Study of current benthic foraminifera as environmental bioindicators in the mediterranean coasts, northwest Morocco

Ayoub El Bakkali[1*], *Haitam* Afilal[1], *Abdellah* Trankil [1], *Halima* Rezqi[2], *Lhoussain* Ed-Daoudy[3] and *Abdelhamid* Rossi[1]

[1] LR&DGéoAp/FSTT/Abdelmalek Essaadi University, Tétouan
[2] Université Mohammed Premier Oujda, Oujda, Morocco
[3] EMRN. FSTT. Abdelmalek Essaadi University, Tétouan

Abstract. In this project, we introduce a novel methodology for analysing the environmental conditions in the coastal area of Martil (Tétouan, Morocco) using benthic foraminifera as bio-indicators of marine ecological status. Benthic foraminifera have emerged as reliable indicators of environmental pollution, Their sensitivity to environmental changes, wide geographic presence, and short life cycle make them ideal for indicating the ecological status. Our study focused on the Mediterranean coastal region, along a radial perpendicular to the coast, at different depths, at the mouth of the Martil River, in addition to a control sample collected in the Azla region at a depth of 25 meters. Abiotic parameters like pH, temperature, and dissolved oxygen were measured on-site, complemented by detailed sedimentary analyses in the laboratory. A meticulous protocol was followed for the study of microfauna, particularly benthic foraminifera, involving washing, extraction, sorting, species identification, statistical counting, and microscopic imaging. Utilizing CA and AHC analyses, we identified factors influencing benthic foraminifera distribution, such as sediment depth and grain size variations. Specific indices derived from foraminifera data allowed us to assess stress levels accurately. This comprehensive approach provides valuable insights into evaluating the ecological health of Morocco's coastal marine ecosystems, paving the way for informed conservation efforts and sustainable management practices.
Keywords: Benthic Foraminifera, Environmental Bio-indicators, Ecological Quality, Tétouan Region, Martil, Morocco.

1 Introduction

Benthic foraminifera are single-celled organisms that inhabit marine sediments, where they exhibit remarkable adaptability to various environmental conditions. They can tolerate a wide range of temperature, salinity, and oxygen levels, making them well-suited for diverse coastal habitats [1]. Their ability to thrive in different environments allows them to serve as reliable indicators of environmental health.

Anthropogenic waste discharge, such as industrial effluents and sewage, can have detrimental effects on coastal ecosystems. Benthic foraminifera have shown a swift response to these pollutants, making them valuable indicators of environmental degradation . Studies have demonstrated changes in the abundance, diversity, and morphology of benthic foraminifera in polluted areas [2]. These changes can be attributed to the sensitivity of benthic foraminifera to changes in water quality, including increased nutrient levels, heavy metal pollution, and oxygen depletion [3] .

The adaptability and responsiveness of benthic foraminifera make them vital bio-indicators in ecological studies. By monitoring the composition and abundance of benthic foraminifera communities, researchers can assess the health and quality of coastal ecosystems. The FOraminiferal BIo-MOnitoring (FOBIMO) initiative has been established to develop a standardized protocol for benthic foraminiferal monitoring studies, enabling comparisons across different regions and time periods [4]. This standardized approach enhances the reliability and comparability of data, facilitating a better understanding of the impacts of anthropogenic activities on coastal ecosystems.

2 Materials and Methods

2.1. Sample collection

Three samples of surface sediment were taken using a Van Veen grab sampler. The grab samples were carefully opened in the container without disturbing the original arrangement of the deposited sediments. In order to differentiate between living and dead species, 50 g of the top 2-3 cm of sediment from these samples were added to the rose bengal solution (2 g/1 litre of pure ethanol) on the spot [5]. Grain size analysis was done on the remaining samples, and a detailed examination of foraminiferal assemblages was conducted on the dyed sediment samples. Using a multi-parameter instrument, environmental parameters including salinity, pH, temperature, and dissolved oxygen have been measured on-site.

* Corresponding author: ayoub.elbakkali@etu.uae.ac.ma

2.2. Foraminiferal analysis

Foraminiferal studies were conducted using the >125 µm fraction to obtain a minimum of 300 specimens per sample. The methodology described in [4] was followed to study the living assemblage in all samples (Fig.1). All specimens were identified according to the taxonomic order of [5]. The Atlas [6] and the most recent updates on the World Register of Marine Species (WoRMS) were used to identify the taxa.

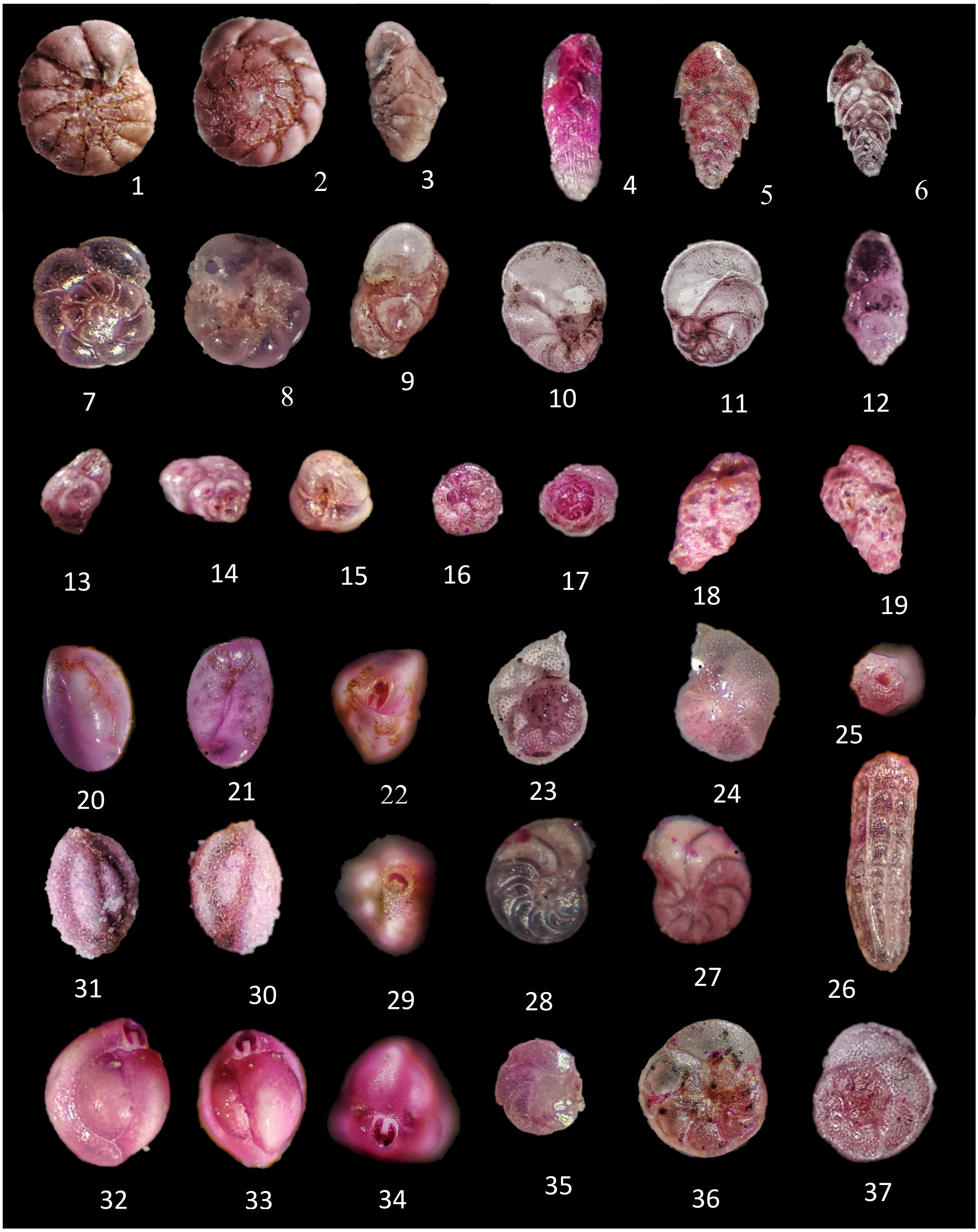

Fig.1. 1,2 and 3 Ammonia beccarii, 4 Bolivina antiqua, 5 and 6 Bolivina alata, 7,8 and 9 Ammonia tepida, 10 and 11 Cancris auricula, 12 Bulimina marginata, 13,14 and 15 Bulimina gibba, 16 and 17 Asterigerinata mamilla, 18 and 19 Textularia agglutinans, 20,21 and 22 Quinqueloculina seminulum, 23 and 24 Cibicides refulgens, 25 and 26 Pyramidulina raphanistrum, 27 and 28 Hanzawaia boueana, 29,30 and 31 Quinqueloculina agglutinans, 32,33 and 34 Triloculina trigonula, 35 Cassidulina laevigata, 36 and 37 Rosalina williamsoni.

2.3. Textural analysis

To perform the textural analysis, the samples were treated with a solution of HCL to remove carbonates and a solution of H2O2 to break down organic matter. We used 100 grams of the treated samples for the textural examination. After that, we dried and screened the sediment samples for 15 minutes using ASTM sieves with a size range of 2 mm to 0.063 mm [7]. Finally, we weighed the sediment fraction retained in each sieve stack to calculate the percentage.

2.4. Ecological indices and statistical analysis

In this study, ecological indices were calculated for living benthic foraminifera, including density, the Equitability Index, and Shannon's Diversity -Index (H'). Additionally, The TSI-Med (Tolerant Species Index for the Mediterranean) was utilized by us [8]. and modified by [9] as a simple way to assess ecological health.

Statistical analyses, including hierarchical clustering and correspondence analysis, were conducted on the eleven most abundant species of benthic foraminifera, which make up over 82% of the population. The purpose was to determine the correlation between environmental factors (such as salinity, depth, dissolved oxygen, temperature, and pH), textural data (% of fine fraction), ecological indices (density, H', Equity, TSI-Med), and benthic foraminiferal assemblages.

3 Results and Discussion

3.1 The foraminiferal species

Benthic foraminifera were generally abundant, where 27 species related to 19 genera were identified. Hyaline Porcelaneous taxa represented 72,71% (23 species), followed by agglutinated 16,4% (2 species), while porcelaneous taxa represented 10,89% (3 species) (Fig. 2).

The Martil area (S1, S2) is dominated by the following species: Porosononion granosum, Elphidium crispum, Ammonia beccarii, Quinqueloculina agglutinans & Textularia agglutinans. In Azla area (S3), Triloculina trigonula was the most frequent species followed by Elphidium crispum, Cassidulina laevigata, Textularia agglutinans and Pyramidulina raphanistrum.

The analysis of the soil textural in the Martil region reveals that the substrate is mainly composed of sand. In contrast, in the Azala region, the substrate consists of sandy loam, suggesting a finer texture with a higher proportion of fine sediment particles. Site S3 exhibits the smallest particles on average, suggesting a sedimentation environment characterized by calm deposition conditions. Sites S1 and S2 have larger particles on average, indicating a more energetic sedimentation environment with a greater particle transport capacity[10].

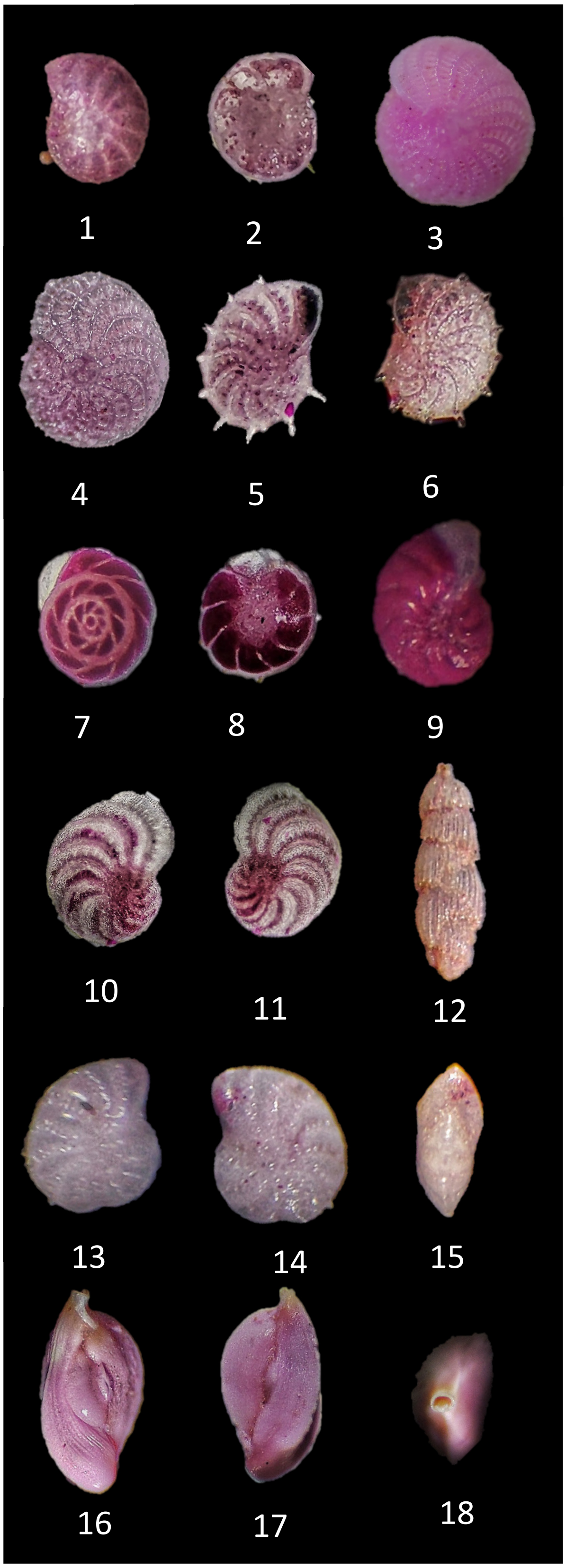

Fig. 2. 1 and 2 Lobatula lobatula, 3 Elphidium crispum, 4 Elphidium macellum, 5 and 6 Elphidium aculeatum, 7 and 8 Eponides, 9 Nonion commune, 10 and 11 Elphidium spp, 12 Rectuvigerina multicostata, 13,14 and 15 Porosononion granosum, 16,17 and 18 Quinqueloculina spp.

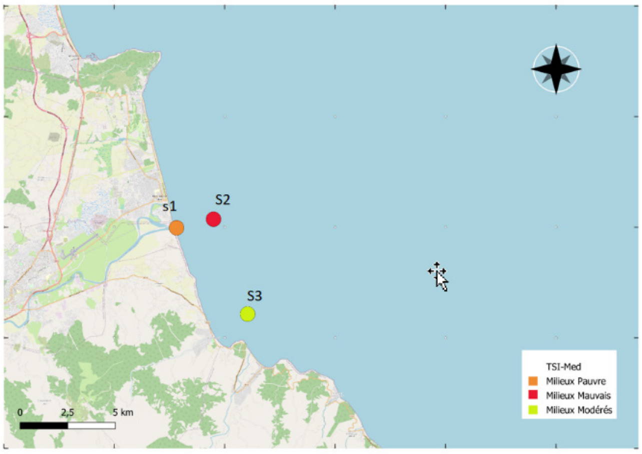

Fig. 3. Mapping of TSI-Med Indices

The evaluation of ecological quality based on TSI-Med, has identified varying ecological states along the studied coast. Sites S1 and S2 displayed a gradual deterioration of ecological status, whereas site S3 exhibited a relatively moderate ecological state.

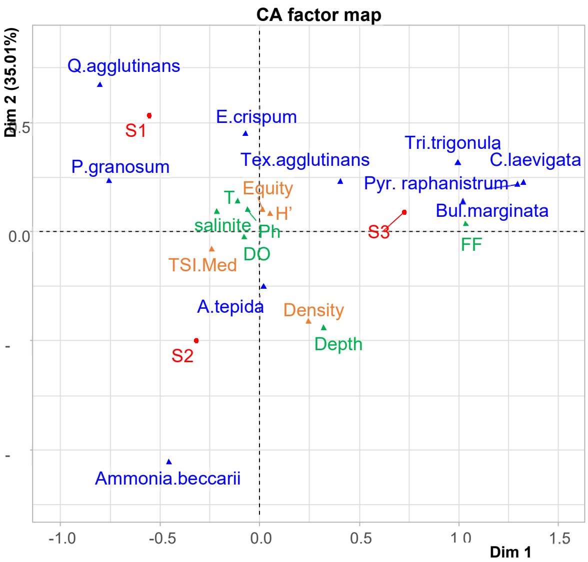

Fig. 4. Graph of Correspondence Analysis

Axes 1 and 2 jointly account for 100% of the total inertia. The first dimension (64.99%) and the second dimension (35.01%) contribute significantly to this variance. The primary influence on the first dimension comes from the fine fraction (grain size). But the second dimension is mainly influenced by density and depth, which exhibit a positive correlation. This implies that, in this dimension, samples with higher density are generally associated with greater depths.
The samples S1 and S2 exhibit an increase in the density of benthic foraminifera, influenced by varying environmental conditions such as depth. However, sample S3, despite sharing a similar depth with S2, displays lower density due to granulometry. This substrate contains a high percentage of fine fractions, which can adversely affect the density of species within the sample [8] .

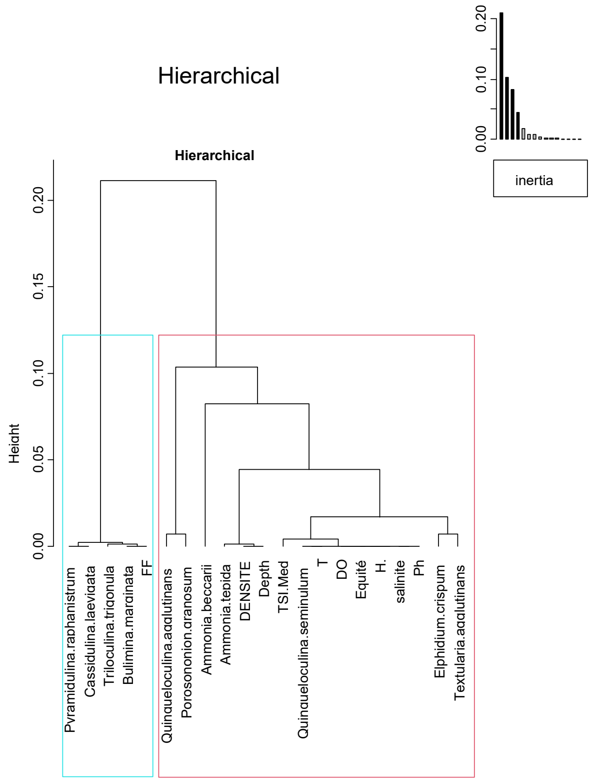

Fig. 5. A Dendrogram of Parameters and Spaces

4 conclusion

In conclusion, this study on the use of benthic foraminifera as a tool for monitoring the marine ecological status along the coast of Martil, northwest Morocco, provides valuable insights into the ecological quality of the region. The results of Correspondence Analysis (CA) and Hierarchical Ascendant Classification (HAC) have revealed that grain size and depth are the primary factors influencing the distribution of benthic foraminiferal species in the radial of the Oued Martil. Sample S3 exhibits the smallest particles, suggesting a calm deposition environment. S2 also indicates a tranquil environment, while S1 suggests an energetic environment with larger particle transport. It is essential to note that the presence of the Oued Martil River plays a significant role in the response of foraminifera in the region, affecting the ecological quality of benthic foraminifera in the Martil region. In summary, this study demonstrates that benthic foraminifera are promising indicators for assessing the ecological status of marine ecosystems along the Moroccan Mediterranean coast.

References

1. J. W. Murray, Ecology And Applications Of Benthic Foraminifer, Cambridge University Press (2006)
2. E. Alve, Benthic Foraminifera In Sediment Cores Reflecting Heavy Metal Pollution In Sørfjorden, Western Norway, Marine Micropaleontology, **26**(1-4), 199-218 (1995)

3. B. K. Sen Gupta, Modern Foraminifera. Springer Science & Business Media (1999)
4. J. Schönfeld, E. Alve, E. Geslin, F. Jorissen, S. Korsun, S. Spezzaferri, N. Risgaard-Petersen, The Fobimo (Foraminiferal Bio-Monitoring) Initiative - Towards A Standardised Protocol For Soft-Bottom Benthic Foraminiferal Monitoring Studies, Marine Micropaleontology, **94**, 1-13 (2012)
5. A. R. Loeblich, H. Tappan, Foraminiferal Genera And Their Classification, Van Nostrand Reinhold, New York. (1987)
6. Y. Lei, T. Li, R. Nigam, M. Holzmann, M. Lyu, Environmental Significance Of Morphological Variations In The Foraminifer Ammonia Aomoriensis (Asano, 1951) And Its Molecular Identification: A Study From The Yellow Sea And East China Sea, Pr China. Palaeogeogr. Palaeoclimatol. Palaeoecol. (2016)
7. C.K. Wentworth, A Scale Of Grade And Class Terms For Clastic Sediments. J. Geo.**30** (5), 377–392 (1922)
8. C. Barras, Live Benthic Foraminiferal Faunas From The French Mediterranean Coast: Towards A New Biotic Index Of Environmental Quality, Ecological Indicators. (2014)
9. B. Parent,B. Christine, B. Erica, M.C. Laurie, C. Constance, B. Éric, M. M. Grégoire, F. J. Jorissen, Comparison Of Four Foraminiferal Biotic Indices Assessing The Environmental Quality Of Coastal Mediterranean Soft Bottoms, Water **13** (22): 3193 (2021)
10. J. Fournier, B. Chantal, P. Raphaël, & Monique Le Vot, Analyse Granulométrique, Principes Et Méthodes.Cnrs, Dinard, 99 Pages (2012)