

Article

Distribution of Fresh-Water Mollusks of the Gharb Area (Morocco)

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Abstract: To assess changes in the fauna of freshwater mollusks in the Gharb Plain (Morocco), 200 sites spread over five districts were surveyed between May 2012 and May 2013. A total of 11 species were identified. *Physella acuta* and *Melanopsis praemorsa* were most frequently encountered. *Bulinus truncatus*, an intermediate host of schistosomiasis in Morocco, and *Planorbarius metidjensis*, an intermediate host of schistosomiasis, were not harvested. The absence of these species may be due to a combination of climatic, biological and anthropogenic factors related to the changes that have occurred in the region.

Keywords: freshwater snails; Gharb; cartography; changes; *Bulinus truncatus*

1. Introduction

There are approximately 6000 freshwater mollusk species described in the world [1]. Among them, many species play an important role in the transmission of parasitic trematodes [2]. There are approximately 350 species of gastropods in the world with medical or veterinary importance, including three main genera acting as intermediate hosts of schistosomes parasitizing humans [3] as follows: *Biomphalaria* (Preston, 1910), *Bulinus* (Müller, 1781) and *Oncomelania* (Gredler, 1881).

With more than 24 freshwater species, the Gharb region is one of the richest regions in Morocco in terms of diversity [4–6]. This region is characterized by a diversity of natural aquatic environments ranging from large rivers to wetlands.

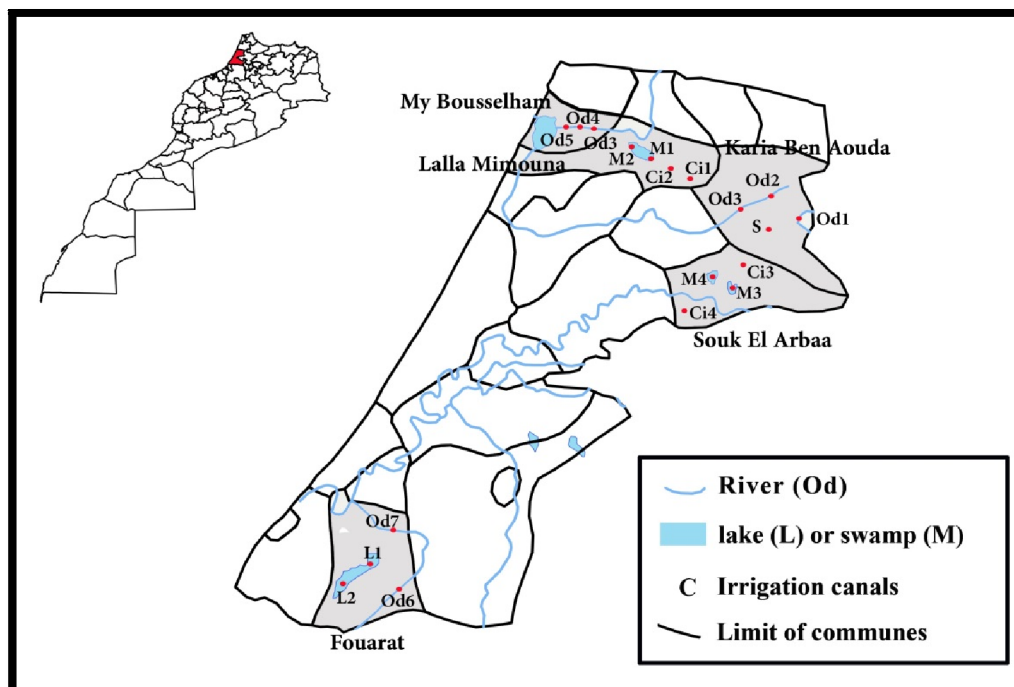
The number of wetlands and Merja (swamps) that provide a habitat favoring mollusks has been reduced by water projects related to the management of the agricultural plains.

The present study aimed to provide an inventory of the freshwater mollusk fauna of the Gharb region to locate the area of parasitic diseases. We suggested a hypothesis to explain the disappearance of certain species and proposed a new mapping of freshwater mollusks in the Gharb region.

2. Study Area

This study was conducted in the Gharb region (Kenitra Province, Morocco) (Figure 1).

Figure 1. Geographic distribution of sampling areas for freshwater mollusks (red dots).



Oued Sebou is the main river of the region, and it has two main tributaries, namely Beht on the left bank and Ouergha on the right bank. The annual water yield is approximately 6.6 billion m³ or approximately 27% of the national potential of usable water [7], which makes this region the most important watershed in Morocco.

3. Methodology

Between May 2012 and May 2013, 200 sites were surveyed. The aquatic habitats sampled were swamps, irrigation canals and rivers (Figure 1). The sites were selected according to their proximity to human habitations, their epidemiological history in schistosomiasis and the presence of suitable biotopes for freshwater mollusks.

4. Sampling Method

In most cases, the prospected sites were shallow (15 to 170 cm), and the sampling time was 15 min per site. The prospecting was performed according to the method described in the Guide of Control of Schistosomiasis of the Ministry of Health of the Kingdom of Morocco [8].

Species visible to the naked eye were collected by hand. This easy and inexpensive method requires no special equipment and has been used by several authors [9–11].

We also used two types of drags as follows:

1. For irrigation canals, a rectangular drag (20 × 12.5 × 170 cm) was used with a cutting frame covered with a 1 mm mesh net. The dredge was used to scrape the bottom and shoreline vegetation serving as support for freshwater mollusks. This technique has also been used by Khallaayoune and Laamrani [12] and Maqboul [5].
2. For other habitats (rivers and swamp), we used a rectangular drag with a diameter of 20 cm and a length of 170 cm. The drag was pushed through the vegetation or along the bedrock surface, and the contents were stirred carefully to detach mollusks from the vegetation. The contents were sorted in a tray using pinchers, and all specimens were kept alive in a wooden box with holes for ventilation. Collected mollusks were identified in the laboratory of Biology and Health at the Sciences Faculty of Kenitra.

5. Identification of Mollusks

Freshwater mollusks were identified according to adult shell characteristics [13] using the Guide of Control of Schistosomiasis of the Ministry of Health of the Kingdom of Morocco [8] and the key established by the Danish Bilharzia Laboratory [14].

6. Results

6.1. Species Inventory

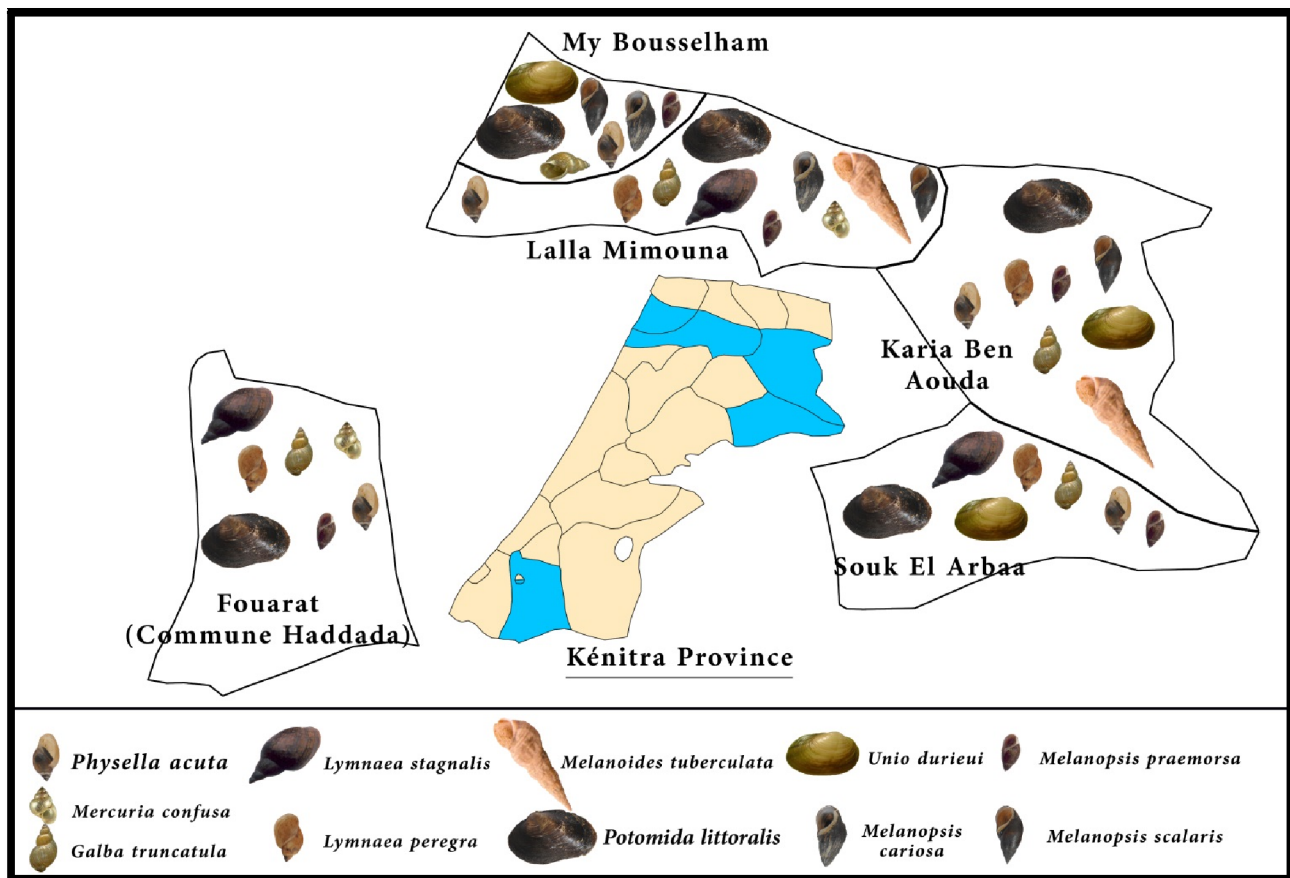
A total of 11 species, including 9 gastropods and 2 bivalves, were collected (Figure 2).

Figure 2. Freshwater mollusks in the Gharb region in Morrocco (May 2012 to May 2013).



The highest species richness was found in the Lalla Mimouna (10 species) and Kariat Ben Aouda (eight species) communes. In the remaining sites, seven species were found (Figure 3).

Figure 3. Species richness in the Gharb region (May 2012 to May 2013).



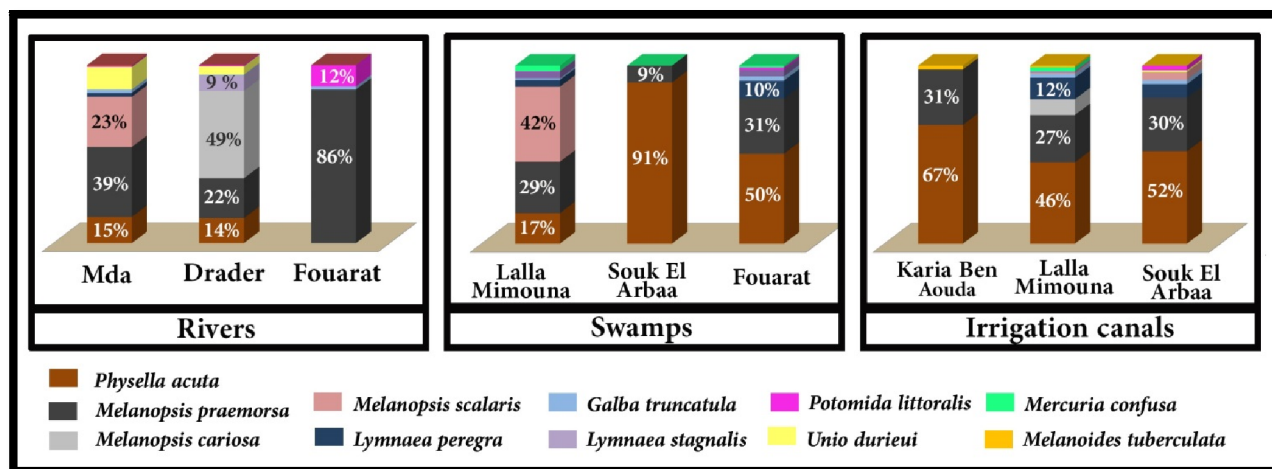
6.2. Relative Abundance

The relative abundance (Ar), expressed as a percentage, is the number of individual species (ni) (expressed in our study per unit of time) compared to the total size of the sample (N) as calculated using the following formula: $Ar = ni/N \times 100$.

The distribution of the species depended on the seasons and the prospected habitat (Figure 4). The community in the rivers was dominated by the genus *Melanopsis* as follows:

1. At Oued Mda in the commune of Karia Ben Aouda, *Melanopsis praemorsa* and *Melanopsis scalaris* were dominant with relative abundances varying between 24 and 65% for *Melanopsis praemorsa* and between 17 and 44% for *Melanopsis scalaris*;
2. At Oued Drader in the commune of Moulay Bouselham, *Melanopsis cariosa* dominated with a relative abundance varying between 29 and 62%;
3. At Oued Fouarat, two species were found, namely *Melanopsis praemorsa* (relative abundance between 57 and 96%) and *Potomida littoralis*;
4. *Physella acuta* was more abundant in the irrigation canals and swamp in Souk El Arbaa;
5. The relative abundance for the remaining species was low (<9%).

Figure 4. Relative abundance of species harvested by area prospected in the Gharb region (Morocco) from May 2012 to May 2013.



6.4. Shannon-Wiener's Index (H) and Equitability Index (e)

The Gharb region was characterized by low Shannon-Wiener's indexes (between 0.69 and 1.32) and low equitability values (0.29 to 0.55) (Table 1), which confirmed the dominance of one species. Thus, the species *Physella acuta* and *Melanopsis* sp. dominated most habitats prospected.

Table 1. Values of Shannon Index (H) and equitability index (e).

	Kariat ben Aouda	My Bouselham	Lalla Mimouna	Souk El Arbaa	Fouarat
H	1.21	1.23	1.32	0.69	0.69
e	0.50	0.51	0.55	0.29	0.32

7. Discussion

Among 40 species of freshwater mollusks known and documented in Morocco [15], a total of 11 species were recently collected in the Gharb region that do not transmit parasites to humans or livestock (except *Galba truncatula* implicated in the transmission of *Faciola hepatica*). Other studies from the same area [4–6] found different numbers of species (Table 2) as follows: Maqbool [5] listed 20 species, Fadli [4] identified 22 species and Laamrani [6] sampled 7 species (research confined to irrigation canals).

Table 2. Comparative table of the species currently present compared to those previously reported.

Species	MAQBOUL [5]	LAAMRANI [6] (irrigation canals)	FADLI [4]	Present study
<i>Acroloxus lacustris</i>	-	-	+	-
<i>Gyraulis laevis</i>	-	-	+	-
<i>Lymnaea palustris</i>	+	-	+	-
<i>Lymnaea peregra</i>	+	+	+	+
<i>Lymnaea stagnalis</i>	+	-	+	+
<i>Lymnaea truncatula</i>	+	+	+	+
<i>Margaritifera marocana</i>	+	-	+	-
<i>Melanoides tuberculata</i>	+	-	+	+
<i>Melanopsis cariosa</i>	+	+	+	+
<i>Melanopsis costata</i>	+	-	+	-
<i>Melanopsis mourebeyensis</i>	+	-	+	-
<i>Melanopsis praemorsa</i>	+	+	+	+
<i>Melanopsis scalaris</i>	+	-	+	+
<i>Mercuria confusa</i>	-	-	+	+
<i>Physella acuta</i>	+	+	+	+
<i>Pisidium casertanum</i>	+	-	+	-
<i>Planorbarius metidjensis</i>	+	-	+	-
<i>Planorbis planorbis</i>	+	-	+	-
<i>Potomida littoralis</i>	+	+	+	+
<i>Succinea debilis</i>	+	-	+	-
<i>Theodoxus maresi</i>	-	-	+	-
<i>Unio durieui</i>	+	-	+	+

In other regions of Morocco, the following species were found: Bouka collected 17 species in the central Middle Atlas [16]; Saoud collected 22 species in the Tingitane Peninsula (6 of which were bivalves) [17]; Kharboua found 20 species in the coastal plain and 16 species in the eastern region [13,18]; Moukrim [19] found 11 species in Souss; Fadli collected 20 species in Loukkos and 17 species in the plains of Tadla [4]; and Laamrani found only 9 species in irrigation canals of Tassaout (Haouz Plain) [20].

In our study, *Bulinus truncatus*, the intermediate host of schistosomiasis in Morocco, and *Planorbarius metidjensis*, considered a potential intermediate host by some authors but not confirmed by World Health Organization (WHO), were not found [21,22].

Surveys performed by the health authorities as part of malacological monitoring confirmed the absence of the intermediate host, *Bulinus truncates*, since 1985 [23]. According to interviews conducted by the health professionals involved in schistosomiasis control, *Planorbarius metidjensis* also has not been reported for several years. Nevertheless, some authors have confirmed the presence of both species in the study area [4,15].

Several species have disappeared. This impoverishment may be due to several causes as follows:

Biological causes because the biological cycle of certain mollusks is irregular with peaks of high reproduction spaced by periods of low to very low productivity. This trend was observed by Gaud [21]: In 1947, Gaud found the frequent presence of *Physella* and *Bulinus* in Algerian sites, but he could not

find *Bulinus* in 1948 even in the stations that housed the most during the previous year. These stations were reviewed systematically, and the exact same sampling points that were controlled in 1947 were explored.

Regarding *Physella* mollusks, their presence, number and distribution in the sites remained almost identical to what was found in the previous year. Gaud made the same observation in Kariat Ben Aouda (Gharb region).

Moreover, between 1947 and 1952, the same author reported an absence of *Bulinus* in Marrakech irrigation canals. Twenty years before, however, Baltazard collected more than 4000 specimens of *Bulinus truncates* in a few days and in the same area [24].

In recent years, the presence of this species has been reported by the health authorities of the Region of Marrakech in these irrigation canals [23].

Therefore, these mollusks experience large fluctuations in abundance as previously concluded by Gaud [25] and Golvan [26].

Anthropogenic causes due to the construction of large irrigation systems in the Gharb area. The increased use of water resources for human purposes has contributed to the reduction or even disappearance of marsh and Merja (swamp), which are both typical habitats of freshwater mollusks.

Unlike other irrigation systems in central and northern Morocco, the construction and operation of the large irrigation system in the Gharb area had no impact on the introduction of schistosomiasis according to Laamrani [6]. Conversely, the irrigation system may have contributed to the disappearance of the intermediate host and, therefore, the elimination of schistosomiasis in these sites.

Finally, the main stations formerly occupied with *Bulinus* (for example, the Gnafda swamp) experienced a disappearance of *Bulinus* following remediation work (filling) or after years of drought, which led to a total drying up of these sites.

Ecological causes may explain the absence of *Bulinus truncates* due to the abundance of *Melanopsis praemorsa*, which is considered a direct competitor of that species [15,27]. *Melanopsis praemorsa* was found in 98% of the prospected stations.

8. Conclusion

In the Gharb region (Morocco), which was the area of our study, the combination of climatic, biological and anthropogenic factors led to a change in the distribution and composition of freshwater mollusks.

Of the 24 species of freshwater mollusks previously found in the area by various authors, only 11 species, which are not harmful to human health or livestock (except *Galba truncatula* implicated in the transmission of *Fasciola hepatica*), were collected during this research.

Our study confirmed the absence of *Bulinus truncatus*, which is a snail intermediate host of human schistosomiasis (specifically of *Schistosoma haematobium*) previously found in the region.

Author Contributions

Hicham BARKIA, Youssef EL GUAMRI, Mohammed TAHIRI, Aziz BARKIA, Rajae YACOUBI and Driss BELGHYTI performed the malacological monitoring. Hicham BARKIA, under the supervision of Kadija El KHARRIM and Driss BELGHYTI, realized the identification of mollusks

and calculation of diversity indices. Hicham BARKIA realized the maps and image processing. All authors critically revised the manuscript for intellectual content and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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