LITTORAL BENTHIC COMMUNITIES AS INDICATORS OF ENVIRONMENTAL QUALITY IN MEDITERRANEAN WATERS

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ABSTRACT

Sampling of benthic communities from the Catalonia rocky littoral (NW Mediterranean) was carried out in 1999-2000 to study the environmental quality of the waters, using the organisms as bioindicators, and DCA analysis as ordination method. Coverage of the main organisms was used as descriptors of the ecological state. *Cystoseira mediterranea* was the dominant species in the north coast, whilst the central and south coasts were mainly dominated by *Corallina* elongata and *Mytilus galloprovincialis*. Samples in reference zones (non-polluted areas, with almost nil human influence) were also introduced in the analysis to compare the water quality of the different stations in the Catalan coast with these of "pristine" areas. Our results are compared with previous data obtained in 1982. We observe changes in the structure of the littoral communities since 1982, with an apparent increase of the environmental quality. There is a decrease in the abundance of green-algae but we do not observe an increase in the abundance of *Cystoseira*. These changes can be related to the implementation of the management of the residual waters since 80's years.

KEY-WORDS: Benthic communities, bioindicators, environmental quality, littoral, Mediterranean Sea

INTRODUCTION

Benthic organisms integrate the effects of long-term exposure to natural and anthropogenic disturbances (Borowitzka, 1972). Thus, the use of benthic communities in marine pollution assessments is based on the concept that they reflect not only conditions at the time of sampling but also conditions to which the community was previously exposed. There are numerous traditional methods that identify disturbances in soft-bottom communities using macrofauna as bioindicators (e.g. Pearson and Rosenberg, 1978). For rocky benthic organisms, macrophytes are the most interesting group as integrators of the environmental quality (e.g. Levine, 1984). Studies on the effect of sewage outfalls and industrial dumping on macroalgae reveal the sensitivity of some brown algal species, mainly of the genus *Cystoseira* to pollution (e.g. Bellan-Santini, 1968; Soltan *et al.*, 2001).

Species of the genus *Cystoseira* dominate Mediterranean littoral communities (Feldmann, 1937) but they are replaced by *Corallina elongata* or *Mytilus galloprovincialis* in disturbed or polluted environments (Bellan-Santini, 1968; Ballesteros *et al.*, 1984). These two

species can also disappear when the degree of eutrophication is very high and green algae predominate (Ballesteros *et al.*, 1984). The appearance of species of blue-green algae is characteristic of very degraded environments (Golubic, 1970).

The Catalan coast can be used as an example of a heavily man-modified coast, with different sections of coast affected by different uses, from recreational to urban and industrial. In this work, benthic communities of the upper infralittoral zone were studied in 1999 and 2000 in order to (1) describe their composition; (2) establish its relationship with physical, chemical and biological variables from the water column; (3) make a comparison with data obtained with the same methodology in 1982; and (4) compare results from the catalan coast with those in pristine areas (reference zones). This study provides an observational basis for monitoring and future experimental works.

MATERIALS AND METHODS

The study was carried out in the Catalan coast (Spain, NW Mediterranean; Fig. 1). 152 and 50 stations (may-june 1999 and 2000, respectively) were sampled in the upper infralittoral zone during spring (highest development of communities).

Fig. 1: Location of study area and sites (Northwestern Mediterranean Sea). Reference zones are included in the map.

Long-term temporal changes were analyzed comparing present data with data obtained in a study carried out in 1982, using the same methodology in 89 stations along the coast (included in our 152 stations visited in 1999). In order to compare the environmental quality of the stations selected in the Catalan coast with those situated in almost pristine areas, and in the aim of implementing the Water Framework Directive, three reference zones were sampled during spring 2001 (Fig. 1): 4 samples in the coast of the Parc Naturel Régional de Corse (France), 3 samples in Formentera (Balearic Islands) and 4 samples in Menorca (Balearic Islands).

For each sample, the whole community was collected from a 15x15 cm surface, using a hammer and a chisel. One sample by site was collected in 1982 and 1999, while two replicate samples were taken in 2000. Samples were preserved in formaline sea-water at 4% and sorted in the laboratory. Algae and invertebrates were identified and quantified in terms of coverage (horizontal surface) (Ballesteros, 1992).
Detrended Correspondence Analysis (DCA) was used to show affinities and differences between samples, sites and time, using CANOCO software (ter Braak, 1988). Species appearing in less than 2% of the samples were eliminated from the analysis. The short-term temporal variability was analyzed comparing the data obtained in years 1999 and 2000, whilst data obtained in 1982 were included to look for the existence of long-term changes.

Several environmental factors were taken into account to interpret the results of the DCA (degree of exposure of the coast, type and nature of the sampled substrate, orientation of the sampled site, distance to the closest city, distance to the closest sewage outfall), as well as several chemical and biological variables of the sea-water (nitrates, nitrites, ammonium, phosphates, silicates, total and phecal coliforms and phecal streptococci) (1994-1999 average data). Pearson correlations were used to test the relationships amongst environmental and biological variables and the main axes obtained in the DCA.

RESULTS

Results from the DCA analysis for 1999 are represented in Figure 2. Both main axes explain 22,2 % of the total variance. Samples are distributed into three distinct groups. The first axis represents a gradient between samples dominated by *Cystoseira mediterranea* and samples dominated by *Ulva* spp. Samples dominated by *Mytilus galloprovincialis*, *Corallina elongata* and *Lithophyllum incrustans* are situated in a intermediate zone. The interpretation of the second axis is not so evident, although samples with *Mytilus* have the highest values of this axis, those with *Lithophyllum incrustans* have the lowest values, and *Corallina elongata* is situated in the middle.

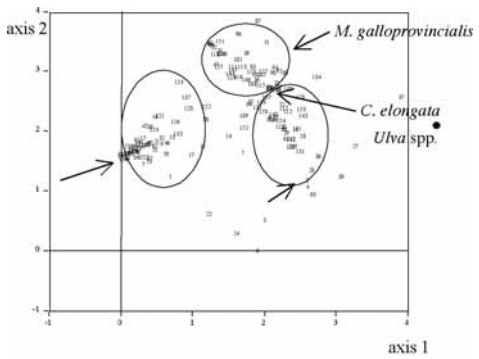

Fig. 2 : Ordination of samples and main species in the plane defined by the first two axes obtained from a DCA including the 152 samples studied in 1999.

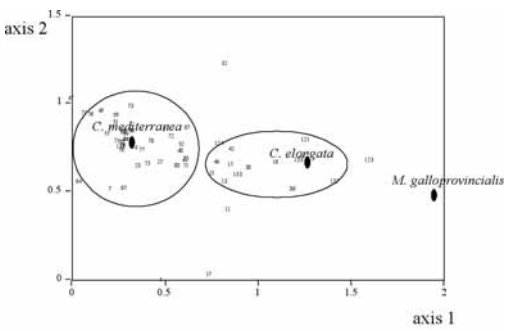

Fig. 3 : Ordination of samples and main species in the plane defined by the first two axes obtained from a DCA including only the samples of the Cystoseira mediterranea group displayed in Fig. 2.

A new DCA has been performed with samples included in the "*Cystoseira*" group. Two subgroups can be distinguished (Figure 3) according to the relative abundance of *Cystoseira mediterranea*, *Corallina elongata* and Mytilus galloprovincialis. The first group includes dense stands of *Cystoseira mediterranea*, whilst the second group includes partially degraded communities still dominated by this species, but with a significant coverage of *Corallina elongata* and *Mytilus galloprovincialis*. The first two axes explain 31.7 % of the total variance of the data (23 % and 8,7%, axis 1 and 2, respectively).

Biological and chemical variables show positive and significative correlations ($p<0.05$) with first axis for nitrites ($r=0,316$), ammonium ($r=0,347$), phosphates ($r=0,301$), and phecal streptococci ($r=0,354$), and negative correlations ($r=-0,337$; $p<0.05$) for the distance to the closest city. No significative relationships are observed for the second axis.

The short-term temporal variability was analyzed comparing the data obtained in 1999 and 2000. 50 stations sampled in 1999 were sampled again in 2000. The distribution of samples along the axes 1 and 2 represents 34,7 % of the variability in the data set. Our results show that the 75 % of stations did not change the species composition and the dominance of species. A high degree of coincidence between two successive assessments is observed.

The long-term temporal variability was analyzed comparing present data with data obtained in 1982. We have included also samples obtained in the reference zones in the analysis. The first two axes explain 11,9% of the total variability (Fig. 4). Most of the stations from 1982 are placed far away from the *Cystoseira mediterranea* sites, and close to the sites dominated by green algae. Therefore, the number of stations with indicators of eutrophication decreases from 1982 to 2000. Communities of *C. mediterranea* or *C. amentocea* var. *stricta* (depends on the site) are representative of the reference zones and, thus, these communities indicate the highest environmental quality.

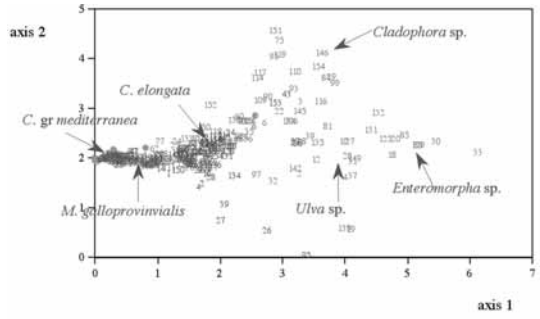

Fig. 4. Ordination of samples and main species in the plane defined by the first two axes obtained from a DCA including the samples studied in 1982 (89 stations), in 1999 (152), in 2000 (50), and in the reference zones (11). 1982 is represented in green, 1999 in blue, 2000 in red, and reference stations with orange circles.

DISCUSSION

We propose 5 categories of communities as indicators of the environmental quality of the littoral waters (high quality=category 1, and low quality=category 5): (1) Very abundant *Cystoseira mediterranea*: communities with total dominance of *C. mediterranea*. Stations grouped with values between 0 and 0,5 for the first axis in Figure 3; (2) *Cystoseira mediterranea*: other species, such as *Corallina elongata* and *Mytilus galloprovincialis*, are also present and sometimes abundant. It corresponds with the rest of stations in the Figure 3; (3) *Corallina* or *Mytilus*: communities where *Corallina elongata* and *Mytilus galloprovincialis* are the most abundant species. It corresponds with stations with values higher than 1 for axes 1 and 2 in the Figure 2; (4) *Lithophyllum* incrustans: communities with total dominance of L. incrustans. It corresponds with stations separated in Figure 2; and (5) Green algae: communities where *Ulva* spp., *Cladophora* spp. are the dominant.

This category includes stations situated close to the situation of these species in the Figure 2. The geographical representation of the 152 sites sampled in 1999 according to these 5 categories of environmental quality is represented in Fig. 5.

In view of these results, it can be concluded that littoral benthic communities are good indicators of environmental quality and can be used in water quality assessments. The changes in the specific composition and dominance of the communities are signs of alteration. Species with high quality environmental requirements, such as *Cystoseira mediterranea*, disappear from disturbed sites. But it is the presence of *C. mediterranea* the most indicative sign of good ecological status of littoral waters. In contrast, green algae can be considered as indicators of pollution and indicate bad ecological status. Species of the genus *Cystoseira*, being perennial plants, integrate environmental changes over a long period of time. Thus, community replacements and changes in the abundance of the main species can be used to monitor long-term changes.

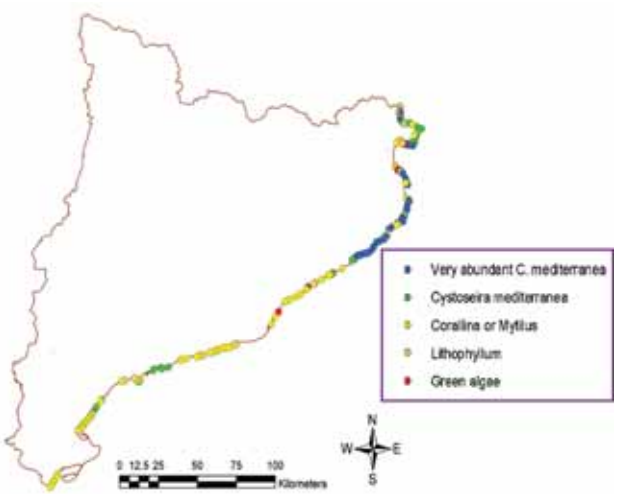

Fig 5. Geographical representation of the 152 sites sampled in 1999 according to the 5 categories of environmental quality defined in the text.

In the last 20 years it seems to be an improvement of the environmental quality along the Catalan coast as the number of stations with species indicators of eutrophication has decreased from 1982. Although there is not a recovery of *Cystoseira mediterranea*, the proliferation of green algae has decreased. This could be related to the implementation of a new system of sewage discharges from urban areas and the industry since 1980's.

In conclusion, littoral benthic communities, (1) show a geographic gradient along the catalan coast in relation to the degree of disturbance, (2) could be good indicators of the environmental quality, and (3) could be used in a monitoring program to study the water quality.

ACKNOWLEDGEMENTS

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REFERENCES

Ballesteros E. (1992) - Els vegetals i la zonació litoral: espècies, comunitats i factors que influeixen la seva distribució. Arxius de la Secció de Ciències CI., Institut d'Estudis Catalans, Barcelona : 616 pp.

Ballesteros E., Pérez M. and Zabala M. (1984) - Aproximación al conocimiento de las comunidades algales de la zona infralitoral superior en la costa catalana. Collect. Bot., 15 : 69-100.

Bellan-Santini D. (1968) - Influence de la pollution sur les peuplements benthiques. Rev. Intern. Oceanogr. Med., 10 : 27-53.

Borowitzka M.A. (1972) - Intertidal algal species diversity and the effect of pollution. Aust. J. Mar. Fresh. Res., 23 : 73-84.

Feldmann J. (1937) - Recherches sur la végétation marine de la Méditerranée. La côte des Albères. Rev. Algol., 10 : 73-254.

Golubic S. (1970) - Effect of organic pollution on benthic communities. Mar. Poll. Bull., 1: 56-57.

Levine H.G. (1984) - The use of seaweeds for monitoring coastal waters. In: Algae as ecological indicators, L. E. Shubert (ed.), Academic Press, London : 189-210.

Pearson T.H. and Rosenberg R. (1978) - Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Ocean. Mar. Biol. Ann. Rev., 16 : 229-311.

Soltan D., Verlaque M., Boudouresque C.H. and Francour P. (2001) - Changes in macroalgal communities in the vicinity of the mediterranean sewage outfall after the setting up of a treatment plant. Mar. Poll. Bull., 42 : 59-70.

Ter Braak C.J.F. (1988) - CANOCO – a FORTRAN program for canonical community ordination by (partial) (detrended) (canonical) correspondence analysis (version 2.1), T.N.O. Institute of Applied Computer Science, Wageningen.