Assemblages of freshwater snail's community in the Aghien lagoon in relation to environmental variables (Côte d'Ivoire; West Africa)

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Abstract- We studied the dynamic of aquatic snail's populations in relation to environmental variables in the Aghien lagoon. Snails and physico- chemical variables were sampled monthly from July 2014 to June 2015 at eleven sampling site. Samplings were performed by the kick sampling technique and Van Veen Grab methods.. A total of 1316 individuals divided into 16 taxa belonging to 4 orders and 10 families were identified. Stations located on the banks were more diversified. Taxa such as *Melanoïdes tuberculata, Indoplanorbis exustus* and *Lymnaea natalensis* have appeared frequently in all stations. The stations located on the longitudinal axis of the lagoon are characterized by Thiaridae such as *Potadoma liricincta, Pachymelania fusca, Pachymelania byronensis*. The canonical correspondence analysis revealed that turbidity, pH and phosphorus strongly influenced the distribution of snail in the study sites. Three invasive species, *Aplexa marmorata, Indoplanorbis exustus and Melanoïdes tuberculata* were reported. Several surveyed species in our basins are important intermediary host of parasites, particularly Planorbidae *Indoplanorbis exustus* who constituted potential risk to public health.
Index Terms-*Fresh water Snail, population, dynamic, Aghien lagoon, Côte d'Ivoire*

I. INTRODUCTION

Benthic macroinvertebrates are of importance to aquatic biologist because they can indicate pollutional effects on the environment (Chapman and *al.*, 1982). Snails occupy a prominent place among aquatic organisms suitable for biological monitoring (Goldberg, 1986; Salanki, 1989) and they are used often for passive and active biomonitoring and in hazard and risk assessment (Borcherding and Volpers, 1994; Allan J.D. and Flecker, 1993; Kiblut, 2002). Then, the distribution of aquatic organisms relative to their habitat is of central importance to ecology (Nanami and *al.*, 2005). Studies established a pattern of relationship between aquatic fauna, depth, substrate and organic contents of sediment (Ramirez and *al.*, 1998; Edia and *al.*, 2013; Bony and *al.*, 2013). Moreover, stream-dwelling macroinvertebrates are generally thought to be distributed according to environmental factors (Minshall and Robinson, 1998). Furthermore, according to Nanami and *al.* (2005), numerous studies have suggested that variability in physical factors, chemical factors and biological factors provide diverse habitats, and species specific habitat association of organisms in response to environmental variability has been found. Thus, the nature of this distribution provides an initial insight into the types of ecological processes that regulate populations and assemblages. Despite its importance, few studies have been published on the distribution of benthic macroinvertebrates among stream habitats for tropical systems. In Côte d'Ivoire, little information is available about the ecology of aquatic snails in Aghien lagoon. This study aims to show the population dynamic of aquatic snail's communities in relation to environmental variables in this lagoon.

II. MATERIALS AND METHODS

II.1 Study site

The Aghien Lagoon is located in the Southeastern of Côte d'Ivoire between latitudes 5°22'N and 5°26'N and longitudes 3°49'W and 3°55'W (Figure 1). This lagoon is located to the north of the Ebrié Lagoon from which it is separated by the Potou Lagoon. The Aghien and Potou Lagoons communicate through a natural channel (Koffi and al., 2014).The Aghien Lagoon could reach 11 m deep (Guiral and Ferhi, 1989). This lagoon covers an area of 20 km² for a perimeter of 40.72 Km. It is supplied by two main tributaries, Djibi and Bété Rivers, and is almost exclusively continental all year long (Traoré and *al.*, 2014). This gives to the hydrosystem a fluvial character (Aliko, 2017).The Aghien Lagoon is subject to an equatorial climate characterized by four seasons (Durand and Chantraine, 1982). The monthly distribution of these seasons is shown in Table I.

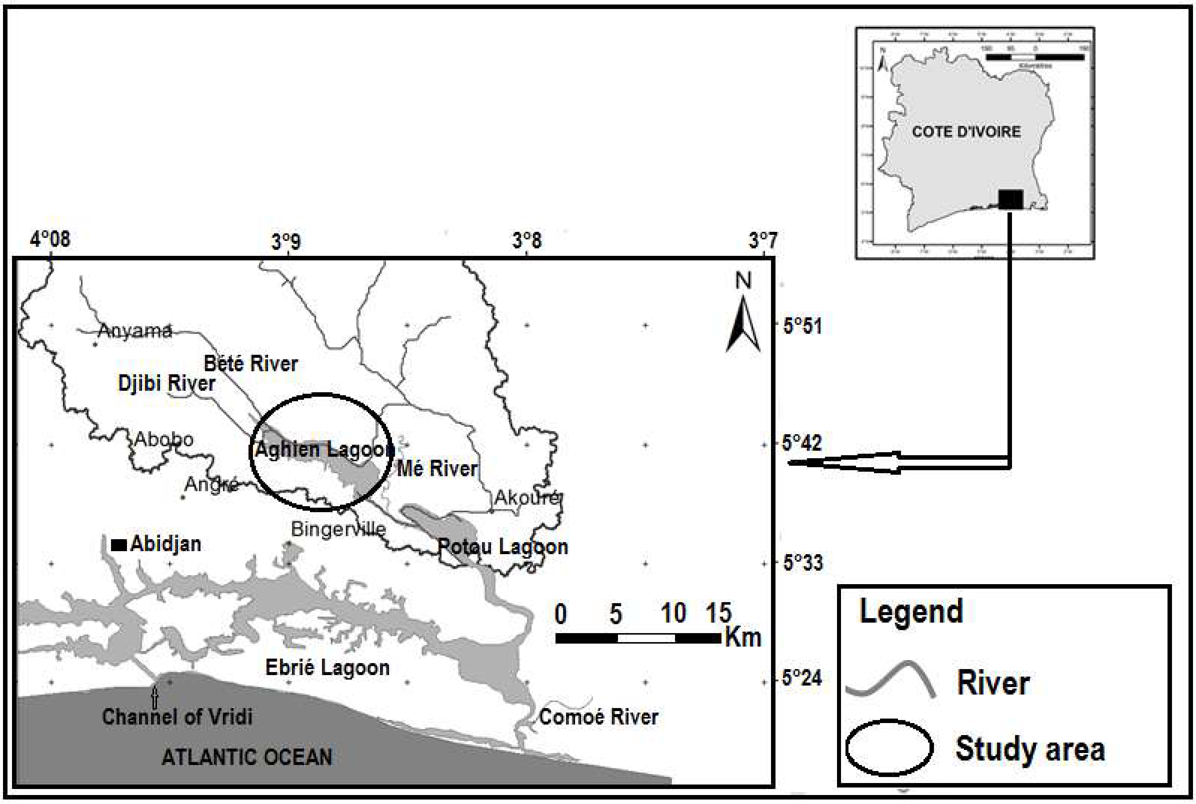

Figure 1:- Location of the Aghien Lagoon in the South-Eastern of Côte d‟Ivoire.

Table I:- The four climatic seasons of the Aghien Lagoon according to Durand and Chantraine (1982).

Long dry season (LDS)	December, January, February, March
Long wet season (LWS)	April, May, June, July
Short dry Season (SDS)	August, September
Short wet season (SWS)	October, November

II.2 Sampling procedure

Sampling sites were selected to cover a fair degree of habitat heterogeneity in Aghien Lagoon. Studies stations are located along the main axis of the lagoon with two transects perpendicular to the longitudinal transect (Figure 2). The first transect is located opposite the of Akandjé city in order to determine if the water quality varies according to the distance to shore. The second transect is located in the western area of the lagoon. Macroinvertebrates sampling was carried out for twelve months at monthly intervals between June 2014 and May 2015.

Benthic fauna were sampled in each of the eleven stations defined on Aghien lagoon following a longitudinal rampe with a kick net (250 microns mesh size) following SASS method (South African Scoring System) (Dickens and Graham, 2002). The samples were collected 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 collect was also done using a Van Veen grab. At each site, three (03) sediment samples corresponding to a total area of 0.15 m^2 were taken at several depths. At the exit of water, the contents net were washed on a sieve of 0.5 mm. All samples were fixed in 70% alcohol. In the laboratory, all samples were sorted using a binocular microscope, counted and identified at the lowest taxonomic level by combining the appropriate key (Dejoux and *al.*, 1981; Mary, 2000).

At each campaign, each sampling site was characterized by measuring water temperature (°C), turbidity (NTU), pH, conductivity (µS/cm), and dissolved oxygen (mg/l) with portable sensors. Water were taken from each sample site (station), stored in polyethylene bottles (500 ml) and kept at a temperature below 4°C to stop all the activities and metabolism of the organisms in the water. At the laboratory, these water samples were kept in a refrigerator for further determination of phosphorus, Phosphate, ammonium ($NH4^+$; mg/l), nitrate (NO_3^-; mg/l) and nitrite (NO^{2-} ; mg/l).

Figure.2: Map of Aghien lagoon with sampling sites, *the annotations "Point" of sampling sites map will be replaced by the suffix "ST" in the following text to name the sampling sites (Stations)*

II.3 Data analysis

Biological indices such as Taxa richness (S); Abundance, Shannon index (H) and Equitability (J) were used in the calculation of taxa richness and diversity (Ramade, 2003)

- Taxa richness (S): is a measure of species richens
- Shannon index diversity (H), H = - Σpi*log2pi. Where pi represents the relative abundance of species i in the sample (pi = ni / N).
- Equitability J index (H'max = log 2 S). J = H ' / log 2 S. Where; H was the Shannon and weavers index S was the number of species in samples.
- Occurrence percentage (F): F = Fi * 100 / Ft. where Fi = number of records containing species i and Ft = total number of surveys conducted. Depending on the value of F, four groups are distinguished (Albertoni, 2007) : - very frequent taxa (F ≥ 70%); - frequent taxa (40% F <70%); - infrequent taxa (10% F <40%); - sporadic taxa (F <10%).

The Shapiro-Wilk normality test was made to evaluate the normality of the different physicochemical parameters measured. The Kruskal-Wallis (multiple comparisons) and Mann-Whitney (two-sample comparison) tests were performed for the different comparisons. The distribution patterns of the taxa data were displayed using the Self-Organizing Map (SOM) by means of the toolbox developed by (Kohonen, 1995) for Matlab. The SOM training was made to classify the 132 samples (11 stations x 12 campaigns) according to the distribution of the aquatic snails. A map of 20 cell (4-line x 5-column) was chosen because the smallest quantification and topography errors are obtained at this size In order to characterize the distribution of the populations of these insects according to physicochemical parameters, a canonical correspondence analysis was carried out (Palmer, 1993) using the CANOCO program (Canonical Community Ordination, Version 4.5). The analysis was used in RDA (ReDundancy Analysis).

III. RESULTS

III-1 Variations of physicochemical parameters

Table II present the differents averages of the physicochemical parameters. For all the abiotic descriptors considered, there are no significant differences between the variations in the different studied stations (Kruskall Wallis test p> 0.05). However, for the abiotic, there is a significant difference between the variations from one season to another (Kruskall Wallis test and Mann-Whitneyp U test <0.05) (Table II).

Table II: Seasonal variations of physical and chemical parameters: Long dry season (LDS), Long wet season (LWS),: Short dry Season (SDS), Short wet season (SWS)

Parameters	LWS	LDS	SWS	SDS
Temperature (°C)	27.64±1.02^{a}	27.13±2.92^{a}	28.40±1.41^{b}	26.94±0.69^{a}
Conductivité (µs/cm)	79.74±6.52^{a}	70.74±7.30^{c}	66.90±2.63^{b}	54.53±3.19^{d}
Turbidity (UNT)	19.24±14.67^{a}	14.89±4.67 ^{c}	28.25±12.22^{b}	101.02±39.80^{d}
pH	8.07±1.05^{a}	7.56±0.75^{b}	7.63±0.56^{b}	6.72±0.62^{c}
Total phosphorus (mg/l)	0.38±0.40^{a}	0.2±0.17^{b}	0.24±0.08^{b}	0.26±0.13^{b}
Phosphate (mg/l)	0.08±0.05^{a}	0.10±0.15^{b}	0.07±0.10^{a}	0.12±0.05^{b}
Dissolved oxygen (mg/l)	5.07±0.83^{a}	7.67±0.85^{b}	6.89±0.83^{c}	5.50±1.03^{a}
Nitrates (mg/l)	1.37±1.14^{a}	0.41±0.40^{b}	1.35±0.95^{a}	1.79±1.00^{a}

Nitrites (mg/l)	0.02±0.03[a]	0.01±0.0[a]	0.04±0.07[b]	0.11±0.10[c]
Ammonium (mg/l)	0.18± 0,14[a]	0.16±0,17[a]	0.27±0.30[b]	0.13±0.05[c]

III.2 Taxonomic composition

For the branching of snails, a total of 1316 individuals were collected belonging to the classes of gastropods and bivalves. This class contains 09 families including 04 belonging to the Cenogasteropods, 04 belonging to the Basommatophores and 01 to the Archeogasteropods. The most diverse families are Thiaridae and Planorbidae with respectively 05 and 04 taxa. Bivalves are the least diversified class with only one taxon (Musculium) belonging to the family Sphaeriidae of the order Veneroids.
Spatial variations of the diversity index data are presented in Tables III. The station ST11 had the greatest taxonomic richness while the largest number of individuals (387 ind.) was harvested at the station ST10. However, in open water any taxon of snail has been recorded at the station ST5. Globally, the stations on the banks have more diversified taxonomic richness than those located in open water (ST3, ST5, ST7 and ST9). The Shannon H index at the stations ST2 and ST4 are the highest (1,913 and 1,912) while the station ST3 has the lowest value (0.9743). For equitability, the stations ST4 and ST9 had the higher values (0.9195 and 0.9366) while the lowest value is noted at the station ST10.

Table III : Spatial variations of diversity index

Diversity	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11
Taxa Richness_S	7	9	3	8	0	10	5	12	4	12	15
Individuals	87	183	8	172	0	67	36	208	19	387	149
Shannon_H	1.432	1.913	0.9743	1.912	0	1.797	1.343	1.868	1.298	1.584	1.895
Equitability_J	0.7359	0.8706	0.8869	0.9195	0	0.7804	0.8343	0.7516	0.9366	0.6374	0.6999

III.3 Seasonal variation of Snails abundance

Seasonal variation of snail's abundance was indicated in Figure 3. The short wet season recorded the highest abundance of snails with 433 individuals collected while the lowest abundance is recorded in the short dry season. At the taxa level, *Indoplanorbis exustus* was most abundant during the short wet season. The *Melanoïdes tuberculata*, *Indoplanorbis exustus*, *Lymnaea natalensis*, *Pachymelania byronensis*, *Pachymelania fusca Potadoma liricincta* and *Aplexa marmorata* taxa were recorded in all four seasons. However, *Bulinus guernei* and *Bulinus truncatus* were only harvested in a single season.

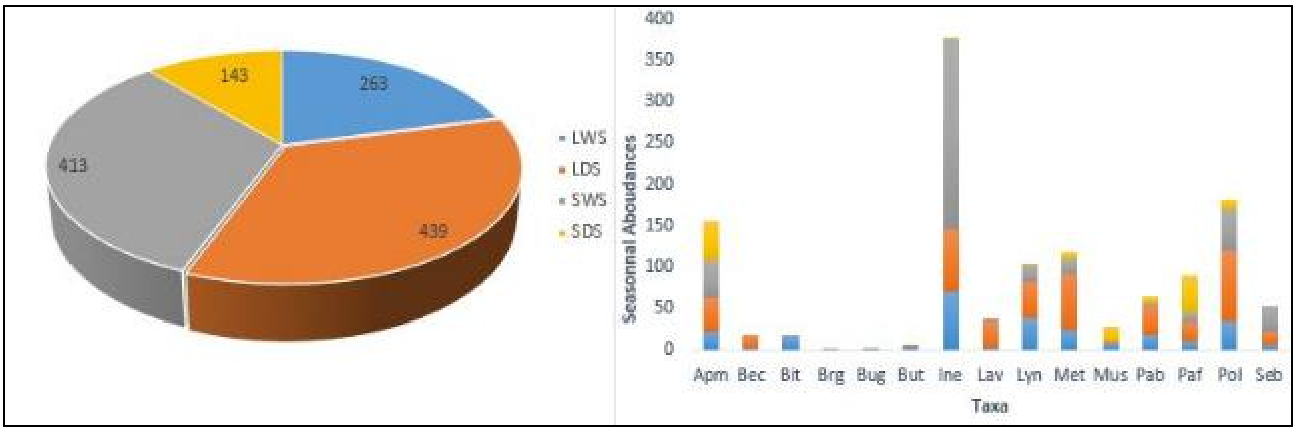

Figure 3 Seasonal abundances of snails

III.4 Snails Occurrences

The taxa occurrences are presented in Table IV. Taxa such as *Melanoïdes tuberculata*, *Indoplanorbis exustus* and *Lymnaea natalensis* have appeared frequently in all stations located on the banks of the Aghien lagoon (ST1, ST2, ST4, ST6, ST8, ST10 and ST11). However, in the stations located in the middle of lagoon, there is sporadic appearance of taxa like *Musculium sp.* and *Melanoides tuberculata*, whereas the Thiaridae *Pachymelania byronensis*, *Pachymelania fusca* and *Potadoma liricincta* were collected infrequently in the downstream station of the lagoon (ST7 and ST9).

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Table IV: List and occurrences of aquatic snails taxa in the Aghien lagoon: Code: **** = very frequent taxa (F ≥ 70%); *** = frequent taxa (40% F <70%); ** = infrequent taxa (10% F <40%); * = sporadic taxa (F <10%).

ORDRE	FAMILLE	TAXON	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11
Vénéroïdes	Sphaeriidae	*Musculium sp.*	-	-	*	-	-	-	*	*	-	**	**
Archaeogastéropodes	Neritidae	*Septaria borbonica*	-	*	-	*	-	-	-	****	-	***	**
Basommatophores	Lymnaeidae	*Lymnaea natalensis*	**	***	-	***	-	**	-	**	-	**	*
	Physidae	*Aplexa marmorata*	**	***	-	**	-	**	-	-	-	***	**
	Planorbidae	*Bulinus guernei*	-	-	-	-	-	*	-	-	-	-	-
		Bulinus truncatus	-	-	-	-	-	*	-	**	-	-	-
		Indoplanorbis exustus	**	****	-	***	-	**	-	**	-	***	***
	Viviparidae	*Bellamya capillata*	-	*	-	-	-	-	-	-	-	-	*
Cénogastéropodes	Ampullariidae	*Lanistes varicus*	*	**	-	**	-	**	-	-	-	**	**
	Bithyniidae	*Bithynia tentaculata*	-	-	-	**	-	-	-	*	-	-	*
	Hydrobiidae	*Hydrobia gabonensis*	*	*	-	**	-	**	-	-	-	*	*
	Thiaridae	*Bridouxia giraudis*	-	-	-	-	-	-	-	*	-	-	*
		Melanoïdes tuberculata	**	***	*	****	-	**	*	**	*	***	**
		Pachymelania byronensis	-	-	-	-	-	*	**	***	**	**	**
		Pachymelania fusca	-	*	-	-	-	-	**	***	**	*	***
		Potadoma liricincta	*	-	*	-	-	**	**	****	***	***	***

III.5 Classification of samples from SOM

The cells of the self-organizing map were classified into three groups (I to III) from a hierarchical classification analysis of the SOM cells with the Ward method and the Euclidean distance (Figure 1). The groups are illustrated by different patterns on the Kohonen map (Figure 4, 5). Group III (test G, p <0.05) contains the samples mainly from stations ST9 and ST11. This group is restricted to taxa such as *Musculium sp*,. *Septaria borbonica, Potadoma liricincta, Pachymelania byronensis* and *Pachymelania fusca.* Group II (G-test, p <0.05) is composed of samples mainly from ST4, ST6, ST10 and ST2 stations and is composed of taxa such as *Aplexa marmorata, Bellamya capillata, Bithynia tentaculata, Bridouxia giraudis, Bulinus truncatus, Bulinus guernei, Indoplanorbis exustus, Lanistes varicus, lymnaea natalensis* and *Melanoides tuberculata.* However, the group I has no indicator taxa but contains samples from stations ST6, ST 7 and ST10.

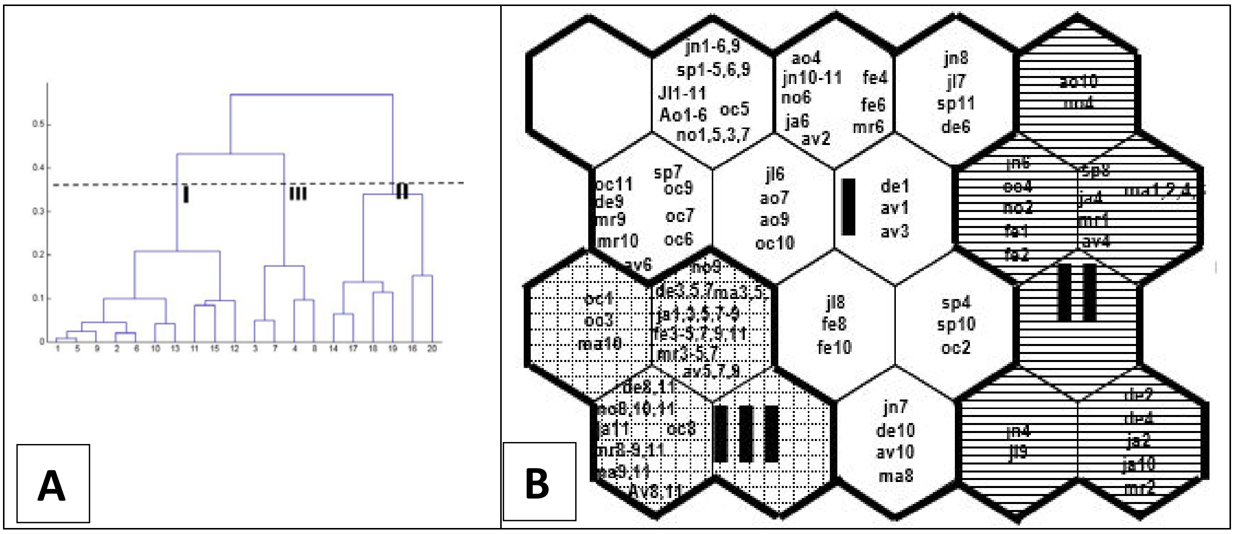

Figure 4: **A** : Hierarchical classification of SOM cells with the Ward method. **B** : Classification of samples with environmental variables in the SOM layer. The Latin numbers I, II and III= represent different identified groups by clusters. The acronyms in the hexagonal units represent different samples (station–month–number of sample).

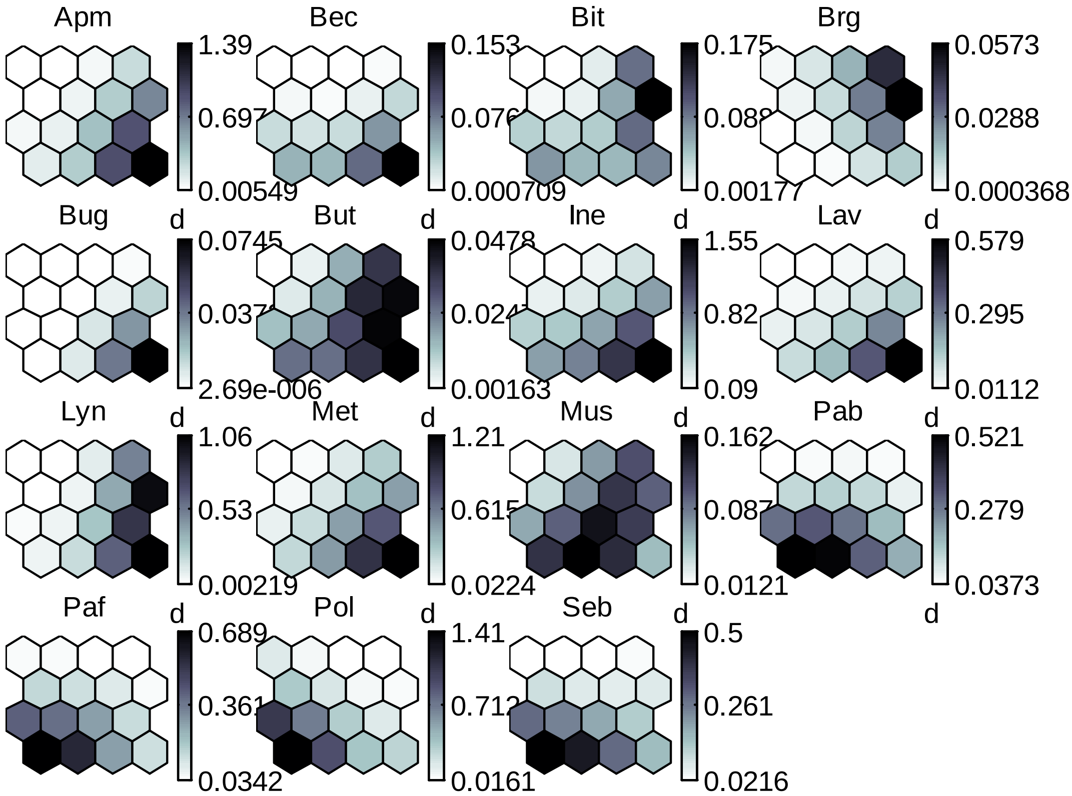

Figure 5.Component planes displaying the contribution of each environmental variable to classification of samples.Dark represents high values of each variable, whereas pale is for low values. The values were calculated during the learning process of the network. **Apm**=*Aplexa marmorata*, Bec=*Bellamya capillata*, **Bit**=*Bithynia tentaculata*, **Brg**=*Bridouxia giraudis*, But=*Bulinus truncatus*, Bug=*Bulinus guernei*, **Ine**=*Indoplanorbis exustus* **Lav**=*Lanistes varicus*, **Lyn**=*Lymnaea natalensis*, Met=*Melanoïdes tuberculata.* **Mus**=*Musculium sp*, **Pab**=*Pachymelania byronensis*, **Paf**=*Pachymelania fusca*, **Pol**=*Potadoma liricincta*, ***Seb***=*Septaria borbonica*

III.6 Influence of physicochemical parameters on the distribution of snails:

A redundancy analysis (RDA) was performed between the 10 physico-chemical parameters and the abundances of the 15 taxa of aquatic snails (Figure 6). The representativity of all the axes is very significant (p-value<0.05). Axis I is significant (p-value = 0.0017) and expresses 51.16% of the information, Axis II expresses 27.1%, for a total of 78.26% for both axes. The analysis of the graph shows that phosphorus, pH and turbidity was most influenced the variation of abundances of snails. Axis I reveals an association of phosphorus, ammonia, nitrite and nitrate with *Aplexa marmorata, Bulinus guernei and Melanoides tuberculata* while *Pachymelania fusca, Potadoma liricincta, Septaria borbonica, Bridouxia giraudis* and *Bulinus truncatus* are associated with turbidity. This taxa are negatively pegged to parameters like pH, phosphorus, temperature, nitrates and ammonia. On this same axis I, the conductivity is associated with *Pachymelania byronensis* and negatively correlated with *Bellamya capillata* and *Bithynia tentaculata* which are associated with phosphate. On axis II, *Pachymelania fusca, Potadoma liricincta, Septaria borbonica, Bridouxia giraudis and Bulinus truncatus* are influenced by very low temperatures, pH and dissolved oxygen levels. However, taxa such as *Indoplanorbis exuts and Lymnaea natalensis* are almost unaffected by the measured physicochemical parameters.

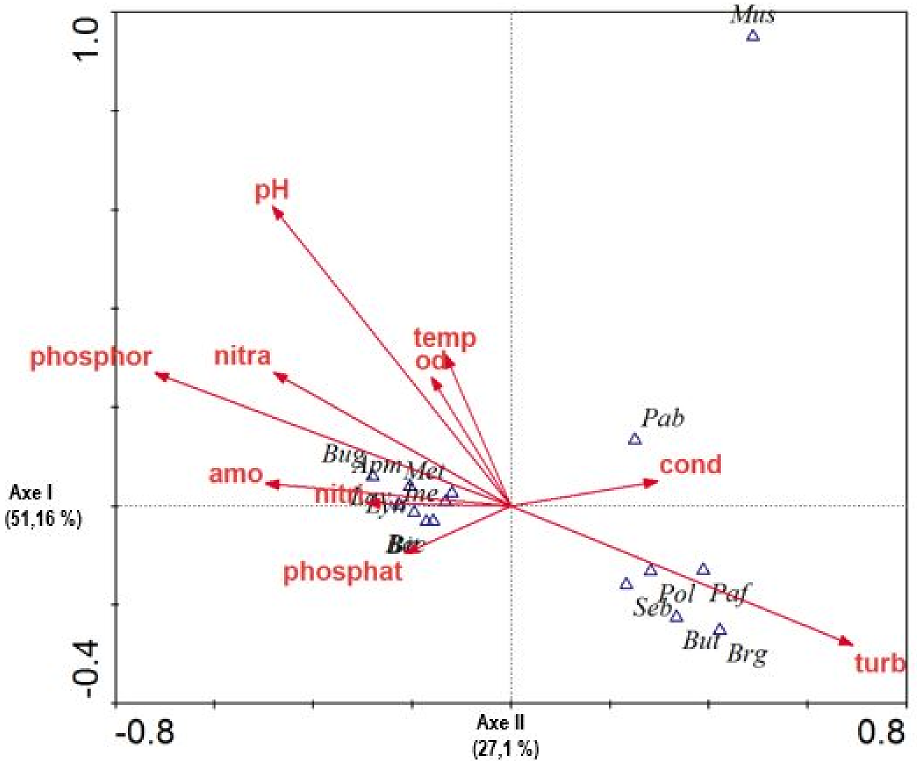

Figure 6: Canonical correspondence analysis (RDA) highlighting the influence of physicochemical parameters on the distribution of snails in Aghien lagoon. **Apm**=*Aplexa marmorata*, **Bec**=*Bellamya capillata*, **Bit**=*Bithynia tentaculata*, **Brg**=*Bridouxia giraudis*, **But**=*Bulinus truncatus*, **Bug**=*Bulinus guernei*, **Ine**=*Indoplanorbis exustus* **Lav**=*Lanistes varicus*, **Lyn**=*Lymnaea natalensis*, **Met**=*Melanoïdes tuberculata* **Mus**=*Musculium sp.,,* **Pab**=*Pachymelania byronensis*, **Paf**=*Pachymelania fusca*, **Pol**=*Potadoma liricincta*, ***Seb***=*Septaria borbonica*

IV. DISCUSSION

Overall, at the spatial level, all the means of the abiotic variables do not differ significantly between the stations while they differ according to the seasons, this shows that the variations of these parameters correlate with the impacts induced by the seasons but are not influenced by human activities in their immediate environment. The fluctuations observed would be attributable to a homogeneous distribution at all the stations of the Aghien lagoon of the impacts of anthropogenic and seasonal activities such as domestic and industrial discharges, runoff water (Humbert, 2012).

In general, the faunal composition of lagoon snails corresponds to that described in African freshwaters (Ogbeibu and Oribhabor, 2002; Diomandé and Gourène, 2005). The gastropods are divided into three orders: Basommatophores, Cenogasteropods and Archeogasteropods. This class contains 09 families However, the order of the Cenogastropods are quite well diversified with 08 species belonging to 04 families. The most diverse families are Thiaridae and Planorbidae. Species such as *Lymnaea natalensis*, *Melanoïdes tuberculata*, *Indoplanorbis exustus, Aplexa marmorata*, which are intermediate hosts of parasites of *Schistosoma mansoni* (Diomandé, 2009) frequently appeared in the records. The best indices of diversity namely great taxonomic richness, abundance and Shannon index were recorded at the stations located on the banks of the Aghien lagoon, which would be linked to favorable conditions for the proliferation of certain species of snails such as plants. This is not the case at the stations located in the open where all the organisms such as *Potadoma liricincta*, *Pachymelania fusca and Pachymelania byronensis* have only taken from the bottom of the water. This finding is consistent with the results of stations located along the longitudinal axis of the lagoon which are preferentially populated by Thiaridae.

This observation is correlated with the SOM map result which classifies them in group III, which states that these snails are found preferentially in downstream of the Aghien lagoon towards the canal with the Potou lagoon. Group II given by the SOM shows that the snails have a preference for shelters located on the bank and near to habitations where there are domestic discharges that would induce a change in environmental conditions.

Canonical analysis shows that turbidity, pH and phosphorus have strongly influenced the dynamics of snail's population in the Aghien lagoon, which shows the impact of seasonal human activities on the distribution of these organisms. Indeed, through the residues of the factories and agricultural activities, the mineral elements are precipitated in the lagoon by the runoff waters which would modify strongly the turbidity, the contents in phosphorus and acid.

V. CONCLUSION

Several species of snails colleted in the Aghien lagoon are important intermediate hosts of parasites, particularly Planorbidae *Indoplanorbis exustus*, which pose a potential risk to public health was most abundant in the four seasons. The stations on the banks are richer and more diversified than those located in open water. Phosphorus, pH, and turbidity mainly influence the spatial distribution of snails. *Melanoides tuberculata* is a quasi-ubiquitous species whose spatial distribution is weakly influenced by pH, phosphorus and turbidity.

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