International Journal of Multidisciplinary and Current Research
ISSN: 2321-3124
Research Article
Available at: http://ijmcr.com

Water Quality and Dynamic of Schistosomiasis Intermediate Host Snails in the Lake Areas, District of So-Ava, Southern Benin

Ablavi A. Onzo-Aboki[1], Moudachirou Ibikounlé[1,2,*], Elokou Alabi[1], Samoussou Dine Mahama[1], Armel Djenontin[1], Cédric Pennetier[4] and David Courtin[5]

[1]Départment de Zoologie. Faculté des Sciences et Techniques. Université d'Abomey-Calavi. 01BP526 Cotonou. Bénin
[2]Programme National de Lutte contre les Maladies Transmissibles. Ministère de la Santé. 01BP882 Cotonou. Bénin
[3]Département de Physiologie Animale. Faculté des Sciences et Techniques. Université d'Abomey-Calavi. 01BP526 Cotonou. Bénin
[4]IRD. UMR224 MiVEGEC. France
[5]IRD. UMR216 MERIT. France

Received 05 Oct 2018, Accepted 07 Dec 2018, Available online 09 Dec 2018, **Vol.6 (Nov/Dec 2018 issue)**

Abstract

Objectives: *Urinary schistosomiasis is known to be endemic in the lake Nokoué areas of the District of So-Ava. For the past ten years, the National Control Programme for Communicable Diseases of the Ministry of Health has been making efforts to control schistosomiaisis morbidity through mass drug treatment with Praziquantel. This study aimed to assess the diversity and dynamic of potential snails known as schistosomiasis intermediate hosts.*
Methodology and Results: *This study was carried out for 12 months (from July 2015 to June 2016) and consisted in the periodical analysis of the physical and chemical water parameters (temperature, oxygen concentration, pH, nitrite and nitrate rates. Salinity, total dissolved solids (TDS) and, biochemical oxygen demand) in relation with diversity, distribution and relative abundance of freshwater snails (Bulinus forskalii, B. globosus and B. truncatus). To this end, seven harvesting sites on Lake Nokoué were, reasonably selected for monthly hydrobiological and malacological data monitoring. The results showed a variable correlation between the dynamic of schistosomiasis intermediate host snails and several physico-chemical water parameters. Bulinus globosus was negatively influenced by salinity and nitrate rates while B. forskalii was negatively influenced by pH, Oxygen, TDS, salinity and nitrate rates. The three species of freshwater snails were strongly influenced by the water temperature.*
Conclusion: *The results suggest a seasonal schistosome transmission induced by the seasonal dynamic of intermediate host snails. Water quality seems appropriate to the development of host snails from December to March and would be the strong period of schistosomiasis transmission. However, furthermore studies will need for well understanding the dynamic transmission necessary for developing adapted strategy control.*

Keywords: *Nokoué Lake, So-Ava, freshwater host snails, urinary schistosomiasis.*

1. Introduction

Schistosomiasis remains one of the most widespread poverty-related Neglected Tropical Diseases (NTD) in the world and particularly affects people living in disadvantaged communities with limited access to safe drinking water or inadequate sanitation facilities such as many countries in sub-Saharan Africa (Hotez *et al*., 2009; WHO, 2018). It is also present in developed countries such as Corsica in France (Holtfrete *et al*., 2014; Boissier *et al*., 2015). According to World Health Organization estimates the disease causes an annual loss of 1.7 to 4.5 million (WHO, 2018) and fifty percent of endemic countries are located in Africa and it is estimated that about 85 to 90% of people at risk live in sub-Saharan Africa (Chitsulo, 2000). The parasite has a life cycle whose development necessarily passes through a final vertebrate mammalian and intermediate host which is a pulmonary gastropod snails (*Bulinus*, *Biomphalaria*) living in fresh waters and its contamination was caused by contact with waters containing cercarial larvae released by snails that have previously been infested by miracidia from the hatching of eggs released into the water by urines or patients' feces (WHO, 2006). The control of this endemic requires preventive chiomiotherapy (PCT), sanitation and vector control.

In Benin, schistosomiasis is known as a public health problem and epidemiological studies reveal the presence of two human species: *S. haematobium* (urinary form) widely distributed and whose infestation frequencies can vary from 4% to 100% and the species *S. mansoni*

[*]Corresponding Author: Tél: +229 9764 5885; Fax: +229 2130 00 28, ORCID ID: 0000-0002-3640-0175
DOI: https://doi.org/10.14741/ijmcr/v.6.6.16

(intestinal form) found in a focused manner with prevalence up to 60% (Ibikounlé *et al*., 2009; 2013). The district of So-Ava was known as hyper-endemic to urinary schistosomiasis with prevalence of up to 100% (Ibikounlé *et al*., 2009; 2013; 2014a,b) and thanks to the technical and financial support of the ENVISON project of Research Triangle Institute International funded by USAID, PCT campaigns with Praziquantel have started since 2015 in the endemic districts according to WHO guidelines (WHO, 2006). This study aim to evaluate influence of water quality on schistosome intermediate host snail dynamics in Lake Nokoué areas in the District of So-Ava in order to optimize the preventive action undertaken by National NTD program.

2. Materials and Methods

2.1. Study area

The study was conducted in Lake Nokoué located in the District of So-Ava (between 6°20′ and 6°30′00″ N and 2°20′00 and 2°25′00″ E) which is one of the eight Districts in the Atlantic Department in southern Benin. The human population is about 100,000 inhabitants with an area of 218 km² according to the latest General Population and Housing Census (INSAE-RGPH4. 2015). It is a permanent natural lake influenced by the Atlantic Ocean and filled by waters from the northern half of Benin. The average annual rainfall was about 1255.8 mm (INSAE-RGPH4, 2015). The climate is mainly sub-equatorial, with two dry seasons (August-September and December-March) and two rainy seasons (April-July and October-November). The average monthly temperatures vary between 22°C and 35°C. More than 82% of the population of the District of So-Ava live on water or in flood-prone areas. The ethnic groups present in the District are the Toffin (70%), Fon and Aizo (20%), Yoruba (8%) and others (2%) and the main activity is fishing.

2.2. Water and snail Samplings

Sampling was carried out over a 12-month period and focused on monthly water sampling for the measurement of physico-chemical parameters combined with the collection of potential snails as intermediate hosts of schistosomiasis. Twelve sampling campaigns were carried out between July 2015 and June 2016.

Seven villages (So-Ava, Sotchanhoué, Sotchanhoué-quartier, Sotchanhoué-Mariakpa, Sozounko-Gbedoutin, Sozounko-Somaï and Sozounkp-Zounhomè) (Figure 1) were chosen based on previous work of Gnohossou (2006), Goussanou (2012) and Ibikounlé *et al* (2009 and 2013). The selection criteria were: i) the level of schistosomiasis endemicity, ii) the variation of water physico-chemical parameters and iii) the type of environment. Water samples for physico-chemical analysis were taken from 1.5-litre plastic vials. Samples are taken between 08:00 and 11:00 AM and water was immediately covered with aluminum foil and then returned to the laboratory for analysis. Some analyses were carried out on site and others in the laboratory.

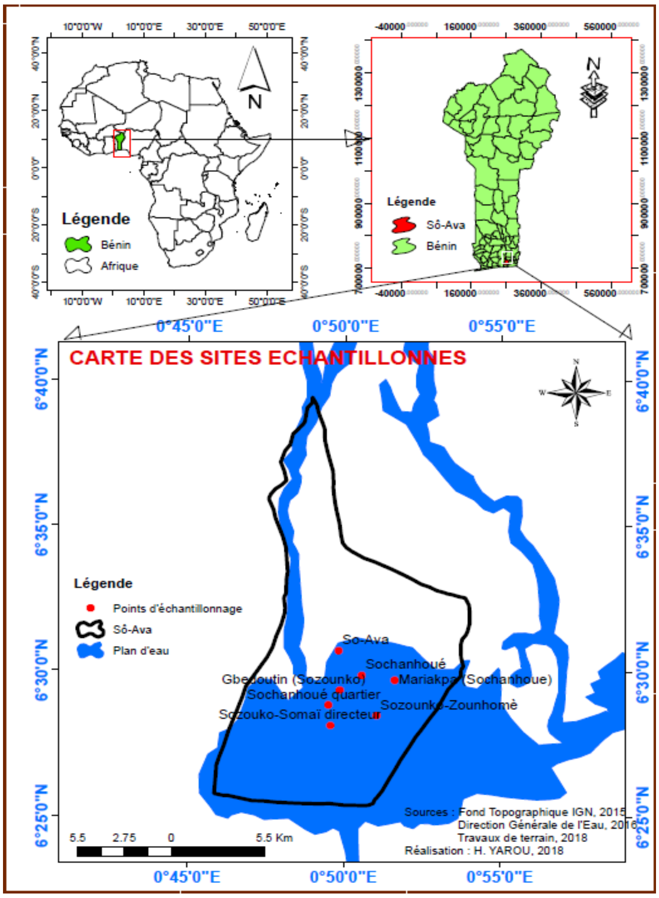

Figure 1. Sampling sites

Snail Sampling: Freshwater snails were searched as initially described by Ibikounlé *et al* (2013) in the mud and on floating leaves using metal sieves or strains with elongated (1.5 to 2 m) rounded, 20 cm diameter shallow and round bottom (dipping technique). The meshes of the sieve are about 2 mm in diameter. Snails were harvested by dipping the sieve into the water under the floating leaves. By small shocks the snails previously attached to the leaves detach and were recovered from the bottom of the sieve. Sometimes relatively large snails are collected on sight in shallow vessels. At the level of each village malacological prospection lasts one hour and was carried out by two teams of 3 people (one boat conductor and two collectors per team). The first seven successive days of each month were reserved for prospection (1 day per village). To reduce the mortality of the samples collected the snails are stored in labelled plastic boxes each containing water and a few leaves of the sampling medium as food. They are covered with a perforated cover with a few holes to allow the air to be renewed in the enclosure.

2.3. Water analysis

Nine physical and chemical water parameters were measured monthly between 8am and 11am: temperature, pH, salinity, turbidity, Total Dissolved Solids (TDS), dissolved oxygen, nitrate rate, nitrite rate and biochemical oxygen demand (BOD5). The data were obtained in two stages (in situ and in the laboratory) depending on the case.
- In situ: pH, temperature and dissolved oxygen were determined using a multiparameter pH/Oxi340i/SET device. Conductivity, turbidity, total dissolved solids and salinity were determined using a cond340i/SET conductivity meter. The geographical coordinates were recorded using a GARMIN GPS of the GPS 72 hours.
- In the laboratory: nitrates and nitrites were determined by molecular absorption spectrophotometric analysis techniques with reagents such as: 4-aminobenzene sulfonamide, sodium salicylate. The BOD5 is measured in the laboratory of the General Directorate of Water of the Ministry of Energy and Water.

2.4. Parasitological test

Specimens of snails brought back to the laboratory were sorted and identified using Brown's (1994) identification key. The specimens of each group of snails were counted and subjected to a parasitological test. The snails were then placed in small groups of 10 in pill boxes containing well water and exposed to natural light. This makes it possible to separate within a group of snails infested individuals (releasing at least one type of cercariae) from healthy individuals. This test lasts 24 hours for each batch of snail. If the cercarial emission was detected in a pill box the infestation test was repeated individually to isolate the parasitized snail. To determine all positive cases, a second control test was carried out the following month. In the case of parasitized snails a secondary sorting was carried out according to the type of cercariae emitted. The different types of cercariae were then collected and studied in order to identify the species involved in the transmission of schistosomiasis in the study area. The figure 2 show an example of site of snail collection.

Figure 2: Site of snail collection

2.4. Statistical analysis

The summary tables of the descriptive statistical results (means, standard deviations) and graph construction were produced using the Excel spreadsheet (version 2007) and the SPSS software (IBM SPSS Statistics 20). Normality was verified using the Ryan-Joiner test while the Levenne test was used to check the homogeneity of variances. The results of these two tests made it possible to choose between parametric and non-parametric tests. Thus the one-factor Analysis of Variance (ANOVA) (when normality was verified and variances were homogeneous and Kruskal-Wallis or Mood median test if not used in combination with multiple comparison tests (Tukey and Tamhane) for comparing the means of different physico-chemical parameters as well as the biological parameters obtained between the sampled stations. The factor considered was either site or month. Also, the Correspondence Factor Analysis conducted with Minitab (16) made it possible to establish and describe in a two-dimensional plan dependence or concordance between the abundance of the different macroinvertebrate families harvested and the study site. Pearson and Spearman Rho correlation matrices were developed to verify the existence of a bivariate correlation between studied environmental factors biological data and analytical results (Alhou, 2007; Amri *et al*., 2014).

3. Results

3.1. Physico-chemical of water

The descriptive statistics of the measured data and the significance of their variation over the twelve samples and between the different sites are summarized in Table 1. This table shows the temporal variations of the physico-chemical parameters of water measured between July 2015 and June 2016.

Table 1. Average of temporal variations of the physical and chemical parameters of water

Parameter	July 2015	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June 2016
Temperatur (°C)	27.3±0.4 [26.8-27.9]	26.1±0.3 [25.5-26.3]	27.3±0.2 [27.1-27.5]	29.9±0.6 [29.2-30.8]	30.9±0.8 [30.1-32]	30.8±0.8 [29.8-31.9]	25.5±0.4[25-26.2]	31.6±1.1 [30-32.8]	31.6±1.1 [30-32.8]	33.5±0.6 [32.8-34.5]	31.9±0.3 [31.4-32.2]	30.8±0.9 [29.1-31.6]
PH	5.6±0.7 [4.7-6.4]	6.3±0.5 [5.4-7.1]	6.5±0.1 [6.4-6.6]	6.6±0.1 6.5-6.7]	6.6±0.1 [6.4-6.8]	6.9±0.2 [6.8-7.2]	7.6±0.8 [6.8-8.8]	7.9±0.6 [7.2-8.9]	7.9±0.6 [7.2-8.9]	8.2±0.5 [7.3-8.6]	7.9±0.5[7.2-8.5]	6.9±0.4[6.4-7.5]
O2 (mg/L)	1.32±0.35 [0.8-1.7]	2.41±0.48 [1.7-32]	2.3±0.2 [2.1-2.8]	0.79±0.16 [0.67-1.16]	0.78±0.18 [0.50-0.98]	1.08±0.26 [0.74-1.54]	2.3±0.99 [1.2-3.7]	3.9±0.9 [2.3-5.3]	3.9±0.99 [2.3-5.3]	3.49±0.90 [2.08-4.42]	3.28±1.33 [1.3-5.32]	3.2±1.1 [0.96-4.25]
TDS (mg/L)	548.1±667.9[86-1791]	297.3±300.6[77-787]	36.1±1.9 [35-40]	81.3±27.9 [60-140]	137.1±28 [100-180]	147.0±124 [71-422]	2100±1288 [320-3770]	6989±845 [6000-8150]	6989±846 [6000-8150]	11323±2883 [6150-15550]	9032±2817 [3560-12300]	3307±27863 [310-8485]
Salinity	0.5±09 [0.0-2.20]	0.2±0.3 [0.0-0.8]	0.0±0.0 [0.00]	0.03±0.08 [0.0-0.2]	0.0±0.0 [0.0-0.0]	0.03±0.08 [0.0-0.2]	1.7±1.23 [0.1-3.3]	6.19±1.5 [3.2-7.5]	6.19±1.5 [3.2-7.5]	13.79±3.7 [7.1-19.4]	10.86±3.58 [4.0-15.1]	3.74±3.36 [0.2-10.10]
Turbidity (NTU)	60.9±28.7 [34-119]	84.4±31.7 [42-120]	31.9±2.5 [30-37]	13.0±3.2 [9.0-19.0]	0.0±0.0 [0-0]	52.0±19.2 [29-79]	25.9±14.5 [12.0-56.0]	16.7±5.6 [9.0-26.0]	16.7±5.6 [9.0-26.0]	11.6±1.9 [8.0-13.0]	1.6±2.9 [0.0-8.0]	15.3±9.2 [5.0-34.0]
Nitrates (mg/L)	0.3±.02 [0.1-0.7]	0.2±0.1 [0.1-0.5]	0.1±0.0 [0.1-0.1]	3.4±3.0 [0.7-8.3]	1.8±1.3 [0.1-4.0]	1.9±1.3 [0.1-3.8]	3.2±2.9 [0.1-7.9]	0.8±0.3 [0.3-1.1]	0.8±0.3 [0.3-1.1]	5.6±3.1 [2.4-11.6]	6.2±12.3 [0.1-33.5]	4.1±6.0 [0.1-13.9]
Nitrite (mg/L)	0.0±0.01 [0-0.02]	0.02±0.04 [0-0.10]	1.0±0.6 [0-2.0]	0.02±0.01 [0-0.03]	0.02±0.02 [0-0.06]	0.02±0.02 [0-0.06]	0.08±0.06 [0-0.16]	0.01±0.01 [0-0.04]	0.01±0.01 [0-0.04]	0.4±0.01 [0.01-0.08]	0.05±0.03 [0.01-0.08]	0.14±0.3 [0-0.81]
DBO5 (mg/L)	3.6-676.8	0.0-0.15	0.0-0.94	0.0-0.5	0.0-1.4	0.0-4.6	0.0-0.0	0.0-0.0	0.0-0.7	0.2-4.5	5.0-312.5	2.7-85.9
	4.4±4.2 [0-10]	15.4±8.2 [7.0-30.0]	18.1±24.7 [6.0-74.0]	16.1±21.7 [4.0-65.0]	4.9±1.6 [3.0-7.0]	8.6±6.8 [3.0-22.0]	7.6±4.8 [4.0-18.0]	8.4±7.5 [3.0-25.0]	8.4±7.5 [3.0-25.0]	6.9±5.6 [2.0-18.0]	6.6±4.1 [2.0-12.0]	8.7±4.1 [4.0-16.0]

The analysis showed that the average temperature of Lake Nokoué varies from 25°C (January) to 33.5°C (April). The highest values of pH (8.2), TDS (11323 mg/L), salinity (13.79); nitrite rates (0.4 mg/L) were recorded in April and the lowest values were recorded in July (5.6), September (36.1 mg/L), November (0) and July (0 mg/L) respectively. Turbidity varies from 0 NTU in November to 84.4 NTU in August. The highest values for nitrates (6.2 mg/L); and Biochemical Oxygen Demand (18.1 mg/L) were recorded in May, July and September respectively compared to 0.1 mg/L (September), 0 µg/L (January and February) and 4.4 mg/L (July). As for oxygen the highest value was recorded in February and March (3.92 mg/L) and the lowest in November (0.78 mg/L).

All environmental variables: temperature, pH, dissolved oxygen, total dissolved solids, salinity, turbidity, nitrates, nitrites and biochemical oxygen demand show a significant difference ($p < 0.05$) between July 2015 and June 2016 (Table 2).

Table 2 p-values of ANOVA test for the spatial and temporal variation of the physico-chemical parameters of the water of Lake Nokoué

Variable	Between month	Site levels
T°C	0.0001*	0.994
Ph	0.0001*	0.397
O2	0.0001*	0.178
TDS	0.0001*	0.740
Salinity	0.0001*	0.594
Turbidity	0.0001*	0.515
NO_3^-	0.0001*	0.783
NO_2^-	0.003*	0.892
DBO_5	0.032*	0.02*

* : p< 0.005

Table 3: Spatial variation of physico-chemical parameters of water of Lake Nokoué

Parameter	Sochanhoué	Sochanhoué-Quartier	Sozounko Somaï	Sozounko Zounhomè	Sozounko Gbedoutin	Sochanhoué Mariakpa	Sô-Ava
T°C	29.6±2.6	30.1±2.9	29.9±2.7	29.9±2.7	29.9±2.7	29.6±2.4	29.4±2.4
	[25.0-32.8]	[25.4-33.7]	[25.4-33.3]	[25.5-33.8]	[25.8-34.5]	[26.1-33.8]	[25.3-32.8]
pH	6.7±0.6	6.8±0.9	7.4±1.1	7.1±1.1	7.4±0.1	7.2±0.7	6.9±0.7
	[5.3-7.5]	[4.7-8.0]	[5.2-8.9]	[5.2-8.4]	[6.3-8.8]	[6.4-8.4]	[6.1-8.5]
O2	2.4±1.2	2.3±1.3	3.1±1.8	2.3±1.2	2.5±1.3	2.6±1.5	1.5±0.6
	[0.7-4.0]	[0.6-4.1]	[0.5-5.3]	[0.8-3.9]	[0.7-4.2]	[0.7-4.9]	[0.9-2.3]
TDS	2732±3686	2924±3991	3934±4323	4960±5393	3389±4256	3861±4676	2108±2947
	[35-10050]	[35-10580]	[36-12000]	[37-15550]	[35-12580]	[35-12350]	[40-7000]
Salinity	2.9±4.3	3.2±4.8	4.3±5.1	5.5±6.6	3.6±4.9	4.1±5.5	1.5±2.4
	[0-12.2]	[0-13.3]	[0-14.7]	[0-19.4]	[0-14.6]	[0-15.2]	[0-7.1]
Turbidity	17.8±13.8	19.9±14.3	30.3±33.5	26.1±23.2	28.7±28.9	28.4±29.7	41.3±43.4
	[0-44]	[0-42]	[0-116]	[0-82]	[0-84]	[0-103]	[0-120]
Nitrates	2.5±2.6	2.5±3.5	1.5±1.8	4.2±9.5	2.3±3.9	1.2±1.4	2.5±3.7
	[0.1-7.9]	[0.1-11.8]	[0.1-6.6]	[0.1-33.5]	[0.1-13.9]	[0.1-4.0]	[0.1-11.6]
Nitrite	0.1±0.3	0.1±0.3	0.1±0.3	0.2±0.6	0.2±0.3	0.1±0.3	0.0±0.0
	[0.0-1.0]	[0.0-1.0]	[0.0-1.0]	[0.0-2.0]	[0.0-1.0]	[0.0-1.0]	[0.0-0.1]
	0.0-135.1	0.0-312.5	0.0-160.2	0.0-351.0	0.0-379.8	0.0-428.4	0.0-676.8
DBO5	5.3±2.6	6.5±7.7	7.8±4.4	9.9±4.0	6.1±2.3	14.7±7.4	16.3±24.9
	[0-9]	[0-30]	[0.0-20]	[3.0-20.0]	[2.0-11.0]	[3.0-25.0]	[2.0-74.0]

From one site to another, the average of temperature varies from 29.4°C (So-Ava) to 30.1°C (Sochanhoué). In So-Ava, the dissolved oxygen level (1.5 mg/L), TDS (2108) and salinity (1.5 mg/L) are low. High values are recorded in So-Mayi for dissolved oxygen (3.1 mg/L), TDS (4960 mg/L) and salinity (5.5 mg/L). The highest nitrates and nitrites were recorded in Zounhomey (4.2 mg/L) for nitrates, Zounhomey and Gbèdoutin (0.2 mg/L) for nitrites, the lowest values are recorded in Mariakpa (1.2 mg/L) for nitrates and So-Ava (0 mg/L) for nitrites. The Sochanhoué site was characterized by a low pH (6.7) and biochemical oxygen demand (5.3 mg/L). The highest values were recorded in Gbèdoutin (7.4) for pH and Zounhomey (9.9 mg/L) for biochemical oxygen demand.

The most high values have been recorded at Gbèdoutin (7.4) for the pH at Zounhomey (9.9mg/L) for the biochemical demand in oxygen mean while only the biochemical demand in oxygen presents a significant difference to threshold of 5% between the stations (table 2)

3.2. Diversity of Snails

Several snail species were collected, but six species of gastropoda snails were considered in this study analysis. These are four snail species known as potential intermediate hosts of schistosomiasis (*Bulinus forskalii*, *B. globosus*, *B. truncatus* and *Indoplanorbis exustus*) and two other non-vector snails known to be less sensitive to environmental pressures (*Lanistes variscus* and *Physa marmorata*). The diversity of the six snail species was presented in Table 4.

Table 4 Diversity of Snails in Lake Nokoué

	I. Exustus	*B. Truncatus*	*B. Globosus*	*B. Forskalii*	*P. Marmorata*	*L. variscus*
Sochanhoué	40	0	0	212	55	0
Sochanhoué.Quatier	35	111	112	315*	37	01
Sozounko Somaï	28	0	0	05	36	01
Sozounko Zounhomè	21	112	0	17	29	01
Sozounko Gbèdoutin	37	0	121*	29	24	0
Sochanhoué Mariakpa	46	0	0	17	45	0
So-Ava	10	0	145	149*	628	01
Total 1	217	223	378	744	854	04
Total 2	2420					

*: snails found naturally infected by schistosome cercaria.

A total of 2420 specimens of the six snail species were collected, including 55.58% of snails known as intermediate hosts of schistosomiasis. *B. forskalii* and *I. exustus* were collected from all study sites. *B. globosus* was harvested in October and December while *B. forskalii* was harvested in September, October and June.

Figure 2 showed the taxonomic distribution of snails according to study sites and sampling months assessed with the Correspondence Factor Analysis (CFA). This analysis relates a structure of communities on the different sites. The CFA from July 2015 to June 2016 explains 54.56% of the observed variability, of which 33.98% is explained by axis 1 and 20.58% by axis 2. An analysis of this distribution shows that *bulins* were not observed in July, August, February, March, April and May. It should be noted that Sochanhoué Quartier and Zounhomey environmental conditions seem to be favorable for *B. forskalii* development in the months of November and December. Gbèdoutin, Sotchanhoué, Mariakpa and Somaï environmental conditions were favorable to *I. exustus* in September, November and December, *B. forskalii* in October, sometimes by *P. marmorata* in December while So-Ava prefers much more *P. marmorata* in the months of September, October and November, Zounhomey is preferred more by *B. truncatus* in December, while in Sochanhoué, in January there are more *B. forskalii*.

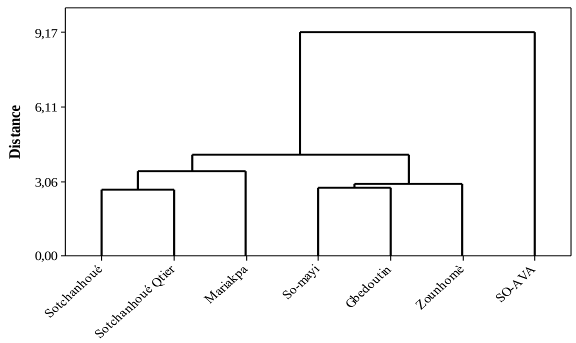

Figure 2 Dendrogram of the absolute abundance of *bulins* at the sampled sites in Lake Nokoué, using the Ward method

From the analysis of the absolute abundance of bulins at the seven stations sampled on Lake Nokoué, we can distinguish three groups of stations:

The first group was composed of Sochanhoué; Sochanhoué Quartier and Mariakpa sites, the second group composed of So-Mayi, Gbèdoutin and Zounhomè and the third group composed of Sô-Ava. The first group seems to be preferred much more by *B. forskalii* while the second group is preferred by both *B. forskalii* and *B. globosus* while in Sô-Ava, there is more *P. marmorata* (third group); this is confirmed by the correlation factor analysis (CFA). The difference here is that *B. truncatus* prefers Zounhomè more.

3.3 Water quality and snail dynamics

The table 5 described the correlation between water quality parameters and dynamic of snails.

Table 5 Non-parametric correlations (Tau-Kendall) between *Bulinus* and physico-chemical parameters at the stations

Sites	*Parameter*	*I. exustus*	*B. globosus*	*B. forskalii*	*P. marmorata*
Sotchanhoué	O_2	-0.736**	-0.481	-0.265	-0.704*
	Salinité	-0.530	-0.280	-0.017	-0.641*
Sotchanhoué Quartier	O_2	-0.754**	-0.301	-0.440	-0.727**
	TDS	-0.405	-0.251	-0.278	-0.615*
	Salinity	-0.530	-0.273	-0.263	-0.642*
So Mayi	O_2	-0.725**	-	-0.374	-0.790**
	TDS	-0.533	-	-0.652*	-0.765**
	Salinity	-0.643*	-	-0.526	-0.817**
	DBO5	-0.638*	-	0.117	-0.417
Zounhomé	O_2	-0.538	-	-0.366	-0.680*
	Salinity	-0.609*	-	-0.469	-0.639*
Gbedoutin	O2	-0.736**	-0.306	-0.415	-0.519
	TDS	-0.432	-0.306	-0.641*	-0.260
	DBO5	0.360	0.220	0.654*	0.130
Mariakpa	O2	-0.779**	-	-0.760**	-0.761**
	TDS	-0.767**	-	-0.831**	-0.595*
	Salinity	-0.641*	-	-0.642*	-0.532
	$NO3^-$	0.519	-	0.386	0.684*
So Ava	TDS	-0.506	-0.522	0.009	-0.800**
	** : significant correlation at 0.01				
	* : Significant correlation at 0.05				

A table provides a summary of the abundance of *Bulinus* snail that showed a correlation with at least one physico-chemical parameter per site. In Sotchanhoué, Sotchanhoué Quartier, So-Mayi and Mariakpa, *I. exustus* and *P. marmorata* are negatively correlated with oxygen rate; but in Zounhomè, *P. marmorata* is negatively correlated with dissolved oxygen while in Gbèdoutin, *I. exustus* is negatively influenced by dissolved oxygen. In Sotchanhoué and Sotchanhoué Quartier, salinity have a negative influence on *P. marmorata*, which is also negatively influenced by TDS. *B. forskalii* and *P. marmorata* are negatively correlated with electrical conductivity and TDS while *I. exustus* is negatively correlated with biochemical oxygen demand at So-mayi. In contrast, in Zounhomè, *I. exustus* and *P. marmorata* are negatively influenced by salinity. In Gbèdoutin, *B. forskalii* is negatively correlated with electrical conductivity, TDS and biochemical oxygen demand. *I. exustus*, *B. forskalii* and *P. marmorata* but the first two species are negatively correlated with salinity while the last species is negatively correlated with nitrates. Finally, in So-Ava, *P. marmorata* is negatively correlated with electrical conductivity and TDS.

4. Discussion

4.1 Water quality variations

The results shown a spatial and temporal variation in the physico-chemical parameters of the waters of Lake Nokoué. The temperature varied between 25°C and 33.5°C. The values are high and remain similar to those of previous studies (Dovonou *et al.*, 2011; Goussanou, 2012). Oxygen was a useful parameter for water and an excellent indicator of its quality. Its value provides information on the degree of pollution and therefore on the degree of self-purification of a watercourse. These results are identical to those reported by Mama (2011) on Lake Nokoué in Benin, which are 5mg/L. Examination of the pH shows that the lake water has a pH of 6.3 ± 0.5 on average in August; 6.5 ± 0.1 in September; 6.6 ± 0.1 in October and November 6.9 ± 0.2 in December; 6.7 ± 0.8 in January; 7.9 ± 0.6 in February and March; 7.9 ± 0.5 in May and 6.9 ± 0.4 in June. This approved the results of Gnohossou (2006), Mama (2011), Dovonou *et al*, (2011) who found a pH between 6.3 and 7.8. The lower pH is obtained in July (5.6±0.7) showing that these stations are acid during this period. The acidity of the lake in October would be related to the nature of the waters it receives from these tributaries. The salinity of Lake Nokoué varies from month to month at the stations. It is nil in the months of September and November (0g/L) lower in October and December (0.03±0.08g/l), low in July and August (0.5±0.9g/L and 0.2±0 respectively,3g/L), significant in January (1.69±1.23g/L), high in February, March (6.19±1.5g/L) and very high in April and May (13.79±3.7g/L and 10.86±3.58g/L respectively). Although there are differences in values between the results, the conclusions are comparable to those of Gnohossou (2006), Mama (2011), Dovonou *et al.*, (2011) and Goussanou (2012). This difference can be explained by several factors. The salinity of the environment is controlled by dilutions (freshwater inflows from tributaries and direct precipitation) that lower it and tides (saline intrusions) via the Cotonou channel that increase it (Mama, 2011; Dovonou *et al.*, 2011; Goussanou, 2012). These same factors have also been identified as causes of salinity fluctuations in Lake Ahémé (Dèdjiho *et al.*, 2013), Epe Lagoon (Uwadiae, 2014) and the Niger Delta intertidal zone (Zabbey and Hart, 2014). As in October, a decrease in salinity favours the proliferation of aquatic species, more specifically water hyacinths (Eichhornia crassipes), which, by developing, prevent the penetration of solar rays into the water and contribute to the depletion of dissolved oxygen, which is a threat to fish (Lalèyè, 2003). However, when it increases and reaches concentrations of 7 g/L, it inhibits the proliferation of Eichhornia crassipes (Lalèyè, 2003).

The main mineral substances present and measured as dissolved ions are nitrates (NO3-) and nitrites (NO2-). The nitrite concentration (1 mg/l) in September is higher than that recorded by Dovonou *et al* (2011) in the same month. The nitrate concentration (6.2mg/l) measured in May is lower than that obtained by Dovonou *et al* (2011). This difference can be explained by the lack of similarity between the sampled stations, the organic load currently available in the lake, climatic variability and temperature. Indeed, the quantity of nutrients varies spatially (from upstream to downstream and dependent on human activities), and is a function of the rate of decomposition of the branches used to build the acadjas (Rodier *et al.*, 2009; Mama *et al.*, 2011). Dissolved Total Solids (DTS) are important in ecological studies because they represent the total concentration of substances dissolved in water (inorganic salts and some organic materials). The values range from 36, 1±1, 9 mg/l to 11323±2883 mg/l. Although the values are different, the TDS shows a similar trend to that of salinity and conductivity. The same view is shared by Fishar *et al* (2006); Edia *et al* (2013) and Abdel-Hamid *et al* (2014) who have demonstrated that there is a strong dependence between temperature, mineralization parameters (pH, conductivity and TDS), organic load, salinity and water flow velocity.

4.2 Schistosomiasis host snails diversity

The species inventoried in this work are already reported in Benin by Ibikounlé *et al* (2006) and in Côte d'Ivoire by N'Guessan *et al* (2003). The simultaneous presence of *B. truncatus*, *B. globosus*, *B. forskalii* is indicative of the existence or absence of urinary schistosomiasis in the study area. The low presence of *B. truncatus* on Lake Nokoué during this study could be explained by the inadequacy of this study environment for this species; this is contrary to the results obtained by N'Guessan *et al.*, (2014) ; Tian Bi *et al.*, (2011) and Groga (2010) in the Taabo-village region of Côte d'Ivoire. Similarly, the low presence of *B. globosus* could be justified by a non-compliance of the study environment with this species. This seems more plausible as *B. globosus* proliferates in streams with vegetation cover. Our results confirm those of the work carried out in the locality of Taabo by Tian Bi *et al*, (2011). As for *B. forskalii*, the population trends in our study show a population explosion following numerous spawnings deposited after the first rains by snails that survived the estimation period. Thus, the high population densities of *B. forskalii* coincide with the rainy season, which seems to provide it with favorable breeding conditions. Similar observations had been made by Mc Cullough (1957) in Ghana.

4.3 Water quality and snail dynamics

These results showed that *B. forskalii* would therefore be influenced by these temperatures, which are significantly negatively correlated (r=-0.798). This result means that high water temperature values correspond to low population values of *B. forskalii*. The pH values were negatively correlated with the dynamics of *B. forskalii*. These results are contrary to those obtained by N'Guessan (2003) in Côte d'Ivoire on bulinus populations, who showed that pH has a small influence on snail populations, which can support all pH values, but with a preference between 6 and 9. Our study showed that the population of *B. forskalii* and *I. exustus* increases when the dissolved oxygen concentration decreases. Thus, the low concentration of dissolved oxygen in the waters could be explained by the fact that the waters of Lake Nokoué are supplied by rivers from fresh waters responsible for the negative redox potential, thus showing that the environment is reducing (Isabelle, 1999).

Conclusion

Lake Nokoué was characterized by a variation of physico-chemical parameters over time and space. Physico-chemical parameters such as salinity, temperature, dissolved oxygen, mineralization parameters (pH and TDS) vary depending the month and site. Salinity did not vary on average from one month to another but varied from site. These parameters are dependent on periodic hydro-climatic variations in the lake and anthropogenic actions. Malacologically, three species of snails (*B. forskalii*; B. globosus; *B. truncatus*) were identified in this study and two (*B. forskalii*; *B. globosus*) found naturally infected by schistosome cercariae are responsible for the transmission of schistosomiasis. The dynamic of schistosome intermediate host snails suggested seasonal schistosomose transmission to the population of Sô-Ava.

References

[1]. Abdel-Hamid MI, Abdel-Aal EI, Azzab YA, 2014. Spatial quality improvement of a toxic industrial effluent, based on physico-chemistry, algal community changes and algal bioassay. *African Journal of Aquatic Science* 39, 1-16.

[2]. Alhou B, 2007. Impact des rejets de la ville de Niamey (Niger) sur la qualité des eaux du fleuve Niger. Thèse de Doctorat, Université de Namur, Belgique. 230p.

[3]. Amri N, Jamili S, Shahidian M, 2014. A study on the primary production of the périphyton epilithics and biomass macrobenthos in Kordian river (North West of Iran). *International Journal of Ecosystem* 4, 75-82.

[4]. Boissier, J., Moné, H., Mitta, G., Bargues, M.D., Molyneux, D., Mas-Coma, S. (2015) Schistosomiasis reaches Europe. Lancet Inf Dis 15(7):757–758.

[5]. Boukari M, 2013. Evaluation de la qualité physico-chimique de certains tributaires usés du lac Ahémè au Bénin. Journal of applied biosciences 70, 5608-5616.

[6]. Brown DS,1994. *The freshwater snails of Africa and their medical importance*. 2ème édit. Champigny, 6p ;

[7]. Chitsulo L, Engels D, Montresor A, Savioli L, 2000. The global status of schistosomiasis and its control. *Acta Tropica*, 77: 41-51.

[8]. Dèdjiho CA, Mama D, Tomètin L, Nougbodé I, Chouti W, Sohounhloué CKD, Boukari M, 2013. Évaluation de la qualité physico-chimique de certains tributaires d'eaux usées du lac Ahémé au Bénin. *Journal of Applied Biosciences* 70, 5608-5616.

[9]. Dovonou F, Aina M, Boukari M, Alassane A, 2011. Pollution physico-chimique etbactériologique d'un écosystème aquatique et ses risques écotoxicologiques: Cas de Nokoue au Sud Benin. *International Journal of Biological and Chemical Sciences* 5,1590-1602.

[10]. Edia OE, Bony KY, Konan KF, Ouattara A, Gourène G, 2013. Distribution of Aquatic Insects among Four Costal River Habitats (Côte d'Ivoire, West-Africa). *Bull. Env. Pharmacol. Life Sci* 2, 68-77.

[11]. Fishar MR, Thorne RPW, 2006. Physical-chemical conditions and macroinvertebrate fauna in the River Nile from Aswan to Cairo. *African journal of Aquatic Science* 31, 247-259.

[12]. Gnohossou P, 2006. La faune benthique d'une lagune ouest africaine (le lac Nokoué au Bénin), diversité, abondance, variations Temporelles et spatiales, place dans la chaine trophique. Thèse de doctorat, École Nationale Supérieure Agronomique de Toulouse (ENSAT), France. 141p

[13]. Goussanou A, 2012. Diversité du phytoplancton du lac Nokoué. Mémoire de Master, Université d'Abomey-Calavi. 45p.

[14]. Holtfreter, M.C., Moné, H., Müller-Stöver, I., Mouahid, G., Richter, J. (2014) Schistosoma haematobium infections acquired in Corsica, France, August 2013. Eurosurveillance19: 20821

[15]. Hotez, P.J., Kamath, A. (2009) Neglected tropical diseases in Sud-Saharan Africa: Review of their prevalence, distribution, and disease burden. Plos Negl Trop Dis 3(8): e412

[16]. Ibikounlé M., 2006*, les Schistosomes au Bénin : Epidémiologie et écologie des interactions hôte-parasite.*

[17]. Ibikounlé M., Gbedjissi L.G., Ogouyèmi-Hounto A., Batcho W., Kinde-Gazard D., Massougbodji A. (2014a). Schistosomiasis and soil-transmitted helminthiasis among schoolchildren of Nikki and Perere, two northeastern towns of Benin. *Bull Soc Pathol Exot*; 107(3):171-176. https://doi.org/10.1007/s13149-014-0344-y

[18]. Ibikounle M., Ogouyèmi-Hounto A., Sissinto-Savi de Tové Y., Dansou A., Courtin D., Kindé-Gazard D., Mouahid G., Moné H., Massougbodji A. (2014b). Freshwater snails and Epidemiology of urinary schistosome among schoolchildren in Pehunco area, North West of Benin. Malacologycal survey. *Bull. Soc. Pathol. Exot.* 107: 177-184. DOI 10.1007/s13149-014-0345-x

[19]. Ibikounlé M., Mouahid G., Sakiti N.G., Massougbodji A., Moné, H. (2009). Freshwater snail diversity in Benin (West Africa) with a focus on human schistosomiasis. *ActaTropica* 111, 29-34. DOI 10.1016/j.actatropica.2009.02.001.

[20]. Ibikounlé M., Satoguina J., Fachinan R., Tokplonou L., Batcho W., *et al* (2013). Epidemiology of urinary

schistosomiasis and soil-transmitted helminthes in schoolchildren in district of So-Ava, southern Benin. *J Appl Biosci*; 70: 5632-5639

[21]. INSAE-RGPH4. Enquête Démographique et de Santé du Bénin 2011–2012 [Internet]. 2013 [cited 2015 Dec 21]. Available from: https://www.google.bj/ search? newwindow= 1&q=ICF+ International %3A+Enque %CC%82te+De%CC%81mographique+et+de+Sante%CC%81 +du+Be%CC%81nin+2011-2012&oq=ICF+International% 3A+Enque%CC%82te+De%CC%81mographique+et+de+Sant e%CC%81+du+Be%CC%81nin+2011.2012&gs_l=serp.3.2041 .27869.0.28503.4.4.0.0.0.0.380.1323.2-1j3.4. 0.0.1c.1. 64. serp. 1.3.940.wArQarihWT4

[22]. Isabwe A, Ruberanziza E, Mupfasoni D, Ruxin J, Clerinx J, White PT, 2012. Potential for transmission of schistosomiasis in kayonza district. Revue Médicale

[23]. Khalil M, Islam Z, Islam R, 2002. Effects of age in the structure of the bursa of Fabricius of deshi chicken of Bangladesh. *Mymensingh Medical Journal*, 11(2): 91-3.

[24]. Lalèyè P, Atachi P, Moreau J, Dauta C, 2003. Influence de la salinité sur la répartition spatiale des invertébrés du lac Nokoué. 3rd International Conference of the Pan African Fisheries Society, Cotonou (Benin), 10-14 Nov. 2003.

[25]. Mama D, Deluchat V, Bowen J, Chouti W, Yao B, Gnon B, Baudu M, 2011. Caractérisation d'un Système Lagunaire en Zone Tropicale: Cas du lac Nokoué (Bénin). *Uropean Journal of Scientific Research* 56, 516-528.

[26]. N'Guessan AN, Garba A, Orsot N, N'Goran KE, 2014. Evaluation de la morbidité échographique de la bilharziose urinairechez les écoliers de 6 localités autour du barrage de Taabo (Côte d'Ivoire).wandaise 69 (2) : 14-19.

[27]. Uwadiae RE, 2014. Environmental Characteristics and Community Structure of Benthic Macroinvertebrate of Epe Lagoon, Nigeria. *International Journal of Environmental Sciences* 3, 36-44.

[28]. WHO (2006). Preventive chemotherapy in human helminthiasis-Coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and programme managers; ISBN 92 4154710 3.

[29]. WHO (2018). Schistosomiasis. Fact Sheets updated. http://www.who.int/news-room/fact-sheets/detail/schistosomiasis.

[30]. Zabbey N, Hart AI, 2014. Spatial variability of macrozoobenthic diversity on tidal flats of the Niger Delta, Nigeria: the role of substratum. *African Journal of Aquatic Science* 39, 67-76.