Sub-Littoral Algal Communities

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Abstract
A great storm affected the Catalan coast during the 26th December 2008 damaging a number of infrastructures and the seabed. Althought the exposed upper sub-littoral communities are adapted to natural strong hydrodynamic conditions, the extreme storm of 2008 was considered an exceptional event with potential desctructive effects on natural communities. With the aim to assessing the effect of this storm on those communities a detailed cartography along a 2-km stretch of the Catalan coastline was surveyed. This stretch had been thoroughly studied in 2004; the same study was repeated in spring 2009. The results showed very little difference between both samplings indicating that the upper sub-littoral communities were not significantly affected by the storm.

Image: Sub-littoral algal communities of the Costa Brava, by Miguel A. Mateo

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Changes in the sub-littoral algal communities after the storm of Sant Esteve 2008

By

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Resumen

Un fuerte temporal azotó la costa catalana el 26 de Diciembre de 2008. La fuerza del temporal provocó fuertes destrozos en estructuras artificiales como puertos y espigones y sus efectos se pudieron registrar hasta profundidades considerables. A pesar de que las comunidades que se desarrollan en el infralitoral superior en lugares expuestos están adaptadas de forma natural a niveles de hidrodinamismo elevados, la fuerza del temporal fue excepcional. Para evaluar tal efecto, durante la primavera de 2009 se realizó una cartografía bionómica exhaustiva de un tramo de costa de 2 km de costa que ya había sido cartografiado en 2004. La comparación de los dos muestreos no muestra grandes diferencias, sugiriendo que las comunidades litorales no fueron afectadas significativamente por este temporal.

Abstract

A great storm affected the Catalan coast during the 26th December 2008 damaging a number of infrastructures and the seabed. Although the exposed upper sub-littoral communities are adapted to natural strong hydrodynamic conditions, the extreme storm of 2008 was considered an exceptional event with potential destructive effects on natural communities. With the aim to assessing the effect of this storm on those communities a detailed cartography along a 2-km stretch of the Catalan coastline was surveyed. This stretch had been thoroughly studied in 2004; the same study was repeated in spring 2009. The results showed very little difference between both samplings indicating that the upper sub-littoral communities were not significantly affected by the storm.

Introduction

A monitoring project with the objective of assessing the coastal water quality through biological indicators according to the Water Framework Directive (WFD, 2000/60/EC) has been carried out since 2000 to the present. The CARLIT methodology (Ballesteros et al. 2007), based on cartography of upper sublittoral benthic communities, is an accurate indicator of water quality. The benthic communities not only reflect water conditions at the time of sampling but also conditions to which the communities have been previously exposed (Reish, 1987). The effects of anthropogenic and also natural disturbances are accumulative and the communities integrate all of these (Borowitzka, 1972).

This work is aimed at determining the possible effects of the storm of December 2008 on the upper sublittoral macroalgal communities. We compared the results of a cartographic study carried out in 2004 in the context of another study (Arévalo et al. 2007) and a study performed in spring 2009 after the storm.

boat along the shoreline. Different communities characterised by dominant species were assigned to previously established categories. These categories were then mapped onto high-resolution geo-referenced surface images (orthophotos, aerial photos and nautical charts). The sectors were homogeneous and were always longer than 50m in order to obtain a rapid general representation of the coast.

The CARLIT sampling method was improved by measuring directly in the field the exact length of the coast occupied by each community and by characterising the sectors according to the dominant species. The coastline was divided into sections and each section was subdivided into sectors. Benthic communities, along with *facies* within a community and dominant species, were visually quantified as the number of sectors occupied by a given community or dominant species within each section.

Table 1. Main geomorphological and community features used as a criteria to establish homogeneous sectors along the coast.

Geomorphologica factors	Levels
Coastline morphology	High continuous coast
	Low continuous coast
	Metric Blocks
	Decimetric Blocks
Natural or artificial	

Materials and Methods

The detailed mapping of coastal communities was based on the CARLIT methodology (Ballesteros *et al.*, 2007) with some modifications to obtain a higher resolution. The methodology consisted in accurately mapping long sectors of the rocky shoreline by means of *in situ* visual identification of the upper sublittoral benthic communities as well as identifying the dominant characteristic species from a dinghy

The presence and abundance of each species or community were determined not only according to the water quality but also to the natural geomorphological variability of the coastal environment (Ballesteros, 1992). Therefore, in each sector we defined the community and the geomorphological factors that most influence whether the littoral communities can become established and develop.

In order to assess the possible effects of the storm on upper sublittoral benthic communities, a 2 km length sector of rocky shoreline from the northern Catalonian coast, near Tossa de Mar, was mapped between point A (X=494237, Y=4618351) and point B (X=493839; Y=4618062) (Figure 1). This sector was first mapped during the spring of 2004 and then again later after the storm during the spring of 2009. Although CARLIT has been applied every year along the entire Catalan coast since 2000, the scale of the data obtained is not comparable with the detailed cartography of the 2004 map. The chosen coastal area was carefully examined to identify homogeneous sections, both in terms of community and geomorphological features that mainly influence the coastal communities (see Table 1). Each homogeneous section was measured and characterised according to the benthic community and the dominant species.

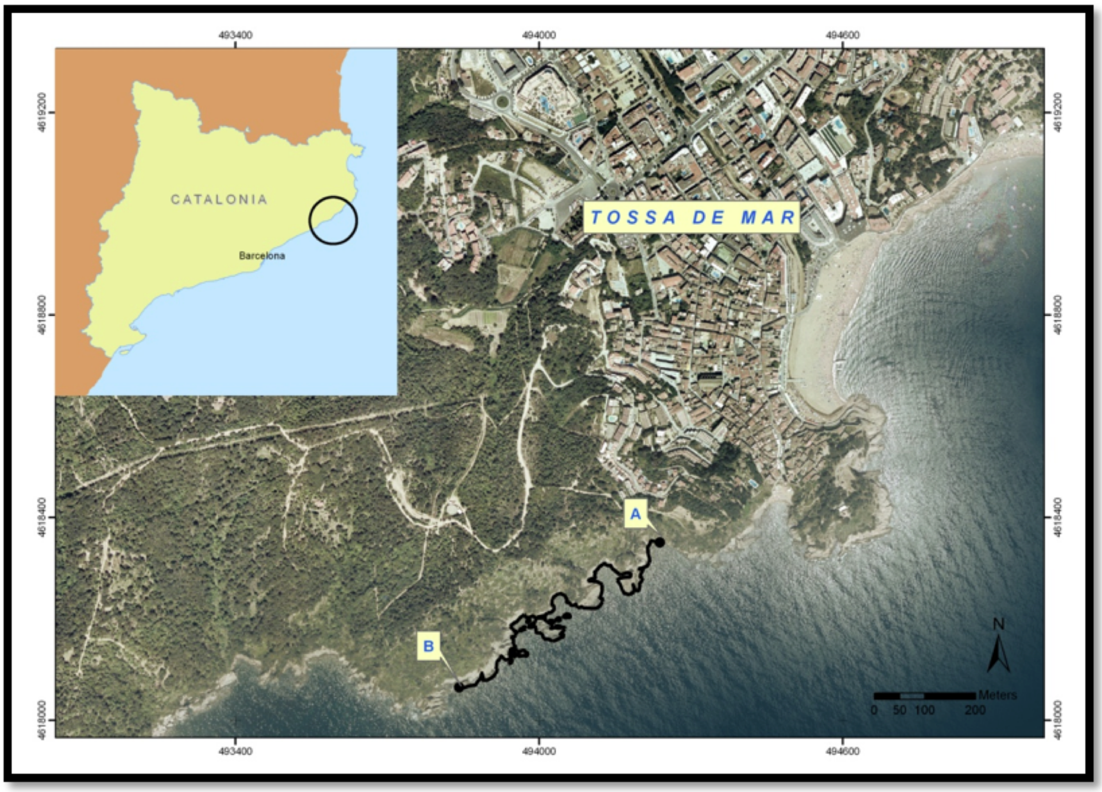

Figure 1. Location of the 2 km sector of the coastline in which were placed the 198 sectors studied.

The sections were classified into six categories to facilitate comparison according to the characteristic dominant species of each community:

1) *Cystoseira mediterranea* (Cm): a highly structured brown alga that is typical of clean waters and strong hydrodynamic conditions. This alga is a slow growing species, so the occupation of free spaces generally occurs within a short distance of established adult populations. The presence and degree of cover of *C. mediterranea* are considered a good indicator of water quality.
2) *Corallina elongata* (Ce): a stress resistant calcified alga that is found in both clean and polluted waters and on any rocky substrate. It grows alone or with other algae, such as *Cystoseira mediterranea. C. elongata* is one of the fastest growing species among the corallinaceae, so it is able to colonise new areas in a very short time. It is particularly sensitive to any natural (Gros, 1978; Verlaque, 1987) or anthropogenic stress (Thibaut, T.; Soltan et al., 2001).
3) *Lithophyllum incrustans* (Li): a crustose corallinaceous alga that is found in overgrazed zones without erect algae, or as a basal stratum in dense forests of *C. mediterranea.*
4) *Hypnea musciformis* (Hm): an alga usually found in calm shallow waters with a broad geographical distribution.
5) Ulvaceae (UL): opportunistic group of green algae which is common in anthropogenically or naturally disturbed sites.
6) Diverse photophyllic algae (PA).

The presence and relative abundance of *C. mediterranea* was recorded according to three levels: a) very abundant (CmVA), when it formed a dense continuous horizon along the shoreline; b) abundant (CmA), when it occurred abundantly without forming a continuous horizon, usually sharing the substrate with other algae; and c) rare (CmR), when some isolated individuals were found among other algae (mainly *Corallina elongata*). All data were recorded on a high-resolution orthophotography in which each position of each section of the sampled coast was identified.

All the data were transferred rigorously to a geographical information system (ArcGIS v 10.0 ESRI) in which the sectors of the shoreline were georeferenced. The sampling data from 2004 was then placed on top of the data from 2009 in order to compare the communities, section by section, before and after the storm.

The results obtained in 2004 were compared with those of 2009 by means of a chi-square test between the 2004 values, taken as expected values, and the 2009 values, which were the values observed in the analysis. The test was carried out with the STATISTICA © 6.0 statistical package.

Results & Discussion

The sectors that were studied in 2004 were revisited in the spring of 2009 after the storm of December 2008. The number of sectors ascribed to the categories defined in 2004 (taken as expected values) was significantly different from the number observed in 2009 (observed values) according to a chi-square test (Table 1).

Table 1. Observed (2009) *vs*. Expected (2004) frequencies of the 8 established categories among the sectors along the coastline studied section (Chi-Square = 55,32238 df = 7 p < 0.0001).

	Obs (2009)	Exp (2004)	O - E	(O-E)**2
Cystoseira (abundant.)	65,0	43,0	22,0	11,3
Cystoseira (rare.)	62,0	37,0	25,0	16,9
Corallina elongata	34,0	69,0	-35,0	17,8
Cystoseira (very abundant)	23,0	38,0	-15,0	5,9
Lithophyllum incrustans	10,0	8,0	2,0	0,5
Hypnea cruciformis	3,0	0,0	3,0	0,0
Photophyllic algae	1,0	0,0	1,0	0,0
Ulvaceae	0,0	3,0	-3,0	3,0
TOTAL	198,0	198,0	0,0	55,3

There was a sharp decline in the sectors dominated by *Corallina elongata* (which decreased by 50.7%) and to a lesser extent by “Very Abundant *C. mediterranea*” (-39.5%). Other sectors, categorised as “Abundant *C. mediterranea*” and “Rare *C. mediterranea*” increased from 2004 to 2009 (33.8% and 40.3% respectively). In short, there was a decreasing cascade effect, in which some sectors where *C. mediterranea* was very abundant moved to a lower level so that this alga became simply abundant or even rare. Other minor changes between the two years were the disappearance of the Ulvacea dominated sectors in 2009, along with the appearance of 3 new sectors dominated by the opportunistic alga *Hypnea musciformis*, as well as one sector dominated by other photophillic algae that were absent in 2004. Sectors dominated by *Lithophyllum incrustans* also increased from 8 to 10 in 2009 (Figure 2).

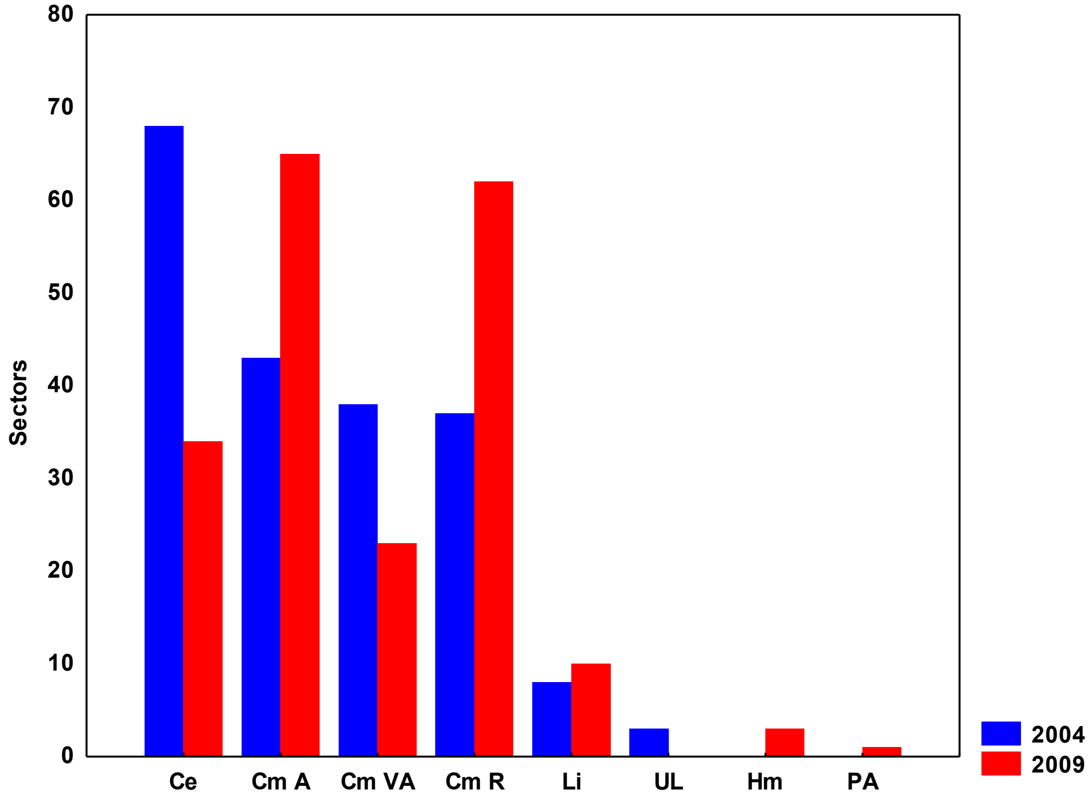

Figure 2. Frequency of sectors occupied by the different categories along the studied section of coastline (Ce: Corallina elongata; CmVA: very abundant *Cystoseira mediterranea*; CmA: abundant *C. mediterranea*; CmR: rare *C. mediterranea*; Li: *Lytophyllum incrustans*; UL: ulvaceae; Hm: Hm: *Hypnea musciformis*; PA: photphyllic algae).

Since the sectors were georeferenced exactly in both years, it was possible to place each of the 198 sectors side by side to determine whether there were any qualitative changes, whether a species was substituted by another, or whether there were quantitative variations in the dominance of *C. mediterranea*. The species that decreased greatly was *C. elongata*, which was the most widespread and dominant species in 2004. It occupied up to 69 sectors in 2004 but merely 34 in 2009. From the 45 sectors in which *C. elongata* disappeared, in 40 it was replaced by *C. mediterranea*, in 3 by *Hypnea musciformis* and in 2 by *Lithophyllum incrustans* (Figure 3). *C. mediterranea* also lost some sectors, although in absolute terms this alga became the most abundant in 2009. *C. mediterranea* disappeared from 6 sectors in which it had been rare in 2004 and was replaced by *C. elongata*. In the sectors where it had been very abundant or abundant in 2004, it was not replaced by any other alga.

Conclusions

It seems clear that, despite the extreme violence of the storm and that the studied section of the coastline is very open to the wave action of easterly storms, the effects were much lower than expected. It has been previously reported that *C. mediterranea* and *C. elongata* are the dominant species of upper infralittoral

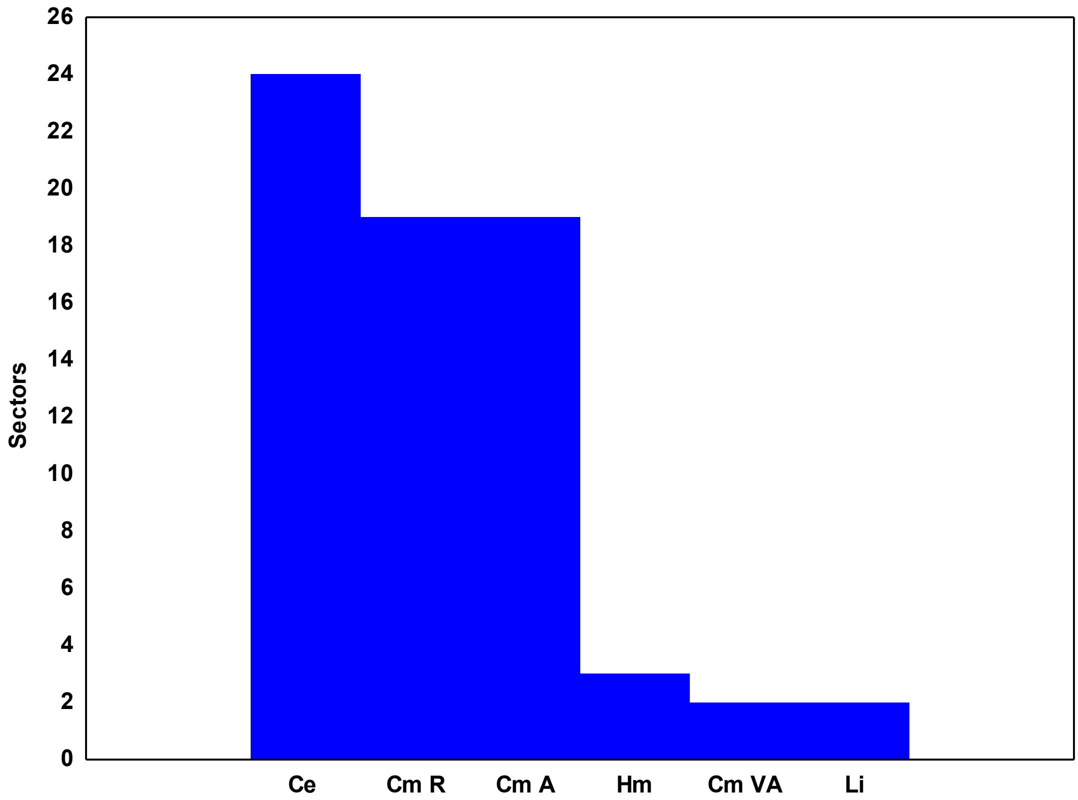

Figure 3. Changes suffered in 2009 (after the storm) by the 69 sectors occupied by Corallina elongata in 2004 (Ce: remaining *Corallina elongata*; Cm R: Rare *C. mediterranea*; Cm A: Abundant *C. mediterranea*; Hm: *Hypnea musciformis*; CmVA: Very Abundant *C. mediterranea*; Li: *Lytophyllum incrustans*).

benthic vegetation in exposed Mediterranean coastal areas and that some *Cystoseira* species are tolerant to wave energy (Ercegovic 1952); this was supported by the results obtained in this study. The results that stand out are the spatial progression of *C. mediterranea*, in spite of the loss of some densely populated sectors, and the sharp regression of *C. elongata.* These results suggest that the expansion of *C. mediterranea* may have been favoured by the depletion of *C. elongata*. A possible explanation would be that the storm cleared the substrate previously occupied by *C. elongata* in many sectors, facilitating colonisation by *C. mediterranea*. Even if other factors, such an improved water quality, enhanced the development of *C. mediterranea* before the storm hit the coast, the results suggest that *C. mediterranea* tolerated the storm better than *C. elongata*.

The time period of five years between the two cartographic studies is too long to be able to attribute all the changes in the coastline communities to the storm. Although *C. mediterranea* and *C. elongata* are species with low growth rates and long life cycles (perennials), 5 years is enough time for the two species to colonise free sectors of coast or to lose the occupied ones.

In conclusion, some results suggest that *C. mediterranea* was slightly favoured by the action of the storm.

However, the time period between the two cartographies was too long to identify precisely the changes in the communities produced by the storm. The upper infralittoral benthic macroalgal communities were not greatly affected by the extreme Sant Esteve storm.

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