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Diversity and Distribution of Aquatic Snails in the Upper Bandama Fauna and Flora Reserve (North-center Côte d'Ivoire)

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Abstract**—** *The Upper-Bandama fauna and flora Reserve is a 122,162 ha protected area which is threatened by the anthropogenic activities. This study aimed to highlight its functioning with the use of freshwater snails in the Bamdama watercourse. The sampling was carried out between January 2018 and February 2019 using a kick net and Van Veen grab on twelve stations. A total of 762 individuals of Gastropods and Bivalves belonging to 22 taxa, 9 Orders and 12 Families were collected. In Gastropods, the Planorbidae family was most diversified with 05 taxa and in Bivalves Sphaeriidae was most diversified with 02 taxa. Melanoides tuberculata (Thiaridae) and Biomphalaria pfeifferi (Planorbidae) where the most abundant in Bamdama (respectively 22.86 and 17.68%) and in Nambyon rivers (26.19 and 22.62%). On the other hand, Biomphalaria pfeifferi and Tomichia ventricosa (Tomichidae) with each 17.64% of the total abundances where dominants in the ponds. In general, the redundancy analysis shows that turbidity and conductivity are the parameters that most influence the distribution of snails. The strong presence of the invasive species Melanoides tuberculata in the hydrosystems of the reserve could be a brake on the diversity of local malacological fauna, hence the need for monitoring of the snails communities of this reserve.*

Keywords**—** *Diversity, freshwater snails, Ivory Coast, Upper Bandama reserve.*

I. INTRODUCTION

The hydrosystems of the Upper-Bandama fauna and flora reserve (RFFHB) are subject to strong anthropogenic pressures, including the location of agro-food industries upstream of the reserve, intensive agriculture, artisanal fishing at the site. The use of pesticides and traditional gold panning (Carreti & Loyer, 2012; OIPR, 2015). Moreover, the unstable socio-political situation that prevailed in Côte d'Ivoire between 2002 and 2011 accentuated the clandestine settlement of populations. Hence the increase in the invasion of these media by aquatic plants and algae, inducing their enrichment in suspended matter (Halle & Bruzon, 2006).

Today, with the Ivorian State taking over this reserve through the Ivorian Office of Parks and Reserves (OIPR), it is gradually setting up, quality monitoring systems water from the reserve. These systems include methods based on monitoring biological communities, including the aquatic macroinvertebrates that live there. These organisms are used as indicators of the quality of aquatic environments because of their sedentary nature, their great diversity and their variable tolerance to pollution and habitat degradation (Moisan & Pelletier, 2008). In addition, they reflect particularly well the ecological status and integrity of aquatic environments by reacting very quickly to changes in their environment. Finally, they are an essential component of the food web of aquatic ecosystems (Barbour et al., 1996 & Tachet et al., 2006) and actively participate in the transformation of organic matter. The presence or the absence of a species, the richness and the specific diversity, are thus indices of a good or bad quality of the waters. The reserve has benefited from very few studies, especially those concerning its benthic macrofauna. Therefore, the establishment of such a monitoring system relies entirely on the knowledge of this aquatic component. Thus, the present study aims to show the diversity and distribution of snails of the reserve of fauna and flora of Upper Bandama.

II. MATERIALS AND METHODS

A. Study Site

Established by decree N ° 73-133 of the 21/03/73, the Upper-Bandama fauna and flora reserve (RFFHB) covering 123 km² is located in the North-center of Ivory Coast, between, 8° 10' 25,3" and 8° 38' 25,01" N and 5° 12' 14,1" and 5° 37' 55.3" W. The RFFHB is crossed from north to south by the white Bandama River for a distance of 160 km, or 15% of its total length. This zone is subject to a sub-humid tropical climate, sometimes referred to as sub-Sudanian transition (Guillaumet & Adjanohoun, 1971). It is characterized by two seasons, one dry, from November to March, accented by the harmattan between January and February and the other rainy, covering the period from April to October. Heavy rainfall and a larger flood recorded in September with a flow of 300 m^3/s. The average annual rainfall is about 1230 millimeters. Other climates characteristics are relatively large thermal amplitudes are of the order of 26.6 ° C and a humidity ranging from 35 to 79 %.

B. Sampling Procedure

During this study, eight (8) seasonal sampling campaigns were conducted between January 2018 and February 2019 on the reserve, at the frequency of four (4) sampling campaigns per season. A total of twelve (12) sampling stations were visited, of which eight (8) are arranged along the Bandama River longitudinal gradient, two (2) of which are outside the reserve respectively upstream under the influence of anthropogenic activities and downstream in a relatively well-preserved area. Of the four (4) other stations, two (2) are located in the Nambyon River and two (2) ponds (fig. 1). All stations were sampled with a kick net and Van Veen Grab. Overall, 36 sampling sites were defined. The samples were

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collected at each site for two to three minutes by submerging the kick net and dragging it into the water column. The net has also been banged against the bottom substrate to dislodge and collect sediment organisms. The survey was also done using a Van Veen grab. At each site, three (03) sediment samples corresponding to a total area of 0.15 m² were taken. *In situ*, the samples were washed on a 500 µm mesh vacuum screen and fixed with 5% formalin. In the laboratory, the organisms were sorted, identified and counted. The identification was made at the lowest taxonomic level by combining the appropriate literature including those of Brown, (2005), Dejoux (1981), Mary (2000), De Moor *et al.* (2003a and 2003b) and Forcellini *et al.* (2011).

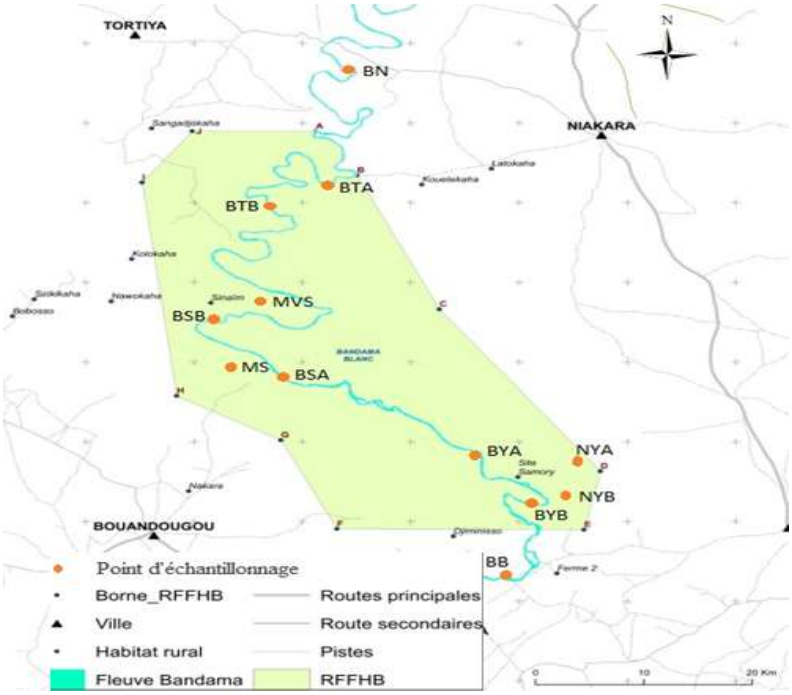

Fig. 1. Location of the sampling stations in the Upper-Bandama Fauna and Flora Reserve (RFFHB).
Pond = MS and MVS stations; Nambyon River = NYA and NYB Stations; Bandama = BN stations; BTA; BTB; BSA; BSB; BYA; BYB and BB.

III. Results

A. Taxonomic Composition

A total of 762 individuals of 22 taxa belonging to 12 families 9 orders and 2 classes (Bivalves and Gastropods) were collected and identified during the study period (Table I).

The class of Gastropods is the most diversified with 19 taxa, or 95% of the global taxonomic wealth. In contrast, Bivalves have 3 taxa, or 5% of the total number of taxa.

The gastropods have 10 families grouped between 7 orders: Architaenioglossa, Littorinimorpha and Sorbéoconcha (2 families each), Basommatophores, Cycloneritida, Mesogasteropods and Stylommatophores (1 family each). In this class 2 orders represent 58.2% of the taxonomic richness. These are: Architaenioglossa (6 taxa), of which the Ampullariidae family is the most diversified (4 taxa) and the Basommatophores (5 taxa). With regard to Bivalves, the 3 taxa of this class belong to 2 families (Margaritiferidae and Sphaeriidae) grouped between 2 orders (Unionida and

Venerida), of which the family of Sphaeriidae (2 taxa) is the most diversified.

B. Spatial Variations of Taxonomic Richness

The taxonomic richness of the snails sampled in the Upper-Bandama Reserve is also presented in Table I. Two Gastropods *Biomphalaria pfeifferi* (Planorbidae) and *Lanistes neavei* (Ampullaridae) where common to all stations. Five (5) taxa are subservient to one station, of which: three (3): *Bulinus africanus*, *Gabbiella* sp. and *Pila occidentalis* at Nambyon Yayakaha A (NYA), located in the Nambyon downstream, *Clithon longispina* in the Bandama at Bandama Tortiya A (BTA), upstream and *Melanopsis* sp., at the middle course at the station Bandama Sinaïm A (BSA). The highest taxonomic richness was displayed at the middle course inside the reserve in the fluvial part of Bandama the BSA and BSB stations (Bandama Sinaïm A and B) and downstream outside the reserve the BB station (Bandama Badasso) with 14 taxa each. They are followed by Nambyon Yayakaha A (BYA), located downstream, inside the reserve (13 taxa). The lowest taxonomic richness was recorded at the middle course in the two pools with respectively 7 taxa in the Sinaïm pond (MS) and 4 taxa in the pond Vodougue Sinaïm (MVS).

The distribution of taxonomic richness according to the environments surveyed indicates that four (4) Gastropods: *Biomphalaria pfeifferi*, *Cleopatra guillemei*, *Lanistes neavei* and *Melanoides tuberculata* are common to the three habitats. They represent 18.18% of the global taxonomic wealth. Five (5) taxa of this taxonomic category, representing 22.72% of the global taxonomic richness, are located only in the Bandama River: *Bulinus forskalii*, *Clithon longispina*, *Helisoma* sp., *Lanistes nyassanus* and *Melanopsis* sp. On the

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other hand, four (4) taxa subservient to the Nambyon River. These are: Gastropod snails (*Bulinus africanus*, *Gabbiella* sp., and *Pila occidentalis*) and *Pisidium abditum* (Bivalve).

The distribution of taxonomic richness along the upstream-downstream gradient indicates that the downstream of the reserve is more diversified (19 taxa, including 2 Bivalves). However, upstream has the lowest value of taxonomic richness (14 taxa, including 2 Bivalves).

TABLE I. Taxonomic list of snails of Hydrosystems of the Upper Bandama Reserve from January 2018 to February 2019.
* = accidental taxa; ** = accessory taxa; *** = constant taxa .; Pond = MS and MVS stations; Nambyon River = NYA and NYB Stations.
Bandama = Stations BN; BTA; BTB; BSA; BSB ; BYA; BYB et BB.

	Upstream			Middle stream				Downstream				
Taxa	BN	BTA	BTB	BSA	BSB	MS	MVS	BB	BYA	BYB	NYA	NYB
Margaritifera margaritifera	*	**	**		***			*		**		***
Pisidium abditum											*	*
Pisidium sp.	***	**	*	*	**			*	***	***	***	**
Lanistes ciliatus	*			**	*	*	**	*				
Lanistes neavei	*	***	**	***	***	*	**	*	***	***	**	***
Lanistes nyassanus				*				*				
Pila occidentalis											*	
Bellamya capillata	***			**	**			**	*	*	*	***
Bellamya crawshayi	*		*	***	*			*		**	*	*
Biomphalaria pfeifferi	*	***	***	***	***	*	**	***	**	***	***	***
Bulinus africanus											*	
Bulinus crystallinus		*	*		*	*						
Bulinus forskali				*	*			*				
Helisoma sp.	*	*	*							*		
Clithon longispina		**										
Gabbiella sp.											*	
Tomichia ventricosa	*	*	*	***	*	*	***	*				
Cleopatra guillemei	***	***	***	**	**	*		**	***	***	***	**
Melanopsis sp.				*								
Melanoides manguensis				*	*			*			*	*
Melanoides tuberculata	***	***	***	**	*	*		***	***	***	***	***
Bulinus natalensis	*			**	*			*	*	*	*	*

C. Spatial Variations of Abundances

In all 12 sampling stations in the Upper Bandama Reserve, 762 individuals of aquatic molluscs were counted. The gastropods appeared the most abundant. They comprise 657 individuals, or 86.22% of the total population and dominate numerically by *Melanoides tuberculata*. As for Bivalves, they have 105 individuals and represent 13.78% of the organisms harvested. *Pisidium sp*. is the most abundant taxon of this class.

Figure 2 shows the distribution of mollusc numbers at the different habitat stations surveyed in the Upper Bandama reserve. In relation to the main taxa, those representing at least 10 % of the total number of organisms harvested at at least one of the 12 sampling stations. On the Bandama, *Melanoides tuberculata* (Thiaridae) is best represented. This taxon constitutes the bulk of the workforce at the BTA, BYB, BTB, BSA, BYA, and BN. Stations with respectively 33.33, 26.67, 25.67, 22.78, 32.69 and 29.41% of the workforce of these stations (figure 2a). On the other hand, *Biomphalaria pfeifferi* (Planorbidae) (19.35%) and *Tomichia ventricosa* (Tomichidae) (27.03%) make up the bulk of the crops at the BSB (Bandama Sinaïm B) and BB (Bandama Badasso) stations respectively. Regarding the Nambyon River, *Melanoides tuberculata* (Thiaridae) is best represented with 30.76% of the NYB (Nambyon Yayakaha B) station. While, *Biomphalaria pfeifferi* (Planorbidae) 33.78% dominates numerically at the NYA (Nambyon Yayakaha A) station. In the case of ponds, *Biomphalaria pfeifferi* (Planorbidae) and *Tomichia ventricosa* (Tomichidae) dominate the malacological fauna of the ponds. They each represent 17.64% of the total workforce (figure 2b).

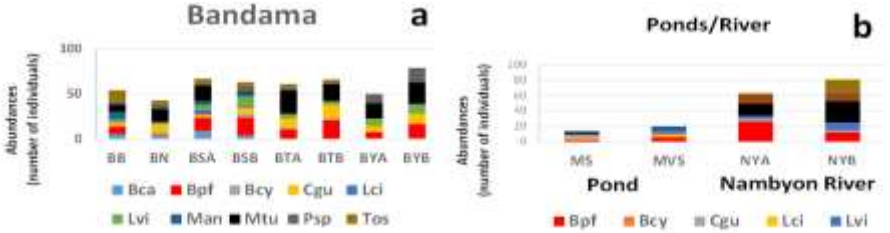

Fig. 2. Abundances of the ten (10) main taxa of aquatic molluscs in the Upper Bandama Reserve by habitat types. (a) at the stations on the Bandama River; (b) at stations in Nambyon River and pools.
Bpf = *Biomphalaria pfeifferi*, **Bcy** = *Bulinus crystallinus*, **Cgu** = *Cleopatra guillemei*, **Lci** = *Lanistes ciliatus*, **Lvi** = *Lanistes neavei*, **Mtu** = *Melanoides tuberculata*, **Tos** = *Tomichia ventricosa*, **Psp** = *Pisidium sp.* , **Man** = *Melanoides manguensis*, **Bca** = *Bellamya capillata*.

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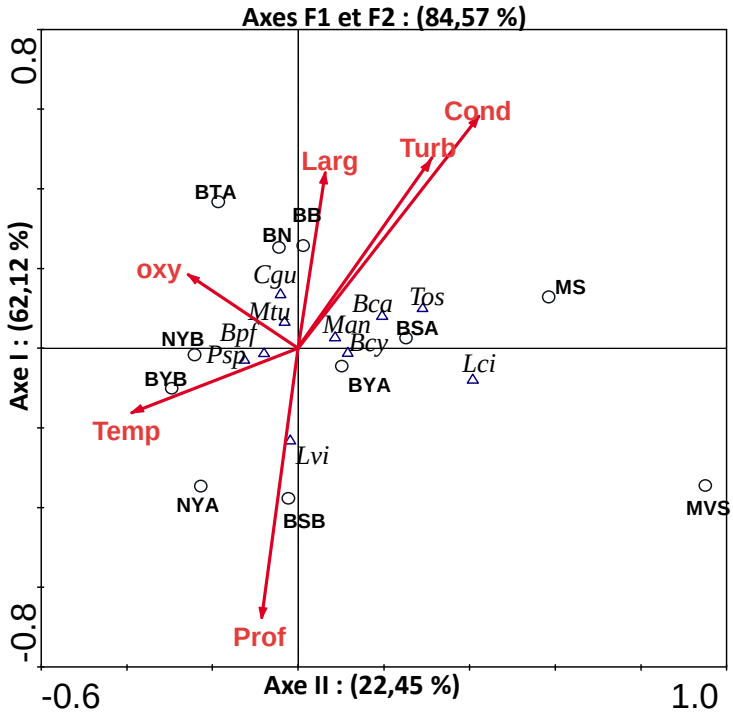
D. Correlation between physico-chemical parameters and the distribution of snails

A redundancy analysis (RDA) was performed to establish a relationship between the ten main taxa sampled and the physicochemical parameters recorded at the different stations. The representativity of the first two axes is significant (*p-value* = 0.0096) and displayed a total of 84.57% of the information (Axis I, 62.12%; Axis II, 22.45%) (Fig. 3). On axis I (FI), *Biomphalaria pfeifferi* (Bpf) and *Pisidium* sp. (Psp) are negatively influenced by low values of dissolved oxygen and temperature. This transpands downstream into the Nambyon River at Nambyon Yayakaha B (NYB) and into the Bandama River bed at Bandama Yayakaha B (BYB).

Axis II (F2) is weakly and positively correlated with the width of the wet bed. This gradient opposes the depth at sampling points strongly correlated to this same axis. This axis runs in the Bandama River the stations Bandama Tortiya A (BTA) and Bandama Nabedjakaha (BN). Then downstream the Bandama Badasso (BB) station located in the Bandama River outside the reserve. *Melanoides tuberculata* (Mtu) and *Cleopatra guillemei* (Cgu) are the taxa that characterize these stations. In contrast, in the Bandama River, Bandama Sinaim B (BSB) is located in the middle course. This station is characterized by *Lanistes neavei* (Lvi).



Redundancy analysis (RDA) of the ten (10) main taxa of aquatic molluscs and environmental variables.
Temp: Temperature, **Turb:** Turbidity, **Cond:** Conductivity, **Oxy:** Dissolved Oxygen. Width: Wet Width and Depth: Depth at Sampling Points. **Bpf** = *Biomphalaria pfeifferi*, **Bcy** = *Bulinus crystallinus*, **Cgu** = *Cleopatra guillemei*, **Lci** = *Lanistes ciliatus*, **Lvi** = *Lanistes neavei*, **Mtu** = *Melanoides tuberculata*, **Tos** = *Tomichia ventricosa*, **Psp** = *Pisidium sp*., **Man** = *Melanoides manguensis*, **Bca** = *Bellamya capillata* Mares = MS and MVS stations; River = NYA and NYB Stations; Bandama = BN stations; BTA; BTB; BSA; BSB; BYA; BYB and BB.

IV. Discussion

In general, the composition of the Malacological fauna of the Upper-Bandama reserve corresponds to that of the anthropogenic watercourses of the tropical regions of Africa (Edia, 2008, Foto *et al.*, 2011). From the point of view of taxonomic composition, 22 taxa were recited. Gasteropods are fairly well represented in terms of taxa (19 taxa), orders (7 orders) and families (10 families). The high diversity of Gastropods could be related to the water covered by aquatic plants and to the presence of rocky substrates and rock blocks on the Bandama River and the Nambyon river. Indeed, aquatic plants, rocky substrates, and rock blocks are an important component of the multi-level ecology of snails. In that they serve as sources of food and support for the growth of the periphyton, the main food source of snails. In addition, they provide well-oxygenated spawning sites for breeding and provide shelter for various predators (Bony, 2008).

In addition, the diversity of gastropods collected during this study is explained by the efficiency and complementarity of the method and sampling techniques used, namely the combined use of the Van Veen dump and the troubleau fillet. These techniques have made it possible to explore a wide diversity of molluscan populations.

However, no Pulmonary of the genus Potadoma has been inventoried during the work of (Binder, 1957, Brown, 1979, Sellin *et al.*, 1980) in the region that is to say, upstream from Lake Kossou. is included in this taxonomic list. This

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difference could be justified by the sampled habitat types and the areas surveyed.

With regard to the spatial distribution of abundances, *Melanoides tuberculata* (Thiaridae) predominantly dominates the malacological fauna in the Bandama River and the Nambyon River. This result could be explained by the rapid growth of this species by parthenogenesis (a mode of reproduction in which the egg develops without fertilization) and the depletion of resources (Pointier & McCullough, 1989, Pointier *et al.*, 1989). This gives it a competitive advantage over other local species of molluscs, particularly those of the family Planorbidae (Pointier, 2001). It is also responsible for the rarefaction and even the disappearance of these molluscs in certain habitats (Pointier & Jourdane, 2000, Pointier *et al.*, 2004). The negative influence of this so-called invasive species could explain the low abundance of other families of molluscs. More so, the absence of the pulmonary of the genus Potadoma in our samples. This dominance of *Melanoides tuberculata* in the river and river is also due to the fact that it is known as a species that does not have a high ecological requirement. It has the potential to spread in polluted environments as well as in good quality waters (Bony, 2008). *Melanoides tuberculata* is the intermediate host of some parasites, such as *Schistosoma mansoni*. As the reserve is basically a sanctuary, a refuge area for species, the strong presence of this invasive species could be a brake on a higher diversity of local malacological fauna.

V. CONCLUSION

The strong presence of the invasive species (*Melanoides tuberculata*) in the hydrosystems of the Haut-Bandama reserve could be a barrier to the high diversity of local malacological fauna. According to Pointier, 2001, this species is responsible for the rarefaction and even the disappearance of certain species of molluscs, particularly those of the family Planorbidae. Therefore, the need to adopt new conservation methods through the monitoring of the shellfish communities of the reserve is necessary. The integrated management of these communities in the spatio-temporal monitoring of the waters of the Haut-Bandama reserve is not such an innovative approach?

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