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The freshwater malacological composition of Moulouya's watershed and Oriental Morocco

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- ✓ Oriental Morocco.

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Abstract

In this paper, we present new and interesting data on the distribution of freshwater mollusks in Oriental Morocco and the watershed of Oued "river" of Moulouya. During our repetitive campaigns in hard to reach territories visited for the first time, and a compilation of published and unpublished records, we were able to list at least 23 species belonging to 18 genera and 11 families. This work is devoted to monitoring the malacological settlement and updating the few data available about these taxa, shows new records and attempts to clarify their distribution by giving an overview of the ecology of each species.

Abbreviations codes:
SIBE : Site of Biological and Ecological Interest
C : campaign
*: first record

1. Introduction

In addition to climate change, the aquatic ecosystems of the Oriental Morocco and Moulouya's watershed suffer from a severe degradation that is becoming increasingly worrying, due to the expansion of multiple pollution sources from domestic, industrial and agricultural backgrounds [1-3]. This anthropic activity, worsened and accentuated by dry seasons, has a major impact on aquatic biodiversity, such as benthic macroinvertebrates [4-8]. Thus, the knowledge of the ecology and biogeography of these organisms is, from now on, an important concern.

The freshwater malacology of North Africa had an unprecedented privilege since 1864, under the leadership of Bourguignat [9], Morelet [10] and Pallary [11, 12], whose works were mainly based on taxonomy. Kharboua was among the first Moroccan malacologists to be interested in the freshwater mollusks, in 1988, he cataloged 20 species from the Coastal plateau. The systematic of Moroccan freshwater mollusks were revised later in 1998 by Ghamizi, who identified 82 species of the continental waters of the entire country.

Early work carried on freshwater mollusks in Oriental Morocco and the catchment area of Moulouya was done by Kharboua in 1994, he mentioned the presence of nine species: *Melanoides tuberculata* (Müller, 1774) ; *Melanopsis costellata* (Ferussac, 1823) ; *M. premorsa* (Linnaeus, 1758) ; *Belgrandia* sp. (Bourguignat, 1870) ; *Lymnaea truncatula* (Müller, 1774) ; *L. peregra* (Müller, 1774) ; *Gyraulus laevis* (Alder, 1838) ; *Planorbis metidjensis* (Forbes, 1838) ; *Bulinus truncatus* (Audouin, 1827) and probably *Margaritifera marocana* (Pallary, 1918) (under *M. margaritifera* (Linnaeus, 1758)).

Thereafter, a revision of this list was done by Berrahou *et al.* [13, 14] in a work conducted on Moulouya's main rivers, and adding five species to the list : *Mercuria similis* (Draparnaud, 1805) (under *M. confusa* Frauenfeld 1863) ; *Physella acuta* (Draparnaud, 1805) ; *Gyraulus laevis* (Alder, 1838) ; *Ancylus fluviatilis* (Müller, 1774) and *Pisidium casertanum* (Poli, 1791). Finally, the recent work of Taybi [6], whose main results are presented in this paper.

To update the data on the geographical distribution of freshwater mollusks in the watershed of the Moulouya, we visited 45 localities along its catchment area, with the large permanent watercourses: Oued Anzegmir (High Atlas), Oued Melloulou (Middle Atlas) and Oued Za (High Plateaus), visited during three sampling campaigns, complemented by 43 stations distributed in all over East Morocco, from the regions of Nador and Saidia North, Figuig southeast, Talessint and Bouanane southwest.

1.1. Target area

Morocco is currently divided into 12 administrative regions including Oriental Region (Figure 1) which occupies the entire eastern end part of the country and covers an area of 90 127 km^2. This area is bounded to the north by the Mediterranean Sea, east and south by the Morocco - Algerian border and to the west by the administrative regions Tangier-Tetouan, Al Hoceima, Fez-Meknes-Tafilalt Draa.

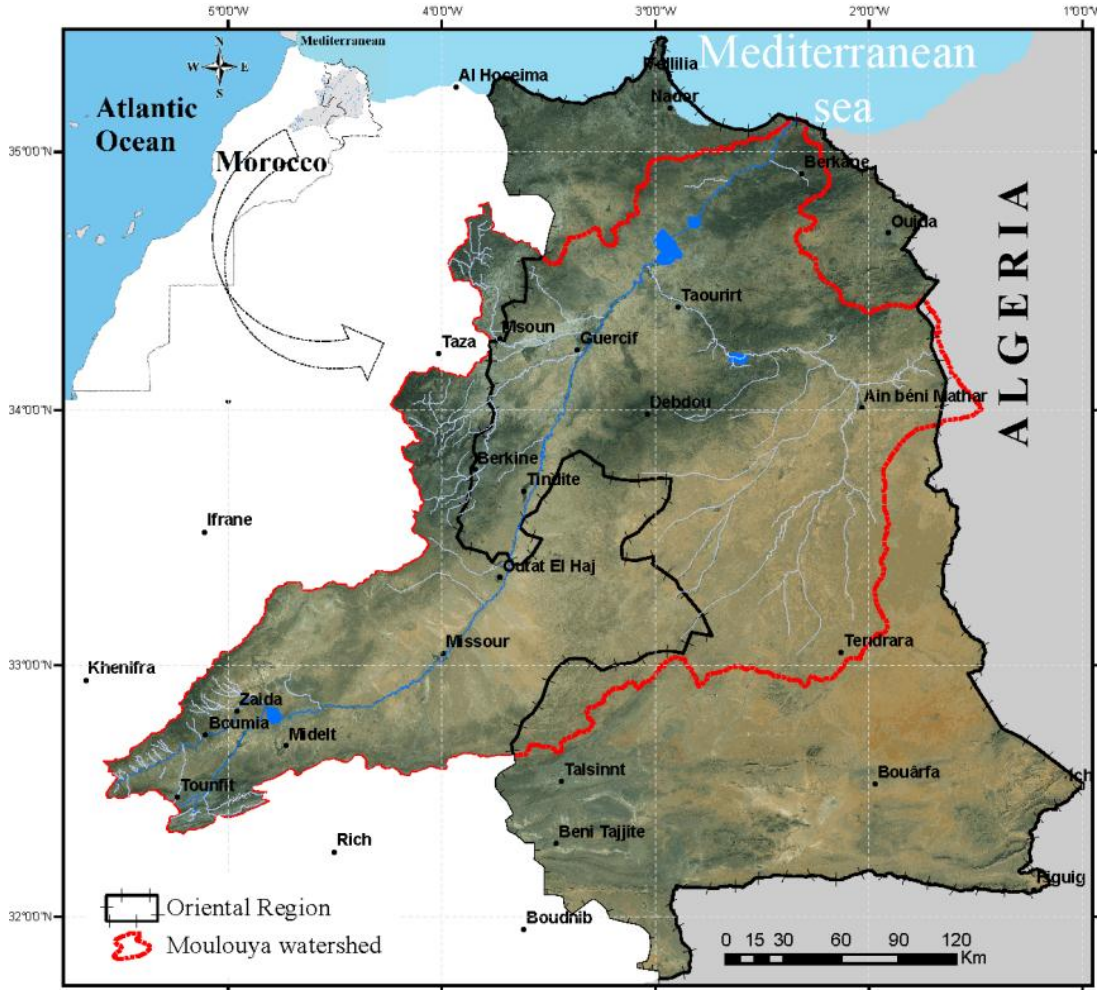

Figure 1: Location of the Eastern Morocco and the Moulouya's watershed

The Oriental region includes the wilaya of Oujda (Oujda-Angad prefecture) and the provinces of Berkane, Taourirt, Jerada, Nador, Figuig, Driouch and Guercif. The watershed of the Moulouya (Figure 1), which covers nearly 55,860 km^2 to the east of Morocco, covers much of the Oriental region. It is located between the parallels 36 and 39 degrees North and the meridians 5.5 and 7 degrees West, bordered to the northeast by the Mediterranean sea, northwest through the chain of Beni Bouyahi to the west by the mountains of eastern Rif and Middle Atlas, south by the High Atlas, its limit corresponding to Morocco- Algerian the border. With a length of 520 km, the Moulouya is the largest North African river flowing into the Mediterranean. It starts at the junction of chains of the High and Middle Atlas, its main affluents are perennial : Oued "river" Anzegmir, Oued Melloulou and Za, other tributaries flow only during the floods (3-5 floods on average per year) that can last for hours to days. The river flows through various Mediterranean bioclimatic zones, which change according to altitude and continentality.

2. Material and methods

The field surveys were conducted between 2011 and 2016, in which 45 localities were visited along the watershed of the great Moulouya, with large permanent rivers: Oued Anzegmir (side of the High Atlas) Oued Melloulou (Middle Atlas side) and Oued Za (High Plateaus) visited at least during three sampling campaigns, completed by 43 localities distributed all over Oriental Morocco, from the regions of Nador and Saidia North, Figuig southeast and finally Talessint and Bouanane southwest.

The samplings of benthic fauna, essentially qualitative, were carried out using a kick net, landing nets and clamps. The identification was done by using Motic 1100200500081 SMZ-168-BL Binocular Stereo Zoom Microscope. Meanwhile, a detailed description of the aquatic environment is made (appendices). In addition, the various impacts which the localities are subjected to, are offered in the following works [1-4, 7].

The identified species were conserved in 96 ° alcohol in labeled tubes and deposited in the collection of aquatic macroinvertebrates in Water Sciences, Environment and sustainable development Laboratory in the University of Mohammed First in Oujda and the Natural History Museum of Marrakesh. While all the maps were created using the ArcGIS software.

3. Results

Basing on our finding and previous works, a total of 23 fresh water mollusks species, belonging to 11 families and 18 different genera were listed.

Family Ancylidae

***Ancylus fluviatilis* (Müller, 1774)**

Localities : M5 : C1-C2-C3 ; M7 : C1-C2-C3 ; M8 : C1-C2-C3 ; M9 : C1-C2-C3 ; M10 : C2 ; Z5: C2-C3 ; Z6: C1 ; Z9: C1-C2-C3 ; Z10 : C1-C2-C3 ; S1: C1-C2 ; S2: C1-C2-C3 ; S3: C1-C2-C3 ; S4: C1-C2-C3 ; S5: C1-C2-C3 ; O10: 18/11/2015 ; O12: 01/02/2015 ; N10 : 5-6-7/02/2015 ; N14: 12/05/2016.

Habitat: This species is rheophilous, preferring fast-flowing rivers and streams usually on a bedrock. Also found in cold and well-oxygenized waters, even in coastal lakes with high-energy waves. This specie is sensitive to changes of the waters' chemistry and temperature.

Distribution : Western Palearctic elements, *A. fluviatilis* is widespread throughout Europe and North Africa, showing in its southeast range of its distribution some isolated populations in the mountainous areas of the Levant, the Arabian Peninsula and Ethiopia [15, 16, 17, 18, 19, 20, 21, 22, 23].

In Morocco, it was reported in the Coastal Plateau [24], the Rif [25, 26], the Haouz plain [27], the Middle Atlas [28, 29], the High Atlas [30, 31, 32] and the Anti-Atlas [26].

It is one of the most common elements of the malacological fauna of lotic waters in the Oriental Morocco [13, 14]. However, we mention its presence for the first time in the sub-catchment of Oued Melloulou, in the watershed of the Nador's lagoon with the mountains of Gourougou, the Ain Sfa spring and finally the mountainside of Jebel Mahser (Figure 2).

Family Neritidae

***Theodoxus fluviatilis* (Linnaeus, 1758)**

Localities : M19 : C1-C2-C3 ; M20: C1-C2-C3; M21: C1-C2-C3 ; M22: C1-C2-C3.

Habitat: This is a Potamo-rheophilous mollusk; it lives only in well-oxygenated running waters with high levels of calcium, on hard substrates (rocks, pebbles, ...) and very close to the surface. It can also be found sometimes in brackish water thanks to a good capacity for osmoregulation, it can tolerate a certain amount of salinity.

Distribution: The species is considered Holarctic, occurring the Nearctic and Palearctic regions. The range of this species is the largest of *Theodoxus* genera in the Palearctic [33], covering Europe from Scandinavia [34] to Greece and Crete [35, 36], and from Ireland and the Iberian Peninsula [37, 38] to the sea of the Baltic States [39]. This species is also recorded in Asia [40] and North Africa [24]. In Morocco, it was reported in the Rif [41], the Coastal Plateau [24], the High Atlas [26] and the Middle Atlas [29]. It was reported in the catchment area of Moulouya and Oriental Morocco by Kharboua [42] and Berrahou *et al.*, [13, 14]. During the study, this species was also found downstream Moulouya where it was reported 15 years ago (Figure 2).

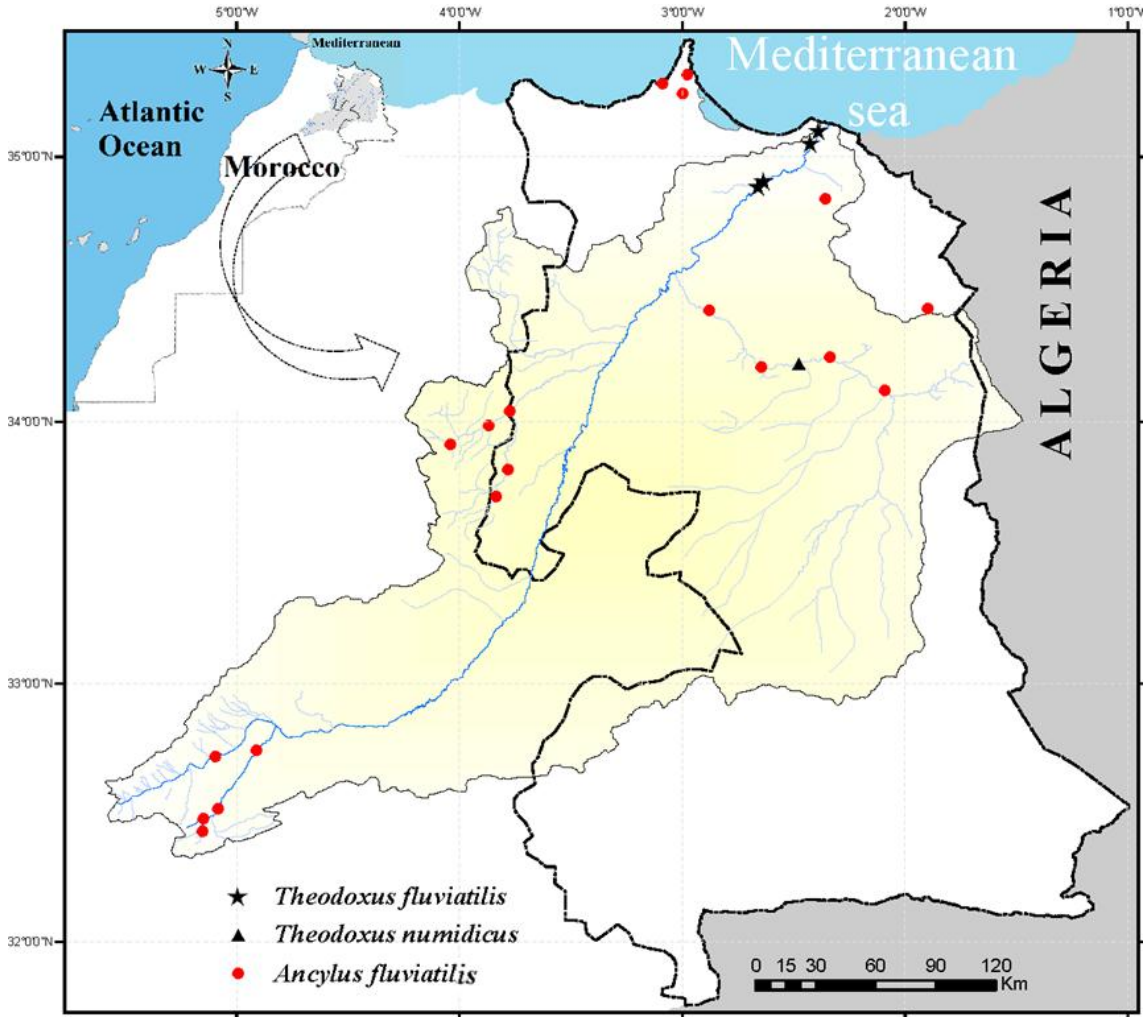

Figure 2: Distribution of *T. fluviatilis*, *T. numidicus* and *A. fluviatilis* in the study area

Theodoxus numidicus* (Récluz, 1841)

Localities: Z8: C1-C2-C3.
Habitat: This freshwater snail is particularly demanding, limited to pure cold water springs and streams. This species is very stenotopic in the studied area, found only in springs, underneath rocks.
Distribution : This is a Maghrebian endemic species restricted to Morocco and Algeria. It is rare throughout its range of distribution.
In Morocco, it was reported in the last 20 years in few localities. While its recent distribution in Algeria, is unknown and probably very localized according to the IUCN Red List of Threatened Species.
During our sampling campaign, this endangered specie was found only at Gaffait spring belonging to the Oued Za's watershed (High Plateaus) (Figure 2), where it is highly threatened because of the important anthropic action that the area knows during summer.

Family: Planorbidae

***Bulinus truncatus* (Audouin, 1827)**

Habitat : It can live in the temporary still waters, artificial ponds, ditches and slow streams. During the summer, the species sinks in the mud and resumes its activity afterwards following the water topping.
Distribution : This Afrotropicale species is widely distributed in Morocco, where it is known from the Rif and the Middle Atlas [41], the river system of Tensift [43], the Coastal Plateau [24] and finally in the waterways of the High Atlas [26, 32]. In Oriental Morocco, Kharboua reported this snail from a single locality which it is Bouanane (Figure 3). We have not been able to find this species despite our numerous visits to the region.

Anisus spirorbis* (Linnaeus, 1758)

Localities : M2 : C1-C2 ; M3 : C1-C2-C3 ; Z9 : C2-C3.
Habitat : It frequent stagnant hydrosystems or with low flow, it can also be found in the artificial water pipes, where it sinks in the mud, or moves on the stones and among the aquatic plants.
Distribution : Holo-Palearctic species, widely distributed in Europe [48], present in Western Asia [17] and North Africa. In Morocco, it was reported in the Coastal Plateau [24], the Middle Atlas [26, 29] and recently in the Rif [25]. This is the first record of this specie in Moulouya's watershed and the Oriental Morocco, found at Ait Boulemane (High Moulouya) and surrounding the dam of Oued Za (High Plateaus) (Figure 3).

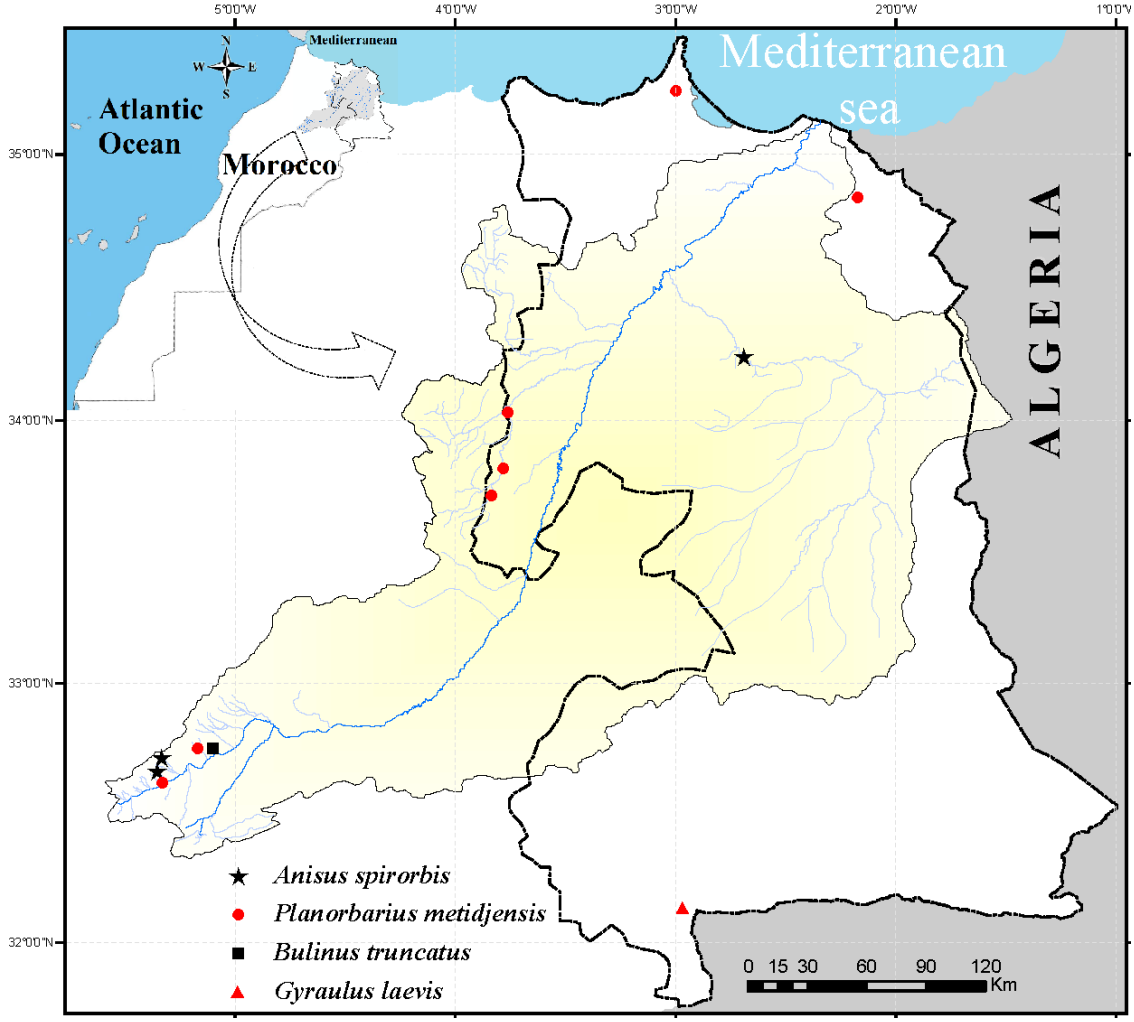

Figure 3: Distribution of *A. spirorbis, P. metidjensis, B. truncatus and G. laevis* in the study area.

***Planorbarius metidjensis* (Forbes, 1838)**

Localities : M1 : C2-C3 ; M4 : C1-C2 ; S4: C2-C3 ; S5: C3; S6: C3 ; O14: 6/06/2016 ; N12 : 12/05/2016.
Habitat : This species may be found in natural or artificial lentic environments, such as permanent or semi-temporary streams and irrigation systems, where it enters in the mud, between the rocks or among aquatic plants and different substrate.
Distribution : The species is located in the western part of the Mediterranean area, south of the Iberian Peninsula and northwest of Africa, between Morocco, Algeria, southern Portugal and southwestern Spain [17]. It is widely distributed in Morocco where it was reported in the High Atlas [31, 43], the Haouz plain [27], the Coastal Plateau [24, 26, 44, 45, 46] and finally the Rif [25]. In the Moulouya's Watershed and Oriental Morocco, it has been reported at Ain Sfa spring by Kharboua [42] and in the mountains of Beni Snassen by Ait El Abed [47]. This is the first time this species is reported from the Eastern Middle Atlas (High Moulouya and sub-catchment of Oued Melloulou) and the mountain of Gourougou (Figure 3).

Gyraulus laevis **(Alder, 1838)**

Habitat : The species seems to develop in still waters or with low current, where it sinks in the mud or between algae and aquatic plants, it rarely frequents temporary water bodies.
Distribution : Holarctic species, occupying the North Caucasus, North Africa, Europe, Middle East, North Asia and North America [48]. In Morocco, it was reported for the first time from the Coastal Plateau [24], later in the High Atlas [32], the Middle Atlas [29] and recently in the Rif [49]. In the Moulouya's watershed, it was reported in 2001 by Berrahou et *al.* at the Arhbalou spring (Figure 3). Since then, the species has completely disappeared despite our several campaigns to the site, probably because of the strong anthropic action that knows this source [3, 6, 7].

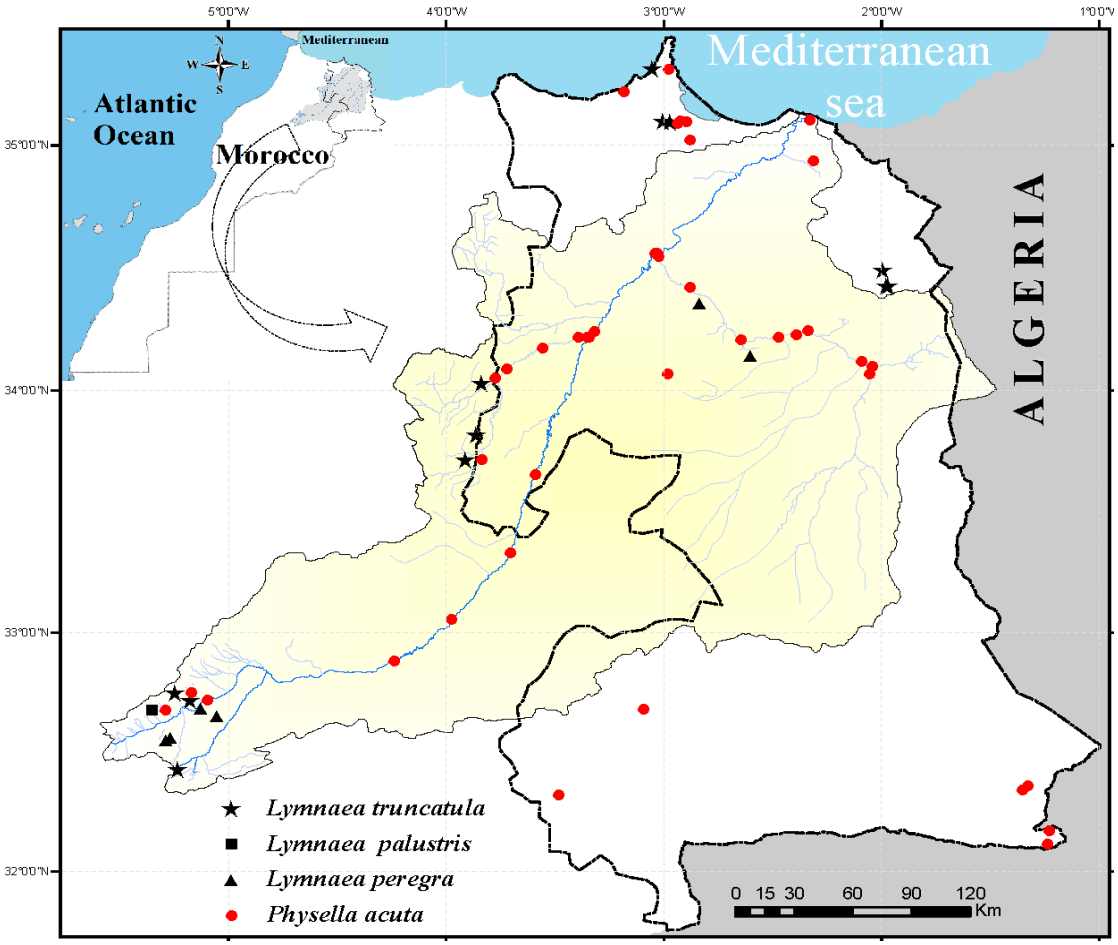

Figure 4: Distribution of *L. truncatula, L. palustris, L. peregra and P. acuta* in the study area

Family: Lymnaeidae

Lymnaea peregra **(Müller, 1774)**

Localities : M1 : C1-C2-C3 ; M2 : C1-C2-C3 ; M4 : C1-C2-C3 ; M5 : C1-C2 ; Z9 : C1-C2-C3 ; Z10 : C1-C3.
Habitat : This species is common in lakes or streams with very low current. It lives in lentic environments with detritus deposits; it can tolerate a certain degree of organic pollution.
Distribution : It is widely distributed in the Palearctic, where it occupies Europe, northern Asia and North Africa [17]. In Morocco, it was reported from the High Atlas [30- 32], the Middle Atlas [29], the Rif [25, 26] and finally from the Rharb region and the Coastal Plateau [24, 44-46]. This taxa was previously reported in the Moulouya's watershed [13, 14, 42]. However, this is the first time *L. peregra* is found in the catchment area of Oued Za (Figure 4).

Lymnaea palustris **(Müller, 1774)***

Localities: M2 : C2.
Habitat : The species lives in swamps, ditches, low current streams, slightly acidic and extremely rich by the aquatic vegetation.

Distribution : Palearctic species, distributed through Europe [50, 51] and North Africa [52]. In Morocco, it was reported in the Gharb region and the Coastal Plateau [24, 26, 44, 45], finally in the Rif [41]. *L. palustris* is new to the watershed of the Moulouya. During the sampling period, it was found only at Ait Boulemane (Figure 4), belonging to the High Moulouya.

***Lymnaea (Galba) truncatula* (Müller, 1774)**

Localities : M4 : C2-C3 ; M5 : C3 ; M7 : C2-C3; S4: C2-C3 ; S5: C3 ; S6: C3 ; O9 ; 19/09/2015 ; O10: 18/11/2015 ; O11: 18/11/2015 ; N14: 12/05/2016; N16 : 28/09/2016 ; N17 : 29/09/2016.
Habitat : It frequent the standing waters or hydrosystems with a very low flow, often among the algae and macrophytes, it can also colonize the artificial pipes and semi-temporary pools.
Distribution : Holarctic species, occupying the Tropical and Southern Africa [17]. In Morocco, it was mentioned in the High Atlas [30-32], the Middle Atlas [29], the Haouz plain [27], the Rif [25], finally in the Gharb region and the Coastal Plateau [24, 26, 45, 46]. In the Eastern Morocco and Moulouya's watershed, it has been reported only at Sidi Yahia and Ain Sfa springs [42]. Our study broadens its distribution area, in fact, we report it and for the first time in the High Moulouya, Oued Anzegmir, Oued Melloulou, the mountainous slopes of Jebel Mahser and finally in catchment area of Mar Chica's lagoon (Figure 4).

Family: Physidae
***Physella acuta* (Draparnaud, 1805) (= *Physa acuta sensu auct.*)**

Localities : M3 : C1-C2-C3; M4 : C1-C2-C3; M5 : C1-C2-C3; M11 : C3; M12 : C3; M13 : C3; M14 : C3 ; M15 : C3; M16 : C3; M17 : C3; M18 : C3; Z3: C1-C2-C3; Z4: C1-C2-C3 ; Z5: C1-C2-C3 ; Z6: C2-C3 ; Z7: C1-C2-C3 ; Z8: C1-C2-C3 ; Z9: C1-C2-C3 ; Z10 : C1-C2-C3 ; Z12 : C1-C2-C3 ; S4: C1-C2-C3 ; S7: C3; S8: C3 ; S9 : C3 ; S10: C3 ; S11: C3 ; O2: 27/04/2016 ; O8: 22/02/2016 ; O18: 27/07/2016 ; N1: 30/04/2016 ; N13: 12/05/2016 ; N14: 12/05/2016 ; N15 : 05/04/2014 ; N16 : 28/09/2016 ; N17 : 29/09/2016 ; F2 : 21/05/2016 ; F3: 21/05/2016 ; F4: 22/05/2016 ; F5: 22/05/2016 ; F7: 21/01/2016 ; F8: 19/01/2015.
Habitat : It can live in all kinds of environments, although it lives preferentially among the aquatic vegetation. It tolerates high levels of salinity, temperature and organic material. During the summer, it invaded the aquatic ecosystems of the Moulouya, where it was sampled especially from small ponds next to the watercourses.
Distribution : It was once thought that the native distribution of *P. acuta* is Mediterranean [53]. However, when *P. heterostropha* was considered as synonymous, then the native distribution of the species became North American [54]. The species appears to have a first spread in the Mediterranean areas and then more slowly in Northern Europe [54, 55]. Its distribution also includes Africa, Asia and Australia [56] and widely distributed in North Africa [9, 57].

In Morocco it is reported in the High Atlas [30-32], the Middle Atlas [29], the Central Plateau [24, 45, 46], the Haouz plain [27] and finally the Rif [25]. It is the most distributed malacological element in the catchment area of the Moulouya and Oriental Morocco [6, 13, 14]. However, this is the first record of this species from the watershed of Oued Melloulou, the Nador's lagoon, and finally the regions of Figuig and Talessint (Figure 4).

Family: Hydrobiidae
***Mercuria similis* (Draparnaud, 1805) (=*confusa* Frauenfeld, *sensu* Boeters, 1971)**

Localities : M4 : C3.
Habitat : Obvious crenophilous species, usually found in springs and streams. Its distribution is limited by its stenothermal condition. Thus, it preferentially occupies hypogenous habitats where the temperature does not fluctuate too much.
Distribution : The genus *Mercuria* has a Mediterranean distribution, and *M. similis* is a Mediterranean species predominantly western. In Europe, it is present mainly in France, Italy and Malta [58], while in North Africa, it occupies all the Maghreb [27, 52, 59].

The taxa classified in the new genus *Mercuria* described by Boeters (1971), has been reported in southern Morocco [60], in the Coastal Plateau [24], the High Atlas [31, 32], the Middle Atlas mountains [29], the Haouz plain [27], the Rharb region [45], the Rif and finally the Anti-Atlas [26]. We have found *M. similis* in the catchment area of the Moulouya at Boumia from where it was reported by Berrahou *et al.* in 2001 (Figure 5).

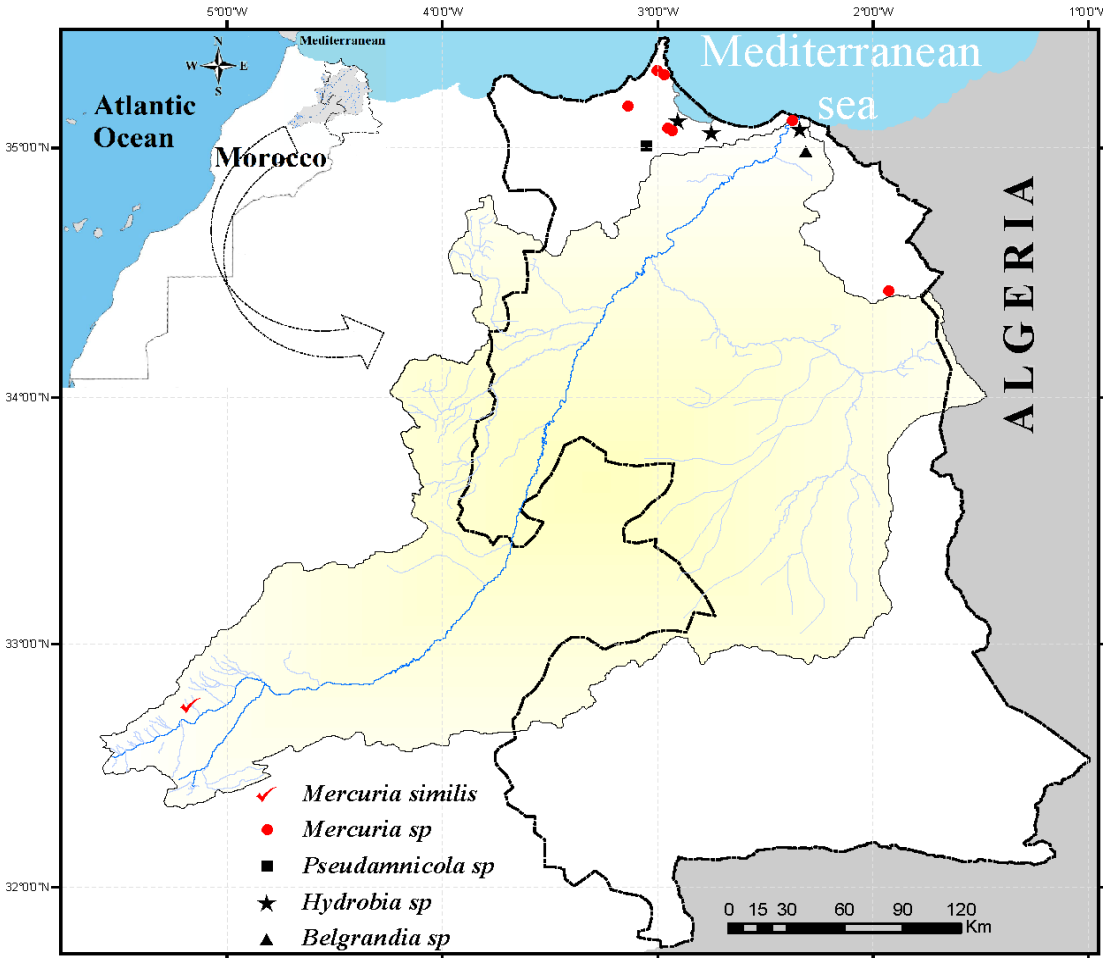

Figure 5: Distribution of *M. similis*, *Mercuria* sp, *Pseudamnicola* sp, *Hydrobia* sp and *Belgrandia* sp in the study area

***Mercuria* sp.**

Localities : O5: 28/04/2016 ; O10 : 18/11/2015 ; N5: 30/04/2016 ; N6: 2/05/2016 ; N9 : 18/05/2015 ; N12 : 12/05/2016 ; N14: 12/05/2016.

Habitat : Due to the wide diversity and the physicochemical conditions of its habitat, we believe that this taxa is represented by many species. It has been sampled from natural and artificial watercourses of low altitudes waters, sometimes highly charged with organic matter; high altitude springs and finally from slightly brackish ponds alongside of the Mediterranean coast.

Distribution : Because of the genetic complexity and the cryptic status of its kind in Morocco, we preferred to keep the identification of this taxa to the generic rank, waiting for further studies. Indeed the genus has been sampled in the catchment area of the Nador's lagoon, the SIBE of Moulouya and the massif mountain of Jebel Himer from where we report it for the first time (Figure 5).

***Belgrandia* sp.**

Habitat : The species of these genera can be cavernicolous and karstic, colonizing the sub-compartment of the aquatic ecosystems, sinking in the underlying substrate, or in pure water sources with dense aquatic plants and fallen leaves.

Distribution : The range of this genus covers North Africa and the Mediterranean region of Europe: the Iberian Peninsula, France, Italy, Croatia and Greece [24, 42, 64]. The first record of *Belgrandia* in Morocco was made by Kharboua in 1988, who found significant populations in the Coastal Plateau's ponds. The same author had reported its presence in the Oriental Morocco for the first time in 1994, at the Tetelella's spring belonging to Berkane Province (Figure 5). Since then the species has not been found, probably due to the destruction of its habitats.

Pseudamnicola* sp.

Localities : N4: 30/04/2016.
Habitat : The specimens were sampled in coastal river systems, forming part of the catchment area of Nador's lagoon, characterized by high bank vegetation, low current and shallow depth with a soft substrate.
Distribution : The genus *Pseudamnicola* has a circum-Mediterranean distribution and it is widely distributed in North Africa, with at least 10 species can be found in the Maghreb (Morocco, Algeria and Tunisia) [27, 59, 61]. However in Morocco this genera needs to be revised. This taxa is new to the Oriental Morocco, from where we allow its first record in the Nador region (Figure 5).

Hydrobia* sp.

Localities : O7: 21/02/2016 ; N2: 01/05/2016 ; N8: 02/05/2016.
Habitat : In the studied area, this species prefer stagnant and slightly brackish water systems near the Mediterranean coast, such as ponds and backwaters.
Distribution : The *Hydrobia* genus is widely distributed in the Palearctic region. In Morocco, it was recorded in the lagoon of Smir [62], the Bou Regreg estuary [63] and finally in the Rif [25, 26]. However, like all Moroccan Hydrobiids, the *Hydrobia* genus requires a revision. This is a new element for the Oriental Morocco, from where we reported it for the first time in the region of Nador (Figure 5).

Family Melanopsidae

***Melanopsis premorsa* (Linnaeus, 1758)**

Localities : Z6: C1-C2-C3 ; Z7: C1-C2-C3; Z8: C1-C2-C3 ; Z9: C1-C2-C3 ; Z10 : C1-C2-C3 ; Z12 : C1-C2-C3; O3: 28/04/2016, ; O4: 28/04/2016 ; O13: 01/02/2015 ; N3: 2/05/2016 ; N4: 30/04/2016 ; N6: 2/05/2016 ; N9 : 18/05/2015 ; N10 : 5-6-7/02/2015 ; N14: 12/05/2016 ; F4: 22/05/2016.
Habitat : In Morocco, it colonizes all kind of freshwaters, sometimes it forms dense colonies in irrigation ditches, it usually live on solid substrate, able to resist the drought by sinking in the mud.
Distribution : This is a species with a circum-Mediterranean distribution, between southern Europe, North Africa and Minor Asia. In Morocco it is reported in the High Atlas [31, 32], the Middle Atlas [29, 43], the Haouz plain [27], the Rharb region [44-46], the Coastal Plateau [24] and recently from the Rif [25]. This species was previously reported in the watershed of Moulouya and Eastern Morocco [13, 14, 42], where it is one of the most common elements of the malacological fauna. During the sampling, it was detected in all stations as part of its range, in addition to the Nador region and the catchment area of Mar Chica's lagoon, where it was found for the first time (Figure 6).

***Melanopsis costellata* Ferussac, 1823**

Localities : M19 : C1-C2-C3 ; M20 : C1-C2-C3 ; M21 : C1-C2-C3 ; M22 : C1-C2-C3 ; Z5: C1-C2-C3 ; Z6: C1-C2-C3 ; Z7: C1-C2-C3 ; Z8: C1-C2-C3 ; Z9: C1-C2-C3 ; Z10 : C1-C2-C3 ; Z11 : C1 ; Z12 : C1-C2-C3 ; O15 : 30/04/2016 ; N1: 30/04/2016 ; N4: 30/04/2016.
Habitat : It can be found in average freshwater courses with low water levels and stony bottom, or on the margins of major rivers and streams, usually in the stagnant sections. It can resist the temporal desiccation and usually shows amphibian habits.
Distribution : This is an endemic Ibero-Maghrebian species, its range covers North Africa (Morocco, Algeria and Tunisia) and Spain, where it is recorded from several provinces in Andalusia [65].
In Morocco, it was recorded in the Middle Atlas [29] and recently in the Rif [49]. In the Oriental Morocco, it has been reported in the Lower Moulouya [13, 14], Figuig and Ain Sfa regions [42], in addition to these areas, we note its presence for the first time in the watersheds of Nador's lagoon, Oued Zeghzel-Cherraa and Oued Za (Figure 6), where it coexists with *M. premorsa*.

***Melanoides tuberculata* (Müller, 1774)**

Habitat : This species colonizes small streams, springs, irrigation channels or partially stagnant waters.
Distribution : Subtropical species, occupying the most part of Africa, the Arabian Peninsula, Mesopotamia, Malta, India, Thailand, Iran and Madagascar. In Morocco, it was recorded probably for the first time in the High Atlas [41]. The presence of this element in the Oriental Morocco was reported in 1994 by Kharboua, who

harvested it in the irrigation canals of Figuig (Figure 6). Since then it has completely disappeared, probably by the destruction of its habitat and the high pressure that undergoes this species by collectors and hobbyists.

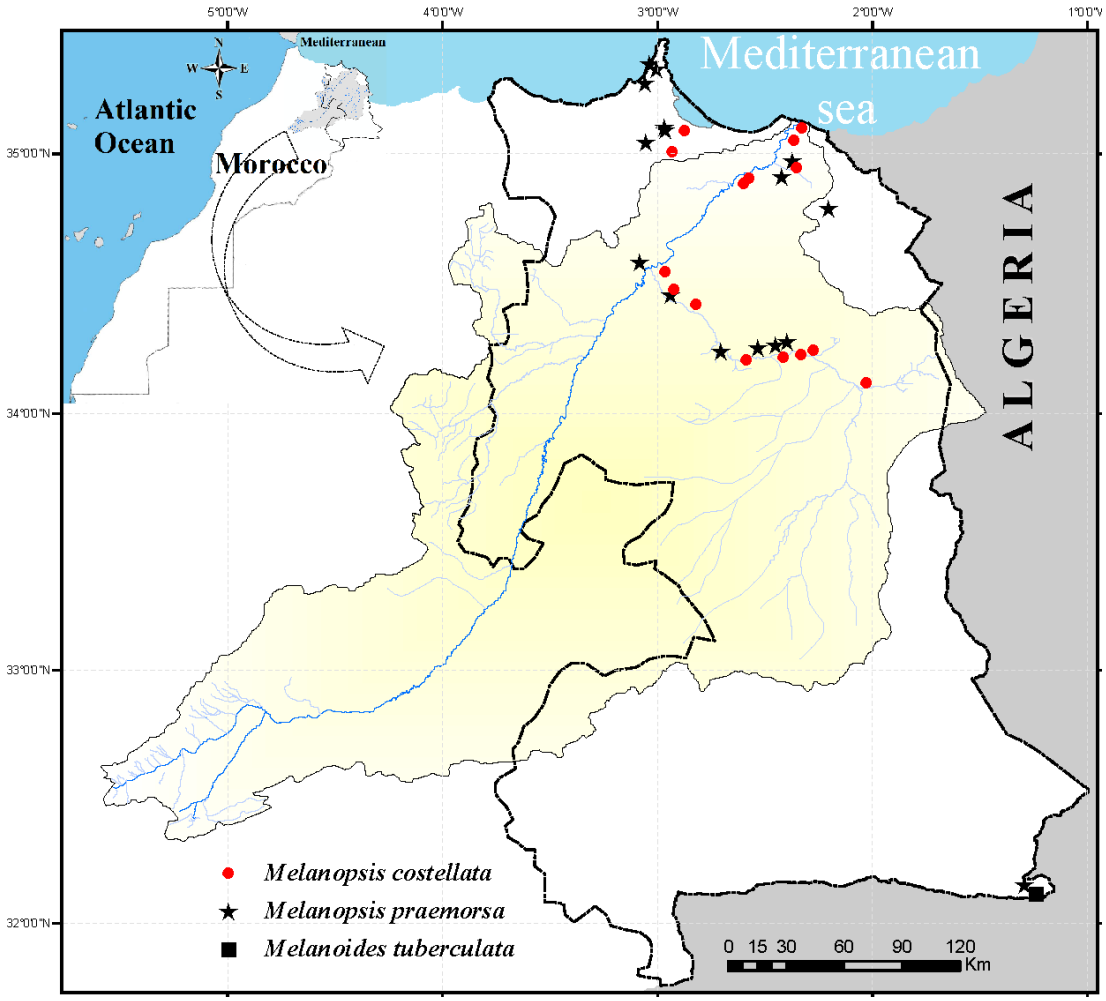

Figure 6: Distribution of *M. costellata*, *M. praemorsa* and *M. tuberculata* in the studied area

Family Unionidae

Unio foucauldianus* (Pallary, 1936)

Localities : M19 : C1-C2-C3 ; M20 : C1-C2-C3 ; M21 : C1-C2-C3 ; M22 : C1-C2-C3.
Habitat : because of its trophic status, this species occupies the potamal sections of the Moulouya's watershed, where flow rates remain high all year round, with a good oxygenation of the water.
Distribution : Maghrebian species, its distribution area in Morocco, includes all the major basins of the Atlantic [66, 67, 68]. Indeed, all the old records of *Unio delphinus* Spengler, 1793 in Morocco are assigned to *U. foucauldianus* [69]. This is the first record of the species in the studied area, where it is located in the large sections of the potamal (Figure 7).

Family Margaritiferidae

***Margaritifera marocana* (Pallary, 1918) (?)**

Habitat : This highly endangered species lives in large rivers, moderately deep with clean oligotrophic waters, fresh in summer and rich by oxygen.
Distribution : Previously considered as a subspecies of *M. auricularia* (Spengler 1793); *M. marocana* was rediscovered in Morocco after being admitted as extinct and became an endemic Moroccan full species [70]. It was reported in the Coastal Plateau [24], the Gharb region [44, 45] and finally in Oued Abid where it is certainty known [70].

In the Watershed of Moulouya and Eastern Morocco, it has been reported in the SIBE (Figure 7) by Kharboua in 1994 and Berrahou *et al.* in 2001 under *M. margaritifera*. Despite the several attempts, our efforts have not led to its capture for the moment.

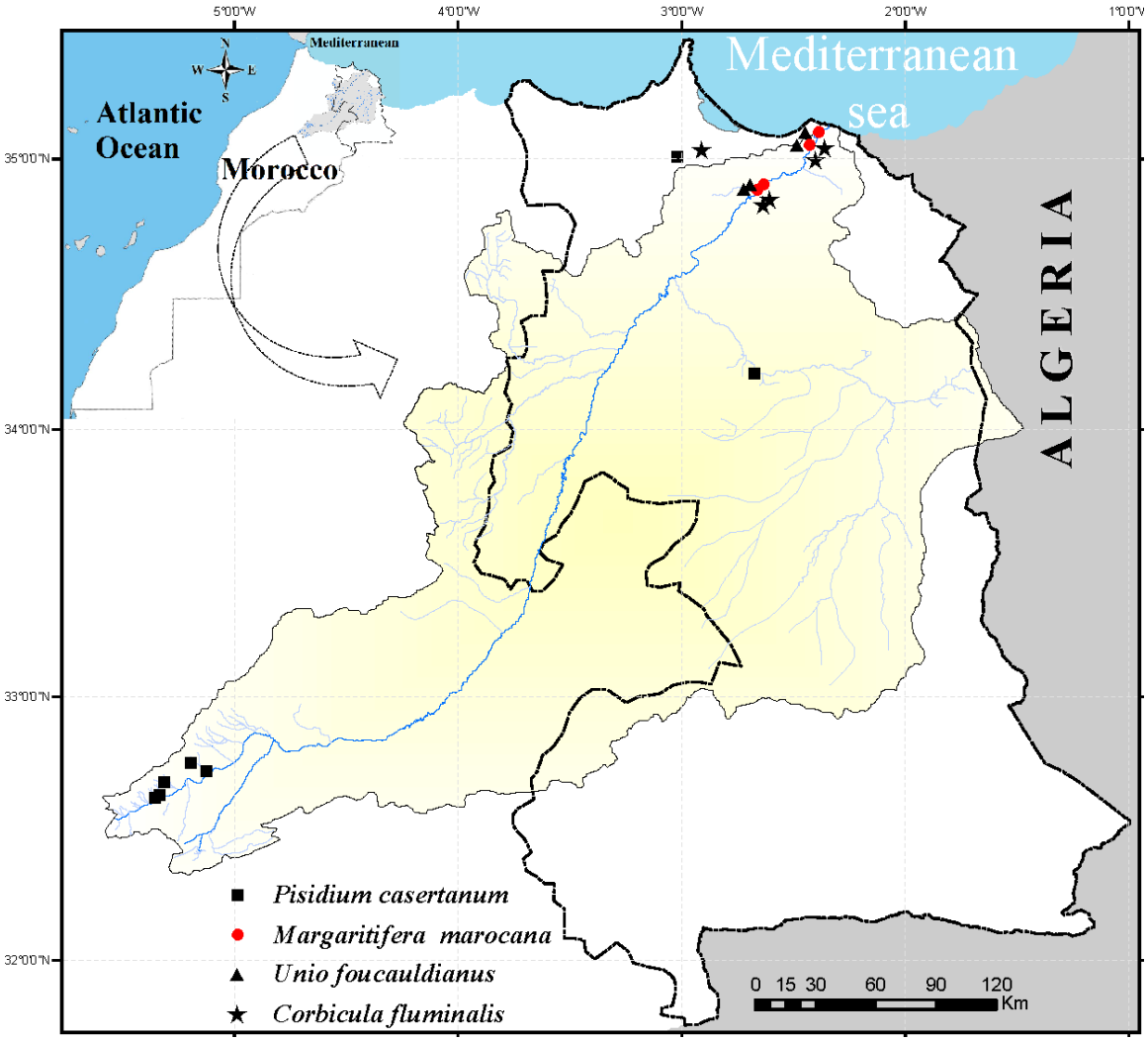

Figure 7: Distribution of *P. casertanum, M. marocana, U. foucauldianus and C. fluminalis* in the study area

Family Sphaeriidae

***Pisidium casertanum* (Poli, 1791)**

Localities: M1: C1-C2-C3 ; M2 : C1-C2-C3 ; M3 : C2 ; M4 : C2 ; M5 : C1 ; N4: 30/04/2016 ; Z9: C2-C3.
Habitat : It lives deep in the mud, fine sediments and organic matter, it can also be found in the sand and between the roots of aquatic vegetation. Despite preferring lentic waters, *P. casertanum* can also live in turbulent waters.
Distribution : Cosmopolitan species. *P. casertanum* is worldwide distributed and one of the most common species of its kind in Europe [71, 72]. In Morocco it is known in the High Atlas [30, 32], the Middle Atlas [29], the Haouz plain [27], the Gharb region [44, 45], the Coastal Plateau [24] and the Rif [25]. Previously it was reported in the watershed of the Moulouya and Oriental Morocco [13, 14]. After all, we report it for the first time in the watersheds of Oued Za and the lagoon of Nador (Figure 7).

Family Corbiculidae

Corbicula fluminalis* (O.F. Müller, 1774)

Localities: M19 : C1-C2-C3 ; M20 : C1-C2-C3 ; M21 : C1-C2-C3 ; M22 : C1-C2-C3 ; N1: 30/04/2016.
Habitat : This bivalva can be found burrowing in various freshwaters (or slightly brackish) sediments: silt, sand, clay, gravel. It can tolerate a wide range of temperature and an important atmospheric exposure.

Distribution : This invasive species is now worldwide distributed. As well, it is present in Asia [18, 73, 74], Africa [75-77], America [78, 79] and Europe [80-83]. This is first record of this taxa in the Oriental Morocco and the watershed of the Moulouya. Indeed, during the sampling period, it was collected from the potamal areas. In addition, it was detected in large canalization transporting water from the Moulouya's river to Nador region (Figure 7).

The chorological categories of freshwater molluscs in the Oriental Morocco and Moulouya's watershed.

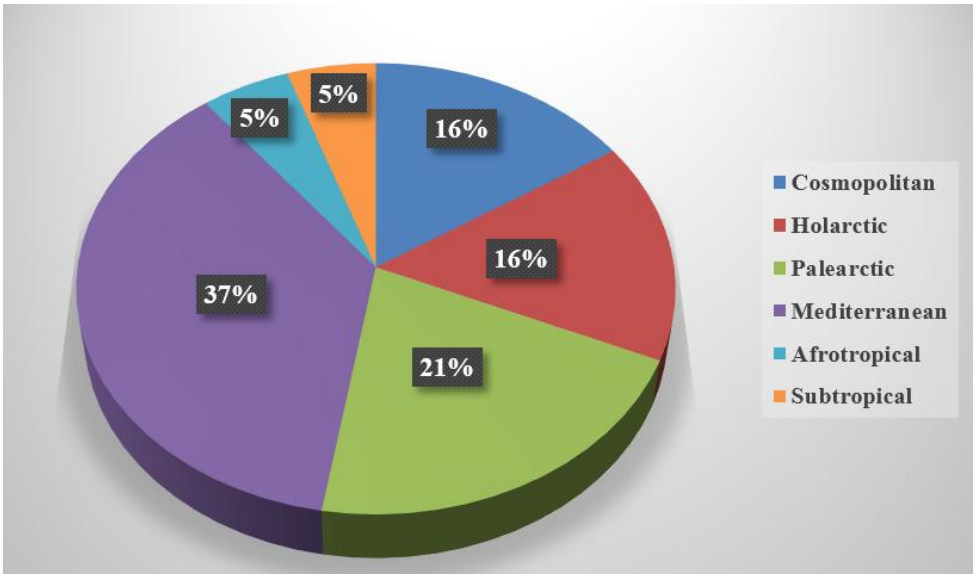

Figure 8: The relative importance of major chorological categories of freshwater mollusks in the Oriental Morocco and Moulouya's watershed.

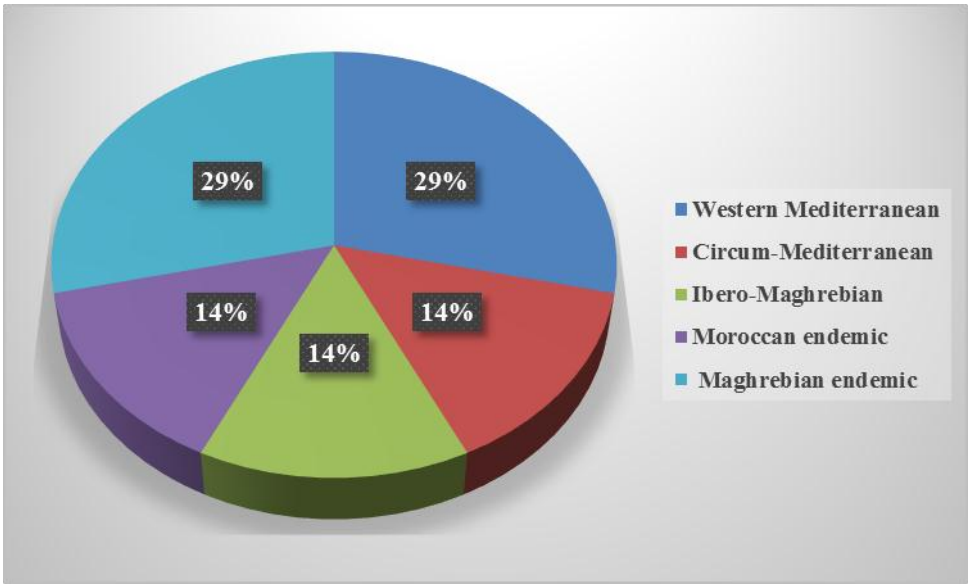

Figure 9: The relative importance of the chorological categories of Mediterranean freshwater mollusks fond in Eastern Morocco and Moulouya's watershed.

Discussion and conclusion

The freshwater malacological fauna of the Moulouya's watershed and Oriental Morocco rises to 23 species. The analysis of this settlement composition shows that it essentially consist of Mediterranean species by 37% (Figure 8), the element with a wide distribution in the Palearctic area are coming in the second place with 21%, followed by the Holarctic and Cosmopolitans taxa (16% each). Species, which the distribution extends either in the Afrotropical or Subtropical region, constitute a minority (10% together). Within the Mediterranean elements of freshwater mollusks in the studied area (Figure 9), there has a clear predominance of the Maghrebian and Moroccan endemic corotype (43% together).

The malacofauna settlement of Eastern Morocco and Moulouya's catchment area, shows therefore a clear dominance the Palearctic elements typically Mediterranean with the high rate of endemism. Our findings confirm those of Giudicelli *et al.* [28], Bouzidi [32] and Mabrouki *et al.* [4, 5], who believe that the communities of the Mediterranean regions are characterized by low species diversity compared to those of central and continental Europe while presenting a high rate of endemism.

It is important to note that some species of mollusks mentioned early in the Oriental region have not been found and probably have disappeared; same remark is done for other macroinvertebrates [4, 5, 8]. Indeed, the reduction of permanent water bodies, notably with the drying up of several rivers between 80s-90s, including Oued Isly, Oued Touissit, spring of Sidi Yahya, caused the disappearance of wildlife that characterized these environments, many species have greatly reduced their regional distribution.

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Appendix –The prospected stations with indications of the locality, altitude, geographic coordinates and type of the aquatic environment.

Code	Stations	GPS	Alt (m)	Sampling dates	Kind of habitat
M1	Ait Boulmane	32°36'56.6" N 5°19'49.2" W	1650	03/05/14-13/06/14-14/07/14	RV
M2	Ait Oha Ohaki	32°37'28.7" N 5°18'32.8" W	1640	03/05/14-13/06/14-14/07/14	RV
M3	Source Arbalou	32°40'33.4" N 5°17'20" W	1670	03/05/14-13/06/14-14/07/14	RV
M4	Krouchene=Irhdis	32°44'49.6" N 5°10'17.1" W	1616	03/05/14-13/06/14-14/07/14	RV
M5	Boumia	32°43'3.4" N 5°5'52.7" W	1515	02/05/14-14/06/14-15/07/14	RV
M6	Zaïda	32°49'3" N 4°57'33" W	1455	02/05/14-14/06/14-15/07/14	RV
M7	Anzar Oufounas	32°25'45" N 5°9'24.8" W	1895	02/05/14-14/06/14-15/07/14	NS
M8	Aval Anzar Oufounas	32°28'41.66" N 5°8'53.42"W	1780	02/05/14-14/06/14-15/07/14	RV
M9	Anzegmir avant barrage	32°31'4.1" N 5°5'3.2" W	1702	02/05/14-14/06/14-15/07/14	RV
M10	Aval Anzegmir	32°44'32" N 4°54'51" W	1455	02/05/14-14/06/14-15/07/14	RV
M11	Tamdafelt	32°52'43.86" N 4°14'16.4"W	985	02/03/14-14/06/14-15/07/14	RV
M12	Missour	33°3'7.96" N 3°58'41.7" W	870	02/05/14-14/06/14-15/07/14	RV
M13	Outat Al Haj	33°19'46.8" N 3°42'14.2" W	770	02/05/14-14/06/14-15/07/14	RV
M14	Tindint	33°39'11" N 3°35'20.6" W	640	02/05/14-14/06/14-15/07/14	RV
M15	Moulouya Amont Melloulou	34°12'59.3" N 3°21'6.8" W	362	23/03/14-24/05/14-07/07/14	RV
M16	Moulouya Aval Melloulou	34°14'29.86" N 3°19'13.4"W	355	23/03/14-24/05/14-07/07/14	RV
M17	Moulouya Amont Za	34°33'36.3" N 3°2'33.4" W	230	23/03/14-24/05/14-07/07/14	RV
M18	Moulouya aval Za	34°33'41.09" N 3°1'49.77"W	222	03/04/14-24/05/14-22/06/14	RV
M19	Sebra	34°53'11" N 2°39'45" W	60	03/04/14-24/05/14-22/06/14	RV
M20	Safsaf	34°54'27.53" N 2°38'8.86"W	50	08/03/14-18/05/14-23/06/14	RV
M21	Pont Hassan II	35°3'5.7" N 2°25'42.4" W	9	18/03/14-18/05/14-23/06/14	RV
M22	Pré-Estuaire	35°5'51.4" N 2°23'19" W	3	18/03/14-18/05/14-23/06/14	RV
S1	Sources O El Bared	33°54'40.2" N 4°2'40.7" W	931	27/03/14-01/06/14-11/07/14	RV+NS
S2	Amont O El Bared	33°58'59.01" N 3°52'15.8"W	630	23/03/14-08/06/14-07/08/14	RV
S3	Douar Ifrane	34°2'20.8" N 3°46'34.1" W	570	23/03/14-08/06/14-07/08/14	RV
S4	Sources Berkine	33°42'43.25" N 3°50'5.83"W	1150	22/03/14-14/06/14-07/08/14	RV+NS
S5	Amont Berkine	33°48'58.2" N 3°47'7.4" W	970	27/03/14-15/06/14-15/08/14	RV
S6	Pont O. Zebzit, Berkine	34°1'36.6" N 3°45'38.6" W	565	23/03/14-08/06/14-15/08/14	RV
S7	Confluence Zebzit Oued El Bared	34°3'02.25" N 3°46'34.1" W	565	23/03/14-08/06/14-15/08/14	RV
S8	Douar Imzaghrou	34°5'15.75" N 3°43'14.7" W	525	23/03/14-08/06/14-15/08/14	RV
S9	Pont Taddarte	34°10'21.4" N 3°33'25.4" W	445	23/03/14-08/06/14-15/08/14	RV
S10	Entrée Guercif	34°12'53.5" N 3°23'34.1" W	377	23/03/14-08/06/14-15/08/14	RV
S11	Aval Melloulou	34°13'1.15" N 3°20'40.4" W	363	23/03/14-15/06/14-15/08/14	RV
Z1	Oued Charef	33°58'53.5" N 2°5'7.5" W	925	19/03/14-17/05/14- 07/08/14	RV+NS
Z2	Pond sur l'O Charef	33°59'33.1" N 2°4'11" W	918	19/03/14-17/05/14-07/08/14	RV
Z3	Petite cascade	34°3'56.8" N 2°3'20.2" W	900	19/03/14-17/05/14-07/08/14	RV
Z4	Oued Lakhrouf	34°5'54.8" N 2°2'38.1" W	897	19/03/14-17/05/14-07/08/14	RV
Z5	Grandes cascades	34°7'5.7" N 2°5'26.8" W	875	19/03/14-17/05/14-07/08/14	RV
Z6	Amont pont Gafait	34°14'31.61"N2°20'11.98"W	785	19/03/14-17/05/14-07/08/14	RV
Z7	Pont de Gafait	34°13'36.8" N 2°23'34.5" W	767	19/03/14-17/05/14-07/08/14	RV
Z8	Gafait	34°14'21.6" N 2°24'34.8" W	750	19/03/14-17/05/14-07/08/14	RV+AS
Z9	Barrage Oued Za	34°12'23.1" N 2°38'52.3" W	625	19/03/14-17/05/14-07/08/14	RV+DM
Z10	Amont Taourirt	34°25'15.6" N 2°52'52.9" W	370	07/06/14-19/07/14-19/07/14	RV
Z11	Aval de Taourirt	34°28'44.51" N 2°59'10.3"W	295	03/04/14-07/06/14-19/07/14	RV
Z12	Melg el Ouidane	34°32'46.51" N 3°1'31.1" W	240	03/04/14-07/06/14-19/07/14	RV
O1	Debdou	33°57'32.64"N 3°2'26.9"W	1344	27/04/16	AS
O2	Mare pas loin de Debdou	34°3'51.4"N 2°58'54.1"W	880	27/04/16	PD
O3	Source Tiffert,	N35°2'16.8" 2°25'36.0"W	83	28/04/16	NS
O4	(Béni znassen) en aval de Zeghzel	34°53'08.3"N 2°20'34.1"W	268	28/04/16	RV
O5	Ain chabbak	N35°6'18.7" 2°20'45.0"W	2	28/04/16	PD
O6	Bassin Oujda	34°39'03.5"N 1°53'59.2"W	627	07/11/15 - 26/02/16 - 23/04/16	AP
O7	SIBE Saïdia	35°07'09.8"N 2°20'15.3"W	0	21/02/16	PD
O8	Canal de Saïdia	35°05'59.0"N 2°19'42.1"W	9	22/02/16	AC
O9	Jbel Mehser	34°29'24.1"N 1°54'57.6"W	1268	19/09/15	AS
O10	Source Himer	34°25'32,5"N 1°53'54"W	1030	18/11/15	NS
O11	Amont Himer	34.2530,2 N 1.5331,1 W	1019	18/11/15	RV
O12	Source Zeghzel	34°50'20.3"N 2°21'21.6"W	442	01/02/15	AS
O13	Ain Sfa	34°45'12.3"N 2°08'36.0"W	652	01/02/2015	AS
O14	Ain Almou	34°50'15.2"N 2°10'22.5"W	1200	06/06/2016	AS
O15	Cherraa	34°56'43.6"N 2°24'48.5"W	80	06/06/2016	PD
O16	Carrière abandonnée	34°34'50.8"N 1°56'13.9"W	719	17/07/2016	AQ
O17	Source Aghbal	34°55'14.0"N 2°06'52.5"W	307	27/07/16	AS
O18	Canal Berkane	34°56'06.8"N 2°18'41.1"W	154	27/07/16	AC
N1	Saguia Selouane	35°05'14.3"N 2°56'03.8"W	84	30/04/16	AC
N2	Kariat Arkmane	35°06'16.5"N 2°44'55.1"W	19	01/05/16	AC
N3	Dardoura	35°03'11.0"N 2°54'18.9"W	134	02/05/16	RV

N4	Oued Ouzej	35°00'21.8"N 2°59'30.8"W	168	30/04/16	RV
N5	Oued Selouane	35°04'36.7"N 2°55'29.1"W	52	30/04/16	RV
N6	O Messoussate	35°03'48.6"N 2°54'23.0"W	68	02/05/16	RV
N7	Marchica (1)	35°10'47.2"N 2°55'19.3"W	5	22/05/15	PD
N8	Marchica (2)	35°09'19.9"N 2°54'24.3"W	3	02/05/16	LG
N9	Rio de Oro	35°17'14.9"N 2°56'37.7"W	12	18/05/15	RV
N10	Mont Gourougou	35°13'55.2"N 2°59'57.1"W	542	05/02/15-06/02/15-07/02/15	RV
N11	Oued Tifassour	N35°16'21.0" 3°5'14.4"W	17	12/05/16	RV
N12	Oued Oumassine	N35°9'50.0" 3°6'36.0"W	79	12/05/16	RV
N13	Oued Kert	N35°12'48.9" 3°11'1.4" W	6	12/05/16	RV
N14	Oued Mariouari	35°18'21.6"N 2°58'38.9"W	85	12/05/16	RV
N15	Barrage Arabat	35°01'03.9"N 2°52'36"W	102	05/04/14	DM
N16	Canal Bouareg	35°05'37.1"N 2°53'36.3"W	26	28/09/16	AC
N17	Canal Granja	35°05'47.2"N 2°55'29.4"W	40	29/09/16	AC
F1	Raknat Naam	32°27'11.3"N 1°41'18.7"W	1168	21/05/16	DM
F2	Barrage Zriga	32°21'29.5"N 1°19'36.4"W	1026	21/05/16	DM
F3	Barrage Sfissef	32°20'23.9"N 1°21'04.6"W	1005	21/05/16	DM
F4	Seguia de Figuig	32°06'47.3"N 1°14'08.8"W	902	22/05/16	AC
F5	O Abbou Lekhal	32°10'05.3"N 1°13'42.4"W	868	22/05/16	RV
F6	Dayat Lahjal	32°29'29.9"N 1°39'47.6"W	1161	22/05/16	PD
F7	Oued Anwal	32°40'46.60"N 3°5'39.74"W	1194	21/01/16	RV
F8	Oued Aït Aïssa	32°19'N 03°29'W	1121	01/19/16	RV

Abbreviations. M: station at the Moulouya Wadi; S: station at Melloulou river; Z: station at ZA river; DM: Dam; AQ: abandoned quarry; AC: artificial channel; AP: artificial pond ; RV: river; LG: Lagoon; PD: pond; AS: arranged source ; NS: natural source.

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