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Biodiversity of aquatic Heteroptera in relation to physico-chemical parameters, the Biological Reserve of Sidi Boughaba and the Merja of Fouarat as a case studies (Gharb Plain, Morocco)

Biodiversidad de heterópteros acuáticos en relación con parámetros físico-químicos, la Reserva Biológica de Sidi Boughaba y la Merja de Fouarat como casos de estudio (Llanura de Gharb, Marruecos)

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ABSTRACT

Given their great importance in aquatic ecosystems, the literature on aquatic and semi-aquatic Heteroptera is quite extensive worldwide. However, relatively little literature is available on the taxonomy and distribution of aquatic and semi-aquatic Heteroptera in the Gharb Plain, specifically the two wetland areas classified as Ramsar sites, the Biological Reserve of Sidi Boughaba and the Merja of Fouarat. Therefore, the present research aims to study the community of aquatic Heteroptera and the physico-chemical variables of these two wetland areas in the Gharb Plain. Additionally, the research aims to document and authenticate the historical review

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of aquatic and semi-aquatic Heteroptera in these wetlands. The results obtained show the existence of two groups of Heteroptera species. One group consists of species that are found in several environments due to their broad ecological tolerance. This is the case of, *Gerris lacustris* (Linnaeus, 1758), *G. lateralis* (Schummel, 1832), *Corixa affinis* (Leach, 1817), *Notonecta glauca rufescens* (Poisson, 1933), *Anisops sardia* (Herrich-Schaeffer, 1849), *Plea leachi* (McGregor, Kirk, 1899), *Naucoris maculatus conspersus* (Stål, 1876), *Hydrometra stagnorum* (Linnaeus,1758) and *Mesovelia vittigera* (Horváth, 1895). On the contrary, species conditioned by several physicochemical factors of the environment, Stenoic species, such as *Sigara lateralis* (Leach, 1817), *S. stagnalis* (Leach, 1817), *Naucoris maculatus angustior* (Lethierry, 1877), *Nepa rubra rubra* (Linné, 1758) and *Gerris thoracicus* (Schummel, 1832).

Keywords — Wetland, Insect, biotypological analysis, Gharb plain.

RESUMEN

Dada su gran importancia en los ecosistemas acuáticos, la literatura sobre Heteroptera acuáticos y semiacuáticos es bastante extensa a nivel mundial. Sin embargo, hay relativamente poca literatura disponible sobre la taxonomía y distribución de Heteroptera acuáticos y semiacuáticos en la llanura de Gharb, específicamente las dos áreas de humedales clasificadas como sitios Ramsar, la Reserva Biológica de Sidi Boughaba y la Merja de Fouarat. Por tanto, la presente investigación tiene como objetivo estudiar la comunidad de Heteroptera acuáticos y las variables físico-químicas de estas dos zonas de humedales en la llanura de Gharb. Además, la investigación tiene como objetivo documentar y autentificar la revisión histórica de los Heteroptera acuáticos y semiacuáticos en estos humedales. Los resultados obtenidos muestran la existencia de dos grupos de especies de Heteroptera. Un grupo está formado por especies que se encuentran en varios ambientes debido a su amplia tolerancia ecológica. Es el caso de, *Gerris lacustris* (Linnaeus, 1758), *G. lateralis* (Schummel, 1832), *Corixa affinis* (Leach, 1817), *Notonecta glauca rufescens* (Poisson, 1933), *Anisops sardia* (Herrich-Schaeffer, 1849), *Plea leachi* (McGregor, Kirk, 1899), *Naucoris maculatus conspersus* (Stål, 1876), *Hydrometra stagnorum* (Linnaeus,1758) y *Mesovelia vittigera* (Horváth, 1895). Por otro lado está el grupo de especies estenoicas, con menor tolerancia y condicionadas por varios factores fisicoquímicos del ambiente, como *Sigara lateralis* (Leach, 1817), *S. stagnalis* (Leach, 1817), *Naucoris maculatus angustior* (Lethierry, 1877), *Nepa rubra rubra* (Linné , 1758) y *Gerris thoracicus* (Schummel, 1832).

Palabras clave — Humedal, insectos, análisis biotipológico, llanura de Gharb.

INTRODUCTION

The Gharb plain is one of the richest areas in surface water, pond, temporary pools, rivers, and irrigation canals. This richness promotes a great biodiversity of aquatic and aerial fauna. The functioning of these areas depends on many factors, including their hydrology, their physico-chemical characteristics, the taxonomic structure and the dynamics of their biocenoses (Gogoi et al., 2019).

In addition, insects often constitute a large fraction of the population of macro-invertebrates in aquatic environments and many of them have a potential indicator of the quality of the environment (Stein, Springer, Kohlmann, 2008; Hauer and Resh, 2017). Among these insects the aquatic and semi-aquatic Heteroptera, Indeed, a large number of species of this group of insects can serve as a bio-indicator for monitoring the state of health of ecosystems (Pichenot, 2016). Due to a more or less important specialization for a food resource (prey or plant) or simply because of its way of life (aquatic species demanding with regard to water quality for example or terrestrial species related to a certain structure of the vegetation), many heteroptera could constitute useful indicators giving an account of the changes, disturbances or degradations occurring in the terrestrial and aquatic ecosystems. In this regard, we study the physicochemical typology of two wetlands in the Gharb plain, classified as Ramsar sites: The Biological Reserve of Sidi Boughaba and the Merja of Fouarat, as well as the biotypological evaluation of aquatic and semi-aquatic heteroptera.

MATERIALS AND METHODS

Study Areas

The Gharb plain is located in the northwest of Morocco. It extends in the low valley of the Sebou River over an area of 3,000 km2 (Figure 1). Its climate varies from sub-humid to temperate winter in the coastal zone and semi-arid to hot winter in the interior of the plain (Amharref, Aassine, Bernoussi, Haddouchi 2007). There are important natural and biological reserves such as Lake Sidi Boughaba, Maamora, Merja Zerka, Lake Fouarat (Figure 2 and 3).

Sidi Boughaba Lake (34°12’56” and 34°15’55” N 6°42’32” and 6°45’27” W) is located on the Atlantic coast of Morocco Northwest, oriented NNE–SSW, and located in a depression of a hilly region (Figure 2). It extends over 5.5 km in length and a varying width of 100 to 250 meters and the depth varies between 0.5 and 2.50 m. The existence of this water body is because the topographic surface is at lower than that of the potentiometric surface of the coastal groundwater, rainwater and runoff waters. The biological Reserve of Sidi Boughaba is 150 ha (Slim et al., 2016). The Canton of forest Sidi Boughaba of 652 ha encompasses the Biological Reserve in addition to a National forest. The Canton’s limits are to the south, the Marabout of Sidi Boughaba to the west, the Atlantic Ocean to the north, the Kasbah of Mehdia to the east, the collective lands in the forest of Maamora. Concerning the water and forests, the biological reserve of Sidi Boughaba is one of the few wetlands consisting of a freshwater lake and a forest of the red juniper (*Juniperus phoenicea* L.).

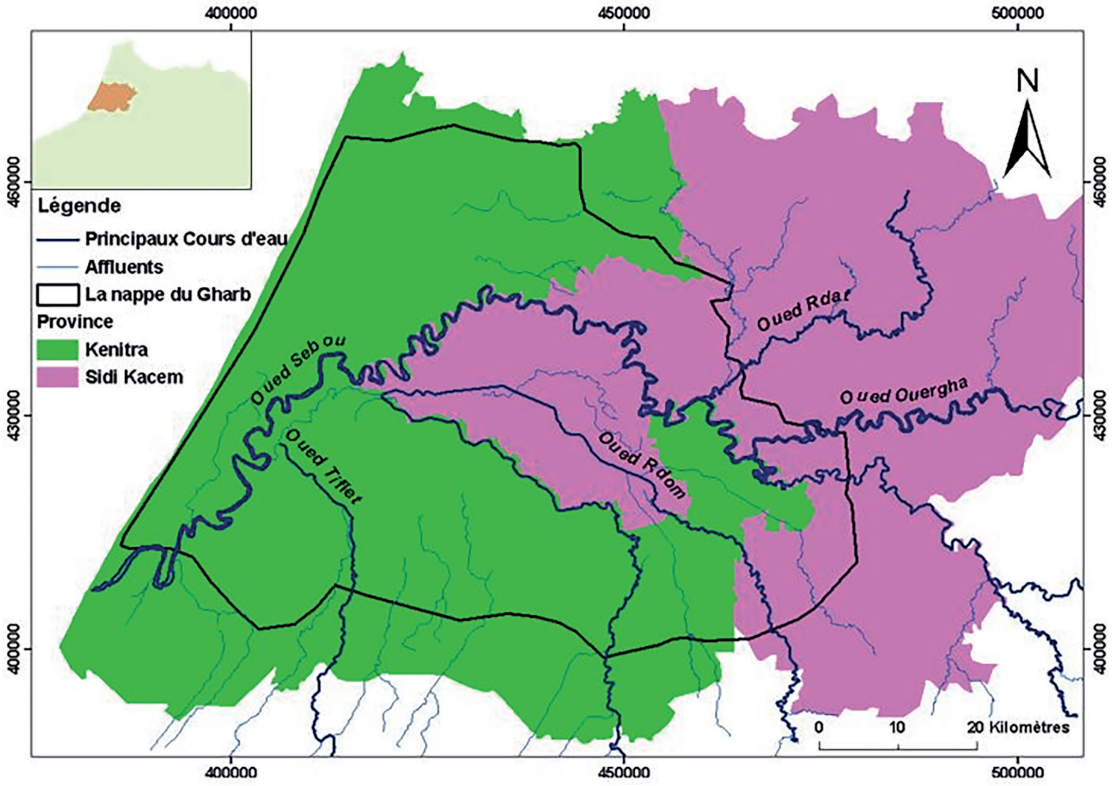

Fig 1. Geographical location of the Gharb plain.

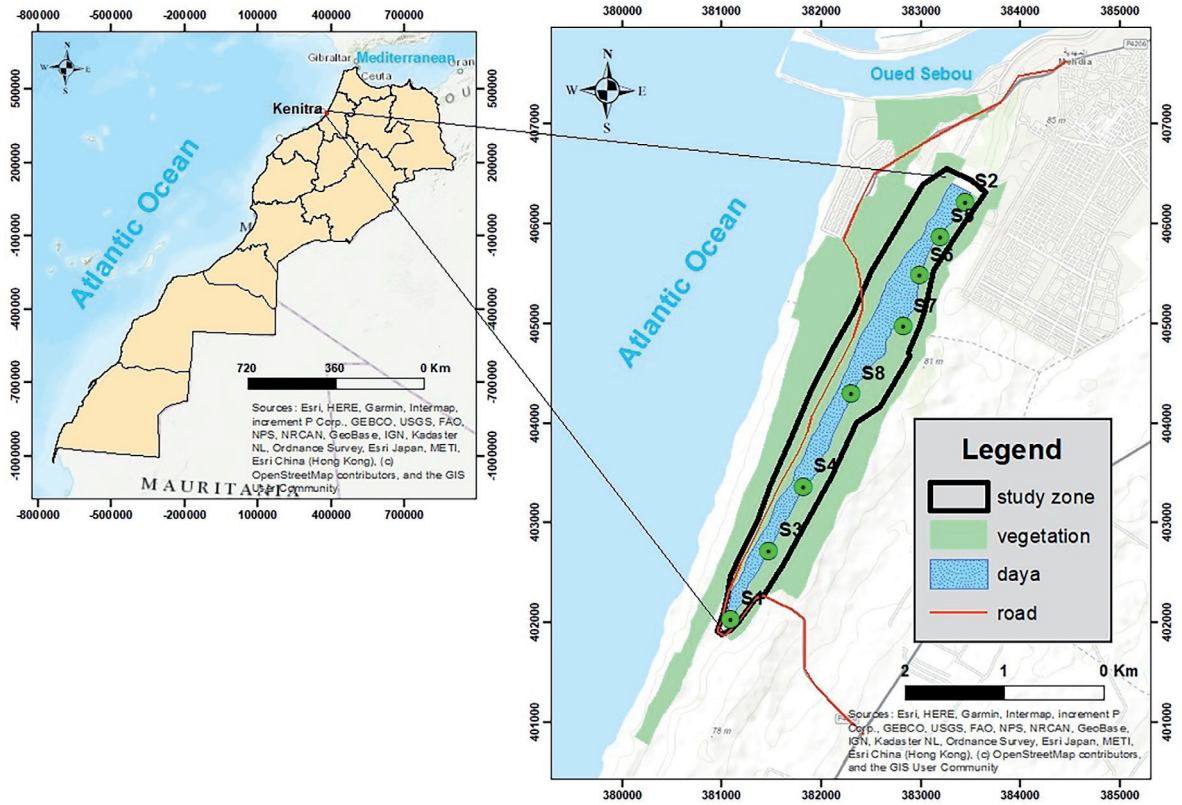

Fig 2. Geographical location of the biological reserve of Sidi Boughaba.

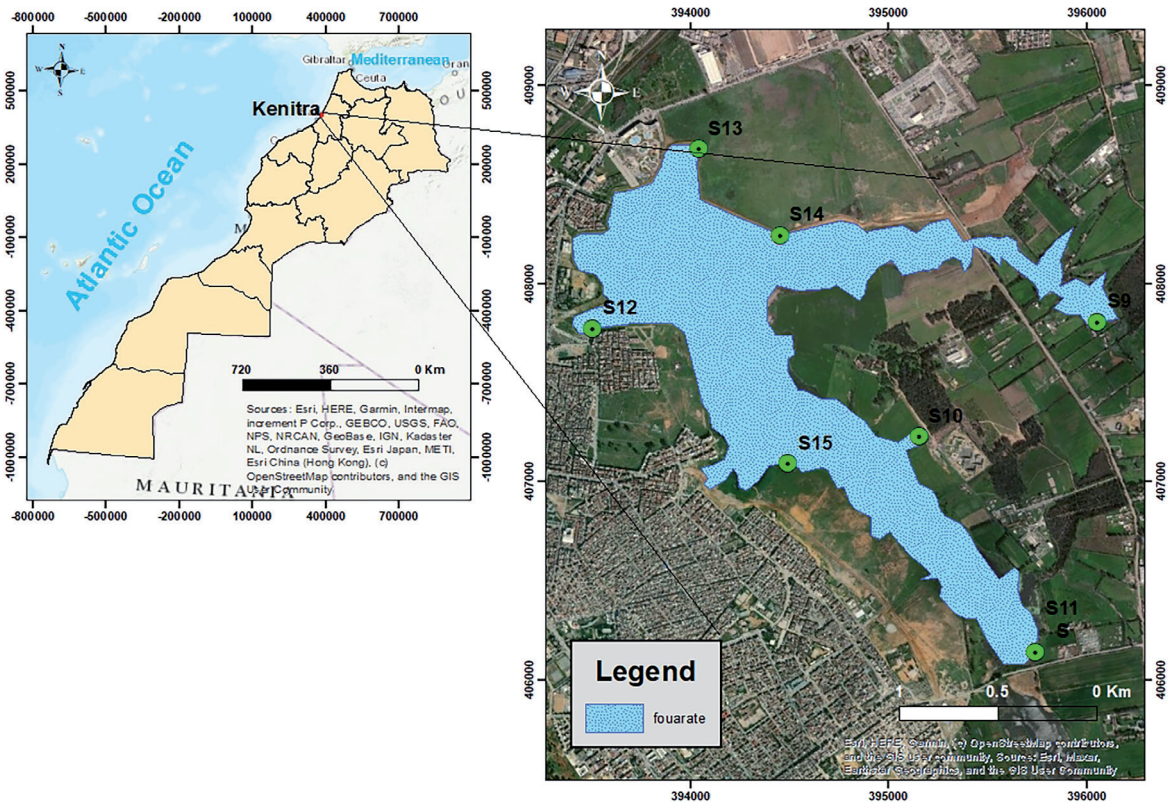

Fig. 3. Geographical location of the Merja of Fouarat.

The Merja of Fouarat (Figure 3), the wet area of Kenitra city, is located in the northwestern of Morocco, at the southwestern end of the coastal plain of Gharb, on the course of the Oued of Fouarat, a small tributary of the terminal courses of the Oued of Sebou (Lahrouz, Dakki, Gmira, 2011). The vegetation is marked by herbaceous and algal plants. This site is located near an industrial area characterized by the massive discharges of liquid and solid waste.

Methodology

The proposed methodology is based on the analysis of bibliographic data that compile an inventory of species reported in two wetlands studied. In addition, field surveys were conducted to update this data and complete the inventory.

At each of the stations studied, 9 physicochemical parameters were measured using electronic equipment or by volumetry. The temperature of the water was carried out using a mercury thermometer graduated in 1/10 of a degree Celsius. The pH was carried out using an Orion Research, Ionalyser model 607 pH meter with an Orion pH 91-05 specific electrode. Additionally, conductivity was measured using a conductivity meter. The other chemical parameters were measured in the laboratory.

Likewise, using a trouble net the authors swept several times and filtered the water at each of the stations surveyed, according to the chemical principles indicated by Rodier, Legube, Merlet (2009).

Choice of stations.— Since our objective is to study the aquatic heteroptera, the choice of stations was guided by their distribution throughout the hydrographic network, taking into account their thermal and hydrological variability, sampling of representative habitats, as well as their accessibility. The field surveys took place from mid-April until the end of December 2022 and covered 15 stations distributed both at Lake of Sidi Boughaba and the Merja of Fouarat.

Sampling of Heteroptera.— The capture of aquatic Heteroptera was carried out using a long-handled circular opening seine net with a mesh opening of 400 μm (Ramdani, 1986; 1988; Himmi, 2007).

Conservation of specimen.— The collected samples were transferred to a plastic basin, rid of large plant debris *in situ*, and then preserved in 70° alcohols. In the laboratory, the contents of the jars were first sorted and/or in order to separate the different classes, orders, and families.

Specimen identification.— The determination of collected specimens was carried out by referring to specialized publications on the identification of macro-invertebrates in general (Tachet, Pierrot, Bournaud., 1986), European or Moroccan keys (Aguesse., Dakki, Gheit, Ramdani, 1982; Ramdani, 1986).

RESULTS

Overall inventory

The inventory of aquatic heteropterans in the freshwater of Lake Sidi Boughaba and Merja of Fouarat allowed estimating the importance of ecosystems/habitats in these two wetlands. The listed inventory (Table 1) includes 24 species, distributed among 9 families.

Specific richness

Figure (4) shows that the Corixidae family largely dominates the faunistic composition of the heteropteran fauna with 7 species, representing a specific richness of 29.16%. This is followed by the Notonectidae with 6 species (25%), and then the Gerridae, which is represented by 3 species (12.5%). The Naucoridae and Nepidae are represented by only two species each, accounting for a specific richness of 8.33% each. Lastly, the Hydrometridae, Veliidae, Mesoveiliidae, and Pleidae are represented by a single species each, resulting in a specific richness of 4.16% each (Figure 4).

Distribution of species collected in each study area

Figure (5) shows that the Lake of Sidi Boughaba is rich in species compared to the Merja of Fouarat. This can be explained, by the fact that the Lake of Sidi Boughaba is a protected site, by the fact that the Merja of Fouarat is a site polluted by liquid waste discharged by nearby factories.

Table 1. Lists of species inventoried in the two study areas (x = presence of species).

Infra-order	Family	Taxa	Merja of Fouarat							Lake of Sidi Boughaba							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nepomorpha (Popov, 1968)	**Corixidae** Leach, 1915	*Corixa affinis* (Leach, 1817)			x	x	x			x	x	x	x	x	x	x	x
		Sigara lateralis (Leach, 1817)		x	x	x	x			x	x	x	x	x	x	x	x
		Sigara stagnalis (Leach, 1817)								x	x	x	x	x	x	x	x
		Sigara scripta (Rambur, 1840)								x	x	x	x	x	x	x	x
		Sigara selecta (Fieber, 1848)								x	x	x	x	x	x	x	x
		Sigara fossarum (Leach, 1817)								x	x	x	x	x	x	x	x
		Hesperro corixa Algirica (Puton, 1890)								x	x	x	x	x	x	x	x
	Notonectidae Leach, 1915	*Notonecta glauca rufescens* (Poisson, 1933)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Notonecta viridis (Delcourt, 1909)								x	x	x	x	x	x	x	x
		Notonecta pallidula (Poisson, 1926)											x	x	x		
		Notonecta maculata (Fabricius, 1794)								x	x	x					
		Anisops sardia (Herrich-Schaeffer, 1849)	x	x	x	x	x	x	x	x	x					x	x
		Micronecta schlotzi (Fieber, 1860)								x	x					x	x
	Pleidae Fieber, 1851	*Plea leachi* (McGregor, Kirk, 1899)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Naucoridae Fallen,1818	*Naucoris maculatus conspersus* (Stål, 1876)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Naucoris maculatus angustior (Lethierry, 1877)								x	x	x	x	x	x	x	x
	Nepidae	*Nepa cenirea* (Linnaeus, 1758)								x	x	x					
		Nepa rubra rubra (Linné 1758)								x	x	x	x	x	x	x	x
Gerromorpha (Popov, 1971)	**Gerridae** Leach, 1815	*Gerris lateralis* (Schummel, 1832)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Gerris lacustris (Linnaeus, 1758)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Gerris thoracicus (Schummel, 1832)										x	x	x			
	Hydrometridae Billberg, 1820	*Hydrometra stagnorum* (Linnaeus, 1758)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Veliidae Amyot et Serville, 1843	*Microvelia pygmaea* (Dufour, 1833)	x	x	x	x	x	x	x								
	Mesoveiliidae Douglas et Scott, 1867	*Mesovelia vittigera* (Horváth, 1895)	x	x	x	x											
Total	9	24	24							12							

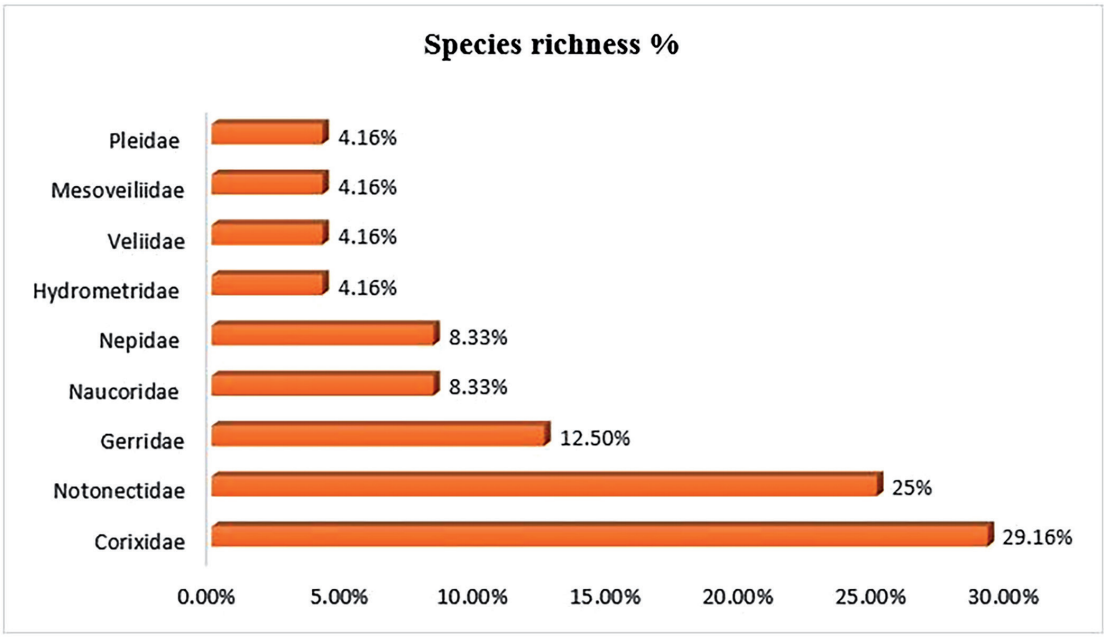

Fig. 4. Species richness of the different families in all the study areas.

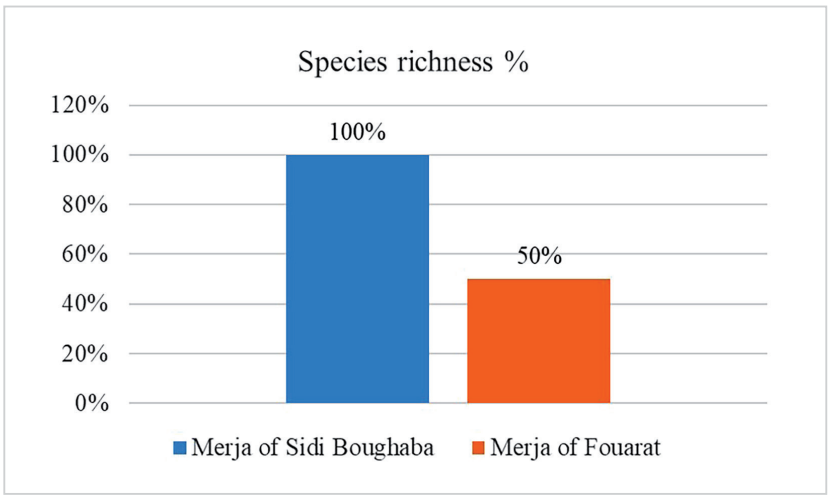

Fig. 5. Species richness collected in each study area.

Physical and chemical data of the surveyed sites

Main characteristics of the surveyed stations.— The main characteristics of the surveyed stations are represented in the table (2), and we notice that the duration of the flooded phase of the studied environment varies depending on the location of the station, ranging from temporary to semi-permanent to permanent. In addition, the vegetation cover of the environment is not homogeneous and varies from 10 to 60%. Besides these variations, the different surveyed stations have depths that vary between 45 cm and 300 cm.

Table 2. Main characteristics of surveyed station.

	Stations to prospect															
	Merja of Fouarat							Lake of Sidi Boughaba								
	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S1	S2	S3	S4	S5	S6	S7	S8
Temporary	T	T	T	SP	P	P	P	T	SP	T	SP	P	P	P	P
Average impoundment duration (MED) (in months)	< 6	6 à 8	6 à 9	6 à 11	12	12	12	5	7	8	9	12	12	12	8
Vegetation cover (VC) (%)	10	30	35	50	50	45	60	25	10	19	16	35	15	40	15
Maximum depth (Pmax) (cm)	45	70	80	115	140	185	250	60	95	50	80	300	230	240	146

Table 3. Spatial variation of physicochemical parameter values.

	Prospected stations															
	Merja of Fouarat							Lake of Sidi Boughaba								
	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S1	S2	S3	S4	S5	S6	S7	S8
Tmin (c°)	13.2	12.7	12.8	12.1	12.1	11.8	11.9	14.2	14	15	14	15	15.6	14.7	13
Tmax (c°)	30.9	29.5	29.1	28.4	26.4	27.2	27.1	27.4	26	25	29	25	25	27	29
pH	7.6	7.8	7.2	7.4	8.2	7.7	7.6	7.1	7.3	8.8	8.7	6.9	8.3	8.1	8.5
CD (μm/cm)	3750	2930	1420	1950	8500	1930	1150	5500	4540	7950	7900	2800	3250	4560	4600
Cl^- (mg /l)	248	190	215	210	256	144	112	510	493	4850	3930	992	1510	2121	3303
DBO_5 (mg /l)	15.88	47.22	59.62	61.45	136.6	88.64	43.71	32.5	43.1	72	62.1	54.5	66.2	55	57.5
NH_4^+ (mg/l)	1.87	3.58	5.62	2.64	12.1	5.56	3.62	1.21	1.17	3.1	2.95	1.74	1.24	0.98	0.93
NO_3^- (mg/l)	0.05	0.1	1.95	1.83	2.6	2.1	0.15	7.5	8.1	9.5	12.1	12.5	11.5	13.5	6.9

Spatial physicochemical variation of the studied environment.— The values of measurements for 8 evaluated parameters are illustrated in Table (3). As shown in the table, the variation of minimum temperatures ranges from 11.8°C to 15.6°C. While the values of maximum temperature range from 25°C to 30.9°C, these temperature variations seem to be influenced by the depth of the medium. Generally, the pH is basic. The conductivity and the levels of Cl-, NH4+, NO3-, and BOD5 are highly variable from one station to another.

Typological and biotypological analysis of the studied environment

Typological analysis.— The analysis of typological data (Figure 6) allowed us to obtain two types of variable groups:

a) The first group is located on the positive side of axis F1, composed mainly of pH, NO3, Cl-, CD, Tmin, and Temporality.

b) The second group of variables is located on the negative side of axis F1, formed by Pmax, Tmax, DBO5, NH4+, and vegetation cover.

The projection of physico-chemical variables on the two axes F1×F2 led us to distinguish two groups of stations: G-S1 and G-S2 (Figure 7).

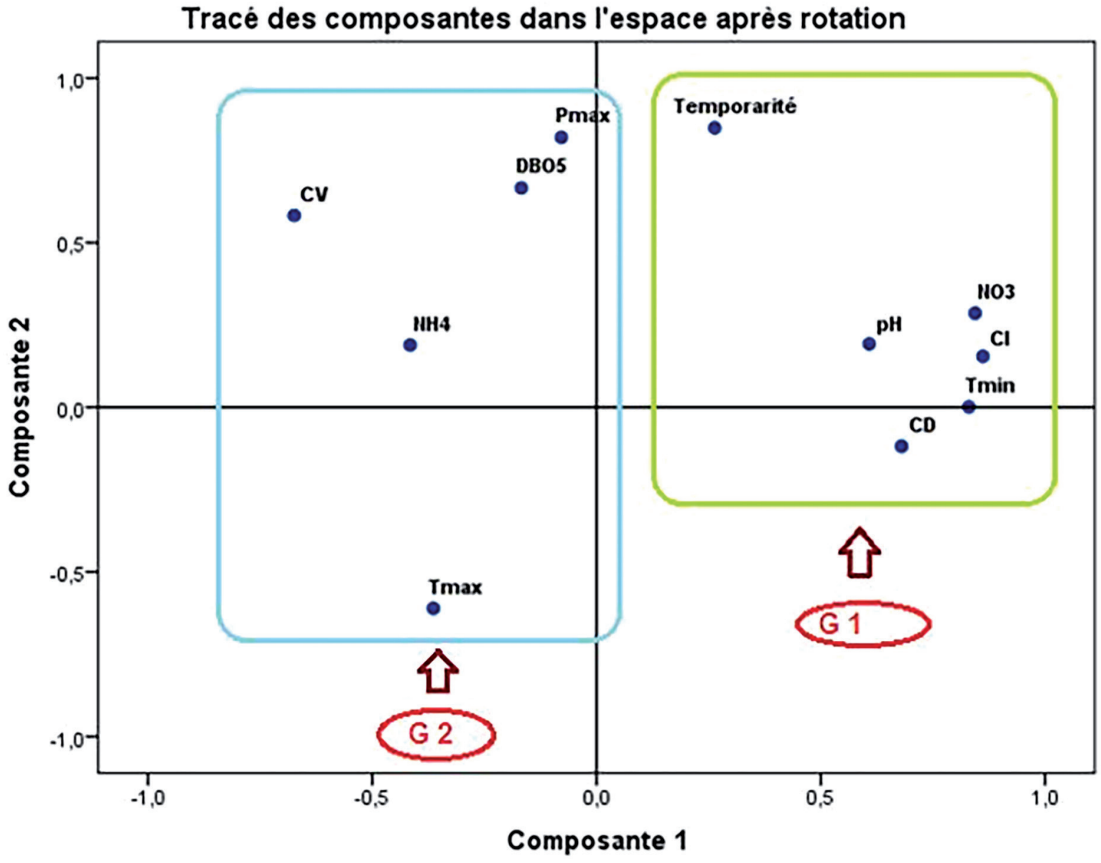

Fig. 6. Projection of the points representing the physico-chemical parameters.

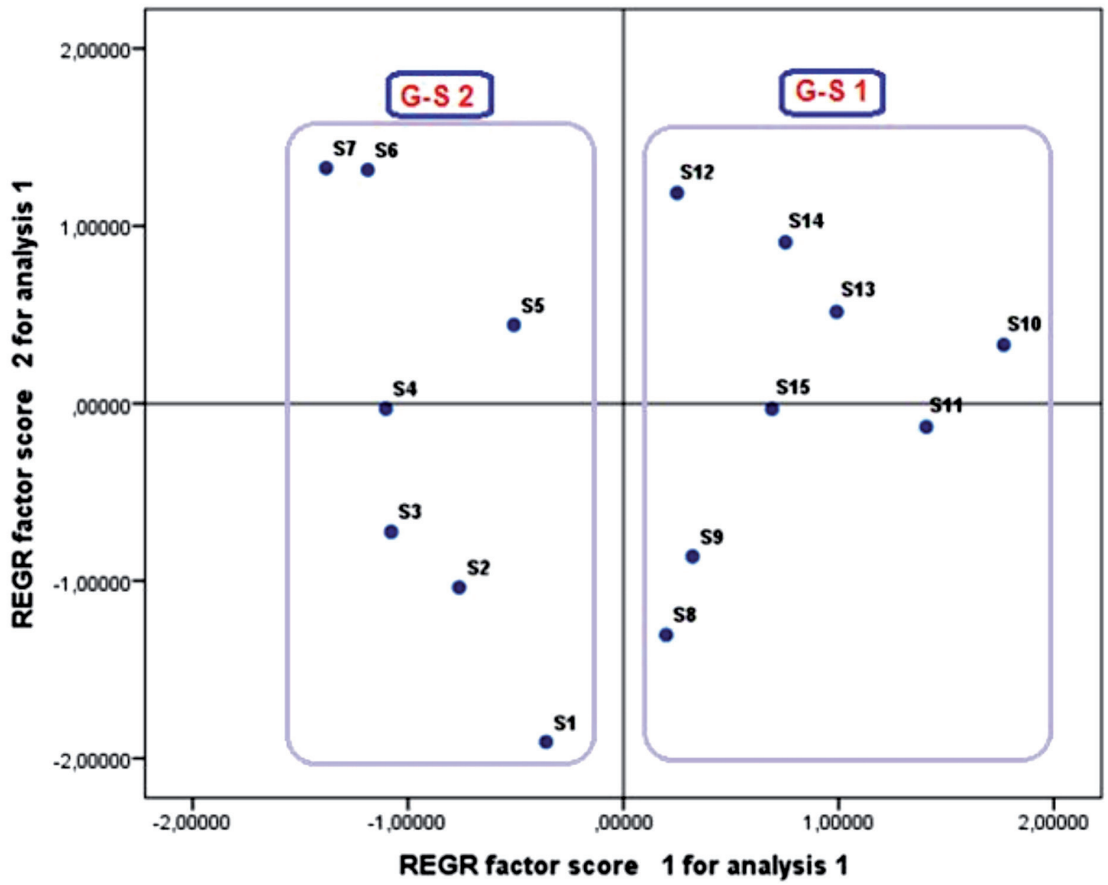

Fig. 7. Projection of the points representing the surveyed stations.

G-S1: formed by stations S8, S9, S10, S11, S12, S13, S14, and S15, all of which are stations in the Lake of Sidi Boughaba, located on the positive side of axis F1, and characterized by pH, NO3-, Cl-, CD, Tmin.

G-S2: group located on the negative side of axis F1, consisting of stations S1, S2, S3, S4, S5, S6, and S7, which are stations in the Merja of Fouarat, and characterized by Pmax, DBO5, Tmax, NH4+, and CV.

Biotypological analysis.— The spatial distribution of heteroptera species in relation to stations is not homogeneous. The analysis of the projection of these species onto the F1xF2 plane contributes to the determination of the physicochemical conditions that could be responsible for the observed spatial distribution of species.

According to this analysis (Figure 8), 4 species groupings can be differentiated:

• Species grouping G 1a: Species from the subgroup that inhabit stations S9, S12, S14, and S15 Examples: *Sigara selecta*, *S. fossarum*, *Gerris lateralis*, and *Nepa cinerea*.

• Species grouping G 2a: These are species that characterize stations S4 and S11 Examples: *Sigara lateralis*, *S. stagnalis*, *Naucoris maculatus angustior*, *Nepa rubra rubra*, *Gerris thoracicus* and *Mesovelia vittigera*.

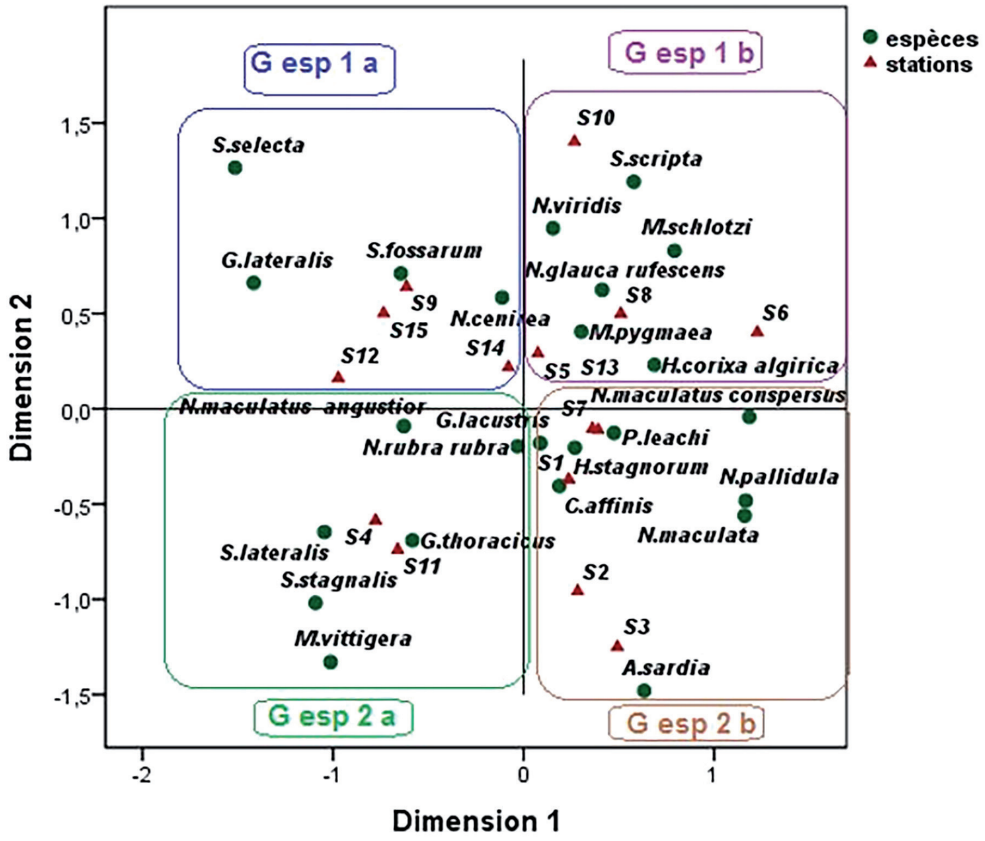

Fig. 8. Distribution of species in relation to surveyed stations.

• Species grouping G 1b: Group of species that colonize stations S5, S6, S8, and S10 Examples: *Sigara scripta*, *Notonecta viridis*, *N. glauca rufescens Micronecta schlotzi*, *Microvelia pygmaea* and *Hesperrocorixa algirica*

• Species grouping G 2b: Species in this group inhabit stations S1, S2, S3, and S7. Examples: *Anisops sardia*, *Notonecta maculata*, *Notonecta pallidula*, *Corixa affinis*, *Hydrometra stagnorum* and *Plea leachi.*

DISCUSSION

Twenty-four species of aquatic heteropterans were sampled across the two study areas, representing 31% of the heteropteran fauna in aquatic environments in Morocco, which includes 77 species and 11 families *sensu* Dakki (1997). These species collected in the two study areas belong to 9 families, which are grouped into two infraorders: Nepomorpha and Gerromorpha. Globally, these infraorders consist of approximately 5,000 species distributed among twenty families (Polhemus and Polhemus, 2007). The distribution of Nepomorpha species is linked to the physicochemical characteristics of the water, while Gerromorpha species are associated with the type of water body (Morales-Castaño and Rendón, 2008).

Nepomorpha.— The most represented family is Corixidae with 7 species, accounting for 29.16% of all taxa collected in the two study areas. Nieser (2002) states that Corixoidea are found in stagnant water or in slow-flowing parts of streams. Notonectidae are represented by 6 species, accounting for a specific richness of 25%. The family Pleidae is represented by one species, *Plea leachi*. The family Naucoridae is represented by two species, namely *Naucoris maculatus conspersus* and *N. maculatus angustior*. In Sidi Boughaba, representatives of the Nepidae family are *Nepa cenirea* and *Nepa rubra rubra.*

Gerromorpha.— As for Gerromorpha, the family Gerridae is represented by three species *Gerris lateralis, G. lacustris,* and *G. thoracicus*. The Hydrometridae, Veliidae, and Mesoveliidae are represented by only one species each, namely *Hydrometra stagnorum, Microvelia pygmaea*, and *Mesovelia vittigera*, respectively.

The results obtained show that the dispersion of collected species is not homogeneous, as some species can be found in both study areas, indicating that they are ubiquitous or euryecious species with a wide ecological tolerance to environmental constraints. This is particularly the case for *Gerris lacustris, G. lateralis, Corixa affinis, Notonecta glauca, Anisops sardia, Plea leachi, Naucoris maculatus conspersus, Hydrometra stagnorum,* and *Mesovelia vittigera.*

On the other hand, other species inhabit specific habitats conditioned by physicochemical factors of the environment (Slim et al., 2021), and/or the aquatic vegetation of the environment (Ilie and Olosutean, 2018). It should be noted that certain corixidae are detritivores or algae consumers (Sifelhak, 2020). Meanwhile, Gerridae are predators, feeding on insect or other invertebrate carcasses that have fallen into the water (Tachet, Bournaud, Richoux, 2010).

Baaloudj, de los Ríos-Escalante, Esse (2022) mention that among aquatic biological communities, insects are commonly used to assess the overall health of aquatic ecosystems (Hellawell, 1986; Barbour et al., 1996). Furthermore, these organisms are sensitive to environmental conditions and are generally used as indicators of disturbance (Warwick and Clarke, 1993) due to their quick response to environmental disturbances (Norris and Hawkins, 2000; Butcher, Arbisi, Atlis, Mcnulty, 2003). Aquatic heteropterans are one of these organisms, and they are important components of aquatic ecosystems for several reasons: on one hand, they act as both consumers of algae and dead leaves at lower trophic levels, and as prey for fish and other organisms at higher trophic levels (McCafferty, 1981). Similarly, the results of Skern, Zweimüller, Schiemer (2010) show that heteropterans are considered indicators of aquatic habitats.

CONCLUSION

It appears clear that the ecological distribution of aquatic heteropterans can be divided into two groups. One group consists of species that can be found in a wide range of habitats, known as ubiquitous or euryecious species, which have a broad ecological tolerance to environmental constraints. On the other hand, the presence

of the other group of species is conditioned by several physicochemical factors of the environment. These are stenoecious species.

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CONFLICTS OF INTEREST

As a doctor in animal ecology and systematics, I conduct research on this subject.

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