



Composition and structure of the malaco fauna of sources Ain Regarg, Sidi bouali and Tataw middle Atlas (Morocco)

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Article published on August 31, 2015

Key words: Malacofauna, Diversity, Sources, Middle atlas.

Abstract

An approach to the diversity of malacofauna associated with sources of Middle Atlas is carried out at three stations in the Fez-Boulemane region (Morocco) between January 2013 and December 2013. The selection of stations was based on their mapping, lithology, the physicochemical nature of their waters and on their proximity to human settlements. Six mollusc species were inventoried in this Malacological survey. Are Melanops is *Praemorsa*, *Theodoxus numidica*, *Theodoxus numidica* (Zebra), *Horatiasp*, *Pisidium personatum* and *Pisidium casertanum*. The descriptive analysis of the population of shellfish revealed a similarity between the biocenotic habitats Regrag Ain and Sidi Bouali. Biotic and abiotic factors in the distribution of snails are the calcium concentration, temperature, water and human activity that has clearly affected the malacofauna diversity of sources of the Middle Atlas.

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Introduction

Despite advances in current knowledge on the taxonomy, morphology and biology of the gastropods, aspects of anatomy, life cycle, reproduction, dispersal strategies, behavior and genetics of many species are still poorly known.

The Maghrebian malacofauna appears to have possessed its typical features since at least the late Miocene (about 6 to 7 million years ago) or even earlier during the Oligocene-Miocene the northern part of Maghreb and the southern part of the Iberian Peninsula. Formed the Rifobetic Cordillera surrounding the Alboransea: hence they belonged to the same biogeographic region: 1) An Endemic Maghre-bian distribution e.g the genus *Eideella*, 2) An Ibero-Mghreben distribution e.g the genus *Horatia*, 3) A wetern Mediterranean or Alboran distribution e.g the genus *Mercuria*, 4) A circum mediterranean distribution e.g, the genus *Pseudamnicola* (Damme, 1984).

Species-complex mentioned also do show these distribution patterns compared to other parts of the Mediterranean region, the degree of endemicy is uncommonly high in the Maghreb, which made (Damme.1984) suggest the freshwater mollusks in the Maghrebian Province should be distinguished biogeographically. It should be considered as an ancientons, persisting and diversifying for at least 6 million years (Helle, 1993).

The Moroccan freshwater system is the most extensive, within the Maghrebianregion, where a diversified molluscan fauna appears to live in the aquifer (Mazlanm and *et al.*1994) In addition to the historical records, during the last decade an abundance of new species has been discovered in this country (Ghamizi. 1998).

Some species of them are considered as an intermediate host of some parasitic diseases of humans and livestock such as schistosomiasis (responsible for the Bilharziasis), fascioliasis, paramphistomosis and its intermediate snail hosts.

The fact remains that these species remain the poor relations of environmental policies, mainly because they are poorly known. This overall disregard for several reasons: few charismatic species, observation difficulty (either because of their size, either because of their living environment); conflict taxonomy; difficulty of determining the field.

With the increasing need for knowledge bases on natural heritage, Checklists, have become an essential tool of communication between taxonomists and species names of users (naturalistic data managers, managers of natural areas, ecologists, geneticists, museum curators, teachers and legislators). And in this context that our research work fits.

Thus, to admit that there is not a comprehensive inventory of the benthic malacofauna with colonizing wetlands and particularly the sources of fresh water. Yet in a perspective of sustainable development and the need for establishment of a bio-monitoring program, it is essential to bring this kind of information. We look at this in the descriptive study of the mollusk population in the three important springs of Middle Atlas which are none other than Ain Regrag (AR), Sidi Bouali (SB) and Tataw (T) of the Imouzer Marmoucha.

The main aims of our study have been to determine the abundance and composition of gasteropodes and to determine what environmental variables influence the occurrence of individual species in these springs. Considering the population studied, we used some classic ecological descriptors in order to characterize and compare the description, distribution, functional structure and organization of population mollusk. These descriptors parameters are species richness, species diversity index, equitability index, relative abundance, frequency, degree of preference and similarity.

Materials and methods

The study area

Spring Tatawof the Imouzer Marmoucha (T)

Located in the eastern part of the Middle northern Atlas, and edged in the East by the valley of medium Moulouya, Immouzermarmoucha 1713m of altitude, at the end of the Middle Atlas, on the side of Taza (degree of latitude: 33°28' 37 N, degree of longitude: 4°17' 44 W).

The region is characterized by the outcrop of lime stones and of dolomites of the Jurassic allowing the storage of underground water, where from flow the emergences of Tataw. Waters of the source mother (debit 430 l/s) are clear; its substrate of gravels to a great extent and of blocks by places, vegetation is composed of rushes, reeds and phanérogammes. Floods are frequent in autumn and in winter, linked to the torrential rains which pass by the region (Nechad and *et al.* 2014)¹ (Fig. 1).

Spring Regrag (AR)

Located in quarantine kilometres in the south of Fès. Ain Regrag is part of the hydro geological unit of the middle Atlas Limestone plateau. The ground-water sheet which occupies a surface of 1500 km². Regional climate is of Mediterranean type characterised by the alternation of hot and dry season and cold and humid season.

The main value of this exurgence domiciles in its feature, permanent running water in strong debit 305 l/s. Ain Regrag, is not a righteous man a resource in water jealously preserved by populations bordering the street throughout its history, it is also a true seaside station thanks to its lake and its banks glide covered by a short vegetation (lawn) which makes a particular type of source of fresh water of North African mountain (Nechad and *et al.* 2014)² (Fig.1).

Spring Sidi Bouali (SB)

located in the middle of olive fields. Sidi Bouali corresponds to a resurgence) situated in 18 km in the city of Sefrou, sources mother and its resurgences are completely natural, following the example of (AR), the source of Sidi Bouali is located within touches liasiques thanks to its spiritual value, and until last years the source was not ransacked by anthropogenous activities, the neighbouring population tried rather to preserve it (Nechad and *et al.* 2014)¹ (Fig. 1).

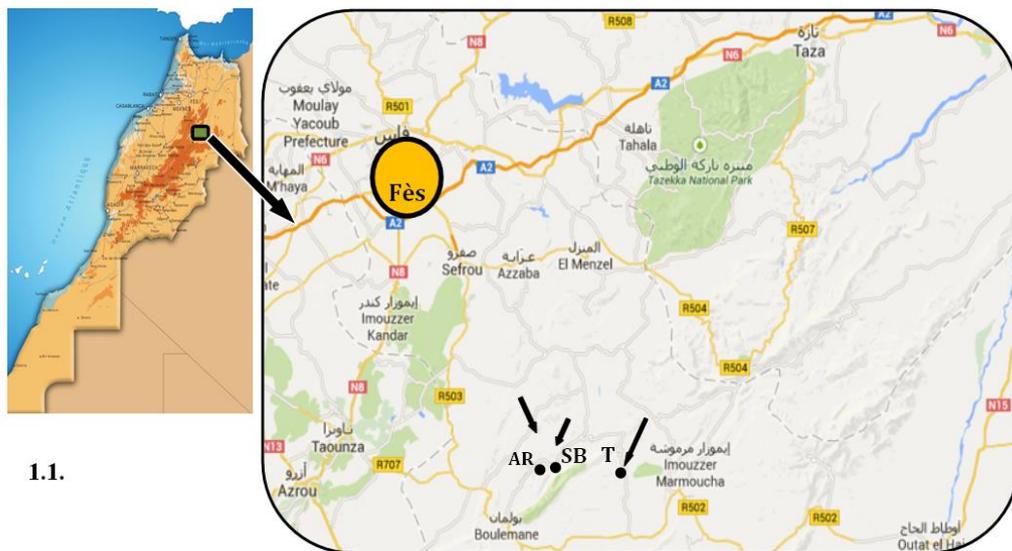


Fig. 1. Geographical location sources regrab, Ain Sidi Bouali and Tataw.

Sampling methods

A monthly sampling of benthique fauna is performed every 4 weeks a year, is a total of 12 months of sampling, allowing to cover an annual cycle. The first sampling was performed on January 1st, 2013. All macro invertebrates, are harvested, determined in type and counted, but bioecological study of populations is more specifically centered on molluscs the most predominant class in terms of density and of biomass.

The harvest is made with the aid of a net Surber of a diameter of stitch 500 µm. The Surber sampler consists of two interlocking frames that support a capturing net. The clamps and flexible knives for removing the accolade malacofauna to the stone surface without damaging the shell.

Snails were collected were collected by hand, from the substratum or aquatic vegetation, dead leaves and stones, or collected by sieving mud and vegetation.

The material was fixed in 70% ethanol broken specimens was not included into the matrix of measures At the same time as these biological study, the samples of water intended for physicochemical analyses have of the study in the same places of sampling was facts during the year to have precisely the evolution of these parametres in time local and to control their synchronism with the ecology of the malacofauna.

Sampling and measurement of physico-chemical parameters

A monthly samplin of the samples of water is performed every 4 weeks a year, it is a total of 12 months of sampling, between January, 2013 and December, 2013. According to recommendations of the WHO, every month in bottles in polyethylene, a volume of 1,5 litres intended for physicochemical analyses, from main resurgence is taken. They were then kept in 4°C during the transport in the laboratory, then analyzed in 24 hours that follow. The methods of analyses those are recommended by norms (AFNOR. 1997; Rodier.1996). The measures of the temperature, the pH, and electrical conductivity were taken on the ground with the aid of an analyser multiparametres pH/conductivity temperature Cyber Scan PC10. Used methods are: the volumetriy for the dissolved oxygen, bicarbonates, chlorides, the calcium and the magnesium and the spectrophotometer of molecular absorption for sulphates and orthophosphates.

Expression of results

Index of species diversity

The index the most used is the Shannon-Wiener expressed by the following formula. It is the quantity of information brought by a sample on structures of the population is from which the sample and on the way comes the individuals are divided into various kinds (DAGET. 1976):

$$H' = -\sum (ni / N) \cdot \text{Log}_2 (ni / N)$$

H' : Specific diversity.

N : Sum of the numbers of species

ni : Size of the population of the species

The index of species diversity is high when the taxonomic richness is important and the distribution of individuals among taxa is balanced.

Index of species Equitability

Knowledge of species diversity index is used to determine equitability; the equitability is a second fundamental dimension of diversity (Ramade and *et al.* 1984).

According to (Dajoz. 1971), that is the distribution of the number of individuals per species. It is the ratio between the maximum diversity (H max), it is expressed as following:

$$E = H' / H_{max} \quad H_{max} = \text{Log}_2 (S)$$

S : Is the number of species forming the stand.

It varies between 0 and 1, goes to 0 as almost all the staff focused on a species; it is 1 when all species have the same abundance.

Relative abundance

Relative abundance of a species is the percentage of the number of this species relative to the total number of individuals collected from a station. It is expressed by the following formula:

$$P_i = \frac{Ab(a)}{Ab(t)} \cdot 100$$

Ab (a): total number of individuals of a species, Ab(t): total number of individuals.

Frequency

The frequency of a species represents the percentage of samples where the species are present relative to the total number of samples. It is given by the following formula:

$$F_i = \frac{Pa}{Pt} \cdot 100$$

Pa: number of samples where the species "a" is harvested

Pt: total number of samples.

- Basic species: $P_i > 10\%$ and $F_i > 50\%$
- Constant species: $P_i < 10\%$ and $F_i > 50\%$
- Companion species: $20 < F_i < 50\%$
- Catch species: $5 < F_i < 20\%$
- Sporadic species: $F_i < 5\%$.

Results and discussion

Habitat

Fig. 2 provides an overview of the evolution of some physicochemical parameters of the waters of three stations during the study year. For several variables the influence of seasonality is very clear recorded temperatures oscillate around 11.4°C (T), 18°C (AR) and 17°C (SB), the lowest value mark the winter period. Therefore, the three sources classify the cold spring, according to the classification of Schoeller (Schoeller. 1962). The hydrogen potential is slightly neutral to alkaline a well as well in times of rain in dry period, its average levels 8.04 for (T), are 7.08 to (AR) and 7.20 for (SB), ions Ca²⁺ record of 148(mg/l) averages. 146,68 (mg/l) and 100,91(mg/l) for SB; AR and T. The waters of the two sources AR and SB are so heavily loaded in on Ca²⁺. We believe that this was linked to the extent of the karst reservoir which Gush resurgences.

Indeed, the results show a distribution in two groups of statements

A summer surveys group and another group of winter surveys and the physicochemical characteristics are opposed, the first is characterized by high alkalinity and Calcium values, while only second is marked by high dissolved oxygen concentrations. For the value of pH and temperature influence of the factor “season” is not notable. Registers a slight degradation of the water quality during the summer season, being, the lithology of area which is mainly limestone seems to be at the origin of the high Ca²⁺ levels.

The quality of the waters have shown that magnesium concentrations much lower than those of the calcium, recorded averages respectively are 19,76 (mg/l), 39,53 (mg/l) and 40,57 (mg/l). The highest concentrations are marked during the dry season. The results agree with those obtained by (ABHS. 2013) when the waters the springs samples taken in the month of October 2012. The temporal profiles of dissolved oxygen have revealed that the contents of this parameter are higher during the wet period. Indeed, all the registered maxima mark the cold season, at the level of the station, they are 5,6 (mg/l) at (SB), 7,52 (mg/l) in (T) and 7,2 at source (AR) in November. This would be mainly due to the decrease in the temperature of the water, because cold water contains much more dissolved oxygen than warm water (Hébert. 2000). At the same, it should be noted that (AR) station is subservient by important vegetal cover of macrophytes and algae which explains the wide availability of oxygen dissolved compared to (SB) and (T). Overall, the dissolved oxygen in the area is far from deficit. and PO₄³⁻ of water sources AR, SB, and T (January 2013/December 2013).

Diversity of molluscan species harvested

The bioecological study of the malacological fauna benthic in study area allowed to inventory six species in 12 samples during the sampling period of the month from January 2013 to December 2013 is represented in Table1.

Table 1. Species diversity malacological harvested in the three stations to study.

	Ain Regrag	Sidi Bouali	Tataw	Total
<i>Melanopsis praemorsa</i>	2442	1474	1	3916
<i>Theodixus numidica</i>	365	305	0	670
<i>Theodoxux numidica (zebra)</i>	387	4	0	391
<i>Horatia sp.</i>	112	288	0	400
<i>Pisidium personatum</i>	2	0	12	14
<i>Pisidium casertanum</i>	0	0	2	2
Total of species	3308	2071	15	5393

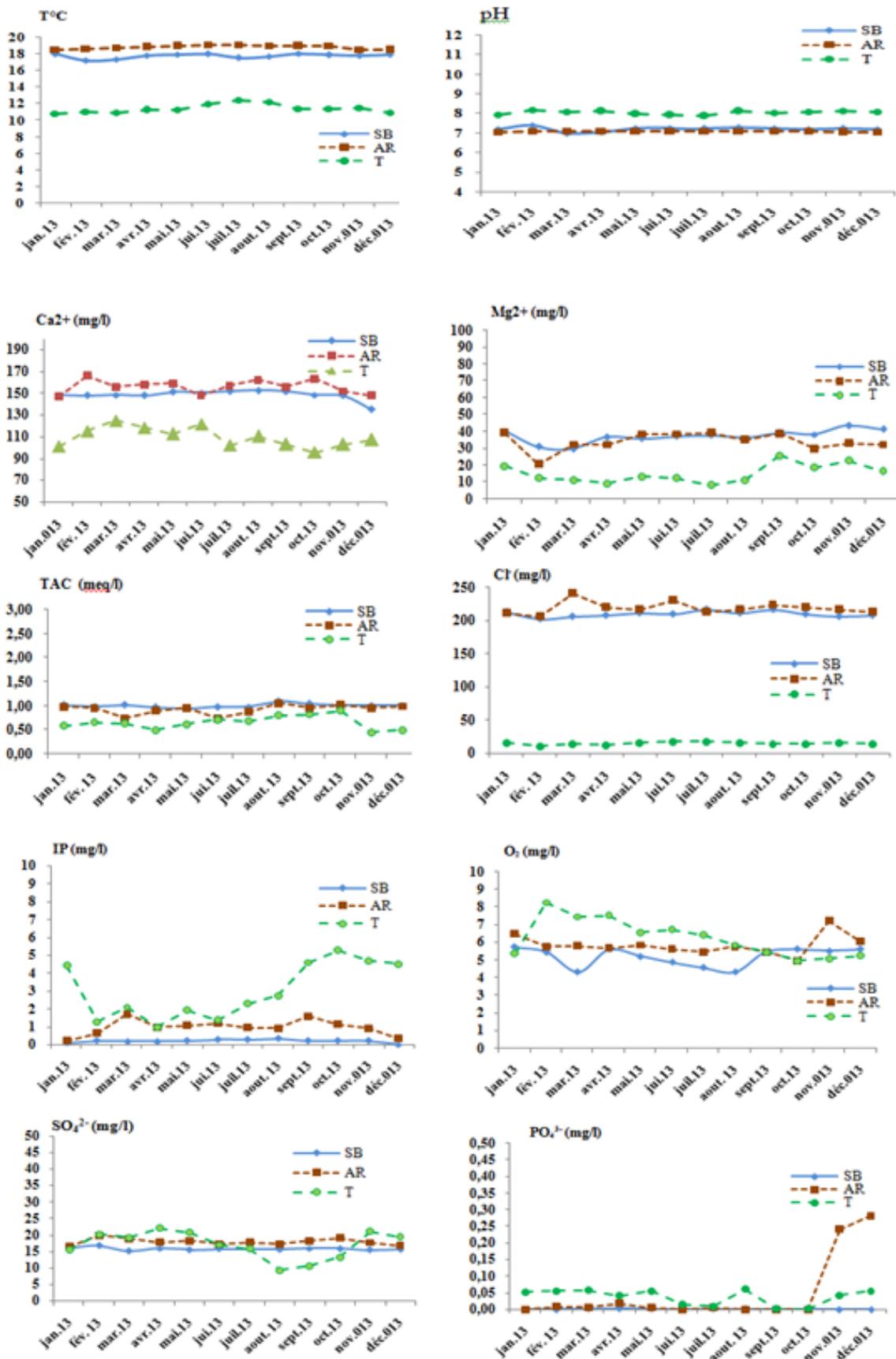


Fig. 2. Spatio temporal variation of the chemical parameters T°C, pH, Ca²⁺; Mg²⁺, TAC, Cl, IP, O₂, SO₄²⁻

1. *Melanopsis praemorsa*: The shell is fusiform. The spire consist of 5 to 6 rounds separated by deep sutures. Apex is acute. The final round is developed, it occupies between 70 and 75% of the total shell. The opening is oval sized 4,3x 3,2 mm, about half the height of the shell. The peristome is continuous, labial edge arched and sharp.

2. *Theodoxus numidica*: The shell in this genus is semioval. The columella and inner whorls are dissolved. Species in the genus *Theodoxus* are highly variable in size, in color pattern of the periostracum, in details of the operculum and in the radula, and all these factors can make identification to species level very challenging. *Theodoxus* needs rough surfaces in order to be able to digest its food, so a stony substrate is necessary. Green algae are not consumed; *Theodoxus* has no cellulases.

3. *Theodoxus numidica* (Zebra): for this specimen we can decide if it is a separate species or that it is only the zebra shape the *doxusnumidca* study is underway

4. *Horatia* sp.: The shell is small, discoid almost flattened valvatiforme formed 2,5 to 3 convex spiral turns, fast winding, each turn overlaps the preceding one resulting in a large navel and below convex appearance of the shell above. The last lap is the most developed, especially at the end giving a flared elliptical opening, We would like to point out that it would be probably a new specimen and these are the results of molecular identification in progress which will confirm this saying.

5. *Pisidium personatum*: The 2.5-3.5mm. Shell is a characteristic round-regular oval shape. It has centrally placed low, rounded umbos. The surface (periostracum) is dull or silky with very fine irregular concentric striations.

6. *Pisidium casertanum*: Belongs to Sphaeriidae. They are easily recognized by conchological characteristics. Shell rounded and inflated, in rivers oblique and solid. Animal whitish or greish, slightly transparent, foot not very long, siphonsubconical (www.animalbase.uni-goettingen.de/zooweb/servlet/AnimalBase/list/references/new).

Monthly changes in wealth gastropods in the 3 stations

The results for the monthly importance of gastropods are given in Figs 3, 4 and 5.

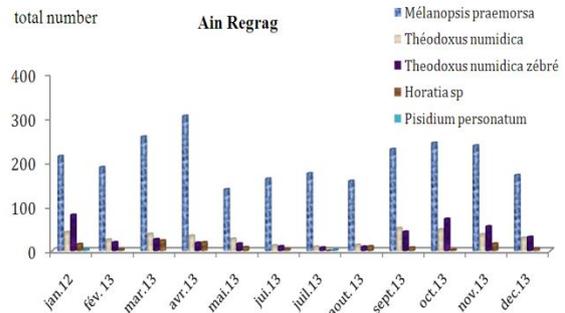


Fig. 3. Temporal evolution of total number of gastropods identified in the source Ain Regrag.

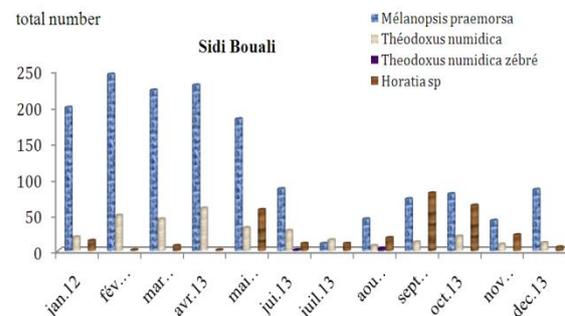


Fig. 4. Temporal evolution of total number of gastropods identified in the source Sidi Bouali.

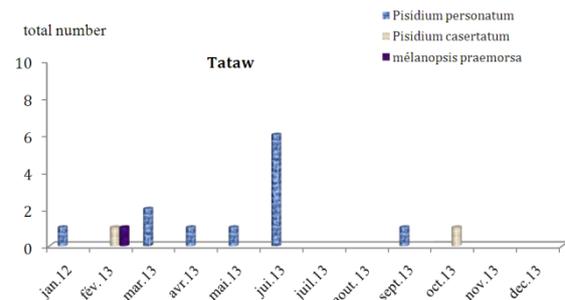


Fig. 5. Temporal evolution of total number of gastropods identified in the source Tataw.

It is clear that in the stations Ain Regrag and Sidi Bouali, gastropods are present during different months of exploration with a richness not exceeding 6 species, the actual wet period recorded a significant increase of 376 individuals who we in Ain Regrag and 290 in Sidi Bouali all confused species.

Furthermore, the summer period, recorded a tangible decrease compared to the other months of the year. This reduction in activity is explained by the decrease in dissolved oxygen levels and calcium ions and the increase of organic matter as a result of the Anthropic pollution sever punishment during the summer.

However, Tataw that records the lowest average temperature (11°C) and lowest Ca²⁺ ion contents compared to the other two stations (100.91 (mg / l)) is marked by lower species richness than 3 species and the reason for this decline is clear, it is above the low concentration of calcium ions key factor in the synthesis of the shells of gastropods.

Index of species diversity

Highest index of diversity was noted in the spronain Regrag (H'=1.21) due to the presence of 6 species with high abundance. The lowest value of this index was recorded in the source Tataw (H'=0.99) where only three species *Pisidium personatum*, *Pisidium casertanum* and *Melanopsis praemorsa* were sampled with low densities (Fig. 6).

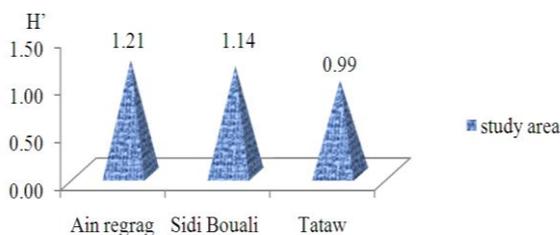


Fig. 6. Index of species diversity of Ain Regrag, Sidi Bouali and Tataw.

Index of equitability

Concerning equitability index, this measures the distribution of individuals within species, regardless of species richness. Its value ranges from 0 (dominance of one species) to 1 (equal distribution of individuals in the species), it usually has high values between 0.52 at Ain Regrag and 0.62 at Sidibouali and Tataw. These high values of equitability are due to low representation of molluscan species in those three Habitat especially in Ain Tataw where the number of species of the lowest brand value (3) (Fig.7).

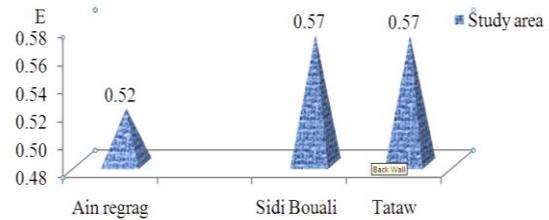


Fig. 7. Index of equitability of Ain Regrag, Sidi Bouali and Tataw.

Relative abundance and frequency

A comprehensive analysis of the data in the table 2 leads us to infer that the six species collected in the three stations of studies can be classified into two group according to their spatial dispersion, a first consortium comprising *Melanopsis praemorsa*, *Theodoxus numidica*, *Theodoxus numidica* (Zebra) and *Horatiasp* colonizing Ain Regrag and Sidi Bouali party and against a second group made up of mostly two species of the genus *Pisidium* and sporadically *Melanopsis praemorsa*.

In the sources Ain Regrag and Sidi Bouali, *Melanopsis praemorsa* dominates the mollusk population of reservoirs (Pi = 74% (AR) et Pi = 71.5% (SB) and Fi = 100%). It was collected in all biotop studied with relatively high densities. *Theodoxus numidica* (Pi = 10,89% (AR) et Pi = 14,56% (SB) et Fi = 100%) is also widely represented in the facies of reservoirs dam. According to the classification of (Vala. 1985). These two taxa are considered as fundamental species of the facies. *Horatia* sp (Pi = 3,34% (AR) et Pi = 13,75% (SB) et Fi = 100 %) is classified as a constant species. Indeed, it was removed in almost all stations surveyed, but with very low densities. Other species like *Pisidium personatum* (Pi = 0,15% and Fi = 16,67% AR), can be considered as sporadic species in the AR and almost absent in the source SB source, moreover it can be considered basic in Tataw sources despite its low density followed *Pisidium casertanum* (P= 13,33% and Fi=16.67%) Catch species that we have not harvested in the two other stations during the twelve months of sampling, it is mainly due to the water temperature as these two species are considered species sources of high- altitude mountain (Mouthon. 1981), this dispersion is also the result of the difference in ion concentration Ca²⁺ plays an essential role in the chonchilologique formation for molluscs.

Table 2. Relative abundance of species at Ain Regrag, Sidi Bouali and Tataw.

	Ain Regrag		Ain sidi Bouali		Ain Tataw	
	Pi	Fi	Pi	Fi	Pi	Fi
<i>Melanopsis praemorsa</i>	74,08	100,00	71,50	100,00	6,67	8,33
<i>Theodoxus numidica</i>	10,89	100,00	14,56	100,00	0	0
<i>Theodoxus numidica (Zebrea)</i>	11,54	100,00	0,19	25,00	0	0
<i>Horatia</i> sp.	3,34	100,00	13,75	100,00	0	0
<i>Pisidium personatum</i>	0,15	16,67	0	0	80,00	50,00
<i>Pisidium casertanum</i>	0	0	0	0	13,33	16,67

Conclusion

The biocological study of the malacological fauna of the 3 stations Fès-Bouleman region, allowed to list 6 species in 12 samples taken from January 2013 to December 2013. There is a higher richness in relation to moisture of the season. Snails are found everywhere even during the hottest months. On the malacological species analyzed, *Melanopsis praemorsa* is the most characteristic species of the ainregrag and Sidibouali and considered- Catch species at Tataw, this finding may be due to that *M. praemorsa* is a freshwater gastropod ubiquitous in Mediterranean distribution. Attending all kinds of substrates: mud, sand, stone and cemented walls of irrigation canals and having a changing diet. (Mazlanm and *et al.* 1994; Mouahid and *et al.* 1996; Elkarmi *et al.* 2006) indicated that this species are common in Morocco and can colonize all continental water bodies. These species have shown a clear indifference the abiotic environmental conditions for recolonization and development of its ecological niche in diverse habitats. The ability is related to the reproductive system that. The presence of eggs and different size classes throughout the year shows that its reproduction is continuous (Idaghdour, 1991). This ability keeps insurance reproduction during episodes of colonization of new habitats or during colonization of habitats subject to ecological disturbances like drying, predation and alteration of environmental conditions. *Pisidium casertanum* has been exclusively sampled in Tataw, So it seems that the species presents an ecological preference for cold water (Bespalaya and *et al.* 2015).

The index of Shannon - Weaver varies between 0,99 and 1,24 bits. It is highest in the Ain Regrag. The equirepartition of station indicates a balance between the numbers of different species present.

Finally, if a number of outcomes were identified during this study, many issues remain to be clarified, including the relationship between the trophic level and malacofauna which is listed there.

Acknowledgments

Following this work, I'am so thankful to , Mohamed Ghamizi, Professor at the Faculty of Science Semlalia, Cadi Ayad University in Morocco who welcomed me in his lab and helped in determining the species found here that the expression of my deep gratitude.

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