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Population dynamics of *Physa acuta* (Mollusca: Pulmonata) in the lakes of Rif mountains (Northern Morocco, Ouergha watershed)

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Abstract
The present study is first of its kind that deals with freshwater gastropod populations at Annasser Lakes, Rif mountains, Northern Morocco from eight selected sampling stations. Gastropods were collected from September 2002 - December 2003. A total of eleven species were recorded among which *Physa acuta* was the species most represented of aquatic snails in the studied areas. Gastropod population was higher in spring and summer, while low population was evident in winter. The present study on population dynamics of *P. acuta* in Annasser pond shows that the life cycle of the species followed a seasonal pattern. This cycle was mainly governed by the duration of submersion at the habitats studied. Indeed, the life cycle of the species is permanent ponds was bivoltine with two annual generations per year and two breeding periods in spring and autumn seasons. In the temporary ponds, the species was univoltine with just generation per year but had two annual breeding periods.

Keywords: Freshwater snails, *Physa acuta,* pouplation dynamics, life cycle, Ouergha watershed.

1. Introduction
Freshwater molluscs have been known to play significant roles in the public and veterinary health and thus need to be scientifically explored more extensively [1]. Freshwater gastropods are bioindicators and play a vital role in purifying water bodies since they are saprophytic. Some gastropods are of great importance for being intermediate hosts of infectious trematodes and other parasites of animals and human beings [2]. They feed on algae, zooplankton and organic wastes and provide food for many types of fish, birds and human beings. Dillon [3] described that distribution of freshwater gastropods depends on their abilities to colonize a habitat and survive there. Survival of gastropods is regulated by various physico-chemical factors and type of body water (current, stagnant, permanent or temporary) that play major role to determine the ecological traits associated with a particular species.
Only little information is available on the ecology of aquatic freshwater molluscs of mountain lakes in Morocco. Scientific studies of freshwater molluscs in the mountain lakes of Ouergha basin are still scarce, for two main reasons. First, colonization of mountain lakes and brooks is often limited to the very few species that can tolerate extreme environmental conditions. Second, abundances of such highly tolerant species in their aquatic biotopes are usually very low, which significantly complicates both their detection and quantification.
This study has two objectives. First, the present work aims to identify specific richness of malacological colonization of two important lakes of Ouergha watershed. Second, the study seeks to describe the population dynamics and seasonal variation of *Physa acuta* in pond of Annasser. This species is the most represented of aquatic snails in the studied areas. Our investigation was conducted for a hydrological cycle in 2003-2004 in the temporary and permanent ponds of Annasser. The monitoring of natural populations of *P. acuta* was carried out in order to describe the demographic and ecological functioning of this species in the study area. Therefore, it is possible to generate life cycle and determination of voltinism from seasonal fluctuations densities and breeding.

2. Material and methods
2.1. The study area
The basin area of Ouergha river (Fig. 1) is located in north of Morocco between 34° 20 '~ 35° 10' north latitude and 3° 50'~ 5° 30' west longitude. Elevations of mountains are between 100 and 2450 m. The total area of the catchment is 7325 km^2.

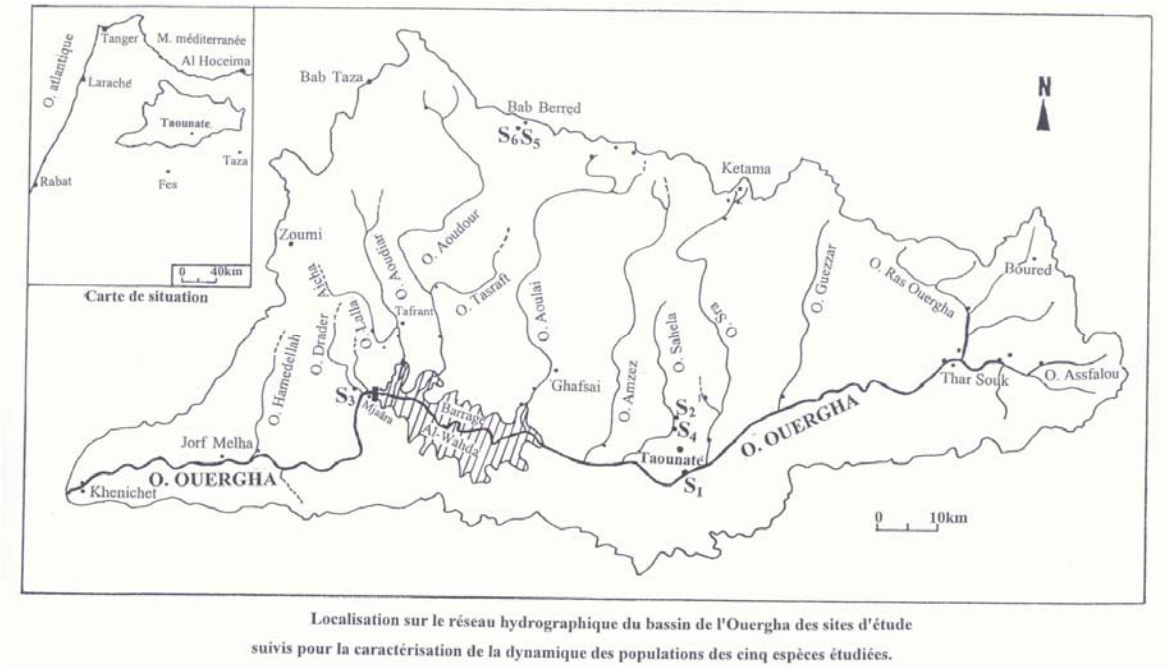


Fig 1: Location of the sampling stations in Ouergha watershed

This watershed is set on the southern slopes of the Rif arch mountain chain of Alpine orogeny. In the northern region of the basin, are located the largest number of high ridges of the Rif chain whose high altitude exceed 2000 m. The morphology of the basin is characterized by a relief that contains very strong slopes, a fundamental factor in erosion susceptibility.

The climate of the basin is mediterranean type ranging from suhumid to semi-arid. In these bioclimatic zones are linked different stages of vegetation that are largely related to the altitude. Al-Wahda Dam is situated in the basin of the Ouergha with the retention capacity over than 3,700 million m^3. It is the largest dam in Morocco that can protect Gharb plain against floods and can irrigates 100,000 hectares in the same plain.

Ponds of Annasser are the only existing important natural stagnant water bodies in the Ouergha basin. They are located 5 km west of Bab Berred city. The substrate is muddy, gravelly, rocky, sandy and muddy. Aquatic vegetation is composed by *Ceratophyllum demersum, Scirpus sp, Typha angustifolia, Juncus sp, Polygonum amphibium, Potamogeton pectinatus* and grasses.

2.2. Zonation of the temporary pool

We divided the temporary pool of Annasser into 4 habitats according to vegetation zonation forming four areas characterized by dominant plant species:

- a first zone (biotope P1) dominated by *Ceratophyllum demersum*, the depth of the water layer is between 85 and 125 cm,
- A second zone (biotope P2) composed by *Scirpus* sp, the depth is between 50 and 85 cm,
- A third zone (biotope P3) formed by *Typha angustifolia, Juncus sp*, *Polygonum amphibium* and *Potamogeton pectinatus.* The depth of this belt is between 15 and 50 cm,
- A last zone (biotope P4) composed by a lawn grass the depth of which is between 0 and 15 cm.

2.3. Zonation of the permanent pool

The permanent pool was divided into four habitats depending on the nature of the substrate.

- Biotope P_1: gravelly substrate, rocky and without vegetation. Deep of 55 cm, partly considered as a source of feeding the pond.
- Biotope P_2: sandy, gravelly and without vegetation. Deep of 234 cm.
- Biotope P_3: muddy substrate, rich in plant debris with abundant aquatic vegetation. Deep of 72 cm,
- Biotope P_4: silty mud substrate with riparian vegetation. Deep of 28 cm.

The choice of stations was done on malacological data available, specific diversity of freshwater molluscs in each biotope of the pond, the proximity of human settlements and finally the coverage of the maximum area. At each sample, we measured or estimated the following environmental parameters (Table 1): Altitude, the type of water body, width of the water body in beginning of summer, maximum width of the water body, water depth, speed of water current, nature of the substrate, presence of filamentous algae, Abundance of aquatic plants.

Table 1: Abiotic records of stations studied in Annasser pond

	Morpho-dynamic parameters						**Substrate parameters**			
	Alt (m)	TP (class)	LMo (m)	LMx (m)	Pr (cm)	VC (cm/s)	SG (%)	SF (%)	AF (class)	VA (%)
S_5	1200	2	84	120	234	0	0	100	4	70
S_6	1200	2	42	65	125	0	0	100	3	80

Legend table

Alt: altitude, **TPE**: type of water body (1-source, 2-dam or pond, 3-rivulet, 4-stream and river), **LMo**: width in beginning of summer, **LMx**: maximum width **Pr**: water depth, **VC**: speed of water current, **SG**: coarse substrate, **SF**: thin substrate, **AF**: filamentous algae (1-unnoticeable, 2-scarce, 3-abundant, 4-very abundant, **VA**: aquatic vegetation (1-no plants, 2-intermediate, 3-abundant density, 4-very abundant plant).

2.4. Sampling methods

2.4.1. Sampling by Surber sampler

This method was used in rivers and springs. The Surber sampler consists of two interlocking frames that support a capturing net. One frame outlines the area of stream bed to be sampled while the other supports the net. The sampler is intended for use in shallow (30 cm or less) flowing waters. We used a colander square (32 cm square) which is fitted with a mosquito net of 0.8 mm mesh size. The principle consists in scraping the bottom within the area bounded in front of the filter surface. The fauna stopped by strainer is recovered and carried to the laboratory and identified by using standard keys and monographs.

2.4.2. Quadrat method

The quadrat method has been widely used in plant and faunal studies. A quadrat is a four-sided figure which delimits the boundaries of a sample plot. Quadrat sampling involves counting all individuals within a known area (or volume). Since density (D) and population size (N) are related, as $N = D$ x area, we can estimate the density for the sample and from this compute the total population.

2.4.3. Visual search

Visible species were taken by hand. Hunting shall be performed during a delimited period between 15 to 30 minutes. The alternative is not to set a time and consider that the sampling is completed when the habitat was enough sampled.

2.4.4. Age-classes

The age of the snail is deducted from the measure of the shell lengths with a simple caliper. Three age-classes for *P. acuta* were defined on the basis of shell lengths, thickness of the outer lip and its degree outward flare:

- the class of tiny juveniles **C1**: size under 2,5 mm;
- the class of juveniles **C2**: size between 2,5 and 5,5 mm;
- the class of adults **C3**: size over 5, 5 mm.

3. Results and Discussion

3.1. Species richness

Eleven species of freshwater molluscs were sampled in the eight component biotopes of Annasser pond, they are:

- *Lymnaea truncatula*
- *Lymnaea peregra*
- *Lymnaea maroccana*
- *Physa acuta*
- *Planorbarius metidjensis*
- *Anisus spirorbis*
- *Ancylus fluviatilis*
- *Succinea debilis*
- *Pisidium casertanum*
- *Pisidium personatum*
- *Pisidium nitidum.*

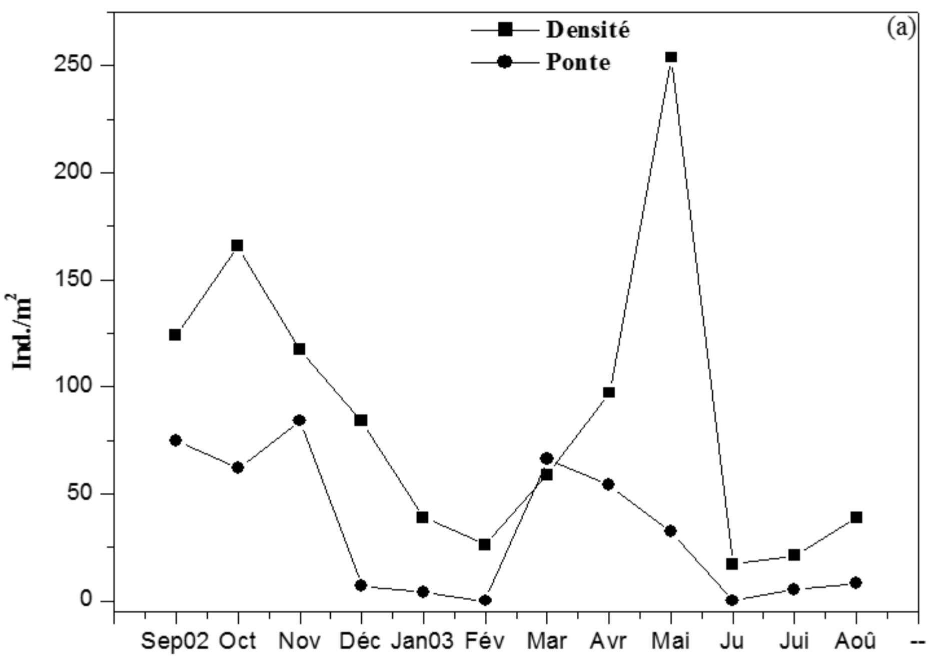
Planorbarius metidjensis, Anisus spirorbis and *Lymnaea maroccana* are considered as exclusive species of the pond in the Ouergha watershed.

The physical structure of the pond is recognized to have an important influence on the density and composition of species communities. Indeed, the species richness in those biotop increases with the heterogeneity of habitat serving for protection against predators as well as the diversification of ecological niches that allow sharing of resources [4, 5, 6]. Ghamizi [6] has reported 40 superficial species of freshwater snail in Morocco.

3.2. Population dynamics of *Physa acuta* (Fig. 2, Fig. 3)

3.2.1. Reproduction Activity

The reproductive activity of *P. acuta* is highest during the spring and fall seasons. During the winter season, lower reproduction was recorded. Transitional populations of the species are distinct from all other populations by the lack of autumn breeding. This absence is mainly due to the loss of breeding during the summer drought.



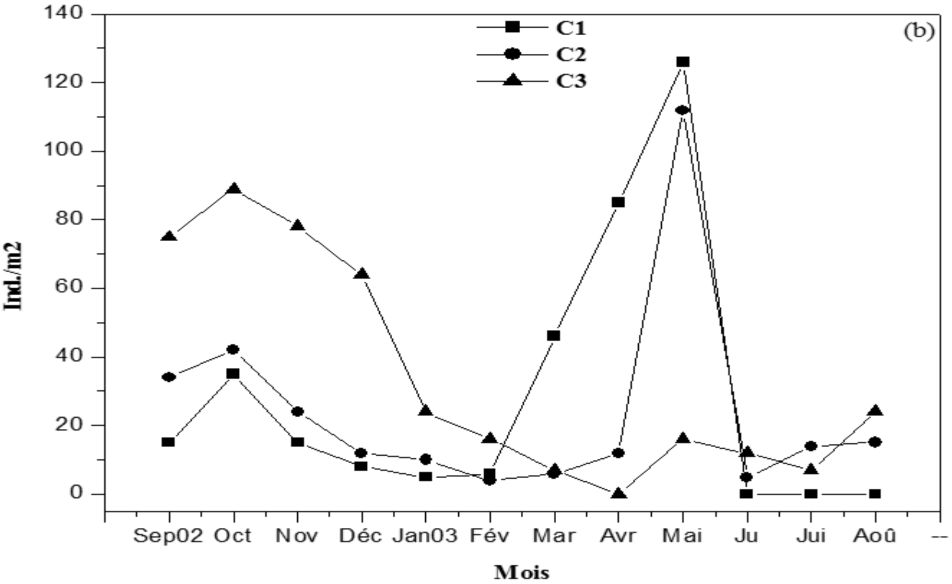


Fig 2: Temporal fluctuations of the total density (a), breeding (a) and size classes (b) of Physa acuta in the permanent pond (S5).

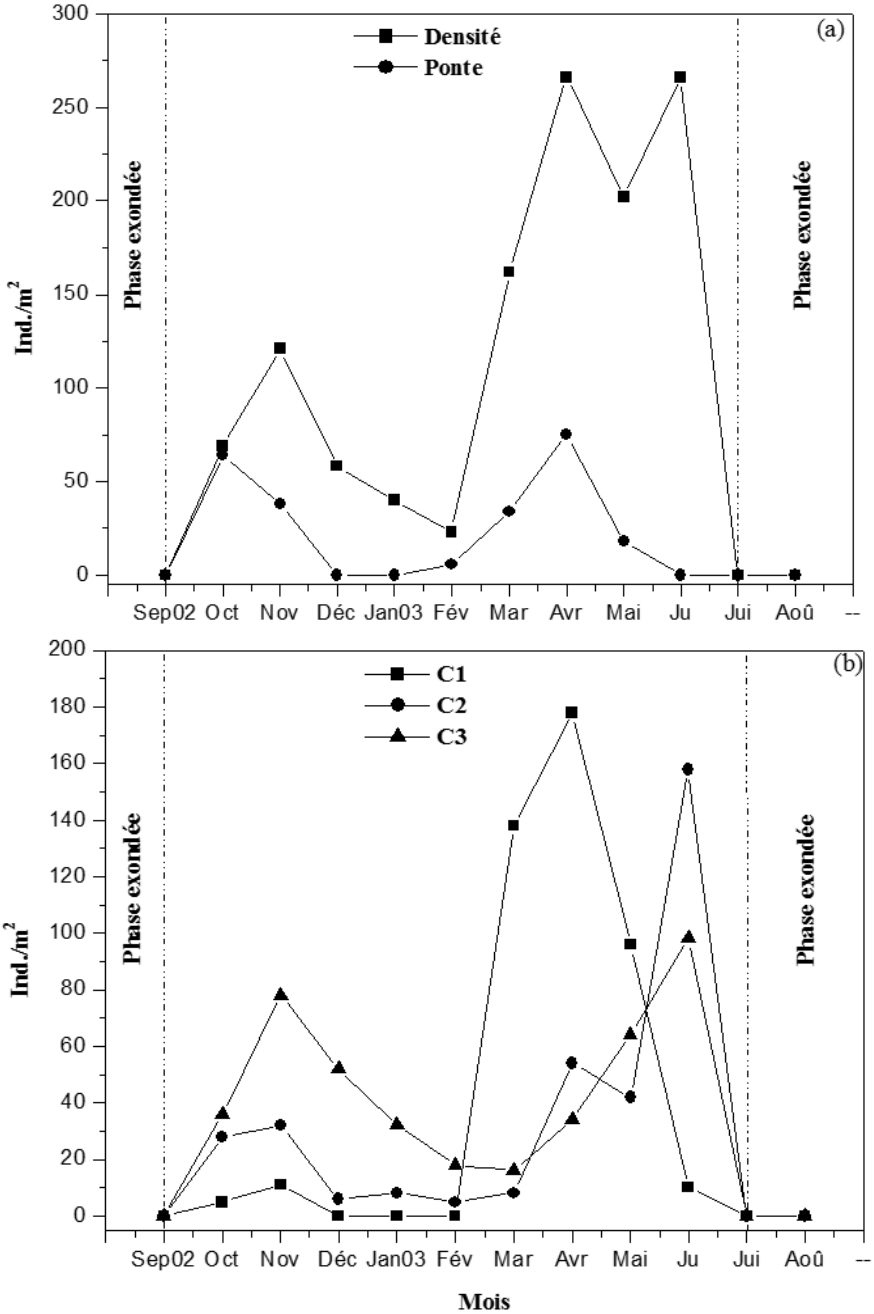


Fig 3: Temporal fluctuations of the total density (a), breeding (a) and size classes (b) of Physa acuta in the temporary pond (S6).

3.2.2. Recruitment of population

The majority of *P. acuta* populations studied in closed environments present an important recruitment during the spring season. Such recruitment is usually the result of significant reproductive activity generated in the early spring or the end of winter breeding, but no winter growth. However, the recruitment of populations was lower in the autumn season. Therefore, it appears that recruitment is continuous throughout the year, while it is predominantly in the spring period.

3.2.3. Size of potential breeders

The potential breeders have larger average sizes in the fall than in spring season. These results are in agreement with those of Clampitt [7] and Brown [8].

3.2.4. Transition between cohorts

The main population cohorts of disappears a year after its appearance. The transfer between cohorts happened in mid-winter and mid-spring.

3.2.5. Life cycle

The life cycle of *P. acuta* had a simple annual pattern of two generations per year with two breeding periods happening in the spring and autumn seasons. The main recruitment phase of the tiny juveniles populations occurring in the spring and autumn, especially in the spring, with the lowest recruitment occurring in the winter. The spring cohort (main generation) can continue to exist for one year from spring to winter or next spring. Breeding season started in the beginning of spring season and just a few representatives of this generation who survive until the following autumn. This type of life cycle is in the type IIa defined by Hunter [9].

In the temporary ponds, the life cycle of of *P. acuta* had only one annual generation with two annual breeding periods (fall and spring). The episode for major recruitment population occurs in the spring. The breeding happening into fall period in the temporary pond showed an anecdotal recruitment in winter. This univoltine cycle of *P. acuta* is identical to the type II described by Hunter [9].

The population dynamics of *P. acuta* in Annasser pond shows that the life cycle of the species follow a seasonal pattern. Indeed, the reproduction is optimal between the fall and spring season with a high peak reproduction in the spring. This seasonal dynamic seems to be extrinsic for species because, whatever the season, snail individuals placed in laboratory can breed within favorable conditions [10, 11, 12, 13, 14, 15].

The life cycle is mainly governed by the duration of submersion at the habitats studied. The bivoltine of populations increase in the permanent environments making two periods of breeding (fall and spring seasons) followed by two episodes of recruitment of juveniles individuals, often more massive during the spring season. The spring generation will eventually reproduce in the same season, but particularly in the fall and in the following spring even adults of this generation die massively between February and April. The fall generation begins to reproduce until the following spring and rare are the representatives of the generation that survived until the next fall season. If we compare the temporal distribution of two generations, it clearly appears that the spring generation is more spread out in time than the fall generation.

The univoltine populations with a single annual generation is confined to the temporary sites of the pond. They also have two breeding seasons (in fall and spring), but the episode of major recruitment occurs in the spring. The existence of two peaks of reproduction does not imply the presence of two generations per year because of the recruitment from breeding happening in fall season is low. Therefore, there is an effective generation per year (univoltine species), with a transition between generations between March and June after as suggested by Clampitt [7], Brown [8] and Duncan [16].

Several ecological and environmental factors may be implicated in the definition of life cycle of *Physa acuta* populations, the most predominant are the summer drought [17, 18, 19, 20, 21, 22, 23, 24], temperature and filamentous algae [10, 15, 25, 26] and finally predation and competition [21].

4. Conclusion

Seasonal variations of *P. acuta* populations were recorded in density and species richness at Annasser pond. The population dynamics shows that the life cycle of the species follow a seasonal pattern. Indeed, the reproduction is optimal in the fall and spring seasons with a reproduction peak in the spring. The univoltine populations with a single annual generation is confined to the temporary sites of the pond. However, the bivoltine populations is related to the permanent ponds. In the temporary sites, the species was capable of surviving by estivating during droughts and by hibernating during the coldest months. Under naturally fluctuating conditions, a boom-and-bust pattern of population dynamics is observed, with snails showing explosive growth and drastic declines in relation to alternating favorable and unfavorable periods. Depleted populations may rapidly recover because these snails are hermaphrodites capable of reproducing by both cross- and self-fertilization [3].

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