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Ecological Diagnosis of the Algerian West Coast Marine Environment by Using Benthic Macroalgae

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ABSTRAT

The main objective of this study is to carry out an ecological diagnostic of intertidal rocky marine habitats in Oran coastline (South Western Mediterranean). The ecological status and ecological quality were assessed by using the abundance and composition of benthic macroalgae to indicate shifts in the aquatic ecosystem in Nine (9) targeted stations. The floristic inventory has revealed a total of 18 taxa, including 5 Rhodophyta, 8 Phaeophyta and 5 Chlorophyta. The calculation of environmental quality indices (average cover, global average cover and species richness) showed a heterogeneity in the composition and the distribution of macroalgae between the different stations as well as a very high diversity at the station (S1) which was characterized by the presence of fourteen (14) species of algae of the three groups compared to the other stations. The algal flora of the Oran Bay was characterized by the dominance of Chlorophyta, followed by Phaeophyta and Rhodophyta.

***Key words :** Biodiversity, Biotic indices, Intertidal zone, Macroalgae, Oran coastline*

Introduction

Coastal marine ecosystems are environments that are increasingly affected by human activity. Industrialization and the development of cities and human societies in the coastal zone are the main causes of the increase in ecological pressure on these environments. However, the Algerian coasts are not spared by this pollution. Indeed, several studies have demonstrated the impact of anthropogenic activities on Algerian coastal ecosystems (Rouane Hacene *et al.,* 2015; 2018; Benaissa *et al.,* 2017; Rouabhi *et al.,* 2019). However, in order to counter the degradation of natural marine environments, it is essential to develop tools for assessing and monitoring the quality of the marine environment. (Pinedo *et al.,* 2007; Bélanger 2009). Thus, over the last few decades, the science of bioindication has been developed. The latter is based on the use of living organisms to assess the environmental conditions of a given environment, using numerous tools (bioindicators, biomonitors, bioaccumulators, biomarkers, etc.) and allowing the management and maintenance of coastal marine ecosystems. Among the various bioindicators, seaweeds can be used to assess the quality of the marine environment. These sessile organisms provide a local picture of contamination. In addition, they are sensitive to disturbances in the water column and sediments (García-Seoane *et al.,* 2018). Benthic macroalgae are very good bioindicators of water quality in marine ecosystems (Borowitzka, 1972; Munda, 1974 ; Littler and Murray 1975 ; Murray and Littler 1978; Belsher 1979; Levine, 1984; Kautskyl *et al.,* 1986 ; Philips, 1994 ; Perez *et al.,* 2000). They have the capacity to bioaccumulate various pollutants including heavy metals (Leal *et al.*, 1997 ; Haury *et al.*, 2000 ; Villares *et al.*, 2001; Lauret *et al.*, 2011). They can therefore be used to assess different types of contaminants in aquatic environments. Their stand dynamics are strongly influenced by the seasons (Lauret *et al.*, 2011), the biotope, abiotic environmental conditions (Augier and Boudouresque, 1971; Selosse, 2000) and pollution (Manneville, 2006). Through the structure of benthic stands and the organization of species within these stands, it is possible to assess the overall quality of the environment through structural bio-indices (Bellan, 1984; Grimes, 2003). Indeed, biodiversity has long been regarded as mere inventories of biological diversity. Biodiversity is increasingly included in environmental assessments through the use of indicators for pollution detection and nature protection work (Grimes, 2003). The seaweed diversity of the Mediterranean is still not completely known, especially in some areas of its African coasts (Ould-Ahmed *et al.,* 2019). The first inventories of benthic marine algae in Algeria are essentially due to the work of Montagne (1856) and Debray (1893, 1897). Subsequently, research by (Feldmann 1954; Feldmann and Magne, 1964; Lawson and John, 1977) confirmed their findings and constitute the bulk of recent knowledge on algal flora (Boudouresque, 1984). However, no studies have been carried out on algal diversity along the Oran coastline, especially in recent years.

The present study was conducted to establish an inventory of macroalgae inhabiting the intertidal zone, in order to : (i). Determine the geographical distribution of benthic macroalgae at the level of the Oran Bay, (ii). Select the most representative species of this area, applying the methodology adopted for the study of the phycoflora of this coastline. (iii). Establish an ecological diagnosis by carrying out a global analysis of the phytobenthos by comparing analytical and synthetic parameters.

Materials and Methods

Description of sampling area

The monitoring benthic macroalgae of the mid-littoral stage of the Oran coastline during the autumn season has targeted nine sites (S1-S9), they are indicated on the map (Figure 1). Their choice is based

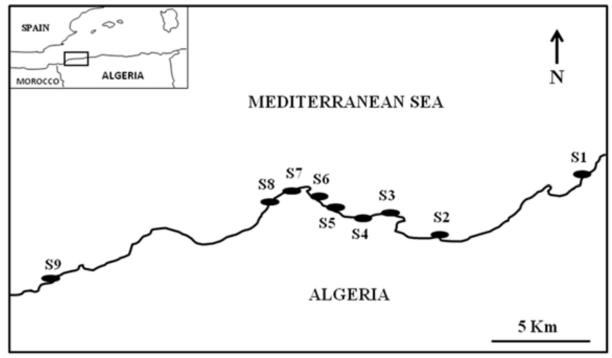

Fig. 1. Geographic location of the study stations on the Oran coast

on; the importance of the algal flora and the ease of access and work to ensure a representative sampling and the quality of the study site as a function of distance and proximity to pollution sources.

Sampling methods

In order to calculate the recovery rate of each species in an algal belt, a 25cm×25cm PVC quadrat was used (Waern 1952; Molinier and Piacard 1952; Harmelin and True 1964; Boudouresque 1967, 1974). Nine (9) surveys were conducted in each site and geo-referenced using a GPS. Algae not identified on site were collected, preserved in seawater and 5% formalin (Harmelin and True, 1964) and transported to the laboratory. The algae are examined in the laboratory, under binocular magnifying glass and/or optical microscope. The identification of species sampled was based on the characteristics of structure and growth (sometimes observable with a magnifying glass) and cytology or reproduction, which can only be properly analysed under the microscope.

The statistical method we have adopted for this study is Principal Component Analysis (P.C.A.). This method focuses on the correlation analysis of the variables. Statistical analysis was performed using the software STATISTICA (version 12.5.19).

Results

The inventory allowed the identification of eighteen (18) species of marine benthic macroalgae, including eight (8) species of the Phaeophyta group, five (5) species belonging to the Rhodophyta group and five (5) species of the Chlorophyta group, out of eighty-one (81) surveys carried out at the nine (9) targeted sites in the Bay of Oran. The complete list of species

Table 1. Florestic inventory of benthic macroalgae of the nine stations, all the species listed are mentioned in the following table.

Chlorophyta	Rhodophyta	Phaeophyta
Chaetomorpha aerea	*Asparagopsis armata*	*Cystoseira compressa*
Chaetomorpha linum	*Corallina elongata*	*Cystoseira tamariscifolia*
Enteromorpha linza	*Halopithys incurva*	*Dictyota dichotoma*
(Ulva linza)	*Halopithys musci formis*	*Dilophus spiralis*
Ulva lactuca	*Jania rubens*	*Padina pavonica*
Valonia macrophysa		*Sargassum acinarium*
		Scytosiphon lomentaria
		Petalonia fascia

identified from the intertidal is given in (Table 1). Global average cover of the three (3) benthic macroalgal species calculated in the target sites are shown in (Fig. 2). Global average cover of the three (3) benthic macroalgal groups calculated in the target sites are shown in (Fig. 3).

The species richness of the three (3) benthic macroalgal groups calculated in the target sites are shown in (Fig. 4). Total average cover for each species of benthic macroalgae present at the stations are shown in (Fig. 5).

The calculation of the average cover, global average cover and species richness reported the presence of the three (3) algal groups at six (6) stations (S1, S2, S5, S6, S7 and S9) with a wide range of richness percentages.

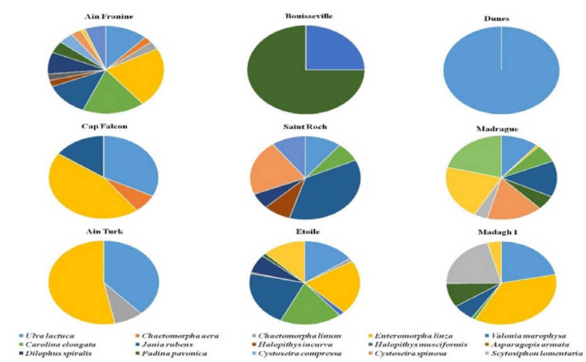

Fig. 2. Global average cover calulated of each Macroalgae in the nine stations.

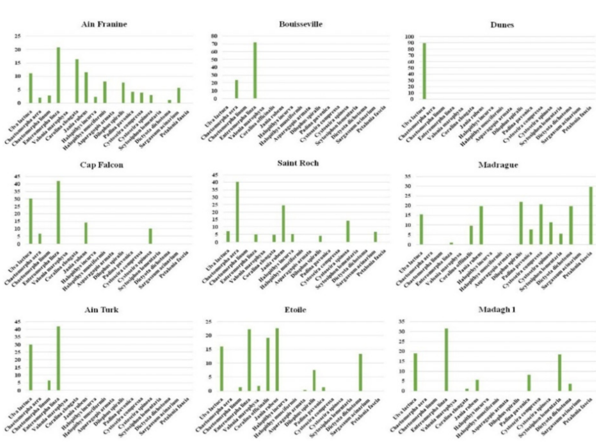

Fig. 3. The speific richeness of each species at the nine stations

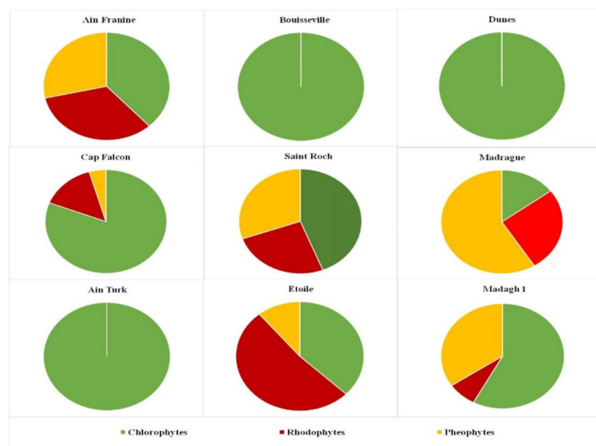

Fig. 4. The Average cover of the three groups of algae in each site has been determined

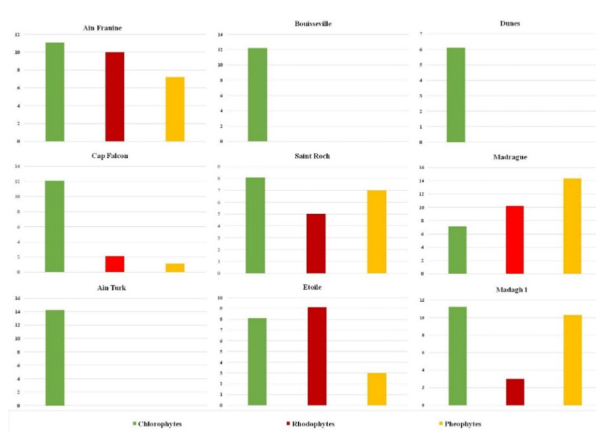

Fig. 5. Specific Richness of the three groups of algea in the nine stations

The most dominant species in three (3) sites is *Enteromorpha linza (Ulva linza)* with a total average cover of 22% to 72%. *Chaetomorpha aera*, the most dominant species at station S2 while at station S7 a dominance of the Rhodophyta group was remarkable, with average cover of 204% and a total average cover of about 23% for the *Jania rubens* species.

Station S6 shows a species richness favorable to the Phaeophyta group ; their total average cover was very high compared to the other two groups and the highest average cover was that of the species *Petalonia fascia*.

Stations S3, S4 and S8 were characterized by the presence of the chlorophyta group only and a dominant of *Enteromorpha linza (Ulva linza)* at station S3 and S4 and *Ulva lactuca* at station S8.

The results of the distribution of the different species of algae were integrated into a multivariate analysis to detect patterns of variation. The results of the principal component analysis (PCA) indicated that the two principal components accounted for 95.00% of the total variance (PC1 = 30.26%; PC2 = 21.46%) (Fig. 6a). The study of the correlation between species revealed a rather varied distribution of benthic macroalgae with a very significant correlation between brown red algae : *Petalonia fascia*,

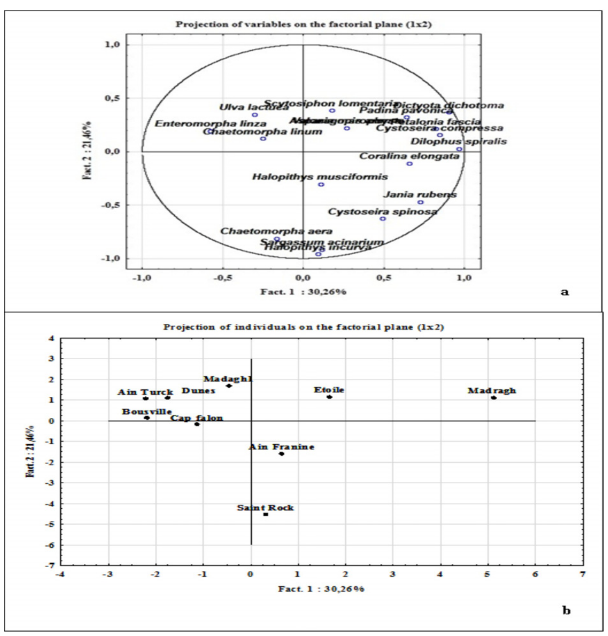

Fig. 6. Distribution of the different species of algae and stations integrated into amultivariate analysis of principal component analysis (PCA) (a) Projection of variables (species of algae); (b) Graphical representation of discrimination between sites

Dictyota dichotoma, *Dilophus spiralis*, *Cystoseira compressa*, *Scytosiphon lomentaria* and *Padina pavonica*. These species form a homogeneous and distinct group with very high correlation factors that vary between 0.80 and 0.98 (Table 2). The results also indicate a very significant correlation between the brown alga *Sargassum acinarium* and the red alga *Halopithys incurva* (R=0.94).

The three algae *Ulva lactuca*, *Chaetomorpha linum*, and *Enteromorpha linza (Ulva linza*) form a distinct group indicating their distributions and ecological habitat specific to green algae.

The representation in Figure 6b clearly separates the sites of Madragh, Ain Turck, Dunes, Bouisville, Cap Falcon. We also notice that the site of Ain Franine is grouped with Saint Rock and Etoile with Madragh.

Discussion

80% of the sea pollution comes from land-based human activities, shipping, the introduction of invasive species, overexploitation of fishery resources, degradation, fragmentation and loss of habitats are all factors responsible for the erosion of marine biodiversity. Exacerbated by climate change, this anthropisation threatens to destroy the fragile balance of marine ecosystems and the biodiversity they contain (Amara, 2010). In recent years, pollution in coastal areas has become increasingly important at all environmental, health and economic levels (Harrison *et al.*, 2014). In these different ecosystems, pollutants cause disturbances to living beings (fauna and flora) and basic abiotic compartments (Merzouk, 2016; Chabane *et al.*, 2018; Belhaouari and Bezzina, 2019). The same findings have been reported by several studies along the western Algerian coast confirming the impact of urban and agricultural wastewater discharges (Rouane Hacene *et al.*, 2015; Benaissa *et al.*, 2017; Rouabhi *et al.*, 2019), and effluents from industrial units and desalination plants (Benaissa *et al.*, 2017 ; Rouane Hacene *et al.*, 2018). Different approaches are possible to assess the exposure and/or biological effects of pollutants emitted in a given ecosystem (Harrison *et al.*, 2014). A distinction can be made between in situ studies, either direct, using plant or animal organisms collected on site (passive bioindication), or indirect, using animals or plants transferred to the site (active bioindication), and experimental or bioassay models, in which living species are exposed in the laboratory to samples taken from a site (Harrison *et al.,* 2014). Among the living marine organisms used in biomonitoring of aquatic environments, macroalgae have been extensively tested for contamination of estuarine and marine waters (Vasquez and Guerra, 1996).

Macroalgea have been widely used as excellent biomonitors (Haug *et al.,* 1974 ; Phillips 1990; Meinesz *et al.,* 2011) beause: the majority of them are sessile; they are widely distributed and accessible throughout the year; they can withstand large areas of salinity, turbidity and high levels of contamination; and they can be maintained under research centre conditions (Phillips, 1977; Levine 1984; Maeda and Sakaguchi 1990; Vasquez and Guerra 1996; Farias *et al.,* 2018).

Benthic macroalgae have been used in biomonitoring since the 1950s, although the standard protocol that would allow widespread implementation of the technique has not been developed yet (García-Seoane *et al.,* 2018).

The use of community parameters has an significant role to play in the understanding of emission disturbances in marine life. Of these, the diversity indices were most commonly used with varying degrees of success (Littler and Murray, 1975 ; Belsher, 1979).

Many previous research has also found that descriptive statistics are an excellent means of describing the number of species detected per sample, the abundance of individual species and biomass, and then summarizing this information as measures of species diversity and richness. If the community is subject to disturbance by pollution, the competitive balance will be disturbed and species diversity will change. (Breugnot *et al.,* 2008)

The present study focused on the distribution of benthic macroalgae along the coast of Oran during the autumn season and from a total of eighty-one (81) surveys identified eighteen (18) species of macrophytes belonging to the mediolittoral (intertidal zone) stage, of which five (5) species represent the Chlorophyta group, five (5) species belong to the Rhodophyta group and seven (8) species to the Phaeophyta group.

The current analysis of the distribution of benthic macroalgae in the Oran coast and in the nine (9) target stations shows that the distribution of the three algae groups was heterogeneous. The presence of the three classes (green, red and brown) was noted at six (6) sites with varying proportions.

Ain Franine (S1) is the most diverse station, the species richness was high (maximum) for all three groups of algae. A total of 14 species were inventoried but the average cover mean chlorophyte recovery was most remarkable, the overall species recovery rate showed a dominance for the green alga *Enteromorpha linza (Ulva linza).*

On the other hand, the two stations Madagh1 (S9) and la Madragh (S8) have a lower algal diversity, with a specific richness favorable to brown algae at the station Madragh (S8), compared to the other two groups.

The dominant species is *Petalonia fascia*. A high species richness of chlorophyceae was recorded at the station Madagh1 (S9) which was characterized by a high average cover and a high global average cover for *Enteromorpha linza* (*Ulva linza).*

Concerning the stations : Saint Rock (S2), Cap Falcon (S5) and Etoile (S7), the species richness (Q) was more or less the same for the three groups of algae but the average coverage and global average coverage were low compared to the previous sites ; algal diversity was medium. The first two station were characterised by a dominance of the Chlorophyceae group, with a very favorable average coverage for the species *Enteromorpha linza* (*Ulva linza)* at Cap Falcon and *Chaetomorpha aera* at Saint Rock (S2), while the 'Etoile' site is caraterized by a dominan of the Rhodophyceae group, their specific richness was very remarkable compared to the other groups, the dominant species and the red alga *Jania rubens*.

The *Enteromorpha linza (Ulva linza)* species was dominant at sites S3 and S4. Indeed, this result is probably linked to pollution due to anthropogenic activity (wastewater). While *Ulva lactuca* is the only species present at the third site S8 where there is a desalination plant with a capacity of 500 m^3/d which discharges a significant amount of salt.

The study of the correlation between species revealed a rather varied distribution of benthic macroalgae with a very significant correlation between brown algae : *Petalonia fascia, Dictyota dichotoma*, *Dilophus spiralis*, *Cystoseira compressa*, *Scytosiphon lomentaria* and *Padina pavonica*. These species had very high correlation factors. The results also indicate a very significant correlation between the brown alga *Sargassum acinarium* and the red alga *Halopithys incurva*. The three algae *Ulva lactuca, Chaetomorpha linum*, and *Enteromorha linza (Ulva linza)* form a distinct group indicating their distributions and ecological habitat specific to green algae.

In this western zone of the Algerian coastline, the maximum specific richness is observed in the stations far from wastewater discharges. However, polluted stations are characterized by the abundance of *Ulva* and *Chaetomorpha* and generally the absence of phaeophyta. These results corroborate with several previous studies which confirm the dominance of green algae in highly disturbed environments and near freshwater inputs, such as *Ulva* (Bellan and Bellan, 1972) or *Enteromorpha* (Kadari–Meziane, 1994; Bouiadjra, 2012). Other studies on the effect of wastewater discharges as well as other sources of pollution on macroalgae indicate a marked sensitivity of brown algae (Soltan *et al.,* 2001). Overall, this study of the distribution of benthic macroalgae along the Oran coast shows that the use of analytical and synthetic parameters reflects a certain imbalance in the populations in the mid-littoral zone throughout the targeted stations. These results support several previous work (Boudouresque, 1971; Borowikza, 1972; Munda, 1974; Little and Murray, 1975; Phillips, 1977; Belsher, 1977, 1979; Levine 1984; Boudouresque, 1984 ; Kautsky *et al.,* 1986; Perez *et al.,* 2000; Seridi *et al.,* 2007). The overlap indices indicate the quality of each station studied, implying that these macrophytes are excellent indicators and can be used as bioindicators of the quality of marine ecosystems (Perez, 2000). Indeed, the life and distribution of algae on marine shores depends on a whole set of factors that are very different from those that condition the existence of terrestrial plants (García-Seoane *et al.,* 2018). Indeed, macroalgae are distributed essentially according to the availability of the substrate, hydrodynamic conditions, the degree of immersion that organizes them into belts and the amount of light. Variations in environmental, physical or chemical factors, such as illumination, acidification, and increases or decreases in temperature and/or nutrient levels, profoundly modify the composition of communities (Nauleau, 1988).

The distribution of algae in ocean basins is limited to shallow rocky environments where they find sufficient light to support photosynthesis and a stable substrate to attach to (Tamigneaux and Ladd, 2016). Some species with fragile or very long thallus are shredded or torn from the substrate by strong waves, while others require highly oxygenated, wave- and current battered water to survive. Calm coastlines are more prone to siltation, whereas battered coastlines are rocky or sandy. (Selosse, 2000). In addition, rainfall or strong sunshine in the upper mediolittoral and supra-littoral regions cause the salt content of the algae living there to vary greatly (Augier and Boudouresque, 1971).

Areas with variable salinity limit the adaptation of algae. This instability disrupts the metabolism, sometimes to the point of species elimination. Only green algae are resistant to harsh conditions; in some areas, either muddy and brackish or rich in nitrates, green algae (especially *Ulva latuca* and *Enteromorpha linza (Ulva linza)* can be seen from afar, especially from spring to summer; they grow very fast, are resistant to emersion and break off easily to accumulate on top of beaches to form "green tides" (Manneville, 2006).

According to Mallefet (2008), the color of thallus does not always correspond to the nature of the chloroplastic pigments, which allow the algae to be attached to a group. The presence of many other pigments (carotene, xanthophyll) in variable quantities can be misleading, not to mention the calcareous incrustations that can mask the colours of the key pigments (Lauret, 2011). This was confirmed by identifying the alga *Halopithys musciformis* which presents a green thallus but belongs to the Rhodophyta group.

Our inventory carried out on the Oran coast confirms the absence of Laminariales and the rarity of Fucales, the genus Cystoseira was widely present at the sites : Ain Franine, Madragh and Madagh1 and represented by two species *tamariscifolia* and *compressa*. According to Boudouresque (1971), the Mediterranean algal flora is characterised by the size of the species, which is relatively small compared to cold regions. It is characterised by a rarity of Laminariales if compared to that of the Atlantic. Fucales are represented by a small number of genera. On the other hand, the genus *Cystoseira* constitutes a major element of Mediterranean phytosociology.

Conclusion

The present study shows that the composition, abundance and distributtion of macroalgae of the Oran coast aerea reflecting an inherent spatial heterogeneity in benthic systems. In the nine targeted stations, 18 taxa were identified, their environmental quality indices (average cover, global average cover and species richness) calculated are varied from one species to another at the same site and from one site to another. The ecological statut and conditions were very differents which explains the absence and or presence of certain species in this coastal zone.

The study of the correlation between species revealed a rather varied distribution of benthic macroalgae with a very significant correlation between brown algae : *Petalonia fascia*, *Dictyota dichotoma*, *Dilophus spiralis*, *Cystoseira compressa*, *Scytosiphon lomentaria* and *Padina pavonica*. The results also indicate a very significant correlation between the brown alga *Sargassum acinarium* and the red alga *Halopithys incurva.*

The three algae *Ulva lactuca*, *Chaetomorpha linum*, and *Enteromorpha linza (Ulva linza)* form a distinct group indicating their distributions and ecological habitat specific to green algae.

The results has clearly confirmed several previous studies which have prouved that environmental quality indices provides an excellent tool for using macroalgae coastal communities for ecological quality assessment.

The studies of phytobenthos by (Boudouresque *et al.,* 1984) have shown that the composition of the Western Mediterranean algal flora is characterised by the total absence of the genus belonging to the family Laminariales, the rarity of the genus Fucales on the other hand an abundance of the genus Cystoseira especially at sites with little or no pollution the presence of certain taxa indicates the good health of the benthic ecosystem, as in the case of the brown algae, *Cystoseira compressa*. On the other hand, other species testify the poor quality of the environment, such as *Enteromorpha linza* (*Ulva linza*), whose avarege cover was high at the Bouisville site and *Ulva lactuca* at the Dunes site.

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References

Amara, R. 2010. Impact of anthropisation on biodiversity and the functioning of marine ecosystem. The Electronic. *Journal of Environmental Sciences.* 1492-8442.

Augier, H. and Boudouresque, C.F. 1971. Concepts of marine eco-bioenotics : excursions in the Mediterranean. Regional Centre for Educational Documentation Marseille.p.109.

Bélanger, D. 2009. *Use of macrobenthic fauna as a bio-indicator of the quality of the coastal marine environment.* MSc Thesis. Faculty of science. University of sherbrooke. Sherbrooke, Québec, Canada.

Bellan, G. 1984. Other title Biological indicators and indexes in the marine field. *Ecology Newsletter.* 15 : 13-20.

Bellan, G., Bellan-Santini, D. 1972. Influence of pollution on marine settlements in the Marseille area. Marine Pollution and Sea Life. *Mediterranean Marine Ecosystems Springer US.* 396–401.

Belhaouari B., and Bezzina, Z. 2019. Study of the macroalgae and application of ecological evaluation index (EEI-c) in the coastal waters of Algeria. *Aquatic Biology.* 7: 254-259.

Belsher, T. 1977. Analysis of the repercussions of urban pollution on the Mediterranean macro phytobenthos (Marseille, Port-Vendres, Port-Cros). Doctoral thesis. Aix-Marseille University. France

Belsher, T. 1979. Pollution index definition test, Mediterranean Sea. *Int. Expl. Sci. Medit, Rapprt*. 4 : 25-26.

Benaissa, M., Rouane-Hacene, O., Boutiba, Z., Guibbolini-Sabatier, M. and Risso-de Faverney, C. 2017. Ecotoxicological impact assessment of the brine discharges from a desalination plant in the marine waters of the Algerian west coast, using a multibiomarker approach in a limpet. *Patella rustica*. *Environ Sciences Pollution Research.* 1-12.

Borowitzka, M. A. 1972. Intertidal algal species diversity and the effect of pollution. *Freshwater Resources.* 23: 73-84.

Boudouresque, C.F. 1967. Contribution to the phytosociological study of the algae populations of the Var coasts. *Végétation Nether1.* 22 (1-3) : 84-184.

Boudouresque, C.F. 1971. Qualitative and quantitative study methods for Benthos (in particular the phytobenthos). *Tethys.* (3) 1 : 79-104.

Boudouresque, C.F. 1974. Minimum area and marine algae stands. *Phycological Society.* 141-157.

Boudouresque, C.F. 1984. Ecological groups of marine algae and benthic phytocenoses in the Mediterranean Sea. *Giornale Botanico Italiano.* 118(Suppl. 2) : 7-42.

Bouiadjra Benabdallah, B. 2012. *The study of the benthic algal flora and the impacts of its invasive species in front of the Mostaganem coast.* Thesis Doctorate. Abdelhamid Ibn Badis Mostaganem University.

Breugnot, E., Dutartre, A., Laplace-Treyture, C. and Haury, J. 2008. Local distribution of macrophytes and consequences for sampling methods in large river. *Hydrobiologia.* 610 : 13-23.

Chabane, K., Bahbah, L. and Séridi, H. 2018. Ecological Quality Status of the Algiers coastal waters by using macroalgae assemblages as bioindicators (Algeria, Mediterranean Sea). *Mediterranean Marine Science*. 19: 305-315.

Debray, F. 1893. List of marine and freshwater algae harvested to date in Algeria. *Scientific Bulletin of France and Belgium.* 25 : 1-19.

Farias, D. R., Hurd, C. L., Eriksen, R. S. and Macleod, C. K. 2018. Macrophytes as bioindicators of heavy metal pollution in estuarine and coastal environments. *Marine Pollution Bulletin.* 128 : 175–184.

Feldmann, J. 1954. Inventory of marine flora in Roscoff. *Trav. Stat. Biol.* 6 : 1-152.

Feldmann, J. and Magne, M.F. 1964. Additions to the inventory of Roscoff's marine flora : algae, fungi, lichens. *Works Roscoff Biological Station.* 15 (New supplement) 1-23.

García-Seoane, R., Fernández, J. A., Villares, R. and Aboal, J. R. 2018. Use of macroalgae to biomonitor pollutants in coastal waters : Optimization of the methodology. *Ecological Indicators.* 84 : 710–726.

Grimes, S. 2003. Assessment and National Diagnosis of the marine pollution of the Algerian coast related to activities carried out on land, Strategic Action Programme (SAP) to combat Inventory of Roscoff's marine flora, work of the Roscoff Biological Station.

Harrison, PJ., Hurd, CL., Bischof, K. Lobban, CS. 2014. *Pollution, Seaweed Ecology and Physiology.* Cambridge University Press, C Hurd, PJ Harrison, K Bischof, CS Lobban (ed), Cambridge, United Kingdom, pp. 374-412.

Harmelin, J.C. and True, M.A. 1964. Cartographic limitation of the current extension *Posidonia oceanica* (Delille) meadows in the Gulf of Marseille. *Recl. Tray. Stn. Mar. Endoume.* 34 : 157—160.

Haug, A., Melsom, S. and Omang, S. 1974. Estimation of heavy metal pollution in two Norwegian fjord areas by analysis of the brown alga Ascophyllum nodosum. *Environmental Pollution.* 7(3) : 179–192.

Haury, J., Peltre, M. C., Muller, S., Thiébaut, G., Trémolières, M., Demars, B., Barbe, J., Dutartre, A., Guerlesquin M. and Lambert, E. 2000. Aquatic macrophytes as bioindicators of lotic systems - Interests and limits of macrophytic indices. Bibliographical synthesis of the main European approaches for the biological diagnosis of watercourses. UMR INRA-ENSA EQHC Rennes & Phytoecologie Univ. Metz. Agence de l'Eau Artois-Picardie, Etudes sur l'Eau en France no87, Min. Ecologie Dév. durable, 101.

Kadari-Meziane, Y. 1994. *Contribution to the study of the impact of pollution on the spatio-temporal distribution of phytobenthic stands in the bay of Bou- Ismail* (Algeria). PhD thesis, Teacher Training College. Algeria.

Kautskyl, N., Kautskyl, H., Kautskyl, U. and Waern, M. 1986. Decreased depth penetration of *Fucus vesiculosus* (L.) since the 1940's indicates eutrophication of the Baltic Sea. *Marine Ecology Progress Series.* 28 : 1-8.

Lauret, M., Oheix, J., Derolez, V., Laugier, T. 2011. Guide to the recognition and monitoring of lagoon macrophytes in Languedoc-Roussillon, Lagoon Monitoring Network, Ifremer, 148p.

Leal, M.C.F., Vasconcelos, M.T., Sousa-pinto, I. and Cabral, J.P.S. 1997. Biomonitoring with benthic macroalgae and direct assay of heavy metals in seawater of the Oporto coast (northwest Portugal). *Marine Pollution Bulletin.* 34 : 1006–1015.

Lawson, G. W., and John, D. M. 1977. The marine flora of the Cap Blanc peninsula : its distribution and affinities. *Botanical Journal of the Linnean Society*. 75 : 99–118.

Levine, H. G. 1984. The use of seaweeds for monitoring coastal waters, (E. Shubert, Éd.) Algae as Ecological Indicators. *Academic Press.* 20 : 189–210.

Littler, M. M. and Murray, S. N. 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. *Marine Biology.* 30 : 277–291.

Maeda, S. and Sakaguchi, T. 1990. Accumulation and detoxification of toxic metal elements by alga, In : Akatsuka I (ed.) *Introduction to Applied Phycology.* Academic Publishing, 109-13.

Mallefet, J. 2000. Impact of an extract of brown algae "*Ascophyllum nodosum*" and "*Fucus vesiculosus*" on glucose homeostasis in overweight/obese prediabetic subjects. Extract from the quarterly review "Hippocampe" n° 177 - September *Official Journal of the Ligue Francophone of Research and Underwater Activities, France.*

Manneville, J. 2006. Contribution to the synusial study of the coastal vegetations of marine macroalgae of the French Atlantic coasts. *Acta Botanica Gallica.* 153(2) : 219-234.

Meinesz, A., Boudouresque, C.F., Falcontti, C., Astier, J. M., Bay, D., Blanc, J.J., Bourcier, M., Cinelli, F., Cirik, S., Cristiani, G., Geronimo, I. DJ., Giaccone, G., Harmelin, J. G., Laubier, L., Lovric, A.Z., Molinier, R., Soyer, J., Merzouk, A. and Johnson, L.E. 2011. Kelp distribution in the northwest Atlantic Ocean under a changing climate. *Journal of Experimental Marine Biology and Ecology.* 400 : 90-98.

Merzouk, A. 2016. State of knowledge of seagrass beds and portrait of algal resources on Quebec's coasts. *Final Report. Merinov.* 137 p.

Molinier, R. and Picard, J. 1951. Biology of the Zosterae meadows of the French Mediterranean coasts. C.r. hebd. Seanc. *Academy of Sciences.* 233 : 12-14.

Molinier, R. and Picard, J. 1952. Research on seagrass beds on the French Mediterranean coast. *Annals of the Institute of Oceanography.* 27 : 157-234.

Molinier, R. 1960. Study of the marine biocenosis of Cape Corsica. *Vegetatio.* 9 : 3-5.

Montagne, C. 1856. Sylloge Generum Specierumque Cryptogamarum. J.B *Bailliere* Edit., Paris.

Murray, S. N. and Littler, M. M. 1978. Patterns of algal succession in a pertubated marine intertidal community1. *Journal of Phycology.* 14 : 506–512

Munda, I. M. 1974. Changes and succession in the benthic algal associations of slightly polluted habitats. *International Journal of Medical Oceanography.* 34 : 37-52.

Nauleau, O. 1988. Bibliographical analysis of the conditions of development of colonial algae with macroscopic formations, Study report of the SRAE Franche Comité on behalf of the Rhone-Mediterranean Corsica Water Agency., Lyon, 25 p.

Ould-Ahmed, N, Gomez, Garreta, A., Ribera Siguan, M-A. 2019. Checklist of the benthic marine macroalgae from Algeria, part II: *Ulvophyceae.* Anales del Jardín Botánico de Madrid,76.

Pinedo, S., García, M., Satta, M. P., Torres, M. and Bellesteros, E. 2007. Rocky-shore communities as indicators of water quality: A case study in the Northwestern Mediterranean. *Marine Pollution Bulletin.* 55 : 126–135.

Perez, T., Garrabou, J., Sartoretto, S., Harmelin, J.-G., Francour, P. and Vacelet, J. 2000. Mass mortality of marine invertebrates: an unprecedented event in the north-western Mediterranean, Academy of Sciences. *Scientific and medical Elsevier SAS.* 323 : *853–865.*

Phillips, D. J. H. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments. *Environmental Pollution.* 13 : 281–317.

Phillips, D. J. H. 1990. Use of macroalgae and invertebrates as monitors of metal levels in estuaries and coastal water. In: Heavy Metals in the Marine Environment, CRCPRESS Boca Raton. 81-99.

Philips, D. J. H. 1994. *Macrophytes as Biomonitors of Trace Metals in Biomonotoring of Coastal Waters and Estuaires.* CRC Press, Boca Raton *FL*. 85-103.

Rouabhi, Y.L., Philippe Grosjean, P., Boutiba, Z., Rouane Hacene, O. and Richir, J. 2019. Reproductive cycle and follicle cleaning process of *Mytilus galloprovincialis* (Mollusca : Bivalvia) from a polluted coastal site in Algeria. *Invertebrate Reproduction and Development.* 63(4) : 255-267.

Rouane-Hacene, O., Boutiba, Z., Belhaouari, B., Guibbolini-Sabatier, E., Francour, P. and Risso-de Faverney, C. 2015. Seasonal assessment of biological indices, bioaccumulation and bioavailability of heavy metals in mussels *Mytilus galloprovincialis* from Algerian west coast, applied to environmental monitoring. *Oceanologia.* 57 : 362-374.

Rouane-Hacene, O., Benaissa, M., Boutiba, Z., Belhaouaria, B., Guibbolini-Sabatier, M., Francour, P. and Risso-de Faverney, C. 2018. Seasonal assessment of biological indices, bioaccumulation and bioavailability of heavy metals in sea urchins *Paracentrotus lividus* from Algerian west coast, applied to environmental monitoring. *Environmental Science and Pollution Research.* 25(12) : 11238-11251.

Selosse, M.A. 2000. An example of algal-invertebrate symbiosis in Belle-Isle-en-Mer : the planar Convoluta roscoffensisand the prasinophyceae Tetraselmis convolutae. *Acta Botanica Gallica.* 147(4) : 323–331.

Seridi, H., Ruitton, S. and Boudouresque, C. F. 2007. Is possible to calibrate the pollution level of the region of Algiers (Mediterranean Sea) by exploiting marine macrophytes?. *Elsiver*. 330(8): 0-614.

Soltan, D., Verlaque, M., Boudouresque, C.F. and Francour, P. 2001. Changes in macroalgal communities in the vicinity of a mediterranean sewage outfall after the setting up of treatment plant. *Marine Pollution Bulttin.* 42 (1) : 59-70.

Tamigneaux, É. and Johnson, L. E. 2016. Saint Lawrence macroalgae : an essential component of unique marine ecosystem and a precious natural resource in a context of global change. *The Canadian Naturalist.* 140(2) : 6.

Vasquez, J. A. and Guerra, N. 1996. The use of seaweeds as bioindicators of natural and anthropogenic contaminants in northern Chile. *Hydrobiologia.* 326 : 327-333.

Villares, R., Puente, X. and Carballeira, A.2001. *Ulva* and *Enteromorpha* as indicators of heavy metal pollution. *Hydrobiologia.* 462 : 221-232.

Waern, M.1952. Rocky-shore Algae in Oregrund Archipelago. *Acta Physio Geogr.* 30 : 1-298.