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Indices to monitor coastal ecological quality of rocky shores based on seaweed communities: simplification for wide geographical use *

Índices para monitorização de qualidade ecológica de costas rochosas com base em comunidades de macroalgas: simplificação para utilização em áreas geográficas alargadas

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ABSTRACT

This study focuses on intertidal rocky shore seaweed community features used for the assessment of ecological quality of coastal water bodies for the Water Framework Directive (WFD). An alternative index to those developed in the British Isles, in northern Spain and in mainland Portugal is proposed. Results from the application of all indices to a dataset collected on Azorean shores are compared and the suitability of the features used in each index discussed. The features included in the proposed index were selected to allow its applicability throughout a large geographic area.

Keywords: Ecological quality; macroalgae; intertidal; index comparison; wide geographic use

RESUMO

Este estudo centra-se em características de comunidades de macroalgas do intertidal rochoso para avaliação da qualidade ecológica das massas de águas costeiras no âmbito da Diretiva-Quadro da Água (DQA). É proposto um índice alternativo aos desenvolvidos nas Ilhas Britânicas, no norte da Espanha e em Portugal continental, que resulta da comparação da aplicação de todos os índices a um conjunto de dados recolhidos em praias açorianas, discutindo-se a adequação dos parâmetros utilizados em cada índice. Os parâmetros incluídos no índice proposto foram selecionados de forma a permitir a sua aplicação numa área geográfica alargada.

Palavras-chave: *Ecological quality; macroalgae; intertidal; index comparison; wide geographic use*

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1. INTRODUCTION

In the European Union the implementation of the Water Framework Directive - WFD (EC, 2000) and the Marine Strategy Framework Directive – MSFD (EC, 2008) has led to the development of biological indicators to monitor the environment and protect biological diversity of marine ecosystems.

The WFD considers ecological status as a reflection of the quality, structure and functioning of aquatic ecosystems and is based on the assessment and monitoring of biological communities that reflect the physical and chemical quality of their habitats. The generic criteria to evaluate biotic communities include: taxonomic composition; abundance; and presence of sensitive taxa. The ecological status of a water body based on several single shores is expressed as a numerical value between 0 (bad) and 1 (high), known as EQR (Ecological Quality Ratio). The tools developed for the WFD to monitor coastal waters in the NE Atlantic using macroalgae consist of the British tool (BT) implemented in the British Isles (BI) and in Norway (Wells *et al.,* 2007), the Spanish tool (ST) used on the Atlantic north coast of Spain (Juanes *et al.,* 2008) and the Portuguese tool (PT) developed for the mainland territory (Gaspar *et al.,* 2011; Neto *et al.,* 2011). Member States are expected to intercalibrate methods to ensure coherence in the results they produce. For this purpose countries were grouped into wide Geographical Intercalibration Groups (GIGs). Eleven countries or parts of countries with an open Atlantic coast were placed in the NE Atlantic GIG (NEA-GIG) that extends from sub-polar conditions in Norway to warm subtropical waters in the Azores, and warmer waters off the African Coast in the Canaries. Inevitably, big variation in coastal communities poses difficulty in the generalized application of ecological quality assessment criteria. The need to have consistent methods across wide geographical areas within each GIG raises some issues that must be considered when applying these criteria.

The objective of this study was to propose an alternative tool that surpasses the shortcomings identified in the existing ones. A database of seaweed community features from Azorean shores was used to compare the ecological quality classification that is achieved from using the proposed new tool and the others developed within the NEA-GIG, namely the Azorean version of the British RSL (Reduced Species List) tool (RSL-AZ; see Wallenstein, 2011; Wells *et al.*, 2007), the Spanish CFR ("Calidad de Fondos Rocosos" – Quality of Rocky Bottoms) tool (Juanes *et al.*, 2008), and the Portuguese MarMAT (Marine Macroalgae Assessment Tool) tool (Neto *et al.,* 2011).

2. METHOD

The suggested tool combines several features adapted from the RSL, CFR and MarMAT tools and was named PAN-EQ-MAT (PAN for general use, EQ for ecological quality and MAT for Macroalgae Assessment Tool).

2.1. Features used

Species richness (**S**) – total number of species based on the Reduced Species List (RSL suggested by Wallenstein (2011) for the Azores region as the species occurring at least in 20% of a pool of 88 survey sites across 6 islands of the archipelago; Table 1);

Table 1. Reduced Species List (RSL) suggested by Wallenstein (2011) for the Azores region and respective Ecological Status Group (ESG) and opportunistic status classification (ESG = 1 – late successional species; ESG = 2 – early successional species; Opportunistic = 0 – non opportunistic species; Opportunistic = 1 – opportunistic species)..

Tabela 1. *Lista de Espécies Reduzida proposta por Wallenstein (2011) para a região dos Açores e respetivo estatuto ecológico (ESG) e oportunista (ESG = 1 – espécies sucessionais tardias; ESG = 2 – espécies sucessionais iniciais; Opportunistic = 0 – espécies não oportunistas; Opportunistic = 1 – espécies oportunistas).*

	ESG	Opportunistic
Rhodophyta		
Acrosorium venulosum	2	0
Aglaothamnion sp.	2	0
Amphiroa fragilissima	1	0
Amphiroa rigida	1	0
Asparagopsis armata	1	0
Caulacanthus ustulatus	1	0
Centroceras clavulatum	2	0
Ceramium ciliatum	2	0
Ceramium diaphanum	2	0
Ceramium virgatum	2	0
Chondracanthus acicularis	1	0
Chondria dasyphylla	1	0
Corallina elongata	1	0
Falkenbergia rufolanosa	2	0
Gastroclonium reflexum	2	0
Gelidium microdon	1	0
Gelidium pusillum	1	0
Gelidium spinosum	1	0
Grateloupia dichotoma	1	0
Gymnogongrus crenulatus	1	0
Gymnogongrus griffithsiae	1	0
Haliptilon virgatum	1	0
Herposiphonia secunda	1	0
Hypnea musciformis	2	0

Table 1. continuing
Tabela 1. *continuação*

Jania adhaerens	1	0
Jania capillacea	1	0
Jania pumila	1	0
Jania rubens	1	0
Laurencia majuscula	1	0
Laurencia minuta	1	0
Lomentaria articulata	1	0
Lophosiphonia reptabunda	1	0
Nemalion helminthoides	2	0
Osmundea truncata	1	0
Plocamium cartilagineum	2	0
Polysiphonia denudata	2	0
Pterocladiella capillacea	1	0
Symphyocladia marchantioides	1	0
Heterokontophyta		
Fucus spiralis	1	0
Halopteris filicina	1	0
Nemoderma tingitanum	1	0
Padina pavonica	2	0
Sphacelaria sp.	1	0
Stypocaulon scoparium	1	0
Chlorophyta		
Chaetomorpha pachynema	2	1
Cladophora prolifera	2	0
Cladophora sp.	2	0
Codium adhaerens	1	0
Ulva compressa	2	1
Ulva intestinalis	2	1
Ulva rigida	2	1

Total abundance/cover (**C**) - based on the substratum cover by all species listed in the RTL relative to the total area on the shore that is covered by macroalgae;

Opportunistic species abundance/cover (**Oc**) - based on the substratum cover by ESG2 species [Orfanidis *et al.,* 2001 introduced a classification of seaweeds into Ecological Status Groups (ESGs) with two levels: ESG 1 - late successional species; and ESG2 - early successional species)] relative to the total area on the shore that is covered by macroalgae (see ESG and opportunistic classification in Table 1).

All features that are subject to latitudinal variability in the RSL, CFR and MarMAT tools have been avoided in the proposed index, namely the number and/or proportion of red and green species.

2.2. Value ranges

The variation ranges of the features used in the proposed index and the respective classifications are given in Table 2. Considering that the proportion of red species and the ESG ratios are significantly higher on Azorean shores than on British shores while species richness and the proportions of green and opportunistic algae tend to be lower on Azorean shores (Wallenstein, 2011) it is expected that the classification of Azorean shores using the boundaries set for each of these parameters by Wells (2008) for the BI would be biased. Therefore, the adaptation of the BT to the seaweed community features' variation ranges in the Azores according to the findings of Wallenstein (2011) consisted of using modified boundaries for each feature. Since there are no Azorean shores with an a priori classification of bad to moderate, no boundaries were proposed for these classes. The moderate-good boundary was calculated as the average value minus the standard deviation for each feature, based on their respective scores for 88 shores in the archipelago, and the good-excellent boundary set as the average value plus the standard deviation (Wallenstein, 2011).

Table 2. Quality classification and EQR variation ranges for all features used in the PAN-EQ-MAT tool.
Tabela 2. *Classificação da qualidade e intervalos de variação do rácio de qualidade ecológica (EQR) para todos os parâmetros utilizados no índice PAN-EQ-MAT.*

Quality	Bad to Moderate	Good	High
EQR	**[0.0-0.6[**	**[0.6-0.8[**	**[0.8-1.0]**
S – Species richness	[0-18[	[18-21[	≥21
C - Total cover (%)	[0-30[	[30-50[	≥50
Oc - Opportunist cover (%)	[100-20[	[20-10[	≤10

2.3. Ecological quality calculation metrics

The EQR value for a single shore was obtained from conflation of partial EQR values for each algal feature measured – EQR_S, EQR_C and EQR_{Oc}. On a given shore, the partial EQR value for each feature was calculated according to the sliding scale formulae defined by Wells *et al.* (2007) based on the value of each feature on that shore (Table 3) and the range values of the class into which it falls (Table 2).

Shores were classified based on the final ecological quality ratio (EQR) for all these features combined together. The final classification status of each shore was calculated through the weighted average of all partial EQR values. Juanes *et al.*

(2008) suggest that each feature should be given a different importance, namely 15/100 to species richness, 40/100 to total cover, 30/100 to opportunistic cover and 15/100 to physiological status. Excluding the latter indicator due to its subjectivity, the relative weight given to S, C and O was converted to 15/85 (=0.18), 40/85 (=0.47) and 30/85 (=0.35), respectively, and the weighted average EQR was calculated accordingly.

2.4. Pool of samples

A pool of 25 shores from the Azores was included in the present study, of which 16 are located in Santa Maria and 9 in Graciosa (Fig.1), using both the extensive qualitative data and seaweed abundance data that had been collected by Wallenstein & Neto, (2006).

Table 3. Features used for the EQR calculations (S - total nº species; C - total substratum cover; Oc - Opportunisic species substratum cover; Gp - green species proportion; Rp - red species proportion; ESG - ratio between n.º of ESG1 species and nº of ESG2 species; Op - opportunistic species proportion; R – n.º of red species; O/ESG - ratio between nº of opportunistic species and nº of ESG1 species; Sh - shore description score) with all four indices (PAN-EQ-MAT, RSL-AZ, CFR and MarMAT), their respective scores in each surveyed shore, and correlation between them. At the bottom at the table "x" indicate which features are used in each of the four indices.
Tabela 3. *Parâmetros utilizados no cálculo dos EQR (S - nº total de espécies; C – cobertura total do substrato; Oc – cobertura do substrato por espécies oportunistas; Gp – proporção de algas verdes; Rp – proporção de algas vermelhas; ESG – rácio entre o nº de species ESG1 e o nº de espécies ESG2; Op – proporção de espécies oportunistas; R - nº de espécies vermelhas; O/ESG – rácio entre o nº de espécies oportunistas e o nº de espécies ESG1; Sh – parâmetro de avaliação da costa) com os quatro índices (PAN-EQ-MAT, RSL-AZ, CFR e MarMAT), respetivos valores em cada local de amostragem e correlações. No fim da tabela o caractere "x" indica quais os parâmetros utilizados em cada um dos quatro índices.*

		S	C	Oc	Gp	Rp	ESG	Op	R	O/ESG	Sh
Sites	**1**	15	0.45	0.18	0.33	0.53	1.50	0.13	8	0.22	17
	2	3	0.37	0.86	0.33	0.67	2.00	0.33	2	0.50	8
	3	11	0.60	0.30	0.18	0.73	1.75	0.18	8	0.29	10
	4	19	0.61	0.31	0.05	0.79	1.71	0.00	15	0.00	14
	5	17	0.49	0.08	0.12	0.76	2.40	0.00	13	0.00	12
	6	12	0.57	0.25	0.25	0.58	1.00	0.08	7	0.17	16
	7	12	0.61	0.37	0.25	0.58	0.71	0.17	7	0.40	8
	8	11	0.74	0.03	0.18	0.55	2.67	0.00	6	0.00	13
	9	13	0.66	0.29	0.08	0.77	3.33	0.00	10	0.00	12
	10	16	0.81	0.36	0.19	0.63	0.78	0.06	10	0.14	14
	11	12	0.73	0.20	0.25	0.58	2.00	0.08	7	0.13	8
	12	17	0.74	0.03	0.18	0.71	1.83	0.00	12	0.00	16
	13	10	0.69	0.63	0.20	0.60	4.00	0.00	6	0.00	8
	14	15	0.60	0.15	0.27	0.60	2.00	0.07	9	0.10	16
	15	15	0.67	0.25	0.27	0.53	1.14	0.13	8	0.25	14
	16	15	0.55	0.20	0.20	0.67	1.50	0.13	10	0.22	14
	17	10	0.74	0.14	0.20	0.80	1.00	0.10	8	0.20	10
	18	22	0.90	0.51	0.27	0.59	1.20	0.14	13	0.25	8
	19	9	0.55	0.40	0.00	0.89	3.50	0.00	8	0.00	10
	20	21	0.60	0.08	0.14	0.76	2.50	0.10	16	0.13	10
	21	26	0.72	0.12	0.19	0.65	1.36	0.12	17	0.20	9
	22	19	0.82	0.16	0.11	0.79	1.38	0.05	15	0.09	16
	23	23	0.57	0.23	0.17	0.74	1.88	0.13	17	0.20	12
	24	26	0.73	0.12	0.15	0.73	1.36	0.12	19	0.20	13
	25	17	0.67	0.11	0.18	0.76	2.40	0.12	13	0.17	12

Table 3. continuing
Tabela 3. *continuação*

Correlations	**C**	0.39									
	Oc	-0.49	-0.23								
	Gp	-0.21	-0.15	0.26							
	Rp	0.12	-0.07	-0.12	**-0.80**						
	ESG	-0.28	-0.19	0.15	-0.44	0.30					
	Op	-0.16	-0.35	0.44	0.66	-0.24	-0.45				
	R	**0.94**	0.31	-0.50	-0.45	0.43	-0.15	-0.22			
	O/ESG	-0.15	-0.28	0.43	0.67	-0.30	-0.56	**0.97**	-0.24		
	Sh	0.20	-0.04	-0.50	-0.04	-0.07	-0.24	-0.31	0.17	-0.32	
Indices	**PAN-EQ-MAT**	x	x	x							
	RSL-AZ	x			x	x	x	x			
	CFR	x	x	x							x
	MarMAT	x		x	x			x	x	x	x

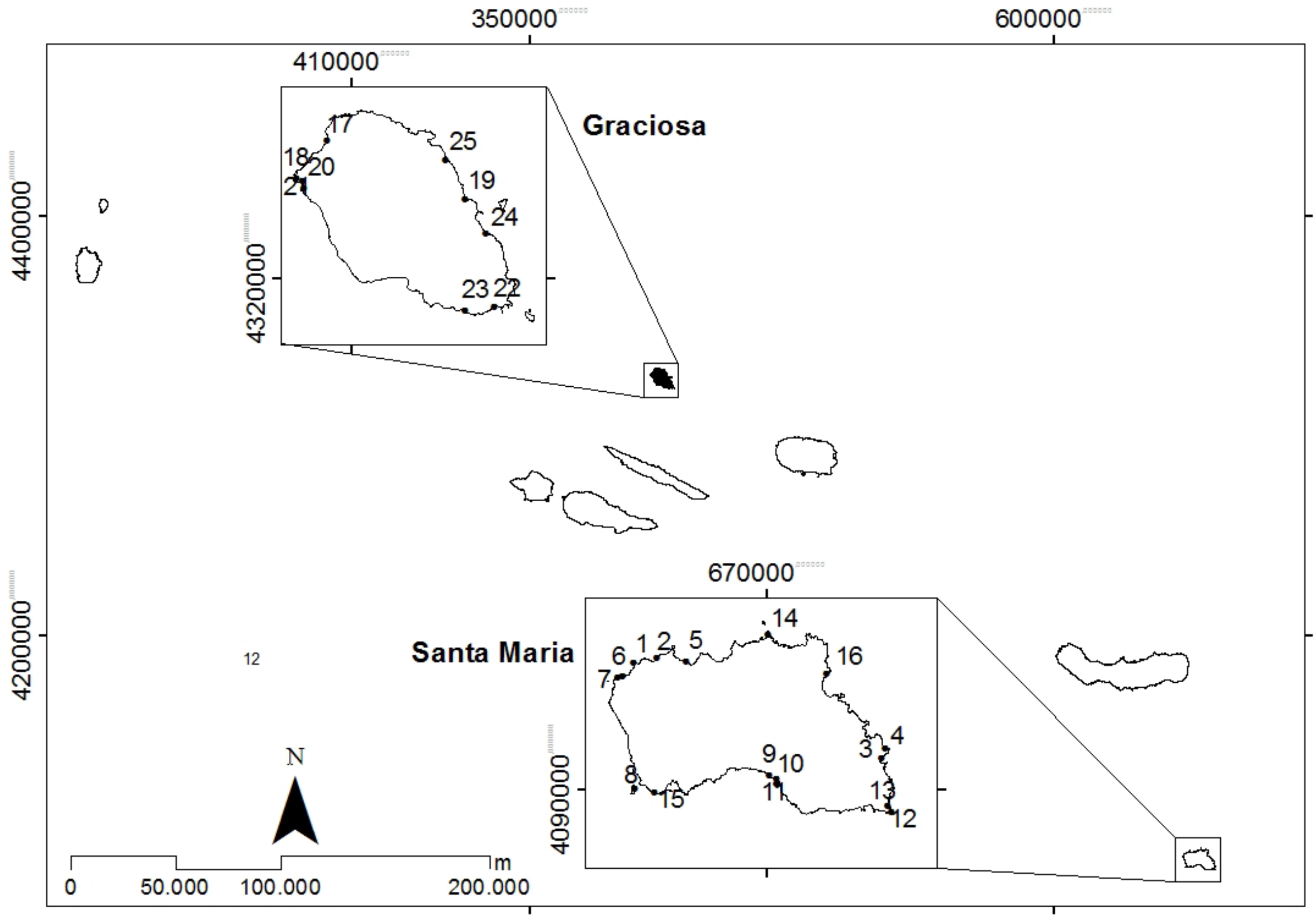

Figure 1. Map of the Azores with inserted detail of Graciosa and S. Maria Islands where surveyed shores are indicated.
Figura 1. *Mapa dos Açores com inserção de detalhe das ilhas Graciosa e de Santa Maria, onde são indicados os locais de recolha.*

2.5. Data

EQR values were calculated and ecological quality of shores classified using the 4 indices (PAN-EQ-MAT; RSL-AZ; CFR and MarMAT) based on the features' scores displayed in Table 3 and the EQR-quality conversion scale defined in Table 2.

2.6. Data treatment

The correlation coefficient between all variables used in each method was calculated to assess the redundancy of some of the seaweed community features considered to assess ecological quality – high correlation between variables meaning that compared features reflect the same effect on the community and are therefore redundant.

The 4 methods were compared based on:

a) the correlation coefficients between the EQR values obtained with each method – high correlation between EQR values meaning that compared methods provide similar quantitative results
b) the percentage of matching classifications between indices (number of shores classified identically using any two indices divided by the total number of shores) – high matching % meaning that compared methods provide similar qualitative results

3. RESULTS

The bottom part of Table 3 shows the correlation coefficients between all features used in the four tools, and which of the features is used in each tool. The PAN-EQ-MAT and the CFR tools are those that rely on features that are not strongly correlated, while the RSL-AZ tool is based on the proportions of red and green species that are strongly negatively correlated (-0.80), and the MarMAT tool is based on the number of red species that strongly correlates with the total number of species (0.94), and on the O/ESG ratio that correlates strongly with the proportion of opportunist species (0.97).

The ecological quality ratio (EQR) values and the corresponding classification of all 25 shores using the four methods, the correlation coefficients between EQR values and the matching classification percentages between the different methods are displayed in Table 4.

There is a tendency for EQR values to come out lower both with the RSL-AZ and the MarMAT tools. The CFR tool always produces higher EQR values than any other index, while showing a discrete scale (0,05) rather than a continuous numerical scale like that of the remaining 3 tools.

Only two shores (8%) are classified lower than "good" when applying the PAN-EQ-MAT index, whereas 20% of the shores are classified as "high" and 72% as "good". When applying the RSL-AZ tool, 20% of the shores are classified lower than "good", 52% as "good" and 28% as "high". When using the CFR tool 80% of the shores were classified as "high" and 20% as "good", frequently assigning higher classifications than the remaining methods. The MarMAT tool classifies 20% of the shores lower than "good", 60% as "good" and 20% as "high". In general, it seems that the qualitative classification is highly divergent as there are only 4 shores with identical classification using the 4 methods. Despite these inconsistencies, 18 in a total of 25 sites have been classified as "high" and/or "good" according to all reduced species list (RSL) based methods.

The simultaneous analysis of the correlation between EQR values and the matching % of classifications do not translate into a clear similarity/dissimilarity pattern between indices. If on one hand PAN-EQ-MAT and RSL-AZ are closer to MarMAT and CFR closer to PAN-EQ-MAT, both in terms of EQR correlation and matching percentage of classifications, on the other hand MarMAT is closer to PAN-EQ-MAT in terms of EQR values and closer to RSL-AZ in terms of classification match.

4. DISCUSSION

The index here proposed is intended to combine the features considered most relevant for the overall objective of such a tool, namely to reflect ecological features of seaweed communities that are responsive to environmental stressors while complying with the guidelines set out by the European Environmental Agency.

The metric system adopted for the calculation of EQR values follows that of Wells (2008) because it builds on a sliding scale rather assigning a fixed value for each feature's range of variation as is the case of the CFR and MarMAT tools. It is thus expected to produce a continuous numeric scale of EQRs that vary according to the scores of each feature on any shore. This is considered advantageous over a scale of discrete values, and was therefore adopted for the index proposed.

The RSL, CFR and MarMAT tools use multimetric approaches based on ecological features of seaweed communities. Some of these features are strongly correlated and should not be included together to avoid over counting their impact on the final measure. This is the reason why the number of red species was excluded and a combined version of ESG and opportunistic classification adopted for the new proposed index.

The RSL, CFR and MarMAT methods share the same philosophy of using a reduced set of taxa (e.g. species, genus) as a surrogate for the full species list in reference conditions for the region where it is to be implemented. A RSL requires expert knowledge for the definition of the species representative of high quality shores and those that are sensitive to pollution, but once the RSL is defined field work requires less taxonomic expertise and is less time consuming. The need to apply these methods across a wide areas with geographical differences in species composition require that the reduced taxa lists are defined for each region separately, as suggested by Wells *et al.* (2007) in dividing the British Isles data set into three separate regions. Therefore, applying these methods to Azorean macroalgal communities required the establishment of the RSL for this region (Wallenstein, 2011).

Using species richness is consensual between the RSL, CFR and MarMAT methods as an alternative to using species composition. Furthermore, the comparison between intertidal seaweed communities from the BI and the Azores,

Table 4. EQR values and shore classification for each shore calculated using the PAN-EQ-MAT, RSL-AZ, CFR, and MarMAT tools; EQR value correlation coefficients and matching classification percentages between indices.
Table 4. *Valores do EQR e respetiva classificação dos locais amostrados, utilizando os índices PAN-EQ-MAT, RSL-AZ, CFR, e MarMAT; Coeficientes de correlação entre os valores EQR e percentagem de coincidência de classificação e entre índices.*

		EQR values					Classification			
		PAN-EQ-MAT	**RSL-AZ**	**CFR**	**MarMAT**		**PAN-EQ-MAT**	**RSL-AZ**	**CFR**	**MarMAT**
Sites	**1**	0.64	0.54	0.80	0.61		good	moderate	high	moderate
	2	0.38	0.59	0.70	0.28		poor	moderate	good	bad
	3	0.66	0.70	0.75	0.69		good	good	good	good
	4	0.65	0.84	0.75	0.81		good	high	good	high
	5	0.74	0.82	0.90	0.81		good	high	high	good
	6	0.64	0.59	0.85	0.61		good	moderate	high	moderate
	7	0.66	0.53	0.85	0.61		good	moderate	high	moderate
	8	0.82	0.72	1.00	0.67		high	good	high	good
	9	0.67	0.84	0.85	0.72		good	high	high	good
	10	0.69	0.62	0.75	0.69		good	good	good	good
	11	0.73	0.74	0.95	0.67		good	good	high	good
	12	0.83	0.79	1.00	0.72		high	good	high	good
	13	0.60	0.74	0.85	0.53		moderate	good	high	moderate
	14	0.71	0.69	0.90	0.67		good	good	high	moderate
	15	0.69	0.54	0.85	0.67		good	moderate	high	moderate
	16	0.68	0.63	0.90	0.75		good	good	high	good
	17	0.74	0.65	0.90	0.69		good	good	high	good
	18	0.76	0.66	0.85	0.69		good	good	high	good
	19	0.61	0.86	0.75	0.67		good	high	good	good
	20	0.87	0.91	1.00	0.86		high	high	high	high
	21	0.87	0.78	0.90	0.86		high	good	high	high
	22	0.76	0.75	0.90	0.78		good	good	high	good
	23	0.77	0.82	0.85	0.83		good	high	high	high
	24	0.86	0.82	0.90	0.86		high	high	high	high
	25	0.78	0.79	0.90	0.78		good	good	high	good
		Correlations between EQR values					**Matching classifications (%)**			
		0.46				**RSL-AZ**	0.44			
		0.77	0.30			**CFR**	0.36	0.28		
		0.82	0.65	0.44		**MarMAT**	0.60	0.72	0.28	

provided by Wallenstein (2011), showed that species richness does not differ significantly between these two regions. It can therefore be a useful feature for wide geographical application, and was thus included in the proposed index.

The CFR method of Juanes *et al.* (2008) and Guinda *et al.* (2008) recommends the use of abundance based on scientific evidence regarding the importance of overall substratum cover by macroalgae in relation to environmental disturbance. The RSL method of Wells *et al.* (2007) does not use seaweed abundance based on the grounds that the area covered by macroalgae on rocky shores in the BI can vary considerably between highly wave-exposed animal-dominated shores and sheltered algae-dominated shores (Hawkins *et al.,* 1992), and thus substratum cover was considered as an unsuitable feature. However, if the survey method considers that the overall cover shall be measured as the abundance of species that are part of the RSL relative to the total area covered by seaweeds in a given shore, it will not depend whether it is an animal-dominated or an algae-dominated one. Some authors argue that abundance assessment with quadrats can be very time consuming. However, using high resolution digital photography can overcome such a problem by allowing the identification of seaweeds to a fairly acceptable taxonomic level that can be helped with specimen identification in the lab, as in various studies (*e.g.,* Magorrian & Service, 1998; Ducrotoy & Simpson, 2001; Pech *et al.,* 2004; Álvaro *et al.,* 2008; Smale *et al.,* 2010). Furthermore, regarding sampling resolution for biomonitoring studies, Bates *et al.* (2007) suggest the use of lower taxonomic resolution (genus/family levels) for abundance assessment of less conspicuous species with conspicuous ones sampled at species level. Based on this evidence and to cope with the WFD guidelines to include abundance for the assessment of macroalgae community response to stressful conditions, substratum cover has been included in the proposed index.

Another common feature between RSL, CFR and MarMAT tools is opportunistic species. However, in the RSL tool opportunist species are only those considered to potentially constitute a bloom problem on sedimentary shores like the foliose green seaweeds, while in the CFR and MarMAT tools they include also filamentous red, brown and green algae. Green opportunistic algae are commonly known to respond to nutrient enrichment and may be more sensitive to changes in water quality than other opportunists (Karez *et al.,* 2004). *Ulva* (*Enteromorpha*), *Chaetomorpha* or *Cladophora* are in fact the most usual species to form blooms, although the filamentous *Ceramium* and *Ectocarpus* and the foliose *Porphyra* can also reach nuisance proportions (Fletcher, 1980; Vogt & Schramm, 1991; Fletcher, 1995). Nevertheless, macroalgal opportunists may be naturally abundant on rocky shores and represent no anthropogenic interference, nor an environmental impact (Wilkinson & Wood, 2003; Petersen *et al.,* 2005; Wells, 2007), and blooms of macroalgae are generally considered a problem on relatively sheltered, sedimentary shores rather than on hard substrata (Scanlan *et al.,* 2007). The classification of species as opportunist vs. non-opportunist is widely considered as crucial in assessing the impact of coastal water nutrient and/or toxic substances enrichment (*e.g.,* Arévalo *et al.,* 2007; Krause-Jensen *et al.,* 2007; Scanlan *et al.,* 2007; Wells *et al.,* 2007). The development of suitable and accurate indices based on macroalgae as pollution and nutrient enrichment indicators requires a consensus about the sensitivity level assigned to each species (Guinda *et al.,* 2008), as also mentioned by Borja *et al.* (2003, 2007) for a generalized application of the AMBI index with invertebrate fauna of soft sediments. Similarly, it would be desirable to have a global seaweed species database with an indication of each species' sensitivity to pollution and nutrient enrichment based on scientific information as the one mentioned by Wilkinson & Rendall (1985) referring to freshwater systems.

Although in the RSL tool Wells *et al.* (2007) suggest that the number of opportunist species as a proportion of the total number of species to be used as a measure of community response to nutrient enrichment, most authors propose the use of abundance measures of such species based on evidence that they occur naturally in high ecological quality communities, but outcompete other species in growth under stressful conditions (*e.g.,* Goshorn *et al.,* 1999; Pinedo *et al.,* 2006; Arévalo *et al.,* 2007; Krause-Jensen *et al.,* 2007). Given the highly variable nature of opportunistic species proportion (Wallenstein, 2011) and the fact that where macroalgal blooms are a concern it is the abundance rather than the number of opportunistic species that matters (Scanlan *et al.,* 2007), it seems more sensible to use substratum cover and abundance of representative taxa as set out generically by the WFD. As a matter of fact, most authors that have been working on the application of this Directive using macroalgae to assess ecological quality of coastal waters, have incorporated abundance in the tools developed (Orfanidis *et al.,* 2001; Pinedo *et al.*, 2006; Arévalo *et al.*, 2007; Ballesteros *et al.*, 2007; Scanlan *et al.*, 2007; Guinda *et al.,* 2008; Juanes *et al.,* 2008; Neto *et al.* 2011; Orlando-Bonaca *et al.,* 2008), with the exception of Wells *et al.* (2007). Opportunist cover, rather than the proportion of opportunistic species, was also included in the index here proposed given the importance of such a feature evidenced in scientific literature (see above). However, it is here suggested that all early successional species as in the ESG2 sense, whether nuisance opportunists or naturally fast growing species, are included in this category as means to incorporate the rationale behind Orfanidis *et al.* (2001)'s work. A great proportion of substratum covered by annual fast growing species, might be indicative of a community's successional stage caused by natural factors, but can also be indicative of an environmentally disturbed community. Expert knowledge would be necessary to analyze cases of extreme opportunist cover.

The changes in proportion of Rhodophyta and Chlorophyta species have been considered to be indicative of anthropogenic influences and shifts in quality status (Giaccone & Catra, 2004; Wells *et al.,* 2007). However, care must be taken when applying such measures to a wide geographical scale, as the proportion of red species increases and the proportion of brown species decreases with latitude (Lüning, 1990; Tittley & Neto, 1995, 2006; Terra *et al.,* 2008; Wallenstein, 2011). Similarly, the ratio between the number of late and early successional species, as proposed by Wells *et al.* (2007) and Wells (2008), differs substantially between Azorean and British shores. This feature has been criticized by Arévalo *et al.* (2007) and Ballesteros *et al.* (2007) for being an oversimplification of the functional-form model of macroalgae defined by Littler & Littler (1980) that does not distinguish stress-sensitive perennial species. Using specific ecological classifications of seaweed species in different geographical areas or different impact sources can lead to an unmanageable tool use, and it does not allow any comparison of results between different areas or impacts. The classification proposed by Orfanidis *et al.* (2001) has proven effective for the purpose it has been created for and has been applied in several regions (Panayotidis *et al.,* 2004; Wells *et al.,* 2007; Orlando-Bonaca *et al.,* 2008; Ivesa *et al.,* 2009; Orlando-Bonaca & Lipej, 2009). Therefore, it seems more sensible to focus scientific attention on the assignment of seaweed species to each of the two functional groups that best reflect their sensitivity to environmental disturbance, rather than having each research team using alternative approaches.

Red/green/brown species proportions and the ESG ratios differ significantly between the Azores and the BI (Wallenstein, 2011), thus reflecting geographically sensitive characteristics of seaweed communities. Using such features to evaluate the ecological quality of seaweed communities over a large geographical area like the NEA-GIG requires an adaptation of the value ranges of such features in order to reflect local patterns, as suggested by several authors (*e.g.,* Borja & Muxica, 2007; Hernández *et al.,* 2010; Bermejo, 2012). These features have therefore been excluded from the index here proposed due to the desirability to have a tool that can be applied over a wide geographical area without adaptation.

Despite the differences between the 4 methods, the manner in which EQR values are ranked is fairly consistent between them, which means that they value shore quality in a similar way. However, the CFR one produces higher EQR values and consequently inflates classification results. Some inconsistencies between this and the other 3 methods arise due to the partial score calculation scheme that results in a non-continuous EQR value scale and is therefore insensitive to intermediate rankings. Nevertheless, independently from the index used, shores are majorly classified as "good" and/or "high" as would be expected (Neto *et al.,* 2009). However, the establishment of "good-moderate-poor-bad" boundaries is crucial, and requires a pool of data from polluted shores. The lack of severely degraded shores makes it difficult to establish such boundaries. If one is defining a scale based on biological communities under pristine conditions, the other end of the quality spectrum would be necessary to allow the definition of a reliable quality scale.

This model works well for Azorean coastal communities, despite its sensitivity to naturally species poor shores, as it generally classifies shores as having good and/or high ecological quality. This is what is expected from a previous evaluation of Azorean shores by Neto *et al.* (2009), who simultaneously surveyed qualitatively and quantitatively several shores of S. Maria, S. Miguel, and Terceira, and classified them as having good and/or high ecological quality. In fact these shores do not differ significantly from any other shores on any island that have been surveyed for different purposes by the Marine Biology Group of the University of the Azores, thus leading to the belief that there is a generalized good and/or high ecological quality of Azorean shores.

The EQR values obtained with the proposed index correlate fairly well with the CFR and the MarMAT tools also indicating consistency between them. However, it needs to be tested in other geographical areas where other methods have been implemented to compare results, namely in the BI, Spain and Portugal. It would also be beneficial to have a wider geographical application of this method, namely in other Macaronesian archipelagos, to spread the area covered by ecological quality assessment surveys. It is also crucial that this method is tested under several pollution conditions as recommended by Guinda *et al.* (2008) to verify its applicability to impacted shores other than by nutrient enrichment. The calibration of this method is quite difficult in the Azores where pollution is nearly absent and its possible impacts are rapidly diluted by the effect of strong wave action. Such a scenario forces one to work only with the top end of the quality scale, without the bottom end to calibrate its boundaries. The nearest scenario in the Azores archipelago where coastal communities are subject to environmental conditions comparable to coastal pollution are those coastal communities where shallow water hydrothermal activity leads to increased temperature, acidity and heavy metal concentration within enclosed bays (Wallenstein *et al.,* 2012).

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