CAN FUNCTIONAL GROUPS BE USED TO DISCRIMINATE BETWEEN SITES ALONG A WATER QUALITY GRADIENT IN MALTESE COASTAL WATERS?

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ABSTRACT

This study investigates whether macroalgal functional groups can be used to distinguish between rocky shores subject to different degrees of anthropogenic stress. Macroalgae from seven sites situated along the rocky upper infralittoral (0-50 cm depth) of Malta and Gozo were seasonally sampled in 2003 and 2004. A total of 86 macroalgal species belonging to the following functional types were found: 6 articulated, 23 corticated-terete, 6 crustose, 35 filamentous and 16 foliose. The ANOSIM procedure applied to the percentage cover of each functional group detected significant differences between years, sites and seasons. The SIMPER procedure showed that the functional groups foliose, crustose and corticated-terete mostly contributed to determine the observed patterns in hierarchical group-average linkage cluster analysis and nMDS ordination. On the basis of the multivariate analyses made, it may be concluded that functional groups discriminated among sites.

KEYWORDS: Rocky shores; Macroalgal assemblages; Malta; Multivariate analyses; Functional groups.

INTRODUCTION

Macroalgae dominate subtidal rocky shores of temperate seas, where they have a fundamental role in determining biomass production and biodiversity of coastal systems. Macroalgae are considered as good descriptors of benthic communities and are widely utilized to characterize and monitor coastal systems; they are also one of the biological quality elements for the evaluation of ecological quality required by the European Water Framework Directive (WFD, 2000/60/EE) [1]. The structure of macroalgal assemblages is usually described by species composition and abundance, but the use of functional groups is becoming more widespread. However, in the Mediterranean Sea, the functional groups approach has received little attention and results have been variable [2, 3]. The present work investigates if functional groups are as good as species to distinguish between seven rocky shores which are subject to different degrees of anthropogenic stress and which were therefore expected to have a different ecological status.

MATERIALS AND METHODS

Seven shores around Malta (Fig. 1) were selected to have the same substratum type and comparable slopes but different degrees of anthropogenic impact. Site selection was based on the results of a long-term monitoring programme of local inshore waters based on measurement of dissolved nutrients, chlorophyll *a* concentration and of water transparency as indicators of environmental quality [4].

Five replicate 0.5 m × 0.05 m quadrats were placed at random in the upper infralittoral zone at each site and the percentage cover of each species of macroalga present was recorded three times a year in 2003 and 2004. Site locations included the Malta Freeport which is a large commercial transhipment centre, the Grand Harbour which is subject to episodes of eutrophication, and a reference site in Gozo.

Each macroalgal species identified was assigned to the appropriate algal functional group based on the model proposed by Steneck & Dethier [5]. The following functional groups were used: filamentous, foliose, corticated-terete, articulated calcareous and crustose. Leathery macroalgae were not present in the assemblages studied.

The species and functional group datasets were analysed using non-metric multidimensional scaling (nMDS) and hierarchical group-average linkage cluster analysis, both based on the Bray-Curtis similarity measure, and ANOSIM. Principal Components Analysis (PCA) was applied to water parameters. Computations were made using PRIMER 6 [6].

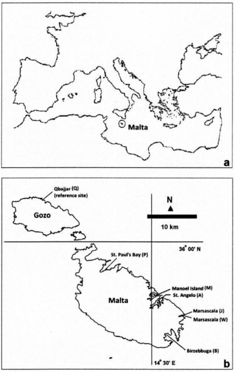

FIGURE 1 - Maps showing the location of: (a) the Maltese Islands in the Mediterranean; (b) the seven study sites.

RESULTS AND DISCUSSION

PCA ordination of environmental variables (Fig. 2) clearly distinguished the sites with PC1 and PC2 collectively explaining 77.3% of the variation; PC1 appeared related to chlorophyll *a* content and BAC, and PC2 to dissolved phosphate. The sites could therefore be arranged in a series with Qbajjar as the reference site and, in order of deteriorating water quality, St. Paul's Bay, Marsascala (J), St. Angelo, Manoel Island, Birzebbuga and Marsascala (W).

A total of 86 macroalgal species were found: 19 Chlorophyta, 25 Heterokontophyta and 42 Rhodophyta. Of these, 6

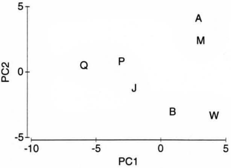

FIGURE 2 - PCA ordination of the sites based on mean values of salinity, temperature, dissolved nitrate, dissolved phosphate, Beam Attenuation Coefficient (BAC) and chlorophyll *a* content, recorded between 1998 and 2003 as given in the '*Monitoring Programme for Coastal Waters*'[4]. Site codes are as given in Fig. 1. Percentage variation explained collectively by PC1 and PC2 = 77.3%.

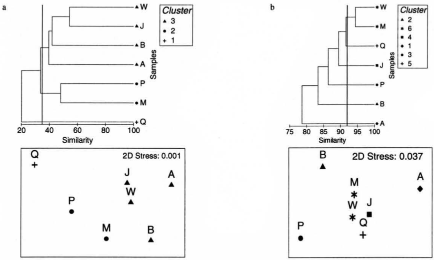

FIGURE 3 - Hierarchical group-average linkage clustering and nMDS ordination plots for mean infralittoral macroalgal percent cover for (a) species, and (b) functional groups. Site codes are as given in Fig. 1.

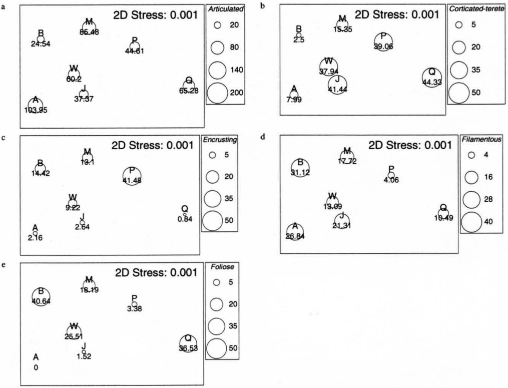

FIGURE 4 - NMDS ordination diagrams (based on fourth root transformed data and the Bray-Curtis similarity measure) for the 2003 and 2004 combined macroalgal percent cover datasets, with values of mean percent cover of: (a) articulated; (b) corticated-terete; (c) crustose; (d) filamentous and (e) foliose macroalgae, as overlays. Site codes are as given in Fig. 1.

were articulated, 23 corticated-terete, 6 crustose, 35 filamentous and 16 foliose species. One-way ANOSIM on the percentage cover of each functional group detected significant differences between sites both in 2003 (Global $R = 0.413$; $P < 0.001$) and in 2004 (Global $R = 0.283$; $P < 0.001$). The ANOSIM Global R value for the species list was also significant ($R = 0.731$; $P < 0.001$). The SIMPER procedure showed that the functional groups foliose, crustose and corticated-terete species mostly contributed to determine the observed patterns in the cluster analysis and nMDS (Figs. 3 and 4). Several species assigned to the corticated-terete group, including *Gracilaria* spp., *Acanthophora* spp. and *Gigartina* spp., are known to dominate in degraded marine infralittoral ecosystems [7] and in fact, *Gigartina* sp. contributed to 30% coverage at Marsascala (J) and 24% at Marsascala (W).

CONCLUSIONS

On the basis of the multivariate analyses made, it may be concluded that the functional groups approach did discriminate between the sites. However, the ordination obtained using functional groups did not agree with that obtained when using water quality parameters. Moreover, compilation of species lists permitted a higher resolution separation of the infralittoral macroalgal communities at the various sites. For example, Qbajjar was distinct from the rest of the sites studied when the species dataset was used, but not when the functional groups dataset was employed. These results are in agreement with other studies where both approaches were used (for example, [8]). Species ordination also does not correspond to the water quality ordination but, the reference site was clearly separated from the others and three of the four sites with bad ecological status (according to the PCA ordination) group together on the same side of the nMDS plot.

Therefore, functional groups may allow the evaluation of the structure of Mediterranean macroalgal communities in relation to the degree of anthropogenic impact, although with more loss of information than using species-level data. Clearly, further work is necessary to optimise ecological status evaluation protocols and to find a robust and cost-effective monitoring method using a combination of the species and functional groups approaches.

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