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Diversity of aquatic macroinvertebrates in relationship with the environmental factors of a lotic ecosystem in tropical region: the Sô river in South-East of Benin (West Africa)

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Abstract
The present study was aimed to study the diversity of aquatic macroinvertebrate populations in relation to the abiotic parameters of the Sô River. For this purpose, aquatic macroinvertebrates were sampled monthly between February 2016 and April 2017 on 12 sampling stations and in various habitats along the Sô River. Similarly, twenty environmental variables were measured to assess the environmental characteristics of Sô river.
The recorded fauna consists of 2053 individuals corresponding to 44 families and 61 taxa belonging to three main zoological groups (Arthropods, Molluscs, Annelids). The stand population showed that Coleoptera (17.06%), Basomatophora (14.19%), Heteroptera (11.37%), Odonata (10.26%), Mesogasteropoda (9.01%) and Decapoda (9%) are the most abundant orders. Another oders constitute only a small fraction of the total fauna harvested. The redundancy analysis performed shows that abiotic parameters that strongly influence taxonomic diversity and taxon abundance are: current velocity, nitrogen and phosphorus compounds, mineralization parameters and canopy.

Keywords: Diversity, macroinvertebrates, envronmental characteristics, Sô river

1. Introduction

Benin has a dense hydrographic network with five large basins draining several streams and lakes [1]. One of the most important is the Sô River. More than half of the river's watershed is occupied by plantations, vegetable gardens and wild garbage deposits. There are also many different swine and cattle parks on its course, and daily serves as fraudulent traffic of hydrocarbons from Nigeria. This strong anthropisation of the Sô river basin can lead to significant disturbances in its functioning [2]. Indeed, according to [3], the ecological quality of a hydrosystem is closely linked to the tenure of its watershed.
Thus, faced with these many factors that risk imbalance of the biological integrity of organisms, it is necessary to make an inventory of the health of this river.
For the sustainable management of aquatic disturbances, integrity monitoring systems are developed using aquatic organisms [4]. In these biomonitoring systems, aquatic macroinvertebrates are a biological group used as bioindicators [5-11].
Aquatic macroinvertebrates are an important link in the aquatic food chain [12-14]. They are the most important source of food for several species of amphibians, birds and fish [15-17] and therefore play a key role in aquatic ecosystems. The structure of their stand changes when their environment is disturbed, which allows a better characterization of the spatio-temporal distribution of pollution [18-19]. These organisms, which are widely distributed in the different strata of water, are characterized by their differential polluo-sensitivity; characteristic used in bioindication of aquatic ecosystems [20]. The use of these organisms in monitoring the integrity of rivers in Benin is very limited by a lack of knowledge. The only available data are those of [21-26]. None of his studies have focused on the Sô river despite the various activities developed on its watershed.
The present study aimed to overcome this deficiency by providing an initial database on the Sô river macrofauna. The objective was to evaluate the diversity of this fauna and to identify the abiotic parameters that structure these stands.

2. Materials and Methods

2.1 Study area and sampling stations

The Sô River is between 6°24' and 6°32' North Latitude and 2°27' and 2°30' East Longitude. It is situated in the municipality of Sô-Ava, municipality to which it owes its name. With a length of 84.4 km, the river Sô takes its source in the lake Hlan and is connected to the Oueme River by backwaters. This river is one of the old arms of the Oueme River, which has since detached itself, and which pours its waters northwest of Lake Nokoue to the level of the lake city of Ganvié [27]. Throughout the basin of this river, the local inhabitants practice important agricultural activities (potatoes, cassava, maize and vegetable crops) requiring the use of fertilizers and the raising of pigs and oxen left in ramming along the banks. Similarly, for their fishing activities, many branches are used to make the acadjas that abound the river and finally the fraudulent traffic of the hydrocarbons which is observed daily is as many anthropic activities that develop in this environment.

2.2 Choice of stations

In order to investigate the variability of environmental parameters, the river was subdivided according to the longitudinal stratification proposed by [28] and [29]. As well, upstream to downstream of the river, twelve sampling stations were selected. The stations have been chosen according to the accessibility of the station, the presence or absence of urban agglomerations, the existence of agricultural activities or a pollution gradient, the diversity of the biotope and the presence or absence of vegetation. These characteristics make it possible to refine the spatial portrait of the quality of the water along the river. Table 1 presents the geographical coordinates of the selected stations by sector. The geographical location of the river basin and study stations is given in the Fig 1.

Table 1: Sampling sites of the Sô River

Sites	Names	Geographic coordinates	Different sectors
ST1	Vêky	N07°16'98.4'', E002°35'82.2''	Lower course
ST2	Sindomey	N07°15'84.3'', E002°32'50.0''	
ST3	Dogodo	N07° 18'40.2'', E002°33'56.3''	
ST4	Ahomey-Gblon	N07°22'65.2'' ; E002°34'02.2''	
ST5	Ahomey-Ounmey	N07°25'40.3'' ; E002°33'79.1''	Average course
ST6	Ahomey-Lokpo	N07°27'28.3'' ; E002°33'17.7''	
ST7	Zoungomey	N07°29'86.2'' ; E002°33'78.3''	
ST8	Kinto Oudjra	N07°33'84.3'' ; E002°35'81.2''	
ST9	Togbota	N07°39'40.6'' ; E002°34'81.3''	Upper course
ST10	Tota	N07°40'98.2'' ; E002°38'99.8''	
ST11	Rhlampa	N07°48'45.4'' ; E002°37'47.9''	
ST12	Djigbé-Ovo	N07°52'96.2'' ; E002°35'99.8''	

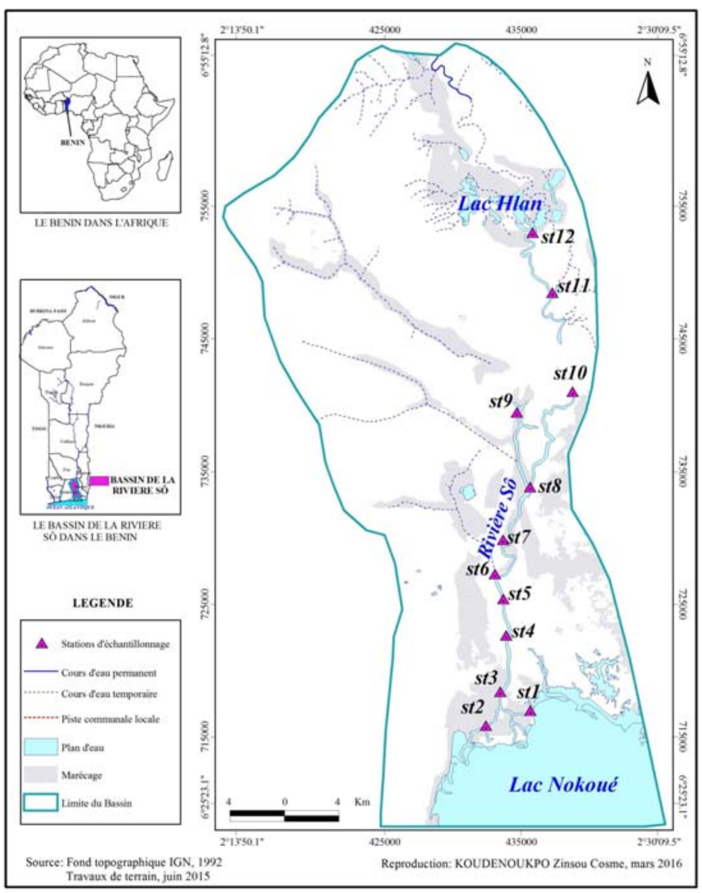

Fig 1: Map of the Sô river basin showing the sampling stations

2.3. Collection data
The abiotic and biotic data were taken monthly for 15 months (February 2016 to April 2017).

2.3.1 Measurement of abiotic parameters
Measurements and water sampling took place between 06:30 and 10:45. During each campaign and at each of the stations described above, transparency and depth were measured using a Secchi disk; a multi parameter, Model SX736 pH/mV/Conductivity/DO Meter, having two probes allowed to measure pH, temperature dissolved oxygen, salinity, TDS and electrical conductivity. After these measurements, water samples were taken from double-capped polyethylene bottles containing 1000mL, stored in a cooler at 4 °C and then returned to the laboratory. In the laboratory, chemical parameters such as calcium, magnesium, total nitrogen, nitrite, nitrate, ammonium, orthophosphate, total phosphorus and chlorophyll a were measured by ion chromatography using a DIONEX ICS-1000 ion chromatograph at Nesler, Diazotation, Cd reduction, Nessler and ascorbic acid according to [30].
The surface velocity (Vs) of the water was measured according to the method of [22]. It consists in timing the time taken by a float to travel a distance of 1 m measured at the decameter. This exercise was repeated three times. The speed is then equal to the distance traveled (1m) relative to the average time (in seconds). The velocity of the current Vc is drawn according to the relation: Vc = 0.80*Vs [31]; it is expressed in (cm/s).
The canopy closure rate and coverage by aquatic plants were estimated and expressed as a percentage.

2.3.2 Collection, identification and enumeration of organisms
Sampling was carried out on each of the twelve study stations defined. Three different materials were used for the collection of organisms following the recommendations of [22]. This is the Ekman type bucket (surface area = 0.025 m^2) for sampling at the bottom of the Sô river, a cloudy type net with a handle, for sampling in hard-to-reach areas And the net is dragged slightly along the bottom along a transect through as many habitats as possible) and finally a sieve to harvest the organisms if they are attached to the roots of the macrophytes.
The sorting and determination of the harvested biological material was carried out using a binocular microscope by removing all organisms and separating them into large systemic groups in tubes containing 70% ethanol.
The identification of the organisms was made through key findings of [32-38].
The minimum taxonomic level reached in our study is the family. Indeed, this taxonomic level allows global discrimination of sites in bioindication studies [39, 40, 41].

2.4 Statistical and Index analysis of Data
2.4.1 Ecological index
The analysis of community structure is based on taxonomic richness, the Shannon-Weaver diversity index and the Piélou evenness index [42]. Generally, these indices are calculated by considering the species as a taxonomic level. Moisan and Pelletier [41] estimate that the structuring of macroinvertebrate communities in rivers, including metric variables and Shannon diversity indices and evenness, can be defined at the taxonomic level of the family. This taxonomic level has allowed several authors of [43-44], to show that polluted areas have weak indices compared to unpolluted areas. With reference to the approach of these authors, we have opted for the family as a taxonomic level for the computation of diversity indices.
For example, the Shannon diversity index was used to estimate the taxonomic diversity of the stands studied. It is weak when the individuals encountered all belong to a single species or when all species are represented by a single individual: H 'is more sensitive to rare species [45]. The higher the index, the more stable the stand, ie it is not subject to the action of abiotic factors or a pollution factor [46]. This index is expressed in individual bits-1 and is calculated according to the relationship [47]. It is obtained by the formula:

$$H' = - \sum_{I=1}^{S} \left(\frac{ni}{N} \log 2 \quad \frac{ni}{N} \right)$$

H′ is the diversity index of Shannon and Weaver;
Nor is the strength of the species i in a sample;
N is the total number of individuals of the sample.

As to the Index of evenness (E), it has helped to compare the measured diversity with the maximum theoretical diversity [48]. This index was developed to account for the relative abundance of each taxon, the regularity of distribution of taxa or equitable distribution [49], and the quality of stand organization. It varies from 0 (when a species dominates the whole stand and is a polluted environment) to 1 (when the species are equi-frequent and their abundance is identical and it is a healthy environment) [50]. It is obtained by the formula:

$$E = H'/\log_2(S)$$

H' is the Shannon index and S the specific richness

2.4.2 Statistical analyses
The ANOVA test with two variations factors (sectors-seasons) was used to show the variability of environmental parameters from one sector to another, and from one season to another. For organisms, the Chi-two test was applied to the different densities in order to show their spatial and seasons variability.
These univariate analyzes were carried out using software R version 2.15.3 with the FactoMineR package.
In order to analyze the correlation between environmental factors and the distribution of macroinvertebrates along the Sô River, two matrices have been developed. The first presents the abundance of taxa in the monthly samples and the second, the explanatory variables (environmental variables) of all the sampling stations. The relationship between densities of macroinvertebrates and the explanatory variables was examined by submitting the matrices to a redundancy analysis (RDA) using the CANOCO version 4.0 software [51]. RDA is a proprietary ordination developed specifically to link multi-varied ecological data and plot diagrams that show both similarity based on macroinvertebrate densities between sampling stations and the contribution of explanatory variables [6, 10, 52]. All densities taken into account in the Redundancy Analysis (RDA) were logarithmically transformed. The relevance of the analysis was first verified by a Monte-Carlo permutation test [53] on 499 random permutations [54].

3. Results

3.1 Environmental Characteristics of the Sô River

The median values and standard deviation of the 20 environmental variables measured in the Sô River are presented in Table 2. The measured variables have median values consistent with aquatic life, with the exception of nitrogen and phosphorus compounds.

The ANOVA test with two variation factors (sector-season) carried out showed that the variables vary more seasonally than spatially. Among the 20 parameters studied, 12 of them (depth, transparency, salinity, dissolved oxygen, orthophosphate, total phosphorus, conductivity, TDS, salinity, dissolved oxygen, calcium and magnesium levels, current velocity) Significantly from one sector of the river to another. However, at the seasonal level, all parameters show highly significant variations ($p<0.001$) with the exception of the proportion of plant debris with non-significant variation ($p>0.05$).

Table 2: Spatial and seasonal variations in the median and extreme values of the 20 environmental parameters measured during the study period on the Sô River. (HC = higher course, AC = average course, LC = lower course, LRS = large rainy season, SDS = small dry season, SRS = small rainy season, LDS = large dry season

	Sectors			Seasons				Significance	
Variables	**LC**	**AC**	**HC**	**LRS**	**LDS**	**SRS**	**SDS**	**Secteurs**	**Saisons**
Trans (m)	0.75±0.44	0.85±0.44	2.31±9.25	0.83 ±0.40	1.28 ±0.41	0.54 ±0.14	3.29 ±13.20	*	***
Depth (m)	3.74±1.66	3.59±0.68	3.35±1.48	3.67 ±1.45	3.18 ±1.19	3.56 ±1.42	3.84 ±1.16	*	*
Température	28.60±1.64	27.98±1.71	27.90±1.37	28.17 ±0.71	28.31 ±2.63	28.41 ±1.74	27.67 ±0.85	NS	*
pH	7.32±0.55	7.10±0.61	7.07±0.53	7.46 ±0.44	6.95 ±0.61	6.61 ±0.44	7.29 ±0.36	NS	***
CE (µS/cm)	2929.10±4403.19	1530.80±2257.12	611.93±653.89	3139.83±4121.89	993.83±822.56	143.98±47.62	659.35±1458.28	*	***
TDS (mg/l)	1487.11±2618.68	217.70±273.27	129.49±318.30	1214.38±2304.95	41.72±13.14	65.45±19.32	504.62±1171.70	*	***
Sal (mg/l)	1.61±1.42	0.35±0.44	0.40±0.63	0.67 ±1.02	1.17 ±1.20	0.94 ±1.22	0.34 ±0.78	***	*
DO (mg/l)	6.40±2.67	7.42±2.71	7.54±2.53	6.14 ±1.40	9.73 ±2.91	6.77 ±2.85	5.99 ±1.91	*	***
NO_2^- (mg/l)	0.14±0.13	0.15±0.19	0.13±0.18	0.09 ±0.10	0.07 ±0.04	0.41 ±0.24	0.12 ±0.08	NS	***
NO_3^- (mg/l)	2.22±3.08	1.93±2.48	2.19±3.59	0.55 ±0.50	0.58 ±0.49	4.35 ±4.39	6.05 ±2.59	NS	***
NH_4^+ (mg/l)	1.37±1.58	1.00±1.10	0.74±0.72	1.09 ±1.27	1.27 ±1.65	0.86 ±0.74	0.74 ±0.21	NS	*
AzoT (mg/l)	4.39±2.48	4.34±2.90	4.95±3.52	3.65 ±1.27	3.15 ±3.63	6.83 ±3.12	6.67 ±2.54	NS	***
OrthoP(mg/l)	0.63±1.50	0.24±0.22	0.19±0.08	0.58 ±1.35	0.19 ±0.06	0.22 ±0.08	0.16 ±0.17	*	***
PhosT (mg/l)	1.64±1.86	1.16±1.69	1.201.67	1.09 ±0.85	2.41 ±2.85	0.56 ±1.11	1.09 ±0.94	*	**
Ca^{2+} (mg/l)	50.08±66.59	21.03±16.33	18.57±17.63	33.46 ±27.47	48.19 ±72.49	8.02 ±3.13	15.42 ±17.55	**	***
Mg^{2+} (mg/l)	69.64±121.83	20.51±31.14	18.43±28.82	36.67 ±80.30	71.46 ±104.85	5.16 ±2.00	13.16 ±27.17	*	***
Chl a (mg/l)	0.003±0.001	0.033±0.001	0.017±0.002	0.009±0.001	0.013±0.001	0.005±0.001	0.008±0.001	NS	*
Vitesse (m/s)	0.4 ±0.1	0.51±0.1	0.62±0.13	0.71±0.01	0.93±0.13	1.56±0.16	1.71±0.01	**	**
DV(%)	13±2.11	15±1.66	17±2.24	24±6.10	71±8.12	56±9.13	67±8.01	NS	NS
Canopy (%)	10±1.09	25±2.12	80±11.41	24±4.11	84±17.11	46±13.27	44±16.91	*	*

Values represent mean ±standard deviation. (Kruskal-Wallis tests, NS no significant $p>0.05$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$)

3.2 Composition of aquatic macroinvertebrates

In this study, 2053 individuals were harvested, including Arthropods (81.77%), Molluscs (16%) and Annelids (8%). These individuals are divided into 6 classes, 13 orders, 44 families and 58 genera 5 (Table 2). The insect class predominates with 76.04% of the total abundance, followed by the Gasteropoda (11.44%), the Crustacea (5.73%), followed by the Oligochaetes, the bivalves and the Hirudinata with less than 5% each (Fig. 2).

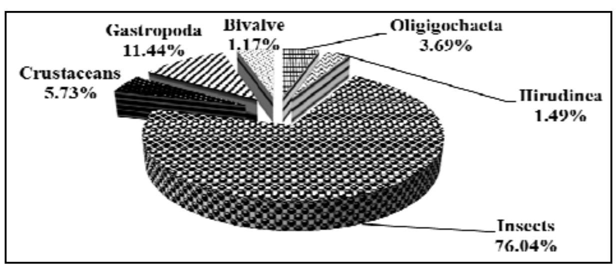

Fig 2: Relative frequency of different classes of aquatic macroinvertebrates harvested in the Sô River during the study period

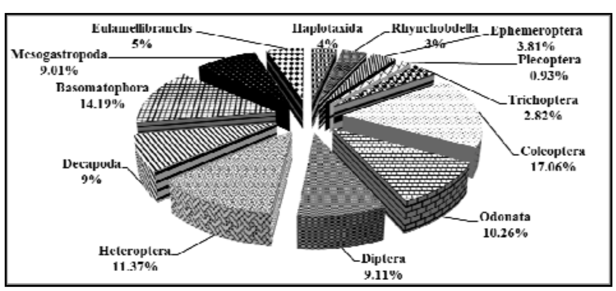

Fig 3: Relative abundance of different orders of aquatic macroinvertebrates in the Sô River during the study period

Among the 13 orders of macroinvertebrates sampled, the Coleoptera dominated with 17.06% of total abundance, followed by Basomatophores (14.19%), Heteroptera (11.37%), Odonata (10.26%), Mesogateropods (9.01%), Decapoda (9%). Haplotaxida, Rhynchobdella, Ephemeroptera, Trichoptera and Pecoptera represent less than 5% each of the total abundance of harvested wildlife (Fig. 3).

Table 2: Taxonomic list of aquatic macroinvertebrates harvested in the Sô River during the study period

Phylum	Orders	Families	Taxa
Annelids			
Oligochaeta	Haplotaxida	Lumbricidae	*Eiseniella*
		Tubificidae	*Tubifex*
		Haplotaxidae	*Haplotaxis*
Hirudinea	Rhynchobdella	Glossiphonidae	*Glossiphonia*
			Helobdella
Arthropoda			
Insecta	Ephemeroptera	Baetidae	
			Baetis
			Procleon
			Centroptilum
		Caenidae	*Caenis*
			Caenomedea
		Ephemerellidae	*Ephemerella*
		Ephemeridae	*Ephemera*
		Leptophlebiidae	*Leptophlebi*
		Tricorythidae	*Dicercomyzon*
	Plecoptera	Capnidae	*Capnia*
	Trichoptera	Hydropsychidae	*Polymorphanisus*
		Polycentropodidae	*Dipseudopsis*
	Diptera	Chironomidae	*Chironomus*
			Cryptochironomus
		Simulidae	*Simulium*
		Ceratopogonidae	*Bezzia*
		Syrphidae	Indeterminate 1
	Odonata	Gomphidae	*Ictinogomphus*
			Gomphus
			Lestinogomphus
			Paragomphus
			Phyllogomphus
		Libellulidae	*Libellula*
		Corduliidae	*Phyllomacromia*
	Coleoptera	Dytiscidae	*Hygrotus*
			Laccophilus
		Elmidae	*Elmis*
			Potamodytes
		Chrysomelidae	Indeterminate 2
		Gyrinidae	*Gyrinus*
		Hydrophilidae	*Helochares*
		Hydrobidae	*Hydrobia*
		Noteridae	*Noterus*
	Heterotera	Nepidae	*Laccotrephes*
			Nepa
		Veliidae	*Microvelia*
			Velia
		Naucoridae	*Naucoris*
		Corixidae	*Corixa*
		Pleidae	*Plea*
		Notonectidae	*Notonecta*
		Gerridae	*Gerris*
		Hydrometridae	Indeterminate 3
Crustaceans	Decapoda	Portunidae	*Callinectes amnicola*
		Potamidae	*Potamon*
		Peneaeidae	*Penaeus*
Molluscs			
Gastropoda	Basomatophora	Planorbidae	*Planorbis*
		Physidae	*Physa*
		Lymneridae	*Lymnaea*
	Mesogastropoda	Bythinidae	*Gabbiella*
		Thiaridae	*Melanoides*
			Potadoma
			Potadoma
Bivalve	Eulamellibranchs	Mutelidae	*Mutela*
			Mutela
		Sphaeridae	*Sphaerium*
Total	12	44	61

3.3 Variations in the density of organisms

In all three areas of the Sô River, the densities obtained fluctuate between 29 and 1582 ind/ m^2 with maximum values obtained during the large rainy season and in the small dry season (Fig. 4). In the upper reaches of the river, densities are relatively high at stations ST11 and ST12 with high seasonal variability (Fig. 4C). At the other stations, the values are lower than those above and vary very little regardless of the station. In the middle course of the river, seasonal variation is significant where large values are recorded (Fig. 4B). Finally, in the lower reaches, densities are more or less low and vary very little regardless of the season (Fig. 4A).

The density does not show any significant seasonal variation in the three sectors of the Sô River (Kruskall-Wallis test, p> 0.05). On the other hand, the spatial variation shows significant differences in the different sectors (Kruskall-Wallis test, $p<0.05$). In the upper reaches of the river, differences between ST11 ST12 on the one hand and ST9 and ST10 stations on the other are marked (test for multiple rank comparisons, $p<0.05$). In the mean course, the differences are marked between the stations ST6 on the one hand and the stations ST7, ST8 and ST9 on the other hand (test of multiple comparisons of the ranks, $p<0.05$). In the lower reaches of the river, differences between stations ST1 and ST2 on the one hand and stations ST3 and ST4 on the other (test for multiple rank comparisons, $p<0.05$) are marked. There was no significant difference between the intersectoral variations of the river (ANOVA 1, $p > 0.05$).

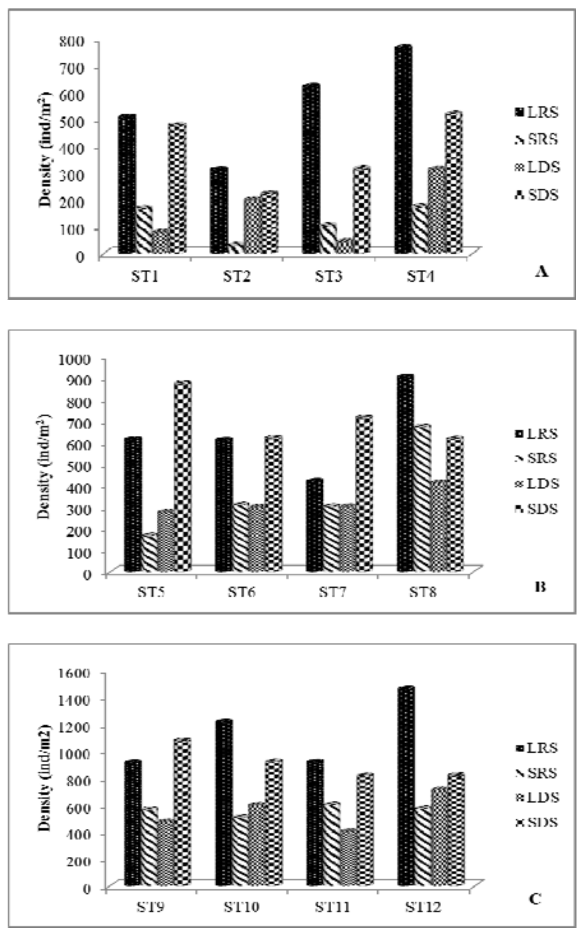

Fig 4: Spatio-temporal variations in density in the three sectors of the Sô River (A= Sampling stations of LC; B= Sampling stations of AC; C= Sampling stations of UC; LC= lower course, AC= average course, UC= upper course, LRS= large rainy season, SRS = small rainy season, LDS= large dry season, SDS= small dry season)

3.4 Relative abundance of orders

The relative abundances of the different orders by zoological group are presented in Table 3. Ephemeroptera, Trichoptera and Pleoptera are abundant in the upper reaches and weakly represented or absent in the middle and lower reaches of the river. The other insects (Diptera, Heteroptera, Coleoptera, Odonata) show no great variations from one sector to another. On the other hand, they are more abundant in the river during the great rainy season. Decapod crustaceans are more abundant during the dry season in the inner course and poorly represented in the other sectors. The high abundances of Haplotaxida and Rhynchobdella were observed in the course during the great rainy season especially in the lower course.

As for the three orders of Mollusc (Mesogastropoda, Basomatophora, Eulamellibranchs), they are more abundant in the inner and upper courses of the river.

Table 3: Relative abundance of different orders of aquatic macroinvertebrates; UC = upper course, AC = average course, LC = lower course; LRS= large rainy season, SRS = small rainy season, LDS = large dry season, SDS = small dry season

	Sectors			Seasons				Significance	
Orders	**LC%**	**AC%**	**UC%**	**LRS%**	**SDS%**	**SRS%**	**LDS%**	**Sectors**	**Seasons**
Haplotaxida	3.17	2.07	2.11	3.26	0.19	1.18	0.08	*	***
Rhynchobdella	6.04	7.11	1.19	2.02	0.24	0.19	0.03	*	**
Ephemeroptera	0.19	1.32	8.19	3.18	2.97	2.81	2.44	***	NS
Plecoptera	0	0	2.79	0.11	1.39	0.17	0.66	***	NS
Trichoptera	0	0.19	2.54	2.13	2.17	1.71	1.67	*	NS
Diptera	4.42	1.71	2.67	8.11	7.07	6.41	6.19	***	*
Odonata	3.19	2.73	4.22	9.91	4.19	5.77	5.71	**	*
Coleoptera	4.11	6.44	8.19	16.97	9.02	11.47	8.33	**	NS
Heteroptera	3.06	4.96	2.73	11.04	8.16	9.37	6.22	**	NS
Decapoda	7.17	1.31	0	3.27	6.19	5.81	8.21	NS	***
Basomatophora	4.62	1.88	7.26	13.49	12.36	10.28	9.19	*	NS
Mesogastropoda	2.72	4.46	3.09	6.71	5.27	6.01	8.11	*	NS
Eulamellibranchs	1.09	2.37	2.29	4.39	2.46	2.22	1.71	NS	NS

3.5 Specific diversity and evenness

The variations in the Shannon diversity index (H') and the Piélou evenness (E) are illustrated in Figure 5. On the whole, there is a good distribution of numbers between taxa (E ≥ 0.65) except during the major dry season where an evenness value of less than 0.50 was recorded at stations ST2 and ST3 (Fig. 5C). The greatest diversity was obtained at stations ST9, ST10, ST11 and ST12 whatever the season, with overall values larger during the major rainy season (Fig. 5A).

The seasonal variation of these indices did not differ significantly (Kruskall-Wallis test, p> 0.05).

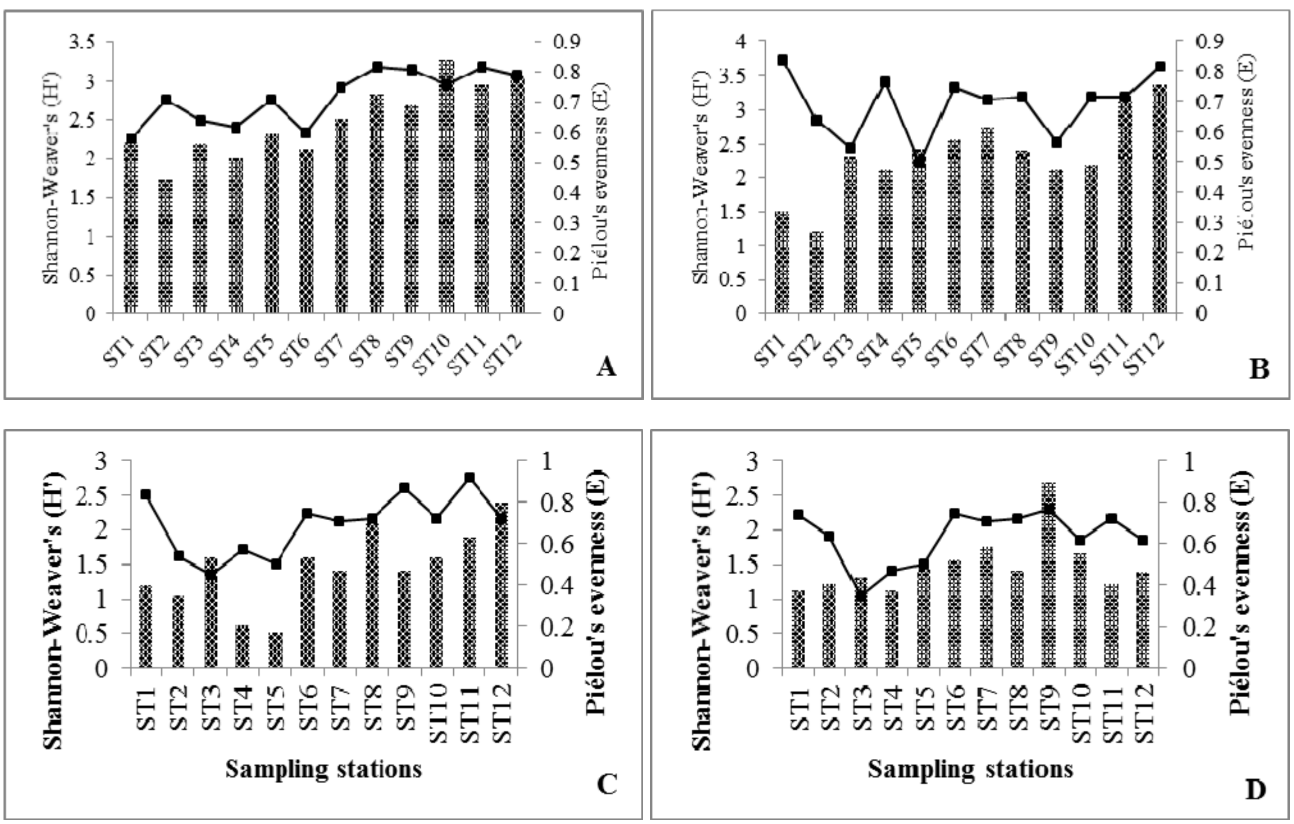

Fig 5: Spatial and temporal variations of the Shannon index and Piélou evenness in the Sô River; A = large rainy season, B = small rainy season, C = large dry season, D = small dry season.

At the spatial level, the variation is significant for the Shannon index (Kruskall-Wallis test, *p*<0.05), with the difference between station ST12 on the one hand and stations ST2, ST3 and ST4 on the other (Test of multiple comparisons of ranks, *p*<0.05).

3.6 Influence of environmental variables on the distribution of macroinvertebrates

The RDA results show that the correlation between environmental factors and macroinvertebrate densities is mainly explained by the first two axes (Fig. 6). The representativeness of all axes, given by the Monte Carlo test, is significant (P-value = 0.0484, F-ratio = 7.002). The axes 1 and 2 are very significant (p1-value = 0.003 and p2 = 0.007) and express 51.07% and 38.61% respectively of the information, ie a total of 83.61% for both axes. Figure 6 shows a distribution of the 13 orders of macroinvertebrates harvested according to the study stations. On axis 1, there is a positive correlation of Haplotaxides, Odonates, Basomatophores, Eulamellibranches and Mesogasteropods, as opposed to Ephemeroptera, Trichoptera, Decapoda and Rhynchobdella which are negatively correlated to this axis. Axis 2 is positively correlated with the Plecoptera and negatively with the Coleoptera, Diptera and Heteroptera.

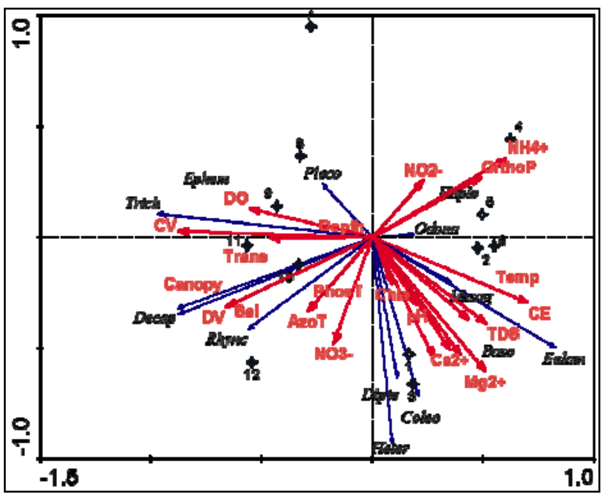

Fig 6: Redundancy Analysis (RDA) showing the relationships between environmental variables, biological variables and Sô River study stations

From this analysis, the velocity of the current, dissolved oxygen and transparency influence the variation in density of the Ephemeroptera, Trichoptera and Pleoptera. Total phosphorus, pH and Chl a, are responsible for the density of Diptera, Coleoptera and Heteroptera. There is also a correlation between Mollusc densities (Mesogastropoda and Eulamellibranchs). Decapod crustaceans are influenced by depth, canopy and plant debris.

4. Discussion

This resulted in a list of 61 taxa of aquatic macroinvertebrates throughout the Sô River. The listed fauna is mainly composed of Insects, Molluscs, Annelids and Crustaceans. These results corroborate those of Ben Moussa [4] which indicates that Oligochaeta, Crustaceans, Molluscs and Insects constitute most of the benthic fauna of the lotic environment.

Moreover, the taxonomic list is similar to that established in other lotic environments as indicated by the work of Ben Moussa [4] in the Khoumane River in Morocco. On the other hand, our results diverge from those of Egnima Bamou [55] on the Nga river in Cameroon, which harvested only 1453 individuals in 2 branch lines, 3 classes, 10 orders and 59 families. This lower taxonomic diversity results, on the one hand, from the type of sampling protocol, namely the monohabitat approach of Tiller and Metzeling [56], which does not take into account the diversity of microhabitats and, on the other hand, Which would have occurred at the time of identification. Similarly, the taxonomic richness of the Sô River is far superior to that obtained by [6] in the Agnéby River in Côte d'Ivoire under humid equatorial climate in four seasons, where only 28 families of macroinvertebrates were counted. This difference can be explained by the diversity of the different habitats surveyed and the gear used.

The taxonomic richness observed shows the predominance and the great diversity of the insects, which reflects the anthropic character of this watershed and the very good quality of the waters of the Sô River. According to [41, 35, 10], the majority of aquatic insects are highly sensitive to pollution and/or habitat modification and are therefore the first to disappear in a disturbed environment. In addition, the order of the Ephemeroptera, which is one of the taxa most sensitive to pollution [32], presents a great wealth in family, which confirms the words of these authors. Work carried out in the United States by [57] indicates that the specific richness of the Ephemeroptera decreases drastically with the urbanization of the basins.

In general, populations of the macroinvertebrates of the Sô River are mainly dominated by Arthropods with a predominance of Coleoptera, Heteroptera, Odonata and Decapoda, which account for more than 80% of total abundance. These results are characteristic of watercourses in areas with little or not anthropized, and fit well with the results obtained by [56] on the Nga in Cameroon, which also have a stand dominated by Arthropods (99.25%), with a preponderance Decapoda, Odonata and Coleoptera (70.61%).

On the spatial scale, the increase of upstream to dowstream of the abundance of benthic macrofauna can be explained by the increasing gradient of nutrient input into the environment [57], and on the other hand, by the increasing diversification of upstream microhabitats [39], all this added to the drift of benthic populations [60, 61]. The stations of the upper reaches of the Sô River have a fairly balanced structure with annual abundances varying between 441 individuals and 1586 individuals. The middle course has a less balanced structure than the previous one with a lower abundance (about 349 individuals); only a few macroinvertebrates (mainly Odonata), can be adapted to this biotope proliferate.

As for the stations of the lower reaches, sites most affected by the organic pollution, they also have an unbalanced structure with proliferation of Oligochaeta, Chironomidae and Simulidae which support the organic pollution. This imbalance is also justified by the total absence of the Plecoptera. This group, known for its strong sensitivity, is non-existent; this suggests, in view of our samples, either the existence of a pollution of organic origin which is a limiting factor of life for this group; or the ecological requirements of this group (temperature, dissolved oxygen, edge vegetation and substrate nature). Also, the high levels of calcium and magnesium (hardness) in the waters of the Sô River can also explain the absence of Plecoptera, which according to [62] support poorly the very calcareous waters.

On the temporal level, the decrease in abundance and the number of families observed would be due to hydrological changes resulting from the transition between the great dry seasons to the short rainy season, because after Frontier [63] transition periods seasonal are usually positively correlated with a decrease in biodiversity. The slight increases observed during the large rainy season would result from the rise in rainfall, resulting in the emergence of new habitats and the addition of nutrients (bedding) to the environment by runoff. According to [2]), the rainy months are broadly in favor of a greater diversity of benthic macroinvertebrate taxa. The new declines recorded in October are due to floods because, according to [61], the floods create conditions of instability of the funds and cause the drift of the stands. In addition, floods correspond to a period of reduced activity for these organisms, with species taking refuge in low-flow areas.

Moreover, the analysis of the diversity indices indicates that the entire environment, the average values of the Shannon index are relatively low. However, values of the Piélou evenness index (average E> 0.60) show that the stands are well distributed on all the stations of the river. By comparing the three sectors of the river, the highest values of the Shannon (3.81) and evenness (0.86) index were obtained in the upper reaches. This sector is therefore relatively more diversified and shows a very stable stand. The stand distribution of aquatic macroinvertebrates in the upper reaches of the Sô River is more regular than that of the other two sectors (middle and lower reaches). This situation could be the consequence of a relative spatial heterogeneity of the environmental conditions of the river. Indeed, in this river, on all the environmental parameters measured, several variables vary very significantly from one sector to another. Another explanation is that the upper course of the river is subject to less anthropogenic pressure, unlike the other two sectors, especially the lower reaches, the latter being the most polluted part of the river [64].

Finally, the redundancy analysis explains the factors responsible for the distribution of organisms in the environment. The densities of the Ephemeroptera, Pleoptera and Trichoptera now a peak in the great rainy season with increasing oxygen, transparency and current velocity. The increase in its indicator variables for good quality water [30], justify the abundance of these polluo-sensitive groups. It's the same for the abundance of Molluscs, which appear extensively in the downstream course of the river with high values of calcium and magnesium concentrations, conductivity and TDS. The high calcium and magnesium hardness values would justify the abundance of the Molluscs in this watercourse, especially in the highly mineralized lower course, because these organisms require calcium for the development of their shell. The complex calcium and magnesium-TDS-conductivity-temperature would be at the origin of the proliferation of molluscs. These results are similar those of [6, 9, 10, 17]. The gastropod fauna was dominated by P. acuta which presents the highest relative abundance (76.95%) at the study period. Not surprising, this alien invasive pulmonate is tolerant of polluted waters where it may occur in large numbers, up to 3,000/m^2 [9, 10]. Pulmonates are better adapted to harsher conditions due to the fact that they are able to assimilate atmospheric air via a vascularized mantle cavity.

5. Conclusion

The present study conducted that aquatic macroinvertebrates of the Sô River are rich and diversified with 3 branches, 6 classes, 13 orders, 44 families and 62 genera. It is mainly represented by Arthropods (81.77%) and largely dominated by Hexapods with 7 orders 31 families and more than 43 genera. Generally, faunal wealth is lower downstream (the stations are subjected to enormous anthropogenic pressures) compared to the upstream end of the Sô river basin, which shows a disturbed stand on the downstream part. The highest densities were observed mainly in the great rainy season and the small dry season in the upper reaches of the river. The taxonomic diversity of the aquatic macroinvertebrates of the Sô River depends directly on the velocity of the current, the nitrogen and phosphorus compounds, the mineralization parameters, the canopy and the density of the vegetation cover.

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7. References

1. Boko M. Changements climatiques et impact socioéconomiques sur le littoral Béninois (Afrique de l'Ouest). Rapport de recherche, Centre Béninois de Recherches Scientifiques et Technologiques. 2004, 57.
2. Koudénoukpo ZC, Chikou A, Adandédjan D, Hazoume R, Youssao AKI, Mensah GA *et al* Laleye A. Philippe. Caractérisation physico-chimique d'un système lotique en région tropicale : la rivière Sô au Sud-Bénin, Afrique de l'Ouest. Journal of Applied Biosciences. 2017; 113:11111-11122.
3. Tolley-Jordan LR, Owen JM. Habitat influences snail community structure and trematode infection levels in a spring-fed river, Texas, USA. Hydrobiologia. 2008; 600:29-40. doi:10.1007/s10750-007-9173-3.
4. Ben moussa A, Chahlaoui A, Rour E, Chahboune M. Diversité taxonomique et structure de la macrofaune benthique des eaux superficielles de l'oued khoumane. Moulay idriss Zerhoun, Maroc Taxonomic diversity and structure of benthic macrofauna of surface water of Khoumane River. Moulay idriss Zerhoun, Morocco). Journal of Mater Environment. 2014; 183-198.
5. Clarke RT, Furse MT, Gunn RJ, Winder JM, Wright JF. Sampling variation in macroinvertebrate data and implications for river quality indices. Freshwater Biology. 2002; 47:1735-1751.
6. Diomandé D, Kotchi YB, Oi Edia E, Konan KF, Gourène G, Diversité des *et al.* (Côte d'Ivoire; Afrique de l'Ouest). European Journal of Scientific Research. 2009; 35:368-377.
7. Foto Menbohan S, Zébazé Togouet SH, Nyamsi Tchacho NL, Njiné TN. Macroinvertébrés Benthiques du cours d'eau Nga: Essai de Caractérisation d'un Référentiel par des Analyses Biologiques. European Journal of Scientific Research. 2010; 43:96-106.
8. Chabot B. Les facteurs de sélection des bio-indicateurs de la qualité des écosystèmes aquatiques : Elaboration d'un outil d'aide à la décision. Mémoire de maîtrise en environnement. Université de Sherbrooke, Québec. 2014, 104.
9. Tchakonté S, Ajeagah GA, Diomande D, Camara IA, Ngassam P. Diversity, dynamic and ecology of

freshwater snails related to environmental factors in urban and suburban streams in Douala-Cameroon (Central Africa). Aquatic Ecology. 2014; 48:379-395. doi 10.1007/s10452-014-9491-2.
10. Tchakonté S, Ajeagah GA, Diomande D, Camara IA, Nyamsi Tchatcho NL, Ngassam P *et al.* Impact of urbanization on aquatic insect assemblages in the coastal zone of Cameroon: the use of biotraits and indicator taxa to assess environmental pollution. Hydrobiologia. 2015; 755:123-144. Doi10.1007/s10750-015-2221-5.
11. Koudenoukpo ZC, Chikou A, Togouet Zébazé SH, Mvondo N, Hazoume RU, Houndonougbo PK, *et al.* Zooplanctons et Macroinvertébrés aquatiques: vers un assemblage de bioindicateurs pour un meilleur monitoring des écosystèmes aquatiques en région tropicale. International Journal of Innovation and Applied Studies. 2017; 20:276-287.
12. Clarke A, McNally R, Bond N, Lake PS. Macroinvertebrate diversity in headwater streams: a review. Freshwater Biol. 2008; 53:1707-1721.
13. Alvarez M, Pardo I. Dynamics in the trophic structure of the macroinvertebrate community in a Mediterranean, temporary stream. Aquat Sci. 2009; 71:202-213.
14. Vaughan IP, Ormerod SJ, Large-scale, long-term trends in British river macroinvertebrates. Global Change Biology. 2012. doi:10.1111/j.1365-2486.2012.02662.
15. Xu J, Zhang M. Primary consumers as bioindicator of nitrogen pollution in lake planktonic and benthic food webs. Ecological Indicators. 2012; 14:189-196.
16. Wang B, Liu D, Liu S, Zhang Y, Lu D. Wang L. Impacts of urbanization on stream habitats and macroinvertebrate communities in the tributaries of Qiangtang River, China. Hydrobiologia. 2012; 680:39-51.doi:10.1007/s10750-011-08996.
17. Camara IA, Bony YK, Diomande D, Edia EO, Konan FK, Kouassi CN, *et al.* Freshwater snail distribution related to environmental factors in Banco National Park, an urban reserve in the Ivory Coast (West Africa). African Zoololgy. 2012; 47:160-168. doi:10.3377/004.047.0106.
18. Feumba R, Ngounou Ngatcha BN, Tabue Youmbi JG, Ekodeck GE. Relationship between climate and groundwater recharge in the Besseke watershed (Douala–Cameroun). JWARP. 2011; 3:607-619. doi:10.1007/s00027-011-0218-3.
19. Tening AS, Chuyong GB, Asongwe GA, Fonge BA, Lifongo LL, Tandia BK *et al.* Nitrate and ammonium levels of some water bodies and their interaction with some selected properties of soils in Douala metropolis, Cameroon. African Journal of Environmental Sciences and Technology. 2013; 7:648-656. doi:10.5897/AJEST12.082.
20. Furse M, Hering D, Moog O, Verdonschot P, Johnson RK, Brabec K, *et al.* The STAR project: context, objectives and approaches. Hydrobiologia. 2006; 566:3-29.
21. Gnonhossou PM. La faune benthique d'une lagune ouest africaine (le Lac Nokoué au Bénin) : diversité, abondance, variations temporelles et spatiales, place dans la chaîne trophique. Thèse de Doctorat. Institut National Polytechnique de Toulouse. SEVAB. 2006; 169.
22. Adandédjan A. Diversité et déterminisme des peuplements de macroinvertébrés benthiques de deux lagunes du sud-Bénin : la lagune de Porto-Novo et la lagune côtière. Doctorat unique en Sciences Agronomiques de l'université d'Abomey-Calavi. 2012; 239.
23. Odountan H, Abou Y. Can Macroinvertebrate Assemblage Changes Be Used as Biological Indicator of Water Quality of the Nokoue Lake (Benin)? Journal of Environmental Protection. 2015; 6:1402-1416.
24. Agblonon Houelome MT, Adandédjan D, Chikou A, Imorou Toko I, Bonou C, Youssao AKI *et al.* Evaluation de la qualité des eaux des ruisseaux du cours moyen de la rivière Alibori par l'étude des macroinvertébrés benthique dans le bassin cotonnier du Bénin, International Journal of Biological and Chemical Sciences. 2016; 10: 2461-2476.
25. Odountan H, Abou Y. Structure and Composition of Macroinvertebrates during Flood Period of the Nokoue Lake. Benin Journal of Ecology. 2016; 6:62-73.
26. Zinsou LH, Gnohossou P, Adandedjan D, Laleye P. Profil de distribution des macroinvertébrés benthiques du delta de l'Ouémé à partir du Self Organizing Map (SOM). Afrique Science. 2016; 12:1813-1828.
27. Lalèyè P. Ecologie comparée de deux espèces de Chrysichthys, poissons Siluriformes (Claroteidae) du complexe lagunaire « Lac Nokoué-Lagune de Porto-Novo » au Bénin. Thèse de doctorat, Université de Liège. 1995; 199.
28. Tachet H, Bournaud M, Richoux P Usseglio-Polatera P. Invertébrés d'eau douce : systématique,biologie, écologie. CNRS édition, Paris. 2000; 587.
29. Ahouanssou Montcho S. Diversité. Exploitation des poissons de la rivière Pendjari (Bénin, Afrique de l'Ouest). Thèse de doctorat, Université d'Abomey-Calavi. 2011, 225.
30. Rodier J. L'analyse de l'eau. 9ème édition, DUNOD, Paris. 2009, 1384.
31. Agbossou EK. Cours d'Hydrologie : Différentes méthodes de détermination de la vitesse du courant à partir de la vitesse surface. DESS/AGRN/FSA. 2005; 198.
32. Durand, JR, Lévêque C. Flore et faune aquatiques de l'Afrique sahelo-soudanienne (Tome I et II). Paris, France: ORSTOM. 1980, 390-483.
33. Merrit RW, Cummins KW. An introduction to the aquatic insects of north America, second edition, Dubuque (Iowa), Kendall/Hunt Publishing Company, USA. 1984, 722.
34. Tachet H, Richoux P, Bournaud M, Usseglio-Polatera P. Invertébrés d'eau douce. Systématique, biologie, écologie. CNRS éditions, Paris. 2010, 628.
35. Moisan J. Guide d'identification des principaux Macroinvertébrés benthiques d'eau douce du Québec, surveillance volontaire des cours peu profonds. Direction du suivi de l'état de l'environnement, Ministère du Développement Durable, de l'Environnement et des Parcs. 2006, 82.
36. Moisan J. Guide d'identification des principaux macroinvertébrés benthiques d'eau douce du Québec, Surveillance volontaire des cours d'eau peu profonds. Direction du suivi de l'état de l'environnement, ministère du Développement durable, de l'Environnement et des Parcs, Québec, Canada 2010, 82.
37. Brown DS. Freshwater Snails of Africa and their Medical Importance. Taylor and Francis LTD London. 1980, 487.
38. Lafont M. Introduction pratique à la systématique des organismes des eaux continentales Françaises. 3: Annélides Oligochètes. Bulletin mensuel de la société

Linnéenne de Lyon. 1983; 4:107-135.
39. AFNOR. L'Indice Biologique Global Normalisé français (IBGN): ses principes et son évolution dans le cadre de la Directive Cadre Européenne sur l'eau. NF T. 2004, 90-350.
40. AFNOR. Qualité écologique des milieux aquatiques. Qualité de l'eau. Prélèvement des macroinvertébrés aquatiques en rivières peu profondes. Association française de normalisation. Norme expérimentale T. 2009, 90-333.
41. Moisan J, Pelletier L. Guide de surveillance biologique basée sur les macroinvertébrés benthiques d'eau douce du Québec - Cours d'eau peu profonds à substrat grossier. Direction du suivi de l'état de l'environnement, ministère du Développement durable, de l'Environnement et des Parcs, Québec, Canada. 2008, 86.
42. Spellerberg IF, Fedor PJ. A tribute to Claude Shannon and a plea for more rigorous use of species richness, species diversity and the Shannon-Wiener index. Global Ecology Biogeographical. 2003; 12:177-179.
43. Zouggaghe F, Moali A. Variabilité structurelle de peuplement de macroinvertébrés benthiques dans le bassin versant de la Soummam (Algérie, Afrique du Nord). Revue d'Ecologie (Terre Vie). 2009; 64:205-321.
44. Sanogo S, Kabre AT. Dynamique de structuration spatio-temporelle des populations de familles de macroinvertébrés dans un continuum lac de barrage – effluent-fleuve, Volta Burkina Faso. Journal of Applied Biosciences. 2014; 78:6630-6645.
45. Daly-Yahia MN, Souissi OS, Daly-Yahia OK. Spatial and Temporal Structure of Copepods in the Bay of Tunis (Southwestern Mediterranean Sea). Zoological studies. 2004; 43:366-375.
46. Côté R, Bussières D, Desgagné P. Distribution spatio-temporelle du phytoplancton et du zooplancton dans le lac Saint-Jean (Québec), un réservoir hydroéléctrique. Revue des Sciences de l'eau, Revue des Sciences de l'Eau. 2002; 15:597-614.
47. Shannon CE, Weaver V. The mathematical theory of communication. Urbana, IL: University of Illinois III. Press. 1949; 4:1-125.
48. Davis AM, Thorburn PJ, Lewis SE, Bainbridge ZT, Attard SJ, Milla R *et al.* Environnemental impacts of irrigated sugarcane production: Herbicide run-off dynamics from farms and associated drainage systems. Agriculture Ecosystem. 2011. doi: 10.1016/j.agee.2011.06.019.
49. Gbemisola A, Oriola A. Zooplankton associations and environmental factors in Ogunpa and Ona rivers, Nigeria. Revue Biology Tropical. 2003; 51:391-398.
50. Harris R, Wiebe P, Lenz J, Skjoldal HR, Huntle M. ICES Zooplankton Methodology Manual, Academic Press, San Diego. 2000; 28.
51. Ter Braak CJF. Smilauer P. CANOCO Reference manual and user's guide to Canoco for Windows (version 4). Center for Biometry Wageningen. 1998; 351.
52. Monney IN, Ouattara NR, Etilé NM, Aka M, Bamba, Koné T, Distribution du zooplancton en relation avec les caractéristiques environnementales de quatre rivières côtières du Sud-est de la Côte d'Ivoire**.** Journal of Applied Biosciences. 2016; 98:9344-9353.
53. Manly BFJ. Randomization and Monte Carlo Methods in Biology. Chapman and Hall, London. 1991; 281.
54. McQuoid MR, Godhe A. Recruitment of coastal planktonic diatoms from benthic versus pelagic cells: Variations in bloom development and species composition. Limnology and Oceanography. 2004; 49:1123-1133.
55. Egnima Bamou CH. Structure des peuplements de Macroinvertébrés benthiques dans le cours d'eau Nga. Mémoire de DEA, Université de Yaoundé I. 2007; 63.
56. Foto SM. Etude de la pollution de deux cours d'eau à Yaoundé: l'Abiergué et le Mfoundi. Etude physico-chimique et biologique. Thèse de doctorat de troisième cycle, Université de Yaoundé. 1989, 142.
57. Carlisle DM, Meador MR, Moulton SR II, Ruhl PM, Estimation and application of indicator values for common macroinvertebrate genera and families of the United States. Ecological Indicators. 2007; 7:22-33.
58. Tchakonte S. Evaluation de la qualité des eaux du cour d'eau Nga par les macroinvertébrés benthiques. Mémoire de Master, Université de Yaoundé I. 2011; 40.
59. Vannote R, Minshall GK, Cummins J, Sedell, Cushing C. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 1980; 37:130-137.
60. Dajoz R. L'évolution biologique au XXIe siècle: les faits, les théories. Péronnas, Lavoisier. 2012; 326.
61. Angelier E. Ecology of streams and rivers.Science Publisher, Inc. Enfield. 2003, 211-213.
62. Lounaci A. Recherche sur la faunistique, l'écologie et biogéographie des macroinvertébrés des cours d'eau de Kabylie. Thèse de doctorat d'état. 2005; 209.
63. Frontier S. Utilisation des diagrammes rang-fréquences dans l'analyse des écosystèmes. Journal de Recherche en Océanographie. 1976; 35-48.
64. Foto MS, Zebaze Togouet SH, Nyamsi Tchatcho NL, NJINE TT. Macroinvertébrés du cours d'eau Nga: Essai de Caractérisation d'un Référentiel par des Analyses Biologiques, European Journal of Scientific Research. 2010; 43:96-106.