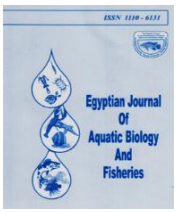
Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(6): 883 - 895 (2023)
www.ejabf.journals.ekb.eg




# Taxonomic Diversity and Spatial Distribution of Crustaceans in an Aquatic Ecosystem Classified as a Ramsar Site: The Merja of Fouarat (Kenitra, Morocco)

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**ARTICLE INFO**

**Article History:**
Received: Oct. 29, 2023
Accepted: Nov. 20, 2023
Online: Dec. 22, 2023

**Keywords**:
Aquatic crustaceans,
Composition,
Distribution,
Merja of Fouarat

**ABSTRACT**

Aquatic crustaceans have a cosmopolitan distribution; despite their great importance in aquatic ecosystems, literature on this group is relatively scarce, especially in the Merja of Fouarat. Therefore, in the present article, a contribution was made to enrich the data on this group. The results show the existence of 34 species, divided into five families, all belonging to a single superorder of Diplostraca. Furthermore, these results show that the distribution of the different species is not homogeneous and that the species *Daphnia pulex, Daphnia magna, Megafenestra aurita, Simocephalus expinosus, Alona elegans elegans, Alona pulchella, Alona rectangula, Chydorus sphaericus, Dunhevedia crassa, Pleuroxus letourneuxi, Macrothrix hirsuticornis,* and *Macrothrix laticornis*, are ubiquitous species that can be found at sites with temporary, semi-temporary to permanent impoundment. While, the species *Ceriodaphnia dubia, Ceriodaphnia quadrangulata, Daphnia atkinsoni, Daphnia chevreuvi, Daphnia similis, Scapholeberis kingi, Simocephalus vetelus, Alona affinis, Alona elegans lebes, Alona esteparica, Biapertura karua, Ephermeroporus phintonicus, Leydigia ciliata, Tretocephala ambigua, E chinsca rosea,* and *Moina brachiata* are strictly confined to sites with temporary impoundment. However, the species *Ceriodaphnia reticulata, Acroperus harpae, Alona costata, Eurycercus lamellatus, Graptoleberis testudinaria, Moina micrura,* and *Moina salina* are restricted to sites with semi-permanent to permanent flooding.

## INTRODUCTION

Through their flora and fauna potential, wetlands constitute natural reservoirs and contribute to the major biological and ecological balances. Thus, to better understand the dynamics of an organism, a population or a community, the knowledge of an organism and its environment is important **(Qadri & Yousuf, 1982).**

The class of crustacean's objective of this study belongs to the branch of the arthropods, and constitutes a very important group in terms of specific

richness (approximately 45000 species) **(Lefebvre, 2005)**, and remarkable from the point of view of the diversity of forms and the variety of habitats where it is found.

Aquatic crustaceans, which constitute the majority of resident species, bring together more than 90% of the total number of the animal community inhabiting these biotopes. They represent the most characteristic element of the stand since they are strictly subservient to this biotope through their resistance ecophase **(Giudicelli & Thiery, 1998)**.

At the present time, when the media are relaying the need for studies on biodiversity, crustaceans are still only rarely taken into account in faunal inventories. The reason is partly due to the small number of specialists in the group, researchers, amateurs and professionals.

This research work was thus carried out in order to acquire knowledge on the local species of aquatic crustaceans, locate their habitats, and identify the physico-chemical factors on which their distribution depends.

## MATERIALS AND METHODS

### 1. Study zone

The Merja of Fouarat at an altitude of 34° 15' N; 06°32 W is located in the plateau of Maamora (Fig. 1). It was classified in 2015 in the Ramsar list (convention relating to wetlands of ecological importance for birds).

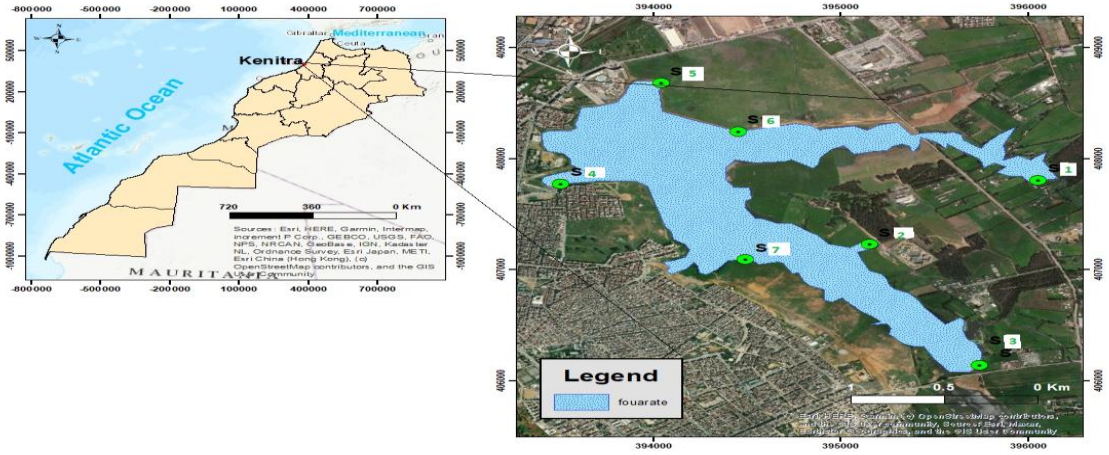


**Fig. 1.** Location of the Merja of Fouarat

### 2. Sampling

The study took place during the rainy season from December 2020 to March 2021, a period conducive to the appearance of temporary pools which constitute the habitat of these crustaceans. Water samples were taken at each site to determine the temperature, pH, conductivity, and salinity, as well as the taxonomic identification of the crustacean fauna. The macro-invertebrates were taken from a surface of 1/ 20m² using a kick net in a qualitative way. Subsequently, they were preserved in a 70% alcohol solution to be then sorted, and identified by Ecology, Biodiversity and Environment Laboratory of Ibn Tofail Kenitra University using a binocular magnifying glass and a microscope and sometimes with the naked eye. This diagnosis was made using the determination keys cited in the literature. Only the class of crustaceans was taken into consideration.

## RESULTS

### 1. Inventories of species collected

The sampling of species of aquatic crustaceans in the study area allowed us to collect a total of 34 species, belonging to a super-order and five family (Table 1).

**Table 1**. Species of aquatic crustaceans harvested during the study period along of the study area

| Super-order | Family | Species |
|---|---|---|
| Diplostraca | Daphnidae | *Ceriodaphnia dubia* |
| | | *Ceriodaphnia quadrangulata* |
| | | *Ceriodaphnia reticulata* |
| | | *Daphnia atkinsoni* |
| | | *Daphnia chevreuxi* |
| | | *Daphnia magna* |
| | | *Daphnia pulex* |
| | | *Daphnia similis* |
| | | *Megafenestra aurita* |
| | | *Scapholeberis kingi* |
| | | *Simocephalus expinosus* |
| | | *Simocephalus Vetelus* |
| | | *Acroperus harpae* |
| | | *Alona affinis* |

| | | |
|---|---|---|
| | Chydoridae | *Alona costata* |
| | | *Alona elegans elegans* |
| | | *Alona elegans lebes* |
| | | *Alona pulchella* |
| | | *Alona rectangula* |
| | | *Alona esteparica* |
| | | *Biapertura karua* |
| | | *Chydorus sphaericus* |
| | | *Dunhevedia crassa* |
| | | *Leydigia ciliata* |
| | | *Pleuroxus letourneuxi* |
| | | *Tretocephala ambigua* |
| | | *Graptoleberis testudinaria* |
| | Macrothricidae | *Echinisca sp* |
| | | *Macrothrix hirsuticornis* |
| | | *Macrothrix laticornis* |
| | Moinidae | *Moina brachiata* |
| | | *Moina micrura* |
| | | *Moina salina* |
| | Eurycercidae | *Eurycercus lamellatus* |
| **Total** | **5** | **34** |

## 2. Species richness of taxa collected in the study area

Fig. (2) displays that the Chydoridae family is the most diversified, with a specific richness of 42.85%, followed by the Daphnidae family with a specific richness of 34.28%. Furthermore, the Moinnidae family and the Macrothridae family are represented by a specific richness of 8.57% for each and lastly comes the Erycercidae family which is represented by a small proportion of 2.85%. Note that the different families belong to a single superorder Diplostraca.

## 3. Main characteristics of the surveyed stations

The main characteristics of the prospected stations are represented in Table (2), hence we notice that the average impoundment duration varies from minus 6 to 12 (in months) in the seven stations. Moreover, it is stable in the stations S5, S6, and S7. In addition, the importance of the vegetation cover varies between 10 and 60%. Moreover, it is very important in the stations S4, S5, S6, and S7 with a percentage of 50, 50, 45, and 60%, respectively, in addition to these variations, the different surveyed stations present depths that vary between 45 and 250cm.

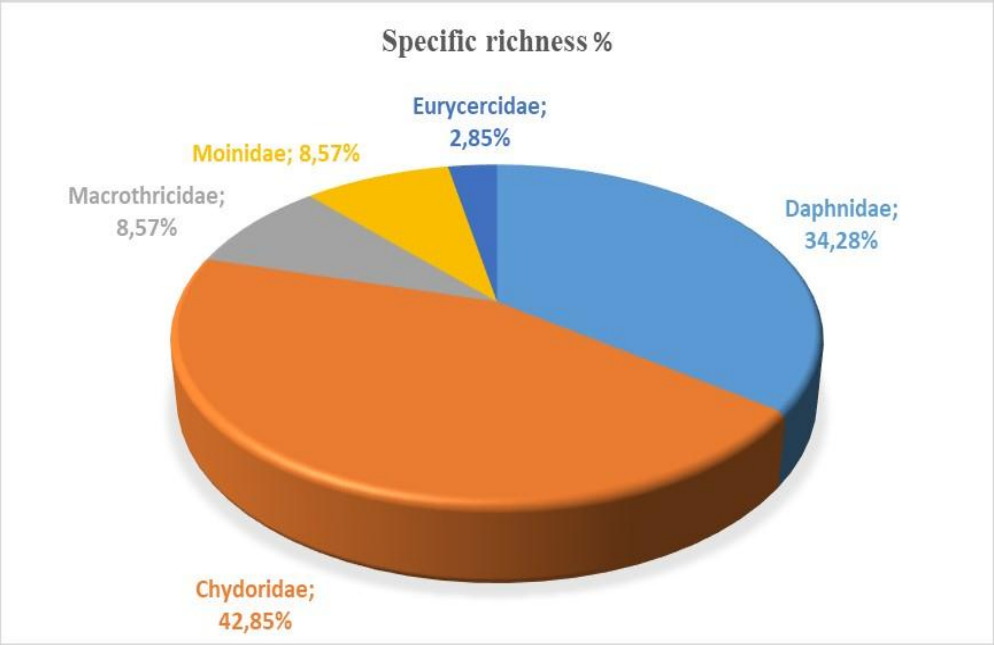


**Fig. 2.** Specific richness according to families

**Table 2.** Main characteristics of the surveyed stations

| **Station to prospect** | **S1** | **S2** | **S3** | **S4** | **S5** | **S6** | **S7** |
|---|---|---|---|---|---|---|---|
| Average impoundment duration (MED) (in months) | < 6 | 6 to 8 | 6 to 9 | 6 to 11 | 12 | 12 | 12 |
| Importance of vegetation cover (CV) (in %) | 10 | 30 | 35 | 50 | 50 | 45 | 60 |
| Maximum depth (Pmax) (in cm) | 45 | 70 | 80 | 115 | 140 | 185 | 250 |

## 4. Spatial physico-chemical variation of the environment studied

The values of the measurements of twelve evaluated parameters are shown in Table (3). As shown in Table (3), the duration of the flooded phase of the environment studied varies according to the location of the station from temporary, semi-permanent to permanent. The amount of plant cover in the environment is not homogeneous and varies from 10 to 60%, and the water depth of the different stations varies from 45 to 250cm. The variation of maximum and minimum temperatures seems to be influenced by the depth of the medium; moreover, the pH values vary from 7.2 to 8.2. The conductivity and the contents of Cl- and BOD5 are highly variable from one station to another. Furthermore, the variation is the same for nitrogenous substances.

**Table 3**. Spatial variation in the values of physicochemical and biological parameters

| **Prospected station** | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|
| Temporary | T | T | T | MS | P | P | P |
| PC **(%)** (%) | 10 | 30 | 35 | 50 | 50 | 45 | 60 |
| Pmax(cm) | 45 | 70 | 80 | 115 | 140 | 185 | 250 |
| T min(°) | 13.2 | 12.7 | 12.8 | 12.1 | 12.1 | 11.8 | 11.9 |
| Tmax(°) | 30.9 | 29.5 | 29.1 | 28.4 | 26.4 | 27.2 | 27.1 |
| pH | 7.6 | 7.8 | 7.2 | 7.4 | 8.2 | 7.7 | 7.6 |
| CD(µm/ cm) | 3750 | 2930 | 1420 | 1950 | 8500 | 1930 | 1150 |
| Cl-(mg/ l) | 248 | 190 | 215 | 210 | 256 | 144 | 112 |
| SO42-(mg/ l) | 21.2 | 11.8 | 66.9 | 58.4 | 67.3 | 51.6 | 19.4 |
| BOD5(mg/ l) | 15.88 | 47.22 | 59.62 | 61.45 | 136.6 | 88.64 | 43.71 |
| NH4+(mg/ l) | 1.87 | 3.58 | 5.62 | 2.64 | 12.1 | 5.56 | 3.62 |
| NO3- (mg/ l) | 0.05 | 0.1 | 1.95 | 1.83 | 2.6 | 2.1 | 0.15 |

T: Temporary, P: Permanent, SP: Semi-permanent

The analysis of Fig. (3) reveals that, in comparison to the projection of the surveyed stations on the C1 axis, two groups of stations are located on either side of the C1 axis. These groups exhibit distinct characteristics concerning the variables under investigation:

- **First group (G1):** Formed by stations S1, S2 and S3, which are all located on the positive side of the C1 axis. These are stations with a temporary impoundment duration. The values found for the constituent variables of this axis are Cl-, CD, Tmin, and Tmax.
- **A second group of stations (G2**): Which are located on the negative side of the C1 axis, namely S4, S5, S6 and S7. These are stations whose impoundments are semi-permanent for station S4 and permanent for stations S5, S6 and S7. The values found for the constituent variables of this axis are pH, BOD5, NH4+ SO42-, Pmax, and PC.
- This analysis also indicates that, in relation to the physio-chemical gradient represented by the C2 axis, the G2 group can be further subdivided into two subgroups, namely G2a and G2b (Fig. 4). Thus, the G2b station subgroups and the G1 group, unlike the G1a subgroups, are characterized by high pH, electrical conductivity, chloride, and ammonium concentrations.

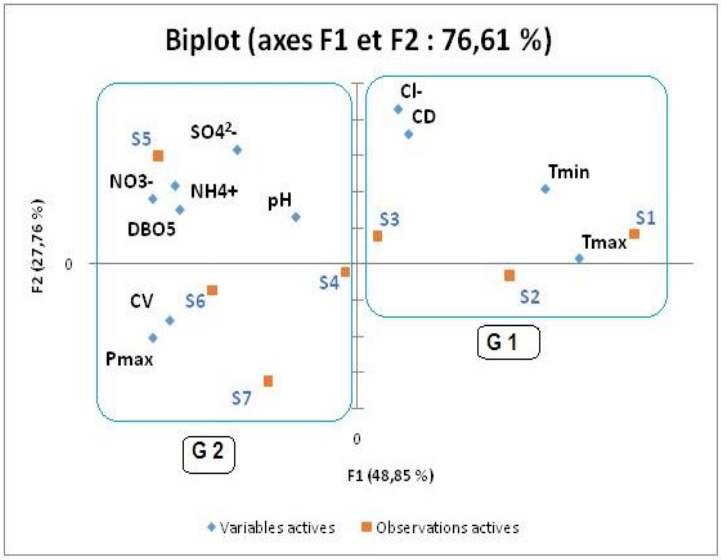


**Fig. 1.** Projection of the points representing the surveyed stations and the physico-chemical parameters

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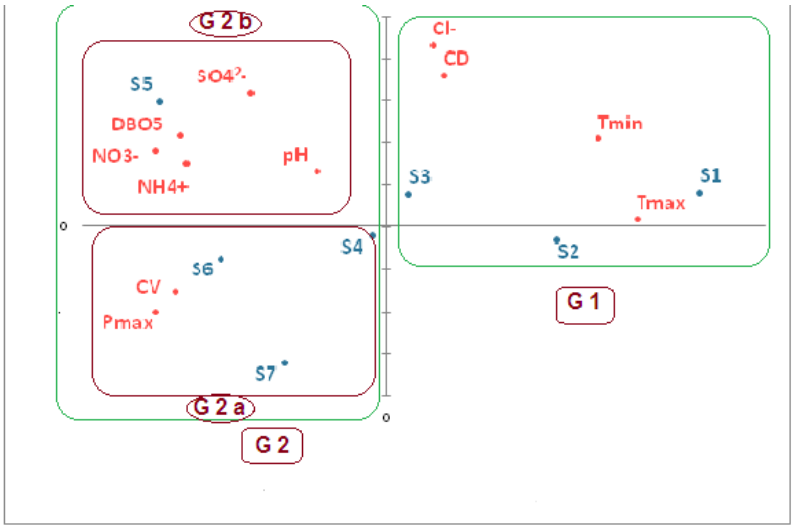


**Fig. 4.** Projection of points representing surveyed stations and physico-chemical parameters

## 5. Spatial distribution of collected species in the five zones of study during the 2020/2021 study period

Table (4) shows the distribution of the different taxa collected from each study site.

**Table 4.** Spatial distribution of collected species in the study area during the 2020/ 2021 study period

| Super-order | Family | Species | Daya area | | | Merja area | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
| Diplostraca | Daphnidae | *Ceriodaphnia dubia* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Ceriodaphnia quadrangulata* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Ceriodaphnia reticulata* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | | *Daphnia atkinsoni* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Daphnia chevreuxi* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Daphnia magna* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Daphnia pulex* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Daphnia similis* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Megafenestra aurita* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Scapholeberis kingi* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Simocephalus expinosus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Simocephalus Vetelus* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | Chydoridae | *Acroperus harpae* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | | *Alona affinis* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Alona costata* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | | *Alona elegans elegans* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Alona elegans lebes* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Alona pulchella* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Alona rectangula* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Alona esteparica* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Biapertura karua* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Chydorus sphaericus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Dunhevedia crassa* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Leydigia ciliata* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Pleuroxus letourneuxi* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Tretocephala ambigua* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Graptoleberis testudinaria* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | Macrothricidae | *Echinisca* sp. | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Macrothrix hirsuticornis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | *Macrothrix laticornis* | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Moinidae | *Moina brachiata* | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| | | *Moina micrura* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | | *Moina Salina* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | Eurycercidae | *Eurycercus lamellatus* | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| **Total** | **5** | **34** | **27** | **27** | **27** | **19** | **19** | **19** | **19** |

Thus, this distribution is unequal, and it is correlated with physico-chemical factors of each site; we can distinguish three groups of species in Fig. (5).

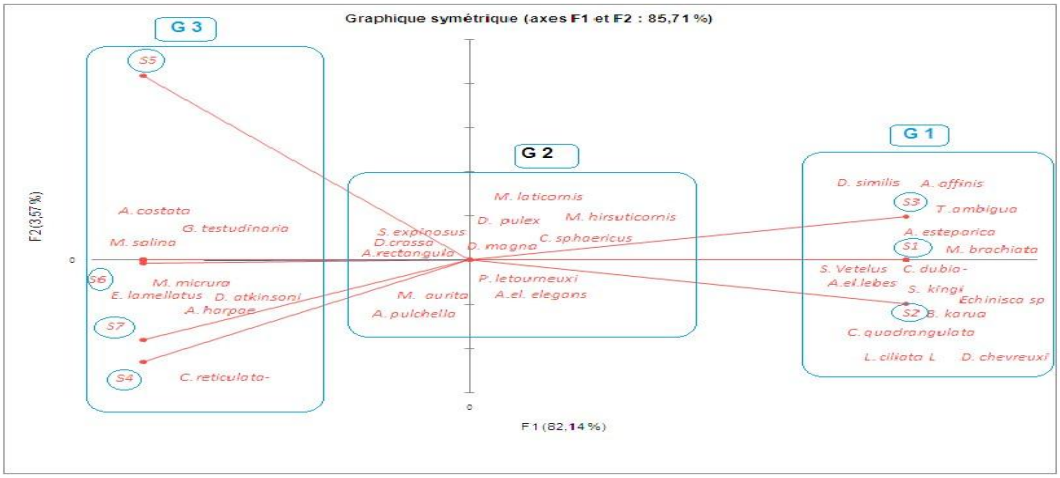


**Fig. 5.** Distribution of species in relation to surveyed stations showing:

- **Group 1**: Located on the positive side of the C1 axis, and made up of *Daphnia similis, Alona affinis, Tretocephala ambigua, Alona esteparica, Moina brachiata, Simocephalus Vetelus, Ceriodaphnia dubia, Scapholeberis kingi, Alona elegans lebes, Echinisca sp, Biapertura karua, Ceriodaphnia quadrangulata Daphnia chevreuxi,* and *Leydigia ciliata,* which are grouped in areas S1, S2 and S3.
- **Group 2**: Integrates species *Macrothrix laticornis, Daphnia magna, Daphnia pulex, Megafenestra aurita, Simocephalus expinosus, Alona elegans elegans, Alona pulchella, Alona rectangula, Chydorus sphaericus, Dunhevedia crassa, Pleuroxus letourneuxi, Macrothrix hirsuticornis*, and *Macrothrix laticornis*, which can be found along the study area.
- **Group 3**: Located on the negative side of the C1 axis, which includes the species *Alona costata, Ceriodaphnia reticulata, Acroperus harpae, Graptoleberis testudinaria, Moina micrura, Moina salina*, and *Eurycercus lamellatus*, which are found only in stations S4, S5, S6 and S7.

## DISCUSSION

Environmental variations are one of the main factors that determine the lifestyles of organisms, thus water has a number of physico-chemical properties that play a decisive role in the distribution of aquatic species **(Slim *et al.*, 2021)**.

As a result, the physico-chemical study of the waters of the Merja of Fouarate has made it possible to highlight the variability of the quality of these waters according to the stations studied. Therefore, the duration of the flooded phase of the environment studied varies according to the location of the station from temporary, semi-temporary to permanent. Note that the amount of plant

cover in the environment is not homogeneous and varies from 10 to 60%, and the thickness of the water layer varies from 45 to 250cm.

The variation of minimum and maximum temperatures is between 11 and 30°C. **King (1972)** in his study points out that the latter is one of the main factors that govern the chemistry of the surrounding environment, and seems to be influenced by the depth of the environment, which influences the heating of the waters and therefore the installation and proliferation of fauna and flora **(Slim *et al.*, 2021)**. Similarly, it acts on the oxygen content. The shallow surface allows air to spread widely and mix well. In lakes, the depth is such that it leads to thermal stratification **(Boualam, 1992, as cited in Chakri, 2007)**. In this regard, temperature plays an important role in determining dissolved oxygen (DO) concentration in freshwater habitat. Other factor that determines DO values include salinity **(Chapman & Kimstach, 1996, as cited in Slim *et al.*, 2021)**.

In addition, the pH values vary between 7.2 and 8.2, values that are suitable for common life in fresh water **(Chapman & Kimstach, 1996, as cited in Slim *et al.*, 2021)**.

In addition, the values of the conductivity and the contents of Cl- and BOD5 are highl variable from one station to another. However, the variation is the same for nitrogenous substances.

Among the cladoceran crustaceans inventoried in Morocco **(Aoujdad *et al.*, 2014)**, 35 species populate the surveyed environment and are grouped into five systematic families. The Chydoridae family and the Daphnidae family are the most represented, with 15 species (42.85%) and 12 species (34.28%), respectively. The Macrothricidae and Moinidae families are represented by only three species each (8.57%), followed by the Eurycercidae family with a single species (2.85%). It is worthnoting that, all of these species are cladoceran crustaceans.

The factorial analysis of the correspondences shows that the distribution of the species harvested in relation to the stations studied is not homogeneous, and changes spatially. These results are similar to those reported by **Hynes (1970)** and **Townsend and Hildrew (1984)**. Moreover, it closely depends on the physico-chemical characteristics of the water, some of which act directly as controlling factors, which confirms the results found by **Qadri and Yousuf (1982)**, **Richards *et al.* (1993)**, **Tate and Heiny (1995)**, **Benbow *et al.* (2003) Slim *et al.* (2021)**.

Changes in the structure of these benthic communities are often assessed by examining taxonomic compositions **(González *et al.*, 2003)**. Similarly, to better understand the dynamics of an organism, population or community,

knowledge of the organism and its environment is important **(Qadri & Yousuf, 1982)**.

Thus, according to the results obtained, we can divide the communities of harvested crustaceans into three groups:

- Those that colonize the entire study area (S1, S2, S3, S4, S5, S6, and S7), known as ubiquitous species, these are: *Daphnia pulex, Daphnia magna, Megafenestra aurita, Simocephalus expinosus, Alona elegans elegans, Alona pulchella, Alona rectangula, Chydorus sphaericus, Dunhevedia crassa, Pleuroxus letourneuxi, Macrothrix hirsuticornis,* and *Macrothrix laticornis*.

- Those that only colonize a narrow portion of the biotope, which can themselves be divided into two subgroups:

- Those subject to temporary flooding (S1, S2, and S3), this is the case in particular of *Ceriodaphnia dubia, Ceriodaphnia quadrangulata, Daphnia atkinsoni, Daphnia chevreuvi, Daphnia similis, Scapholeberis kingi, Simocephalus vetelus, Alona affinis, Alona elegans lebes, Alona esteparica, Biapertura karua, Ephermeroporus phintonicus, Leydigia ciliata, Tretocephala ambigua, Echinsca rosea,* and *Moina brachiata.*

- Those that are subservient to permanent flooding (S4, S5, S6 and S7), this is particularly the case for *Ceriodaphnia reticulata, Acroperus harpae, Alona costata, Eurycercus lamellatus, Graptoleberis testudinaria, Moina micrura,* and *Moina salina.*

**Ramdani (1982)** reports in his study that Daphnia magna behaves as a restricted species, this during our results, shows that *Daphnia magna* tolerates acidic and basic pH, while *Daphnia pulex* would not thrive below pH= 7, which confirms the results of **Sahraoui (2016)**. Therefore, the pH strongly influences the biological diversity of ecosystems. Furthermore, according to **Harridi *et al*. (2020)**, the majority of aquatic organisms needs a pH close to neutrality (6- 9) in order to survive. Significant variations in pH can therefore compromise certain essential functions, such as respiration and reproduction. Thus, acidified waters are characterized by a significant decline in density and biological diversity **(Landry *et al*., 1922; Hade, 2002)**.

Benthic macroinvertebrate communities form an important part of freshwater ecosystems. They serve as food for a large number of fish, amphibians and birds. It is a very diverse group, and the organisms that compose it, are seriously affected by different forms of disturbance, natural or anthropogenic.

## CONCLUSION

This research work carried out on the aquatic crustaceans of the Merja of Fouarat has made it possible to take stock of the knowledge available on this

zoological group. In total, 34 species are listed, among them 7 species adapt to different types of habitats ranging from temporary to semi-permanent and permanent. Furthermore, the remains of the listed species are located only in specific places, and this depends on physico-chemical factors environment.

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