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MONITORING OF MEDITERRANEAN MARINE EUTROPHICAT ION: STRATEGY, PARAMETERS AND INDICATORS

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MONITORING OF MEDITERRANEAN MARINE EUTROPHICATION: STRATEGY, PARAMETERS AND INDICATORS

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1. INTRODUCTION

Since the 1980s the MED POL Programme, the marine pollution assessment and control component of the Mediterranean Action Plan, has been organizing and following up a regional marine monitoring programme, together with Mediterranean scientific institutions. Since then, and until now, in addition to complementary parameters chosen by the countries, only three groups of parameters have been considered mandatory, i.e. heavy metals in biota and sediments, halogenated hydrocarbons in biota and sediments and microbiological parameters for bathing waters.

During the last Meeting of MED POL National Coordinators (28-31 May 2001, Venice), it was decided that eutrophication parameters would become mandatory and would be included in the MED POL Phase III monitoring programme. As a result, the MED POL secretariat has worked on the definition of a set of indicators and a monitoring strategy for monitoring eutrophication in the Mediterranean Sea.

MED POL intends to propose a simple monitoring strategy in which the selected parameters should preferably be comparable with others already existing and being used in the region and elsewhere.

The aim of this report is to propose a first set of parameters and indicators and the relevant sampling strategy for monitoring and assessing the eutrophication phenomenon at the Mediterranean level.

2. BACKGROUND INFORMATION AND RATIONALE

2.1 Mediterranean eutrophication

The scientific awareness of the eutrophication phenomenon has evolved in the last twenty years and the definitions given to describe them have evolved as well. The following definitions ranging from 1968 to 1999 show the main progress done:

“Eutrophication in its most generic definition that applies to both fresh and marine waters, is the process of enrichment of waters with plant nutrients, primarily nitrogen and phosphorus, that stimulates aquatic primary production. Its most serious manifestations are algal blooms (red tides), algal scum, enhanced algal growth, and at times a massive growth of submersed and floating macrophytes (Vollenweider, 1968; 1981). Sometimes, these manifestations are accompanied by or alternate with cycles of visible bacteria blooms (Aubert, 1988) and fungal development”.

“Eutrophication is a process in which the bioavailability of nutrients in the considered recipient is increased. It becomes a nuisance if the concentration in nutrients exceeds some threshold values that vary in a large range according to the typology of the ecosystem. This state of nuisance results in lack of diversity and complexity of the considered ecosystem, involving perturbation (if not disappearance) of the secondary productivity level. Eutrophication may be linked to and be part of both organic and biological pollution on the one hand, and may cause toxic effects on the other hand”. (Carbenier, 1990)

“Eutrophication is an excessive increase in primary production, generally caused by excess in available phosphorus” (Labroue et al., 1995).

“Eutrophication (noun) - an increase in the rate of supply of organic matter to an ecosystem***.”***
The “organic matter” sources are both autochtonous and allochthonous. (Scott W. Nixon, 1995)

“Eutrophication is an environmental perturbation caused by an excess in the rate of supply of organic matter (both autochtonous and allochthonous) to an ecosystem. (G.Izzo, in: EEA 1999a)

In all the above definitions there is a general agreement in identifying nutrients as the main cause of eutrophication, although only some identify both inorganic and organic nutrients (organic carbon included); the real progress, a part the evident reduction of the number of words, is the substitution of the term increase (of nutrients) with the term excess. This is the most important improvement because it implicitly recognizes the existence of a characteristic threshold in the environment. This threshold is not easily identified in each environment, but at least for shallow marine ecosystems, it could be found as "an increased production of biomass which exceeds the recycling (aerobic materialization) capacity of the ecosystem" (G.Izzo, in: EEA 1999a).

In summary, eutrophication is caused by the load of nutrient (i.e. nitrogen, phosphorus and organic carbon) from human activities in quantity exceeding the carrying capacity of the receiving environment. The morphological and hydrological characteristics of a water body like shallowness and/or limited water recycling enhance the sensitivity to eutrophication problems. This is typical of coastal bays and lagoons that are more at risk for the vicinity to the urbanized coast. Nevertheless even larger basins as the Adriatic, Gulf of Lions and the northern Aegean Sea suffer from eutrophication problems. 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. Cage culture fish farming also often causes eutrophication problems at a local level.

Mediterranean surface waters in the open sea are classified among the poorest in nutrients (oligotrophic) of the world's oceans. The morphology, the hydrology and the absence of significant up welling of the Mediterranean basin as a whole are considered the general characteristics that keep the nutrients out of the biological recycling process. Evaporation exceeds precipitation and freshwater load. According to G. Manzella: "due to the Gibraltar Sill the Mediterranean sea imports heat and exports salt" (EEA/UNEP 1999). The water deficit caused by evaporation is mainly compensated for by the net inflow of Atlantic Water through the Strait of Gibraltar of about 500 km^3 $year^{-1}$, the water contribution from the Black Sea that is about 160 km^3 $year^{-1}$, by the river discharge that is about 260 km^3 $year^{-1}$ and by precipitation that is about 780 km^3 $year^{-1}$ (Mariotti et al.2001). According to G. Manzella: "due to the Gibraltar Sill the Mediterranean sea imports heat and exports salt" (EEA/UNEP 1999). The estimated water residence time in the basin proper is around 75-100 Years. These recently updated data raise the question: is there a risk for the eutrophication of the Mediterranean Sea as a whole?

Eutrophication in the Mediterranean basin, at the moment, appears to be limited mainly to specific coastal and adjacent offshore areas. Several and sometimes severe cases of eutrophication are evident, especially in sensitive areas as enclosed coastal bays which receive elevated nutrient loads from rivers, together with direct discharges of untreated domestic and industrial waste (EEA/UNEP 1999; Fig. 1).

Algal blooms, diversity reduction of marine species and depletion of oxygen as well as potential human health risks related to the ingestion of seafood contaminated by pathogens or toxic algal blooms are some of the problems associated with Mediterranean eutrophication. Side effects (e.g. hypoxia/anoxia, algal blooms) have been reported in several places in the Mediterranean Sea, but they are confined to limited areas rather than widespread phenomena. In the report "State and pressures of the marine and coastal Mediterranean environment" (EEA Environmental assessment series N°5; EEA/UNEP 1999) a first attempt to summarize in a table a list of observed events caused by eutrophication have been made.

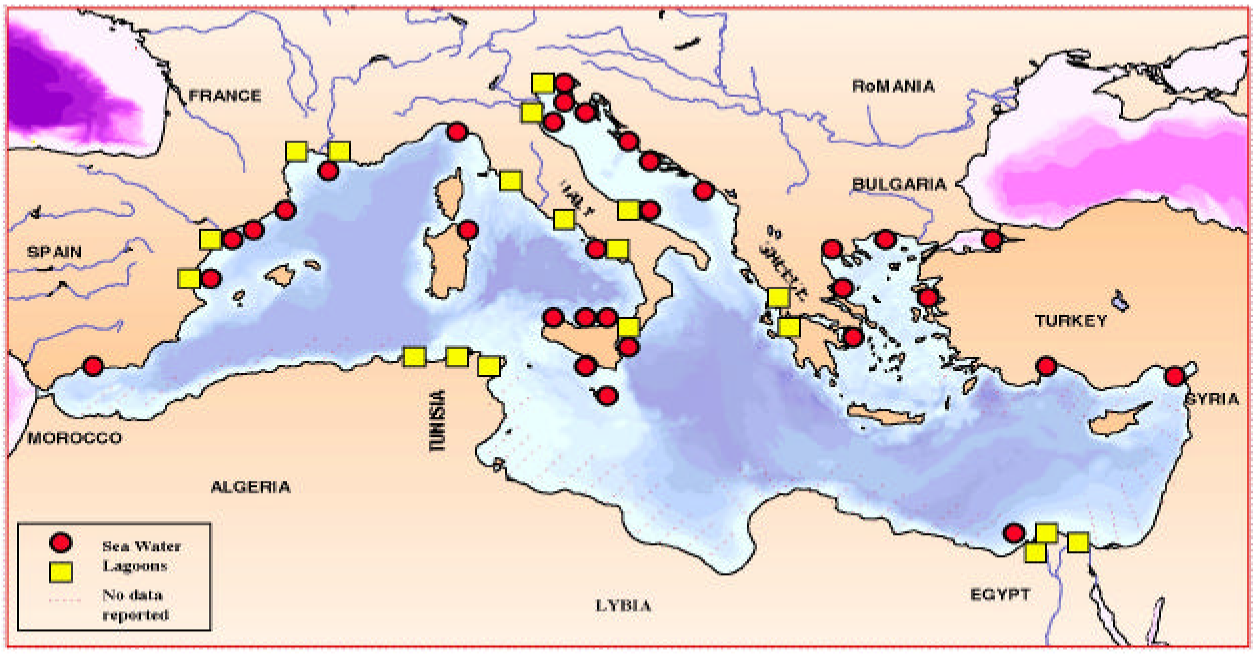

FIG. 1 Mediterranean areas where eutrophication phenomena have been reported. Source: EEA/UNEP 1999

The Adriatic, 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). 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).

2.1.1 River loads

With a few exceptions, all river systems discharging in the Mediterranean Sea are small. The Rhone, 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. Net inflow from the Black Sea amounts to 163 km^3 per year.

Besides urban (and industrial) sewage, agriculture is a major anthropogenic nutrient source to the Mediterranean Sea. Due to the specific morphology of the Mediterranean basin, intense agricultural activity is carried out in the limited coastal plains, often as a result of reclamation of wetlands. The main pressures from agriculture are soil erosion and nutrient surplus from excessive fertilization and livestock.

Also large river basins like the Nile, Rhone and Po Basins are subjected to agricultural pressures. The first six drainage regions, following a tentative ranking of the risk of soil erosion and nutrient losses, are found in peninsular Italy, Sicily, Sardinia, Greece, Turkey and Spain (EEA/UNEP 1999). 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. The total estimated loads are about 304 ton/year N and 22 ton/year P.

The nutrient levels found in Mediterranean rivers are about four times lower than those in western European rivers, but in all documented cases the nitrate levels are dramatically increasing (EEA/UNEP 1999). Never the less, depending on the river size and location, the concentration ranges are enormous, over an order of magnitude for nitrate and more for ammonia and phosphate as compared to the open waters (EEA/UNEP 1999). A recent paper emphasized the change in N: P ratio and a dramatic silicate decrease in Mediterranean waters due to Danube and Nile rivers damming (Turley, 1999). This means that silica requiring phytoplankton do not have their essential growth nutrients and may explain the unbalanced growth of other toxic forms which do not require silica.

2.1.2 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 1).

About 450 million people live in the Mediterranean coastal states, and more than 135 million tourists visit the coastal regions per year. Out of 230 coastal cities, with information available, about 45% were without sewage treatment plants, and about half of the total volume of sewage is discharged untreated. Where treatment plants were present only 38% of them had secondary treatment (UNEP/MAP 1999). In UNEP/MAP (1999) an identification of priority pollution hot spots and sensitive areas in the Mediterranean region is made and the nutrient load mainly from sewage to the areas given.

Table 1. Nutrient load 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	976000	1570600	16941000		
Mixed	75234	259691		804244	1729853
Aquaculture	394	8678	38225		

Marine aquaculture has shown a large expansion in production in a number of Mediterranean countries over recent decades, and increases from 1693 metric tons in 1970 to 131493 tons in 1999 (fin fish 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 1; Fig. 2).

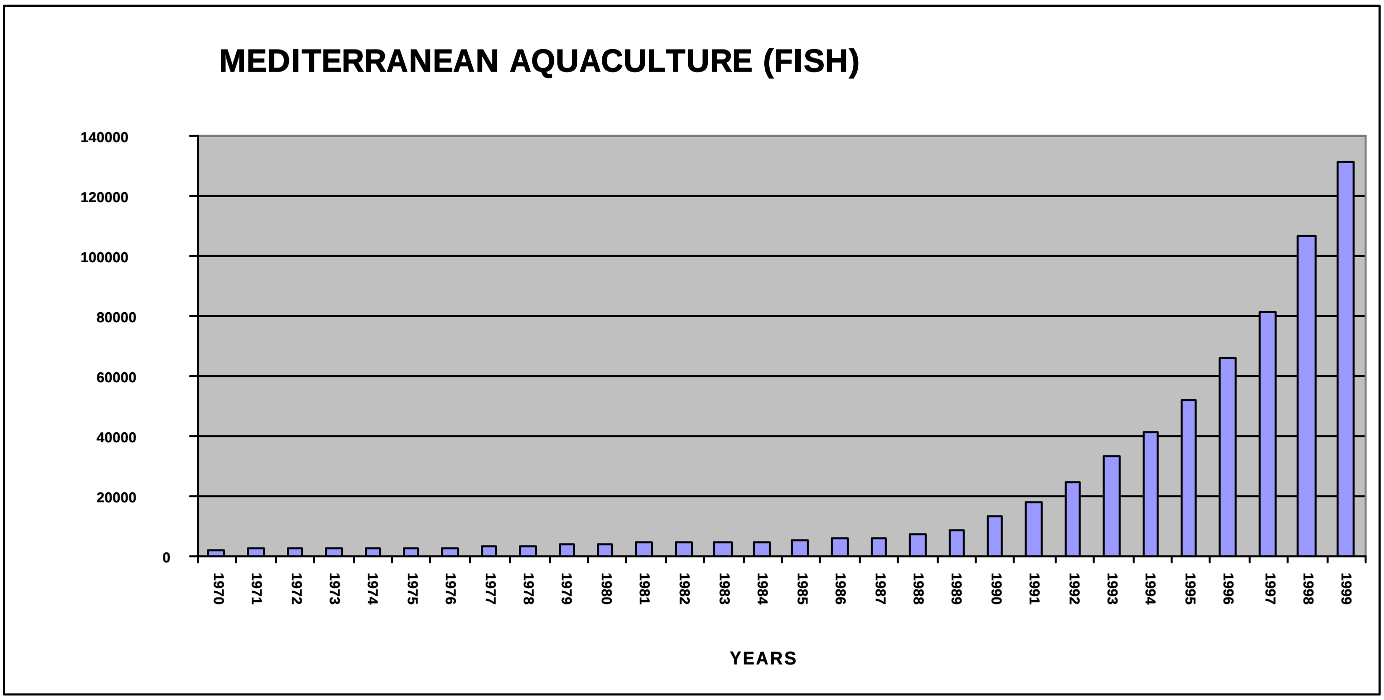

FIG. 2. Trend of marine aquaculture (fish only) from 1970 to 1999. Source: FAO database

2.2 Indicators and DPSIR approach

The term “indicator” generally describes a compact yet effective way to present given environmental information in a format that is best suited to inform subsequent response in environmental management. 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**” (see below).

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

1. to supply information on environmental problems, in order to enable policy-makers to assess their seriousness;
2. to support policy development and priority setting, by identifying key factors that cause pressure on the environment;
3. to monitor the effects of policy responses.

In addition, environmental indicators may be used as a powerful tool to raise public awareness on environmental issues. Providing information on driving forces, impacts and policy responses, is a common strategy to strengthen public support for policy measures.

When selecting parameters and relative indicators must be kept in mind that there is a difference between the scientific research perspective and the environmental research perspective (Fig. 3). The environmental monitoring needed to support the management of an environmental issue is different from what is needed for the purpose of scientific research. Nevertheless scientific research has to feed environmental management by helping in the selection of the best available parameters to be used as indicators.

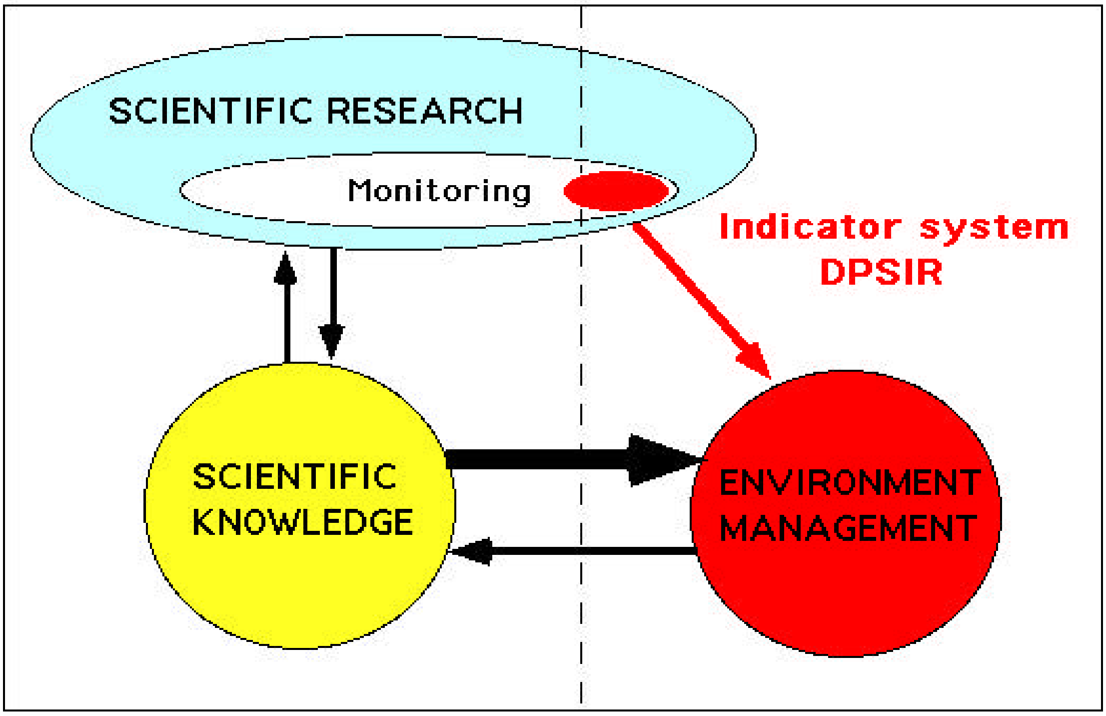

FIG.3- The relation between scientific and management perspective for environmental monitoring

The DPSIR is an approach to the system of indicators widely accepted for the marine environment and coastal zone to obtain: - an information reporting system (a structure for organising and reporting on monitoring data); - a tool for communicating with policy-makers in particular, and also with the general public (Fig.4).

DPSIR is also a tool for improved understanding of environmental problems; - an information and assessment tool for the identification 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. This framework is chosen as a starting point because of its simplicity and wide acceptance, and the fact that it can be applied on any scale. Modifications of the OECD PSR framework have resulted in alternative frameworks, e.g. the *PSR/Effects* (PSR/E) model of the EPA in the US (EPA, 1994), the PS/Impact/R model of the LTNEP (Swart et al, 1995) and the *Driving forces/PS/Impact/R* (DPSIR) model introduced by the RIVM in 1995 and used by the EEA

(Wieringa, 1996). The framework adopts a causal approach and identifies the causal chain. The indicators are the attributes of the framework; they summarise information or, more specifically, the raw data concerning a selected issue or problem.

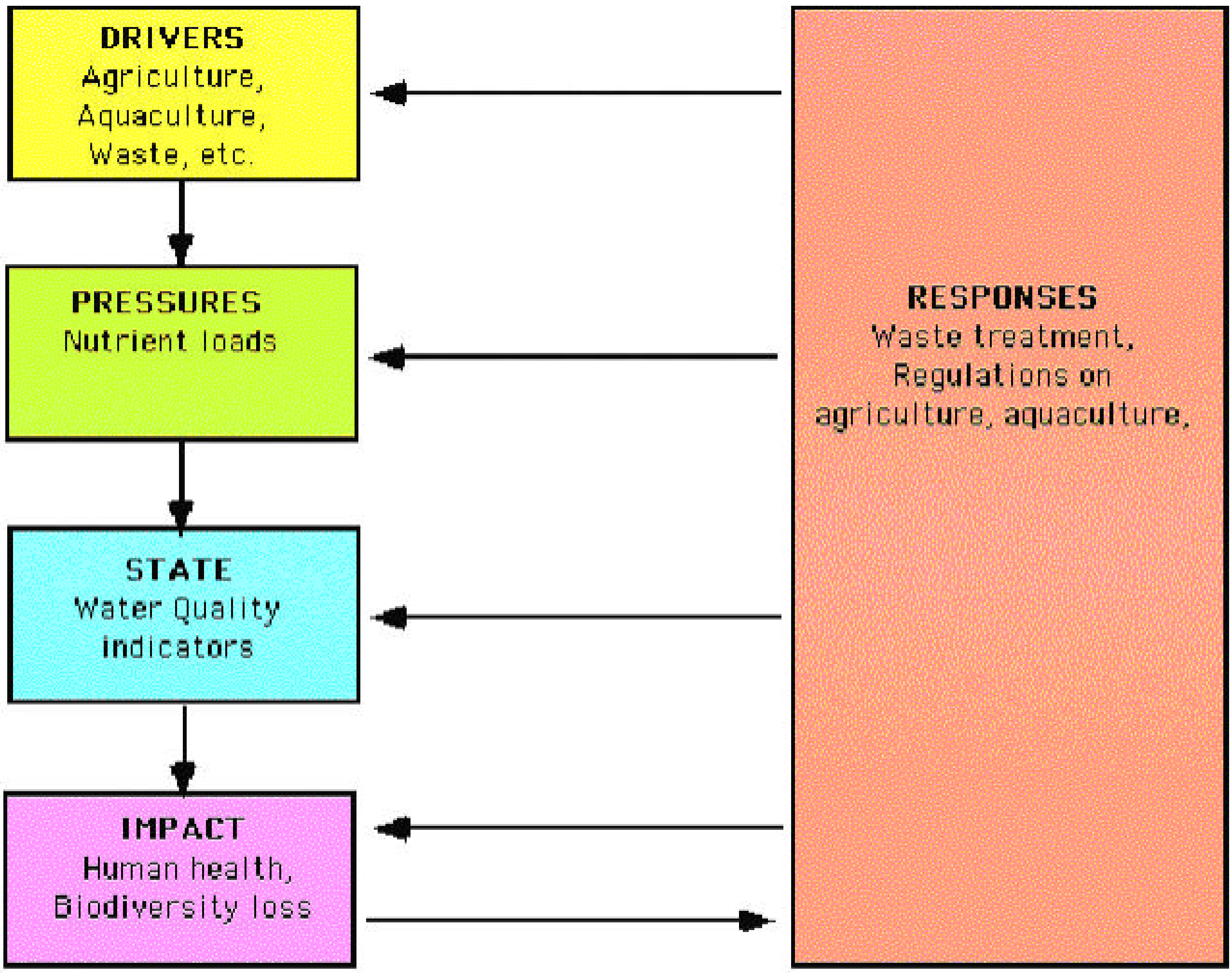

Fig. 4 The DPSIR Framework applied to eutrophication

In order to select parameters potentially able to be used as indicators for the coastal zone, the following selection criteria should be applied:

- Relevance to the coastal zone (according to expert opinion);
- Relevance to Mediterranean countries policy (e.g. European policy);
- Availability of adequate time series and reasonable spatial coverage;
- Comparability of the data;
- Availability of standards/reference values;
- Degree of independence of natural weather-related fluctuations;
- Spatial aggregation.
- Explicit relevance to models. Modules describing the internal relationships within the DPSIR framework are indispensable to the use of indicators in strategic environmental assessments.

2.3 UNEP activities on eutrophication

UNEP has considered eutrophication a relevant issue for the Mediterranean Sea and as published three important documents on this topic:

1. UNEP/FAO/WHO 1996. Assessment of the state of eutrophication in the Mediterranean Sea. *MAP Technical Reports Series* No. 106. UNEP, Athens, 211 pp.
2. EEA/UNEP 1999. State and pressures of the marine and coastal Mediterranean environment. EEA Environmental assessment series N°5
3. UNEP/WHO 1999. Identification of priority pollution hot spots and sensitive areas in the Mediterranean. *MAP Technical Reports Series* No. 124. UNEP, Athens, 90 pp.

The first report (UNEP/FAO/WHO, 1996) is a huge and quite recent report dealing with all the aspects of Mediterranean eutrophication and identifying a series of gaps for the detailed assessment of the phenomena at the regional level. The report recommends to extend and coordinate a monitoring action within the MED POL programme, linked to "a geo-related inventory of land based sources". Moreover it stresses the need for a scientific action focused on the following objectives:

- Factors controlling eutrophication processes;
- The structure and function of eutrophic ecosystems and the relevant hydrodynamics as the basis for the determination of their receiving capacities for eutrophicants;
- Classification of the stages and degrees of eutrophication on the basis of quantitative parameters;
- Investigation of the recovery processes in ecosystems that have been modified due to anoxia and mortalities induced by eutrophication;
- Further development of scientific methods as needed, particularly for the monitoring and ecological assessment programmes.

This list implicitly recognizes the existing uncertainty on marine eutrophication, that is also stressed in the identification of monitoring parameters: quote" No single analytical tool is adequate to measure the degree of eutrophication of a given water body- and moreover – The ecological assessment of the state and the extent of eutrophication requires an investigation of community structure and diversity, ..."unquote.

The second report (EEA/UNEP, 1999) jointly produced by EEA and UNEP, identifies eutrophication as one of the main issue of concern for Mediterranean coastal zone. In section 4.1 the most relevant available information on Mediterranean eutrophication is presented. A particular effort has been done to summarise in a synoptic table the main ecological effects of eutrophication as reported by different countries. In this report it is also stressed that is not possible to assess Mediterranean eutrophication phenomena solely on nutrient concentration.

In the third report (UNEP/WHO, 1999), although the identified gaps in data gathering, there is an inventory of land based sources and sensitive areas in Mediterranean region. The most relevant data of eutrophication pressures are summarized in Table 1. From this report it appears clearly that although eutrophication in the Mediterranean is mainly limited to the coastal zones it is an issue of concern since it interests areas of important economic and natural value where there is a high density of population.

2.4 Mediterranean countries' activities on eutrophication

All Mediterranean countries are affected by marine eutrophication although to a different level (Fig.1) and national monitoring programmes are already being performed. The sampling strategy and the parameters adopted are not the same for all countries nevertheless it appear to be a general good knowledge of the affected areas. In table 2 are summarised the Mediterranean countries' monitoring activities in the framework of MED POL.

Table 2. Inventory of the computerized data regarding the eutrophication parameters in MED POL database

COUNTRY	SAMPLING PERIOD	NUMBER OF STATIONS	SAMPLING (3) FREQUENCY / YEAR	PARAMETERS (4)
Algeria	1989-1990	10	2-4	BOP, NUT, Chl-a
Croatia	1992	4	3	BOP, NUT
Cyprus	1999-2000	28	1-2	NUT
Ex-Yugoslavia	1983-1991	27	2-4	BOP, NUT
Greece	1987-1990 1995	13 9	4 11	Chl-a BOP, NUT, Chl-a
Italy (1)	1987-1989 1992, 1994, 1997	126 31	4-12 12	BOP, NUT, Chl-a
Lebanon	1984-1988	10	5-8	BOP, NUT
Morocco	1983-1990 1993	8 8	2-4 3-4	BOP, NUT NUT
Slovenia	1996-2000	15	1-12	BOP, NUT, Chl-a, TRIX
Spain (2)	1991	31	1	BOP, NUT, Chl-a
Turkey	1986 1995	15 67	3 1-2	BOP, NUT

(1) More data exist on paper
(2) Some more data exist on diskettes (unreadable)
(3) Sampling frequencies might change with respect to parameters and stations
(4) Parameters like Chl-a and TRIX were occasionally measured

2.5 EEA approach to eutrophication

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 an European scale; in this paragraph are reported the selected indicators and the whole process followed to reach this result.

The mission of EEA is to deliver timely, targeted, relevant and reliable information to policy makers and the public for the development of sound environmental policies in the European Union and other member countries. In order to present scientific information in a form that answers the questions of policy makers, EEA is producing indicator-based reports.

Indicators have been chosen as the best way to present data from different environmental and sectored areas in a comparable and structured way. The DPSIR assessment framework is being followed, which stands for **D**riving Force, **P**ressures, **S**tate, **I**mpact and **R**esponses (EEA Technical report No 25, http://reports.eea.eu.int/TEC25/en).

The obligation to publish regular reports on related environmental indicators is especially significant and is a key task for the agency in the future.

Eutrophication has been identified has one of the main issues of the European coastal zones.

In March 1999, a questionnaire covering eutrophication was submitted to the National Focal Points in Belgium, Denmark, Finland, France*, Germany, Greece*, Iceland, Ireland, Italy*, the Netherlands, Norway, Portugal, Spain*, Sweden and U.K. (* Mediterranean countries). Data were received up to mid-August in 1999 and were gathered in a database (MARINEBASE) that was used for testing the parameters as indicators.

In November 2000 a first draft report "Testing of Indicators for the Marine and Coastal Environment in Europe" was circulated and, after receiving and accommodating comments, was printed in June 2001 as a Final Draft.

In June 2001 the same working group of ETC/ Water also produced a report titled: "The potential core set of indicators for the Marine and Coastal Environment where the indicators are aggregated according to the requirement of the Water Framework Directive".

On 14-15 June 2001 an IRF (Inter Regional Forum) **"**EEA - MARINE CONVENTIONS JOINT WORKSHOP ON INDICATORS" was held in Ispra, Italy. The ETC work programme on indicators and the reporting needs of the European environmental policy were discussed (Annex1).

As a follow up of the IRF meeting the 17th July 2001 EEA Topic Team for Water produced a document titled: Towards a core set of indicators for water environment.

All the above mentioned documents have been discussed in a meeting in Vienna June the 19th 2001, to achieve an agreement on a final document " a core set of indicators for water environment " to be delivered in autumn.

The core set of EEA (state/pressure) indicators for marine eutrophication is being identified trough the following process:

- ETC questionnaire (March 1999) to the regional conventions and NRC;
- organisation of the database (MARINEBASE) on delivered data (autumn 1999);
- testing of indicators included in the MARINEBASE and preliminary conclusions (spring 2000);
- proposal for "a potential core set of indicators" (June 2001);
- IRF meeting 14-15 June 2001;
- elaboration of an EEA official position on requirements for the core set of indicators (expected for July 2001);
- possible conclusions and final proposal by the end of 2001.

In the whole process the study has been carried out on the basis of available data delivered trough the questionnaire. Only in the EEA' July document produced by the ETC/water topic team is outlined the difference between using existing data and identifying the need for new data and tools/methodologies for constructing indicators. Moreover in the same report we find that: "The indicators proposed to date have therefore tended to concentrate on making best use of available data rather than starting with the questions first".
This statement identifies the need for new and more effective indicators for eutrophication assessment.
This need is also 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 environment are integrated in the theme Water Quality as table 4.1 and 4.2 of the report (EEA Technical Report, 2001 under preparation) and are showed below in Table 3.

Table 3. EEA selected indicators for state assessment of marine eutrophication

Headline Indicator	**EEA Indicator theme**	**General description**	**Indicator parameters**	**Comments**
	Nutrients	Concentrations of substances	**winter conc. NO2 +NO3, PO4, N/P ratio,** **Chlorophyll a** **Bottom oxygen** TRIX (Trophic Index)= **=Log(Ch*D%O*DIN*P/PO$_4$)-(-15) /1.2**	Mean summer tot-P, tot-N, in N forms, P04 Spring peaks, seasonal Mean, annual minimum duration of low oxygen values, TRIX index allows for Spatial information using SeaWifs images

3. CONCLUSIONS AND RECOMMENDATIONS

The development of indicators is an ongoing process in Europe. The European Environment Agency (EEA) has invested a big effort in selecting and testing a preliminary set of indicators for assessing marine eutrophication on the basis of available data. The common view expressed in EEA documents and discussed in the IRF (Inter Regional Forum) meeting is that further work as to be done to identify and test new indicators for the assessment of marine eutrophication. OSPAR is identifying indicators for biological state variables to be applicable for the development of ecological quality objectives and HELCOM started developing new indicators for eutrophication in the Baltic Sea.

UNEP/MEDPOL is at the beginning of this process although some Mediterranean countries have both long experiences in the study of eutrophication processes and are partners of ETC/MCE (now ETC/Water) consortium. Nevertheless, in the EEA report on indicators testing, we can read this recommendation:

The monitoring obligations and maintenance of the MEDPOL database, to which all the countries around the Mediterranean contribute, are not at present adequate to meet the data needs identified in this report for the Mediterranean coastal zones of France, Spain, Italy and Greece. There is a need either to improve data collection through the MEDPOL database or to *organise direct data gathering through national databases in order to improve the ETC/MCE indicator database.*

As a result, it is suggested to UNEP/MEDPOL to adopt the EEA approach and start developing a regional approach in the identification of new eutrophication indicators and data needs that meets the specificity of the Mediterranean environment.

The main difficulty in identifying a list of suitable parameters for monitoring marine eutrophication is to find a cost-effective strategy. No single analytical parameter is adequate to measure the degree of eutrophication of a given water body. It is generally accepted that a good assessment should be done on the basis of the structure and diversity both of plankton and benthos communities. Nevertheless such an approach would be rather costly. Therefore a proper selection of monitoring parameters should be done.

Vollenweider (UNEP/FAO/WHO 1996) proposes a major list of parameters containing suspended solids, light penetration, chlorophyll, dissolved oxygen, nutrients and organic matter to be determined either at the surface or at various depths.

A French group of experts from IFREMER proposes a list of parameters capable to trace the “disequilibrium in the ecosystem”. The dissolved oxygen and chlorophyll are on the top of the list; nutrients also are considered to be useful descriptors.

EEA after the testing of a huge database gathered in ICES has restricted the list of mandatory parameters and sampling period as showed in Table 3.

A group of Italian experts working for the Environmental Ministry propose to adopt the “TRIX INDEX” for assessing Mediterranean eutrophication (this is also recommended by EEA) (Vollenweider et al. 1998). The trix index is a dimensional number obtained by applying a mathematical formula to the results of monitoring parameters as nutrients, oxygen and chlorophyll.

All these proposals are oriented towards adopting “traditional” monitoring parameters (such as nutrients, chlorophyll and oxygen) as a basis for selecting indicators that are slightly different only in the computational system applied to the parameters. Although this is a reasonable proposal, it nevertheless leaves some gaps in the final assessment. In fact the indicators supported by the aforesaid parameters are able to assess “ a trophic potential” of a water mass, but do not inform on the actual state of the affected environment and on changes in biological communities. Moreover, while designing the monitoring strategy in terms of sampling frequency and spatial coverage, it should be taken account that most of the above mentioned parameters are non-conservative and are affected by short-term variations. Eutrophication is a long-term process and an effective assessment should be done on the basis of those parameters that change on a long time scale (e.g. biological communities) (Fig.5).

Unfortunately there is not yet a general agreement on which biological parameters should be used for the development of new indicators. A useful suggestion comes from a scientific paper from Gray (1992). The author proposes a general model of the long term environmental changes induced by eutrophication (Fig. 6).

Gray’s approach emphasizes the long term changes induced by eutrophication on the affected ecosystem and proposes a grading of the main observed events. This model needs to be discussed and tested in the Mediterranean region to see if it is generally applicable and what changes can be introduced in the different grades. It would be advisable that a group of regional experts build such a model for the Mediterranean affected areas.

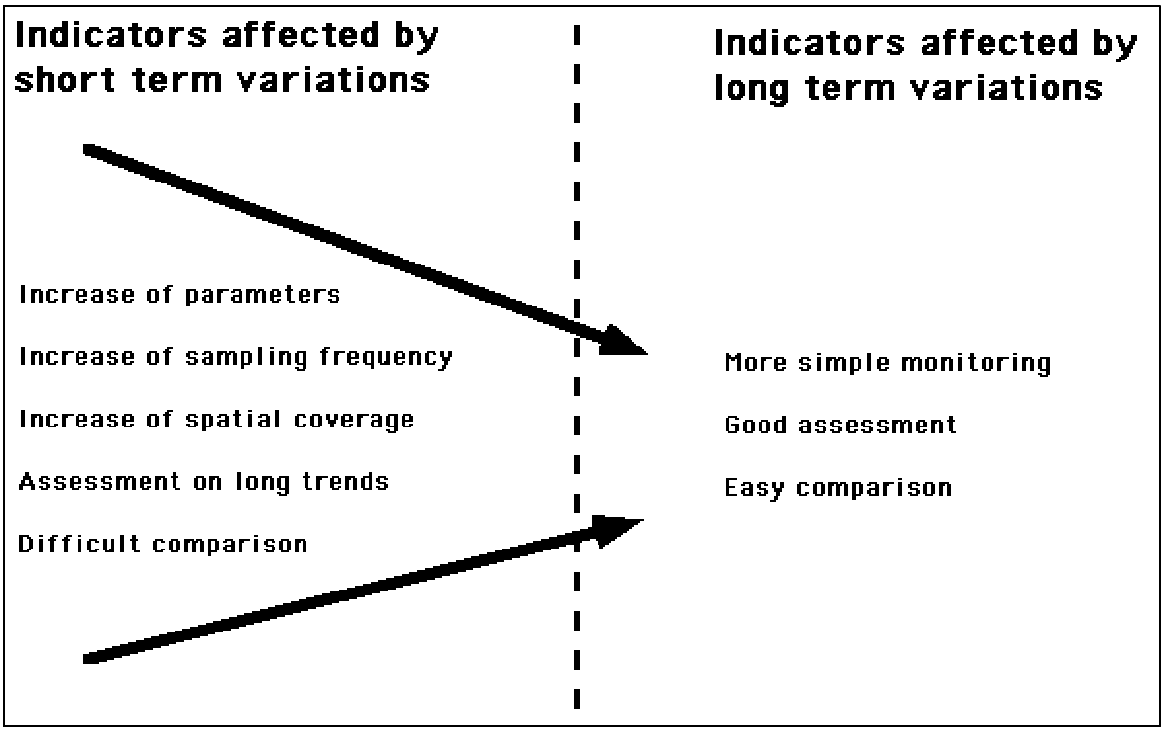

FIG. 5 Monitoring strategy and effective assessment. In this figure are summarised two different approaches that can be followed in the choice of parameters and indicators for the assessment of eutrophication: the choice of indicators supported by parameters affected by short term variations (right side of the figure) results in a more complex monitoring and a less effective assessment; the choice of indicators supported by parameters mainly affected by long term variations results in a less complex monitoring and a more effective assessment.

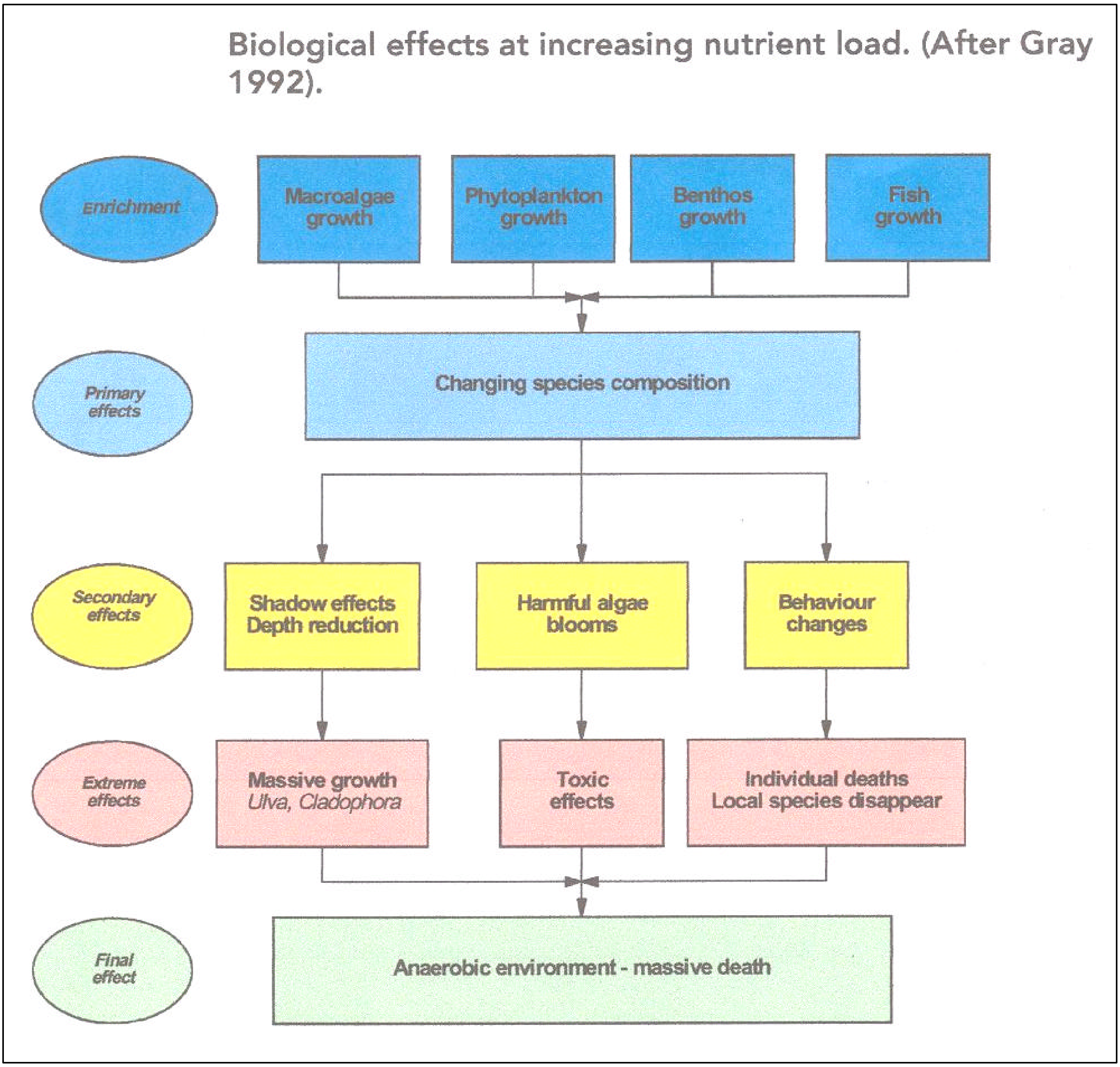
Biological effects at increasing nutrient load. (After Gray 1992).
Enrichment
Macroalgae growth
Phytoplankton growth
Benthos growth
Fish growth
Primary effects
Changing species composition
Secondary effects
Shadow effects Depth reduction
Harmful algae blooms
Behaviour changes
Extreme effects
Massive growth Ulva, Cladophora
Toxic effects
Individual deaths Local species disappear
Final effect
Anaerobic environment - massive death

FIG. 6

3.1 UNEP/ MED POL proposal for assessing Mediterranean eutrophication

All the above-mentioned experiences, gaps and recommendations bring to propose a general MEDPOL strategy based on three different lines:

1. In the short term adopt a group of basic parameters/indicators as showed in Table 4
2. In the medium term start collecting historical records of events and data (algal blooms, bottom anoxia, nutrients, chlorophyll, etc.) for each affected area in the Mediterranean;
3. In the long term start developing new more effective indicators trough the coordination of a Mediterranean working group of experts.

3.1.1 Short term strategy

For each affected area (see paragraph 3.2.) adopt the following list of mandatory parameters in a national monitoring plan:

Table 4 - Mandatory parameters to be monitored from each country

Temperature (C°)	**Dissolved oxygen (mg/l)**
PH	**Chlorophyll “a” (μg/l)**
Trasparency	**Total Nitrogen (N mg/l)***
Salinity (psu)	**Nitrate (N mg/l)**
Ortophosphate (P –PO_4 mg/l)	**Ammonium (N mg/l)**
Total phosphorus (P mg/l)	**Nitrite (N mg/l)**
Silicate (SiO_2 mg/l)	**Phytoplankton (number and species composition)***

STATE INDICATORS supported:

Trix index
Nitrate and Orthophosphate (winter concentrations vs. reference value)

3.1.2 Medium term strategy

For each affected area start collecting observations and data to be organized in a database of historical records of events. The database will support a better assessment of the ecosystem quality. The contents of the database need to be discussed in an “ad hoc” working group. An other

* not mandatory

important topic that should be discussed in the working group is the adoption of the remote sensing for chlorophyll data: applicability, calibration needs, gaps, etc.

3.1.3 Long term strategy

Organize a working group of regional experts that develop, test and propose a new indicator system based mainly on sensitive biological communities and defines the content of the database of historical records to be fed from each country.

3.2 Sampling Strategy

A necessary first step towards the development of the UNEP MED POL proposed indicator database is that the countries themselves should identify the monitoring stations and the sampling frequency able to detect temporal trends.
To this end, coastal zones –wherever possible - should be related to the back lying catchment's areas.

3.2.1 Sampling frequency

The optimal sampling frequency should be chosen as a right compromise between a high frequency able to cover the parameter variability that is in most of the cases site dependent and the best cost-effective strategy of the sampling programme. Each country has is own responsibility for the best choice according to the parameter variability in the affected area. The sampling frequency chosen by each country has to take account the objective to detect a change in concentration over a selected period (e.g. 10 years).

The minimum mandatory sampling frequency is seasonal. A monthly sampling frequency is strongly recommended.

3.2.2 Spatial coverage

Each country is responsible for the choice of the most representative sampling stations in order to detect changes over a selected period (e.g. 10 years). The spatial distribution of the monitoring stations should take account of inputs and the oceanographic characteristics of each area. In most cases it will be possible to decide only after sampling and after a statistical analysis of the bulk of data of the whole monitoring plan.

A minimum sampling plan can be suggested as follow:

1. Design one transect perpendicular to the coast line of the affected area
2. Chose three sampling stations for each transect according to the bottom typology
    a. High slope (more than 50 m. depth at 3000 m. from coastline).
    b. Medium slope (more than 5 m. at 200 m. and less than 50 m. at 3000 m. from coast line)
    c. Low slope (less than 5 m. at 200 m. from coastline)

        a) Distance from the coastline= 1 at 100 m., 2 at 3000 m., 3 between the first two if the distance is more than 1000 m. Otherwise only the first two.
        b) Distance from the coastline= 1 at 200 m., 2 at 1000 m., 3 at 3000 m.
        c) Distance from the coastline= 1 at 500 m., 2 at 1000 m., 3 at 3000 m.

Vertical profiles:

it is recommended to collect more samples for each sampling station in order to have vertical profiles for all parameters. The number of vertical samples must not be less than three (surface, medium depth, bottom). It is recommended in particular to collect continuous profiles for salinity, temperature and oxygen trough the use of a CTD multiprobe apparatus.

Before the beginning of the regional monitoring programme on eutrophication a quality assurance programme should be organized by UNEP MED POL as it is going on for inorganic and organic pollutants (see UNEP(DEC)/MED WG. 196/3).

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