Testing Different Approaches for Quality Assessment Using the Benthic Community: Examples from the Northern Adriatic Sea

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Habitat quality indicators for the marine coastal environment are in great demand following recent developments in the Water Framework Directive (WFD) which establishes that the ecological status of the water has to be determined by the condition of the biological elements including macrobenthos. Each member State should identify useful monitoring procedures for its water bodies and take into account the peculiar characteristics of its different coastal environments. In Italy, the Northern Adriatic Sea is an enclosed and very shallow sea, strongly influenced by the runoff of several rivers draining an intensively cultivated and inhabited area, resulting in a generally high trophic condition. Moreover these rivers create along the coastline a continuum of different environments, such as deltaic areas and bar-built estuaries. For this reason, we considered two different approaches: (i) the application of two biotic indices, from those indicated by WG COAST, to soft bottom macrobenthos data in the coastal environment, and (ii) the development of a fuzzy logic model based on hard bottom macrobenthos data in the lagoon environment.

The soft bottom samples were collected by Van Veen grab seasonally from July 1996 to July 2002, in six stations at different depths (3 m, 8 m, about 12 m), in two locations: Porto Garibaldi, closer to the Po river delta and Cesenatico, southward. The main chemical-physical parameters were weekly measured by the Oceanological Structure Daphne II of Cesenatico. Two biotic indices were applied on these data: the Ambi index by Borja *et al.* (2000) and the Bentix index by Simboura & Zenetos (2002).

The Ambi rates the shallow stations (3 m depth) as the most disturbed ones even though such disturbance, in most of the samples, is slight. The intermediate stations (8 m depth) and the deeper stations (about 12 m depth) are generally classified as slightly disturbed or undisturbed. On the other hand, the Bentix rates the shallow stations as the least disturbed, generally undisturbed. The intermediate and deeper stations mostly appear heavily disturbed with the exception of the intermediate southern station, which presents variable conditions, from moderately to heavily disturbed. The non parametric Spearman correlations between the two values of the indices and some chemical-physical and structural parameters have been calculated. The Ambi values are positively correlated with abundance and Simpson dominance, and negatively correlated with richness, diversity and evenness. In Figure 1, the Ambi and Bentix index variations are compared at the deeper station of Cesenatico. Most of the organisms sampled during the study period are assigned by the Ambi to the ecological group I, as is the Crustacean *Ampelisca diadema*.

For this reason, Ambi generally classifies the samples as undisturbed, or slightly disturbed in the case of high density of the Mollusc *Corbula gibba* (GIV). On the contrary, the Bentix index assigns *A. diadema* to group II (tolerant species) and *C. gibba* (a first order opportunistic species) to group III. Thus, most of the samples are classified as heavily disturbed, also due to the fact that groups II and III have the same weight in the index formula (Simboura & Zenetos, 2002). The quality level shifts to moderately disturbed when a slight increment in group I occurs.

In conclusion, the contrasting quality levels which emerge from the two indices appear mainly due to the different assignment of the species to the ecological groups, but also to the different number and weight of the ecological groups in the formula calculation. In all our stations, Ambi correlates better than Bentix both with the community structure and the chemical-physical parameters and seems more appropriate in describing the variations observed in our environment. As underlined by one of the Bentix authors (Simboura, 2004), the estuarine characteristics of this area, which hosts a low biodiversity with few species and high density, could represent a limit for the application of this index.
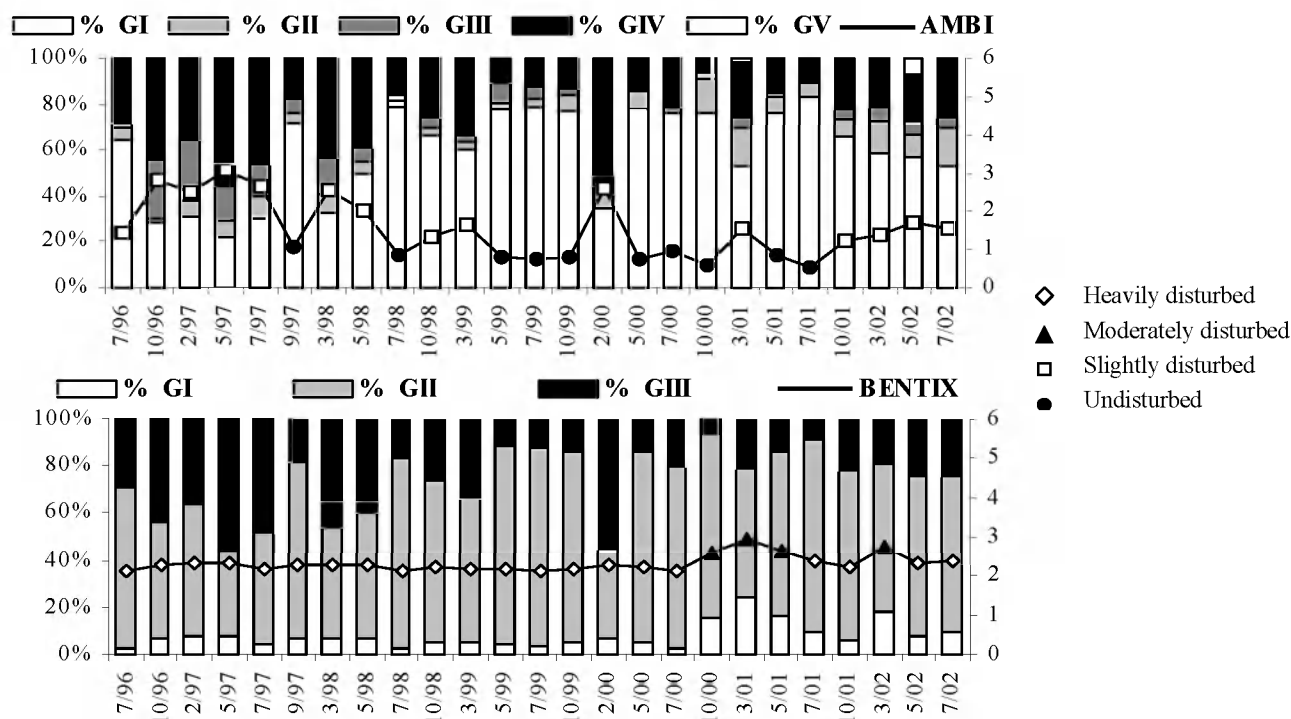

Figure 1. *Variations of Ambi and Bentix indices at the deeper station of Cesenatico. The histograms represent the percentage of abundance in each ecological group (G), the line shows the index values. Symbols correspond to the disturbance levels listed in the legend (right of the graph).*

A different approach has been implemented in some Northern Adriatic lagoons, using the sessile benthos living on hard bottoms such as wooden piles. A first proposal of classification of the Venice lagoon into six ecological sectors (Table 1), based on non-quantitative benthos abundance data and subjective knowledge, was presented by Occhipinti-Ambrogi *et al.* (1998). Marchini & Marchini (2004) used the fuzzy logic approach for the development of a model able to use those abundance qualitative data as input to identify an ecological sector out of the six previously put forward.

The fuzzy set theory, proposed in 1965 by L. Zadeh as a method for handling uncertainty, is particularly useful for processing vague expert knowledge and imprecise data. In the fuzzy systems a variable is not represented by a numerical value (e.g. phosphate concentration value), which has little meaning for a non-expert operator, but by an adjective that expresses a property of the variable (e.g. *limiting* or *high* phosphate concentration). The uncertainty is expressed by a membership function: an intermediate value of phosphate concentration is neither *limiting* nor *high*, but can assume partial membership grades for both the functions *limiting* and *high*. The concept of partial membership allows us to treat uncertainty as additional information instead of something undesirable to avoid: each variable is not represented by a single numerical value, but by several

adjectives that describe its properties. This approach is very similar to the ecologists' reasoning; furthermore, the fuzzy systems use logic rules (if...then) instead of complicated formulas. For example, the rules for the model of the Venice lagoon were directly obtained from the six definitions shown in Table 1: they were linguistic rules instead of mathematical expressions.

The application of the model in the Venice and Grado-Marano lagoons (Marchini & Marchini, 2004) and in the Sacca di Goro lagoon (Marchini & Occhipinti-Ambrogi, 2004) yielded results in agreement with the experts' assessments and with the literature information, showing that the fuzzy system was able to reproduce the human experience and could be used to interpret spatial differences and temporal trends within a lagoon.

In our opinion, there are three good reasons to recommend the fuzzy approach in the development of biotic indices of ecological quality: (i) a precise classification of the species into ecological groups is not required, so one species with intermediate behaviour can be both sensitive and tolerant at a certain grade and in this way uncertainty provides additional information instead of misclassification errors. Moreover, (ii) different expert judgments can be combined even if they are in disagreement because of the different responses of the species in different areas. Finally, (iii) an index can be built up without (arbitrary) weight coefficients and mathematical functions, but simply using expressions like «good species abundant and bad species scarce, then good water quality».

For these reasons fuzzy logic represents a promising tool for environmental quality evaluation, as it easily deals with qualitative information and allows to transform human experience and knowledge into an objective procedure. In conclusion, our work supports the use of macrobenthos for classification purposes and EcoQ assessments in marine and transitional waters, suggesting that models and indices that summarize expert knowledge can represent a useful management tool if site-specific information and historical knowledge are considered during validation and if the classification of the species into ecological groups is correct..

Table 1. *Ecological sectors defined for the Venice lagoon by Occhipinti-Ambrogi et al. (1998) and used in the "if...then" form by Marchini and Marchini (2004) to create a fuzzy model.*

ECOLOGICAL SECTOR	DEFINITION			
	marine species abundance	lagoon species abundance	oligohaline species abundance	total abundance
LAGOON MOUTHS	high	low	low	low
VIVIFIED LAGOON	high	low	low	medium
ROUGH EUTROPHIC	high	high	low	high
CALM EUTROPHIC	low	high	low	high
URBAN	low	high	low	low
ESTUARINE	low	low	high	low

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