ECOLOGICAL INDICATORS 8 (2008) 743–753

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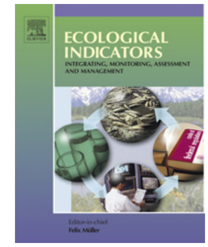


# Comparison of two methods for quality assessment of macroalgae assemblages, under different pollution types

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ARTICLE INFO

*Article history:*
Received 31 October 2007
Received in revised form
8 January 2008
Accepted 14 January 2008

*Keywords:*
Ecological status assessment
Indices and indicators
Macroalgae
Intertidal
Marine pollution
Water framework directive

ABSTRACT

The selection of adequate methodologies for the assessment of different biological quality elements is urgently needed for the application of the water framework directive (WFD 2000/60/EEC). In the case of macroalgae in coastal waters of the North East Atlantic, two methodologies have been proposed: the reduced species list (RSL) index and the quality of rocky bottoms (CFR) index. Both methods use multimetric approaches to evaluate the quality of macroalgae assemblages, which are based on community characteristics (species/populations richness, cover, percentage of opportunistic species, ecological state groups ratio, etc.). In this paper the results of applying both indices on three different types of pollution gradients in the North coast of Spain (bay of Biscay) are presented, in order to test their usefulness and intercalibration possibilities. In general terms, the CFR index responded more accurately than the RSL index to the pollution gradients under study. With respect to the indicators used in the current evaluation, richness, opportunistic species and cover seemed to be the most accurate for quality assessment of macroalgal communities. While the first two indicators are taken into account in both indices, the latter (cover) is only considered in the CFR index, even though the abundance of macroalgae is one of the aspects to be included in the evaluation of this biological element, according to the WFD.


## 1. Introduction

According to the water framework directive (WFD 2000/60/EEC) macroalgae are one of the biological quality elements to be evaluated for the assessment of the ecological status of coastal water bodies. Recently, several methodologies have been proposed to accomplish this task e.g. the ecological evaluation index (EEI) (Orfanidis et al., 2001), the reduced species list index (RSL) (Wells, 2004; Wells et al., 2007), the littoral cartography methodology (CARLIT) (Ballesteros et al., 2007) or the quality of rocky bottoms index (CFR) (Juanes et al., 2008). The advantages and disadvantages of these methods have been analysed by Juanes et al. (2008).

In general terms, the conceptual basis of all these approaches consists of an analysis of the relative abundance of pollution sensitive or indicator species. In an increasing pollution gradient it is expected that the most sensitive taxa, generally the most specialized or k-selected species, are gradually replaced by pollution tolerant and indicator species, typically opportunistic or r-selected species. In the case of the EEI and the RSL indices, the classification of species is based on the morphological and functional-form groups described by Littler and Littler (1980, 1984) and subsequently adapted by Orfanidis et al. (2001) to divide species into two ecological state groups (ESG): the ESG I, including species with a thick or calcareous thallus, low growth rates and long life cycles (perennials), and the ESG II, including sheet-like and

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doi:10.1016/j.ecolind.2008.01.004

filamentous species with high growth rates and short life cycles (annuals). However, as stated by Arévalo et al. (2007), the functional-form group hypothesis was originally proposed to predict productivity and other ecological attributes (e.g. grazing resistance, competitive abilities, reproductive effort), but not resistance to pollution.

Thus, in the recent literature on this topic misleading interpretations of the sensitivity levels assigned to the same species are found, as observed in the case of the different quality values assigned to *Corallina* spp. populations by Orfanidis et al. (2001) and Ballesteros et al. (2007). While the first authors considered *Corallina* as a late-successional species (ESG I), which would represent a high ecological quality, the second authors assigned this species to an intermediate-low sensitivity level hence its presence would indicate a moderate ecological quality. So, it seems clear that the development of suitable and accurate indices based on macroalgae as pollution indicators requires, first of all, a consensus about the pollution sensitivity level assigned to each macroalgae species. Similar inconsistencies were found by Puente et al. (2008) when assigning macroinvertebrate species to different sensitive/tolerant groups in estuarine areas.

Before the definitive acceptance of the metrics to be used for the quality assessment of each biological quality element, the WFD demands that member states undertake an intercalibration process among all the proposed metrics. In the case of the North East Atlantic geographical intercalibration group (NEA GIG) two different tools have been proposed for the assessment of macroalgae, the RSL index (Wells, 2004; Wells et al., 2007) and the CFR index (Juanes et al., 2008). The most important difference between these indices is the exclusive use of macroalgae abundance estimates (cover) by the CFR index, which follows the basic requirements of the WFD. Another difference between the indices is that the CFR index is suitable for both intertidal and subtidal areas, while the RSL is only applicable to the former.

On the other hand, both indices include the opportunistic species and the richness among their indicators, though they differ in their way of application. Thus, in the CFR index there is not an exhaustive analysis of macroalgae at the species level, instead only characteristic macroalgae populations with a noticeable presence (>1% cover) are used for the richness estimates. Other studies have also suggested that monitoring efforts should be directed towards perennial species with a sufficient depth distribution (Eriksson and Bergström, 2005), considering that ephemeral algae are probably more stochastic in their occurrence than perennial algae. Regarding the proportion of opportunistic species, the RSL index considers the relative number of opportunistic species in relation with total macroalgal richness, while the CFR index evaluates their relative cover in respect to the total cover.

Another basic characteristic of these methodologies is that they are relatively easy to apply and have an effective cost–benefit relation, so they can be scientifically rigorous and at the same time, useful tools to carry out extensive management works. In this sense, both indices use non-destructive data collection methods but their main difference lies on the way in which the scoring system is applied. While the RSL index requires the identification of all macroalgae species present in a reduced species list for posterior analysis and score assignation of each indicator, the CFR index is designed for its direct application in situ through ranges based scoring system of each indicator. One of the reasons for this simplification in the CFR index is that it was also designed for its application in extensive subtidal areas by SCUBA diving or by remotely operated vehicles (ROVs), which requires a simplified assessment methodology.

Given that the development and selection of evaluation indices is a fundamental task to assess the ecological status of coastal water bodies, the aim of this paper is to test and validate the suitability of the CFR and the RSL indices to monitor water quality by examining intertidal macroalgae communities. In order to analyse the possibilities and requirements for the intercalibration of both methods, the capability of each method to adequately detect and quantify differences in the quality of coastal macroalgae communities along different types of pollution gradients was studied at both the global index (CFR and RSL) and the single indicator levels (richness, cover, etc). The degree of adjustment of the quality assessment results obtained by the two methods was then statistically analysed.

## 2. Methodology

### 2.1. Study area

The experimental design was carried out in the summer 2006 at three places located along the coast of Cantabria (N Spain), each one exposed to different types of urban and industrial discharges (Fig. 1). The first site, Liñera, is located near a secondary-treatment urban waste-water plant for about 15,000 inhabitant equivalents, discharging directly on the coastline. The high concentrations of total nitrogen (24 mgN/l), total phosphorous (3 mgP/l), Biological oxygen demand (28 mgO/l) and total suspended solids (63 mg/l) (average values of unpublished data from the environmental department of the Government of Cantabria), produce turbidity and oxygen demand in the surrounding coastal area, but especially an increment of the natural levels of nutrients with the resulting eutrophication risk. At the second place, Usgo, a high density inert industrial effluent of a sodium carbonate factory, mainly composed of $CaCl_2$ (TSS:23 g/l and 1400 $m^3$/h flow), with 65 °C and pH 11, has been discharged for 40 years directly on the coastline, and since 2002 through a submarine outfall (−15 m depth) (Revilla et al., 2007). Siltation, turbidity and abrasive effects in this coastal area are easily recognized. The third site, Ontón, is located near the industrial effluent of a fluoride factory which discharges about 11.5 t/year of fluorides directly on the coastline (MMA, 2001), with an average concentration of 29.7 mg/l and point measured values of pH 11.75 (unpublished data from the environmental department of the Government of Cantabria).

The intertidal zonation pattern of the macroalgae communities along the Cantabrian coast can be divided into two main fringes; the mid-littoral (dominated by *Corallina* spp. and accompanied by Calcareous encrusters, *Caulacanthus ustulatus*, *Ceramium* spp., *Chondracanthus* spp., *Osmundea* spp., etc...) and the infralittoral (dominated by *Bifurcaria* spp. and accompanied by *Stypocaulon scoparia*, *Codium* spp., *Cladostephus* spp.,