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Wastewater impact on macroalgae biodiversity in Essaouira coast (Morocco)

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Abstract

Some events could affect the biological diversity and living resources in marine areas. Under the influence of human activities, the Atlantic ocean ecosystem has changed. Taking this into consideration, a new approach of studies is absolutely necessary in order to estimate the major modifications that occurred on macrophytobenthos, under the influence of harmful factors that disturb the quality of marine environment and its biodiversity. The aim of this study is to determine the macroalgal biodiversity of the Essaouira coast in relation to the main abiotic factors. Two stations were chosen: Moulay Bouzektoune station (S1) located at 15 km far from Essaouira as a control, and the Bab Dokkala station (S2) located in the city where some industrial and domestic wastewaters are rejected without any treatment. The results show a high diversity of macrophytobenthos at S1 station with 79 taxa of macroalgae including 56 Rhodophyceae, 14 Chlorohyceae and 9 Phaephyceae, whereas at S2 station, only 44 species were inventoried including 31 Rhodophycae, 8 Chlorophycae and 5 Phaeophycae

Some physico-chemical parameters were measured to assess the pollution impact degree on the two stations studied. The results show that in Bab Dokkala station, where it pours sewage from the city of Essaouira without pretreatment, there is an increase of nitrite, ammonium, total phosphorus and orthophosphates, with a slight decrease of pH.

Thus, the algal biodiversity and abiotic parameters show that Bab Doukkala station is impacted by domestic wastewater coming from the city of Essaouira in comparison with the preserved one: Moulay Bouzerktoune.

1. Introduction

The main Morocco spans from Atlantic Ocean and Mediterranean sea. Because of this geographical location, its marine ecosystem coasts are under increasing pressure from the important maritime traffic and the large socio-economical activities [1, 2]. Indeed, humanity strongly influences hydrological and ecological processes, from local to global scales. We currently face more variable environments with greater uncertainty about how ecosystems will respond to inevitable increases in levels of human use and activities via emissions of waste and pollutants and climate change [3]. These pressures can make ecosystems more vulnerable to changes and may suddenly shift from desired to less desired states.

The sustainable management of these sensitive environments first passes by a better knowledge of their biodiversity which is largely affected by the human impact. Among the components of coastal ecosystems, there is the flora which appears as a key compartment to understand the changes from which the marine ecosystems are now suffering [4, 5]. The algae, especially macroalgae, are, among floristic groups, the most abundant and diversified species in shallow marine ecosystems. They colonize a great diversity of marine habitats, from the intertidal zone to hadal zone, and they are considered as indicators for identifying the main conditions that control the structure and the operation of the benthic communities. Only a few works have been done about macroalgal biodiversity in Morocco [6, 7, 8]. Also, some coasts have been neglected.

Thus, the main objective of this study is to determine the abundance and the benthic macrophytobenthos biodiversity of Essaouira coast for the first time in Morocco, as well as the anthropogenic impact through some physico-chemical analysis.

2. Materials and methods

2.1. *Study area*

One of the most important conditions for the development of macrophytes is the presence of a hard substratum of various types. Therefore, the selection of study sites considered as the principal criteria the presence of a rocky- natural or artificial - bottom. In some cases, the algae were collected from the shells of mussels that covered the whole surface of rocky bottoms.

Two sites in the coast of Essaouira (Fig. 1) were selected for harvested the macroalgae for this study.

- Station of Moulay Bouzerktoune (S1), located approximately 15km from the enclosure of the city (31° 64" N, 9° 67" W), is considered as a reference station, less affected by anthropogenic activities, just an ephemeral tourism activities during the summer.
- Station of Bab Doukkala (S2), located in the city (31° 52" N, 9° 75" W), allows us to know the impact of the releases of Essaouira city on the marine macroalgae. Indeed, this urban coast receives domestic and some industrial releases, in addition to a small solid discharge installed there.

Figure 1: The location of sampling stations (red circles) along the Essaouira coast [9].

2.2. *Sample collection*

Within the intertidal zone, the collection of macroalgae samples took place in the two stations selected once a month during spring 2016 (March, April Mai and June). In our study, the sampling was carried out from the shore at low tide on rock substrate following the principle of the quadrats. The algae can be collected by hand or with a knife for the species that are difficult to uprooted, put in plastic containers with a label mentioning the date, and the station of collection. *In situ* sea water is taken in plastic bottles.

The samples intended for identification are conserved into alcohol at 10%. The samples of sea water were put in a cooler and were brought fresh to the laboratory. Some parameters have been carried out *in situ*.

2.3. *Laboratory analysis*

2.3.1. Biotic parameters

The samples of macroalgae were brougth to the laboratory, carefully washed from sediments and associated fauna, and sorted out in three main groups: Chlorophyta, Phaeophyta and Rhodophyta. Species identification was made macroscopically when possible, but for difficult genera, microscopic examination was necessary. Scientific papers and special determination key for macroalgae were used [6, 10].

2.3.2. Abiotic parameters

Some parameters of sea water have been measured *in situ*. Water conductivity, pH, and temperature, measurements were taken at each site, using a portable device (Orion 4 Star).
Other physico-chemical parameters were measured in the laboratory (nitrogen, ammonium, orthophosphate and total phosphorus) using colorimetric assays described by Rodier [11].

2.4. *Statistical analysis*
All physico-chemical experiments were carried out in triplicate and the mean values with standard deviation are presented. Standard deviations were found to be ±1.5%. When the error bars are smaller than the symbols, they are not shown. The data were tested for normality and homogeneity of variance, and tests for significance between treatments using a one-way analysis of variance (ANOVA).

3. Results and discussion

3.1. *Biotic parameters*
The balance sheet of sampling of macroalgae of the two stations located throughout the coastline of Essaouira city has produced an inventory of algal species identified at the studied areas. The analysis of samples carried out during this period of study, shows a total of 90 taxa of macroalgae belonging to 32 genera, 22 families and 16 orders of 3 divisions (16 Chlorophyceae, 11 Phaephyceae, and 63 Rhodophyceae).
This specific richness follows a decrease order from My Bouzerktoune (S1) to the station urban coast'station named Bab Dokkala (S2). Actualy, the maximum specific richness is recorded at My Bouzerktoune with 79 species, while it does not exceed 44 species at Bab Dokkala station (Fig. 2).
Among the 79 species, we notice 14 Chlorophyceae, 9 Phaephyceae and 56 Rhodophyceae, essentially represented by *Caulacanthus ustulatus*, *Halopitys incurvis*, *Gigartina acicularis* and *Chondrus crispus*, followed by Chlorophyceae, dominated by *Ulva lactuca*, *U. rigida*, *Enteromorpha Compressa* and *E. linza*. However, brown algae moderately present during this period are dominated by *Bifurcaria bifurcata*.
At the second station (S2), the 44 species include 8 Chlorophyceae, 5 Phaephyceae, and 31 Rhodophyceae (Fig. 2). In comparison with the first station, we notice the disappearance of the sensitive species. Among the Chlorophyceae, some Ulvaceae are absent (*Enteromorpha Compressa*, *E. linza*, *Ulva fasciata*). Also, the Phaeophycae belonging to the genus *Cystoseira* and the Rhodophyceae belonging to Bangiaceae, Gracilariaceae, Polyidaceae, Rhodymeniaceae and Delesseriaceae families are not present. However, some families are more developed as Codiaceae, Ectocarpacea, Dictyotacea. According to some authors, some macroalgae (e.g. *Codium* genus) overgrow in some coasts while others disappear in response to global climate changes, coastal development, tourism, and environmental pollution [12, 13].

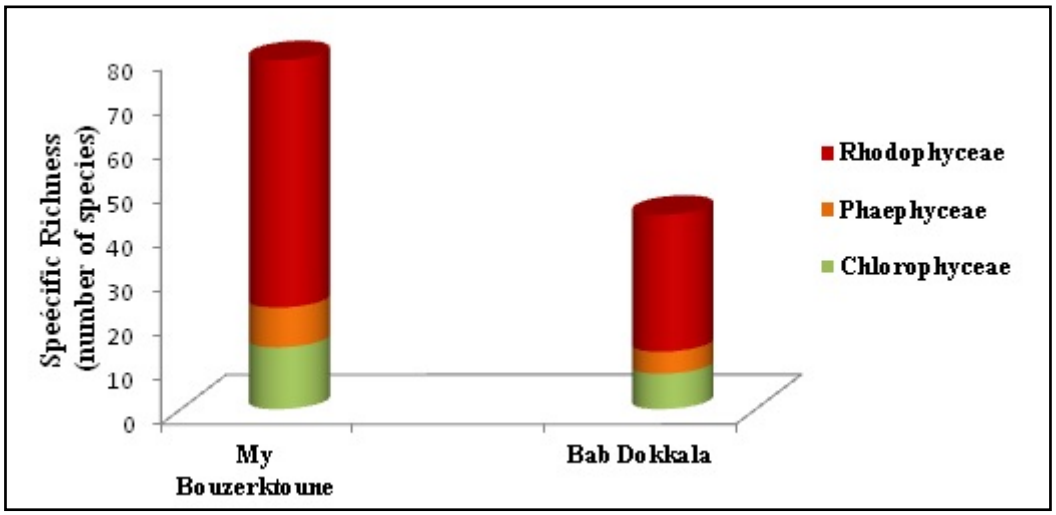

Figure 2: Specific richness in the sampling stations on Essaouira coast.

The station 1, located in the North of the city, is in the shelter of anthropogenic impact because of the currents directly released in the South West. It could be confirmed by the presence of *Cystoseira* genus which mostly indicates a non-affected area [14, 15].
For the Station 2, located in the urban area, near the domestic and some industrial releases, we notice a radical qualitative decline of the specific richness (44 species). According to some authors [16], the disappearance of

most perennial species, due to pollution impact, has a consequence on the disappearance of associated or epiphytic species. Indeed, many epiphytic algae inventoried at the first station, (e.g., *Cladophora socialis Polysiphonia opaca, P. violacae, Lomentaria articulata*) are not found in the second one.

3.2. *Physico-chemical parameters*

The knowledge of the environment, through the analysis of its physico-chemical characteristics is indispensable for any ecological study [17]. Indeed, the characteristics of marine environments result from direct or indirect interactions of various factors, including the hydrological factors which define most of the physico-chemical and biological parameters [18].

3.2.1. Temperature, pH and conductivity

The physico-chemical parameters, and particularly the temperature, conductivity and pH, play a major role in the determination of the structure and dynamics of benthic stands [19].

For the physicochemical parameters measured *in situ* (temperature, pH, conductivity), they usually do not show large differences between the two stations studied. The temperature shows a spatial variation between the two stations studied; it presents a value of 17.9°C in My Bouzerktoune, and 18.8°C in Bab Dokkala (Tab. 1). This variation is due to several factors including the heat exchanges between sea and atmosphere. It especially occurs at the sea-atmosphere interface where the measurements are made, and where the solar lights on algal-bloom-covers. In general, these temperatures characterize the end of the winter season and the beginning of the summer.

In the sea, the temperature of water is mainly determined by seasons. It is secondarily influenced by the topography, depth and potential releases of hot water [20]. The temperature of water is a factor that leads to major ecological implications. Its variations affect biochemical processes and biological activities [18].

The pH of the two sampling sites is slightly alkaline (Tab. 1). This result is expected for sea water and similar in comparable studies [21]. However, it may be influenced by the inputs of continental waters and by some industrial releases [20].

The analysis of the conductivity shows the same value of 43.2 ms cm^{-1} in both stations (Tab.1). This parameter depends on the contribution of the tide inputs, the precipitations and the sunshine. Therefore a high conductivity informs us about a strong mineralization of the water. Our study sites show the usual value for the conductivity which limit is 50ms cm^{-1} [21].

Table 1: Physico-chemical parameters of sea water measured *in situ* during spring.

	Temperature (°C)	**pH**	**Conductivity (ms cm^{-1})**
Station 1	17.9	8.65	43.2
Station 2	18.2	8.16	43.2

3.2.2. Nitrogen and phosphorus compounds

The one-way ANOVA analysis of ammonium ions, has revealed that there is a highly significant difference between the two stations ($F= 41.28$; $0.001<p<0.01$). The first station (My Bouzerktoune) presents an average of 0.14 ± 0.00mg L^{-1}, while the second one (Bab Dokkala) shows the highest average 0.253 ± 0.03mg L^{-1} (Fig. 3). The maximum ammonium concentration allowable in seawater is 0.05mg L^{-1} [21]. It shows that the two stations studied exceed this norm. According to several authors [22, 23, 24, 25], ammonium is the chemical form of the mineral nitrogen preferentially assimilated by the algae even in the presence of nitrate. Thus, in the first station (My Bouzerktoune), where the specific richness is higher, the ammonium is more assimilated than in the second one and could be at the origin of its significant difference. Also, deleterious level of algal decomposition in the urban coast produces more ammonium and could contribute to the increase of its concentration.

Nitrites are considered as an intermediate unstable form. They are produced during a step of the bacterial degradation of proteins, obtained by transformation of ammonia in the presence of oxygen by bacteria of the genus *Nitrosomonas*, to give nitrates [20, 26]. For this parameter, the gap between the two stations is highly significant ($F= 504.802$; $p<<0.001$). In the station of My Bouzerktoune (S1), low nitrite concentration (0.039mg L^{-1}) was recorded (Fig. 3). This value is less than the norm of seawater, which is 0.05mg L^{-1} [21]. This could be attributed to the fact that this station is located in a place where the density of the human population is low, and the anthropogenic activity ephemeral. On the other hand, good oxygenation of water in

this site also promotes the oxidation of nitrites to nitrates. The highest average (2.03 ± 0.15mg L^{-1}) has been registered at Bab Dokkala station (S2) (very high value compared to the standard of nitrites), located in the enclosure of the city of Essaouira, where the high content of nitrites would be attributed essentially to the polysaprobes waters from the sewers of the city.

For the total phosphorus, the statistical test shows a highly significant difference ($F=68.31$; $p<<0.01$) with a low concentration of 0.350mg L^{-1} in the first station (My Bouzerktoune) and a concentration almost 7 times higher at the second one (Bab Dokkala). The analysis of the bioavailable phosphorus shows that the difference between the orthophosphorus concentration recorded in the two sampling stations is highly significant ($F=44.13$; $p<<0.01$). It increases from the station 1 (0.013mg L^{-1}) to the station 2 (0.04mg L^{-1}) (Fig. 3). Overall, these levels recorded are considerably lower than the limit of the standards established for marine water which is 0.2mg L^{-1} [21]. The low concentration noticed in the first station is attributed to the preferential orthophosphorus assimilation by the high quality and quantity of macrophytobenthos in comparison with the second station.

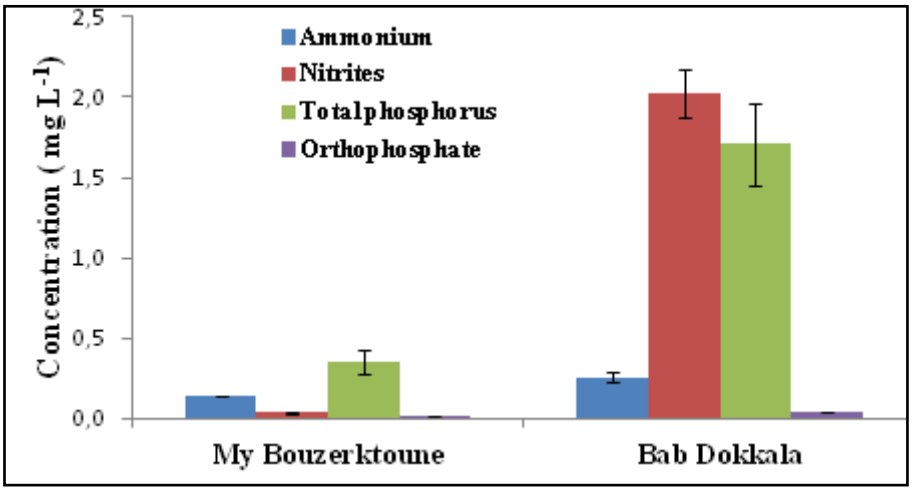

Figure 3: Ammonium, nitrite, total phosphorus and orthophosphate concentrations (mg L^{-1}) recorded in the sampling stations (mean ± E.S) (n=3).

According to some authors, opportunistic and perennial macroalgal species may respond differently to changes in nutrient and light levels. Nutrient enrichment tends to stimulate the growth of opportunistic algae which then shade the perennial species [27, 28, 29]. The abundance of opportunistic algae is therefore likely to increase at the expense of perennial algae as a function of increased nutrient input. Moreover, the number of algal species may decline along a nutrient gradient [30].

It is obvious that anthropogenic activities have affected the normal distribution and growth of macroalgae around Essaouira and these phenomena should be further investigated including other physico-chemical parameters.

4. Conclusion

The anthropogenic disturbances showcase the effects of changing environmental conditions on macroalgal communities in Essaouira's Atlantic coast as well as in neighboring cities, especially the industrial ones. Similar phenomena worldwide, particularly in the western Pacific Ocean, have been reported. In Essaouira, drastic decrease of macroalgal populations, noticed in the urban coast, have been attributed to some physico-chemical factors. Indeed, the statistical analysis of the nutrient parameters (ammonium, nitrites, total phosphorus and orthophosphates) has shown a significant difference between the two sampling sites. However, some chemical concentrations are lower than the standards established for marine waters.

So, the Essaouira urban coast has been subjected to extreme deterioration of macrophytobenthos as a result of complex and multiple anthropogenic pressures together. Further studies should be investigated to assert these results.

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