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Rocky-shore communities as indicators of water quality: A case study in the Northwestern Mediterranean

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Abstract

The collection of 152 samples from the upper sublittoral zone along the rocky coasts of Catalonia (Northwestern Mediterranean) was carried out in 1999 in order to test the suitability of littoral communities to be used as indicators of water quality in the frame of the European Water Framework Directive. Detrended correspondence analysis were performed to distinguish between different communities and to relate communities composition to water quality. Samples collected in reference sites were included in the analysis. Mediterranean rocky shore communities situated in the upper sublittoral zone can be used as indicators of the water quality: there is a gradient from high to bad status that comprises from dense *Cystoseira mediterranea* forests to green algae dominated communities. The geographical patterns in the distribution of these communities show that the best areas are situated in the Northern coast, where tourism is the main economic resource of the area, and the worst area is situated close to the metropolitan zone of Barcelona with high population and industrial development. Thus, Mediterranean sublittoral rocky shore communities are useful indicators of water quality and multivariate analysis are a suitable statistical tool for the assessment of the ecological status.

Keywords: Bioindicators; Quality assessment; Ecological status; Macroalgal communities; Water framework directive; Mediterranean sea

1. Introduction

Studies of benthic communities show great potential for revealing the cumulative effects of disturbances on marine biota as benthic organisms can integrate the effects of long-term exposure to natural and anthropogenic disturbances (Borowitzka, 1972). Use of benthic communities in marine pollution assessments are 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 (Reish, 1987). Upper sublittoral communities thriving in rocky shores are more affected than other benthic communities to urban and industrial effluents (Bellan and Bellan-Santini, 1972) because freshwater and pollutants flow in the sea surface (Soltan et al., 2001). Therefore, the study of these communities has been considered useful in order to analyze changes in the water quality (Fairweather, 1990). In fact, macroalgae, the dominant group of organisms thriving in rocky shores, is one of the key biological elements to be considered in the determination of the ecological quality status of any given coastal water body in the framework of the European *Water Framework Directive* (WFD; 2000/60/EC). Benthic macrophytes are known to be good indicators of the water quality (Borowitzka, 1972; Munda, 1974; Littler and Murray, 1975; Murray and Littler, 1978; Belsher, 1979; Levine, 1984; Kautsky et al., 1986; Phillips, 1994; Perez et al., 2000). Implementation of the WFD needs the development of new methodologies aimed at assessing and classifying

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coastal water bodies in different ecological status which requires knowledge about how macroalgae and upper sublittoral communities respond to anthropogenic impacts.

It has been pointed out that due to the strong association between macroalgal assemblages and environmental factors, the monitoring efforts should be directed towards perennial species (such as algae of the Order Fucales) with a world wide distribution (Eriksson and Bergström, 2005). Studies on the effect of sewage outfall and pollution on macroalgae reveal the sensitivity of some brown perennial species to this kind of disturbance (Bellan-Santini, 1965, 1968; Golubic, 1970; Verlaque and Tine, 1979; Belsher, 1979; Ballesteros et al., 1984; Giaccone, 1991; Janssen et al., 1993; Soltan et al., 2001). Discharge from sewage treatment and industrial plants during several years often produce a change from perennial, stable benthic algae communities to more stress-tolerant and opportunistic species (Chryssovergis and Panayotidis, 1995; Bokn et al., 1996; Díez et al., 1999; Middelboe and Sand-Jensen, 2000).

Species of the genus *Cystoseira* (Fucales, Cystoseiraceae) dominate Mediterranean upper sublittoral communities (Feldmann, 1937; Boudouresque, 1971) and are particularly sensitive to any natural (Gros, 1978; Verlaque, 1987) or anthropogenic stress (Bellan-Santini, 1966; Ballesteros et al., 1984; Hoffmann et al., 1988; Soltan et al., 2001) and, therefore, have experienced profound changes and decline over extensive areas (Thibaut et al., 2005). The highly structured and productive *Cystoseira mediterranea* community is observed in hydrodynamic environments and non-polluted waters along the Northwestern Mediterranean coasts (Boudouresque, 1969; Ballesteros, 1988). Increasing concentrations of organic matter and nutrients drives *Cystoseira*-dominated communities to be replaced by the red alga *Corallina elongata* (Bellan-Santini, 1965, 1968; Ballesteros et al., 1984; Giaccone, 1993) and the mussel *Mytilus galloprovincialis* (Bellan-Santini, 1965, 1968; Bellan and Bellan-Santini, 1972). Green ephemeral algae begin to dominate in highly disturbed environments and near freshwater discharges: *Ulva* (Golubic, 1970; Bellan and Bellan-Santini, 1972; Rodríguez-Prieto and Polo, 1996), *Cladophora* (Belsher, 1977) or *Enteromorpha* (Ballesteros et al., 1984; Kadari-Meziane, 1994). Finally, the dominance of blue-green algae (*Oscillatoria*, *Lyngbya*, *Phormidium*) indicates very degraded environments (Golubic, 1970; Littler and Murray, 1975; Murray and Littler, 1978).

The Catalan coast, in the Northwestern Mediterranean (Fig. 1), is a densely populated area, with sections of the coast affected by high urban and industrial development and coastal modification, but also with other sections devoted to agriculture and tourist development (Table 1; <www.creaf.uab.es>; <www.gencat.net>). All these uses are known to produce changes in environmental conditions affecting the development of rocky shore benthic communi-

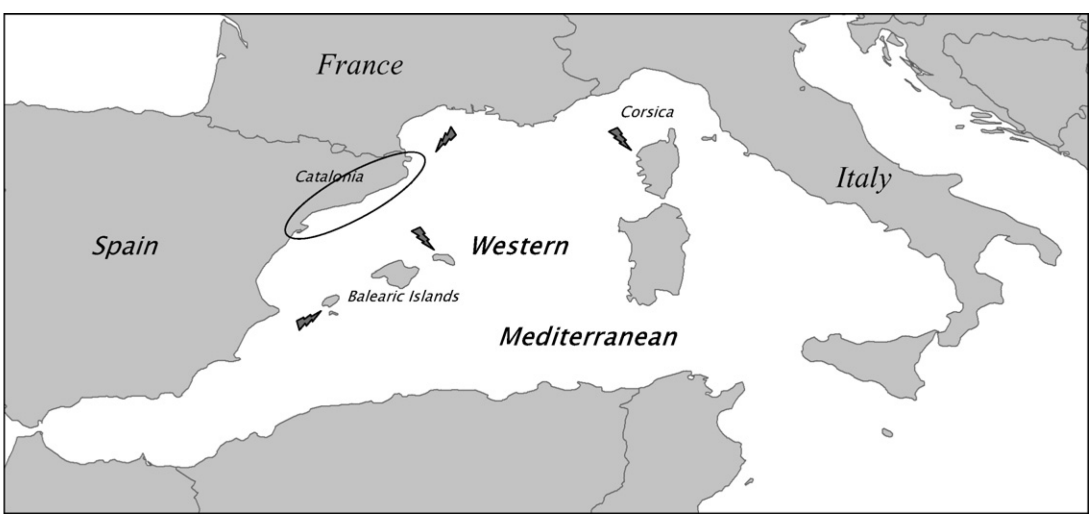

Fig. 1. Location of study area and sites (Northwestern Mediterranean Sea). Reference zones are included in the map.

Table 1
Land uses in Catalonia

	Tourism	Agriculture	Urban development	Forestal	Industrial-1	Industrial-2
Girona	502,622	22,512	9132	39,865	0	0
Barcelona	339,701	12,506	28,574	28,870	109	247
Tarragona	491,221	59,794	12,691	30,380	310	1710

Tourism is expressed in number of available sites in hotels, campings, rural tourism and second homes. Agriculture, urban development and forestal land are expressed in ha. Industrial charge is separated in biodegradable (Industrial-1, DQO; kg dia^{-1} km^{-1}) and non-biodegradable (Industrial-2, m^3 dia^{-1} km^{-1}) sewage. Data from 2004.

ties (Benedetti-Cecchi et al., 2001; Thibaut et al., 2005); moreover, previous studies already detected the existence of different dominant littoral benthic communities along the coast (Ballesteros et al., 1984). Thus, the highly patchy coast of Catalonia – regarding different land uses – can be used as an excellent case study to test the use of littoral benthic communities as indicators of environmental and water quality.

Here we analyze 152 samples from the upper sublittoral communities on rocky shores distributed along the Catalan coast with standard multivariate methods in order (i) to find out the agreement between previous knowledge on indicator species and communities distribution from an heterogeneous coast, (ii) to establish the relationships between community structure and environmental, biological and chemical variables and (iii) to try to classify the coast on different sectors of water quality based on the composition of rocky shore communities in accordance with the five categories of water quality of the WFD. This study also provides an observational basis for future monitoring.

2. Material and methods

The study was carried out on the Catalan coast (Spain, Northwestern Mediterranean), which extends for 400 lineal km (Fig. 1) in three provinces (Girona—north, Barcelona—central and, Tarragona—south). One hundred and fifty two stations were sampled in May–June 1999 coinciding with the time of peak growth of littoral communities (Ballesteros, 1992). Sampling stations were located in zones exposed to surf.

One sample per station was collected in the upper sublittoral zone on gently slopping rocks facing east, south or west. For each sample, the whole community was collected from a 15 × 15 cm surface, using a hammer and a chisel. This surface is large enough to quantitatively represent littoral communities in the Northwestern Mediterranean (Coppejans, 1980; Verlaque, 1987; Ballesteros, 1992). Samples were preserved in formaline:sea-water at 4% and subsequently sorted in the laboratory. Algae and invertebrates were identified to species level and quantified in terms of coverage (horizontal surface; Ballesteros, 1992).

Data sets were analyzed with CANOCO software (ter Braak, 1988). A preliminary detrended correspondence analysis (following recommendations by ter Braak and Šmilauer, 1998) indicated a unimodal response of species variance. DCAs were used to show affinities and differences between species and sites to avoid the arc-shaped distribution of the samples when there is a single strong gradient affecting the samples (Gauch, 1982). Species appearing in less than 2% of the samples were not included in the analysis.

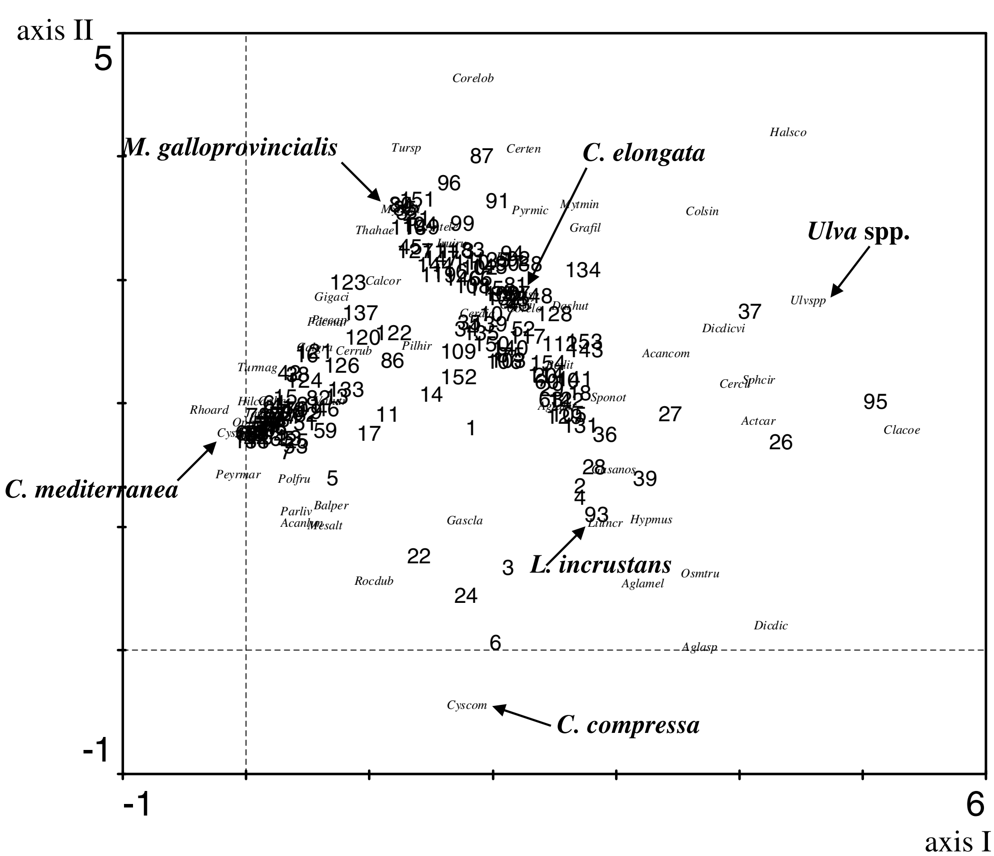

Fig. 2. Detrended correspondence analysis (DCA) ordination plot showing the distribution of samples and species for the coverage data of 152 stations in 1999. Abbreviations of species names are in Table 3. Complete names of the main species are included in the ordination.

Several environmental factors were considered to interpret the community patterns observed with DCAs: degree of coast exposure, type and nature of the sampled substrate, orientation of the sampled site, distance to the closest city (city distance) and, distance to the sewage outfall (sewage distance) from the sampled site. Biological and chemical variables in seawater were also considered: nitrates, nitrites, ammonium, phosphates, silicates, total and faecal coliforms and faecal streptococci (1994–1999 average data). The contribution of the environmental, biological and chemical variables to total explained species-sites variance obtained in the DCA was analyzed by Pearson correlations using environmental variables and values of the stations in the ordination axes 1 and 2 in the multivariate analysis. Neither the environmental nor the taxa data were transformed for the analysis.

In order to comply with the requirements of the Water Framework Directive, it is necessary to define a very high ecological status where communities have no or only very minor disturbance from human activities (reference conditions). The WFD identifies four options to obtain reference conditions: (1) an existing undisturbed site or a site with only very minor disturbance, (2) historical data and information, (3) models, and (4) expert judgment (Annex II, Vincent et al., 2002). A problem in deriving reference conditions in the Catalan coast is the absence of unimpacted areas. Therefore, we have chosen three reference zones outside Catalonia: Façade maritime du Parc Naturel Régional de Corse (France), Parc Natural de Ses Salines (Balearic Islands, Spain) and Reserva Marina del Nord de Menorca (Balearic Islands, Spain) (Fig. 1). All these places have in common a very low human influence with physico-chemical and hydrogeomorphological conditions very similar to the Catalan coast. We have also historical data for benthic communities in the Catalan coast before 1980's (Gibert, 1918; Seoane-Camba, 1975; Polo, 1978) and in the adjacent Albères coast (Sauvageau, 1912; Feldmann, 1937; Gros, 1978; Thibaut et al., 2005) showing that previous littoral vegetation in the Catalan coast was very similar to that currently observed in the selected reference areas. Sampling in reference zones was performed in May–June 2001 with the same methodology used to collect samples in 1999. We sampled 11 stations into reference sites (4 in Corse, 4 in Menorca and 3 in Ses Salines).

3. Results

Results from the DCA analysis for coverage values of 152 samples in 1999 are represented in Fig. 2. Samples are distributed along the plane defined by the two first axes. Axes I and II account for 22.2% of the total variance of the data set (13.3% and 8.9%, for axes I and II, respectively). On the first axis, samples dominated by *C. mediterranea*, situated close to the ordination axis, are opposed to samples dominated by green algae (*Ulva* spp.). A big central group is represented by samples with *M. galloprovincialis*, *C. elongata* and *Lithophyllum incrustans* that are situated with values between 1 to 3 for the axis I. The second axis discriminates samples in this big group in relation to the abundance of the main species. Also, there are some samples situated at very low values for the second axis that are characterized by the dominance of *Cystoseira compressa*.

In order to look for differences between samples at shorter environmental scale the two main groups (one defined by *C. mediterranea* and the other defined by *M. galloprovincialis*, *C. elongata* and *L. incrustans*) have each been subjected to another DCA analysis. We have rerun the analysis considering all the stations and species for each group in each analysis. In the *C. mediterranea* group it is possible to distinguish between two subgroups according to the relative abundance of the dominant species (Fig. 3). Axis I and II account for 31.7% of variance (23% and 8.7%, respectively). Samples with high abundances of *C. mediterranea* are situated at values lower than 1 for the axis I. Species such as *Hildenbrandia canariensis*, *Peyssonnelia rosa-marina*, *Mesophyllum alternans*, *Aglaozonia melanoidea* or *Valonia utricularis* (close to *C. mediterranea* position in the ordination) cover the basal layer of the community. *Polysiphonia fruticulosa* and *Jania rubens* are

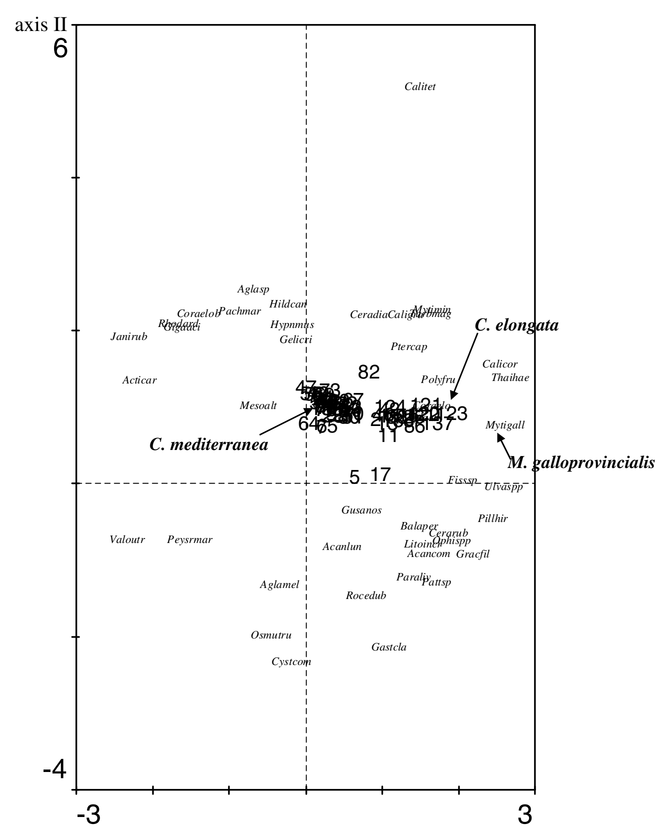

Fig. 3. Detrended correspondence analysis (DCA) ordination plot showing the distribution of samples and species for the coverage data of *Cystoseira mediterranea* group from Fig. 2. Abbreviations of species names are in Table 3. Complete names of the main species are included in the ordination.

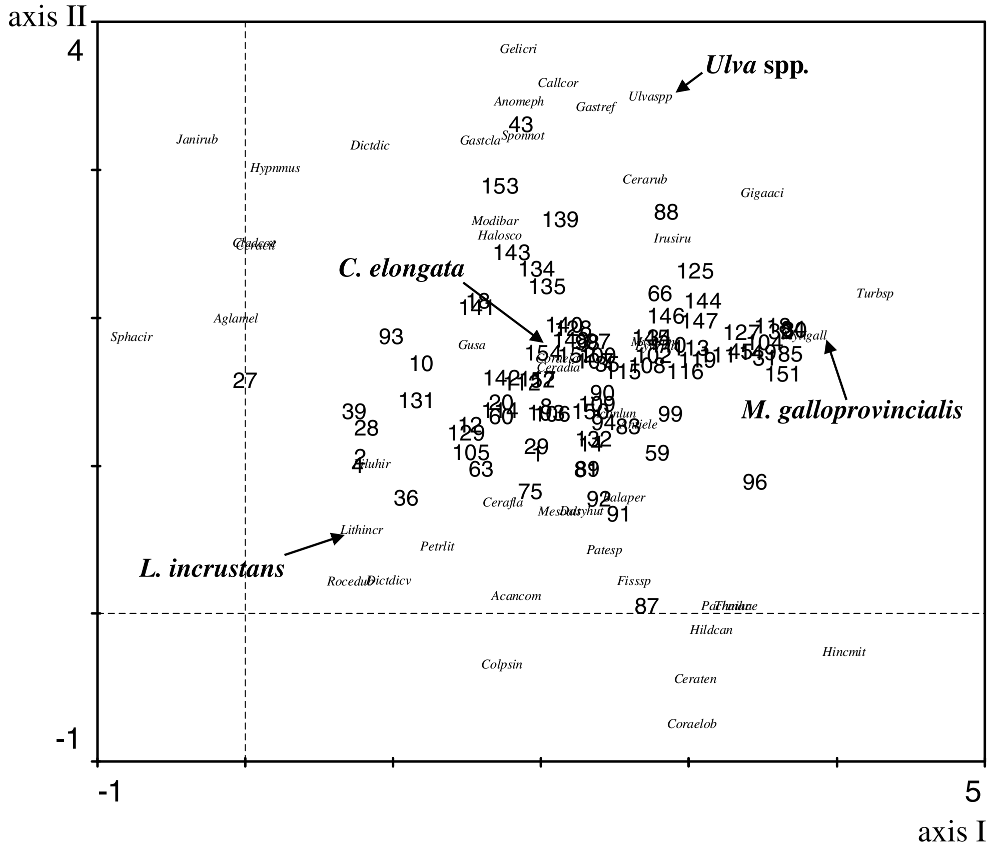

Fig. 4. Detrended correspondence analysis (DCA) ordination plot showing the distribution of samples and species for the coverage data of *Mytillus–Corallina–Lithophyllum* group in the Fig. 2. Abbreviations of species names are in Table 3. Complete names of the main species are included in the ordination.

very common as epiphytes of *C. mediterranea*. Samples with low abundances of *C. mediterranea* are situated at values higher than 1 for the axis I; in fact, they represent partially degraded *C. mediterranea* communities where turfs of *C. elongata* and carpets of *M. galloprovincialis* are already common inside the community. The second axis does not discriminate between stations.

The new DCA performed for the second group (with *C. elongata*, *M. galloprovincialis* and *L. incrustans*) summarizes the 19.4% of the variance in the two first axes (11.1% for axis I and 8.3% for axis II) (Fig. 4). Ordination of samples does not bring forward additional information than that already presented in Fig. 2. The analysis discriminates among stations dominated by *L. incrustans* (low values for axis I), *C. elongata* (intermediate values in the axis I), and *M. galloprovincialis* (highest values for axis I).

Significant correlations between environmental, biological and chemical variables and ordination of samples in the first factor in the analysis of Fig. 2 are displayed in Table 2. Only variables with significative correlations are included in the table. There is a positive relationship between axis I and the biological and chemical variables considered, whilst a negative relationship is obtained between axis I and the city distance. Therefore, axis I can be interpreted as a gradient of environmental quality. In order to comply with the requirements of the Water Framework Directive regarding the classification of localities according to its environmental quality, 11 samples from the reference zones (reference conditions) collected in 2001 are included in a new DCA analysis. Littoral communities in these reference zones are dominated either by *C. mediterranea* or by the

Table 2
Intra-set correlations between environmental, biological, and chemical variables and ordination axis I sorted by the DCA analysis (coverage values)

	Axis I
Environmental variables	
City distance	−0.321***
Chemical variables	
Nitrites	0.299**
Ammonium	0.305**
Phosphates	0.316**
Biological variables	
Total coliform bacteria	0.331***
Phecal coliform bacteria	0.328***
Phecal streptococcus	0.338***

Only variables with significative correlations are included in the table.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

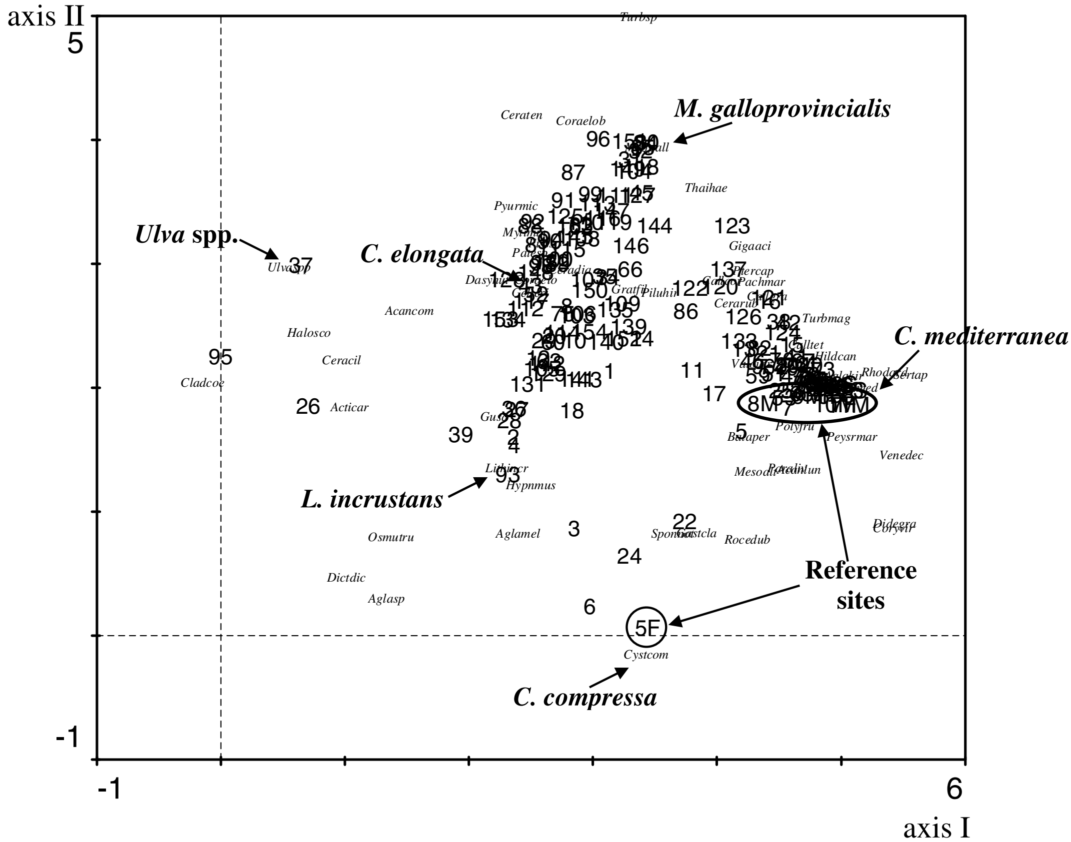

Fig. 5. Detrended correspondence analysis (DCA) ordination plot showing the distribution of samples and species for the coverage data for the Catalan coast and the reference zones. Abbreviations of species names are in Table 3. Complete names of the main species are included in the ordination.

closely related species *Cystoseira amentacea* var. *stricta* (both taxa merged in the DCA analysis). The resulting DCA analysis is showed in Fig. 5. The two first axes account for 23.8% of the total variance of the data. Ordination of the samples is very similar to that displayed in Fig. 2, although in this ordination *C. mediterranea*-dominated communities display high values for axis I and *Ulva*-dominated communities show low values in this axis. Most samples from reference sites are situated together in the plane defined by the first two factorial axes, close to the lower end of the group defined by *C. mediterranea* (see, Fig. 5). Only sample 5F collected in Formentera is far away from the other reference sites as *C. compressa* is the dominant species in this sample.

4. Discussion

The application of Detrended correspondence analysis (DCA) to large-data sets of samples collected in the littoral zone on rocky shores from Catalonia allows the distinction of groups of stations dominated by different communities such as brown algae of the order Fucales, corallines, mussels and green algae.

The results provided in this study show a clear gradient from *Cystoseira*-dominated communities to *Ulva*-dominated communities, with other intermediate stations dominated by corallines such as *C. elongata* or *L. incrustans* or suspension-feeders like mussels (*M. galloprovincialis*). Both the inclusion in the analysis of reference sites data and the correlation between the first axis of the DCA and the variables indicating high anthropogenic impact (e.g., dissolved nutrients in seawater, coliform bacteria, and city distance) relate the first axis of the DCA to the water quality of the sampled sites. Thus, *C. mediterranea* communities grow in pristine environments, far away from big cities and with low nutrient concentrations in seawater, and are opposed to communities of green algae, which are good indicators of high nutrient levels or high disturbances. Díez et al. (2003) already revealed negative relationships between perennial algae and pollution in subtidal communities using canonical correspondence analysis. Communities dominated by *C. elongata* and *M. galloprovincialis* are considered here to be indicators of intermediate quality, while the dominance of *L. incrustans* seems to be related to disturbed environments. Calcareous red and encrusting brown algae are considered to be especially resistant to disturbances (Feldmann, 1937; Cormaci and Furnari, 1991; Rodríguez-Prieto and Polo, 1996).

Our results support previous works (Borowitzka, 1972; Munda, 1974; Littler and Murray, 1975; Murray and Littler, 1978; Belsher, 1979; Levine, 1984; Kautsky et al., 1986; Phillips, 1994; Perez et al., 2000) showing that littoral

Table 3
Abbreviations of species represented in Figs. 2–5

Acancom	*Acanthochitona communis*	Halosco	*Halopteris scoparia*
Acanlun	*Acanthonyx lunulatus*	Hildcan	*Hildenbrandia canariensis*
Acticar	*Actinia cari*	Hypnmus	*Hypnea musciformis*
Aglakir	*Aglaophenia kirchenpaueri*	Irusiru	*Irus irus*
Aglamel	*Aglaozonia melanoidea*	Janirub	*Jania rubens*
Aglasp	*Aglaozonia* sp.	Lithincr	*Lithophyllum incrustans*
Antiele	*Antithamnionella elegans*	Mesoalt	*Mesophyllum alternans*
Balaper	*Balanus perforatus*	Mytimin	*Mytilaster minimus*
Callcor	*Callithamnion corymbosum*	Mytigall	*Mytilus galloprovincialis*
Callgra	*Callithamnion granulatum*	Ophispp	Ophiuroidea spp.
Calltet	*Callithamnion tetragonum*	Osmutru	*Osmundea truncata*
Ceracil	*Ceramium ciliatum*	Pachmar	*Pachygrapsus marmoratus*
Ceradia	*Ceramium diaphanum*	Paraliv	*Paracentrotus lividus*
Cerarub	*Ceramium rubrum*	Patesp	*Patella* sp.
Ceraten	*Ceramium tenerrimum*	Petrlit	*Petricola lithophaga*
Cladcoe	*Cladophora coelothrix*	Peysrmar	*Peyssonnelia rosa-marina*
Colpsin	*Colpomenia sinuosa*	Piluhir	*Pilumnus hirtellus*
Coraelo	*Corallina elongata*	Polyfru	*Polysiphonia fruticulosa*
Coraelob	*Corallina elongata* (bases)	Ptercap	*Pterocladia capillacea*
Cystcom	*Cystoseira compressa*	Pyurmic	*Pyura microcosmus*
Cystmed	*Cystoseira mediterranea*	Rhodard	*Rhodymenia ardissonei*
Dasyhut	*Dasya hutchinsiae*	Rocedub	*Rocellaria dubia*
Dictdic	*Dictyota dichotoma*	Sphacir	*Sphacelaria cirrosa*
Dictdicvi	*Dictyota dichotoma* var. *intricata*	Sponnot	*Spongites notarisii*
Fisssp	*Fissurella* sp.	Thaihae	*Thais haemostoma*
Gastcla	*Gastroclonium clavatum*	Turbsp	Turbellaria sp.
Gelicri	*Gelidium crinale-pusillum*	Turbmag	*Turbicellapora magnicostata*
Gigaaci	*Gigartina acicularis*	Ulvaspp	*Ulva* spp.
Gratfil	*Grateloupia filicina*	Valoutr	*Valonia utricularis*
Gusa	Polychaeta		

benthic communities are good indicators of environmental quality and they can be used in water quality assessments. In particular, *C. mediterranea* seems to be very sensitive to the environmental quality of the water as it decreases its abundance or even completely disappears at increasing pollution levels. In fact, not only *C. mediterranea* (Ballesteros et al., 1984; Rodríguez-Prieto and Polo, 1996) but most species of the genus *Cystoseira* (with the exception of *Cystoseira compressa*) show symptoms of regression when pollution increases (Arnoux and Bellan-Santini, 1972; Bellan and Bellan-Santini, 1972; Munda, 1974, 1980; Giaccone and Rizzi-Longo, 1974; Chryssovergis and Panayotidis, 1995; Hoffmann et al., 1988; Benedetti-Cecchi et al., 2001; Soltan et al., 2001; Thibaut et al., 2005). The replacement of *Cystoseira*-dominated communities by mussel beds or *C. elongata* turfs has been already described in several Mediterranean shores affected by urban and industrial pollution (Bellan and Bellan-Santini, 1972; Gros, 1978; Ballesteros et al., 1984; Soltan et al., 2001; Benedetti-Cecchi et al., 2001). These mats of algal turfs or mussel beds that colonize the substratum after the demise of Fucales inhibit the recruitment and prevent the reinstallation of *Cystoseira* species (Huvé, 1960; Gros, 1978; Benedetti-Cecchi and Cinelli, 1996) probably hindering the restoration of *Cystoseira* populations even after the disappearance of the disturbance effects that caused its regression (Soltan et al., 2001; Thibaut et al., 2005). Positive relationships between the abundance of Ulvales and coastal water sewage is extensively reported in the literature (e.g., Tewari and Joshi, 1988; Desrosiers et al., 1990; Munda, 1993; Chryssovergis and Panayotidis, 1995; Díez et al., 1999), and Levine and Wilce (1980) and Ho (1987) already suggested the possibility of using these algae as bioindicators of coastal water quality. Therefore, the gradient of communities observed in the Catalan shores that comprises dense *Cystoseira* forests, *Cystoseira* populations with coralline turfs and mussels, *C. elongata* and mussel beds, *L. incrustans* barrens, and green algae stands (*Ulva* spp.) is unequivocally related to water quality as showed by our analysis and it can probably be extrapolated to other Northwestern Mediterranean areas as it is supported by the available literature.

In a first attempt of making an assessment of the coastal water quality using upper sublittoral communities as bioindicators in the rocky shores in Catalonia we have taken the outputs of our results and assigned each type of community to an ecological status using five categories as stated by the Water Framework Directive. The five communities/categories are:

(1) Well developed forests of *C. mediterranea* with a dense canopy that allows the growth of sciaphilic algae in the basal layer of the community. Samples are grouped with values between 0 and 0.7 for the first axis in Fig. 3. It would correspond to places with a high ecological status according to the nomenclature of the WFD.

(2) *C. mediterranea* forests with *C. elongata* and *M. galloprovincialis* very abundant below the *Cystoseira* canopy. Samples are grouped with values in the first axis above 0.7 in Fig. 3. It would correspond to places with a good ecological status according to the nomenclature of the WFD.
(3) *C. elongata* turfs or mussel beds. Samples are grouped with values in the first axis above 1.6 in Fig. 4. It would correspond to places with a moderate ecological status according to the nomenclature of the WFD.
(4) Barren areas dominated by the encrusting coralline *L. incrustans*. Samples are clearly separated in Fig. 4. It would correspond to places with a poor ecological status according to the nomenclature of the WFD.
(5) Communities dominated by green algae, mainly *Ulva* spp. Samples are situated close to *Ulva* spp. in Fig. 2. It would correspond to places with a bad ecological status according to the nomenclature of the WFD.

We have also plotted these communities/categories in a map of Catalonia (Fig. 6) to look for geographical patterns and relate these emerging patterns to large-scale occupation and use of the coast and to the anthropogenic impacts on the adjacent coastal area. The Northern coast (Girona) shows a dominance of *Cystoseira* forests; this area holds the lowest population of the Catalan coast (170,000 inhabitants in year 1999; <www.gencat.net>), with almost nil industrial development, high agriculture use and many tourist villages and resorts (Table 1). Most of the stations from the middle part of Catalonia (Barcelona) and the southern part (Tarragona) are mostly dominated by turf-forming algae (*C. elongata*) and the mussel *M. galloprovincialis*. The Barcelona coastal area had a population of more than 2,000,000 inhabitants in 1999 while Tarragona had around 830,000. Barcelona is also a very important industrial area with high urban development. Moreover, approximately 78% of the rocky littoral consists of artificial structures (author's unpublished data) which unquestionably contribute to the moderate and poor ecological status of the stations as artificial substrata usually has distinct communities to those found in nearby rocky shores (Chapman and Bulleri, 2003; Bulleri, 2005). The lowest percentage of high to good status stations observed in Tarragona than in Girona can be explained by a high industrial development and chemical pollution coming from the herbicides and pesticides used to treat the agricultural crops very abundant in this area (Table 1).

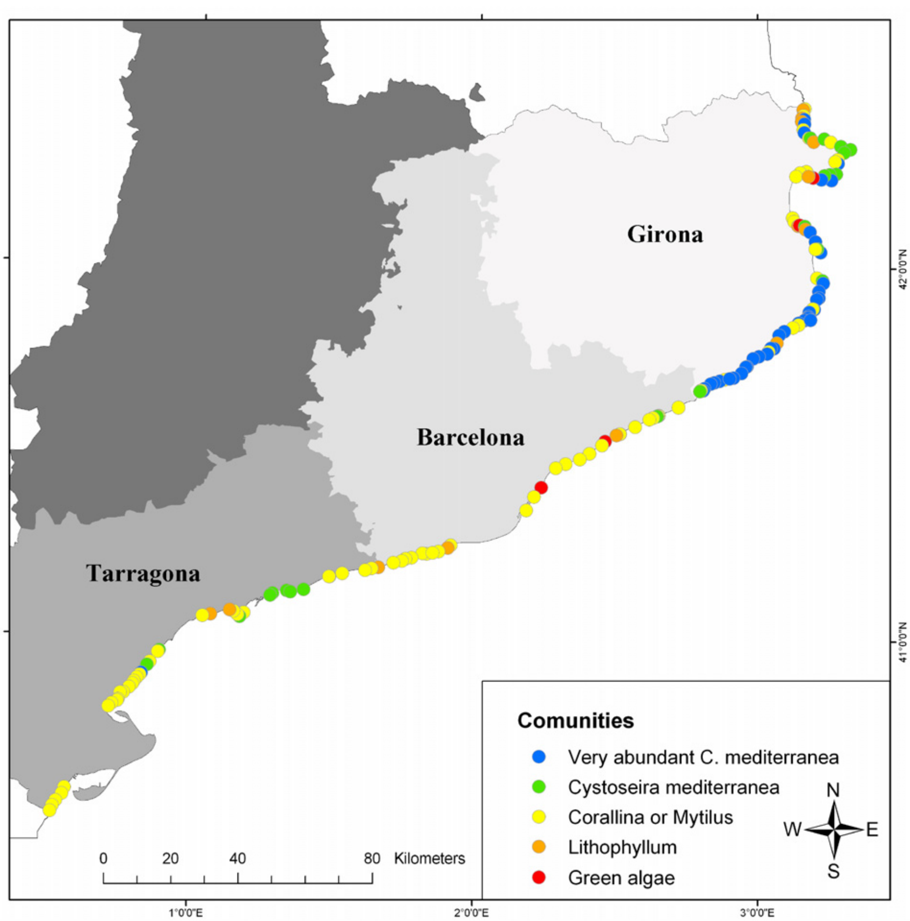

Fig. 6. Geographical distribution of the assigned community/categories of environmental quality for each sampling site along the Catalan coast. Each community/category is defined in the text.

In view of the results presented in this study we conclude that upper sublittoral Mediterranean rocky shore communities can be used as indicators of the water quality following a gradient from high status in places with dense *Cystoseira* forests to bad status in sites dominated by *Ulva* spp. and other green algae. The observed indicator communities show geographic differences in environmental quality along the Catalan coast, with the worst areas situated close to the metropolitan zone of Barcelona and the best areas related to low industrial development and non-extensive agriculture use. Finally, multivariate methods are a good statistical tool to be applied to large-data sets for the assessment of the water quality of sites sampled in extensive monitoring programmes.

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