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The Ramsar Meta-Analysis Study of Commented Inventories of Aquatic and Semi-Aquatic Heteroptera in Two Wet Areas: The Biological Reserve of Sidi Boughaba and the Merja of Fouarat

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ABSTRACT

This work compiled the data from the literature and added the results of surveys carried out in April until September 2023 in two wet areas of the Gharb plain (the biological reserve of Sidi Boughaba and the Merja of Fouarat). Thus, 24 species of aquatic Heteroptera were currently identified, namely *Corixa affinis, Sigara lateralis, Sigara stagnalis, Sigara scripta, Sigara selecta, Sigara fossarum, Hesperro corixa algirica, Notonecta glauca rufescens, Notonecta viridis, Notonecta pallidula, Notonecta maculata, Anisops sardia, Micronecta schlotzi, Plea leachi, Naucoris maculatus conspersus, Naucoris maculatus angustior, Nepa cenirea, Gerris lateralis, Gerris lacustris, Gerris thoracicus, Hydrometra stagnorum, Microvelia pygmaea* and *Mesovelia vittigera*. These species belong to nine families. The richest family was Corixidae with seven species, followed by Notonectidae with six species. Next came Gerridae with three species, followed by Nepidae and Naucoridae with two species each. Pleidae, Hydrometridae, Veliidae, and Mesoveiliidae were each represented by only one species. The comparison of the Heteropteric diversity of the two studied areas showed that the biological reserve of Sidi Boughaba was home to 23 species, while that of the Merja of Fouarat had only 12 species, ten of which were common in the two studied areas, namely: *Corixa affinis, Sigara lateralis, Notonecta glauca rufescens, Anisops sardia, Plea leachi, Naucoris maculatus conspersus, Gerris lateralis, Gerris lacustris, Hydrometra stagnorum* and *Mesovelia vittigera.*

INTRODUCTION

The Gharb plain contains a set of very diverse aquatic environments (pond, temporary ponds, rivers, dams and irrigation canals), and therefore constitutes a very favorable environment for the qualitative and quantitative proliferation of invertebrate fauna, among these are the Heteroptera.

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The first data on the aquatic Heteroptera of Morocco are dated back to 1929 **(Lindberg, 1929; Vidal, 1937; Poisson, 1929, 1940, 1933, 1957)**. Twenty years later, new scientific studies emerged focusing on the study of aquatic macroinvertebrates in Morocco, particularly Heteroptera **(Dakki, 1979; Ramdani, 1980; Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1985, 1994)**.

In 1997, Dakki, carried out a national study of the Moroccan continental aquatic fauna and drew up a list of 76 species of aquatic Heteroptera which are divided into 11 families and 23 genera. The number of aquatic Heteroptera in Morocco then rose to 77 species **(Lmohdi *et al.*, 2008)**. In addition, **Lmohdi *et al.* (2008)** pointed out that the last published work on the aquatic Heteroptera of Morocco was devoted to the eastern part of the country for which a faunal catalog of 24 species was compiled **(Chavanon *et al.*, 2004)**.

As a result of these works, it appeared that few surveys were interested in the localities of the Gharb plain. This present work contributed to the knowledge of the aquatic Heteroptera of the plain of Gharb by studying these insects in two wetlands classified as Ramsar site, the biological reserve of Sidi Boughaba, and the Merja of Fouarat.

MATERIALS AND METHODS

1. Study areas

The Gharb plain is located in the region of Rabat-Sale-Kenitra in the northwest of Morocco and covers an area of 616,000ha (Fig. 1). It contains two wetlands classified as Ramsar sites (The biological reserve of Sidi Boughaba and the Merja of Fouarat).

Sidi Boughaba Lake (34°12’56’’and 34°15’55’’ of north latitude and 6°42’32’’and 6°45’27’’of west longitude) is located on the Atlantic coast of Morocco Northwest, oriented NNE–SSW, and located in a depression of a hilly region (Fig. 2). It extends over 5.5km in length and a varying width of 100 to 250 meters, and its depth varies between 0.5 and 2.50 meters maximum. The existence of this body of water is due to the fact that the topographic surface is at a lower side than that of the potentiometric surface of the coastal groundwater, rainwater and runoff waters. The biological reserve of Sidi Boughaba is 150ha **(Slim *et al.*, 2016)**. The Canton of forest Sidi Boughaba spans 652ha which encompasses the biological reserve and 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 Maâmora. 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 which is very dense by the red juniper (*Juniperus phoenicea* L.)

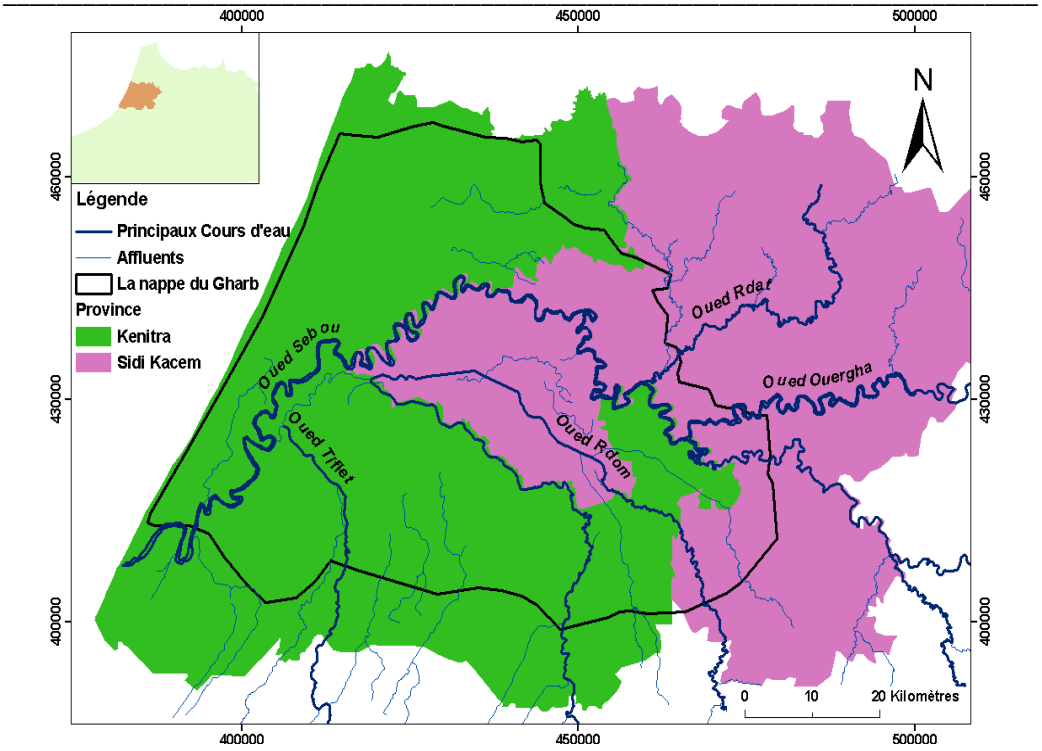

Fig. 1. Geographical location of the Gharb plain **(Slim *et al.*, 2023)**

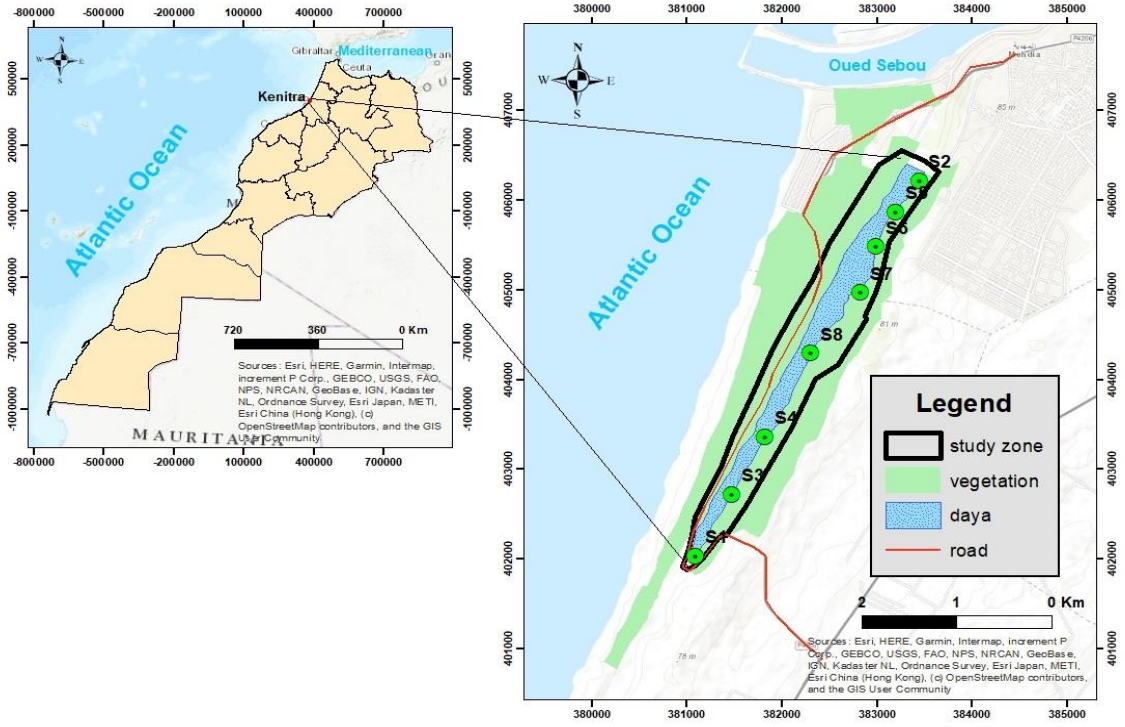

Fig. 2. Geographical location of the biological reserve of Sidi Boughaba **(Slim *et al.*, 2021)**

- The Merja of Fouarat (Fig. 3), the wet area of Kenitra City, is located in the northwestern side 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 course of the Oued of Sebou **(Lahrouz *et al.*, 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.

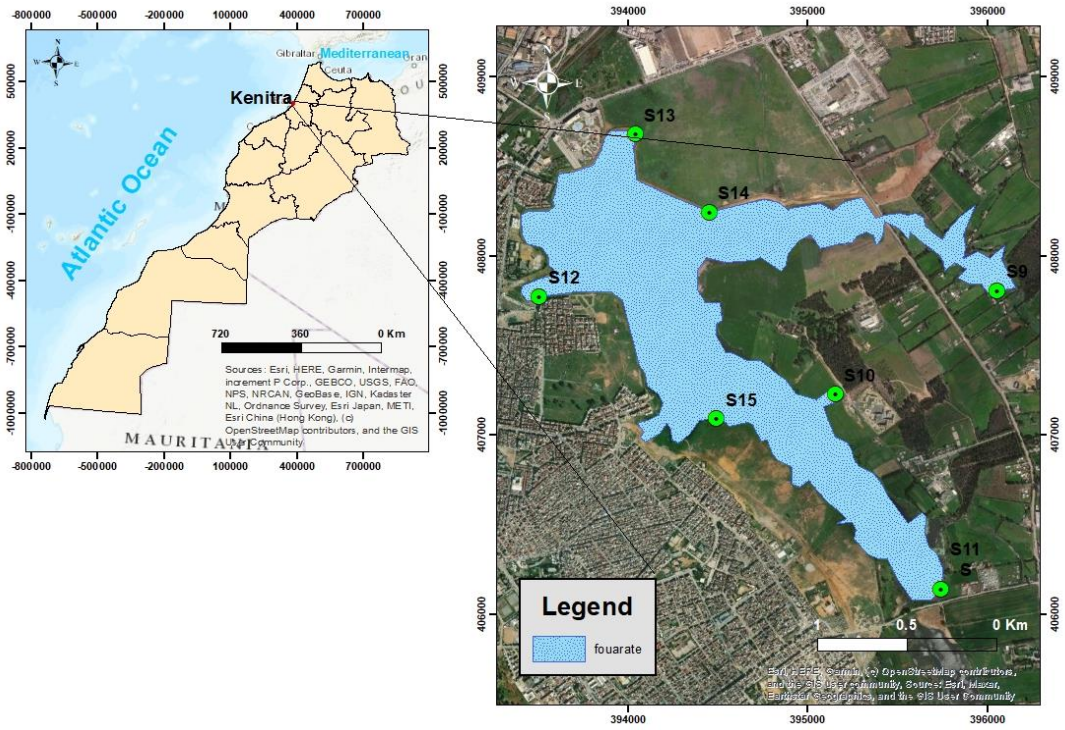

Fig. 3. Geographical location of the Merja of Fouarat **(Slim *et al.*, 2023)**

2. Methodology

The proposed methodology is based on the analysis of bibliographic data which provided an inventory of the species reported in two wetlands of the Gharb plain. In addition, field surveys were conducted to update these data and complete the inventory.

3. Sampling of macro-invertebrates

The method used has been adopted by several authors, including **Himmi (2007)** and **Slim *et al.* (2017)**.

4. Conservation and sorting

The samples taken were transferred to a plastic basin, cleared of large plant debris *in situ* and then preserved in alcohol at 70°C. In the laboratory, the contents of the jars were first sorted with the naked eye and/or under a binocular magnifying glass in order to separate the different classes, orders and families.

5. Identification of specimens

The determination of the collected specimens was carried out using books that are specialized in the identification of macro-invertebrates in general European or Moroccan keys **(Aguesse *et al.*, 1982)**.

RESULTS

The results obtained showed that the distribution of the species was not homogeneous in the two studied areas. Thus, the biological reserve of Sidi Boughaba was a home to 23 species, while the Merja of Fouarat had 12 species, ten of which were common in the two studied areas, namely: *Corixa affinis, Sigara lateralis, Notonecta glauca rufescens, Anisops sardia, Plea leachi, Naucoris maculates conspersus, Gerris lateralis, Gerris lacustris, Hydrometra stagnorum, Mesovelia vittigera* (Table 1).

Table 1. List of collected species

Infra-order	Sub-order	Family	Taxa	Area 1	Area 2
Nepomorpha	Hydrocorises	Corixidae	*Corixa affinis*	1	1
			Sigara lateralis	1	1
			Sigara stagnalis	1	0
			Sigara scripta	1	0
			Sigara selecta	1	0
			Sigara fossarum	1	0
			Hesperrocorixa algirica	1	0
		Notonectidae	*Notonecta glauca rufescens*	1	1
			Notonecta viridis	1	0
			Notonecta pallidula	1	0
			Notonecta maculata	1	0
			Anisops sardia	1	1
			Micronecta schlotzi	1	0
		Pleidae	*Plea leachi*	1	1
		Naucoridae	*Naucoris maculates conspersus*	1	1
			Naucoris maculatus angustior	1	0
		Nepidae	*Nepa cenirea*	1	0
			Nepa rubra rubra	1	1
		Gerridae	*Gerris lateralis*	1	1
			Gerris lacustris	1	1
			Gerris thoracicus	1	0
Gerromorpha	Amphibicorises	Hydrometridae	*Hydrometra stagnorum*	1	1
		Veliidae	*Microvelia pygmaea*	0	1
		Mesoveiliidae	*Mesovelia vittigera*	1	1
Total	**2**	**9**	**24**	**23**	**12**

Area 1: Biological reserve of Sidi Boughaba. **Area 2:** Merja of Fouara.

1. Species data collected

The data for each species, classified alphabetically within each family, were published prior to our survey in 2023.

• **Family Corixidae** (Leach, 1915)

- ***Corixa affinis*** (Leach, 1817).

It is a Palaearctic species **(Aukema & Rieger, 1995)**. In Morocco, the species frequents in the watercourse of the Atlantic coast, the Central Plateau and the western margins of the High Atlas **(Ramdani, 1980; Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1985, 1994)**. In the northern part of the country, it is collected in a pond around the province of Figuig **(Chavanon *et al.*, 2004)**. In our study area, the species shared their distribution in the two study areas.

- ***Sigara lateralis*** (Leach, 1817)

This species has a wide geographical distribution, covering the entire Palaearctic area **(Aukema & Rieger, 1995)**. In Morocco, *Sigara lateralis* appears as the most abundant and common Sigara **(Thiery, 1981)**. Indeed, the species has been mentioned in the watercourse of the coastal Meseta, the Central Plateau, the Middle Atlas and the High Atlas (**Ramdani, 1980; Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1994)**. In its northern part, it also has a very wide distribution in the Rif **(Gheit, 1994)**, and in its eastern part, it has been cited in the surroundings of Oujda **(Chavanon *et al.*, 2004)**. In that case, the species situates on the Merja of Fouarat and the Merja of Sidi Boughaba.

- ***Sigara stagnalis*** (Leach, 1817)

It is a Palaearctic diffusion element **(Aukema & Rieger, 1995)**. In Morocco, the species is mentioned in the coastal Meseta on its Atlantic coast, in the Central Plateau **(Ramdani, 1980; Gheit, 1981, 1985, 1994; Aguesse *et al.*, 1982)** and in the Middle Atlas **(Gheit, 1994)**. It has also been captured in the North side of the country around Nador **(Chavanon *et al.*, 2004)** and in Taounate and Chefchaouen in the Rif **(Gheit, 1994)**. In the literature, *Sigara stagnalis* is associated with aquatic habitats with supra-littoral and continental lentic facies **(Gheit, 1981, 1985, 1994; Aguesse *et al.*, 1982)**, with brackish characters **(Dethier, 1986; Chavanon *et al.*, 2004; Carbonell, 2010; Carbonell *et al.*, 2011, 2012 in Bennas *et al.*, 2016)**. This species can colonize hypersaline aquatic environments **(Carbonell, 2010; Carbonell *et al.*, 2011)**. In this sense, the species is absent in the Merja of Fouarat.

- ***Sigara selecta*** (Fieber, 1848)

This species adopts a West-Palaearctic distribution. In Morocco, the species is known from the main biogeographic domains of the country; the Rif, where it has been recorded in Chefchaouen, Taounate and Nador **(Gheit, 1994; Chavanon *et al.*, 2004; L'mohdi, 2016)**. Furthermore, it has been recorded in the High Atlas around Marrakech **(Thiery, 1981)**, in the Middle Atlas, around Ifrane and Khémisset **(Gheit, 1994)**, and on the Atlantic coast. Moreover, it has been mentioned in Kénitra and Safi **(Gheit, 1981, 1985, 1994; Thiery, 1981)**. During the current study, we found it only on the Merja of Sidi Boughaba.

- ***Sigara scripta*** (Rambur, 1840)

It is a Paleo-Mediterranean ubiquitous species, frequent in Africa, Europe and Asia, as well as in the Iberian Peninsula and in the Eastern Mediterranean **(Jansson, 1986)**. In our study, the species was subservient to the Merja of Sidi Boughaba and was absent in the Merja of Fouarat.

- ***Sigara fossarum*** (Leach, 1817)

It is a Palaearctic species which is presented in northern, central and eastern Europe. It was reported in Portugal, Spain and the Maghreb by **Jansson (1986)**. In Morocco, the species was collected in the coastal Meseta, the Central Plateau and the Middle Atlas and Rif. In the present study, the species was absent in the Merja of Fouarat.

- ***Hesperrocorixa algirica*** (Puton, 1890)

It is an endemic species of North Africa. In Morocco, it exists in the coastal Meseta, the Central Plateau and the Middle Atlas. The species was collected at the level of the Marja of Sidi Boughaba.

• **Family Notonectidae** (Leach, 1915)

- ***Notonecta glauca rufescens*** (Linnaeus, 1758).

It is a widely distributed species covering the entire Palaearctic domain **(Aukema & Rieger, 1995)**. The presence of this species in Morocco has been reported in the Middle Atlas **(Aguesse *et al.*, 1982)**. Later, it was found in the watercourse of the Atlantic coast and the Central Plateau **(Gheit, 1994)**. In our study, the species situated in the Merja of Fouarat and the Merja of Sidi Boughaba.

- ***Notonecta viridis*** (Delcourt, 1909).

It is a western Palaearctic and eastern element that is essentially observed in the coastal waters **(Poisson, 1957)** or in the large river valleys. This type of species is found in the Merja of Sidi Boughaba.

- ***Notonecta pallidula*** (Fish, 1926)

It is a species that originated in the Mediterranean Basin, very abundant in North Africa. In Morocco, it is located in the Meseta, the Central Plateau, the Middle and High Atlas and the Rif. The species was observed in the Merja of Sidi Boughaba.

- ***Anisops sardia*** (Herrich-Schaffer, 1850)

It is a Paleo-tropical species. In Morocco, it is located in the Meseta, the Central Plateau, the Middle and High Atlas and the Rif. The species was found in both studied areas.

- ***Notonecta maculata*** (Fabricius, 1794)

It is a Palaearctic species **(Aukema & Rieger, 1995)**, this Notonecte occupies the whole country. It has been found in the watercourse of the coastal Meseta, the Central Plateau and the Middle Atlas **(Aguesse *et al.*, 1982; Gheit, 1994)**. The species also inhabits a large part of the High Atlas biotopes between 200 and 2000m **(Thiery, 1981)**. In the Riffian area, it has a very wide distribution, since it has been found in the majority of surveyed stations **(Gheit, 1994)**. In our study area, it was the most abundant and common Heteroptera. In fact, it was able to be captured in almost all of the surveyed stations.

- ***Micronecta* (*Dichaetonecta*) *scholtzi*** (Fieber, 1860)

It is a Palaearctic species **(Aukema & Rieger, 1995)**, this Micronecte frequents in the Atlantic and Mediterranean coastal borders **(Ramdani, 1980; Aguesse *et al.*, 1982; Gheit, 1994)**. In addition, the species is mentioned in the Middle and High Atlas, as well as in the Central Plateau **(Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1985, 1994)**. In the North of the country, the species has been listed among the aquatic Heteroptera of the Rif **(Gheit, 1994)** and in the surroundings of Oujda **(Chavanon *et al.*, 2004)**. In the current study, the species was absent in the Merja of Fouarat.

• **Family Naucoridae** (Fallen, 1818)

- ***Naucoris maculatus conspersus*** (Fabricius, 1798)

It is a Palaearctic species that is common in the Mediterranean areas including North Africa **(Aukema & Rieger, 1995)**. In Morocco, the species is

mentioned in the coastal Meseta on its Atlantic coast, in the Central Plateau, and in the Middle and High Atlas **(Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1994)**. It is also captured in the eastern part of the Kingdom, around Oujda **(Chavanon *et al.*, 2004)**. The species shares their repair in the Merja of Sidi Boughba and the Merja of Fouarat.

- ***Naucoris maculatus angustior*** (Lethierry, 1877)

It is a Mediterranean species. In Morocco, it is known in the Meseta and the Central Plateau **(Gheit, 1981, 1985)**. The species was observed in the Merja of Sidi Boughaba.

• **Family Nepidae**

- ***Nepa cinerea*** (Linnaeus, 1758)

It is a Palaearctic species **(Aukema & Rieger, 1995)**. In Morocco, it is cited in the coastal Meseta on its Atlantic coast, in the Central Plateau and in the Middle and High Atlas **(Ramdani, 1980; Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1985, 1994)**. In its northern part, it has been reported in the central part of the Rif **(Gheit, 1994)**. It is also captured in the eastern part of the Kingdom, especially in the surroundings of Oujda **(Chavanon *et al.*, 2004)**. This type of species is present in the Merja of Sidi Boughaba.

-***Nepa rubra rubra*** (Linnaeus, 1758)

It is a species which likes different types of fresh or brackish water habitats. According to **Thiery (1981)**, this subspecies is abundant in the High Atlas, while **Aguesse *et al.* (1982)** indicated that *Nepa rubra rubra* is found in all Moroccan water collections, or in their vicinity.

• **Family Pleidae** (Fieber, 1851)

- ***Plea leachi*** (Gregor & Kirkaldy, 1899)

It is a Mediterranean species. In Morocco, it has been reported in the Meseta and the Central Plateau, in the Middle and High Atlas and in the Rif (Gheit, 1981,1985). The species appeared in the two studied areas.

• **Family Gerridae** (Leach, 1815)

- ***Gerris thoracicus*** (Schummel, 1832)

It is a species with a wide distribution throughout the Palaearctic region **(Aukema & Rieger, 1995)**. In Morocco, this *Gerris* is widespread, but in small numbers, in all bodies of water, from the Atlantic coast **(Ramdani, 1980; Aguesse *et al.*, 1982; Gheit, 1985; Gheit, 1994)** to the High Atlas **(Thiery, 1981; Gheit, 1994)**. In this regard, **Chavanon *et al.* (2004)** mentioned the

presence of the species in the south of Oujda in the north-eastern part of the country. In the Merja of Sidi Boughaba, the species was present, but it was absent in the Merja of Fouarat.

- ***Gerris lateralis*** (Schummel, 1832)

It is a Palaearctic species. In Morocco, it has been reported in the Meseta and the Central Plateau, in the Middle Atlas and in the Rif **(Gheit, 1981, 1985)**. The species appeared in both studied areas.

- ***Gerris lacustris*** (Linnaeus, 1758)

It is a Palaearctic species. In Morocco it has been reported in the Meseta and the Central Plateau, in the Middle and High Atlas and in the Rif **(Gheit, 1981, 1985)**. The species was found in both studied areas.

• **Family Hydrometridae** (Billberg, 1820)

- ***Hydrometra stagnorum*** (Linnaeus, 1758)

It is a Palaearctic element **(Aukema & Rieger, 1995)**. In Morocco, the species is mentioned in the coastal Meseta on its Atlantic coast, in the Central Plateau, the Middle Atlas and the High Atlas **(Ramdani, 1980; Thiery, 1981; Aguesse *et al.*, 1982; Gheit, 1985, 1994)**. In our study area, the species was found in the Merja of Sidi Boughaba and the Merja of Fouarat.

• **Family Veliidae** (Amyot and Serville, 1843)

- ***Microvelia pygmaea*** (Dufour, 1833)

It is a species of the Euro-Mediterranean region. In Morocco, it has been reported in the Meseta and the Central Plateau, in the Middle and High Atlas and in the Rif **(Gheit, 1981, 1985)**. The species was absent in the Merja of Sidi Boughaba.

• **Family Mesoveiliidae** (Douglas & Scott, 1867)

- ***Mesovelia vittigera*** (Horvath, 1859)

It is a species of Ethiopian origin, known from the Mediterranean and African countries. In Morocco, it has been reported in the Meseta, the Central Plateau, and the western margins of the High Atlas. The species appeared in both studied areas.

DISCUSSION

It is noted that twenty-four species of aquatic and semi-aquatic Heteroptera were sampled over the two studied areas (historical and contemporary periods), representing 31% of the heteropteric fauna of aquatic

environments in Morocco, which includes 77 species and 11 families *sensu* (Dakki, 1997). These species collected in the two studied areas belong to 9 families, and are divided into two infra-orders: Nepomorpha and Gerromorpha, which are made up of about 5000 species worldwide, divided into twenty families **(Polhemus & Polhemus, 2007)**.

From a systematic point of view, the species collected belong to two sub-orders: Hydrocorises with five families and Amphibicorises with four families represented by 18 species (75%) and 6 species (25%), respectively.

The Corixidae family which contains the largest number of genera and species **(Tachet *et al.*, 2000)** is represented in our collection by seven species (29.16%), followed by the Notonectidae family with six species (25%), then comes the Gerridae family with three species (12.5%), followed by the Naucoridae and Nepidae families, which are represented by two species for each (8.33%). Therefore, the family Pleidae, Hydrometridae, Veliidae and Mesoveiliidae are represented by only one species for each (4.16%).

It should be noted that most species collected seem to have a wide distribution in the Palaearctic domain, which constitutes the majority group. This situation has also been noted in the southeast of the Iberian Peninsula **(Millán *et al.*, 1988)**.

Similarly, the results obtained showed that the heteroptical composition obtained in the Merja of Sidi Boughaba was doubled compared to that obtained in the Merja of Fouarat, this can be explained by the heterogeneity of the environment **(Slim *et al.*, 2021)**.

Furthermore, the results obtained are comparable to those of **Slim *et al.* (2023)**, where they show the existence of two groups of Heteropteran species. One group consists of species that can be found in various environments, known as ubiquitous or euryoecious species with broad ecological tolerance. This includes *Gerris lacustris, Gerris lateralis, Corixa affinis, Notonecta glauca, Anisops sardia, Plea leachi, Naucoris maculatus conspersus, Hydrometra stagnorum*, and *Mesovelia vittigera*. On the other hand, the presence of the other group is conditioned by several physicochemical factors of the environment. These are stenoecious species, such as *Sigara lateralis, Sigara stagnalis, Naucoris maculatus angustior*, *Nepa rubra rubra,* and *Gerris thoracicus*.

Additionally, the results obtained showed that the Merja of Sidi Boughaba and the Merja of Fouarat are rich and diversified compared to that of the Sebou basin, since **Abbou and Fahde (2014)**, reported the presence of only 3 families, namely: Corixidae (*Micronecta scholtzi*), Notonectidae (*Notonecta maculata*) and Gerridae (*Gerris argentatus*). In contrast, the heteropteric composition obtained in the biological reserve of Sidi Boughaba appears to be

almost identical to that found in the Oued Laou watershed **(Lmohdi *et al.*, 2008)**.

CONCLUSION

The biological reserve of Sidi Boughaba and the Merja of Fouarat now have an inventory base and a collection of validated references permitting to identify the majority of aquatic and semi-aquatic Heteroptera adults that inhabit them. Furthermore, despite the general environmental degradation and the lack of basic ecological information on the Heteroptera communities of the aquatic environments of the Gharb plain, the biological reserve of Sidi Boughaba still has a marked relevance for the conservation of biodiversity, expressed on the one hand by the diversity of its aquatic ecosystems (temporary, semi-temporary and permanent), and by its richness in aquatic and semi-aquatic Heteroptera communities on the other hand.

In this respect, it can be said that the biological reserve of Sidi Boughaba could be considered as a natural laboratory of reference since it is likely to represent the entomological diversity of threatened aquatic sources due to anthropic actions, which intervene directly or indirectly in the modeling and modification of the physiognomy of these species. Thus, monitoring the relative contribution and updating of these different species will be an asset for monitoring the state of wetland biodiversity.

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