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Taxonomic Identification and Biodiversity Assessment of Caprellidae Amphipods, Crustaceans associated with Macroalgae along the Coast of Mostaganem (Algeria)

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Abstract

Caprellidae amphipods form an important group of benthic crustaceans associated with various biotic substrates, particularly macroalgae. This study aimed to identify Caprellidae species and evaluate their biodiversity in association with macroalgae along the coast of Mostaganem (Algeria). Samples were collected from two types of macroalgae: *Ulva* sp. (green alga) and *Cystoseira* sp. (brown alga), at three coastal sites: Stidia, Salamandre, and Hadjadj. The individuals collected were identified to the species level and classified according to their sex. The results identified six species belonging to the genus *Caprella*: *Caprella acanthifera* Leach, 1814; *Caprella andreae* Mayer, 1890; *Caprella danilevskii* Czerniavski, 1868; *Caprella grandimana* Mayer, 1882; *Caprella hirsuta* Mayer, 1890; and *Caprella liparotensis* Haller, 1879. The biodiversity analysis shows a higher abundance of *Caprella* species on the brown alga *Cystoseira* sp. than on the green alga *Ulva* sp., with *Caprella danilevskii* Czerniavski, 1868 being the dominant species. Although species richness is similar between habitats, population structure varies depending on the study site and the type of macroalgae. These results highlight the importance of macroalgae as key habitats for Caprellidae and emphasize their role in maintaining biodiversity in coastal ecosystems of the Mostaganem region.

Keywords

Identification; Marine biodiversity; Caprellidae; Coastal ecosystems; Mostaganem

Introduction

The Mediterranean coastal ecosystems are characterised by a wide diversity of organisms associated with benthic habitats, particularly those linked to macroalgal formations. These

formations constitute complex microhabitats that provide refuge, food, and substrate for several marine invertebrates, among which amphipods occupy an important place. Within this group, Caprellidae amphipods are distinguished by their distinctive morphology and lifestyle, which is often attached to biological substrates, and their ecological role within algal communities (Keito *et al*., 2025).

Caprellidae, also known as "skeleton shrimp", are mainly found attached to macroalgae, hydroids, bryozoans, or other benthic structures. Algal assemblages contribute to the trophic functioning of these ecosystems, as they participate in the food chain by consuming organic particles, microalgae, or microscopic organisms (Caine, 1979; Guerra-García, Ros and Duffy, 2014; Navarro-Barranco *et al*., 2019), while also serving as a food source for many fish and invertebrates (Guerra-García and Thiel, 2001). Thus, these crustaceans play an important role in ecological dynamics and community structure associated with macroalgae. Their unique morphological characteristics favour their fixation on natural substrates (e.g. macroalgae, hydroids, bryozoans) and artificial substrates (e.g. ship hulls, buoys, marine debris) (Caine, 1979; Lolas *et al*., 2021; Nuñez-Velazquez *et al*., 2017). Caprellidae are widely distributed in both coastal and deep-sea environments worldwide (Díaz, Guerra-García and Martín, 2005; Guerra-García and García-Gómez, 2001; Laubitz and Millis, 1972; Lolas *et al*., 2021; Takeuchi and Sawamoto, 1998). Macroalgae constitute an essential habitat for amphipods, providing not only attachment sites that enhance stability in hydrodynamic conditions, but also structurally complex refuges that reduce predation pressure and support diverse food resources, including epiphytic microalgae, detritus, and associated microorganisms (Ferreira, Leite and Machado, 2025).

The genus *Cystoseira*, especially brown algal species, is known to be a particularly suitable host for a wide variety of invertebrates due to its complex three-dimensional structure (Ballesteros, 2006). On the other hand, the structure of green algae of the genus *Ulva* tends to be simpler, which can influence the structure of associated communities (Guerra-García *et al*., 2020; Kraan, 2012). The distribution of Caprellidae in Algeria is influenced by various ecological factors. The abundance and diversity of amphipods are determined by the structural complexity of benthic habitats, especially macroalgal assemblages, since these substrates provide suitable microhabitats for amphipod development (Bakalem, Dauvin and Grimes, 2014; Mansouri and Kerfouf, 2025). The marine amphipod fauna is particularly rich in Algeria, with 342 species known, including members of the family Caprellidae, which is among the richest families in the southern Mediterranean. According to local studies, some 10–15 Caprellidae species have been reported along the Algerian coast (Bakalem, Dauvin and Menioui, 2024). Caprellidae amphipods are still relatively unexplored in many parts of the Mediterranean basin, especially along the Algerian coast, despite their ecological significance.

The Mostaganem coastline, characterized by diverse algal assemblages, represents a promising habitat for the establishment and development of amphipod communities. However, knowledge regarding their species composition, distribution, and diversity remains limited and fragmented. In this context, the main issue addressed in this study lies in the lack of taxonomic and ecological data concerning Caprellidae amphipods associated with macroalgae in this region of the Algerian coastline. The absence of detailed inventories makes it difficult to assess species richness, understand relationships

between these crustaceans and different macroalgal species, and evaluate their role in local marine biodiversity. The interest of this study lies at two complementary levels. On the one hand, from a taxonomic perspective, it aims to inventory and identify the Caprellidae species present in macroalgal assemblages along the Mostaganem coast. This step is essential to improve knowledge of local amphipod fauna, establish reliable taxonomic references, and potentially identify rare or newly recorded species.

On the other hand, the study has major interest from a biodiversity perspective. The species diversity, abundance, and distribution of Caprellidae amphipods will be analyzed to provide deeper insight into the community structure associated with macroalgae and its variability among different algal assemblages. These data are valuable for evaluating ecological conditions of coastal ecosystems, as amphipods are considered reliable bioindicators. Therefore, the taxonomic identification and biodiversity assessment of Caprellidae amphipods associated with macroalgae along the Mostaganem coast will significantly improve our understanding of the benthic marine fauna of the Algerian coastline. The findings will also provide an important scientific basis for biodiversity monitoring, coastal ecosystem management, and the conservation of Mediterranean marine resources.

Materials and Methods

Presentation of the Algerian coast and Study Area

The Algerian coastline is characterized by a relatively narrow continental shelf composed of a succession of bays, gulfs, and rocky headlands. Sediment composition varies with depth, with the proportion of silt generally increasing in deeper waters. The coastal zone supports several ecologically important habitats, including seagrass meadows dominated by *Posidonia oceanica* and coralligenous formations, which are recognized as biodiversity hotspots in the Mediterranean Sea. Surface marine circulation along the Algerian coast is primarily influenced by North Atlantic surface waters, which play a significant role in shaping local oceanographic and ecological conditions (Bakalem, Pezy and Dauvin, 2021).

The study was conducted along the coast of Mostaganem, one of the main wilayas of northwestern Algeria, approximately 400 km west of the capital, Algiers, and known as an important coastal and tourist region, characterized by diverse marine habitats and extensive macroalgal assemblages that provide favorable environments for a variety of marine invertebrates, including amphipod crustaceans (Bengoufa *et al*., 2021).

Sampling Design

Samples were collected on a monthly basis between August 2022 and July 2023 at three locations: Stidia (35°50′06″N, 0°01′03″E), Salamandre (35°54′36″N, 0°03′15″E), and Hadjadj (36°09′03″N, 0°18′06″E), as shown on figure 1. These sites were purposely selected because they support diverse macroalgal habitats dominated by the green macroalga *Ulva* sp. and the brown macroalga *Cystoseira* sp., which provide suitable substrates and shelter for amphipod communities.

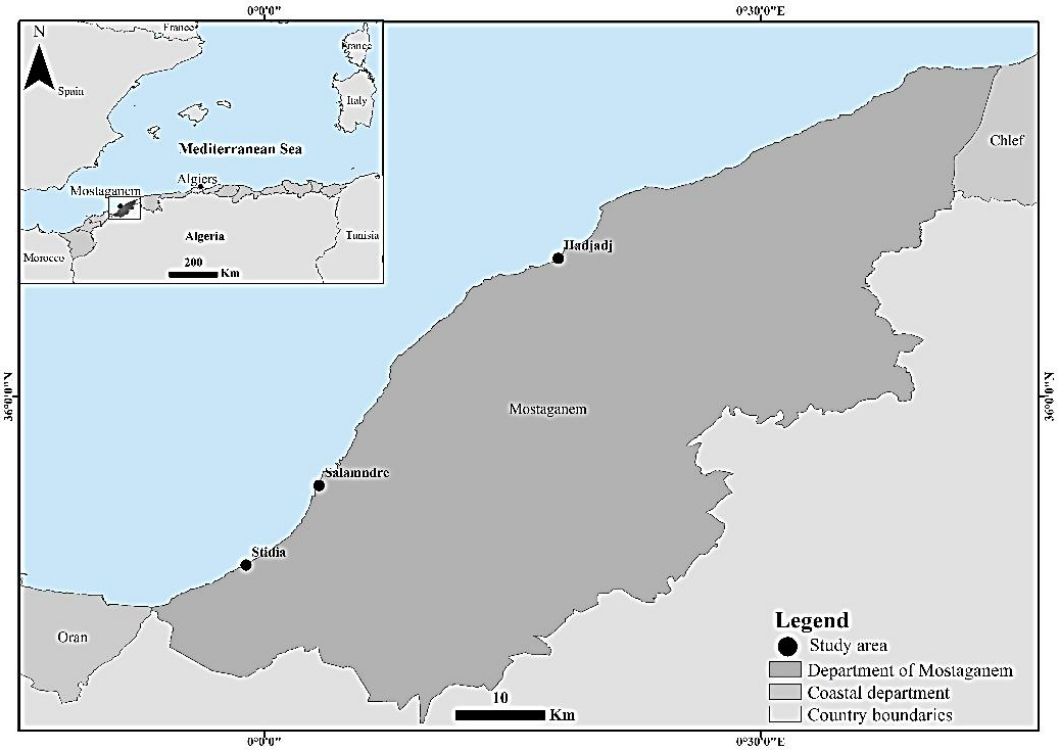

Figure 1: The geographical location of the three selected sites

These coastal areas feature a variety of algal habitats dominated by the green macroalga *Ulva* sp. and the brown macroalga *Cystoseira* sp. Macroalgae were collected manually from shallow intertidal and subtidal zones at the three coastal stations. Sampling was conducted using 25 × 25 cm quadrats randomly positioned within a 1 m² sampling area at each station. For each sampling, three replicate quadrats were collected per station across the predefined depth ranges of [0 to 2 m] for both intertidal and subtidal habitats. This design ensured standardized sampling effort, methodological reproducibility, and representative coverage of both calm and moderately exposed coastal areas (Liang *et al*., 2024). Two types of macroalgae were targeted: the brown alga (*Cystoseira* sp.) and the green alga (*Ulva* sp.). The samples were placed in fine-mesh nets (45 cm × 40 cm, 2 mm mesh) containing seawater to preserve associated organisms and transported to the laboratory.

Laboratory Treatment

In the laboratory, the algae were rinsed with a jet of water to separate the associated fauna, in particular Caprellidae amphipods. The organisms recovered in a collection tray were isolated using a fine brush and then preserved in 70% ethanol. Then, the specimens were observed and identified under a Motic BA310 stereomicroscope. Taxonomic identification of Caprellidae species was carried out using specialised identification keys (Krapp-Schickel and Vader, 1998; Guerra-García and Takeuchi, 2002; Guerra-García and Thiel, 2001).

Specimens were identified to the lowest possible taxonomic level based on a combination of diagnostic characters, including body segmentation and proportions, the morphology of antennae and gnathopods, pereopod structure, gill configuration, and abdominal appendages. Particular attention was paid to sexually dimorphic characters and developmental stage, where applicable, as these may influence the expression of diagnostic features within Caprellidae. Identifications were cross-checked among the cited keys and against original species descriptions and/or relevant regional taxonomic literature to minimise potential misidentification. Specimens showing incomplete or ambiguous diagnostic characters were retained at the most reliable taxonomic level.

Data Collection Techniques

The manuscript used a monthly, field-based quantitative sampling design to collect Caprellidae amphipods associated with macroalgae. The study was carried out between August 2022–July 2023. Three coastal locations in Mostaganem, Algeria—Stidia, Salamandre, and Hadjadj were selected as study sites. Green macroalga *Ulva* sp. and brown macroalga *Cystoseira* sp. Were the target habitats for the present study. Macroalgae were manually collected from shallow intertidal and subtidal zones, and 25 × 25 cm quadrats, randomly positioned within a 1 m² area at each station. Three replicate quadrats per station, sampled across a depth range of 0–2 m. Samples were placed in 2-mm mesh nets containing seawater, transported to the laboratory, rinsed to detach fauna, and specimens were preserved in 70% ethanol. Caprellidae were isolated with a fine brush and identified under a Motic BA310 stereomicroscope using taxonomic keys.

Results and Discussion

Identification of Caprellidae Species

A total of six species of Caprellidae amphipods were identified from the macroalgal assemblages sampled along the Mostaganem coast: *Caprella acanthifera* Leach, 1814; *Caprella andreae* Mayer, 1890; *Caprella danilevskii* Czerniavski, 1868; *Caprella grandimana* Mayer, 1882; *Caprella hirsuta* Mayer, 1890; and *Caprella liparotensis* Haller, 1879. Each individual was classified by sex (male or female). Among the species identified, *Caprella danilevskii* Czerniavski, 1868 and *Caprella andreae* Mayer, 1890 are considered to have a wide geographical distribution, found in both the Atlantic Ocean and the Mediterranean Sea. In contrast, *Caprella grandimana* Mayer, 1882 and *Caprella hirsuta* Mayer, 1890 are generally considered characteristic of Mediterranean waters, highlighting the distinctive biogeographical character of Caprellidae fauna in this region (Guerra-García, Sánchez-Moyano and García-Gómez, 2011). The occurrence of both widely distributed and Mediterranean-affiliated species suggests that the Mostaganem coastline represents a transitional habitat capable of supporting taxa with different biogeographical origins. This pattern may be related to the diversity of macroalgal substrates available, local hydrodynamic conditions, and the influence of Mediterranean circulation processes. Furthermore, the coexistence of these species contributes to the overall structural complexity and ecological functioning of coastal benthic communities.

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Biodiversity of Caprellidae

Presence of Caprellidae in Macroalgae

Table 1: Presence/absence of Caprellidae at the three stations in relation to the two macroalgal species *Ulva* sp. and *Cystoseira* sp.

Species	*Sites studied*					
	Stidia		*Salamandre*		*Hadjadj*	
	Cystoseira *sp.*	Ulva *sp.*	Cystoseira *sp.*	Ulva *sp.*	Cystoseira *sp.*	Ulva *sp.*
Caprella acanthifera Leach, 1814	-	-	-	-	-	+
Caprella andrea Mayer, 1890	+	+	+	-	+	+
Caprella danilevskii Czerniavski, 1868	+	-	+	-	+	-
Caprella grandimana Mayer, 1882	+	+	-	-	+	+
Caprella hirsute Mayer, 1890	+	+	-	-	+	+
Caprella liparotensis Haller, 1879	+	+	-	-	+	+

An analysis of the distribution of Caprellidae at the three study sites (Stidia, Salamandre, and Hadjadj) reveals significant differences in species composition depending on the type of algal substrate. At the Salamandre site, only two species, *Caprella danilevskii* Czerniavski, 1868 and *Caprella andreae* Mayer, 1890, were observed, exclusively associated with the brown alga *Cystoseira* sp. The absence of species on *Ulva* sp. at this site could be linked to the relatively simple morphology of these green algae, which offer fewer microhabitats and attachment surfaces for Caprellidae. Species of the genus *Cystoseira* possess a complex three-dimensional structure that promotes the establishment of diverse epibiont fauna, particularly Caprellidae amphipods.

At the Stidia station, species diversity is higher, with the presence of five species: *Caprella andreae* Mayer, 1890; *Caprella danilevskii* Czerniavski, 1868; *Caprella grandimana* Mayer, 1882; *Caprella hirsuta* Mayer, 1890; and *Caprella liparotensis* Haller, 1879. These species were observed on both *Cystoseira* sp. and *Ulva* sp., and the only species absent were *Caprella andrea* Mayer, 1890 and *Caprella danilevski* Czerniavski, 1868, which are slightly less widely distributed. No additional species were recorded at this station. This higher diversity may be attributed to favorable environmental conditions and increased habitat complexity. At the Hadjadj station, diversity is also relatively high, with four species observed: *Caprella andreae* Mayer, 1890; *Caprella grandimana* Mayer, 1882; *Caprella hirsuta* Mayer, 1890; and *Caprella liparotensis* Haller, 1879 were found on both algal types, whereas *Caprella danilevskii* Czerniavski, 1868 was restricted to *Cystoseira* sp. Additionally, *Caprella acanthifera* Leach, 1814 was observed only on *Ulva* sp., suggesting a possible ecological preference or local adaptation. Overall, the findings indicate that a significant proportion of Caprellidae species are associated with brown algae of the genus *Cystoseira*. This supports previous studies showing that these structuring algae play a key role in benthic community organization and biodiversity maintenance. The morphological complexity of *Cystoseira* thalli provides diverse microhabitats that support feeding, reproduction, and protection against predation.

Comparatively, *Ulva* sp., with its simpler structure and shorter life cycle, appears to provide a less suitable habitat for some Caprellidae species. However, species such as *Caprella andreae* Mayer, 1890; *Caprella grandimana* Mayer, 1882; *Caprella hirsuta* Mayer, 1890; and *Caprella liparotensis* Haller, 1879 demonstrate an ability to adapt to this substrate. These results confirm the importance of algal substrate type in shaping the distribution of Caprellidae and highlight the major ecological role of macroalgae in Mediterranean coastal ecosystems.

Abundance of Caprellidae in Cystoseira *sp.*

The number of individuals of the sampled species found in the brown alga *Cystoseira* sp. at the three study sites is shown in figure 2.

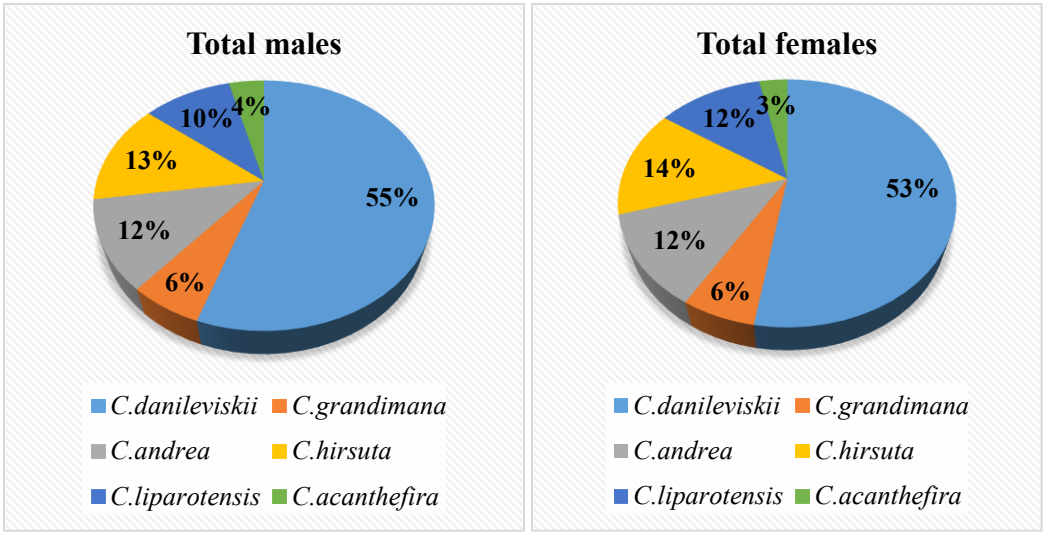

Figure 2: Abundance of Caprellidae species at the three study sites, as expressed in *Cystoseira* sp.

The abundance of Caprellidae associated with the brown alga *Cystoseira* sp. in the three study stations (Stidia, Salamandre, and Hadjadj) reveals a strong dominance of certain species. The results indicate that *Caprella danilevskii* Czerniavski, 1868 is the most abundant species, with 997 individuals, followed by *Caprella hirsuta* Mayer, 1890 (254 individuals) and *Caprella andreae* Mayer, 1890 (217 individuals). In contrast, *Caprella liparotensis* Haller, 1879 (207 individuals), *Caprella grandimana* Mayer, 1882 (109 individuals), and *Caprella acanthifera* Leach, 1814 (67 individuals) show lower abundances. The high ecological plasticity of *Caprella danilevskii* Czerniavski, 1868, as well as its capacity to develop on different algal substrates in coastal environments, likely explains its strong dominance.

Caprellidae are generally known for their adaptability to a wide range of benthic environments and for their association with biotic substrates such as macroalgae, hydroids, or bryozoans, which provide both habitat and food resources (de Paula *et al*., 2021). Furthermore, benthic invertebrates benefit from the complex three-dimensional structure of brown algal assemblages such as *Cystoseira* sp., which provide numerous

microhabitats and increased availability of refuges and trophic resources (Galobart *et al*., 2025; Mancuso, Sarà and Mannino, 2024). The relatively high abundance of *Caprella andreae* Mayer, 1890 and *Caprella hirsuta* Mayer, 1890 may also be related to their ecological affinity with Mediterranean macroalgae. Recent studies have shown that the structure of benthic invertebrate communities associated with macroalgae is strongly determined by the complexity of the algal assemblage, which directly influences the availability of microhabitats and the diversity of epibiotic species, especially amphipods (Navarro-Barranco *et al*., 2023). Conversely, lower abundances of *Caprella acanthifera* Leach, 1814; *Caprella grandimana* Mayer, 1882; and *Caprella liparotensis* Haller, 1879 may be attributed to more specialized ecological requirements, interspecific competition with dominant species, or local environmental differences such as hydrodynamics, substrate availability, and food resources.

Differences in species abundance are commonly observed in benthic amphipod communities, as habitat characteristics and ecological interactions strongly influence their distribution (Bakalem, Dauvin and Menioui, 2024). Overall, the abundance of Caprellidae within *Cystoseira* sp. assemblages highlights the important ecological role of these macroalgae in Mediterranean coastal ecosystems. *Cystoseira* forests are considered habitat-forming (foundation) species that enhance the structural complexity of benthic environments and promote biodiversity, particularly among amphipod crustaceans and other epibiotic invertebrates (Mancuso, Sarà and Mannino, 2024).

Abundance of Caprellidae in Ulva *sp.*

Number of individuals of the sampled species found in the green alga *Ulva* sp. at the three study sites (Figure 3).

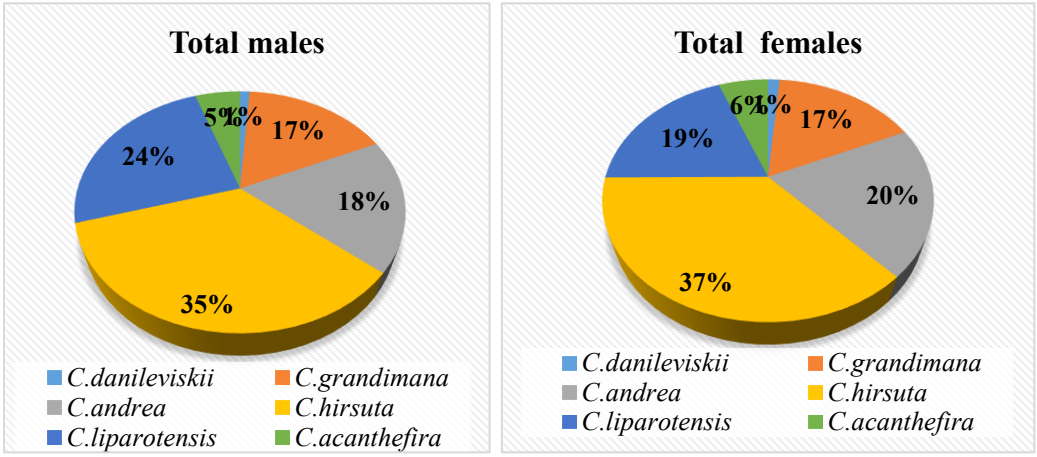

Figure 3: Abundance of Caprellidae species at the three study sites, as expressed in *Ulva* sp.

Caprella hirsuta Mayer, 1890 (198 individuals), *Caprella liparotensis* Haller, 1879 (120 individuals), and *Caprella andreae* Mayer, 1890 (105 individuals) exhibit the highest abundances in the green alga *Ulva* sp. across the three studied stations. In contrast, *Caprella grandimana* Mayer, 1882 (94 individuals), *Caprella acanthifera* Leach, 1814

(31 individuals), and *Caprella danilevskii* Czerniavski, 1868 (7 individuals) show lower abundances. These differences may be related to the ecological characteristics of the algal habitat, as well as to the species' ability to adapt to local environmental conditions.

The dominance of certain species can be explained by the ecological role of macroalgae of the genus *Ulva*, which constitute a structuring habitat for a wide diversity of associated organisms, particularly amphipods and various microfaunal organisms living on the surface or among the algal fronds. The fronds of *Ulva* sp. serve as a substrate for attachment and protection against predators, and as microhabitats of trophic value containing microalgae, bacteria, and particulate organic matter, thus facilitating the settlement and growth of many species of epiphytic and epibiotic microfauna. Several studies have indicated that habitats with high macroalgal cover support high microfaunal diversity, such as protozoa, nematodes, and small crustaceans, highlighting the ecological importance of these habitats in coastal ecosystems (Balsamo *et al*., 2012; Mirto *et al*., 2010).

The high abundance of *Caprella hirsuta* Mayer, 1890 observed in this study may be related to its ecological plasticity and its ability to adapt to shallow algal habitats, which are often characterized by strong hydrodynamics and a high availability of microorganisms and organic particles constituting an important food source. Caprellidae amphipods are known to efficiently exploit algal surfaces due to their specialized limbs, which enable them to adhere to the fronds and obtain food particles and other microorganisms in the water column (Guerra-Garcia and Tierno de Figueroa, 2009). Relatively high abundance of *Caprella liparotensis* Haller, 1879 and *Caprella andreae* Mayer, 1890 could be attributed to their preference for structurally complex algal habitats, which offer a broad range of microhabitats supporting attachment, feeding, and reproduction of amphipods. The structure of macroalgae greatly affects the composition and abundance of associated microfauna, as these microorganisms grow in biofilms and microspaces on the algal surface (Duffy *et al*., 2015; Wahl *et al*., 2012). Conversely, the low occurrence of *Caprella danilevskii* Czerniavski, 1868 and *Caprella acanthifera* Leach, 1814 could be associated with several ecological factors.

Some species exhibit particular preferences towards certain types of substrates or hydrodynamic conditions, which may restrict their occurrence in habitats dominated by *Ulva* sp. Furthermore, variations in environmental parameters such as temperature, nutrient availability, hydrodynamics, and water quality can influence the structure and distribution of microfauna communities associated with macroalgae, which may indirectly affect the distribution of amphipods (Balsamo *et al*., 2012). Finally, the dominance of certain species within a benthic assemblage may also be related to their rapid colonization capacity and high ecological tolerance, enabling them to efficiently exploit available resources in algal habitats. Macroalgae thereby contribute to the organization of coastal microhabitats by facilitating the development of complex microfaunal communities, which play a key role in benthic trophic networks and organic matter recycling (Zeppilli *et al*., 2018). In summary, the findings support that the green alga *Ulva* sp. constitutes an important microhabitat for Caprellidae amphipod communities. However, the composition and distribution of these communities are highly dependent on species ecology, the complexity of the algal habitat, interactions among microfaunal communities, and local environmental factors.

Comparison of Caprellidae Communities associated with the Macroalgae: Cystoseira *sp. and* Ulva *sp.*

Caprellidae assemblages associated with the two types of macroalgae under investigation (*Cystoseira* sp. vs. *Ulva* sp.) show contrasting patterns of distribution and abundance, which can be attributed to species-specific ecological responses to the structural and trophic features of the algal substrates. These findings are consistent with current knowledge of Mediterranean benthic ecology, particularly the role of algal habitat structure in shaping invertebrate communities. *Caprella danilevskii* Czerniavski, 1868 was found to be highly abundant in *Cystoseira* sp. assemblages (997 individuals), followed by *Caprella hirsuta* Mayer, 1890 and *Caprella andreae* Mayer, 1890.

The three-dimensional complexity and structural stability provided by *Cystoseira* sp. can explain this dominance, as it enhances the availability of microhabitats, refuges, and trophic resources. Recent Mediterranean studies indicate that Fucales-based algal communities such as *Cystoseira* sp. are associated with high benthic biodiversity and overall good ecological status, whereas opportunistic Ulvales species are typically linked to disturbed or nutrient-enriched environments. *Ulva* sp. is markedly different: *Caprella hirsuta* Mayer, 1890; *Caprella liparotensis* Haller, 1879; and *Caprella andreae* Mayer, 1890 are more prevalent, whereas *Caprella danilevskii* Czerniavski, 1868 and *Caprella acanthifera* Leach, 1814 are less represented. This suggests that, despite its lower structural complexity compared to Fucales, *Ulva* sp. provides favorable trophic conditions (high microfaunal abundance and particulate organic matter), promoting opportunistic species with high ecological tolerance. *Ulva* sp. is often associated with high microbial productivity and nutrient availability, benefiting flexible amphipod species capable of efficiently exploiting available food resources.

The brown macroalga *Cystoseira* sp. provides a complex three-dimensional environment that facilitates the development of specialized and structure-dependent amphipod populations, supporting the idea that benthic community structure strongly depends on habitat complexity. Conversely, *Ulva* sp., which provides a less complex structure, forms microhabitats that are rich in trophic resources and microorganisms, favoring the dominance of opportunistic or highly tolerant species in environments with variable hydrodynamic conditions. The spatial pattern of *Caprella* species is influenced by factors such as interspecific competition, food preferences, and resource availability, which are regulated by the ecological quality of the habitat.

Generalist and competitive species tend to dominate productive or disturbed environments where *Ulva* is prevalent, whereas more specialized species benefit from the complex microhabitats provided by *Cystoseira*. These findings support existing literature highlighting the importance of algal substrate type in structuring benthic communities such as amphipods. Macroalgae such as *Cystoseira* sp., considered ecosystem engineers (habitat-forming species) in the Mediterranean, play a key role in maintaining benthic biodiversity and overall coastal ecosystem health. The higher proportion of opportunistic species associated with *Ulva* sp. may also indicate fluctuating environmental conditions or local nutrient enrichment, highlighting the influence of environmental quality and coastal management on amphipod community composition.

Table 1: Comparative Occurrence and Habitat of Caprellidae in the Mediterranean

Species	*This study — Presence/Absence*	*Mediterranean habitat*	*Main referenced studies*
Caprella acanthifera Leach 1814	Observed only on *Ulva* sp. at Hadjadj	Opportunistic species; colonizes fine algae, epibionts and various substrates	Krapp-Schickel and Vader (1998); Guerra-García *et al*. (2010)
Caprella andrea Mayer 1890	Found on *Cystoseira* sp. and *Ulva* sp. (except Salamandre *Ulva* sp.)	Ubiquitous species: macroalgae, seagrass beds, debris, artificial substrates	Guerra-García and Izquierdo (2010); Lolas *et al*. (2021)
Caprella danilevskii Czerniavski 1868	Present only on *Cystoseira* sp.	Prefers structured algae (e.g. *Cystoseira*, *Corallina*) and hard substrates	Guerra-García *et al*. (2010); Lolas *et al*. (2021)
Caprella grandimana Mayer 1882	Found on *Ulva* sp. and *Cystoseira* sp.	Generally associated with coastal macroalgae.	Guerra-García, Sánchez and Ros (2009); Lolas *et al*. (2021)
Caprella hirsuta Mayer 1890	Found on *Ulva* sp. and *Cystoseira* sp.	Common Mediterranean species, frequently found on macroalgae	Guerra-García, Sánchez and Ros (2009); Lolas *et al*. (2021)
Caprella liparotensis Haller 1879	Found on *Ulva* sp. and *Cystoseira* sp. (except Salamandre *Ulva* sp.)	Associated with structured algae and seagrass beds; also found in *Posidonia* meadows	Guerra-García, Sánchez and Ros (2009); Lolas *et al*. (2021)

Statistical Analyses

Analysis of Variance (ANOVA)

The results of the ANOVA reveal that the factors studied have differing effects on the measured variable. Firstly, the effect of Site is not statistically significant ($p = 0.742 > 0.05$), indicating that the sites are relatively homogeneous across the three study sites. This lack of spatial variation suggests that local environmental factors are similar across sites and do not exert a strong influence on the analysed variable. Comparable results have been reported in several recent Mediterranean studies, where small-scale spatial variability is often lower than the influence of other ecological factors (Giakoumi *et al*., 2017). In contrast, the effect of Habitat is statistically significant ($p = 0.013 < 0.05$), reflecting a marked difference between the two types of algal habitats. This result highlights the importance of habitat structure as a key ecological factor influencing the distribution of the studied variable. This finding is consistent with several Mediterranean studies showing that algal habitat complexity strongly influences the diversity and organization of benthic communities (Bulleri and Airoldi, 2015; Piazzi and Ceccherelli, 2020; Piazzi *et al*, 2018).

Furthermore, changes in marine habitats, particularly those linked to global change, can significantly alter the structure of associated communities (Vergés *et al*., 2014). The effect of Species was not statistically significant ($p = 0.051$), although it was close to the significance threshold ($\alpha = 0.05$). This indicates a weak tendency toward interspecific

variation; however, the evidence is insufficient to draw a definitive statistical conclusion. This may reflect a real biological effect that is difficult to detect, potentially due to sampling limitations or high intraspecific variability. Similar observations have been reported in recent studies, where species differences are sometimes weaker than the structuring effect of habitat.

Tukey's Test

Multiple comparisons carried out using Tukey's test (95% CI) reveal a clear pattern in the variable under study according to the Habitat factor. Indeed, the brown algal habitat has a significantly higher mean (102.833) than the green algal habitat (30.944), with these two groups belonging to distinct homogeneous classes (A and B, respectively). This difference reflects a strong and statistically significant effect of habitat type on the studied variable. This result confirms the importance of habitat structure as a major ecological factor in shaping benthic assemblages, as widely demonstrated in Mediterranean rocky systems, where habitat complexity directly influences the abundance, diversity, and distribution of associated organisms (Ballesteros, 2006; Piazzi and Balata, 2011). Concerning the Species factor, the results reveal a more nuanced pattern. However, *Caprella danilevskii* Czerniavski, 1868 (167.333), differs significantly from *Caprella acanthifera* Leach, 1814 (16.667), whilst the other species (*Caprella hirsuta* Mayer, 1890; *Caprella liparotensis* Haller, 1879; *Caprella andreae* Mayer, 1890; *Caprella grandimana* Mayer, 1882) form overlapping groups (A/B), indicating the absence of clear significant differences between them. This grouping into intermediate classes suggests high intra-group variability and low overall interspecific differentiation, which is consistent with recent studies showing that species-specific effects are often secondary to structuring environmental effects in Mediterranean benthic communities (Boudouresque *et al*., 2021; Teixidó, Garrabou and Arntz, 2002).

Overall, these results indicate that variability in the studied variable is primarily driven by habitat type, whilst interspecific differences are limited and concern only the extremes of the distribution range. This hierarchy of effects (Habitat > Species) is commonly observed in coastal ecosystems influenced by environmental gradients, where habitat structure constitutes the main ecological filter influencing community organisation (Brustolin, Fonseca and Gallucci, 2022). The significantly higher values observed in brown algal habitats may be explained by their greater structural complexity, which provides more attachment surfaces, refuges and feeding opportunities for associated epifauna, including caprellids. The type and architecture of macroalgal substrates are therefore important factors influencing the abundance and distribution of these organisms (Martínez-Laiz *et al*., 2018; Pinedo, Jordana and Ballesteros, 2024; Vázquez-Luis *et al*., 2009). The marked abundance of *Caprella danilevskii* Czerniavski, 1868 compared with *Caprella acanthifera* Leach, 1814 may reflect species-specific differences in habitat preference and ecological requirements. However, the overlap of the other species within intermediate Tukey groups (A/B) indicates limited interspecific differentiation. Overall, these results support the hypothesis that habitat characteristics play a stronger role than species identity in structuring the studied caprellidae assemblages. Further analysis of the Habitat × Species interaction could clarify whether particular species respond differently to brown and green algal habitats.

Conclusion

This study highlights the diversity of Caprellidae amphipods associated with macroalgae along the Mostaganem coastline. Taxonomic identification of the collected specimens revealed six species belonging to the genus *Caprella*: *Caprella acanthifera* Leach, 1814; *Caprella andreae* Mayer, 1890; *Caprella danilevskii* Czerniavski, 1868; *Caprella grandimana* Mayer, 1882; *Caprella hirsuta* Mayer, 1890; and *Caprella liparotensis* Haller, 1879. These findings indicate a significant abundance of Caprellidae in coastal algal environments within the study area.

Species distribution analysis indicates that macroalgae play a key role in structuring Caprellidae communities. Assemblages of *Cystoseira* sp. show higher abundances and are marked by a dominance of *Caprella danilevskii* Czerniavski, 1868, likely due to the three-dimensional complexity of these algae, which provides more microhabitats, refuges, and food resources. In contrast, the green alga *Ulva* sp., with a simpler structure, also hosts several species, but with a different composition and abundance, particularly *Caprella hirsuta* Mayer, 1890; *Caprella liparotensis* Haller, 1879; and *Caprella andreae* Mayer, 1890. Spatial differences in species composition and abundance are also observed among the three study stations (Stidia, Salamandre, and Hadjadj) and may be attributed to local environmental conditions, including hydrodynamics, availability of algal substrates, and ecological factors. Overall, the findings demonstrate the ecological significance of macroalgae as key habitats for Caprellidae amphipods and the structuring role of brown algae of the genus *Cystoseira* in maintaining benthic biodiversity in Mediterranean coastal ecosystems. Finally, this study contributes to the faunistic inventory of the Algerian coastline and provides baseline data that can support ecological monitoring and sustainable management of coastal marine ecosystems.

Future studies including additional algal habitats, detailed seasonal sampling, and analysis of environmental parameters would further improve understanding of the ecological dynamics of Caprellidae communities in this Mediterranean region.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*
Conceived and designed the research or analysis	Yes	No	No	No
Collected the data	Yes	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	No	No	No
Critical revision of the article/paper	No	Yes	Yes	Yes
Editing of the article/paper	Yes	No	No	No
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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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The ARRIVE Essential 10

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Item		Recommendation	Section/line number, or reason for not reporting
Study design	1	For each experiment, provide brief details of study design including: a. The groups being compared, including control groups. If no control group has been used, the rationale should be stated. b. The experimental unit (e.g. a single animal, litter, or cage of animals).	Materials and Methods – Sampling Design Materials and Methods – Sampling Design
Sample size	2	a. Specify the exact number of experimental units allocated to each group, and the total number in each experiment. Also indicate the total number of animals used. b. Explain how the sample size was decided. Provide details of any *a priori* sample size calculation, if done.	Materials and Methods – Sampling Design Materials and Methods – Sampling Design
Inclusion and exclusion criteria	3	a. Describe any criteria used for including and excluding animals (or experimental units) during the experiment, and data points during the analysis. Specify if these criteria were established *a priori.* If no criteria were set, state this explicitly. b. For each experimental group, report any animals, experimental units or data points not included in the analysis and explain why. If there were no exclusions, state so. c. For each analysis, report the exact value of *n* in each experimental group.	Laboratory Treatment Laboratory Treatment Laboratory Treatment
Randomisation	4	a. State whether randomisation was used to allocate experimental units to control and treatment groups. If done, provide the method used to generate the randomisation sequence. b. Describe the strategy used to minimise potential confounders such as the order of treatments and measurements, or animal/cage location. If confounders were not controlled, state this explicitly.	Sampling Design Sampling Design
Blinding	5	Describe who was aware of the group allocation at the different stages of the experiment (during the allocation, the conduct of the experiment, the outcome assessment, and the data analysis).	Laboratory Treatment
Outcome measures	6	a. Clearly define all outcome measures assessed (e.g. cell death, molecular markers, or behavioural changes). b. For hypothesis-testing studies, specify the primary outcome measure, i.e. the outcome measure that was used to determine the sample size.	Results sections (3.1–3.2) Results sections (3.1–3.2)
Statistical methods	7	a. Provide details of the statistical methods used for each analysis, including software used. b. Describe any methods used to assess whether the data met the assumptions of the statistical approach, and what was done if the assumptions were not met.	Statistical Analyses Statistical Analyses
Experimental animals	8	a. Provide species-appropriate details of the animals used, including species, strain and substrain, sex, age or developmental stage, and, if relevant, weight. b. Provide further relevant information on the provenance of animals, health/immune status, genetic modification status, genotype, and any previous procedures.	Not applicable Not applicable
Experimental procedures	9	For each experimental group, including controls, describe the procedures in enough detail to allow others to replicate them, including: a. What was done, how it was done and what was used. b. When and how often. c. Where (including detail of any acclimatisation periods). d. Why (provide rationale for procedures).	Laboratory Treatment Laboratory Treatment Laboratory Treatment Laboratory Treatment
Results	10	For each experiment conducted, including independent replications, report: a. Summary/descriptive statistics for each experimental group, with a measure of variability where applicable (e.g. mean and SD, or median and range). b. If applicable, the effect size with a confidence interval.	Results and Discussion Results and Discussion