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Classification of coastal waters according to the new Italian water legislation and comparison with the European Water Directive

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Abstract. New legislation for the protection of inland surface waters, transitional waters, coastal waters and ground waters has recently been established in Italy. This law presents a new integrated approach, where all water bodies are considered as complex ecosystems to be studied in each of their components. The new concept of environmental quality of the water body, based on the ecological and chemical status, is also introduced. At the same time (i.e. the end of 2000), the European Community approved the European Water Framework Directive based on the same basic environmental concepts and criteria of the new Italian law. This paper analyses the important points and innovations required by the new Italian legislation for monitoring and classification of marine coastal waters. Details of definitions, parameters, analysis and monitoring programs are discussed. A comparison with the European Water Framework Directive is eventually given, underlining the specific characteristics of the Mediterranean sea, which have to be taken into consideration when applying the European Directive to this particular ecoregion.

Keywords: Biological index; Biological indicator; Chemical status; Coastal environment; Ecological status; Environmental quality; Water legislation; Water management; Water monitoring.

Introduction

Recent environmental legislation for the protection and sustainable management of water resources has recently been adopted both in Italy (Italian Water Directive from 1999-2000) and in Europe (European Water Framework Directive from 2000). Their common innovative perspective is the requirement of establishing a quality status for the different water bodies (rivers, lakes, ground, transitional and coastal waters), based on the analysis of quality elements (biological, chemical, physical and hydromorphological) that characterize the various water typologies.

The overall purpose of the two Directives is to establish a general discipline for surface fresh water, transitional waters, coastal waters and groundwaters with the aim of:

- Preventing further deterioration, protecting and enhancing the status of aquatic ecosystems and connected terrestrial ecosystems;
- Promoting sustainable water use based on a long-term protection of available water resources.

Water bodies have to be defined according to the specific dimensions of the catchment basin or other quantitative parameters. They are considered as ecosystems directly connected to a geographical area, the Basin district being recognized as the most significant territorial unit.

The highly innovative concepts shared by the two legislations is that of the environmental quality of the 'water body' (based on both the ecological and chemical status), and the establishment of water quality targets, requiring a quality classification for each relevant water body. The ecological status should represent the complexity of the aquatic ecosystem, and must therefore include the physico-chemical conditions of the waters and sediments, the water flux characteristics and the water body physical structure, with special attention to the status of the ecosystem's biotic elements, while the chemical status is based on the presence of dangerous micropollutants.

Coastal waters, identified as one of the significant water bodies, thus have to be classified using this integrated view of ecosystem complexity, which requires monitoring and analysis of various parameters and components of the marine environment that were poorly, if at all, considered in past institutional monitoring programmes of coastal waters.

In Italy, as in many other European countries, national programs for monitoring and control of coastal waters previously focused on performing analyses to define the chemical status of waters, and monitoring was often related either to specific or local problems such as euthrophication, hydrocarbon release, sewage and water treatment or else was directed to the detection of microbiological contamination of bathing waters, according to the national legislation complying with the

EC Directive for bathing waters (Anon. 1982).

Monitoring and protection of coastal waters with the integrated view required by the new water Directive has not been implemented before in Italy. Comprehensive legislation approaching the different but interconnected water environments as a whole 'hydrosphere', in which all the components of the ecosystems have to be considered, has not previously been adopted.

The new Italian law no. 152 enforced in May 1999 and implemented in August 2000 (Anon. 2000a) integrates and repeals different laws and regulations in act for water policy, with the aim of harmonizing monitoring, control and protection of the various water bodies. It is very similar in its conceptual basis and principles to the new European Water Framework Directive (WFD), which has been developed at the same time by the European Community and which was finally approved by the EC Parliament in December 2000 (Anon. 2000b). Differences are mainly related to requirements for the various quality elements and their relevance in the classification analysis of the two legislations.

This paper will illustrate only the most important points required by the new Italian water legislation for monitoring and classification of marine coastal waters. A comparison with the European Water Directive then follows, pointing out the differences, where significant, as they underline the need for information, data and research development to implement and apply the new legislation. The specific characteristics of the Mediterranean Sea, which have to be taken into consideration when applying the European Directive to this particular ecoregion, will also be outlined.

Results and Discussion

Italian Water Directive

Main legislative requirements

The most important concept of the new Italian water legislation is that the classification of the different water bodies status has to be accomplished through an integrated analysis of the various components of the aquatic ecosystem.

Monitoring of coastal waters requires the analysis of various chemical, physical and biological parameters of the different components of the ecosystem i.e. water, sediments and biota, following standard strategies regarding location and frequency of sampling, in order to obtain data which is comparable at the national scale.

The monitoring programs are the responsibility of the regional authorities, which manage and coordinate administrative arrangements at the River Basin level, recognized as the significant territorial unit. Each region establishes its sampling plans according to the legal requirements, based on their knowledge of coast types and use within the territory, including identification of the most stressed areas and least pressured areas, that are considered as reference zones.

Before explaining the monitoring and classification details required by the new legislation, it is important to consider the specific characteristics of Italian coastal morphology, in order to understand the legal definition of coastal waters and the related criteria for stations selection and sampling within the monitoring programs.

Main characteristics of Italian coastal morphology and coastal waters definition

The geomorphological characteristics of Italian coasts are very heterogeneous; depth and continental platform size vary considerably: from steep rocky shores where considerable depths (over 500 m) are reached at a short distance from the coastline (e.g. in the Tyrrhenian sea), to long sandy shores with very shallow waters (e.g. in the northern Adriatic Sea) where depth increases so slowly that it remains below 30 m at some km distance from the shore. For this reason, the definition of coastal waters which need to be monitored is based, according to Italian law, on depth criteria, as follows: *'the significant water body which has to be monitored consists of marine waters within 3000 m distance from the coast and however within the 50 m depth'*.

For a consistent analysis of coastal waters along the national coastline, three coastal types are defined by the law: deep, intermediate and shallow, according to sea floor depths at established distance from the shore (Fig. 1 a, b, c).

Monitoring requirements

The main monitoring requirements for coastal waters are reported in Table 1, in which a summary is shown of parameters and analyses to be performed on the three components of the coastal environment, namely water, sediment and biota. The same table gives the required sampling strategy in terms of sampling station location and sampling frequency.

Sampling strategy

Detailed sampling plans for the water, sediments and biota are further specified. For water monitoring, sampling has to be carried out at three stations, along a transect; the location of these stations is established according to the coastal area typology (Table 2).

Water sampling frequency is seasonal; a fortnightly frequency is required in areas where euthrophication can be expected (TRIX values > 5) (Table 1).

For the monitoring of sediment and biota (e.g. bio-accumulation by mussels), the sampling stations have to be located in representative positions for the different anthropogenic inputs of the area (industrial, civil, fluvial and harbour-related), as well as reference stations in a control area where anthropogenic inputs are absent. The surface stratum of sediment has to be sampled; sampling size depends on the sedimentological characteristics and the sedimentation rates of the area. Sediment sampling occurs annually and is repeated in the same time of the year (Table 1).

For the biota, the analysis of pollutant accumulation in mussels is carried out with a sampling frequency of every 6 months (Table 1). Another important analysis is the mapping and characterization of the most important biocoenosis (e.g. seagrass meadows, coralligenous formations) of the area, with the final aim of obtaining a habitat map of the seabed. This type of monitoring has a required sampling interval of 3 yr (Table 1).

Where necessary, some variations and refinements on these general monitoring requirements can be adopted by the authorities in charge of the monitoring programs (i.e. the Regions). According to the particular characteristic of the area, changes in sampling frequency, integration of the required parameters with additional analysis, and substitution of some parameters with more appropriate ones are allowed.

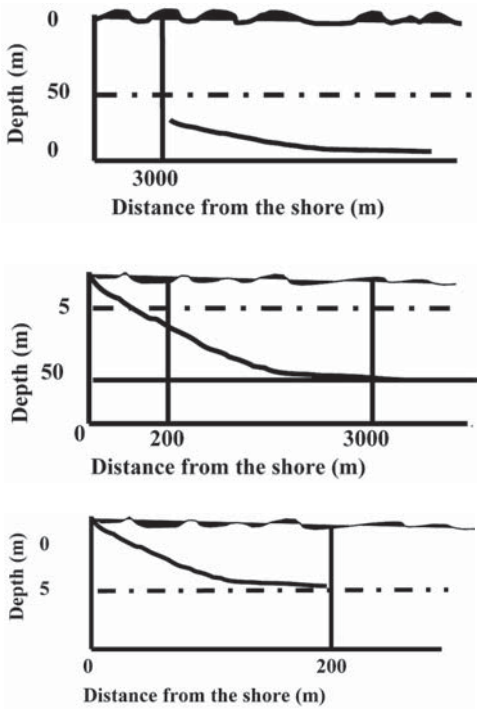

Fig. 1a. Deep coast: depth > 50 m at a distance of 3000 m from the shore; **b.** Intermediate coast: depth > 5 m at 200 m from the shore and depth < 50 m at 3000 m from the shore; **c.** Shallow coast: depth < 5 m at 200 m from the shore.

Table 1. Coastal waters monitoring according to Italian law 152/99.

Sampling matrix	Sampling strategy Spatial definition	Temporal frequency	Parameters
Water	Three stations per transect according to coastal area typology	Seasonal – when TRIX (Trophic Index) values > 5, every 15 days –	Temperature pH Salinity $P\text{-}PO_4$ Total P *Enterococcus* Dissolved O_2 Chlorophyll *a* Total N $N\text{-}NH_4$ $N\text{-}NO_2$ $N\text{-}NO_3$ Phytoplankton qualitative/quantitative analysis
Sediment	Two stations per transect in every relevant homogeneous area: control area – input area	Every year	Grain size PAH PBC, pesticides TOC TBT Heavy metals Biological essay
Biota Mussels Bio-accumulation	Two stations per transect in every relevant homogeneous area: control area – input area	Every six months	PAH PBC, pesticides Heavy metals
Biota	Most important biocoenosis (seagrass meadows, coralligenous, etc.) identification, to obtain an appropriate biocoenotic map	Every three years	Characterization of biocoenosis (seagrass meadows, coralligenous, etc.) and other potential bio-indicators

Table 2. Sampling stations for water monitoring.

Type	Station I	Station II	Station III
Deep	At 100 m distance from the shore	Intermediate position, when the distance between the I and III station is > 1000 m If distance ≤ 1000 m, no need for station II	Where depth ≤ 50 m
Intermediate	At 200 m distance from the shore	At 1000 m distance from the shore	At 3000 m distance from the shore
Shallow	At 500 m distance from the shore	At 1000 m distance from the shore	At 3000 m distance from the shore

Classification: the Trophic Index TRIX

An important innovation of the new legislation is the introduction of a water quality index 'TRIX' (Vollenweider et al. 1998) for the first classification of the trophic conditions of coastal waters.

The index (Table 3) is based on the limited number of parameters which are most commonly measured in monitoring programs of marine waters (chlorophyll, oxygen, nitrogen and phosphorus). Table 4 summarizes the trophic conditions of coastal waters, associating the 'quality status' of the monitored area with a numerical value.

It must be underlined once more that this 'quality status' reflects and is limited to the trophic level of the water body, and is hence not an exhaustive index. Although the use of the trophic index does not provide an integrated classification of the status of coastal waters, it has been provisionally adopted as the only immediately available tool. The water classification resulting from use of the trophic index has to be integrated with other analysis results from the sediment and biota components of the ecosystem. The present legal requirement is the following: '*While waiting for an integrated approach definition to the environmental quality status, a first classification of marine coastal waters has to be accomplished using the trophic index TRIX, integrated with the data resulting from sediment and biota analysis.*'

Table 3. The Trophic Index TRIX (from: Vollenweider et al. 1998).

$TRIX = [\log_{10}(Ch.D\%O.N.P) - (a)]/b$

Ch =	chlorophyll a [µg.dm^{-3}]
D%O =	absolute dissolved oxygen deviation [%] from saturation
N =	dissolved inorganic nitrogen [µg dm^{-3}]
P =	total phosphorus [µg dm^{-3}]
a, b =	constants determined on the basis of the upper and lower limits of the parameters (a = – 1.5 and b = 1.2 for the ranges used with the northern Adriatic data set)

Comparison of the Italian and the European Water Directives

As already stated, the Italian Water Directive shares the conceptual basis and principles of the European Water Directive; these can be summarized as follows:

- The purpose of the Directives is to establish a framework for the protection of all water bodies;
- Administrative arrangements are within River Basin Districts
- The new concept of environmental quality of the water body, based on the ecological and chemical status, guides the requirements of both laws, demanding a quality classification for each relevant water body;
- Water bodies are considered as integrated and complex ecosystems to be monitored in each of their components to establish the quality classification required;
- Integrated classification methods have still to be well developed in both legislations;
- Environmental objectives 'to achieve a good surface water status' have similar timing: the final goals have to be reached by the year 2016;
- Definition of 'good surface water status' is similar, in general terms, in assigning the 'good' value to water bodies not 'ecologically' compromised by human impacts;
- Assignment of 'good' status to the different water bodies depends on the classification used: this important classification process, as mentioned before, still requires relevant and urgent development in both legislations.

While asking for an integrated classification the Italian Directive provides, at the moment, a first classification based only on a water quality index that needs further integration with sediments and biota data. On the other hand the European Directive clearly establishes the quality elements that have to be used for the classification, but it does not indicate a method to

Table 4. Water quality criteria based on the trophic index TRIX (from Italian law Decreto Legislativo n.152, 1999).

Trophic scale	Water conditions	Environmental State
2-4	Low trophic level Good water transparency Absence of anomalous colours of water Absence of subsaturation of oxygen dissolved in the benthic waters	HIGH
4-5	Average trophic level Occasional clouding of water Occasional anomalous colours of water Occasional hypoxias in the benthic waters	GOOD
5-6	High trophic level Low water transparency Anomalous colours of water Hypoxias and occasional anoxias of benthic waters Damages of benthic ecosystem	MODERATE
6-8	Very high trophic level High turbidity of water Widespread and persistent anomalies in water colours Widespread and persistent hypoxias/anoxias in benthic waters Dying off of benthic organisms Alteration of benthic communities Economic damages in the tourism, fishing and aquaculture sectors	POOR

combine the results of their analysis to obtain the required classification.

The European Directive requires a description of the typology of the water bodies involved, together with their reference conditions, which are different in the various European biogeographic regions (as defined in Annex IX of the Directive).

Examining the main differences between the Italian and the European legislation applied to the 'coastal waters' type, some of the specific characteristics of Mediterranean waters, which must be taken into consideration when applying the European WFD to the Mediterranean ecoregion, are immediately apparent.

In fact, due to the geographical location of Italy in the middle of the Mediterranean Sea and to its geomorphological characteristics, Italian coastal waters can well represent the whole spectrum of different water typologies existing in the Mediterranean ecoregion.

Definitions

The definitions of coastal waters according to the two Directives are reported in Table 5. The first clear difference resides in the complexity of the European definition, compared with the Italian, since this definition has to consider the very different situations of the European seas, whose typologies vary according to diverse hydromorphological characteristics. Italian coastal morphology is very heterogeneous, as mentioned before, and depth and continental platform size account for most of the variables in its hydrological characteristics; thus the Italian coastal waters definition is based on the concept of coastal depth.

The European definition considers primarily the variability of the baseline from which territorial waters are measured, as this varies considerably throughout the northern European and western Atlantic coasts, due to the amplitude of tides. Tidal amplitudes are not significant for the Mediterranean Sea: it is thus necessary that the

Table 5. Definitions of coastal waters according to the Italian and European Directives.

Italian	European
Waters external to the low tide line or outside the external limit of an estuary Significant water body to be monitored: Marine waters within 3000 m distance from the coast and within 50-m depth range.	Surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side, from the nearest point of the baseline from which the breadth of territorial waters is measured, extending, where appropriate, up to the outer limit of a transitional water.

Table 6. Coastal waters characterization according to the European Water Framework Directive (from Annex II).

System A	System B
Ecoregion	*Obligatory factors*
Baltic Sea	Latitude
Barents Sea	Longitude
Norwegian Sea	Tidal range
North Sea	Salinity
North Atlantic Ocean	
Mediterranean Sea	
Type	*Optional factors*
Based on mean annual salinity:	Current velocity
< 0,5 ‰ freshwater	Wave exposure
0,5 to < 5‰ oligohaline	Mean water temperature
5 to < 18‰ mesohaline	Mixing characteristics
18 to < 30‰ polyhaline	Turbidity retention time
30 to < 40‰ euhaline	(of enclosed bays)
	Mean substratum composition
	Water temperature range
Based on mean depth of	
shallow waters: < 30 m	
intermediate waters: (30 to 200 m)	
deep waters: > 200 m	

Table 7. Quality elements (QE) required for classification of the ecological status of coastal waters, according to the EC Directive (from Annex V; 1.1.4).

Biological elements
Composition, abundance and biomass of phytoplankton
Composition and abundance of other aquatic flora
Composition and abundance of benthic invertebrate fauna
Hydromorphological elements (supporting the biological QE)
Morphological conditions
Depth variation
Structure and substrate of the coastal bed
Structure of the intertidal zone
Tidal regime – Direction of dominant currents
Wave exposure
Chemical and physico-chemical elements (supporting the biological QE)
General
Transparency
Thermal conditions
Oxygenation conditions
Salinity
Nutrient conditions
Specific pollutant
Pollution by all priority substances identified as being discharged into the water body
Pollution by other substances identified as being discharged in significant quantities into the water body

general European definition be adapted to the specific Mediterranean conditions, when applying it to these coastal waters.

Characterization

The European legislation provides two different systems for characterization of coastal waters, Systems A and B, which differ in the descriptors used to determine the typology. These two systems are shown in Table 6.

The first, system A, subdivides coastal water types based on salinity ranges and water depth. This system would only poorly characterize Italian/Mediterranean coastal waters, since the salinity of all Mediterranean coastal waters would fall within a single class i.e. euhaline, while the different bathymetry would result in conflicting classifications in all the proposed three depth classes.

The second, system B, provides a more detailed characterization although two of the obligatory factors involved, i.e. tidal and salinity differences, while being significant characteristics for northern European and western Atlantic coastal waters, are less relevant in Mediterranean coastal waters.

Classification

The quality elements (QE) required for the classification of coastal waters by the European Directive are grouped into three types; they are shown in Table 7.

The Directive does not provide a methodology for combining the quality elements to achieve a classification scheme: the important statement is that all quality elements have to be taken into consideration, with priority being assigned to the biological ones. Although most of these quality elements are required by both legislations, a very important difference resides in the biological elements that have to be monitored and in the importance assigned to their analysis within the water status classification by the European Directive.

According to the EC Directive, the ecological status of the water body is defined as primarily based on biological elements, while hydromorphological and physico-chemical elements must be used to support the biological data. This is a very important and innovative step that establishes, within the legal framework, a new approach to environmental analysis.

While the physico-chemical parameters required by both legislations are generally similar, the Italian Directive introduces the important innovation of using the trophic index TRIX, and other differences are listed below:

- The Italian legislation requires more detailed analysis of sediment parameters and of the accumulation of pollutants in biota;
- The European Directive requires detailed ecotoxicological tests to be performed on a 'base set' of representative taxa, to establish chemical quality standards for pollutants (Annex V, p.1.2.6).

The latter point once again illustrates the relevance assigned by the European Directive to the biological components of the environment.

Conclusions

The relevance of the recent Italian and European Water Directives resides in the new concept of the environmental quality of the water body, which requires an integrated approach to the study of the diverse aquatic systems considered.

For coastal waters, the Italian legislation requires the analysis of a number of parameters commonly measured in marine waters monitoring programs, together with monitoring of sedimentological and biological components of the coastal environment, which were not considered in the past. While some relevant data from scientific research carried out in different research institutes in various parts of the country does exist (Pusceddu et al. 1999; Buia et al. 2000; Danovaro et al. 2000; Zago et al. 2000), institutional duties or responsibilities in national monitoring of selected parameters using standard methods were not previously defined. Moreover the new law requires the development of the most appropriate indicators and indexes to define the quality status of the aquatic system.

A very important point has been reached with the establishment of a 'trophic' index (TRIX) for classifying the trophic conditions of coastal waters. The relevance of this index has already been discussed; it should be pointed out that its use could well be expanded to other coastal water situations, in the Mediterranean and other seas, especially where eutrophic conditions occur or high nutrient levels are often measured (Giovanardi et al. 2000).

Comparison of TRIX results from different areas would enhance the correct application of the index and the development of exchange of information for an increased common knowledge of the marine environment. At the same time, the limits of the index also require to be clarified. While the TRIX index provides very useful and comprehensive information on the trophic conditions of the coastal waters, through assigning a numerical value to describe some of the quality characteristics of the water body, it does not provide a complete measure, the 'overall quality' of the coastal waters.

Development of adequate research to implement an integrated water quality classification is still needed. This is stated in the Italian legislation, that also suggests the use of appropriate indicators and indexes for the biological components. The standardization of biological indicators and indices for the classification of marine waters still requires further work, and this need represents a pressing challenge for the scientific and technical community managing the marine environment (Casazza et al. 2002).

In the application of the European Directive, the use of the distribution and relationships of particular species and/or groups of species as biological elements/ indicators is taken beyond the stage of basic research to its effective application within the institutional management and protection of the environment. According to the European Water Framework Directive, the biological component is the basic quality element that should provide the information required for the classification of water bodies, supported by hydromorphological and physico-chemical elements. This is a very important innovative vision on the environment that, more than other issues, requires close collaboration between scientists and environmental managers and politicians to enhance the development of the most appropriate research and its application.

Finally, we would like to point out the most important considerations resulting from the comparison between the Italian and European legislation. As already discussed, the application of the European legislation requires feedback from the Member States, based on water typology related to the geographic ecoregions. The very particular characteristics of the Mediterranean Sea, especially in terms of geomorphology (e.g. depth), salinity and tides, the specific importance of which is underlined in the European legislation, needs to be stressed at the Community level.

The correct characterization of the different waters and reference stations is the first step required by the law, and the national monitoring program has to be based on these characterizations to achieve the 'good quality status' in the required time. Thus it is very important that the most appropriate quality elements for the classification of the coastal waters of each specific ecoregion are carefully selected by the Member States. For this reason, the European Commission, together with Member States, decided on a strategy for implementing the Directive (Common Implementation Strategy from 2001) through Working Groups on the different themes (e.g. typology, monitoring, pressure and impacts), which need to be correctly addressed within the various ecoregions. Work in this field is presently in progress.

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