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Evaluation of ecological status of the Persian Gulf inshore waters (Hormozgan rocky bottoms) using macrophytic communities and a macroalgae biological index, EEI

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Abstract

Marine benthic macrophytes (seaweed and seagrasses) are key structural and functional components of some of the most productive ecosystems of the world. They absorb nutrients through their surface directly from the marine environment and thus they are very important biological elements for the estimation of ecological status, representing reliable indicators of coastal waters. The aim of this study was to assess the ecological status and trophic level of Hormozgan rocky bottoms according to Ecological Evaluation Index (EEI) .Sampling was done bi-monthly at seven stations at the intertidal rocky shores, west of Hormozgan Province. In this study a total of 63 species were identified, of which 15 species from seven genera belonged to green algae; 16 species from five genera belonged to brown algae; and 32 species from nine genera belonged to red algae. Coverage data of macroalgae and EEI indicate a high level of eutrophication for *Saieh khosh*, and *Bostaneh*, They are classified as zones with bad and poor ecological status, respectively. Also it has been proved that concentrations of biogenic elements and phytoplankton blooming are higher in these zones. The best values of the estimated metrics at *Tahooneh* and *Michaeil* could be explained with the good ecological conditions in those zones and the absence of pollution sources close to those transects. The values of abundance of macroalgae and EEI indicate moderate ecological conditions for *Koohin, Lengeh* and *Chirooieh*.

Keywords: Ecological evaluation index, Trophic Level, Inshore waters, Macroalgae

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Introduction

Nutrient enrichment from anthropogenic or natural sources is the major source of pressure in high valued transitional and coastal ecosystems, resulting in increased growth of primary producers and production of organic matter and eutrophication (Costanza *et al.,* 1997). Marine benthic macrophytes as photosynthetic sessile organisms being at the base of food web are vulnerable and adaptive to human and environmental stress of water and sediment (especially for seagrasses) (Dencheva 1996; Moncheva *et al.*, 2001; Prodanov *et al.*, 2001; Stefanova *et al.*, 2005). Macrophytic communities grow in the nearest coastal zone, absorb the biogenic elements directly through their entire surface from the marine environment and are the first to react to the pollution from land sources. They respond directly to the abiotic and biotic aquatic environment representing reliable indicators of its changes so their communities are often used as bioindicator of ecological status (Dauer 1993; Bricker *et al.*, 1999; Gibson *et al.*, 2000; EEC, 2000).

Human activities in the last decades have greatly accelerated eutrophication by increasing the rate at which the nutrients and organic substances enter the Persian Gulf. Under such conditions plants are the first to react to the eutrophication factors. This has resulted in decrease of biodiversity and degradation of biological structures of the ecosystem. So the aim of this study was to estimate the present trophic level and to assess the ecological status of Hormozgan rocky shores, according to macroalgae community structure and EEI.

Material and methods

Sampling stations were chosen in the intertidal rocky flats along 250 km of coastline of the Hormozgan Province (Fig. 1) (Table 1).

Sampling was conducted bimonthly from March 2012 to January 2013. At each site, five quadrats were sampled randomly by throwing. The macroalgae were taken from quadrates of 100×100 cm^2 and carried to the laboratory in plastic bags. Some water quality parameters, nutrient content and chlorophyll a (Chl-a) were measured at the sites of plant collections (Figs. 2, 3 and 4).

According to Orfanidis *et al.* (2001, 2003) the assemblage of benthic macrophytes in each sample and the coverage (%) of species (less than 30% coverage, between 30 and 60% coverage, above 60% coverage) belonging to the predefined categories of ESG I and ESG II, was assessed. In order to establish an ecological index representing the degree of stress in each sample, the various combinations of scores in ESG I and II were classified as bad, low, moderate, good and high with the respective scores of 2, 4, 6, 8, and 10 (Table 2).

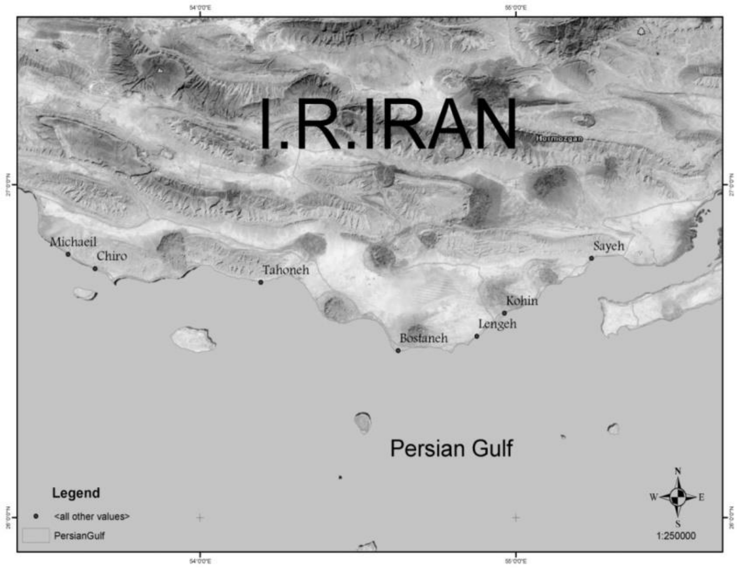

Figure 1: The map of sampling zones shores of Hormozgan Province.

Table 1: Coordinates of the sampling stations.

Stations	**Coordinates**	
Saieh khosh(St1)	26° 47.10' N	55° 19.41' E
Koohin (St2)	26° 36.48' N	54° 57.51' E
Lengeh (St3)	26° 32.37' N	54° 52.35' E
Bostaneh (St4)	26° 30.2' N	54° 37.39' E
Tahooneh (St5)	26° 42.20' N	54° 11.33' E
Chirooieh (St6)	26° 44.50' N	53° 40.4' E
Michaeil (St7)	26° 49.9' N	53° 32.21' E

Source: author's field survey, 2012.

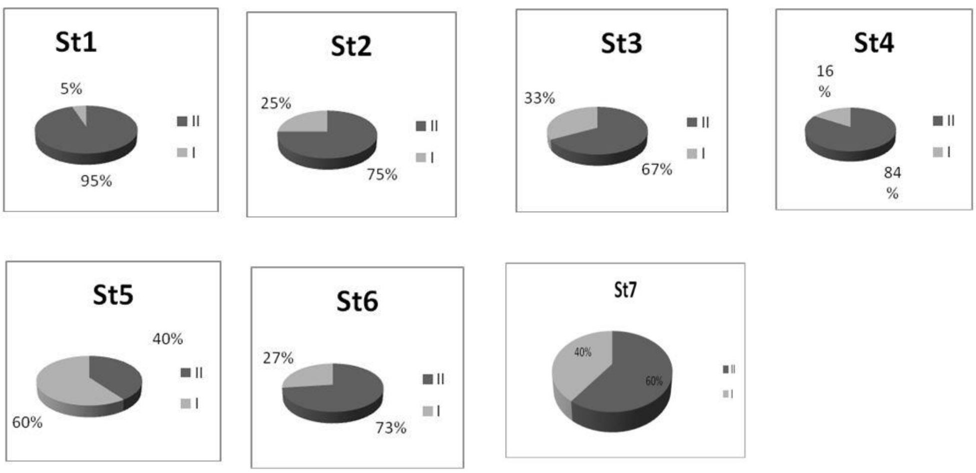

Figure 2: Average macroalgae coverage of two ecological status groups, ESG I and ESG II: 1. ESG II – Percentage coverage values of tolerant species; 2. ESGI – Percentage coverage of sensitive species.

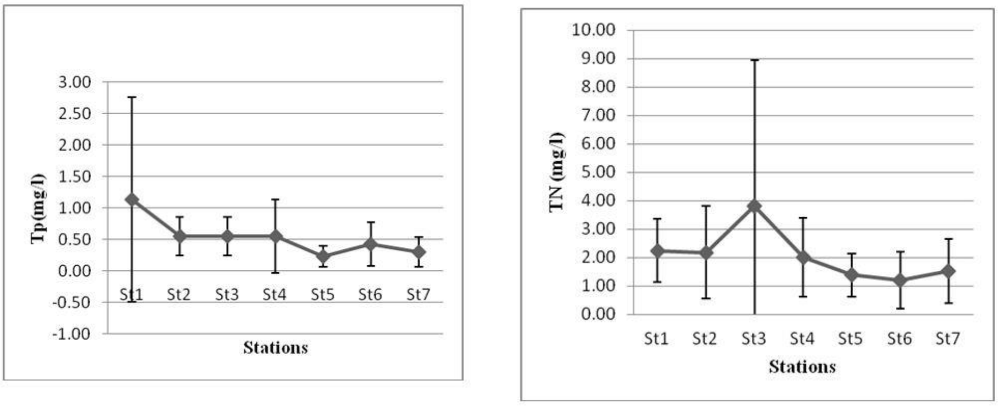

Figure 3: Concentrations of nutrients in the stations.

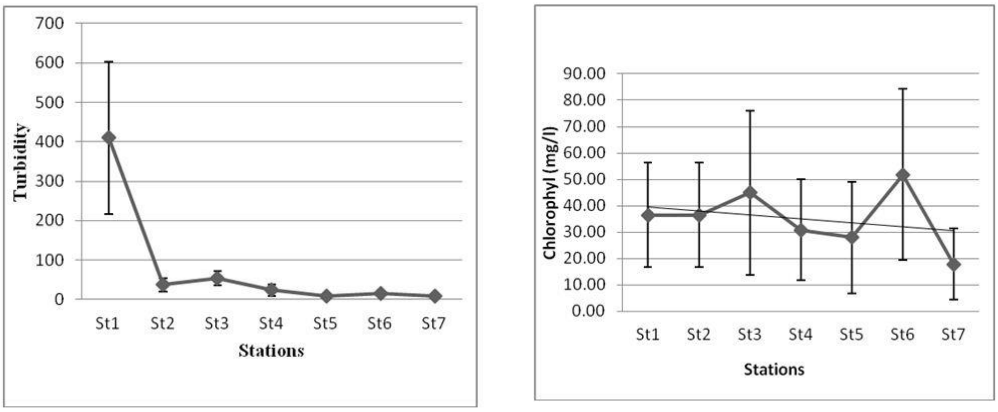

Figure 4: Turbidity and chlorophyll-a in the stations.

Table 2: Values and boundaries of the ecological evaluation.

	High	Good	Moderate	Poor	Bad
EEI	$10 \geq EEI > 8$	$8 \geq EEI > 6$	$6 \geq EEI > 4$	$4 \geq EEI > 2$	$2 \geq EEI > 0$

Source: Dencheva, K., 2009.

Sampling can follow a nonaligned block design, in which a sample is located randomly within a representative permanent cell of dimensions 10m×10 m. The absolute abundance (%) of each ESG is estimated by abundance (%) in each sample. Three samples per season per cell could be an optimum sampling frequency (Orfanidis *et al.*, 2001; Minicheva *et al.*, 2003).

Results

From the investigated samples through 2012–2013, 63 species from 21 genera were established. 15 species from seven genera belonged to Chlorophyta, 16 species from five genera belonged to brown algae and 32 species from nine genus were from Rhodophyta. Five genera belonged to the sensitive group, or K-strategic, and 16 were tolerant, or r-strategic, belonging to the second ESG II, as defined by Orfanidis *et al.* (2001)(Table 3).

The coverage values of the sensitive species were high in Station 5 (60 %), followed by values in Station 7 (40%).

Table 3: Floristic structure of algae from the investigated sampling locations and ecological status groups (ESG).

Genuse	Sampling sites							
	St1	St2	St3	St4	St5	St6	St7	ESG
Acetabularia					+	+		I
Caulerpa		+		+	+	+		II
Cheatomorpha	+		+	+	+	+	+	II
Cladophora	+	+	+	+	+	+	+	II
Dictyospheare		+	+	+			+	II
Enteromorpha	+	+	+	+	+	+	+	II
Ulva						+		II
Colpomenia	+	+	+	+	+	+	+	II
Cystoceria		+	+	+	+		+	I
Dictyota	+		+	+		+	+	II
Padina	+	+	+	+	+	+	+	I
Sargassum		+	+	+			+	I
Acanthophora			+	+	+	+	+	II
ceramium	+						+	II
champia	+	+	+	+	+	+	+	II
Gelidium				+	+	+	+	II
Gracilaria		+	+	+	+	+	+	II
Hypnea	+	+	+	+	+	+	+	II
jania			+	+	+	+	+	I
laurencia	+	+	+	+	+	+	+	II
Polysiphonia	+	+	+	+	+	+	+	II

Source: Author's field survey, 2013.

The higher percentage coverage of sensitive taxa was for *Padina*, *Sargassum and Jania*, indicators of pure waters. The lowest percentage values for the tolerant species were estimated at Station 5 (40%), followed by assemblages in Station 7 (60%). The highest coverage values of the tolerant representatives was registered in St1 (95%), followed by St4 (84%), St2 (75%), St6 (73%) and St3 (63%). There were no sensitive species in St1, St4, St2, St6 and St3 indicating the high level of nutrient pollution in these zones.

Mean concentrations of nutrients and chlorophyll-a were higher in stations 1, 2 and 3; stations 4 and 6, were related mainly to the impact of industrial sewage. They are classified as zones with bad and poor ecological status, respectively (Table 4) (Figs 5 and 6).

Table 4: Ecological status based on the ecological evaluation index (EEI) and correlation ratio of the abundance between the ecological statuses groups (%).

Sampling sites	Ecological evaluation index – EEI	Percentage correlation ratio of the abundance between the ecological status groups ESGI: ESGII (%)	Ecological status
St1	2	5:95	Bad
St2	2.8	25:75	Poor
St3	3.4	33:67	Poor
St4	2.4	16:84	Poor
St5	7.3	60:40	Good
St6	2.9	27:73	Poor
St7	4.2	40;60	Moderate

Source: Author's field survey, 2013.

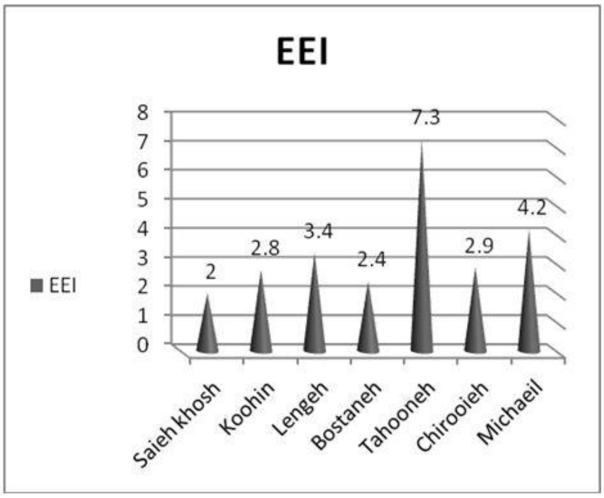

Figure 5: Different EEI in the stations.

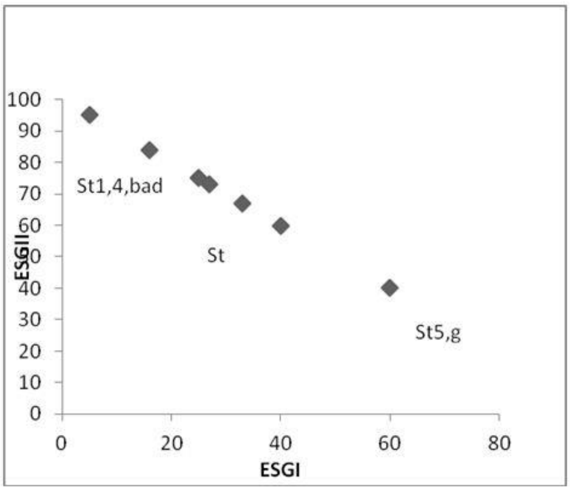

Figure 6: Macroalgal coverage (%) and classification into ecological categories by the use of EEI for samples.

The best values of the estimated metrics at station 5 and station 7 could be explained with the good and moderate ecological conditions and the absence of pollution sources close to those stations.

Discussion

The EEI quantifies shifts in transitional and coastal waters from pristine to degraded state, which is dominated by opportunistic species (Odum, 1985). In general, macrophyte community changes can be better connected to natural or anthropogenic stress when a relevant biotic index links the variability to natural or anthropogenic processes. The successional model and the biotic index EEI are based on the existence of a gradient between two stable states, which represent pristine and degraded conditions (Orfanidis *et al.*, 2001, 2003). The dominance of the late-successional or competitor species of the genera *Cystoseira* formed communities indicative of a pristine state, which is characterized, for example, by low nutrient and clear water conditions, whilst the dominance of ruderals or opportunistic seaweeds as *Ulva* and *Gracilaria* is characterized by high nutrients, heavy metals and turbid conditions. The coexistence of the late-successional and opportunistic species (high species number and their coverage area) form communities that are indicative of intermediate conditions. At intermediate levels of pollution "competitive species'' are replaced by ''stress-tolerant species'', and ''ruderal species'' take their place in highly polluted sites (Are´valo *et al*., 2007).

The phytoplankton concentrations in Hormozgan inshore waters, as indicated by Chl-α estimates, were high (annual mean of Chl-α=51.78 mg L^{-1}), especially for site 1 to 3, the lowest at site 7, with (27.91mg L). Algal biomass and weather conditions seem to influence the oxygen and pH variability pattern at all stations. N/P ratio is indicating all year nitrogen importance for primary production (N/P<16:1; Redfield, 1958) with a decreasing gradient of TP and TN concentrations from site 1 to site 5. Turbidity and suspended material followed similar spatial patterns (Fig. 4) in our study area showing the importance of nutrient induced phytoplankton growth to underwater light regime (Scheffer, 1997), affecting the growth and survival of marine benthic macroalgae (Cloern, 2001; De Jonge *et al.*, 2002).

Maximum Entromorpha and Cladophorepsis coverage was also observed at Stations 1, 2 and 3, followed by *laurencia* and *Cladophora* at sites 4 and 6, which are polluted areas of the Hormozgan rocky shores. Such macroalgal blooms of fast-growing species like *Cladophorepsis* that occur frequently in eutrophic estuarine and coastal ecosystems are generally explained by high nutrient availability (Stamatis *et al.,* 2006). *Padina* species were defined as dominant species from ESGI at all stations with the exception of station 5 and seems to be stress-tolerators which are able to grow in various stress conditions. The absence of long-lived genera like Sargassum, Jania and Cystoceria from ESG I, in stations 1 and 3 should be regarded as indicative of environmental degradation, when correlated with key abiotic parameters, like nutrient inputs, and then reduction of light penetration and development of the highest photophilic brown and red alga (Gibson *et al.*, 2000). On the basis of the obtained data for the year 2007, the ES of Slovenian coastal waters were reconfirmed as High/Good in terms of the European Water Frameworks Directive criteria (Orlando–Bonaca *et al.,* 2009). Ivesa *et al*. (2008), like Arevalo *et al.* (2007), expressed the correct evaluation of the role of algae Cystoceria that belongs to ESGI.

Finally three ecological statuses were established for the Hormozgan rocky shore according to EEI. At stations1, 2, 3, 4 and 6 the ecological status of macroalgae was evaluated as poor. The low ecological status values at these stations in Hormozgan are determined by the prevalence of species with high specific surface area and low biomass, which is typical for the species of ESG II. Also there was a tendency for a decrease of sensitive species and the macrophyte communities as a whole. The value of biomass, specific surface and EEI, indicate a high level of eutrophication for Varna, and Beloslav Lakes and Bourges Bay (Dencheva, 1996). It proved that concentrations of biogenic elements and phytoplankton/blooms are higher in these zones (Rojdestvenskil, 1986, 1993; Stojanov, 1991; Velikova, 1999). The best values of the estimated metrics in Maslen Nos (Dencheva, 1996) are explicable due to the good ecological conditions in this zone and the absence of sources of pollution close to this transects (Rojdestvenskil, 1986, 1993).

The main change in Hormozgan has been the reduction of biomass of Cystoseira species, which is an indication of high water quality. These macrophytes were replaced by other species such as Enteromorpha; Cladophora, which have higher specific surface area, especially in more eutrophic stations (Dencheva, 2009). In site 5 with good ecological status, *Padina* was the dominant ESGI species and some ESGII species like *Caulerpa*, *Dictyospheare*, *Ulva*, *Dictyota* and Ceramium were absent at all times. In site 7, moderate ecological status was determined by predominance of ESGI species, *Sargassum* and *Jania*, which are going to be replaced by the presence and higher coverage of all ESGII species.

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