A Recommended Monitoring Tool for the marine ecological status studies in the Western Moroccan Mediterranean coastal areas

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Abstract. This research provides general guidelines for monitoring the environmental quality state of the marine ecosystems using benthic microfauna as a bioindicator tool in the Western Moroccan Mediterranean coastal areas. The current faunistic composition of 18 superficial sediment samples collected in areas having a wild range of environmental conditions have been the subject of factorial correspondence and hierarchical classification analysis, allowing us to follow the distribution patterns of the benthic assemblages. Considering the influence of both hydrodynamic and sedimental conditions on the superficial sediment, recognized in this study as the main environmental factors affecting the distribution of species in this type of environment, we were able to delineate three environmental units, with specific faunistic response related to the corresponding environmental conditions. Leading us to identify the optimal sampling area for the biomonitoring surveys in this region. Shallow and high-energy coastal areas were found to limit data collection and the representation of the sampling area, while low-energy areas were identified as ideal for environmental surveys, showcasing strong faunistic response to stressful conditions. We recommend to conduct the ecological monitoring studies in the 10–30-meter depth range, where the environmental conditions favor the assessment of the current environmental quality state by the benthic microfauna.

Keywords: Marine ecological status, Benthic microfauna, Bioindicator, Moroccan Mediterranean coasts.

1 Introduction

Along the Moroccan Mediterranean coastline, the Tetouan region is one of the most urbanized zones, carrying many anthropogenic activities, most of which dump their effluents with minor or without any previous treatment toward the sea through multiple effluent sources [1], the large quantity of wastewater from both the urban and industrial dismissals for several years, had promoted stressful conditions in this marine area. Being aware of the ecological changing conditions in many coastal regions, assessing the increasing anthropogenic pressures is a necessity in order to reverse this trend.

As much as water and sediments chemistry can assess the environmental conditions, several limitations can be associated with their application. [2]. Compared to the traditional monitoring tools, the use of bioindicators can present a better alternative in the assessment of the negative impacts of pollutants on biotic systems. While chemistry analysis only provides a snapshot of the environmental conditions at the time of sampling, missing short-term fluctuations and episodic events. Bioindicators provide an extensive view of the ecosystem's health. They can capture the cumulative effects of various pollutants and the effects of environmental changes over time. This approach is particularly valuable since it considers the overall well-being of the ecosystem.

Monitoring the marine environmental status, and particularly describing the anthropogenic impact on living organisms, has traditionally been based on studies of macrofauna, as they respond in a predictable way to anthropogenic and natural stress. [3]. Since the distribution and the faunistic composition of the currently (foraminifera and ostracods) species are influenced by both the abiotic parameters and the pollutants inputs. It is essential to distinguish between the impact of the natural variability of the marine environment and the anthropogenic impact.

Benthic microfauna had been widely used to assess the environmental quality state in many areas of the Mediterranean Sea, due to their exceptional ability to record disturbances in the environmental conditions. Yet not a single study has previously been conducted in Moroccan coastal areas. Research on the benthic communities and their ecological significance are yet to be established in our country.

In a preliminary study conducted on the faunistic composition of the costal fringe in this region, promising results have been showcased in terms of the ability of these organisms to assess the quality of their environment, where the lowest values of the ecological...
indices, and different types of morphological abnormalities were observed distinctively in sediments located in proximity to continental emissaries draining urban and industrial discharges [4]. Thus, this study investigates the bio-indication potential of the benthic microfauna as an assessment tool for the marine ecological status in the Tetouan coastal region. Our aim is to provide valuable insights about the spatial dynamics of species distribution and contribute to a more understanding of the ecological health of the marine ecosystem in question.

2 Methodology

2.1 Sample collection

The study area, shown in Fig. 1, is located in the northwest Moroccan Mediterranean coastline, in April 2022, 18 sample of the superficial sediment layer were taken using a stainless steel Van Veen grab. In order to follow the environmental conditions variations, sediments were taken from 4 distances relative to the costal fringe (50m, 1km, 2km and 3 km).

The adopted protocol in our faunistic analysis takes into account the recommendations of the FOBIMO group (FOraminiferal BIo-MOnitoring) [5], For the use of benthic foraminifera. as a reliable tool in bio-monitoring studies. Although their recommendations were only considered for the analysis of benthic foraminifera, they will also be applied to the analysis of ostracods, as they share the same benthic environment.

2.2 Samples processing

The foraminifera assemblages represent more than 50% of the total sediment biomass [6]. They commonly have short life cycles compared to higher organisms, 3 mouths on average [7]. And respond quickly to environmental changes. For environmental assessment purposes, only the living specimens will be considered in this study. In order to identify the living forms, the collected fractions were immediately stored in containers, filled with pure ethanol and Rose Bengal stain (2 g/l) mixture using an equal volume of the sample [8]. After complete impregnation of the living foraminifera with the rose Bengal coloration, only the >125 µm fraction was analysed for it faunistic content. Each sample was spread on a picking tray, and individuals were picked systematically under a binocular loop. A minimum of 300 individuals were picked from the sample. And the deformed, broken or reworked specimens were recorded separately.

The organic matter content was determined via the samples weight loss of the dried sediment at 105° C after the total organic carbon igniting for two hours at 550° C in a muffle furnace [9]. The particle size analysis was performed by the weight measurement of different sediment fractions separated by dry sieving. For the identification of the faunistic response toward the sediment grain seize distributions, we have divided the retained portions in two fractions the coarse sand fraction >125 µm, and fine sand fraction < 125 µm.

Fig. 1. Conducive and adverse bio-monitoring areas in the Tetouan coastal region.

2.3 Statistical analysis

In order to highlight the environmental conditions impact on the faunal distribution patterns, factorial correspondence analysis, were performed on all the superficial sediment samples collected from various depths along the study area, followed by a hierarchical clustering of the study variables. The multivariate analysis application allowed us to effectively combine and analyse our complex dataset involving faunistic and environmental variables.

3 Results and Discussion

By extracting meaningful dimensions from the samples data, only the first two dimensions of the multivariate analysis will be used as they explain 84.71% of the total variance (Fig. 2).

The first-dimension axis (59.07%) sees succeeding in the order of the negative abscises towards the positives the samples relative positions to the costal fringe. It therefore materializes a gradient of distance from the shore, where the faunal density increases along with the environmental depth. The second axis (25.64%) on the other hand opposes the particle size sediment fractions (coarse and fine sand) located in both ends of the axis periphery, those variables alone contribute the most to the inertia explained by this axis (respectively...
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58.04% and 34.31%). Thus, the corresponding axis distributes the samples based on their particle size range.

**Fig. 2.** Factorial correspondence analysis diagram, distributing sampling points based on the ecological parameters. **BF** broken foraminifera; **RF** reworked Foraminifera; **DEF.BF** deformed benthic foraminifera; **D.LBF** Density of the living benthic foraminifera; **D.PF** Density of the planktonic foraminifera; **D.OS** Density of ostracods; **OM** Organic matter content; **CS** coarse sand fraction, **FS** fine sand fraction.

### 3.1 Environmental units

Depending on the sample’s proximity to the points displaying the study variables and the recognized clusters identifying different trends within the dataset Fig.3. Three main environmental units can be distinguished.

**Fig. 3.** Hierarchical classification of the ecological variables.

#### 3.1.1 Unit 1

The shallow unit, grouping samples collected at the 50 m distance from the continental fringe (depth range 1-4m) characterized by the presence of the highest proportions of the reworked Quaternary and modern broken tests along with the coarse particle size fraction, with the lowest values of the faunal density in all the identified units (1.65-18.32 individual/g).

#### 3.1.2 Unit 2

The medium depth unit (depth range 10-30m), gathering assemblages with the highest percentages of the deformed species and the Organic matter content, these assemblages are found one to two kilometers from the costal fringe, where the granulometric composition is primarily dominated by the fine sand fraction. Characterization a low energy type of environment.

#### 3.1.3 Unit 3

The deep costal unit (depth range 30-45m), where the environmental conditions diverge from one point to the other. The extreme position of the planktonic foraminifera in the graphical representation reflects unsimilar environmental processes between samples of the 3 km range. The lacking of the planktonic deposits on (D3-D4) samples, and their proximity to the coarse particle size fraction reflects high postmortem transport and resedimentation of foraminiferal tests on other locations, leaving the hydrodynamic conditions as the primary factor controlling the species dynamics in this section of the study area.

### 3.2 Sampling Recommendations Regulating the Environmental Variability

As it has been shown by the Factorial correspondence analysis, the faunistic distribution in the Tetouan costal is mainly controlled by the hydrodynamic and sedimental conditions. The variation in those setting, allows for the differentiation between conducive and adverse areas for the benthic microfauna to records the current environmental conditions.

The unstable nature of the shallower costal sediment, constantly exposed to the tidal wave’s activities, displays negative impacts on the total faunal density. The average faunal density found in the shallow unit is 9.8 individuals/g, requiring the examination of around 31g from the sieved fraction in order to pick the minimum specimen number for a representative faunistic composition, making the quantitative data collection in this unit impractical for routine environmental surveys.

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The high hydrodynamic conditions on the other hand influence considerably the assemblage’s composition, giving the advantage to the strong clinging taxa tolerating the strong hydrodynamic conditions at the expense of the less tolerant sensitive taxa [7], it also presents challenges in differentiating between the autochthonous and the Allochthonous assemblages since their test act like sediment particles that can be easily transported by the currents. All of these factors impact negatively the bio indication potential of the benthic microfauna, making the areas under those conditions non recommended for faunistic bioindication studies.
By contrast, low energy hydrodynamic conditions offer a bigger adsorption and accumulation ability to the bottom sediments to the various pollutant input [10]. Making these types of areas, the optimal sampling sections for environmental surveys, where the faunistic assemblages can significantly reflect the current environmental state, as it has been shown by the high rate of the deformed specimens, marking the strong faunistic response to stressful conditions.

As it was delimited in Fig.1, we strongly recommend the bio-indication studies in the Tetouan coastal areas to be concluded in the 10-30m depth range, with the respect of the FOBIMO group instructions regarding sample acquisition, preparation and treatment, as they fulfill the criteria imposed by both the rigorous scientific aspects of the study and the practical requirements of routine environmental monitoring constraints.

4 Conclusions

Revealing the environmental factors influencing the macrofauna distribution patterns in these areas, along with the identification of the environmental units conditioning the faunistic response in each area allowed us to locate where the benthic communities can significantly record and reflect the current environmental state.

This study will give valuable insights for both the environmental managers in their efforts monitoring the status of marine environments with this economically advantageous solution, and the scientific community in contributing to our understanding of the microfaunal dynamics and the ecology of this poorly known region.

References