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Original Article

# Study of the macroalgae and application of ecological evaluation index (EEI-c) in the coastal waters of Algeria

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**Abstract:** The diversity of macroalgae and evaluation of the Algerian coastal waters using EEI-c index were studied. Macroalgae were sampled at seven stations in summer 2019. Coverage data for the macroalgae at each site were analysed at species level. Eleven species have been identified and the results showed the prevalence of *Cystoseira compressa* and *Ulva* sp.. The least abundant species were *Cladophora* sp. and *Corallina elongata*. Classification of sites based on the cluster analysis shewed an agreement with the water degradation information. Based on the results, the EEI-c values were quite homogeneous over all the studied sites, and generally correspond to undisturbed states except for one site.

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## Introduction

Macroalgae are the main primary producer in aquatic water bodies (Graham et al., 2007), and also habitat for microfauna and microflora (Chabot and Rossignol, 2003). The coastal environment that shelters algae is strongly influenced by anthropogenic activities, such as fishing, submarine hunting and leisure activities, urbanisation, industries and agriculture (McManus and Polsenberg, 2004). Therefore, algae are not adapted to these disturbances, declining their communities as seen in the Mediterranean (Thibaut et al., 2005; Serio et al., 2006; Ballesteros et al., 2007). In addition, macroalgae are used as bioindicators of the ecological status of coastal waters (Cabioc'h et al., 2014; Pereira and Neto, 2015). The ecological status assessment is based on macroalgae, invertebrates and angiospermae (Marques et al., 2009; Abbasi and Abbasi, 2012; Badreddine et al., 2018; Belhaouari, 2019).

The EEI-c (Ecological Evaluation Index) is one of the ecological index based on macroalgae (Orfanidis et al., 2011), which is used to assess the ecological status of coastal waters (Gabriel et al., 2014; Caldeira et al., 2017; Amaral et al., 2018; Caldeira and Reis, 2019). Algerian coast macroalgae are poorly studied and their exploitation is still marginal (Chabane et al., 2018; Traich et al., 2018), therefore, the present study aimed to examine the diversity of macroalgae and the evaluation of the Algerian coastal waters using EEI-c index.

## Materials and Methods

Sampling was carried out at six sites (as S1-S6) on the coast of the Tenes in summer 2019 (Fig. 1), selected based on a non-aligned block design, in which a sample is located randomly within a representative permanent cell of dimensions 10×10 m. Each site was selected along the coastline at a depth range of 0.1-0.5 m (Orfanidis et al., 2003). The samples were scrapped using a hammer and chisel in a quadrat of 25×25 cm from 25 squares with five replicates (Boudouresque, 1971; Orfanidis et al., 2001). Characteristics of the sampling sites are presented in Table 1.

Species were identified based on Cabioc'h and Floc'h (2014) and Mangialajo et al. (2008). In each site, total average cover (TAC) of each species was calculated using the formula of TAC = ΣRi/N (Boudouresque, 1971), where Ri is the percentage of

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Table 1. Characteristics of the sampling sites.

| Sites | pH | Temperature | Salinnity | Anthropogenic activities |
|---|---|---|---|---|
| Anglaise Beach (S1) | 8.365±0.17 | 25 ±2.0 | 38.173±0.12 | Swimming |
| Ain El Kadi Beach (S2) | 7.62±0.63 | 24.5±1.0 | 37.974±0.42 | Domesticwaste waters |
| Charrir Beach (S3) | 8.346±0.15 | 24±1.0 | 37.490±0.21 | Swimming |
| Sonaric Beach (S4) | 8.317±0.02 | 25.5±2.0 | 37.940±0.32 | Touristic complex |
| Mainis Beach (S5) | 7.983±0.23 | 25±2.0 | 38.222±0.26 | Swimming and artisanal fishing |
| Cap Kaf-Kala Beach (S6) | 8.35±0.46 | 25.5±2.0 | 37.865±0.57 | Swimming |

Table 2. Ecological status class boundaries coastal waters based on the Ecological Evaluation Index (EEI-c) continuous formula.

| Ecological status classes | EEI-c boundary values | EEI-c EQR boundary values |
|---|---|---|
| High | 9.72±0.46SD | 0.97±0.06SD |
| Good-High | 8.09±0.74 SD | 0.76±0.09SD |
| Good-Moderate | 5.84±0.70 SD | 0.48±0.09SD |
| Moderate-Low | 4.04±0.68 SD | 0.25±0.08SD |
| Bad | 2.34±0.78 SD | 0.04±0.10SD |

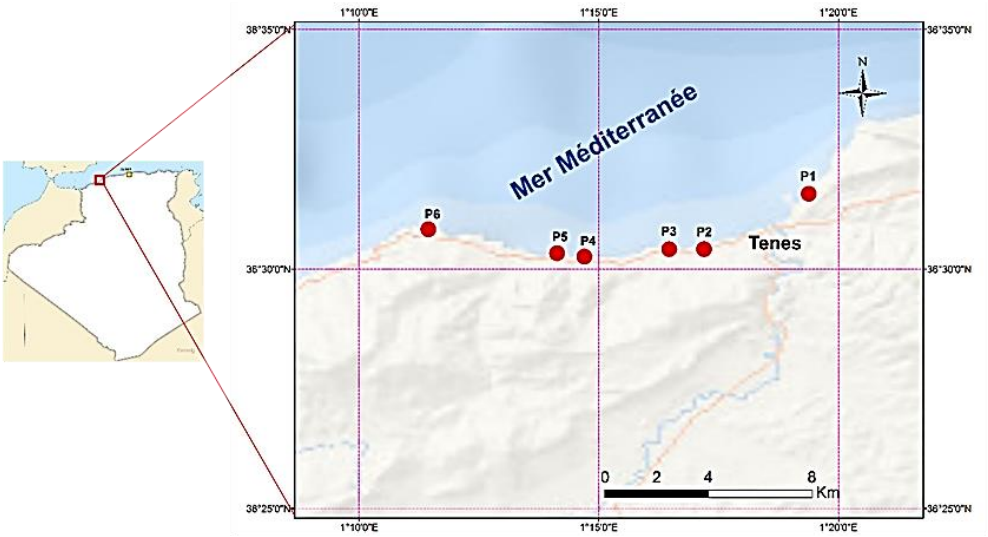


Figure 1. Map of the sampling sites on the coast of the Tenes.

area of the quadrat covered by species i, and N = number of quadrat. Hierarchical cluster analysis (HCA) was performed to establish a hierarchy of clusters (Rokach et al., 2005). HCA is used to classify species with similar behaviour according to a set of variables based on Orfanidis et al. (2011).

Ecological status of the six sites were determined by EEI-c (Orfanidis et al., 2011). Macroalgae were used as bio-indicators of the ecosystem shifts, from the pristine state with late-successional species (ecological state group I) to the degraded state with opportunistic species (ecological state group II). ESG I comprises thick perennial (IA), thick plastic (IB) and shade-adapted plastic species (IC), and ESG II comprises fleshy opportunistic (IIA) and filamentous sheet-like opportunistic (IIB) species (Table 2).

The absolute abundance (% coverage) of ESG I = [(IA*1) + (IB*0.8) + (IC*0.6)] and ESG II = [(IIA*0.8) + (IIB*1)]

The EEI-c was applied using the formula:

$$EEI\text{-}c\ (ESGI, ESGII) = a + b * (ESGI/100) + c * (ESGI/100)^2 + d * (ESGII/100) + e * (ESGII/100)^2 + f * (ESGI/100) * (ESGII/100).$$

The coefficients of the hyperbola are a = 0.468, b = 1.2088, c = –0.3583, d = –1.1289 and = 0.5129, f = –0.1869 (Orfanidis et al., 2011, 2014). The EEI-c can be transformed in accordance to the Ecological Quality Ratios as:

$$EEI\text{-}c\ EQR = 1.25 \times (EEI\text{-}c\ value/RCvalue) - 0.25$$

$$RC = 10$$

Table 3. Specific richness of the sampling sites.

| species | S1 | S2 | S3 | S4 | S5 | S6 |
|---|---|---|---|---|---|---|
| **Phaeophyceae** | | | | | | |
| *Cystoseira compressa* | + | - | + | + | + | + |
| *Cystoseira mediterrania* | + | + | + | + | + | + |
| *Halopteris scoparia* | + | - | + | + | + | + |
| *Sargassum* sp. | + | - | + | + | + | + |
| *Dictyopteris* sp. | + | - | + | + | + | - |
| *Dictyota fasciola* | + | - | + | - | + | + |
| *Padina pavonica* | + | - | + | + | + | + |
| **Rhodophyta** | | | | | | |
| *Corallina elongata* | + | + | + | + | + | + |
| **Chlorophyta** | | | | | | |
| *Ulva* sp. | + | + | + | + | + | + |
| *Ulva lactusa* | + | + | + | + | + | + |
| *Cladophora* sp. | + | - | + | + | + | + |

Table 4. Ecological Evaluation Index EEI-c and EEI-c EQRof the six sites.

| Sites | EEI-c | EEI-c EQR | Ecological status |
|---|---|---|---|
| **S1** | 8.07 | 0.75 | High |
| **S2** | 3.96 | 0.24 | Moderate-Low |
| **S3** | 7.33 | 0.66 | Good-High |
| **S4** | 5.46 | 0.43 | Good-Moderate |
| **S5** | 6.83 | 0.60 | Good-High |
| **S6** | 7.18 | 0.64 | Good-High |

## Results

The species richness (SR) of the studied sites are shown in Table 3. The total species richness of the study area was 11, including seven species of Phaeophyceae, one species of Rhodophyta and three species of Chlorophyta (Table 3). All species were observed in sites S1, S3 and S5 and the lowest species richness in the site 2 with four species.

The average cover of each species in the studied sites is shown in Figure 2. *Cystoseira compressa* reached its highest percentage (94.4%) in S3 and S5. *Cystoseira compressa* is the most abundant species in all sites, except S2, where it does not exist. This site is marked by the presence of *C. mediterrania.* The results showed an abundance of *Ulva* sp. with an average cover of 24.8-78.4% between stations. HCA identified three groups with 70% similarity that the first one consists of sites S1 and S3, and second S4, S5 and S6. The analysis highlights a third group represented by S2.

The results of EEI-c are shown in Table 4 and it revealed that the studied sites are not disturbed, except sites 2 and 4 with a moderate-low and good-moderate status, respectively. The results showed that S1 has high status and S3, S5 and S6 are in good-high status.

## Discussions

The observed macroalgae in the present study are common in the Mediterranean Sea (Cabioc'h et al., 2014; Traiche et al., 2018; Chabane et al., 2018). These eleven species have been already reported in the Algerian coast (Perret-Boudouresque and Séridi, 1989). Biodiversity of the macroalgae is influenced by many biotic and abiotic parameters (Arévalo et al., 2007; Belhaouari et al., 2014, 2017), and the specific richness of algae reaches the highest level in summer (Thibaut et al., 2005; Ballesteroset al., 2007). Based on the results, the members of the genus *Cystoseira* were found in all the sites. It is one of the widely distributed genera of the Fucales (Ochrophyta, Phaeophyceae) (Amico, 1995; Draisma et al., 2010), and the majority of taxa are found in the Mediterranean Sea and the adjacent Atlantic Ocean (Oliveras and Gomez, 1989; Amico, 1995).

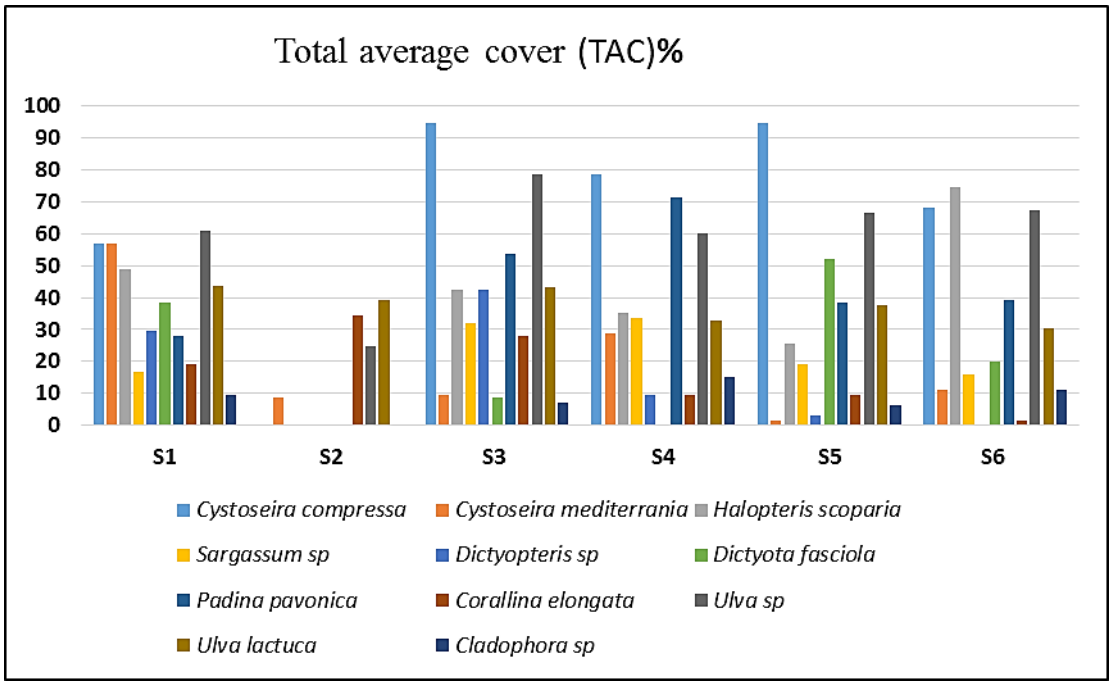


Figure 2. Total average cover of species in the six sites

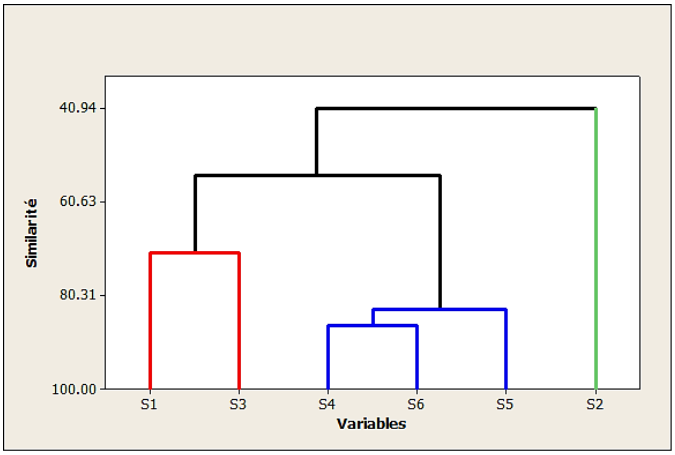


Figure 3. The results of the ascending hierarchical classification of sampling sites.

The average cover results indicate that the dominance of macroalgae in the study area is shared by *Cystoseira* and *Ulva*. *Cystoseira* species are slow-growing and late-succession taxa, i.e. species with low growth rates and long life cycles (ecological state group I) and *Ulva* sp. is a fast-growing opportunistic species i.e. species with high growth rates and short life cycles (ecological state group II) (Orfanidis et al., 2003). Cohabitation between these two macroalgae was reported by Traiche et al. (2018) in the coastal waters of the Chlef. Chabane et al. (2018) reported similar results in the coastal waters of Algiers. The most abundant species i.e. *C. compressa* in the study area are not present in six sites. Species abundance may be influenced by nutrient inputs, coastal hydrodynamics and climatic conditions (Birje et al., 1996; Pereira and Neto, 2015; Traiche et al., 2018). On the other hand, by the anthropogenic pressure (Boudouresque et al., 2009; Gihan, 2013; Bermejo et al., 2016), the combination of these phenomena may explain the difference in overall average cover at the sampling sites.

HCA allowed the acquirement coherent and informative data Sites 1 and 3, representing the same groups, this is due to the types of species that these beaches shelter. These two stations shelter all the species listed in this study. Site 5 shelter 11 species, but it grouped with S4 and S6 which shelter 10 species. It appears that the abundance of species has a strong influence on their classification (Orfanidis et al., 2011; Caldeira et al., 2017; Amaral et al., 2018). Site 2 constitutes an isolated group, by having four species.

The results of EEI-c showed that the site 1 has high quality, explained by non-effecting from any anthropic pressure. The site 2 has low quality, and in accordance with our expectance because of receiving wastewater of the Tenes. Wastewater has a negative

impact on quality of the coastal waters (Smith and Shackley, 2006; Boucetta et al., 2016). This result is in agreement with the classification of the sites in our study. Many studies have shown that with a nutrient enrichment gradient, the most impacted sites are systematically characterized by low taxa richness (Arévalo et al., 2007; Pinedo et al., 2007). Site 4 has a moderate quality; a hotel complex is located near this site, which can have a negative effect on the quality of the coastal waters and their ecological status. Indeed, it is considered that tourist activities can cause multiple negative impacts on aquatic ecosystems (Marchand, 2014; Valavanidis, 2018). The results of EEI-c confirm the reliability of EEI-c to be adapted for evaluation of Algerian coastal.

## Conclusion

This study has allowed us to better understand the biodiversity of the macroalgae and ecological status of Algerian coastal waters. The EEI-c results confirm that the coastal waters of our study area are generally qualified as a good ecological state. The distribution of macroalgae is influenced by anthropogenic activities. This study confirms the importance of preserving macroalgae to protect coastal ecosystems and indicated macroalgae as good indicators of the Algerian coastal waters. We suggest the use of the EEI-c index as part of the biomonitoring and sustainable management of the Algerian coastal.

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