parameters and relative indicators it must be kept in mind, that there is a difference between the scientific research perspective and the environmental research perspective (Fig. 5).

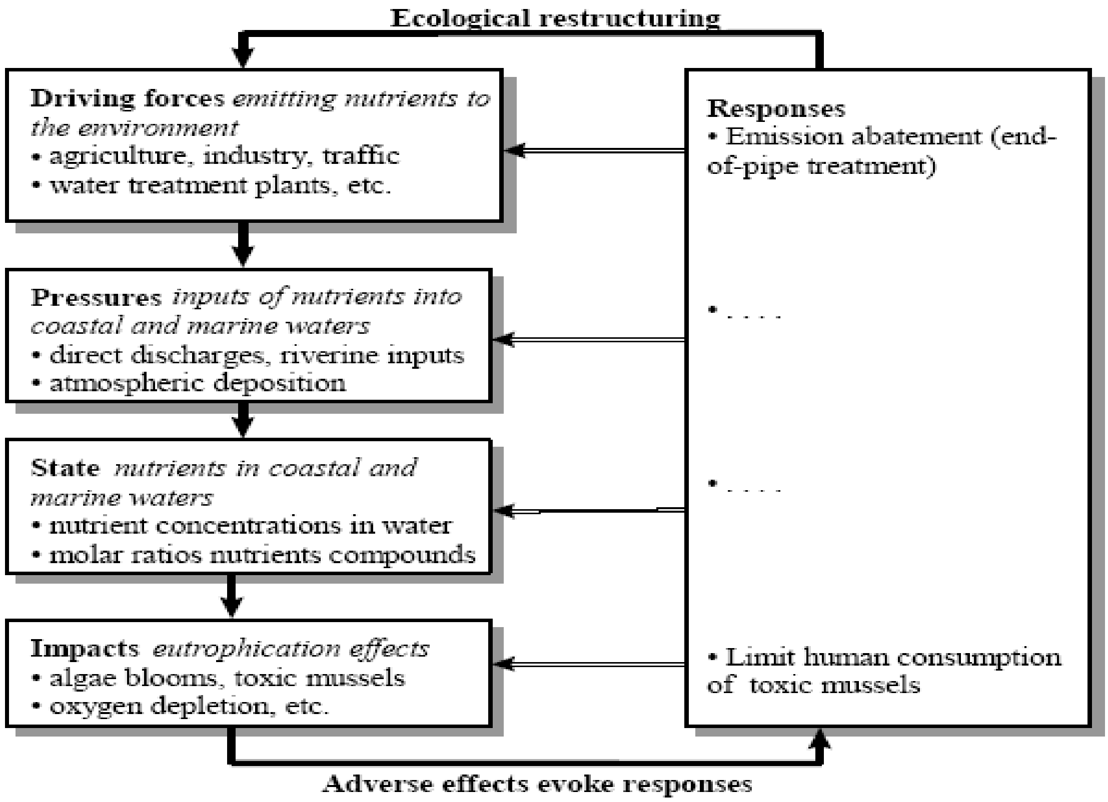


Fig. 4. DPSIR assessment framework in the context of eutrophication (EEA, 2001a).

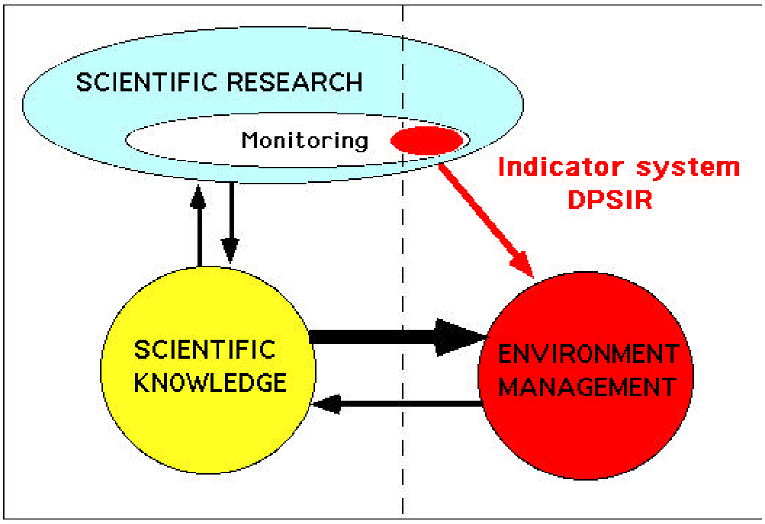


Fig. 5. The relation between scientific and management perspective for environmental monitoring

DPSIR is also a tool for improved understanding of environmental problems and a tool to set priorities for regional environmental problems. Many different frameworks and sets of indicators have been reported in industrialised countries. The most thoroughly discussed system is the *"pressure-state-response" (PSR)* framework of the OECD (1993). The PSR framework and alternatives connect pressures caused by human activities with changes in the state of the environment and responses aimed at improving the state of the environment by reducing the pressures.

According to the DPSIR framework there is a chain of causal links starting with '*driving forces*' (economic sectors, human activities) through '*pressures*' (emissions, waste) to '*states*' (physical, chemical and biological) and '*impacts*' on ecosystems, human health and functions, eventually leading to political '*responses*' (prioritisation, target setting, indicators).

Here it must be noted that this framework is chosen as a starting point for MED POL monitoring and assessment strategy because of its simplicity and wide acceptance, and the fact that it can be applied on any scale.

Within the DPSIR framework, eutrophication assessment belongs to the part of "State" and "Impact". The outcome of the assessment might result in responses and measures. In order to be able to formulate the response, there is a need to understand the links between drivers/pressures, state/impact and the response.

4.2.2. The eutrophication indicators selected by EEA

The European Environment Agency identified marine eutrophication as one of the main issue affecting European coastal zones and dedicated a strong effort to manage this phenomenon at a European scale.

EEA produced a number of reports that have been discussed in several workshops regarding indicators for the marine and coastal environment related also to WFD.

The need for new and more effective indicators for eutrophication assessment was identified and can be found in the recommendations of Inter-Regional Forum Workshop on marine indicators:

- develop maps on EU Eutrophication Risk index and use of remote sensing for chlorophyll “a” indicator/maps

- test phytoplankton indicators

- test indicator of phytotoxins and macrozoobenthos (2nd priority)

- develop indicator on phytobenthos at European scale

- take the OSPAR common procedure (OSPAR, 1997) into account when developing eutrophication indicators

The potential set of indicators identified by the work programme of EEA Topic Centre for Marine and coastal environment (ETC/MCE) for assessing the eutrophication state of a marine are shown below in Table 8.

A detailed summary of the EEA approach to eutrophication can also be found in document UNEP(DEC)/MED WG.231/14.

Table 8. EEA selected baseline indicators for state assessment of marine eutrophication

Headline *Indicator*	**EEA Indicator theme**	**General description**	***Indicator parameters***	***Comments***
	Nutrients	Concentrations of substances	winter conc. NO_2 +NO3, PO_4, N/P ratio, Chlorophyll a Bottom oxygen TRIX (Trophic Index)= =(Log(Chl-a*aD%O*DIN*TP)+ 1.5) /1.2	Mean summer tot-P, tot-N, inN forms, $P0_4$ Spring peaks, seasonal Mean, annual minimum duration of low oxygen values, TRIX index allows for spatial information using SeaWifs images

4.3 OSPAR

The implementation of the OSPAR Eutrophication Strategy aims to achieve ‘a healthy marine environment in the North East Atlantic area between Oslo and Paris, where eutrophication does not occur’ by 2010. PARCOM recommendation 88/2 deals with the reduction of nutrient inputs by 50 percent from 1985 to 1995 in regions where these inputs may likely, directly or indirectly to cause pollution. PARCOM recommendation 89/4 deals with the set up of national action plans to reach the aims set out in PARCOM Recommendations 88/2. OSPAR defines "eutrophication" as the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned, and therefore refers to the undesirable effects resulting from anthropogenic enrichment by nutrients as described in the OSPAR Common Procedure (Fig. 6).

OSPAR has developed a harmonised assessment of eutrophication through the Common Procedure to identify the regions of the OSPAR Marine Area in which these recommendations apply. This consists of an Initial Screening Procedure (a "one-off broad-brush approach") to identify obvious Non-Problem Areas, followed by the application of the Comprehensive Procedure to identify whether other waters should be classified as (Potential) Problem Areas or Non-Problem Areas with respect to eutrophication. The Comprehensive procedure is applied as an iterative process, with periodic reassessments and feedback from its application being used to refine the procedure. The screening procedure has been finalised in 2004

The Comprehensive Procedure (COMPP) consists of a set of assessment criteria that are linked to form a holistic assessment of eutrophication status (OSPAR Commission 2005-3). It is based on a conceptual framework of the eutrophication process (Fig. 6) and a checklist of qualitative parameters for a holistic assessment. The conceptual framework and these categories take into account interactions and cause and effect relationships.

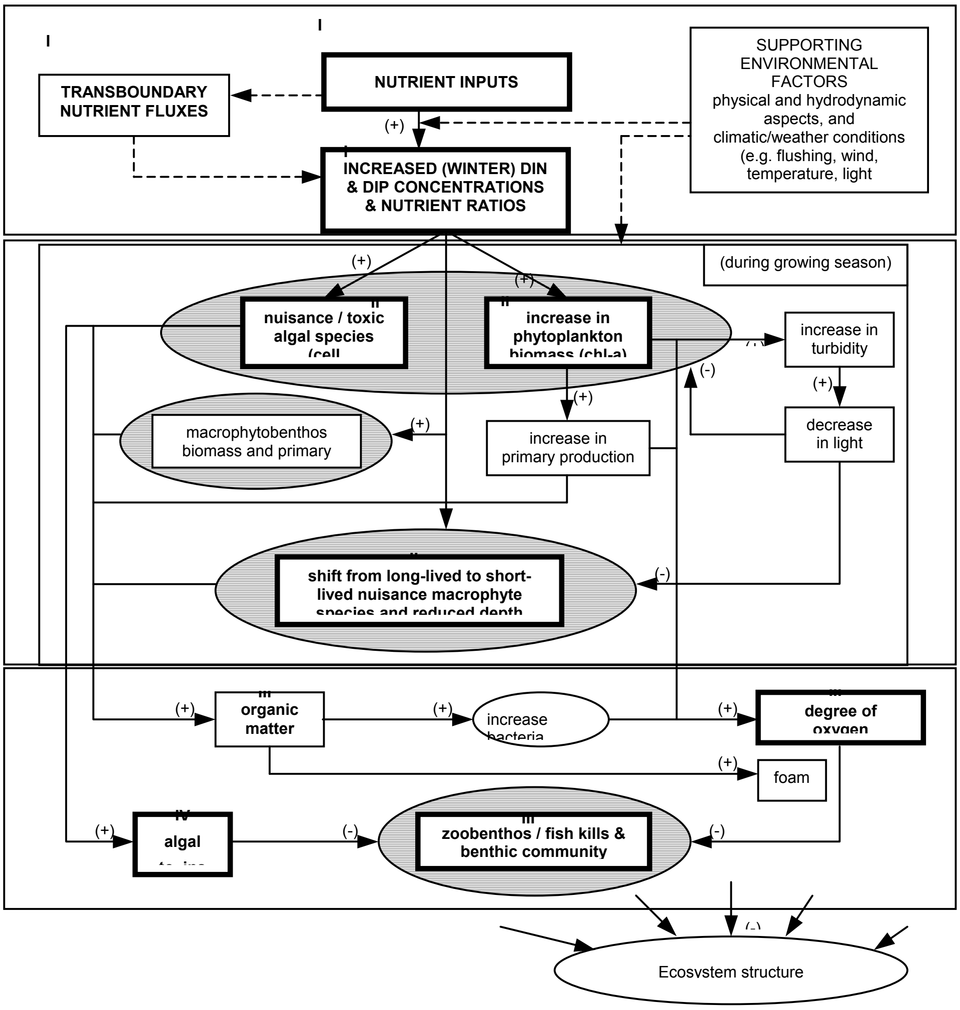


Fig. 6 The Eutrophication Process. Cause-effect relationships (OSPAR, 2002)

4.4 HELCOM

The Helsinki Commission, (HELCOM), aims to protect the marine environment of the Baltic Sea from all sources of pollution, and to restore and safeguard its ecological balance (Table 5). It operates through intergovernmental co-operation and is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" (known as the Helsinki Convention).

Nutrient enrichment and eutrophication is a major environmental problem in the Baltic Sea and is still to be solved. One of HELCOM's overarching goals is to reduce eutrophication and this requires a consensus on assessment procedures as well as a subsequent linking of effects and activities taking place in the drainage basin. Under certain hydrological and environmental conditions nutrient enrichment leads to algal blooms, oxygen depletion and occasionally fish kills (e.g. 2002 in the Belt Sea and 2003 in the Gulf of Gdansk). In many coastal regions the perennial algal belts have reduced and partly replaced by short-lived filamentous algal species.

Since mid 1980, HELCOM has adopted several HELCOM Recommendations to reduce the load of nutrients and oxygen consuming substances from point and non-point sources in the Baltic Sea catchments. In addition the 1988 HELCOM Ministerial Declaration sets goals for all coastal states to decrease their anthropogenic nutrient loading by 50% from 1987 by 1995. Furthermore, in 1992, the Baltic Sea Joint Comprehensive Environmental Action Programme (JCP) was established to facilitate and monitor the elimination of the 132 most polluting sources within the Baltic Sea catchment area - known as "hot-spots".

At present, HELCOM has established monitoring programmes (Table 5), including detailed Guidelines, to quantify inputs of airborne and waterborne nutrients and their sources. Currently, airborne inputs and their sources are assessed annually.

Pollution Load Compilations are periodically carried out in order to compile:

a. Total loads of nutrients on an annual basis (from rivers and coastal areas as well as point sources and diffuse sources discharging directly to the Baltic Sea); and

b. Waterborne discharges from point sources and losses from non-point pollution sources as well as natural background losses into inland surface waters within the catchment area of the Baltic Sea located within the borders of the Contracting Parties.

Since the late 1970's, the joint holistic environmental monitoring COMBINE has been carried out in the Baltic Sea under the co-ordination by HELCOM. It has included quantification of spatial distribution and long-term trends in nutrients, oxygen, phytoplankton, zooplankton, and benthic macrofauna. Cycles of hydrographic parameters, water exchange and fluxes of nutrients between the Baltic Sea and the North Sea and between the Baltic Sea basins, sediment, littoral phytobenthic communities and coastal fish are also included in the HELCOM monitoring programme. The COMBINE program is carried out every year; it focuses on eutrophication and contaminant monitoring and assessment in coastal waters and the open marine environment.

The results are published every five years as comprehensive periodic assessments, which include most of the DPSIR chain as well as structure and functioning of the pelagic system. Background concentrations of nutrients in the open marine environment are used as one of the criteria for assessments. Ecological Quality Objectives (EcoQOs) for eutrophication are also under development

HELCOM MONAS launched in 2004 the project "Development of tools for a thematic eutrophication assessment (HELCOM EUTRO)" which aims at a Baltic Sea wide harmonisation of eutrophication assessment criteria and procedures including the establishment of reference conditions for different parts of the Baltic Sea. The project will be a test of the preliminary Pan-European guidance on assessment of eutrophication in European waters adapted to Baltic Sea specific features. The activities are based on monitoring data produced within the COMBINE programme and other national monitoring and research data, and they cover both the coastal areas and the open sea.

4.5 AMAP

AMAP is an international organization established in 1991 to implement components of the Arctic Environmental Protection Strategy (AEPS).

AMAP does not have a work programme on eutrophication, as this not an issue there, due to very low population densities.

4.6 Bucharest Convention/Commission on the Protection of the Black Sea Against Pollution

According to the provisions of the Bucharest Convention (1992) and Odessa Ministerial Declaration (1993), the Commission adopted the Strategic Action Plan for Rehabilitation and protection of the Black Sea (BS-SAP 1996) (Table 5).

One of the most important features of BS SAP is basin wide approach to combat the eutrophication, i.e. the priority environmental problem of the Black Sea, which implies the strengthening cooperation with river basin programs, especially Danube environmental program. BS SAP devotes particular attention to nutrients and a long term programme to reduce the loads of nutrients and hazardous substances has been undertaken. Special attention is given on study of eutrophication and establishing the indicator-based regional monitoring and assessment system.

5. OVERVIEW OF EUTROPHICATION MONITORING STRATEGIES AND ASSESSMENT METHODS USED IN THE MEDITERRANEAN

A monitoring strategy for eutrophication for the MED POL programme was approved by the National Coordinators in 2003 (UNEP(DEC)MED WG 231/14, 2003).

The short-term adopted strategy proposes site selection criteria and a minimum number of mandatory monitoring parameters, in order to apply the TRIX index, as well as to support EEA’s state indicators. It also includes a minimum monitoring frequency and a sampling stations network.

However, not all the countries that participated in the eutrophication pilot programs with MED POL assistance followed the above monitoring strategy. The majority followed their national or other strategies. Therefore, it is essential to examine these strategies and evaluate existing activities in order to harmonize practices on a basin-wide scale.

5.1 The MED POL adopted strategy for eutrophication monitoring and assessment

Short-term strategy

The first step for the short-term monitoring strategy is the identification of sites as eutrophic or sensitive to eutrophication (being at risk to be eutrophic). MED POL proposed three different site typologies:

- An affected marine site together with a reference site

a. to select hot spot site(s)- affected area

b. to adopt the parameters supporting the TRIX index given in the *"monitoring plan"* below

c. to adopt spatial coverage and frequency recommended within the *"monitoring plan"*

d. to choose a reference site adopting the same monitoring plan and sampling strategy as that for the affected area

- An offshore fish farm

Offshore fish farming is an increasing activity in Mediterranean countries and fish production is an important point source of nutrients and organic matter. This could, mainly in sensitive areas, have a huge impact on the ecosystem and may form potentially risk areas for eutrophication:

a. each country has to choose such a site adopting the same monitoring plan for the marine site (hot spot and reference area; parameters etc.)

b. for better characterization of the site, fish production data must also be collected

- A coastal lagoon

Mediterranean coastal lagoons are very important sites for biodiversity protection and as nurseries for the marine species.

For more information see the relevant documents.

Medium/Long term strategy

For a medium/long term strategy the development of new biological parameters/indicators of eutrophication was proposed. It is basically necessary to introduce biological parameters both for the phytoplankton population dynamics and for the benthic component of the coastal ecosystem.

The monitoring programmes for eutrophication need to be supported by remote sensing techniques and the technical tools/scientific products of operational oceanography.

The conceptual framework of eutrophication, suggests the introduction of new parameters and indicators more related to sediment transformations. Such a proposal is presented to the present meeting.

It must be noted, however, that not all countries followed the above monitoring strategy. It is obvious from the eutrophication pilot programmes and the information collected through the questionnaires that the majority follow their national or other strategies (see section 5.2).

Therefore, it is essential to examine these strategies and evaluate existing activities in order to harmonize practices on a basin-wide scale.

5.2 Monitoring strategies applied for eutrophication studies by Mediterranean countries

The information presented and analyzed below is based on the information collected through the questionnaires sent to Mediterranean countries.

- **Albania**

The monitoring programme of Albania, which started three years ago, does not include all proposed parameters by MED POL but only temperature, pH, salinity, orthophosphate, total P, dis. oxygen, nitrate, nitrite, ammonium for shallow coastal marine sites along the coastline and sporadically nutrients and chlorophyll-a for bays, lagoons and estuaries.

The maximum sampling frequency is seasonal: four samplings per year.

Additional parameters are not monitored (in sediments only heavy metals), however some sporadic data about biological parameters from lagoons exist.

Participation in quality assurance exercises:

a) One laboratory participated in the quality assurance exercise organized by MED POL. The experience gained helped to improve techniques and methodologies for quality assurance practice. It will be very important to continue with this procedure and to be helped through MED POL to find some certified or reference materials for the eutrophication parameters. Also participated in another inter-calibration exercise in 1996, which was organized by RIZA laboratory, Netherlands.

b) Another laboratory is working for ISO accreditation process with the support of ALcontrol laboratory (Dutch lab). Dutch fund support.

No information is available on other research projects relevant to eutrophication.

- **Cyprus**

Not all eutrophication parameters proposed in the MED POL strategy are monitored. For Site 1: temperature, dis. oxygen, salinity, chlorophyll, TN, TP, nitrate, nitrite, ammonium, and phosphate are monitored in the framework of MED POL. For Site 2: chlorophyll, nitrate, nitrite, ammonium, phosphate, occurrence and proliferation of ephemeral macroalgae.

Monitoring frequency is 3-4 times per year, for site 1 for one year and for site 2 for three years. The spatial coverage is a network of 16 sampling stations for site 1 and 12 stations for site 2.

Macrobenthos is monitored additionally. Regarding new proposed parameters for sediments they are informed. They monitor organic matter in sediments and macrozoobenthos.

Participation in quality assurance exercise in 2005 (Interlaboratory proficiency test: nutrients) organized by MED POL in collaboration with IAEA. Suggestion: to include chlorophyll in quality assurance laboratory exercises.

- **Egypt**

Not all the eutrophication parameters proposed by MED POL are monitored. The parameters being monitored are: water transparency (Secchi disk) nitrate/nitrite, ammonia, total N, and orthophosphate, silicate, and chlorophyll.

Sampling frequency is bimonthly, in 31 stations along the Mediterranean coastal area for Coastal Water monitoring programme.

Additional parameters are monitored in research projects such as:

- grain size, % dry matter, loss or ignition, total N, total P, (in sediments)

- benthic populations (to species level), shell length of mussel, % wet and dry tissue weight, condition index for mussel, % lipid content

- degree of oxygen deficiency.

They are aware of the new proposed eutrophication indicators for sediments. It will be considered to monitor in the future such parameters.

Participate in an annual national quality assurance exercise.

Besides eutrophication monitoring, research related to eutrophication is performed in the framework of MSc and PhD degrees in local universities and for remote sensing.

- **France**

According to the information received, there are two types of monitoring programmes: one for the marine environment and another one for the lagoons. In the framework of the monitoring strategy for the lagoons, all the eutrophication parameters proposed by the MEDPOL strategy are monitored, whereas for the open sea, the parameters are defined according to the National framework for the monitoring of the marine environment (RNO). The parameters monitored according to RNO are: temperature, salinity, nitrate, nitrite, ammonium, phosphates, dis. oxygen, silicates, suspended particles, turbidity, chlorophyll-a, phaeo-pigments.

The sampling frequency in the lagoons (regarding the parameters proposed by MEDPOL) is 3 times per year, during summer (June, July, August), whereas in the sea samping is 10-12 times annually. For the lagoons time series exist from 1999 and for the sea from 1974.

The spatial coverage regarding each monitoring system is: For the lagoons, 1 or 2 stations per lagoon or sub-basin of the lagoon and 1 or 2 sampling depths (if the lagoon's depth is >3.5m). For the open sea, sub- surface sampling in 4-10 stations per site.

Additional parameters (in comparison to MED POL) are monitored in lagoons: macrophytes (once every 3 years), phytoplankton (once every year), benthic invertebrates (once every 5 years) and organic enrichment of the sediments (once every 5 years). In the open sea the additional parameters are: benthic population from soft substrates and *Posidonia* meadows. They have not been informed about the new eutrophication indicators in sediments proposed by MED POL and they stress that it is necessary to harmonize monitoring strategies in the framework of the WFD. However, they monitor sediments for the parameters: granulometry, organic matter, total P, total N, macrophytes (species richness, spatial coverage and biomass) and benthic macrofauna.

Participation in quality assurance exercise through Quasimeme (Ifremer, 2006), with satisfactory results. Also they are planning to participate in another exercise concerning lagoons with the Meteorological Research Insitute de Tsukuba (Japan).

Research regarding eutrophication (except monitoring programmes):

- Research for the *Alexandrium minutum* blooms in lagoons (A. Pastoureaud, Ifremer, Sete)

- In postgraduate thesis.

- **Greece**

All MED POL parameters were monitored except TP and TN. From 2007 these parameters are included in monitoring planning, at least for Saronikos and Thermaikos.

Monitoring frequency is monthly for most parameters.

Sampling is performed in a network of hydrographic stations, which can vary between areas. Minimum number of stations usually is about 10-15.

Data on nutrients, dis. oxygen and chlorophyll-phytoplankton exist for at least 30 years for Saronikos gulf and about 20 for Thermaikos gulf, but with gaps during the first years.

Additional parameters monitored regularly in programs are: suspended particles, POC, PON, POP, heavy metals in water, biota and sediments, detergents, hydrocarbons, total coliforms in water and sediments, shift in species composition, frequency of HABs, toxic phytoplankton and toxins, hypoxia/anoxia, micro- and mesozooplankton, phytobenthos and zoobenthos, etc. Proposal for new eutrophication indicators regarding chemistry and biology of sediments is known. Some of the proposed parameters are measured within monitoring programmes.

Two laboratories in the Institute of Oceanography, HCMR, are working for ISO accreditation process.

Additional research related to eutrophication in Greece is:

a. HABs related research,

b. Remote sensing related research

c. Toxin analysis

d. Benthic oxygen depletion

e. Research related to classification regarding ecological status (WFD)

- **Italy**

All the parameters proposed in the MED POL strategy are included in the national monitoring programme.

All mandatory parameters are sampled twice a month. In particular, continuous vertical profiles for salinity, temperature, pH, chlorophyll “a” and dissolved oxygen are collected through the use of a multiprobe apparatus.

Monitoring data are available from July 2001 to March 2006.

The network of sampling stations follows the proposals of the MED POL programme with three sampling stations chosen for each transect:

1 sampling station at 200 m from the coastline and less than 5 m depth,

1 sampling station between 200 m and 3000 m. from the coastline at a depth between 5 m and 50 m.

1 sampling station at 3000 m from the coastline and more than 50 m depth.

In addition, monitoring of benthic populations (macrozoobenthos, seagrass *Posidonia oceanica*) is performed.

Monitoring in sediments includes heavy metals (arsenic, cadmium, chromium, copper, nickel, lead, zinc, vanadium, aluminium, iron and mercury), chlorinated hydrocarbons (chlorinated pesticides and polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), tributyltin (TBT) in hot spots, like marinas and harbours, and TOC (total organic carbon).

Italy participates in quality assurance laboratory exercises regarding eutrophication. During the monitoring programme, a QUASIMEME programme has been organized between laboratories for both the mandatory chemical (basically nutrients) and the biological parameters.

- **Lebanon**

Not all the eutrophication parameters proposed by MED POL are monitored. The parameters being monitored are: temperature, salinity, phosphate, nitrate, nitrite, chlorophyll, and phytoplankton

Sampling is performed monthly. The stations framework covers all the coastal area of Lebanon (before 2000: 14 stations, after 2000: 22 stations)

Toxic phytoplankton species are monitored additionally.

Not aware of new proposed eutrophication indicators for sediments. However, TOC and meiobenthos are monitored in certain stations, but it is not foreseen to monitor the new proposed parameters.

No participation in quality assurance exercises, but planning to participate in IAEA (Monaco) for trace metals.

Besides eutrophication monitoring, research related to eutrophication is performed in the framework of a study regarding phytoplankton and zooplankton population dynamics. Also, remote sensing for chlorophyll is used.

- **Morroco**

Not all the eutrophication parameters proposed by MED POL are monitored. The parameters being monitored are: toxic phytoplankton (monthly and bimonthly), phytotoxins DSP and PSP (when present), bacteria (monthly and bimonthly), pollutants (annually), physicochemical parameters (T^{o}, S, nitrates, nitrites, orthophosphates) and heavy metals (trimonthly).

The framework of stations and the time period depends on ecosystem characteristics.

Aware of the new proposed eutrophication indicators for sediments and can be planned for the future.

No participation in a quality assurance exercise of MED POL.

Besides eutrophication monitoring, research related to eutrophication is performed in the framework of projects:

Identification and study of phytoplankton population dynamics

a. Spatio-temporal evolution of the contamination of the marine environment by toxins (DSP, PSP, ASP)

b. The physicochemical characterization of water masses in lagoons and estuaries

c. Hydrodynamics and currents in lagoons

- **Palestine**

Not all the eutrophication parameters proposed by MED POL are monitored. The parameters being monitored are: temperature, salinity, pH, turbidity, conductivity, dissolved oxygen, total dissolved solids, *E. coli, FS, F.*

Sampling frequency is monthly, in seven stations along Gaza coastline.

- **Slovenia**

All proposed parameters in the framework of the MED POL programme are monitored 6 times a year, except phytoplankton (total abundance and abundance of major groups) which is sampled seasonaly (four times a year). Data exist since 2000.

Spatial coverage of the monitored area consists of two transects, as follows:

- affected sites – 3 stations, 3 sampling depths and
- reference sites -3 stations, 3 sampling depths

Additional parameters (mainly biological) being monitored are:

- occurrence and frequency of Harmful Algal Blooms/toxic phytoplankton,
- degree of oxygen deficiency

Sediment sampling is performed within the research project ECASA (An Ecosystem approach to sustainable aquaculture) around fish cages

Participation in quality assurance exercises:

Analytical performance study for MEDPOL: Determination of nutrients in seawater and of chlorinated pesticides and petroleum hydrocarbons in sediments (IAEA, Monaco; Intercalibration Exercise IAEA-435)

- Intercalibtration exercise for Chlorophyll a (fluorometer) with CIM Rovinj, Croatia
- All samples were delivered in laboratory without problems and the results for nutrients were within the Z-score (-3 to +3).

Additional research related to eutrophication in Slovenia is:

- HABs related research, Phytoplankton production and temporal (monthly) evolution of phytoplankton community
- Benthic oxygen depletion
- Research related to classification regarding ecological status (WFD).

- **Spain**

Spain follows a monitoring strategy for the Region of Murcia, according to national requirements and the Nitrate Directive. Therefore, the criteria for selecting sites, frequency and parameters are based on the strategies defined by these frameworks.

The sampling station network consists of 41 stations in the Mediterranean Sea and 10 in Mar Menor. The sampling frequency is 4 seasonal samplings every four years.

The parameters measured in the water column are different for the Mediterranean Sea from that in Mar Menor. In both areas, the sampling parameters are divided into two groups: the first one can support MED POL requirements while the second group consists of additional parameters:

a) Mediterranean Sea:

Parameters supporting MED POL: nitrite, nitrate, ammonium, P, chlorophyll, dissolved oxygen, transparency, pH, temperature, salinity. Other parameters: BOD, suspended particles, heavy metals, detergents, COD, hydrocarbons, total coliforms, etc.

b) Mar Menor:

Parameters supporting MED POL: nitrite, nitrate, ammonium, P, Si, chlorophyll, dissolved oxygen, transparency, pH, temperature, salinity. Other parameters: BOD, suspended particles, heavy metals, total coliforms

Sampling is performed in sediments as well:

a) Mediterranean Sea: granulometry, organic matter, Redox, heavy metals, hydrocarbons, coliforms, PCBs, pesticides.

b) Mar Menor: the above plus carbonates, TP, TN.

The benthic community is studied:

a) Mediterranean Sea: diversity, abundance, dominant groups

b) Mar Menor: species composition, biomass, Shannon Diversity, polychaetes, molluscs, populations and species.

- **Syria**

Not all the eutrophication parameters proposed by MED POL are monitored. The parameters being monitored are: temperature, salinity, pH, transparency, dissolved oxygen, phosphate, nitrate, nitrite, ammonium and chlorophyll

Sampling frequency of parameters varies according to the project. Samples are taken from surface and usually cover one annual year with monthly sampling.

Additional parameters are monitored in research projects as benthic populations or oxygen deficiency.

Aware of the new proposed eutrophication indicators for sediments, but such parameters are not monitored, though they will consider doing so in the future.

No participation in quality assurance exercises in the framework of MED POL, but planning to participate in the future and had participated in a national quality assurance program (Tishreen University, Syria).

Besides eutrophication monitoring, research related to eutrophication concerns the effect of water quality on the distribution of marine organisms and population dynamics.

- **Tunisia**

Not all the eutrophication parameters proposed by MED POL are monitored. The parameters being monitored are: toxic phytoplankton (bimonthly and every week during HABs), phytotoxins (when present), bacteria (bimonthly), pollutants (annually) and physicochemical parameters (T^o, S, pH, every week).

The framework of stations covers the shellfish culture area, and transects towards open sea. For coastal stations data from 11 years exist, for open stations data from 4 years exist.

Additional parameters existing:

- “red tide” events records for 18 years, toxic events, fish kills, ecological disturbances,.

Not aware of the new proposed eutrophication indicators for sediments, but can be planned. In certain coastal areas phytobenthos, epiphytic microalgae, cysts, etc are monitored.

No participation in a quality assurance exercise of MED POL, but participated in IOC Regional Training Workshop on Harmful Algae, December 2003, Tunis and in Advance course of phytoplankton (Naples, 2005).

Besides eutrophication monitoring, research related to eutrophication is performed in the framework of projects:

-Le phytoplancton de la Baie de Tunis (analyse systématique, bio-géographie quantitative et synécologie des diatomées et dinoflagellés) (étude en cours)

-Relationship between microphytoplankton composition and hydrodynamic structures in Gulf of Gabes (Eastern Mediterranean Sea (travail établi en 2005).

-Répartition spatio-temporelle et caractérisation des populations planctoniques (phytoplancton et zooplancton) dans le golfe de Gabes- thèse en cours 2005-2008

-Projet ELBHIRA – Ecologie des lacs de Bizerte –Ichkeul Hydrodynamisme et ressource Aquacoles. Projet de Recherche sur Contrat INSTM- Ministère de la recherche (2002-2006)

-ESSAHL – Elaboration d’un Schema Sédimentologie et Analyse de l’Hdrodynamisme des Eaux littorales. Projet de Recherche sur Contrat INSTM- Ministère de la recherche (2002-2006).

- **Turkey**

They monitor all proposed parameters for MED POL except TN.

Monitoring frequency was determined in order to cover different periods (well mixed vs stratification, spring bloom vs post bloom, etc)

Data for Izmir Bay exist from 1980 with some gaps, whereas for Mersin Bay only fro 2005 and 2006 and a limited number from early 1990s.

A sampling network of 10-15 stations with standard depths per station exists in Izmir Bay and Mersin Bay in order to assess influence of several nutrient sources.

Additional parameters were sampled in Izmir Bay in some cases (zooplankton, phytoplankton, endofauna) and in Mersin Bay (zoobenthos and phytoplankton).

Regarding the new proposed eutrophication indicators for sediments, in Izmir Bay TOC, macrozoobenthos are already monitored. And more parameters can be included in the continuation of the project.

They participated in quality assurance exercises in 2005 and 2006; nutrient intercalibration exercise by IAEA laboratory (Monaco) and previously from Quasimeme. They want to continue participating in intercalibration programmes based on the availability of funds.

Additional research related to eutrophication in Turkey is remote sensing related research in terms of chlorophyll a, in NE Mediterranean coastal waters including Mersin and Iskenderun bays.

From the information presented above some main conclusions can be drawn:

- Most countries do not monitor all parameters required by MED POL strategy, though in several cases they monitor many more parameters.

- However, most countries agree to modify their monitoring strategy to include all MED POL proposed parameters.

- This is easier for European countries, which due to their obligations to EU directives undertake more detailed monitoring projects.

- Furthermore most countries have a positive thinking regarding introduction of the new proposed parameters, related to the benthic ecosystem, though many countries have not received that information, before the questionnaire.

- Sampling frequency is in most cases seasonal, which is the minimum requirement from MED POL, though is recommended to perform monthly samplings.

- Many countries especially from southern Mediterranean coasts stressed the need for more quality assurance exercises.

- Therefore the monitoring strategy proposed by MED POL seems to be reasonably applicable in Mediterranean coastal waters, with only a small effort by countries

- Existing activities, according to the information received are towards the implementation of MED POL strategy.

5.3 Assessment methods applied for eutrophication studies by Mediterranean countries

- **Albania**

TRIX requirements were not considered for the monitoring programme as not all parameters supporting TRIX are monitored.

A national eutrophication assessment method does not exist and biological quality elements are not used. Quantitative reference conditions for biological or supporting physicochemical elements or boundary values have not been defined. No assessment method is applied. No familiarity with the DPSIR approach. Historical data are not available, since monitoring started only three years ago and is seasonal.

- **Cyprus**

TRIX requirements were taken into account for planning the monitoring programme in site 1. Therefore, all parameters supporting a proper application of TRIX are monitored.

TRIX was applied to data from site 1, in the framework of a pilot project with the aim to investigate and assess the potential impact of nutrients derived from a tuna ranching farm to nutrient and chlorophyll-a dynamics of area. The results demonstrated that water column parameters such as chlorophyll a and nutrients did not show significant spatial and temporal variability and thus cannot be used as indicators in detecting environmental changes from nutrient inputs. Therefore, TRIX does not have applicability on these data

A national eutrophication assessment exists, which uses the biological quality elements: chlorophyll a and macroalgae. Quantitative reference conditions have not been defined for either biological elements nor supporting physicochemical elements. Also, boundary conditions have not been defined for both elements.

The national eutrophication assessment is in compliance to EU directives and WFD and the coastal waters were classified as being of high ecological status.

Other assessment methodologies applied, especially for the benthic communities, are BENTIX and AMBI (Simboura & Argyrou, 2006)

The data planned to be used for eutrophication assessment are obtained through National monitoring programmes, MED POL and the EU project Med Veg. Historical data do not exist, whereas available data to MED POL within the monitoring program.

- **Egypt**

TRIX requirements were not taken into account when planning the monitoring programme; therefore not all TRIX parameters are monitored.

A national eutrophication assessment method exists, which uses the biological quality elements: chlorophyll.

Quantitative reference conditions have been defined for chlorophyll-a and for supporting physicochemical elements. Boundary conditions have been defined for both elements:

a. Level of phytoplankton biomass (expressed as concentration of chlorophyll-a, Nixon,1995)

Very low = < 1 μg/l;

Low = 1μg/l:

Moderate > 1 – 2 μg/l;

High > 2 - 5μg/l;

Very high > 5μg/l

b. Eutrophication is based on concentration of nutrients and classification according to EC methodology and experience from Adriatic waters.

Oligotrophic = <0.5 μM/l NH_4; <0.5 μM/l $N0_3$.

Mesotrophic = >0.5 < 2.0 μM/l NH_4; >0.5 < 4.0 μM/l $N0_3$.

Eutrophic = >2.0 μM/l NH_4; >4.0 μM/l $N0_3$

(Adapted from Vucak, et al., 1982; Franco, 1983 and Marchetti, 1984)

The data used for eutrophication assessment are obtained through the national monitoring programmes of the National institute of Oceanography and Fisheries, EU Commission WRc Ref: CO4150, Egyptian information Monitoring programme (EIMP)/coastal water monitoring, remote sensing authority. Historical data exist, in a time series from March 1998 until present (5 campaigns/year) for eutrophication parameters: chlorophyll, phytoplankton populations, dis. Oxygen, silicate, nitrate, nitrite, ammonia, total N, total P and orthophosphate. These data are available to MED POL and TRIX may apply.

- **France**

A national method for eutrophication assessment exists regarding lagoons (for the Rhône basin, the Lanquedoc-Roussillon lagoons and Corse from 2000, which has been applied also in other European Mediterranean areas, in the framework of the European project DITTY. However, there is no national method for coastal and transitional waters.

For the national method for lagoons biological quality elements such as chlorophyll a, phaeophytin a, phytoplankton, benthic macrofauna and macrophytes are used. For these parameters, through a statistical treatment, the reference and boundary values have been defined. Also, the physicochemical supporting elements (turbidity, phosphates, nitrates, nitrites, ammonium, TN and TP) are used, for which also the reference and boundary values have been defined using statistical treatment. A list of relevant publications is available.

As a EU country, France uses national assessment methods in compliance to WFD and classifies the aquatic ecosystems according to the five quality classes of WFD. The Mediterranean lagoons described as eutrophic (Palavasians lagoons, The Or lagoon) mentioned here have been classified referring to the affected sites as “poor” or “bad”.

In order to assess the eutrophication status according to the three quality biological elements, reference and boundary values have been assigned:

a) for phytoplankton, according to phytoplankton cell size (Table 9):

Table 9. Ecological status classification according to phytoplankton cell sizes, showing threshold values (boundary values) between classes (IFREMER, 2006)

		High		**Good**		**Moderate**		**Poor**		**Bad**
< 2µm	cells/L 10^6		20		50		100		500	
> 2µm	cells/L 10^6		2		5		10		50	

b) for macrophytes (Table 10):

Table 10. Ecological status classification according to macrophytes, showing threshold values (boundary values) between classes (IFREMER, 2006)

CLIMAX Species	DIVERSITY Satisfactory nb sp > 6	Reduced 3 < nb sp < 6	Very weak nb sp < 3
Dominant 75% < BMC	**High**		
Dominant 50% <BMC<75	**Good**		
Present 5% <BMC<50%	**Moderate**	**Moderate**	
Few presents BMC<5%		**Poor**	
Absent		**Poor**	**Bad**

BMC : Relative biomass of climax species

Nb sp: total number of species

Since the fulfilment of the requirements of the assessment according to Table 8 needs a time consuming effort in the laboratory a simplified scheme is that of Table 11.

Table 11: Simplified assessment method for the macrophytes (IFREMER, 2006).

CLIMAX SPECIES	DIVERSITY Satisfactory nb sp > 6	Reduced 3 < nb sp < 6	Very weak nb sp < 3
Dominants RC > 75%	**High**	**High**	
Dominants 50% < RC <	**Good**	**Good**	
Present 5% < RC < 50%	**Moderate**	**Moderate**	
Few present	**Poor**	**Poor**	
Absent		**Poor**	**Bad**

C: relative coverage of climax species (% of the bottom surface occupied by climax species); **nb sp** : total number of the observed species.

c) for Macrofauna (Tables 12 and 13):

Macrofauna species indicators for significant organic matter load are: *Capitella capitata* and *Scololepsis fuliginosus* (or *Malacoceros indicus*).

Table12: Assessment method based on macrofauna (IFREMER, 2006)

				SPECIES RICHNESS			
				Very satisfactory	Satisfactory	Reduced	Very weak
Indicator species for organic matter		Density	zero				Bad
			Very weak			Poor	Bad
			Weak	High	Good	Moderate	Moderate
			Normal	High	High	High	Bad
	Presence		Strong	High	Good	Moderate	Moderate
	Proliferation		Very strong		Moderate	Moderate	Bad

Table 13: Species richness and density values for the benthic macrofauna (IFREMER, 2006).

SPÉCIES RICHNESS:	DENSITY :
	Zero: 0
Very satisfactory: > 30 species	Very weak: 1 to 200 individuals
Satisfactory: 21 to 30 species	Weak: 201 to 1500 individuals
Reduced: 11 to 20 species	Normal: 1501 to 6000 individuals
Very weak : 0 to10 species	Strong : 6001 to 8000 individuals
	Very strong: > 8000 individuals

The assessment procedure takes into account also the supporting physicochemical parameters, as has been mentioned previously. The reference and threshold values for all water column parameters regarding eutrophication are given below (Table 14)

Table 14. Scale of classification of the water column parameters, which is used in Lanquedoc-Roussillon lagoons (IFREMER, 2006).

Variable			High		Good		Moderate		Poor		Bad
│Δ %O_2 SAT│		0		20		30		40		50	
TURBIDITY	**(NTU)**	0		5		10		25		40	
PO_4^{3-}	**(μM)**	0		0,3		1		1,5		4	
DIN	**(μM)**	0		2		6		10		20	

NITRITE	**(µM)**	0		0,3		0,5		0,75		1	
NITRATE	**(µM)**	0		1		3		5		10	
AMMONIUM	**(µM)**	0		11		3		5		10	
Chl-a	**(mg m^{-3})**	0		5		7		10		20	
Chl-a+Pheo-a	**(mg m^{-3})**	0		7		10		15		25	
Total N	**(µM)**	0		50		75		100		120	
Total P	**(µM)**	0		0,75		1,5		2,5		4,5	

Sampling for these parameters in the lagoons is performed every June-July-August. The highest concentration among the three obtained values each year, for every parameter, is chosen in order to fill the Table. The results need to be interpreted by an eutrophication expert.

Though the requirements for TRIX were not taken into account when planning the monitoring programme, as far as the lagoons are concerned, all the parameters required for TRIX calculation are monitored. However, it is not the same with the marine environment, where there are missing parameters for the application of TRIX.

TRIX was applied for lagoons. However, the results were not satisfactory, because according to their estimation, this index was created for coastal marine waters. Therefore they are not planning to apply TRIX, but they apply other methods as AMBI and BENTIX indices for lagoons and the proposed assessment by WFD for open sea.

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.

Furthermore, historical data exist for lagoons from 2000 and for marine environment from 1974, but TRIX has not been applied and will not be since it is not suitable for these data. However these data are available for MED POL.

- **Greece**

TRIX requirements were not considered for planning the monitoring programs, until recently. Therefore now all parameters supporting a proper application of TRIX are monitored.

In agreement with the competent authorities (Ministry of Environment) eutrophication assessment is used for the evaluation of the trophic status of marine waters (Ignatiades et al., 1992; Karydis, 1999). In this assessment biological quality elements (such as chlorophyll-a and phytoplankton) are included.

Quantitative reference conditions for biological quality elements have been defined (0.1 µg l^{-1} for chlorophyll-a, $6X10^3$ cells l^{-1}). Also threshold values have been defined for biological elements according to statistical analysis of long data sets (Karydis, 1999).

Quantitative reference conditions for physicochemical supporting elements have been defined (phosphate 0.07 µM, nitrate 0.62 µM, ammonium 0.55 µM). Also threshold values have been defined for supporting physicochemical elements according to statistical analysis of long data sets (Karydis, 1999). Other literature related to this assessment methodology is: Ignatiades, et al. (1992), Kitsiou & Karydis (1998) and Pagou (2000).

In addition, application of the methodology proposed by WFD (new conceptual framework) is tested. The "Greek" assessment method is partially in compliance with EU directives and WFD. It is planned to amend it, in order to make it compatible with the 5 classes system proposed by WFD. In preliminary trial of this assessment Saronikos ranged from medium to good and Thermaikos from poor to good. These results are close to those derived from the national assessment.

TRIX has been tested with data from Saronikos and Thermaikos for the purposes of this exercise as well to compare the trophic status of the Black Sea and Aegean Sea (Moncheva et al., 2001).

Other assessment methodologies applied for the benthic communities are BENTIX and AMBI.

DPSIR approach is well known and used whenever possible in Greek programmes.

Data for eutrophication assessment are derived from international and national monitoring projects and from research projects. Also, the possibility to use remote sensing data exists.

Historical data exist (since the 1980s for Saronikos and the 1990s for Thermaikos) and are available for eutrophication assessment and to MED POL. They consist of long time series of nutrients, dis. oxygen and chlorophyll-a. Parts of these data have already been used for TRIX in the present report.

- **Italy**

TRIX requirements have been taken into account when planning the national monitoring programme, as a powerful tool to provide information about phenomena that regard critical areas. Therefore, it reflects trends in the state of the environment and monitors the progresses made in realizing environmental policy targets.

All the parameters that support TRIX index have been monitored.

The sources of data used for eutrophication assessment are national, international monitoring projects/programmes, research projects, remote sensing/operational oceanography, and all of them have provided useful data to plan eutrophication assessments especially to identify key factors that pose a pressure on the environment.

Historical data for eutrophication assessment are available from June 2001 to March 2006: the frequency of data has been twice a month.

Besides that, available data exist from July 1996 to December 1999.

The frequency has been once in autumn-winter season and twice a month from June to September.

TRIX index has been applied to historical data and the results are shown in the publication "Qualità degli Ambienti Marini Costieri Italiani 1996-1999" Ministry of the Environment and ICRAM (Central Institute for Applied Marine Research).

New and historical data are available to MED POL to be used in the planned regional assessment of eutrophication.

- **Lebanon**

TRIX requirements were not taken into account when planning the monitoring programme; therefore not all TRIX parameters are monitored.

A national eutrophication assessment method exists which uses the biological quality elements: chlorophyll and phytoplankton populations.

Quantitative reference conditions have defined for chlorophyll a and for supporting physicochemical elements. Boundary conditions have not defined for both elements

The data to be used for eutrophication assessment are obtained through monitoring programmes and research projects. Historical data exist, in a time series since 1999 with monthly observations for phytoplankton populations, nitrate and phosphate. These data are available to MED POL.

- **Morroco**

TRIX requirements were not taken into account when planning the monitoring programme; therefore not all TRIX parameters are monitored.

A national eutrophication assessment method does not really exist. Other methods of eutrophication assessment are not used.

The data used for eutrophication assessment are obtained through the National institute of fisheries research (INRH), the MED POL programme (EIMP)/coastal water monitoring, remote sensing authority. Historical data do not exist.

- **Palestine**

TRIX requirements were not taken in account for planning the monitoring programme; therefore not all TRIX parameters are monitored.

A national eutrophication assessment method does not exist.

TRIX index was not applied but it can be in the future. Other assessment methodologies as AMBI or BENTIX are not used. They are aware of the DPSIR approach. Historical data do not exist

- **Slovenia**

A national eutrophication assessment method does not exist yet.

Biological quality elements planned to be used are: chlorophyll, phytoplankton population and benthic parameters (from 2007 onwards).

Quantitative reference conditions on biological and physicochemical parameters or boundary values (thresholds) between affected and not affected areas have not defined yet, process is going on, expected to complete in 2007.

Slovenia applies the eutrophication methodology proposed by WFD, which classify in 5 classes the water bodies. They plan to compare TRIX index for water quality with WFD classes in near future (2007-2008).

They apply TRIX to their data since they are suitable for this. They also apply the AMBI index in benthic data, regarding ecosystem disturbance and they are familiar with the DPSIR approach.

The sources of data used for eutrophication assessment are:

- Data from national monitoring projects since 1980 (MBP data base)

- National monitoring programme of Slovenia: programme for the assessment and control of pollution in the Mediterranean region (MED POL - PHASE III): reports for 2002, 2003, 2004, 2005

- Bio-filtration and Aquaculture: an evaluation of hard substrate deployment performance within mariculture developments: final report 2003: EU 5th Framework: BIOFAQs Q5RS - 2000-30305, Quality of life and management of living resources - Sustainable fisheries and aquaculture.

Historical data exist, which are available for eutrophication assessment:

- Data from monitoring since 1980 for nutrients (few stations)

- Chlorophyll a, phytoplankton since 1983 (one station)

- Partly phytoplankton composition

However, TRIX has not be applied to these data, but it is planned, and will be available to MED POL

- **Spain**

The assessment of the trophic state in Region de Murcia up to now is based on eutrophication criteria based on primary production rates according to Nixon's scale (1995):

Trophic state	**PP rates**
Oligotrophic	<100 g C m^{-2} y^{-1}
Mesotrophic	100-300 g C m^{-2} y^{-1}
Eutrophic	301-500 g C m^{-2} y^{-1}
Hypertrophic	>500 g C m^{-2} y^{-1}

During the next phase of the monitoring program, that will take place in 2006-2007 in Mar Menor, the proposed classification of trophic status according to TRIX index will be implemented.

- **Syria**

TRIX requirements were not taken in account for planning the monitoring program, therefore not all TRIX parameters are monitored.

A national eutrophication assessment method does not exist.

TRIX index was not applied but it is planned for the future; however, the present data are not suitable. Other assessment methodologies as AMBI or BENTIX are not used.

Not aware of DPSIR approach. Historical data exist (temperature, pH, transparency salinity, phosphates, dis. Oxygen, chlorophyll, nitrate, ammonium, nitrites) but there are not so long to serve for the study of eutrophication trend. However are available for MED POL. TRIX has not applied on these data but is planed to be.

- **Tunisia**

TRIX requirements were not taken in account for planning the monitoring programme; therefore not all TRIX parameters are monitored.

A national eutrophication assessment method does not exist. Other methods of eutrophication assessment used are: evaluation of biological indices (as diversity index, abandunces, etc)

- **Turkey**

TRIX requirements were taken into account when planning the monitoring programmes and all parameters were monitored.

TRIX index was applied to data from Izmir Bay and Mersin Bay and submitted to MED POL.

A national eutrophication assessment methodology does not exist. There is no familiarity with the DPSIR approach.

Data sources for eutrophication assessment are the MED POL programme in Mersin Bay and possibly future national projects. Also, remote sensing and operational oceanography may provide eutrophication data in the future for Mersin Bay.

Historical data do not really exist since in both areas only data sets for one year exist, which are available to MED POL regarding Mersin Bay.

Regarding eutrophication assessment made or planned by Mediterranean countries from the above presented information it can be concluded that:

- Most European countries have adopted national assessment methods, due to their obligations to EU directives, or to follow assessment methods proposed by conventions such as OSPAR (Spain)

- Italy has already fully adopted TRIX, whereas other European countries have only tested it in some case studies (Slovenia, Greece, Cyprus).

- Case studies will help to evaluate TRIX applicability all over Mediterranean. In many cases it seems to work properly, except in the case of Cyprus. Therefore more tests may be needed.

- Southern Mediterranean countries in their majority have not tested TRIX, though they are willing to do so. Also, in many cases they were not familiar with the DPSIR approach.

- Historical data exist in most countries and are available to MED POL and for TRIX tests, therefore supporting the long-term strategy and assessment.

- Regarding eutrophication parameters reference values and class boundaries are not defined in most cases, even in European countries

- It is interesting that all countries that sent information are active in performing even a simple monitoring and assessment activity relevant to eutrophication.

6. ASSESSING THE TROPHIC STATUS IN THE MEDITERRANEAN USING THE TRIX INDEX

6.1 Background and scope of the work

Indicators are essential to monitor changes in the state of the coastal and marine environment, to assess trend in socio-economic pressures and conditions in the coastal areas and to appraise the effectiveness of integrated coastal zone management (Mageau & Barbiere, 2003). In the literature, numerous eutrophication indicators are described, regionally specific and using different thresholds, therefore the need for standardisation of criteria and indices on European scale, as well as in regional scale, as for Mediterranean (which is a subject for MED POL), is urgent and recognized (Cognetti, 2001)

Exisiting eutrophication indices can be classified into 3 main groups: a) trophic indices, b) eutrophication indices and c) nutrient sensitivity (response to nutrient overenrichment) (Druon et al., 2004):

a) Trophic indices attempt to find a general empirical relationship between algal biomass or production and nutrient concentration or loading and sometimes oxygen content (TRIX) or Seccki depth (OECD) (de Jonge, 1990; Nixon, 1992; Moriki & Karydis, 1994; Vollenweider et al., 1998; Zurlini, 1996; Ignatiades, 2005).

b) Eutophication indices are based on monitoring of biotic and/or abiotic parameters. All biotic indices consider changes in the phytoplankton community (Karydis & Tsirtsis, 1996; Tsirtsis & Karydis, 1998; Stefanou et al., 2000; Kitsiou & Karydis, 2000; Danilov & Ekelund, 2001) or the benthic community that accompany eutrophication (Grall et al., 1997; Simboura et al., 2005). Abiotic eutrophication indices use data on nutrient concentration, and/or surface and near-bottom oxygen concentrations (Abdullah & Danielsen, 1992; Justic, 1991, Ignatiades et al., 1992; Karydis, 1996).

c) Nutrient-sensitivity indices are based on the dilution and flushing capacity of estuaries, tides, or light and nutrient limitations (NRC, 2000; Monbet, 1992; Cloern, 1999).

The implementation of policies is dependent on the capacity of ecological indicators to capture the complexities of the ecosystem yet remain simple enough to be easily calculated and routinely monitored (Dale & Beyeler, 2001).

In the Mediterranean Sea, few attempts have been made to scale the trophic status of local regions by the application of empirical indices, statistical analyses, and cartographic procedures (as examples: Giovanardi & Tromellini, 1992; Vollenweider & Kerekes, 1982; Vollenweider et al., 1998; Giovanardi & Vollenweider, 2004; Giovanardi et al., 2006; Ignatiades et al., 1992; Ignatiades, 2005; Stefanou et al., 2000; Karydis & Tsirtsis, 1996; Tsirtsis, 1995; Karydis, 1999; Kitsiou & Karydis, 2001). Also, very good and promising examples regarding the use of remote-sensing data, developed for Mediterranean are the EUTRISK index and PSA index that accompanies it (Druon et al., 2004).

The application of the TRIX index, originally devised for Italian coastal water, brought together in a single formula all the factors that were the direct expression of productivity (e.g. chlorophyll "a") or the nutritional status (total inorganic nitrogen, total phosphorus, etc.). The values of the TRIX index enabled scientists to classify coastal waters by trophic status. But the terms "eutrophic", "mesotrophic" and "oligotrophic" were used subjectively and arbitrarily, owing to the lack of an internationally accepted classification procedure and definition of the concentration ranges and boundaries for each category. One of the reasons why it was difficult to define a threshold value for the various trophic categories is that trophic conditions of vast marine areas, like the Mediterranean, vary considerably from region to region and within regions (UNESCO, 1988; UNEP/FAO/WHO, 1996). The manifestations of eutrophication show various spatial patterns and year-to-year variations, etc. Therefore it is needed not only in the frame of MED POL, but in other policies as well (WFD), to propose a method that would permit to synthesize key data into a simple numeric expression, in order to make information comparable over a wide range of trophic situations.

It is interesting that TRIX has already been used in some European countries for classification of trophic status, due to its simplicity of application. Italian authorities use this index on a routine basis for monitoring the trophic status of the Adriatic Sea and Tyrrhenian Sea (Caiaffa, 1999; Vollenweider et al., 1998; Giovanardi and Vollenweider, 2004; Artioli et al., 2005), in the Lagoon of Venice (Bendoricchio and De Boni, 2005), in fact it has been adopted by Italian legislation for the classification of the trophic status in Italian coastal waters (D.Lgs 152/99). The TRIX index has also been applied for the classification of Slovenian coastal waters (UNEP, 2003). The European Community Joint Research Project has applied this index in the North Sea, close to the Skagerrak/Kattegat areas (EEA, 2001b). Black Sea (Moncheva et al., 2002; Parkhomenko et al., 2003), the Baltic Sea (Vascetta et al., 2004) were also tested, whereas Moncheva et al. (2001) tested TRIX to compare some Aegean and Black Sea gulfs. The parameters used in the calculation of TRIX are commonly measured during a standard monitoring of a water body. However, the general applicability of this index to other European waters is still subject to further evaluation (Ærtebjerg et al., 2001). Nevertheless, TRIX index was used for the trophic classification of 3 Indonesian tropical waters (Jakarta Bay, Lampung Bay and Semangka Bay) and gave interesting and reliable results by distinguishing 3 different trophic states in the 3 bays (Damar, 2003).

Therefore, the TRIX index was chosen by MED POL experts to be tested and evaluated for possible applicability in the Mediterranean basin through some case studies, because the TRIX index works like a multimetric index, moreover it offers the advantage of utilising as components, environmental variables directly measured and routinely collected.

MED POL Pilot Eutrophication Programme is based on monitoring of mandatory parameters that also support the application and interpretation of the TRIX Index. The data collected in a number of pilot programmes have been evaluated for TRIX calculations, to contribute to this Eutrophication Assessment Report (2007).

The analysis of the eutrophication data for TRIX was performed by Dr Franco Giovanardi, ICRAM.

6.2 Analytical data

The data taken into consideration and processed for the scope of testing TRIX Index at a Mediterranean scale were the following:

i. **Slovenia** data set related to 7 coastal sampling stations, from February 2004 to November 2005. Only surface data were considered, for a total number of 82 records.

ii. **Turkey**. The available data were referred to two coastal sites (only surface data):

a) **Izmir Bay**: a data set of 97 records *per* 14 sampling stations, from March 2004 to February 2005.

b) **Mersin Bay**: 134 records of data *per* 17 sampling stations, from March 2005 to May 2006.

iii. **Italy**. NW Adriatic Sea coastal area of the Emilia Romagna Region has been considered. The processed data are related to 12 sampling stations, from June 2001 to July 2005. The comprehensive sample size was of 1188 records related to surface data.

iv. **Greece**. The available data were referred to two coastal sites

a) **Saronikos Gulf**: A complete data-set of 238 records related to Saronikos Gulf, per 5 sampling stations were taken into consideration, from May 2000 to June 2005. Only the analytical data referred to –2, –3 m of depth have been chosen.

b) **Thermaikos Gulf**: A complete data-set of 277 records from Thermaikos Gulf, per 9 sampling stations (mean integrated values over depth) were processed, from May 2000 to August 2004.

UNEP/MED POL provided all the databases.

6.3 Preliminary data screening and calculation of derived variables.

Original data sets have been processed with the aim of:

- Identifying and considering only the surface data.
- Transforming concentration measurement units from µM to µg.
- Calculating other derived variables as:

▪ Dilution factor (F%: percent content of fresh water into the samples)

▪ N/P ratio

▪ aD%O as absolute deviation of the Oxygen from 100% saturation (Parameter necessary for TRIX formulation)

▪ Efficiency Coefficient

▪ TRIX Index

Below, the meaning of these derived variables is discussed briefly.

<u>N/P ratio</u>

Phytoplankton uptakes nutrients, available in the water column, depending on the same molar ratio that these elements present into the algal biomass: elemental N/P ratio = 16 (or N/P = ca. 7.2, if we consider the weights). If the ratio N/P, i.e. the ratio between the weights of Dissolved Inorganic Nitrogen – DIN as N-(NH4+NO3+NO2), and Dissolved Inorganic Phosphorus – DIP as P-PO4, exceeds a value of 7.2 in seawater, we can conclude that Phosphorus represents the factor limiting the algal growth. In general, in coastal areas affected by Eutrophication, the cases of Phosphorus-limitation are usually prevailing on the cases of Nitrogen-limitation.

<u>Dilution factor</u>

The Dilution factor defines the freshwater content of the sea. It is calculated as:

$$F = \frac{S - s}{S} \qquad (1)$$

with *S* = open sea salinity; *s* = measured salinity.

Usually the Dilution factor is reported as F%.

Trophic Index TRIX.[1]

TRIX Index assigns a numerical value (a measure) to the trophic levels of coastal waters.

The final formulation adopted was the following:

$$TRIX\ Index = (Log_{10}\,[ChA \cdot aD\%O \cdot DIN \cdot TP]+k) \cdot m \qquad (2)$$

where:

- *ChA* = Chlorophyll *a* concentration as *µg/L;*
- *aD%O* = Oxygen as *absolute % deviation from saturation;*
- *DIN* = Dissolved Inorganic Nitrogen, $N\text{-}(NO_3+NO_2+NH_4)$ as *µg/L;*
- *TP* = Total Phosphorus as *µg/L.*
- *k* = 1.5
- *m* = 10/12 = 0.833

The parameters *k* and *m* are scale coefficients necessary to fix the lower limit value of the Index and the extension of the related Trophic Scale, i.e. from 0 to 10 TRIX units.

Referring to the *ChA* and *aD%O* components, we have to remark that these factors are direct indicators of productivity. The TRIX Index summarises what the coastal system does (i.e. the contribution of the direct indicators of productivity, as "actual productivity") and what the coastal system could do (contribution of the nutritional factors components, as "potential productivity"). Regarding the interpretation of TRIX values, those exceeding 6 TRIX units are generally associated to highly productive coastal waters, where the effects of Eutrophication are represented by frequent episodes of anoxia in bottom waters. Values lower than 4 TRIX units are typical of scarcely productive waters, while values lower than 2 are generally associated to the open sea.

Efficiency Coefficient (Eff. Coeff.)

The Efficiency Coefficient is defined as:

$$Eff.\ Coeff. = Log_{10}\,([ChA \cdot aD\%O]/[DIN \cdot PT]), \qquad (3)$$

to say as the log of the ratio between the two aggregated main components of TRIX.

Numerically, values are usually negative, ranging in our analyses from –4.48 (recorded in the Ionian Sea) to 0.45 (NW Adriatic Sea). We interpret the location of each case value within the total range of values as a rough though realistic relative "measure of the degree of nutrient utilisation". Thus low values would indicate low, and *vice versa*, high values high nutrient utilisation. Alternatively, one may also think in terms of "actual" (with regard to each value as such), and "potential" productivity (with regard to its location relative to the highest value within the full value range); but this view is more questionable.

([1]) For further and more detailed information on the TRIX Index, we refer to the original paper of Vollenweider *et al.* (1998).

The classification criterion based on the TRIX scale is shown in Table 15.

6.4 Analysis of the data.

6.4.1 __First step__: Cluster Analysis

In order to organise the analytical data in homogeneous groups, corresponding to sampling stations with similar quality characteristics, and then pertaining to the same class, Cluster Analysis has been applied. This kind of analysis provides as result, a hierarchical organisation of the clusters, based on the dissimilarity among *n* objects (i.e. the *n* sampling stations). The calculation algorithm utilised is the algorithm of Ward.

For each regional database, it is available: 1) a graphical representation of the different clusters obtained (dendrogram), and 2) a table with the resulting homogeneous groups of sampling stations and related sample size.

Table 15. Reference values for TRIX means, corresponding trophic state and related coastal water quality conditions.

TRIX annual means	Trophic Status	Water quality Conditions
<4	**Elevated**	Scarcely productive waters. Good water transparency. Absence of anomalous water colours. Absence of Oxygen undersaturation in the bottom waters.
4-5	**Good**	Moderately productive waters. Occasionally water turbidity. Occasionally anomalous water colors. Occasionally bottom waters ipoxia episodes.
5-6	**Mediocre**	Very productive waters. Low water transparency. Frequently anomalous waters colours. Ipoxia and occasionally anoxia episodes in the bottom layers. Suffering of the benthic communities.

>6	Bad	Strongly productive waters. High water turbidity. Diffuse and persistent anomaly in the water colours. Diffuse and persistent ipoxia/anoxia episodes in the bottom waters. High mortality rate of benthic organisms. Alteration of the benthic communities and strong decrease of the biodiversity

6.4.2. ***Second step:*** *Statistical analysis of the sample distributions (Johnson method).*

To study the behaviour of single variables and the nature of the related frequency distributions, the work of Johnson (1949) has been taken into consideration, who described a system of frequency curves that represents transformations of the standard normal curve. By applying these transformations to a standard normal variable, a wide variety of non-normal distributions can be approximated, including distributions, which are bounded on either one or both sides.

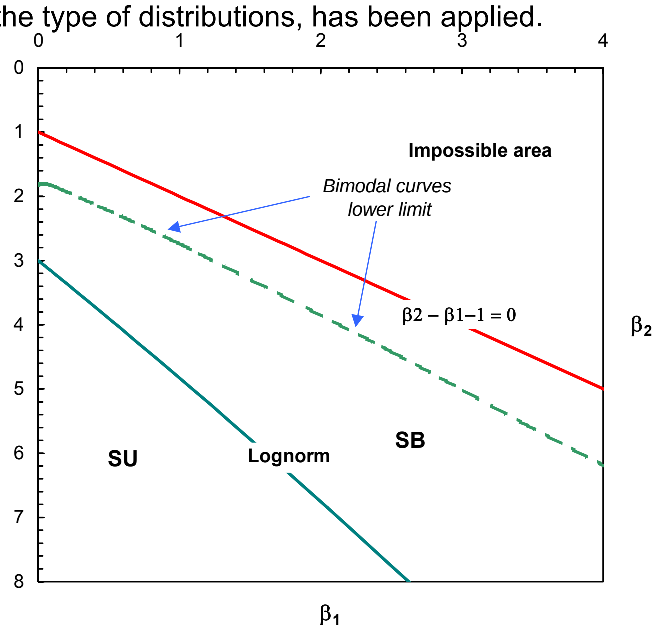
By means of the Johnson method, each group has been processed with the aim of generating:

- a table with all the statistical parameters of the data sample distributions (per variable),

- a table with the expected concentration values corresponding to fixed percentage points: (α = 0.005, 0.075, 0.1, 0.5 (median), 0.9, 0.975, 0.995).

Graphical representations of the histograms and related frequency curves have been also produced. In particular the TRIX frequency distributions and the related *p.d.f.* (Probability Density Functions) have been reported.

To complete the square about the statistical distributions, the **Johnson classification criterion** concerning the type of distributions, has been applied.



Note. The results obtained in this work would not have been reached without the help of the already cited R (V. 2.4.0) software. R is a *free software* easily downloadable *via* Internet. In order to fit frequency curves, we have largely utilised *R* package *SuppDist* (Bob Wheeler - 2005. *SuppDists: Supplementary distributions.* R package version 1.0-13.), that allows to compute the following functions: the density function [*dJohnson()*], the distribution function [*pJohnson()*], its inverse [*qJohnson()*], the random number generator [*rJohnson()*] and the summary function [s*Johnson()*], that gives a list of the whole statistical parameters of the distributions. The command *JohnsonFit()* generates a list containing the Johnson parameters (γ, δ, ξ, λ and *type*), where *type* is one of the four types of Johnson curves: S_N (normal), S_L (log-normal), S_B (bounded) or S_U.(unbounded). The calculation algorithms for the estimate of the Johnson parameters are those of Wheeler (1980) (quantiles method), and Hill et al. (1976) (moments method).

A detailed procedure of application of the Johnson method to the case of analytical data related to water quality variables by means of R program, is also available in Giovanardi et al. (2006).

6.4.3. Trophic classification

As a final result of the adopted procedure of analysis, the trophic classification based on the TRIX scale has been applied. For each regional data set, two tables are provided.

a) First table characterises each group of sampling stations and shows medians and MDAs referred to the variables of interest (fundamental parameters of trophic state). Due to the strong non-normality conditions associated to several original sample distributions, instead of the Group Means and Standard Deviations, the more robust parameters: Group Medians and Median Absolute Deviations (MDA), have been utilised.

b) Second table shows the trophic classification based on TRIX averages values. Probability of exceeding lower boundaries of “good (TRIX>4)”, “mediocre (>5)” and “bad (>6)” trophic status are also reported.

Hereinafter, the results of the statistical elaborations related to the data set of Mersin Bay – Turkey, as an example case study, will be presented in the following section “6.5. Results”

Concerning the other Mediterranean case studies, a final synthetic table that shows the results of the trophic classification by using TRIX scale is provided at the end of this chapter.

6.5 Results

1st case study: TURKEY – MERSIN BAY (Eastern Mediterranean)

A eutrophication monitoring pilot project in the Mersin Bay was carried out during 2005 in the framework of the MED POL programme. Parameters for TRIX estimates were measured at 15 stations on 4 transects (13 nearshore stations, 2 reference stations, Fig. 7). Large inputs of nitrate inflow from the rivers and ammonia from untreated domestic wastes of Mersin city were recorded. Chlorophyll-a concentrations were always high in the near shore zone where the Secchi disc depth was consistently less than 3.0 meters (see also Chapter 5).

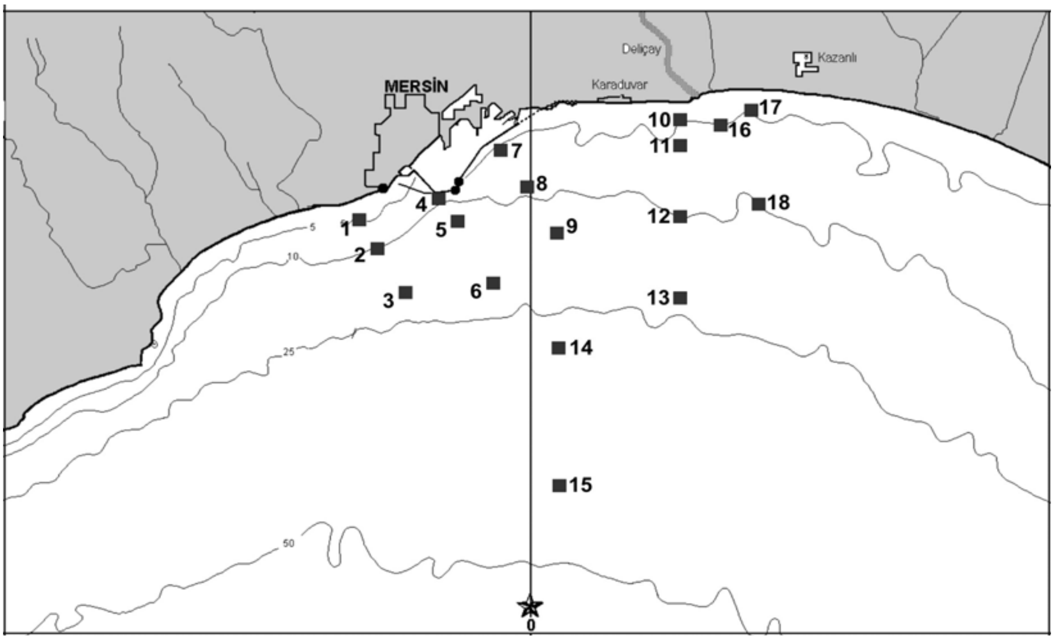


Fig. 7. Codes of the sampling stations and the related geographical location (stations MR1 – MR5, MR6 – MR8, MR9 – MR18 are defined as hot spots and stations MR14, MR15 as reference stations)

The analysis of data followed the procedure described in the previous session and the trophic classification results are given in Tables 16 and 17.

Trophic classification of the Mersin Bay waters.

Table 16. Fundamental parameters of "trophic status". Median values of the sample distributions and related Median Absolute Deviations (MADs)

		Gr_1		Gr_2		Gr_3		Gr_4		The whole data set	
		MR5		MR3, 6, 9, 13, 14, 15, 15A		MR1, 2, 8, 10, 11, 12, 18		MR4, 7			
		N = 8		N =54		N =56		N =16		N = 134	
		Median	M.A.D.	Median	M.A.D.	Median	M.A.D.	Median	M.A.D.	Median	M.A.D.
Secchi depth	*M*	1.50	*0.741*	4.85	*2.743*	3.00	*0.741*	2.50	*0.741*	3.25	*1.557*
Dilution Factor	*%*	4.60	*4.344*	3.15	*3.225*	4.55	*3.417*	4.92	*2.691*	3.70	*3.373*
DO	mg/L	7.06	*1.186*	7.75	*1.097*	8.44	*1.408*	8.14	*1.720*	7.86	*1.320*
O2%sat	%	98.73	*4.633*	108.50	*11.972*	118.79	*11.646*	114.64	*18.733*	111.65	*15.426*
aD%O	%	3.17	*2.810*	8.50	*11.794*	18.79	*11.646*	14.64	*16.694*	11.65	*13.759*
N_NH4	µg/L	209.12	*242.138*	0.56	*0.104*	3.36	*4.151*	25.56	*30.631*	1.89	*1.972*
N_NO2	µg/L	3.71	*2.802*	0.42	*0.208*	1.12	*1.038*	3.01	*2.076*	0.84	*0.830*
N_NO3	µg/L	18.84	*13.091*	1.54	*1.453*	9.38	*11.935*	35.02	*28.244*	5.11	*6.953*

DIN	µg/L	247.99	*253.762*	3.08	*1.868*	21.50	*23.885*	69.26	*51.083*	9.80	*12.039*
P_PO4	µg/L	28.97	*35.367*	0.93	*0.460*	1.40	*1.149*	4.65	*5.285*	1.24	*0.919*
TP	µg/L	53.43	*51.454*	7.89	*5.182*	12.77	*4.670*	17.31	*4.085*	11.75	*6.894*
Si_SiO4	µg/L	175.26	*36.642*	56.45	*37.680*	90.02	*50.801*	107.71	*73.492*	80.05	*51.639*
ChA	µg/L	2.30	*0.904*	0.81	*0.701*	2.62	*1.824*	3.6535	*2.216*	1.59	*1.512*
N_P	-	6.59	*3.855*	3.05	*2.847*	8.99	*10.905*	12.875	*14.322*	6.11	*6.123*
Eff_Coeff	Eff. units	-3.190	*1.068*	-0.785	*1.056*	-0.803	*0.946*	-1.842	*0.932*	-0.938	*1.015*

Table 17. TRIX Trophic Scale Criterion

Group	Sampling stations	Sample size	Actual median values of TRIX distributions	Median of the Absolute Deviation	Actual Trophic Status	N. of cases exceeding the lower limits of the related trophic class, depending on the TRIX scale (*)		
						good (> 4)	mediocre (> 5)	bad (> 6)
						%	%	%
Gr_1	MR5	8	5.508	0.653	mediocre	100	68.8	?
Gr_2	MR3, 6, 9, 13, 14, 15, 15A	54	3.175	1.372	very good	17.6	0	0
Gr_3	MR1, 2, 8, 10, 11, 12, 18	56	4.362	0.739	good	66.24	23.59	0.98
Gr_4	MR4, 7	16	5.102	0.704	mediocre	84.09	50.60	4.34
The whole data set		**134**	**4.133**	**1.201**	**good**	**54.2**	**21.4**	**1.2**

(*) Calculations are based on the integration of the TRIX p.d.f., evaluated by Johnson method.

Comments:

Sampling station MR5 (Group_1) seems to be directly affected by waste waters discharges, with high concentration values of nutrients, in particular ammonia, total phosphorus and phosphorus-orthophosphate. It must be highlighted the relatively high concentrations of chlorophyll for groups 3 and 4, while Group 2 (off-shore sampling stations and reference stations) show typical concentration values of oligo-mesotrophic conditions.

Considering the whole data set, Mersin Bay coastal waters can be classified in a “good” status, but the strong difference in the TRIX average values between Groups 1-Group 4 (mediocre status) and the remaining groups must be remarked. That is to say that the harmful effects of Eutrophication (like e.g. bottom waters anoxia and suffering status of the benthic communities), although locally, represent a real and unacceptable risk.

6.6 Trophic Classification of Significant Mediterranean Coastal Areas based on TRIX Scale Criterion

Concerning the other Mediterranean case studies, the final synthetic table (Table 18) that shows the results of the trophic classification by using TRIX scale is presented hereafter.

Table 18. Comparison of trophic classification of all Mediterranean case studies, according to TRIX index

Regional data set	Sample size	Actual median values of the TRIX distributions	Median Absolute Deviation	Actual Trophic Status	N. of cases exceeding the lower limits of the related trophic class, depending on the TRIX scale (*)		
					good (> 4)	**mediocre (> 5)**	**bad (> 6)**
					%	%	%
Izmir Bay (Turkey)	97	3.122	1.328	very good	28.7	11.8	3.4
Mersin Bay (Turkey)	134	4.133	1.201	good	54.2	21.4	1.2
Emilia Romagna coast (Italy)	1188	5.446	0.970	mediocre	92.4	65.4	26.2
Slovenia coast	71	4.138	0.998	good	52.0	19.3	7.5
					good (>3.3)	**mediocre (> 4.3)**	**bad (> 5.3)**
					%	%	%
Saronikos Gulf (**) (Greece)	238	2.539	0.904	very good	20.0	2.8	0.2

(*) Calculations are based on the integration of the TRIX p.d.f., evaluated by Johnson method.

(**)Note. The lower limits of the trophic classes, depending on the TRIX scale, have been revised in order to take into account the TRIX calculation procedure based on Phosphorus orthophosphate instead of Total Phosphorus. - See at this concerns the original paper on TRIX (Vollenweider et al. 1998)

6.7 Final comments

- The use of TRIX Index and the related trophic scale seem to be particularly useful to represent adequately various trophic conditions that may characterise Mediterranean coastal waters. The examples reported in the previous table demonstrate that different values assumed by TRIX means, allow discriminating typical oligo-trophic coastal environments from eutrophied areas. Obviously, such trophic conditions can be better described by providing "the broad array of the tropho-dynamic processes and the related biological diversities that characterize any coastal environment", but this approach represents rather the object of appropriate and finalized researches, while TRIX Index gives us a direct measurement of the trophic level. Consequently, critical situations can be immediately identified, in order to plan and promote the necessary actions of nutrient control and removal, avoiding the harmful effects of the Eutrophication.

- By inspecting the above table and analysing the averages of TRIX Index for the examined coastal areas, no critical situations (*bad* status), are highlighted, but in some case the risks associated to the Eutrophication are to be considered unacceptable, as e.g. the case of NW Adriatic Sea (Emilia Romagna and Slovenian coasts).

- On the other hand, the above results are referred to the whole regional data set. That is to say that locally, in these coastal environments, we can surely found evident *mediocre* or *bad* trophic conditions, as in the case of Station MR5 (Mersin Bay), or in the case of transect 4 in Emilia Romagna (Porto Garibaldi transect, close to the Po river mouth).

- The adopted approach also allows the characterization of coastal environments that show typical low productivity conditions. e.g., Saronikos Gulf should be classified as being in a “good” or “very good” trophic status. Nevertheless, by means of TRIX Index we can identify, and compare in quantitative terms, trophic changes that reflect an evident differentiation in nutrients (in particular nitrogen) and chlorophyll average concentrations between on-shore and off-shore sampling stations. Off-shore sampling stations seem represent adequately the natural trophic status of low productivity of the Saronikos Gulf. Although the TRIX average values are not comparable with e.g. those related to NW Adriatic situation, we have however to remark that a further increase in the nutrient concentrations in this gulf, can produce harmful effects on a marine coastal ecosystem that, due to its own nature of oligotrophy, result to be highly vulnerable.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Eutrophication is defined as an environmental perturbation caused by an excess in the rate of supply of organic matter as proposed in document UNEP(DEC)/MED WG.231/14.

The information collected from countries through the questionnaire has been analysed. It must be noted, however, that only 14 out of 21 countries have responded.

The conclusions based on the DPSIR approach are:

i. The 14 countries, which responded, designated 72 sites as being eutrophic or at risk to become eutrophic (see Table 4).

ii. Most countries defined nutrient inputs and organic material from domestic sewage due to dense population coastal agglomerations and tourism, as the most important pressure related to coastal eutrophication in most sites.

iii. Riverine inputs of nutrients and organic material as well as diffuse sources related to agriculture and animal husbandry activities are also very important throughout Mediterranean.

iv. A significant part of coastal eutrophication is due to industrial activities, such as food industry, tanneries, chemical industry, textiles, petroleoum refineries and shipyards, located in coastal areas and discharging in enclosed sensitive bays, estuaries, etc. both in the North and South Mediterranean.

v. The role of fish and shelfish farming was also pointed out as significant in several cases for coastal nutrient enrichment and pollution.

vi. In some cases port activities were also indicated as related to eutrophication problems.

vii. Most countries use as eutrophication state parameters the nutrients' concentrations (N, P) and in one case salinity and pH.

viii. As impact parameters the chlorophyll-a concentrations are used, dissolved oxygen and in several cases toxic phytoplankton occurrence, toxins in shellfish tissues, mortality of organisms, N/P or even faecal coliforms.

ix. Only some countries reported thresholds for the above parameters. It is not clear whether the other countries neglected to report them or such values have not been defined in the countries. In all cases, no information is provided regarding the methodology used for the calculation of the threshold.

As regards monitoring, it may be concluded that most Mediterranean countries that had reported, undertake classical monitoring activities. However, not all the countries that participated in the eutrophication pilot programs with MED POL assistance followed the MED POL monitoring strategy. The majority followed their national or other strategies.

The main conclusions are that:

i. Most countries do not monitor all parameters required by the MED POL strategy, though in several cases they monitor many more other parameters.

ii. Most countries agree to amend their monitoring strategy to include all MED POL proposed parameters. This is easier for European countries, which due to their obligations to EU directives undertake more detailed monitoring projects.

iii. Most countries have a positive thinking regarding introduction of the new proposed parameters, related to the benthic ecosystem, though many countries have not received that information, before the questionnaire was sent to them. However, macroalgae and benthos along with phytoplankton are at the basis of the ecological status assessment for the classification of coastal waters according to WFD and other policies, conventions, therefore inclusion of these parameters will help not only understanding the system's behaviour and efficiency/status, but also for compliance and harmonization of methods.

iv. Sampling frequency is in most cases seasonal, which is the minimum requirement within MED POL, though it is recommended to perform monthly samplings.

v. Many countries especially from southern Mediterranean coasts stressed the need for more quality assurance exercises.

vi. Considering the on-going activities in Mediterranean coastal waters, the monitoring strategy proposed by MED POL seems to be reasonably applicable with only a small effort by countries.

In a number of countries national eutrophication assessment methods are performed. The TRIX index has already been used in some European countries for classification of trophic status, due to its simplicity of application. In the present study data from case studies from Slovenia, Italy, Turkey and Greece were used for testing the TRIX index.

Regarding eutrophication assessment methods and the TRIX index the conclusions are:

i. Most European countries have adopted national assessment methods, due to their obligations to EU directives, or to follow assessment methods proposed by conventions such as OSPAR (Spain).

ii. Italy has already fully adopted TRIX, whereas other European countries have only tested it in some case studies (Slovenia, Greece, Cyprus). It seems to work properly, except in the case of Cyprus.

iii. More testing is needed to further evaluate TRIX applicability all over Mediterranean. Southern Mediterranean countries in their majority have not tested TRIX, though they are willing to do so. Also, in many cases they were not familiar with the DPSIR approach.

iv. Eutrophication parameters, reference values and class boundaries are not defined in most cases, even in European countries.

v. It is interesting that all countries that sent information are active in performing even a simple monitoring and assessment activity relevant to eutrophication

As far as the examined case studies on TRIX are concerned:

i. The use of TRIX Index and the related trophic scale seem to be particularly useful to represent adequately various trophic conditions that may characterise Mediterranean coastal waters.

ii. The examples reported in this study demonstrate that different values assumed by TRIX means, allow discriminating typical oligotrophic coastal environments from eutrophied areas. Consequently, critical situations can be immediately identified, in order to plan and promote the necessary actions of nutrient control and removal, avoiding the harmful effects of eutrophication.

iii. By inspecting the results derived from the case studies, no critical situations (*bad* status) are highlighted, but in some cases the risks associated to the eutrophication are to be considered unacceptable, as e.g. the case of NW Adriatic Sea (Emilia Romagna and Slovenian coasts).

iv. The results refer to the whole regional data set from each case study. Meaning that locally, in these coastal environments, we can surely find evident *mediocre* or *bad* trophic conditions, as in the case of Station MR5 (Mersin Bay), or in Emilia Romagna (Porto Garibaldi transect, close to the Po river mouth) and is not a disadvantage of TRIX to highlight these bad trophic conditions.

v. The adopted approach allows also characterizing coastal environments that show typical low productivity conditions e.g. Saronikos Gulf should be classified in a “good” or “very good” trophic status. Nevertheless, in that area also, by means of TRIX Index we can identify, and compare in quantitative terms, trophic changes that reflect an evident differentiation in nutrients (in particular nitrogen) and chlorophyll average concentrations between on-shore and off-shore sampling stations. Offshore sampling stations seem to represent adequately the natural trophic status of low productivity of the Saronikos Gulf. Although the TRIX average values are not comparable with e.g. those related to NW Adriatic situation, we have to remark that a further increase in the nutrient concentrations in this gulf, can produce harmful effects on a marine coastal ecosystem that, due to its own nature of oligotrophy, results to be highly vulnerable.

vi. It is obvious from the above that TRIX is an index of trophic status and that its use as an indicator has not yet been fully evaluated or established.

7.2 Recommendations

Obviously the first issue to be stressed is the harmonization of the monitoring strategies and assessment methods on a basin-wide scale. Before that, it is necessary to validate the proposed procedures and the applicability of TRIX in the framework of the MED POL programme, to fully explore its suitability and potentiality. This evaluation must be part of the biological quality assessment of phytoplankton and be complemented with information on frequency and intensity of algal blooms and composition of abundance of taxa. Towards this objective, the organization of training workshops for Mediterranean scientists involved in eutrophication monitoring and assessment, both on TRIX application and laboratory methods (including taxonomy and toxic species identification) is very important for the successful application of the MED POL eutrophication strategy.

As noted above, eutrophication parameters, reference values and class boundaries are not defined in most cases, even in European countries. Therefore, there is an urgent need for all Mediterranean countries (not only European) to participate in exercises, organized within the framework of the MED POL programme, which would aim towards the definition of such values. Since historical data exist in most countries, their assessment for TRIX tests is very important to trigger a stronger support for the long-term MED POL eutrophication strategy. Such an exercise would also help towards the definition of reference and threshold values.

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