Assessment of the ecological status of Maltese coastal waters using the Ecological Evaluation Index (EEI)

MARTHESE AZZOPARDI, PATRICK, J. SCHEMBRI
marthese.azzopardi@um.edu.mt

Department of Biology, University of Malta, Msida MSD2080, Malta

INTRODUCTION

Benthic macroalgae are a reliable indicator of the trophic status of coastal waters. Macroalgae 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).

AIM

The Ecological Evaluation Index (EEI) described by Orfanidis *et al.* (2001), a specific biological index for the implementation of the WFD in the Mediterranean, was applied to seven sites with different degrees of anthropogenic stress and which were therefore expected to have a different ecological status. One aim was to assess if the EEI would discriminate between these sites and another was to investigate whether the annual EEI value remained stable for each site over a two-year period.

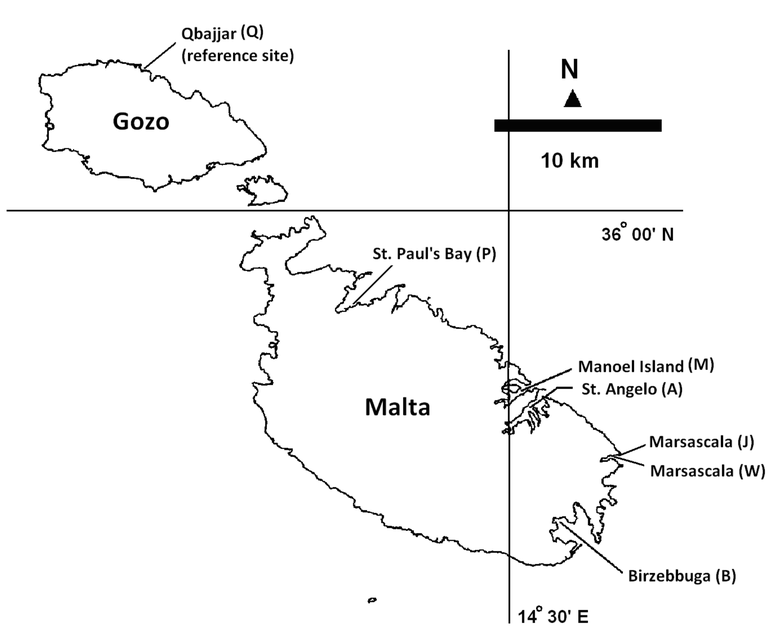


Fig. 1 Map of the Maltese Islands showing the location of the seven study sites.

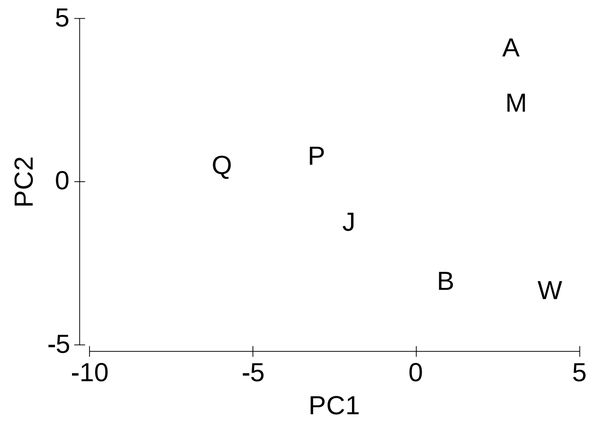


Fig. 2 PCA ordination of the sites based on mean values of salinity, temperature, dissolved nitrate, dissolved phosphate, Beam Attenuation Coefficient (BAC) and chlorophyll *a* content, recorded between 1998 and 2003 as given in the '*Monitoring Programme for Coastal Waters*' directed by V. Axiak (2004). (Site codes are as given in Fig. 1). Percentage variation explained collectively by PC1 and PC2 = 77.3%

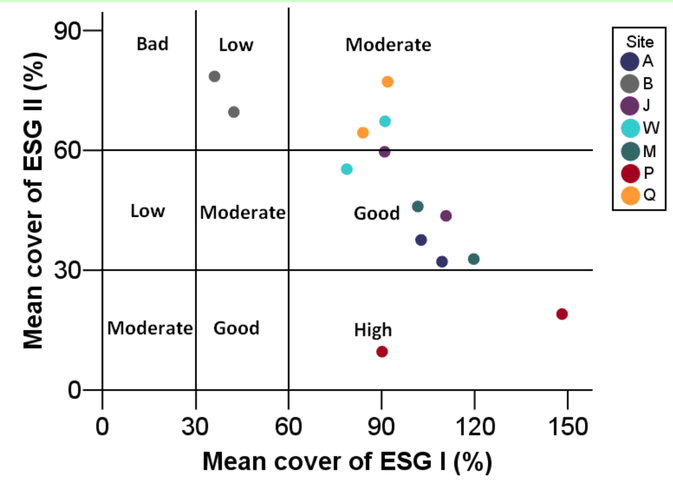


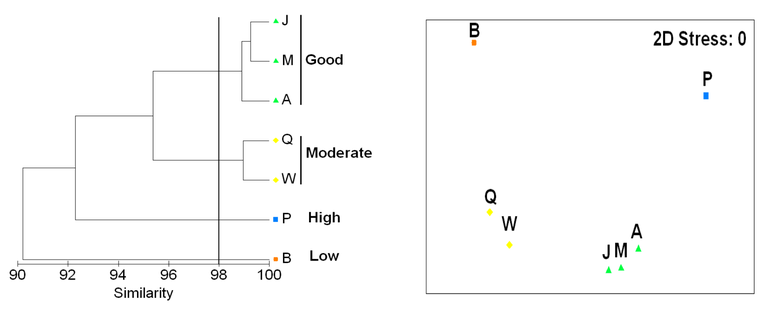
Fig. 3 Categorised scatter plot of the average macroalgal % cover of Ecological Status Groups ESG I and ESG II, for the study sites in 2003 and 2004. The vertical and horizontal lines divide the scatter plot in five Ecological Status Classes as proposed by Orfanidis *et al.* (2001). (Site codes are as given in Fig. 1).

MATERIALS & 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 levels of nutrients, chlorophyll and water transparency as indicators of environmental quality (Axiak, 2004).

Five replicate 0.5 m x 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, the Grand Harbour, which is subject to episodes of eutrophication, and a reference site in Gozo. For each site, the EEI was worked out separately for the 2003 and 2004 macroalgal percent cover datasets as well as for the mean percent cover of both years.

The results were analysed using non-metric multidimensional scaling (nMDS), cluster analysis based on the Bray-Curtis similarity measure, and Principal Components Analysis (PCA). Computations were made using the PRIMER (ver 6) suite of programs (Clarke & Gorley, 2006).



(a) (b)

Fig. 4 (a) Hierarchical group-average linkage clustering plots for mean annual infralittoral macroalgal percent cover of ECG (Ecological Status Group) I and ESG II species recorded over the two-year study period; the Bray-Curtis similarity measure was used to quantify similarity. (b) NMDS plot, for mean annual infralittoral macroalgal percent cover of ESG I and ESG II species recorded over the two-year study period; the Bray-Curtis similarity measure was used to quantify similarity. Colours correspond to the Environmental Quality Standards classes in accordance with the Water Framework Directive. (Site codes as in Fig. 1).

RESULTS

PCA ordination based on environmental variables (Fig. 2) clearly distinguished the sites with PC1 and PC2 collectively explained 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). In total, 86 taxa were recorded: 19 Chlorophyta, 24 Phaeophyta, 42 Rhodophyta and 1 Heterokontophyta. For each site, the Ecological Status Class based on EEI was the same in 2003 and 2004 (Fig. 3), except for Marsascala-W, which was 'good' in 2003 and 'moderate' in 2004. The nMDS ordination (Fig. 4b) had a stress value of 0 and grouped Marsascala-J, Manoel Island and St. Angelo together as 'good status' sites, Qbajjar and Marsascala-W as of 'moderate status', and separated St. Paul's Bay and Birzebbuga from the other sites due to the 'high status' of the former and the 'low status' of the latter.

CONCLUSIONS

The EEI did generally discriminate between sites, however, the St. Angelo and Qbajjar sites (Fig. 5) gave unexpected results. A 'high' Ecological Status was expected for Qbajjar, the reference site, and a lower ranking value was expected for the St. Angelo site due to the depauperate assemblage present there. A relatively high percentage cover by *Halopteris scoparia* (ESG II), contributed towards the 'moderate' Ecological Status obtained for Qbajjar. At St. Angelo, some factors, which may include herbivory, were operating to exclude ESGII macroalgae.

With one exception, the EEI calculated on the annual mean macroalgal percentage cover was consistent in classifying sites to the same ecological status in 2003 and 2004. The ability to discriminate between sites, combined with lack of interannual variation, suggests that the EEI may be a valuable tool in monitoring Maltese rocky shores. However, the anomalous results obtained indicate that it should be used with caution as the index greatly depends on which macroalgae are assigned to which ESG.

(a)

(b)

Fig. 5(a) Shore at St. Angelo spring 2004 showing an extensive pink-purple band of *Corallina elongata* (b) Shore at the Qbajjar reference site in spring 2004 showing extensive patches of *Cystoseira compressa* and *Halopteris scoparia* (dark brown areas).

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