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Research Article.

Marine Faunal Inventory of the eastern Tipaza Coast (Central Algeria, Southwestern Mediterranean Sea): Baseline Data for Biodiversity Assessment.

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ABSTRACT

Coastal ecosystems along the Mediterranean Sea are highly diverse yet spatially heterogeneous, with many areas remaining poorly documented. This study provides a faunistic inventory of marine assemblages along the eastern Tipaza coastline (Algeria) and evaluates spatial patterns of species richness, diversity, and community structure. Sampling was conducted between January and June 2024 at six stations using a combination of field surveys and fishery-dependent data. A total of 282 species across eight phyla were recorded, with Mollusca, Chordata, and Arthropoda being the most species-rich groups. Ecological indices revealed pronounced spatial heterogeneity in community structure; Shannon-Wiener diversity (H') ranged from 2.47 to 4.30, while Pielou's evenness (J') reached 0.89 in the harbor stations. Richness estimators and individual-based rarefaction confirmed these differences, with harbor areas and Posidonia oceanica meadows supporting the highest diversity and sampling completeness (up to 89.9%). Observed richness likely underestimates true diversity, highlighting the importance of continued monitoring. The presence of endemic and invasive species emphasizes the ecological value and vulnerability of these coastal habitats. These baseline data provide essential information for biodiversity assessment, conservation planning, and sustainable management of Mediterranean coastal ecosystems.

KEYWORDS

Marine biodiversity;
Faunistic inventory;
Coastal ecosystems;
Posidonia oceanica;
Tipaza;
Algerian coast.

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1. INTRODUCTION

Marine ecosystems represent the largest reservoir of biodiversity on Earth, hosting an exceptional diversity of taxa, functional traits, and evolutionary lineages shaped over more than 3.5 billion years of biological history (Smith, 1996). This long evolutionary legacy, combined with the vast spatial extent and environmental heterogeneity of marine environments, has resulted in complex ecological systems structured along strong physical, chemical, and biological gradients (Schopf *et al.,* 2018).

The Mediterranean Sea, although accounting for less than 1% of the global oceanic surface and volume, supports a disproportionately high level of marine biodiversity, estimated at 7–18% of the world's known marine species, with endemism rates approaching 28% (Bianchi *et al.,* 2003; Coll *et al.,* 2010). This remarkable richness is the product of a unique palaeogeographical history, pronounced habitat heterogeneity, and its position as a biogeographical crossroads between Atlantic, temperate, and subtropical faunas (Coll *et al.,* 2010). As a semi-enclosed basin, the Mediterranean is also highly sensitive to environmental change, making it a priority region for biodiversity assessment and monitoring (Lejeusne *et al.,* 2010; Micheli *et al.,* 2013).

Over recent decades, Mediterranean coastal ecosystems have been subjected to increasing anthropogenic pressures, including urbanization, industrial and agricultural pollution, habitat modification, overexploitation of biological resources, biological invasions, and climate-driven changes in temperature and circulation patterns (Landry, 2012; Coll *et al.,* 2010). These cumulative stressors have led to significant alterations in species composition, community structure, and ecosystem functioning, particularly in coastal and shelf environments. Faunistic inventories constitute a fundamental component of marine biodiversity research, providing the primary data necessary for taxonomic, ecological, and biogeographical analyses (Bouchet *et al.,* 2002; Appeltans *et al.,* 2012; Costello *et al.,* 2013).

This study aims to enhance knowledge of marine biodiversity along the Coast by compiling an inventory of marine fauna. The primary objectives of the present study were to (i) compile a comprehensive inventory of marine fauna along Tipaza coastline, encompassing multiple taxonomic groups; (ii) quantify spatial patterns of species richness and community structure across representative coastal habitats; (iii) assess diversity and compositional differences among stations using both univariate and multivariate ecological indices; and (iv) evaluate the occurrence of endemic and invasive species in relation to habitat heterogeneity and anthropogenic influence. By establishing this baseline dataset, the study aims to support future monitoring, conservation prioritization, and sustainable management strategies for nearshore marine ecosystems in a region where such integrative biodiversity assessments remain limited.

2. Materials and Methods

2.1. Sampling And Study Sites

The study was conducted along the eastern sector of Tipaza Coast, located in central Algeria on the southwestern Mediterranean Sea. This coastline extends over approximately 120 km and encompasses a wide range of coastal habitats, including rocky shores, sandy and gravel beaches, semi-enclosed bays, fishing harbours, and shallow subtidal soft-bottom areas. The continental shelf width ranges from 11 to 30 km, transitioning into a steep continental slope with an average gradient of 11° (Dan- Unterseh *et al.,* 2011).

2.2. Sampling Design and Data Sources

Sampling was carried out between January and June 2024 using a multi-source approach combining field-based surveys and fishery-dependent data. Six coastal stations were selected to represent the main habitat types and anthropogenic contexts along the coastline (Fig. 1; Table 1). Most stations were visited ten times during the study period, except station T3, which was sampled twice due to logistical constraints.

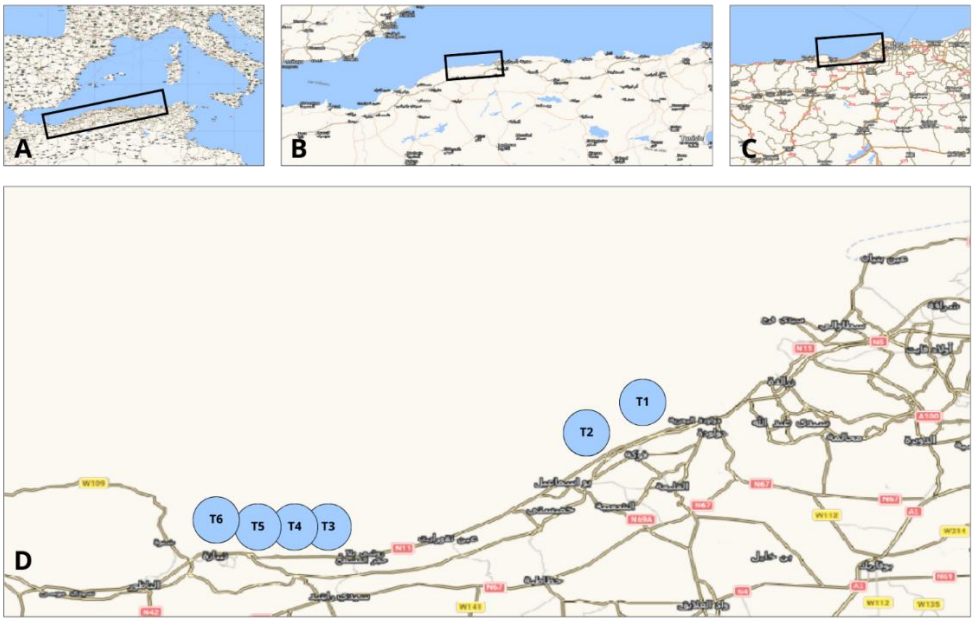

Figure 1. Geographic location of the study area and sampling stations along Tipaza coastline. (A): the Algerian coastline; (B): overview of Tipaza province coastline; (C): view of the eastern part of Tipaza province; (D): locations of the six sampling stations (T1–T6) selected for the study

Field-based sampling was conducted using two complementary approaches to capture local biodiversity. For shoreline and shallow subtidal zones, specimens were collected manually either by beachcombing (collecting sea-wrack and stranded organisms) or through active snorkeling (PMT) in rocky and soft-bottom habitats. For offshore and deeper-water species, fishery-dependent sampling was employed in local harbors. Specimens were obtained directly from fishers using a variety of gear types, including trawlers, seiners, and small-scale artisanal gear (small-scale fisheries).

Table 1. Sampled stations

Station ID	Site name	Latitude (N)	Longitude (E)	Habitat type	Depth (m)	Number of visits
T1	Bou Ismail Harbor	36°38'59''	2°41'31''	Fishing harbour (commercial and artisanal fisheries)	60	10
T2	Bouharoune Harbor	36°37'34''	2°39'19''	Fishing harbour (commercial trawling area)	60-130	10
T3	Cultemare farm	36°35'30''	2°30'39''	Semi-natural coastal area	25	2
T4	Anse de Kouali beach	36°35'27''	2°29'40''	Sandy beach with shallow subtidal zone (Posidonia oceanica nearby)	0-3	10
T5	Tipaza Harbor	36°35'38''	2°27'01''	Fishing harbour (artisanal fisheries)	50	10
T6	Chenoua 2 beach	36°35'57''	2°25'07''	Sandy coastal area	0-2	10

For ethical and regulatory reasons, only one representative individual per fish species was retained for taxonomic identification.

2.3. Specimen Handling and Taxonomic Identification

Collected specimens were transported to the laboratory, where they were photographed and cleaned. Depending on the taxonomic group, different preservation methods were applied for subsequent identification: molluscs were air-dried, while other fragile specimens were frozen. For long-term preservation and detailed anatomical study, a selection of samples was fixed in a 10% buffered formalin solution. Taxonomic identification was performed using regional identification guides and updated nomenclature from the World Register of Marine Species (WoRMS).

2.4. Data Processing and Ecological Indices

2.4.1. Faunistic Inventory and Species Richness

All recorded taxa, including fishes and invertebrates, were used to compile the faunistic inventory and to calculate total species richness at each station.

2.4.2. Alpha Diversity Indices (invertebrates only)

Abundance-based alpha diversity analyses were restricted to benthic invertebrate taxa for which standardized quantitative data were available. The following indices were calculated per station:

Species richness (S): total number of species recorded per station.

Abundance (N): total number of individuals recorded per station.

Dominance (D): Simpson's dominance index, reflecting the degree to which one or few species numerically dominate the assemblage.

Simpson diversity index (1–D): measuring the probability that two randomly selected individuals belong to different species.

Shannon–Wiener diversity index (H'):

$$H' = -\sum p_i \ln(p_i)$$

where p_i is the proportional abundance of species i. (Shannon & Weaver, 1949)

Evenness ($e^{H/S}$): assessing the distribution of individuals among species.

Pielou's equitability index (J): evaluating how evenly individuals are distributed across species (Pielou, 1966).

$$E = \frac{\mathrm{H}'}{\log S}$$

Margalef's richness index: describing species richness standardized by sample size.

2.4.3. Richness Estimators and Rarefaction

Individual Chao-1 (Chao, 1984) and iChao-1 (Chiu *et al.,* 2014) estimators were used to assess sampling completeness. Individual-based rarefaction curves were generated (Sanders, 1968; Hurlbert, 1971) to standardize species richness with respect to sampling effort and to evaluate inventory exhaustiveness.

All indices and analyses were computed using PAST software (version 5.3, Hammer *et al.,* 2001).

Because fish abundance data derived from fishery-dependent sources do not reflect in situ population densities, fish taxa were excluded from abundance-based diversity and rarefaction analyses. This methodological choice aimed to minimize bias associated with heterogeneous sampling strategies.

3. Results and Discussion

3.1. Overall Species Richness and Taxonomic Structure

The present study documented a total of 282 marine species representing 3,168 individuals along Tipaza coastline. Taxonomic analysis revealed a high level of zoological diversity distributed across eight phyla, 25 classes, 90 orders, and 154 families, highlighting the structural and ecological complexity of the studied coastal systems. The relative contribution of each major taxonomic group is illustrated in Figure 2.

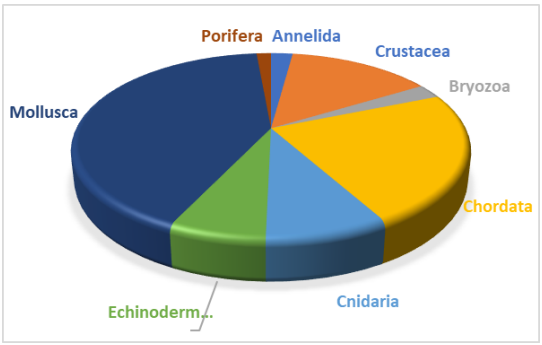

Figure 2. Taxonomic structure of the recorded marine fauna

An analysis of taxonomic richness revealed a ranked distribution of the groups according to species diversity: Mollusca with 117 taxa covering 41.49% of the recorded taxa, Chordata (23.05%), Crustacea (14.18%), Cnidaria (8.51%), Echinodermata (6.74%), Bryozoa (2.48%), Annelida (2.13%), and Sponges (1.42%).

This taxonomic structure reflects the coexistence of soft-bottom, rocky, and biogenic habitats along Tipaza coast, supporting a wide range of ecological strategies and functional groups. The dominance of molluscs and crustaceans underscores the

importance of benthic and bentho-pelagic compartments in shaping local biodiversity patterns.

3.2. Spatial Distribution of Species Richness

Species richness varied markedly among the six sampling stations, indicating pronounced spatial heterogeneity along Tipaza Coast. Station T2 exhibited the highest species richness, accounting for 65.25% of the total recorded species, followed by T4 (38.30%) and T5 (19.50%). In contrast, T6 (10.99%) and stations T3 (7.09%: due to reduced sampling effort at this site, rather than an indication of low biological productivity) displayed the lowest richness values, while T1 accounted for 14.18% of the total species pool (Fig. 3).

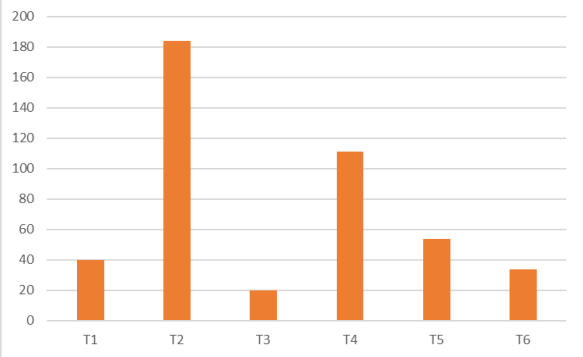

Figure 3. Percentage contribution of each sampling station to total species richness

The observed differences in species richness among sampling stations likely reflect a combination of habitat characteristics, ecological functions, and anthropogenic pressures that vary spatially along the Tipaza coastline.

The exceptionally high species richness observed at T2 should be interpreted with caution, as it partly reflects fishery-dependent sampling, which tends to over-represent mobile and exploited taxa. The dominance of fish species at this station can be explained by the high fishing effort and the diversity of target and by-catch species associated with trawling operations. Trawl fisheries are known to sample a broad spectrum of demersal and bentho-pelagic species, often resulting in elevated apparent species richness compared to non-fishery-based sampling methods (Pauly *et al.,* 1998; Coll *et al.,* 2010).

In contrast, the Anse de Kouali station, characterized by *Posidonia oceanica* meadows and sandy substrates, exhibited a species assemblage dominated by molluscs and associated benthic invertebrates. Seagrass meadows are among the most productive and structurally complex coastal habitats in the Mediterranean Sea, supporting a high diversity of invertebrates and serving as nurseries for multiple taxa (Guidetti *et al.,* 2000; Kalogirou *et al.,* 2010). The dense vegetative structure and food availability provided by *P. oceanica* create numerous ecological niches, explaining the relatively elevated richness of benthic molluscs at this station. Stations located in Tipaza Harbor and Bou Ismail also displayed relatively high species richness and were dominated by fish and select invertebrate taxa.

A total of 12 endemic species were recorded during the survey, representing a relatively small but ecologically significant fraction of the total fauna. Endemic species were unevenly distributed among stations (Table 2).

Table 2. Species richness, abundance, and endemic species per station

Station	Species richness	Percentage (%)	Endemic species
(T1) Bou Ismail Harbor	40	14.18	1
(T2) Bouharoune Harbor	184	65.25	5
(T3) Cultemare farm	20	7.09	0
(T4) Anse de Kouali beach	108	38.30	5
(T5) Tipaza Harbor	55	19.50	1
(T6) Chenoua 2 beach	31	10.99	2

The concentration of endemic species at T2 and T4 further underscores the conservation value of these stations. Endemics are often characterized by restricted ecological requirements and limited dispersal capabilities, making them particularly sensitive to environmental disturbance. Their presence suggests relatively stable local conditions and highlights the need for targeted conservation and monitoring efforts in these areas.

Overall, these patterns highlight the combined influence of habitat characteristics and fishing activities on coastal biodiversity. Fishery-dependent sampling emphasizes the diversity of exploited assemblages, while natural habitats such as *Posidonia oceanica* meadows remain key reservoirs of benthic and functional diversity. Together, these results underline the need to consider both ecological features and sampling context when interpreting spatial patterns of marine biodiversity.

Table 3. Alpha diversity indices and species richness across the six sampling stations along Tipaza coastline

	T1	T2	T3	T4	T5	T6
Taxa richness (S)	29	122	20	111	25	32
Total individuals (N)	146	1198	104	1320	60	172
Simpson dominance index (D)	0.09003	0.01829	0.1346	0.02212	0.0565	0.08119
Simpson's diversity index (1-D)	0.91	0.9817	0.8654	0.9779	0.9435	0.9188
Shannon diversity index (H')	2.834	4.301	2.471	4.169	3.094	2.995
Evenness index ($e^{H/S}$)	0.5866	0.6049	0.5919	0.5826	0.8829	0.6246
Margalef's richness index (d)	5.618	17.07	4.091	15.31	5.862	6.022
Pielou's evenness (J')	0.8131	0.8848	0.7945	0.8764	0.8992	0.8382
Fisher's alpha (α)	10.86	33.98	7.363	28.88	16.09	11.58
Chao-1 richness estimator	33.47	174.8	26.93	120	42.9	35.58
iChao-1 richness estimator	35.88	188.7	32.15	123.5	50.64	36.47

3.3. Alpha Diversity Patterns Across Sampling Stations

Alpha diversity indices revealed marked spatial differences in community structure among the six sampling stations (Table 3). Species richness (S) ranged from 20 species at T3 to 155 species at T2, reflecting strong heterogeneity along Tipaza coastline. Stations T2 and T4 also exhibited the highest numbers of individuals, indicating both elevated richness and sampling intensity.

Shannon–Wiener diversity index (H′) values varied substantially among stations, ranging from 2.47 at T3 to 4.30 at T2. High Shannon diversity values at T2 (H′ = 4.30) and T4 (H′ = 4.17) indicate highly diverse assemblages with a relatively even distribution of individuals among taxa, which is consistent with the corresponding high Pielou's equitability values (J = 0.8848 and 0.8764, respectively). In contrast, lower H′ values at T3 (H′ = 2.47) and T1 (H′ = 2.834) reflect less complex assemblages dominated by a few taxa.

Simpson diversity (1–D) was consistently high across stations (0.87–0.9817), indicating that most assemblages were not dominated by a single taxon. The exception was T3, where the lower Simpson value (1–D = 0.8654) coupled with the highest dominance index (D = 0.1346) revealed a more uneven community structure.

Equitability, as measured by Pielou's index (J), further highlighted differences in community balance, ranging from 0.7945 at T3 to 0.8992 at T5. High J values at T5 and T4 indicate that individuals were

Alpha diversity indices calculated for benthic invertebrate assemblages revealed pronounced spatial heterogeneity among the six sampling stations along Tipaza coastline (Table 3). Species richness (S) ranged from 20 taxa at station T3 to 122 taxa at station T2, indicating strong variability in community composition across sites. Stations T2 and T4 also exhibited the highest numbers of individuals, reflecting both elevated richness and higher sampling intensity.

more evenly distributed among species, even when total richness was moderate.

Richness estimators (Chao-1 and iChao-1) consistently exceeded observed species richness, particularly at T2 and T4, suggesting that additional rare taxa were likely present but not sampled. This emphasizes that the observed alpha diversity represents a conservative estimate of true species richness and highlights the importance of continued monitoring to capture the full diversity of coastal benthic assemblages.

Sampling completeness was assessed by comparing observed richness (S) to the iChao-1 estimator. Coverage values ranged from 49.4% at Station T5 to 89.9% at Station T4. At the most species-rich sites, the inventory captured 64.7% (T2) and 89.9% (T4) of the estimated taxocenosis. Across most stations, the survey documented over 60% of the predicted richness, indicating that while the dominant and structurally important species were effectively recorded, a significant fraction of rare or sporadic taxa remains to be documented.

3.4. Rarefaction and Sampling Completeness

Individual-based rarefaction curves revealed marked differences in standardized species richness among the six sampling stations (Fig. 4). Stations T2 and T4 displayed the highest rarefied richness values across the entire gradient of sampled individuals, confirming that their elevated diversity is not merely an artefact of higher sampling effort but reflects intrinsically richer biological assemblages. In contrast, stations T1, T3, T5, and T6 exhibited lower rarefaction trajectories, with curves rising more slowly and leveling off at substantially lower richness values, indicating comparatively simpler and less diverse communities. For Station T3, the steep slope of the curve despite the low number of individuals suggests that many species remain undiscovered.

Importantly, none of the rarefaction curves reached a clear asymptote, even at the highest sampling intensities. This absence of saturation suggests that additional sampling would likely detect further species in all stations. Such a pattern is typical of Mediterranean coastal ecosystems, where high habitat heterogeneity, patchy species distributions, and the presence of rare or cryptic taxa often prevent inventories from achieving complete exhaustiveness. Consequently, the present survey should be regarded as providing a robust but conservative estimate of local biodiversity.

This analysis reveals that coastal assemblages along Tipaza shoreline are locally structured yet regionally heterogeneous. Stations characterized by high species richness do not simply represent subsets of poorer sites. They host distinct community compositions shaped by local environmental filters, substrate heterogeneity, and varying levels of anthropogenic pressure.

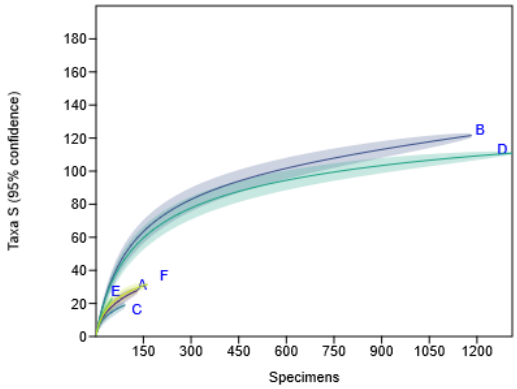

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Figure 4. Individual-based rarefaction curves showing standardized species richness (±95% confidence intervals) for the six sampling stations (A: T1; B: T2; C: T3; D: T4; E: T5; F: T6) along Tipaza coastline

The faunistic inventory conducted along Tipaza coastline revealed a diversified marine assemblage comprising eight major phyla, with Mollusca (117 species), Chordata (65 species), and Arthropoda (40 species) representing the most species-rich groups. This taxonomic structure is broadly consistent with patterns reported from other sectors of the Algerian coastline and the Mediterranean basin, where molluscs and fishes typically dominate coastal biodiversity inventories (Coll *et al.,* 2010; Dauvin *et al.,* 2013).

Mollusca, the most represented phylum in the present study, constitute a dominant component of Mediterranean coastal biodiversity. Similar dominance has been reported from the Gulf of Oran, where molluscs account for a substantial proportion of benthic and demersal fauna, particularly gastropods and bivalves associated with rocky

substrates and seagrass meadows (Kerfouf *et al.,* 2021). The high molluscan richness observed in Tipaza likely reflects habitat heterogeneity, including rocky shores, sandy bottoms, and *Posidonia oceanica* beds, which are known to support diverse molluscan assemblages throughout the Mediterranean (Guidetti *et al.,* 2000).

Among the benthic invertebrates, *Acanthocardia tuberculata* was the most abundant species (131 individuals), followed by *Astroides calycularis* (90), *Anomia ephippium* (87), *Cardita calyculata* (81), and *Bolma rugosa* (70). These species are characteristic components of Mediterranean benthic communities, playing key ecological roles as habitat formers, suspension feeders, or predators. In addition, five species (*Mimachlamys varia*, *Mytilus edulis*, *Hexaplex trunculus*, *Stramonita haemastoma*, and *Paracentrotus lividus*) were recorded across all sampling stations, indicating broad ecological tolerance and highlighting their role as ubiquitous components of the coastal fauna.

Fish species were mainly recorded in harbor environments and landing areas, where specimens were opportunistically collected for taxonomic identification purposes. Due to ethical and logistical constraints, fish abundance data were not included in quantitative analyses, which focus exclusively on benthic invertebrates. Comparable patterns of fish diversity have been documented in harbor areas and fishing zones along the Algerian coast, where fish diversity is often enhanced by fishing activity and the use of fishery-dependent data sources (Pauly *et al.,* 1998; Coll *et al.,* 2010; Alkhalili *et al.,* 2025).

Crustaceans represented an important fraction of the fauna in Tipaza, a level of diversity comparable to inventories conducted in central and western Algerian waters, where decapods and peracarids form a structurally and functionally important component of benthic communities (Grimes *et al.,* 2016; Bakalem *et al.,* 2021). Crustacean diversity is often closely linked to substrate complexity and organic matter availability, which may explain their relatively high representation in mixed habitats.

The detection of three invasive species in the present inventory reflects broader Mediterranean trends, where biological invasions have intensified over recent decades due to shipping, aquaculture, and climate warming (Stamouli *et al.,* 2017; Galil *et al.,* 2018). Although numerically limited in this study, their presence warrants attention, as even low abundances can lead to significant ecological impacts through competition, habitat modification, and trophic disruption.

Overall, the faunistic composition observed along Tipaza coastline is consistent with patterns reported from other Algerian and Mediterranean coastal regions, combining high taxonomic richness with marked spatial heterogeneity. The coexistence of endemic, invasive, and commercially exploited species underscores the ecological complexity of these coastal systems. These findings highlight the importance of continued biodiversity monitoring and habitat conservation, particularly in areas subject to increasing anthropogenic pressure. Protecting habitat heterogeneity and limiting further degradation are essential to maintaining both local

biodiversity and the broader biogeographic integrity of Mediterranean coastal ecosystems.

4. Conclusion

This study provides a comprehensive faunistic inventory of faunal communities along the eastern Tipaza coastline. Results highlight high taxonomic richness and pronounced spatial heterogeneity, documenting 282 species across eight phyla, driven by habitat complexity, local environmental filters, and anthropogenic pressures. Rarefaction and richness estimators indicate that a significant portion of rare taxa remains undetected, underscoring the need for continued monitoring. The presence of endemic and invasive species further emphasizes the ecological importance and vulnerability of these coastal ecosystems. Ultimately, this work constitutes a solid foundation for future ecological studies and long-term monitoring programs in the region. These baseline data provide a fundamental tool for biodiversity assessments, conservation prioritizing, and the sustainable management of Mediterranean coastal habitats in Algeria.

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