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The use of bio-indicators for quality assessments of the marine environment: Examples from the Mediterranean Sea

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Abstract. The aim of this paper is to give an overview of the use of indicators and indices for the evaluation of the status of the marine environment. This procedure represents a new integrated approach, where the coastal marine environment is considered as a complex ecosystem, to be studied in all its components. Recent national and international legislation introduces this new concept of environmental quality, while requiring data and information on parameters which were not evaluated in the past. Until now, monitoring and control programmes for the marine environment focused mainly on the chemical status of coastal waters. However, aspects of the biological quality are fundamental for the description of the ecological status; the need for the development of biological indicators and indices provides a challenge for the scientific and technical community managing the marine environment. Living organisms represent the most appropriate indicators for the environmental quality of a water body, as they integrate biotic and abiotic components through their adaptive response. The available information on the current use of biological indicators and indices are illustrated and suggestions and examples on the Mediterranean sea environment are discussed.

Keywords: Benthic community; Biocenosis; Cartography; Coastal environment; Ecological state; Environmental quality; Index; Indicator; Water legislation; Water monitoring.

Abbreviations: MCSD = Mediterranean Commission on Sustainable Development; OECD = Organization for Economic Cooperation and Development; UNEP-MAP = United Nation Environmental Programme – Mediterranean Action Plan.

Introduction

The use of indicators and indices for the evaluation and assessment of the environmental status of different ecosystems is becoming a widespread procedure to analyse the various and often complex components of a system.

Indicators can be handled as information tools, as they represent an objective system of information and evaluation, when properly selected, and the methodology of their determination and use can be uniformly specified and agreed upon. Indicators are also key tools for linking to policy objectives and targets, for communicating to countries data priorities and reporting complexity in simple ways that policy makers and public can understand. It is important to clarify and share the definitions of indicator and index. According to the Organization for Economic Cooperation and Development (OECD) an 'indicator' is defined as a parameter, or a value derived from parameters, which provides information about the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with the parameter value. An index is referred to as a set of aggregated or weighted parameters or indicators (Anon. 1993).

Selection and validation of the most appropriate indicators for the different systems studied are in progress at different levels. A commonly used method to approach the environmental analysis through selected indicators follows the DPSIR scheme defined by the European Environmental Agency (EEA), integrating a previous OECD model (Anon. 1993). Indicators are subdivided into five groups: **D**riving force, **P**ressure, **S**tate, **I**mpact, **R**esponse, according to the kind of information they provide. This procedure enables an integrated overview of the system, analysing various parameters, that derive from different sources (socio-economic, statistic, environmental data).

The marine environment is a complex system, where a myriad of interrelated forces interact along different gradients, according to the specific area. Focusing the attention on the marine areas that result in primary importance for humans, i.e. coastal zones, we need to examine the hydrological, geomorphological, socio-economic, institutional and cultural systems that exert their influence on the area. In fact, the close links (through both physical and human processes) between the marine and the terrestrial components of the coastal area, imply that an analysis of the marine coastal area status cannot be adequate without the evaluation of the land components, where most of the pressures are generated from.

The aim of this paper is to give an overview on the use of indicators and indices for the evaluation of the ecological status of the marine environment, as recently required by our national (Anon. 1999a) and international (Anon. 2000a) legislations for water protection.

Moreover, considering the particular situation of the Mediterranean Sea, where marine waters are shared by 20 different countries, only a few of them being European, we would like to share our information and points of view to stimulate the development of a common Mediterranean need to establish appropriate indicators and indices for the Mediterranean Sea.

Survey

Use of indicators in the Mediterranean region

In accordance with the recommendations adopted by the 11th Meeting of the Contracting parties to the Barcelona Convention in Malta, 1999, states have been invited to set up a common system of indicators for sustainable development in the Mediterranean region in the framework of UNEP-MAP (Anon. 1999b). In this connection, the Mediterranean Commission on Sustainable Development (MCSD) selected a core set of indicators whose use and adequacy need to be verified (Anon. 2000b). At the moment the Blue Plan of UNEP-MAP is testing their actual use, and the availability of the required data, in the different Mediterranean countries. These selected indicators are classified according to thematic framework (e.g. population and society, territory and human settlements, economic activities,etc), specific topics (e.g. fisheries, biological diversity) and assigned to OECD indicators' group (Anon. 1993). Their number is quite consistent (130). Most of the indicators are conceived for a geographical scale corresponding to the national or country level; however some indicators can also (or exclusively) be calculated either for smaller geographical units (coastal region, coastal strip, spot) or for larger units (marine zones). A further selection for specific information of the most relevant issues can be achieved accord-

Table 1. Sustainable Development Indicators (SDIs) for the marine environment in the Mediterranean region (MCSD 1998-1999).

No.	Indicator	Group	Topic
27	Ratio Artificialized coastline/total coastline	Pressure	Littoral and littoralization
28	Number of tourists per km of coastline	Pressure	Littoral and littoralization
29	Number of moorings in yachting harbours	Pressure	Sea
34	Oil tanker traffic	Pressure	Sea
58	Average value of halieutic catches at constant prices	Pressure	Fisheries, aquaculture
59	Number and average power of fishing boats	Pressure	Fisheries, aquaculture
95	Wetland area	Pressure	Biological diversity, ecosystems
97	Share of fishing fleat using barge	Pressure	Biological diversity, ecosystems
30	Population growth in Mediterranean coastal regions	State	Sea
31	Population density in coastal regions	State	Sea
32	Coastline erosion	State	Sea
35	General quality of coastal waters	State	Sea
36	Density of solid waste disposed in the sea	State	Sea
37	Coastal water quality in some main 'hot spots'	State	Sea
38	Quality of the biophysical environment	State	Sea
60	Production of fisheries per broad species group	State	Fisheries, aquaculture
61	Production of aquaculture	State	Fisheries, aquaculture
98	Threatened species	State	Biological diversity, ecosystems
33	Protected coastal area	Response	Sea
39	Protection of specific ecosystems	Response	Sea
40	Existence of monitoring programs concerning pollutant input	Response	Sea
41	Wastewater treatment rate before sea release for coastal agglomerations over 100000 inhabitants	Response	Sea
42	Harbour equipment ratio in unballasting facilities	Response	Sea
62	Public expenditures on monitoring of fish stocks	Response	Fisheries, aquaculture
99	Total expenditure on management of protected areas	Response	Biological diversity, ecosystems

Table 2. Indicators providing information on the status of the coastal waters and habitat (MCSD 1998-1999).

No.	Indicator	Group	Definition	Unit
35	General quality of coastal waters	State	This indicator aims at describing the quality of coastal waters in accordance with three variables: (1) the bacteriological quality of seawater; (2) the concentration of pollutants in the seawater and in sediments (3) the concentration of pollutants in living organisms	Quality class and quantity/volume
38	Quality of the biophysical environment	State	This indicator is defined by two sub-indicators: (1) ratio of the area of marine phanerogamous beds and the total infra-coastal area (0-50 m) (2) part occupied by *Posidonia oceanica* of the total area of water plant communities	Percentage

ing to the thematic issues required.

Focusing the attention on the marine environment,a selection of 25 indicators (Table1) results, providing information over a wide range of pressure on the environment caused by human activities (i.e. population, maritime traffic, fishing), some societal responses to mitigate negative impacts on the environment (i.e. protected coastal areas, monitoring programs) and a few representing the status of the environment.

Information on the status (quality) of coastal waters and habitat are provided by two indicators: 'general quality of coastal waters' and 'quality of the biophysical environment', reported in Table 2, with their definitions and units.

The general definitions of these indicators point out that the quality of the marine environment, '*in toto*', has to be defined mostly by chemical analysis of different matrices (water, sediment and biota), microbiological analysis in waters, and biophysical measures on important biological components of the habitat.

We would like to focus the attention on the significance of the chemical and biological evaluation of the quality of the marine environment, as the bacteriological aspects answer to human health legislation, more than to environmental requirements, although they are indicative of possible direct human discharges in the sea, causing sanitary risks.

Chemical analysis of waters, sediments and biota are commonly agreed as important component in the evaluation of the quality of the marine environment, although not uniformly and routinely performed in monitoring programmes for seawater quality control.

The importance in considering the biological elements, i.e. the organisms inhabiting a certain environment, and analysing their health status, is a more recent issue that needs to be developed and implemented. Living organisms are in fact the most appropriate indicators for the health status of a water body, as they integrate biotic and abiotic components stimuli into an adaptive response.

Recent legislations for the protection of the marine environment

As already mentioned new legislation for water protection, including marine waters, have been recently adopted both in Italy: 'Italian Water Directive', 1999-2000 (Anon. 1999a) and in Europe: 'European Water Framework Directive' (Anon. 2000a). Their common innovative perspective is the requirement of establishing an ecological status for the different water bodies (rivers, lakes, ground water, transitional and coastal waters), based on quality elements (indicators/indices) from the different matrices water, sediment and biota.

Details on the required elements, their use for classification of coastal waters in Italian law, and the comparison with the European Directive can be found in Casazza et al. (2001).

Here we would like to point out the innovative step represented by the new concept of environmental knowledge and protection, and the requirements needed to comply with the new water legislations. The quality of the water body that needs to be established has both chemical and ecological aspects, implying that the quality elements required include new parameters, not yet commonly measured, in institutional monitoring programmes of coastal waters.

The Italian Water Directive requires the use of indicators and comprehensive indices, where possible. For the marine coastal waters it introduces the use of the throphic index TRIX (Vollenweider et al. 1998) which, through elaboration of the most significant and well-used parameters in marine waters analysis, summarizes in a numerical value the trophic conditions of the coastal waters studied. It has to be used for the classification of the Italian coastal waters, together with data resulting from sediment and biota analysis. More specific considerations on this index and its possible application to other coastal waters (i.e. Mediterranean and others) can be found in Giovanardi et al. (2000) and Casazza et al. (2001).

The European Water Framework Directive clearly defines priorities in the quality elements that define the ecological status of the water body: biological elements are fundamental, followed by hydromorphological, chemical and physico-chemical elements, 'supporting' the biological elements in the classification of the water body.

The quality elements required and the normative definitions for the classification of the ecological status in coastal waters, according to the Directive 2000/60/EC, can be found in Table 3, where we report also on the specifications for the 'high', 'good', and 'moderate' status of coastal waters, only for the biological quality elements; for practical reasons we report only the high status for the other elements.

In the application of the European Directive, the use of biological elements/indicators as particular species and/or groups of species and their distribution and relationships, develops from basic research to effective application in institutional management and environmental protection. Considering the importance and significance of this issue in the development of marine environment studies, an overview of the state of knowledge for marine biological indicators, especially related to the particular Mediterranean ecosystems, is a starting point.

Biological indicators

According to Bellan (1984), biological indicators can be considered as 'detectors' revealing the occurrence of very complex conditions, difficult to be elucidated, deriving from a series of biotic and abiotic elements that cannot be measured individually. When more than one indicator can be used to decode and simplify these phenomena, they can be combined in a 'biotic index' form.

For fresh waters, especially running waters, biological indicators and indices are widely used (e.g. De Pauw et al. 1992). The speed of the current in these waters represents the main factor for determining the qualitative and quantitative distribution of the populations, and it often determines variations in other factors. For the marine environment the establishment of appropriate biological indicators is a more difficult process, as the variables to be considered are more numerous than in fresh waters. Moreover their hierarchy is not clear and it is not easy to define a main gradient that collects most of the sources of variation (Occhipinti Ambrogi & Sala 2000).

Different biocenotic components, mostly from the benthic environment, have been studied to provide evaluations of the marine environment quality. The most used biological indicators, in studies of marine macrobenthic communities, can be grouped in three main categories:

- Indicators at the level of species;
- Indicators at the level of community structure;
- Integrated index.

Indicators based on the presence of species

The presence of a species (or a group of species) in a particular habitat can be considered as an indicator of specific environmental conditions (stress) or can be used to identify the community (Bellan 1984). Thus species can be subdivided in three types: characteristic, indicative and 'sentinel' (Bellan 1991). A characteristic species means that a species is linked to a particular biocenotic composition and structure, so that its presence identifies that community. An indicative species marks the existence of a particular factor, biotic or more often abiotic, within an environment. It provides information in the functioning rather than in the structure of the community. A 'sentinel' species could be considered as an early warning. In fact it is a species that by its presence, or better by its relative abundance has a role of 'warning', signalling imbalance in the environment or distorsion in the functioning of the assemblage. Depending on the situation, one and the same species can belong to all the three types. This is the case, for example, of the polychaete *Platynereis dumerilii* in the north-eastern Mediterranean which is characteristic of the biocenosis of superficial infralittoral settlers on hard substrates (Bellan-Santini 1969). At the same time this species is indicative, within these settlements, of a moderate level of hydrodynamics. Finally, in polluted environments *P. dumerilii* increases its abundance and dominance; thus it can be considered a 'sentinel' species of polluted water. The presence of groups of species and their relationships has often been used to provide an index, based on the ratio between different taxonomic groups, as in the case of the nematods/copepods ratio, in the meiofauna (Raffaelli & Mason 1981).

Indicators of the structure of benthic communities

Studies on communities and their habitats considering variation in species number, abundance and biomass during a certain period of time, have been used to test the first types of index such as the diversity index of Shannon-Weaver (1949) and the dominance index of Simpson (1949). Variations in the community structure have been related to different factors such as organic inputs, chemical analysis and toxicological results, which provide different types of indices. Methods examining differences in community structure such as cluster analysis or ordination analysis have also been used.

It is not our intention to give detailed discussion of the different methodologies and studies in progress. Thus we present a table here (Table 4) from Occhipinti Ambrogi & Sala (2000), that summarizes some of the

Table 3. Quality elements and normative definitions for the classification of ecological status in coastal waters, according to the Directive 2000/60/EC (Anon. 2000a), Table 1.2.4: 'Definitions for high, good and moderate ecological status in coastal waters' (In the 'high' status columns, the parameters to be considered are in bold).

Biological quality elements

Element	'High' status	'Good' status	'Moderate' status
Phytoplankton	The **composition and abundance** of phytoplankton taxa are consistent with undisturbed conditions. The **average phytoplankton biomass** is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type specific transparency conditions. **Planktonic blooms** occur at a **frequency and intensity** which is consistent with the type specific physicochemical conditions.	The composition and abundance of phytoplankton taxa show small signs of disturbance.There are slight changes in biomass compared to type-specific conditions. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbance to the balance of organisms present in the water body or to the quality of the water. A slight increase in the frequency and intensity of the type-specific plankton blooms may occur.	The composition and abundance of planktonic taxa show signs of moderate disturbance. Algal biomass is substantially outside the range associated with type-specific conditions, and is such as to have an impact upon other biological quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months.
Macro-algae and angiosperms	All disturbance sensitive **macro-algal and angiosperm taxa** associated with undisturbed conditions are present. The **levels of macro-algal cover and angiosperm abundance** are consistent with undisturbed conditions.	Most disturbance sensitive macro-algal and angiosperm taxa associated with undisturbed conditions are present. The level of macro-algal cover and angiosperm abundance show small signs of disturbance.	A moderate number of the disturbance-sensitive macro-algal and angiosperm taxa associated with undisturbed conditions are absent. Macro-algal cover and angiosperm abundance are moderately disturbed and may be such as to result in an undesirable disturbance to the balance of organisms present in the water body.
Benthic invertebrate fauna	The **level of diversity and abundance of invertebrate taxa** is within the range normally associated with undisturbed conditions. All disturbance-sensitive taxa associated with undisturbed conditions are present.	The level of diversity and abundance of invertebrate taxa is slightly outside the range associated with the type-specific conditions. Most of the sensitive taxa of the type-specific communities are present.	The level of diversity and abundance of invertebrate taxa is moderately outside the range associated with the type-specific conditions. Taxa indicative of pollution are present. Many of the sensitive taxa of the type-specific communities are absent.

Hydromorphological quality elements

Element	High Status
Tidal regime	**Freshwater flow regime** and the **direction and speed of dominant currents** correspond totally or nearly totally to undisturbed conditions.
Morphological conditions	**Depth variation, structure and substrate of the coastal bed**, and both the **structure and condition of the inter-tidal zones** correspond totally or nearly totally to the undisturbed conditions.

Physico-chemical quality elements

Element	High Status
General conditions	Physico-chemical elements correspond totally or nearly totally to undisturbed conditions. **Nutrient concentrations** remain within the range normally associated with undisturbed conditions. **Temperature, oxygen balance and transparency** do not show signs of anthropogenic disturbance and remain within the ranges normally associated with undisturbed conditions.
Specific synthetic pollutants	**Concentrations** close to zero and at least below the limits of detection of the most advanced analytical techniques in general use.
Specific non-synthetic pollutants	**Concentrations** remain within the range normally associated with undisturbed conditions.

most used indices, based on the structure of benthic communities in the marine environment.

Integrated indices

A few attempts to develop an index that combines the use of different types of analysis together with faunal data have been proposed. Their approach is based on the integrated evaluation of two or three components (i.e. chemical, ecotoxicological and faunistic) to provide a distinction of geographical areas affected by different pollution loads. Some of these indices are reported in Table 4.

So far we analysed biological indicators based on the faunal components of the benthic environment. The analysis of phytobenthic communities, in their structure and distribution, has been used too, providing useful information on the habitat inhabited (Ballesteros et al. 1998; Lovett-Doust et al. 1994).

Marine angiosperms as indicators for marine environment quality

Marine plants constitute important and well-characterized ecosystems. As pointed out by Orth & Moore (1988), submerged angiosperm vegetation can be considered as the 'barometer' of the marine environment

Table 4. Most used indices, based on benthic community structure in the marine environment (Occhipinti Ambrogi & Sala 2000).

Index	**Data type**	**Type of pollution detected**	**Character of parameter**
Dominance index Simpson (1949)	Number of species and relative abundance	All types	Structural
Diversity Index (*H'*) Shannon & Weaver (1949)	Number of species and relative abundance	All types	Structural
Evenness Index (J) Pielou (1975)	Distribution of organisms among species	All types	Structural
Infaunal Trophic Index Word (1978, 1980)	Rate of pollution sensitive taxa/not sensitive taxa	Organic	Structural
Log Normal Distribution Gray & Mirza (1979)	Distribution of number of organisms among species	Organic	Structural
Pollution Polychetes (IPP) Index Bellan (1980)	Ratio polychetes species pollution indicative / clear waters indicative	Organic	Structural
Nematoda/Copepoda Raffaeli & Mason (1981)	Ratio Nematoda/Copepoda in meiofauna	Organic	Structural
Sediment Quality Triad Long & Chapman (1985)	Synthesis of chemical analysis, toxicology tests and faunal data	Organic and Chemical	Chemical analysis of sediments, structural + ecotoxicological, bioaccumulation
SAB curves Pearson & Rosenberg (1978)	Comparison among species richness (*S*), abundance (*A*), biomass (*B*)	Organic	Structural + biomass
ABC method Warwick (1986)	Comparison between abundance and biomass curves	All types	Structural + biomass
S Index (N-B) Beukema (1988)	Sum of differences between numbers and biomass	All types	Structural + biomass
SEP Index McManus & Pauly (1990)	Rate of evenness considering biomass values/abundance values	All types	Structural + biomass
DAP Index McManus & Pauly (1990)	Area in between abundance curve and biomass curve	All types	Structural + biomass
Benthic Index Engle et al. (1994)	Synthesis of chemical analysis, toxicology tests and faunal data	Organic and chemical	Chemical analysis of sediments, structural + ecotoxicological, bioaccumulation
Index of Biotic Integrity Van Dolan et al. (1999)	Number of taxa, abundance, dominance, sensitive species percentage	Organic and chemical	Structural

health. Different species of marine angiosperms do not colonize the same areas permanently: generally there is a dominance of a species which thus names the specific phytocenosis (*Posidonia oceanica* bed, *Zostera marina* bed, etc.). The various species are adapted to different environmental situations (Buia et al. 2000); for example: *Zostera marina* grows on muddy sand and in brackish waters, *Cymodocea nodosa* is less adaptive but can grow both on clean sand and on soft muddy bottoms; *Ruppia maritima* colonizes environments with unstable physical and chemical conditions such as salinity, light, water column depth, current, mostly on muddy bottoms. It is considered a characteristic species of alkaline and hyper-alkaline basins (Reid 1961). The most typical and well-known Mediterranean species *Posidonia oceanica* is the most demanding species of all and it can be found only where waters are clear, on sandy bottoms with abundant nutrients; occasionally it can colonize hard bottoms too (Pasqualini et al. 1995).

Species are distributed along a gradient of required resources, from the least to the most demanding one, reflecting the status of the environment through the different strategies of resource utilization. Thus, the presence (and the absence, too) of a particular species can give a preliminary indication on the environmental conditions of the area and its characteristics (Prange & Dennison 2000; Bearlin et al. 1999; Schlacher-Hoenlinger & Schlacher 1998).

The endemic species *Posidonia oceanica* is often considered as a good indicator of the water quality in the Mediterranean Sea (Pergent et al. 1995). *Posidonia oceanica* beds are a reliable indication of the overall status of coastal waters. Being widespread throughout the Mediterranean, sensitive to oversedimentation (Manzanera et al. 1998) and particularly sensitive to pollution, and to human impact, and having a low regeneration ability, it indicates through its presence and vitality good conditions and through its regression (as shown by dead 'matte') environmental deterioration. Posidonia meadows have a multifunctional importance for coastal environments. An important role, as example, is exerted by the 'matte', the particular structure composed by roots and rhizomes of the growing plant which collects sediments and organic material, and builds up a structure for plant development. The growth of the matte can reach 1m per century: if we consider that beds of 4-5 m height are found in the Mediterranean, the longevity and historical 'memory' of the matte are formidable. The matte structure stabilizes the environment by braking waves and currents, and regulating sedimentation. Hence it functions as a protective structure in coastal areas; reduction of the height of the structure with 1 m has been proven to cause a retreat of the coastline with ca. 20 m (Jeudy De Grissac & Boudouresque 1985). Consequently it is of fundamental importance to develop a cartography of *Posidonia* meadows along the Mediterranean coasts and to monitor progression and regression and control possible modifications. Also, studies on intra- and inter-species relationships within the *Posidonia* community are necessary.

Extensive research has been carried out on the dynamics of *Posidonia* meadows and several descriptors have been used to characterize the vitality of the beds and to assess the impact of some form of degeneration (Pergent-Martini & Pasqualini 2000; Peirano & Bianchi 1997; Walker et al. 2001). Further studies are required to fully use the significance of the different descriptors and to develop standard methods of investigation. For example the characterization of some 'early warning' species in the community, that could indicate the beginning of a regression of the *Posidonia* bed, would be a very interesting and useful tool for the prevention and protection of this unique and fundamental biocenosis for the entire Mediterranean ecosystem.

The importance of cartography

Thematic environmental cartography represents a primary instrument in environmental studies, both for the basic research aspects of ecosystem knowledge, and for the managing and protection of the territory. Ecological cartography is already well-developed in the terrestrial environment, where vegetation mapping or pedological characteristics represent an established fundamental element for environmental studies.

For the marine environment ecological cartography is of similar importance but it has been accomplished much less frequently, due to both a minor tradition in considering the sea as a territory, and, of course, the operational difficulties in mapping sea bottoms. Biological cartography, displaying the biological communities that inhabit the sea floor, provides an image of the benthic environment status, thus giving information on the quality of the ecosystems. Appropriate analysis of the biocenotic variations can identify potential disturbance phenomena, enabling to timely operate in the managing of the coastal ecosystem. Monitoring biocenotic changes by the comparison of biocenotic cartography obtained in different times, provides an evaluation of communities' evolution, supporting the environmental knowledge of the area with precious information. At present biological cartography of coastal environment is still poor, and not standardized at all, particularly for the Mediterranean Sea (Colantoni et al. 1982; Pergent et al. 1991; Vaugelas et al. 1999; Somaschini et al. 1998). Mapping of some particular areas in a monitoring context, for example, the *Posidonia oceanica* beds, have been performed during periods of time, in different countries and regions, with various methods, reporting the obtained data by different scales (Buia et al. 1985; Calvo et al. 1995; Boudouresque et al. 1994; Renom & Romero 2001). Mapping techniques have been developed, but often recent cartographic data do not easily match with information from the past. Thus it is very difficult to establish the correct information provided by old cartography and to compare different maps.

Conclusions

The use of indicators, commonly defined and specified, to provide basic and objective information on the environmental quality of a system, is widespread, also for the evaluation of the marine environment.

Recent innovative legislation on water protection requires integrated analysis of the different aquatic environments; here we need information on the various components of the ecosystems, that were not considered before. Biological elements are particularly outstanding because they provide 'integrated' responses to biotic and abiotic factors that stimulate the environment.

Biological indicators for the marine environment have been studied and used, but further development and research is required to establish the most appropriate indicators for the specific ecosystem analysed.

The sea floor creates different habitats that are influenced by chemical and physical factors as light gradient, wave strength, water temperature; their status depends on the depth, thus on local pressure. Moreover variation in substrate composition, ranging from soft (gravel, sand, pebbles, detritus, mud) to hard (rocks, wreaks, docks), creates a further diversity in the submerged environment. Each of these habitats, possessing its own specific characteristics, is inhabited by a diverse biocenosis.

For the Mediterranean Sea the most used biological zonation follows the Peres & Picard (1964) model, based on the vertical zonation of the benthic environment, subdivided in strata (supralittoral, mediolittoral, infralittoral and circalittoral), consisting of arrangements of plants and animals in belts or strips, usually parallel to the water surface. Within each stratum, the primary environmental characteristics are considered to be almost homogeneous; further variation, due to the substrate, account for the differentiation into ca. 30 biocenotic communities (Ros et al. 1985). Benthic communities represent powerful tools to reveal disturbance to natural conditions: in fact, while chemical and physical parameters can vary within the time scale of the single day, the organisms of a community bear all the variations related to the particular environmental situation. Biological communities, maintaining the historical and spatial memory of natural phenomena and perturbations of the ecosystems can well describe the environmental conditions of their ecosystem. Studies and characterization of indicative species, and/or communities, provide a tool to operate in the conservation of the environment. The elaboration of biological indices, which could compile different and important parameters, synthesizing the collected information into values' ranges, is a very important challenge for marine biological research. Accomplishment of this task will require a considerable amount of efforts and time, due to the complexity of the system and its variety of habitats.

For the Mediterranean Sea, we think that, at present, work should be focused on identifying priorities in common monitoring programmes with uniform sampling and analytical procedures, to support a basic shared knowledge, on the distribution, evolution and possibly the state of the most relevant biocenosis. These data would enable the development of significant biological maps of coastal areas of the Mediterranean Sea, basic tools for the management of the marine coastal environment. At the same time, the characterization of the most appropriate indicators for these communities should progress toward the elaboration of synthetic indices for the most relevant biocenosis, i.e. *Posidonia* meadows, coralligenous, well sorted fine sand (SFBC) (Peres & Picard 1964).

In accomplishing this ambitious but fundamental project, the collaboration between scientific institutions and administrative bodies, in charge of monitoring and control, is a must. A starting point can be made by raising the awareness of the importance of the issue, and to make it well understood and accepted by authorities and politicians in charge of environment management, often not sensitive enough to approach marine environmental problems in a correct and efficient way.

Considering the geophysical characteristic of the Mediterranean Sea and the political subdivision of its coastlines into 20 different countries, belonging to various and diversified economic and cultural realities, a uniform answer to the problem is difficult to achieve. We think that, at the moment, progress could be made by the application of the new European water legislation; in fact it demands from the member states the establishment of typologies and reference conditions, and characterization and classification of water bodies, at the level of ecoregions. These requirements should stimulate an effective collaboration among the Euro-Mediterranean countries, and involvement of other Mediterranean, non-EC countries, which could provide useful contributions. Environmental policies, in fact, must face the physical reality of the environment, to correctly establish the appropriate solutions for the various ecosystems, possessing their specific and unique characteristics, like those of the Mediterranean Sea.

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