Zoodiversity, **57**(6):521–528, 2023
DOI 10.15407/zoo2023.06.521

UDC 595.3(64)

SEASONAL VARIATION (WINTER VS. SUMMER) CRUSTACEAN FAUNA OF THE OUALIDIA LAGOON, MOROCCO

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urn:lsid:zoobank.org:pub:F8C5A2E2-4968-4490-9C9E-D9ED6E4F3986

Seasonal Variation (Winter vs. Summer) Crustacean Fauna of the Oualidia Lagoon, Morocco. El Asri, F., Errhif, A., Tamsouri, M. N., Maanan, M., Zidane, H. — The Oualidia lagoon on the Atlantic coast of Morocco provides important ecosystem services such as aquaculture, fisheries, tourism and high ecological and biological productivity. This is the first study to describe the spatio-temporal distribution of the crustacean community and potential controlling factors in the coastal waters of the Oualidia lagoon. Crustaceans were sampled with a Van Veen grab during two surveys in winter and summer 2013, and taxonomic composition and diversity were determined at 43 sampling sites. Of the eighteen crustacean taxa recorded, fifteen were new to Oualidia Lagoon. *Sphaeroma serratum* was the most abundant species in both seasons. Organic matter and chlorophyll a content were higher, temperature and salinity were lower in winter than in summer. The structure of the crustacean assemblages was characterised by the formation of two main clusters, organised according to a downstream gradient. Canonical Correspondence Analysis (CCA) showed that granulometry, organic matter and salinity strongly influenced the distribution pattern of crustaceans in the lagoon.
Key words: Coastal lagoon, Oualidia lagoon, Atlantic coast, temporal distribution, crustacean assemblage, Morocco.

Introduction

Coastal zones represent the natural interface between land and sea and are valuable ecosystems due to their remarkable productivity and diversity (Archambault & Bourget, 1996), despite their relatively small contribution to the global marine area. These ecosystems are inherently fragile and their ecological balance can change rapidly under the influence of natural or anthropogenic factors (Affian et al., 2009; El Asri et al., 2015, 2017, Maanan et al., 2014, 2015; Pearson & Rosenberg, 1978; Zidane et al., 2008, 2017).

Macroinvertebrates are widely used as indicators of coastal environmental status. Crustaceans are a key group and play an important role in maintaining the functioning of marine benthic ecosystems (Hendrickx, 1995) and are an important source of food for human consumption. In addition, the crustacean fauna is ecologically very sensitive to pollution, making it a good bioindicator of natural or disturbed environmental conditions (Cacabelos et al., 2010).

The Oualidia lagoon is one of the most important lagoon systems in Morocco. It is a RAMSAR wetland of international interest and the most important wintering area for migratory birds in Morocco.

Despite its interest, the studies on the Oualidia lagoon have mainly focused on oceanography (Bennouna et al., 2000; Hilmi et al. 2005; Damsiri et al., 2014; Maanan et al., 2015) and wholesomeness (Bellucci et al., 2002; Zourarah et al., 2007; Hassou et al., 2014). Few studies have focused on benthic biodiversity (Chbicheb, 1996; El Asri et al., 2015, 2017, 2020, 2022).

The novelty of this study is the first examination of crustaceans inhabiting the Oualidia lagoon to provide an overview of the spatio-temporal biodiversity of crustaceans, with particular emphasis on their distribution patterns and community structure, and their relationships with the main environmental variables.

Material and Methods

Study area

The Oualidia lagoon, 34°47' N–6°13' W and 34°52' N–6°14' W, is located on the Atlantic coast of Morocco (fig. 1). The lagoon is 7 km long and approximately 1 km wide. It extends along a north-south depression bounded by a continental cliff and a coastal dune ridge. Water exchange with the ocean occurs through a large inlet about 150 m wide with a shallower, narrower inlet (~50 m wide) that is also active during spring tides. The morphology of the lagoon is characterised by lateral channels connected to a meandering main channel with an average depth of 2 m and a maximum depth (during high tide) that does not exceed 5 m (Carruesco, 1989). Flood tides inundate much of 75 % (2.25 km²) of the lagoon surface, bringing saline water into the inner lagoon region and into a saline marsh beyond the inner dam (fig. 1).

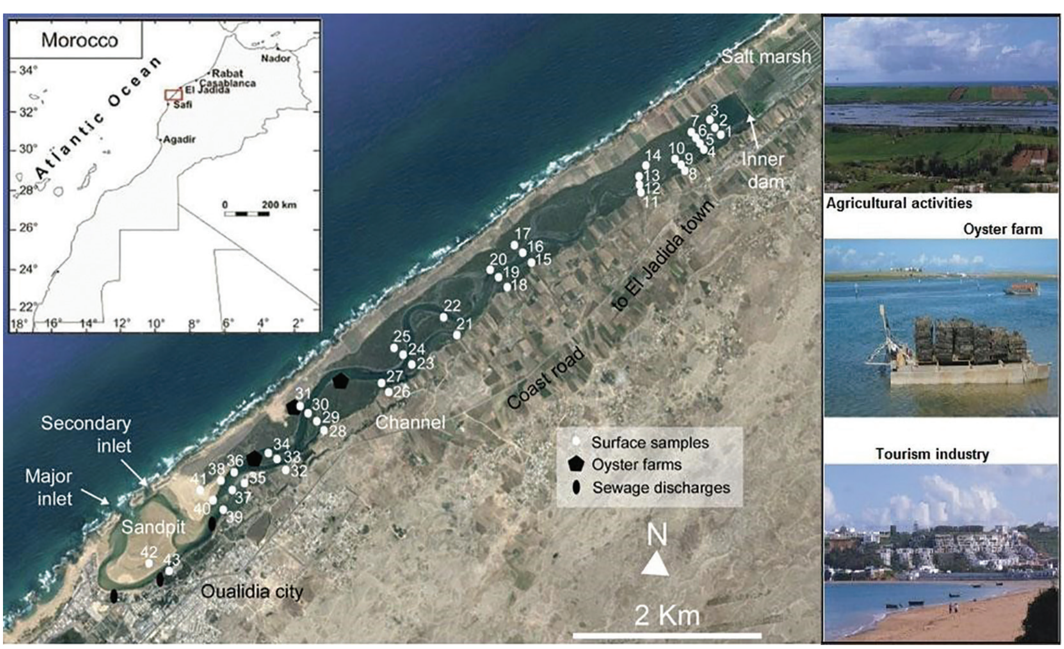

Fig. 1. Location map of the study area and sampling sites in the Oualidia lagoon.

Sampling and data analysis

Forty-three stations (fig. 1) were sampled in winter (March, 2013) and summer (July 2013). All samples (two replicates per station) were collected using a Van Veen grab (0.125 m^2 surface area). Material retained on the mesh (1 mm pore size) was transferred to containers and fixed in a 10 % formalin solution. An additional sediment sample was collected for analysis of grain size, and organic matter and chlorophyll a content. The grain size of the sediment collected at each sampling site was analysed using a laser a laser granulometer (Malvern, Mastersizer) at the LETG (UMR 6554, University of Nantes) and expressed as mean grain size, in μm. The percentage of organic matter (OM, %) of the sediment was obtained as the weight losses of dried samples (24 h, 60 °C) after ignition (4h, 450 °C). Chlorophyll a content (chl-a, mg/m^2) was determined according to the Lorenzen method (Holm-Hansen *et al.*, 1965). Crustaceans were sorted under a binocular microscope and identified to species level, whenever possible. To analyse the structure of the assemblages, the following indices were calculated: (1) species richness (S: number of species per sample); (2) species abundance (N: individuals/m^2); (3) diversity as indicated by the Shannon index (H′, $\log_2$ basis) (Shannon, 1948); and the evenness index (J′) (Pielou, 1966). To separate the stations into homogeneous groups, Hierarchical Ascending Classification (HAC) analyses were applied to the sampling stations, based on Euclidean distance and the Wards method using log10(x + 1) to limit the influence of the most dominant taxa. Wilcoxon tests were used to determine the significance (P = 0.05) of the difference between seasons. All these analyses were performed using STATISTICA version 8 for Windows. Canonical Correspondence Analyses (CCA) were performed using the free software package PAST 3.0 to analyse the relationships between environmental variables and crustacean assemblages. Environmental variables and crustacean densities were log10(x+1) transformed prior to analysis.

Results

Crustacean community structure

8721 crustaceans specimens belonging to 18 taxa were collected during this study (table 1). Among them, 440 individuals from 17 taxa occurred in winter and 8,281 from 13 taxa in summer. The most abundant taxa in winter were *Sphaeroma serratum* (Fabricius, 1787) (23.6 %), *Tanais dulongii* (Audouin, 1826) (28.2 %), *Apseudes* sp. (9.5 %) *Eurydice pulchra* Leach, 1815 (10.2 %). The first one were also dominant in summer (53.7 %) followed by *Corophium* sp. (34.5 %).Crustaceans densities were significantly higher ($p < 0.05$) in summer (0 to 1800 individuals/m^2) than in winter (0 to 104 individuals/m^2) (fig. 2, A). The number of taxa ranged from 0 to

Table 1. List of species present at Oualidia lagoon in winter and summer. + present; – absent

Species	Winter	Summer
Melita palmata (Montagu, 1804)	+	+
Corophium sp.	+	+
Caprella liparotensis Haller, 1879	–	+
Ampithoe sp.	+	+
Gammaridae	+	–
Cyathura carinata (Krøyer, 1847)	+	+
Idotea balthica (Pallas, 1772)	+	+
Eurydice pulchra (Leach, 1815)	+	–
Sphaeroma serratum (Fabricius, 1787)	+	+
Tanais dulongii (Audouin, 1826)	+	+
Apseudes sp.	+	+
Cumacea	+	+
Copepoda	+	+
Ostracoda	+	–
Palaemon elegans (Rathke, 1837)	+	–
Pagurus bernhardus (Linnaeus, 1758)	+	+
Carcinus maenas (Linnaeus, 1758)	+	+
Balanus sp.	+	+

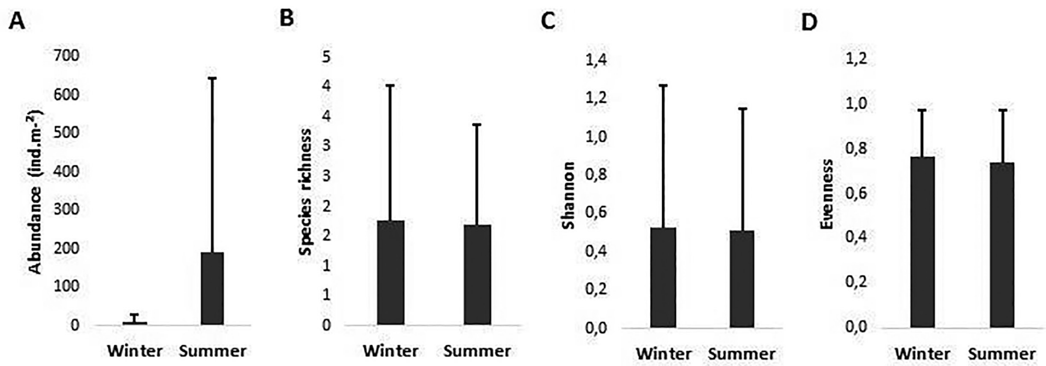

Fig. 2. Changes in the composition and structure of the crustacean assemblage between winter and summer: A — abundance (ind./m²); B — species richness; C —diversity of Shannon (H') and (D) evenness (J'). Mean ± standard deviation.

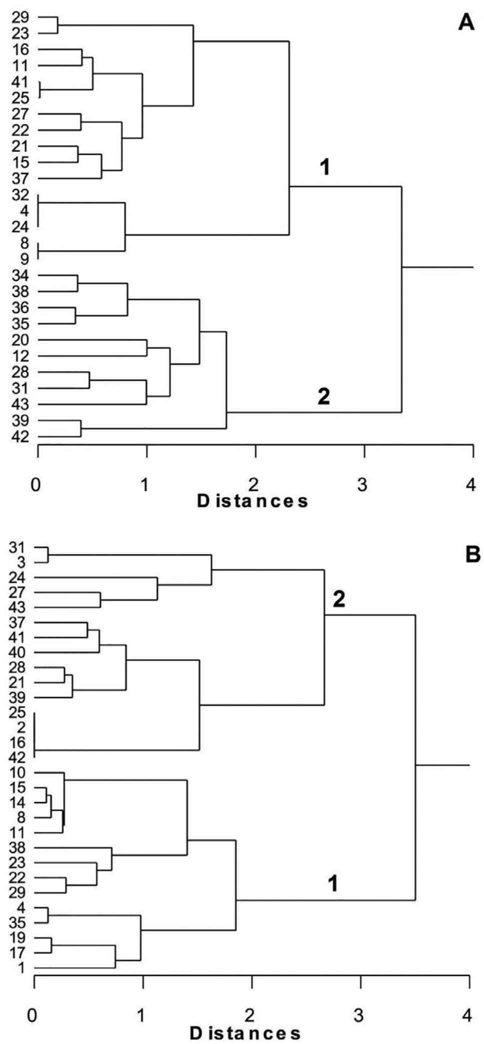

Fig. 3. Dendrogram showing the groups of stations formed by Cluster analysis for the 378 study area; A — winter, B — summer; Gr 1— group 1; Gr 2 — group 2.

10 (winter) or 5 (summer). However, there were non-significant differences ($p > 0.05$) (fig. 2, B). The Shannon diversity was similar in winter (0–2.8 bits) than in summer (0–2.1 bits) ($p > 0.05$) (fig. 2, C) and, similarly, there were non-significant differences in evenness between both seasons ($p > 0.05$) (fig. 2, D).

Two station clusters were obtained both during winter and summer in the Hierarchical Ascending Classification analyses. Group 1 in winter (fig. 3, A) included stations mainly from the inner region of the lagoon, characterized by having sediments mainly composed by silt and clay in different proportions, high temperatures and OM and a low average crustaceans density (10.5 individuals/m²). The dominant taxa was *S. serratum*, followed by Ostracoda. Group 2 consisted of 11 stations mainly close to the lagoon opening, with predominantly sandy sediments, low temperatures and organic matter, and a relatively low average density (24.7 individuals/m²). The dominant taxa was *Tanais dulongi*.

During summer (fig. 3, B), group 1 included stations, mainly located in the inner region of the lagoon, characterized by having relatively high temperatures, high organic matter, clay and silty clay sediments and a high average density (491.4 individuals/m²). The dominant species were *Sphaeroma serratum* and *Corophium* sp. Group 2 included stations located mostly near the lagoon opening, characterized by having low temperatures, organic matter, very low chlorophyll a, a high percentage of sand, and the lowest recorded average density (93.4 individuals/m²). The dominant taxa was *Corophium* sp.

Relationships between the descriptors of the crustaceans assemblages and the environmental variables

In winter, the first two CCA axes accounted for 81.07 % of the observed variance. The taxa composition was mainly related to salinity, OM and granulometry (fig. 4, A). In summer, the first two CCA axes accounted for 87.91 % of the relationships, with the most influencing environmental variables being salinity (fig. 4, B).

In winter, the projections of the taxa on the environmental parameters vectors (fig. 4, B) showed the positive correlations of *Eurydice pulchra, Cyathura carinata, Balanus* sp., *Corophium sp.* with granulometry. In turn, the other taxa like *Idotea balthica, Tanais dulongi, Melita palmata, Sphaeroma serratum, Pagurus bernhardus* were positively correlated with salinity, organic matter, chlorophyll a and temperature. As for the stations, they are left-right oriented for axis 1, which corresponds to a downstream-upstream gradient. Accordingly, downstream stations (e. g., 29, 31, 34, 35, 36, 37, 38) were characterized by larger grain sizes and high salinity, whereas the upstream stations (e. g., 4, 8, 9, 11, 12, 15, 16) were characterized by high temperature and organic matter.

In summer, the projections of the taxa on the environmental parameters vectors (fig. 4, B) showed the positive correlations of *Carcinus maenas, Apseudes* sp. *Caprella liparotensis,*

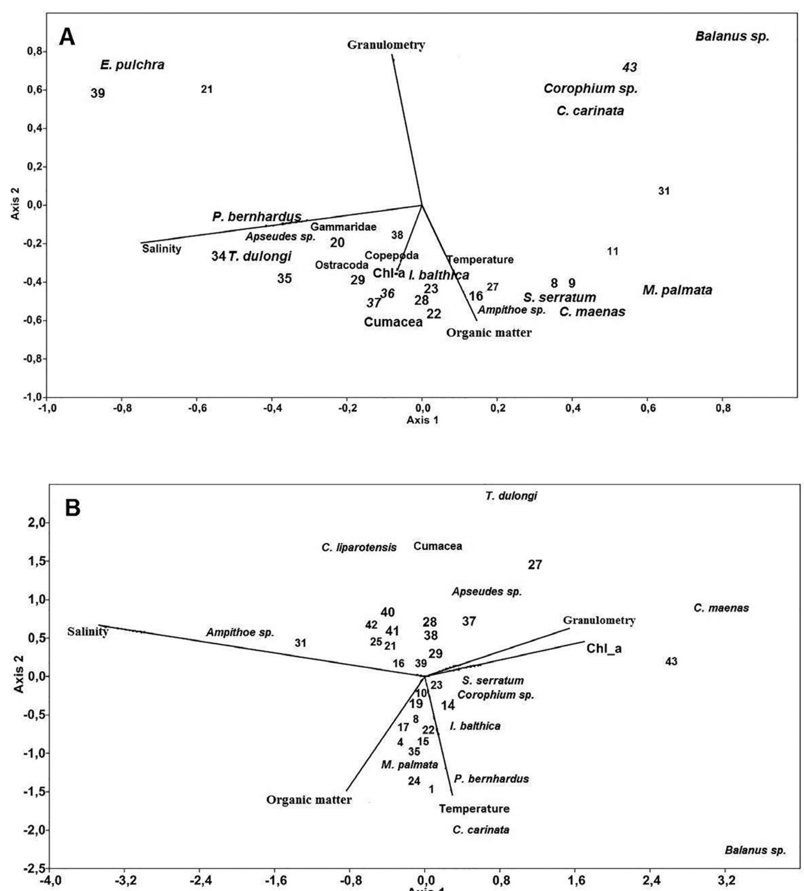

Fig. 4. Canonical correspondence analysis plots: A — winter; B — summer.

Cumacea, Ampithoe sp. Sphaeroma serratum, Tanais dulongi with granulometry, chlorophyll a and salinity. In turn, *Melita palmate, Idotea balthica, Cyathura carinata, Corophium* sp. *Pagurus bernhardus* were positively correlated with organic matter and temperature. As for the stations, they are left-right oriented for axis 2, which corresponds to a downstream-upstream gradient. Accordingly, downstream stations (27, 28, 29, 31, 36, 37, 38, 39, 40, 41) were characterized by larger grain sizes, high salinity and chlorophyll a, whereas the upstream stations (1, 2, 3, 4, 8, 10) were characterised by high organic matter and temperature.

Discussion

This study is the first inventory of all the crustacean taxa found in the Oualidia lagoon in two seasons, winter and summer. In addition, it identifies the main environmental variables that explain the spatial and temporal variations of the crustacean community structure in the study area.

The present study provides the current baseline of crustacean distribution, abundance, and diversity within the Oualidia lagoon. The 18 taxa recorded is within the range of values obtained in other lagoons: Aby lagoon (20 species) (Koaudio et al., 2008); Khnifiss lagoon (15 species) (Lefrere et al., 2015); Smir lagoon (13 species) (Chaouti & Bayed, 2005); Merja Zerga lagoon (13 species) (Touhami et al., 2017); Epe lagoon (11 species) (Uwadiae, 2010). The number of species reported in this study is almost higher than those reported by Chbicheb (1996). These differences in the structure and diversity of the crustaceans assemblages may likely be explained by the increasing levels of organic matter in the sediment, which may also be related with the changes in the hydrodynamics of the lagoon due to the construction of a pit upstream.

The most abundant taxa in winter were *Sphaeroma serratum* (23.6 %), *Tanais dulongii* (28.2 %), *Apseudes* sp. (9.5 %) *Eurydice pulchra* (10.2 %). The first one were also dominant in summer (53.7 %) followed by *Corophium* sp. (34.5 %). The first one *Sphaeroma serratum* was also the most abundant specie in Boughrara Lagoon (Khedhri et al., 2016). This pattern of dominance differs completely with that reported in the Smir lagoon, where the most representative species were *Melita palmata, Corophium acherusicum, Cyathura carinata* and *Sphaeroma hookeri* (Chaouti & Bayed, 2005). The Ichkeul lagoon was dominated by *Gammarus aequicauda, Idotea chelipes* and *Sphaeroma hookeri* (Casagranda et al., 2006). The Merja Zerga lagoon was dominated by *Cyathura carinata* and *Lekanesphaera rugicauda* Touhami et al., 2017). Coastal lagoons are highly variable in terms of environmental conditions, not only between their different areas, but also seasonally. This may certainly contribute to explain the reported changes in composition and dominance of the assemblages inhabiting different lagoons, but also to drastic changes in the species composition through time, particularly if there are associated changes in anthropogenic pressures (Hernandez-Guevara et al., 2008). These changes, however, are not only related to the ability of the species to respond to the environmental changes, but may also result from the existing biological interactions such as competition or predation, or may depend on intrinsic characteristics of the species (Artemis et al., 2006).

The particular combination of geological, hydrographical and environmental characteristics of the Oaulidia lagoon generates a macrofaunal structure characterized by three assemblages that can be clearly distinguished in the HAC (fig. 3, A, B) showing a spatial organization along an inner-to-outer lagoon gradient, in a similar way as previously reported for other lagoons (e. g. Bazaïri et al., 2005)

The diversity, distribution and structure of crustacean assemblages are strongly influenced by environmental parameters (Carrasco and Carbajal 1998; Simboura et al., 2000;

Labrune et al., 2007; El Asri et al., 2017), with particular relevance in the case of sediment characteristics and organic matter (Glémarec, 1973; Martin et al., 2000; Barbosa et al., 2010; Martins et al., 2013).The spatial structure of the crustacean community in the Oualidia lagoon seemed to be determined by the combined influence of granulometry, temperature and salinity, which also seems to be a common trend in lagoon systems (Uwadiae, 2013). However, the environmental factors controlling species distributions may vary from one parallic environment to another. For example, in Smir lagoon (Chaouti & Bayed, 2008), vegetation and grain size were reported as the main factors influencing species structure, while in Sacca di Goro (Mistri et al., 2001), dissolved oxygen, temperature and salinity were the main factors, and in Monolimni lagoon (Kevrekidis, 2004), temperature and depth.

Conclusions

In conclusion, this study analysed the diversity, distribution and relationship with environmental factors of crustaceans in the Oualidia lagoon. The results of the present work showed that the Oualidia lagoon, despite its relatively small size, supports rather diverse crustacean assemblages compared to the taxonomic list of other lagoons. A total of 8721 crustacean individuals belonging to 18 taxa were collected from Oualidia lagoon. *Sphaeroma serratum* was the most abundant taxon. Cluster analysis showed two communities from downstream to upstream in both seasons. According to canonical correspondence analysis, granulometry, organic matter and salinity are the most frequently reported factors determining the distribution and composition of crustaceans in the Oualidia lagoon. Our results provide useful insights for future coastal management monitoring programmes in the Oualidia lagoon. Therefore, further investigations are needed to see the whole picture of the biodiversity status of macroinvertebrates in the Oualidia lagoon, and to monitor the health of the ecosystem, it would be very interesting to study the seasonal variability of the zoobenthic community in the lagoon and its relationship with environmental parameters.

Acknowledgements

We are deeply grateful to all INRH-Oualidia staff for their personal quality and help with the sampling.

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Received 22 February 2023
Accepted 27 June 2023