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Diversity and structure of benthic macroinvertebrates community in relation to environmental variables in Lake Ehuikro, Côte d'Ivoire

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ABSTRACT

Lake Ehuikro is used to supply drinking water to Bongouanou City. Some human activities around the lake are established and may have an effect on water quality and aquatic life. This study was conducted to describe for the first time the diversity and the structure of macro-invertebrate communities in this area. Physico-chemical parameters were measured monthly in three sampling sites and the benthic Macroinvertebrates was collected using a Van Veen grab on a total area of 0.5 m^2 per sample. Principal component analysis showed a clear pattern of separation of these three sampling sites according to the substrate type: gravel-mud, sand-gravel and sand in E1, E2 and E3 stations, respectively. A total of 3285 aquatic Macroinvertebrates belonging 52 taxa, were recorded and the most dominant taxa were *Baetis* sp. (19.85%) and *Tubifex* sp. (11.57%). Multivariate statistical analysis revealed significant differences between the community structure of E1 and E2 samples: the first sample was dominated by 7 taxa including *Tubifex* sp. and *Melanoides tuberculata* while the second by 13 species. The Shannon diversity indices showed high value in lake (3.10) reflecting moderately polluted conditions. Significant correlations between *Tubifex* sp., *Biomphalaria pfeifferi*, *M. tuberculata* and depth, transparency, substrate texture and macrophyte (MAC) were found. The present study revealed that the benthic fauna of the lake Ehuikro dominated by pollution-sensitive taxa. These findings provide valuable information that can be used to establish biotic indices to monitor the human disturbance effect on water quality of Lake Ehuikro.

INTRODUCTION

Lakes, like every surface water source, are very important for water supply in communities, cities, agriculture and industry. Lakes exist as two types of surface water sources such as natural and artificial lakes. In several rural areas of Côte d'Ivoire, artificial lakes are freshwater reservoirs used for irrigation of cultivated land, traditional farming herding and fishing (Da Costa et al., 1998; Da Costa and Dietoa, 2007; Goli Bi et al., 2019). However, these lakes are often used as a source of drinking water supply in large cities, as is the case with Lake Ehuikro located near the Bongouanou city. In recent years several human activities such as agricultural clearing, ranching established around Lake Ehuikro are likely to have an impact on the water quality and aquatic life. Indeed nutrients in polluted waters can come from agricultural fertilizers, septic systems, home lawn care products, and yard and animal wastes. In high concentrations, they can become both an environmental and health threat and increases mortality

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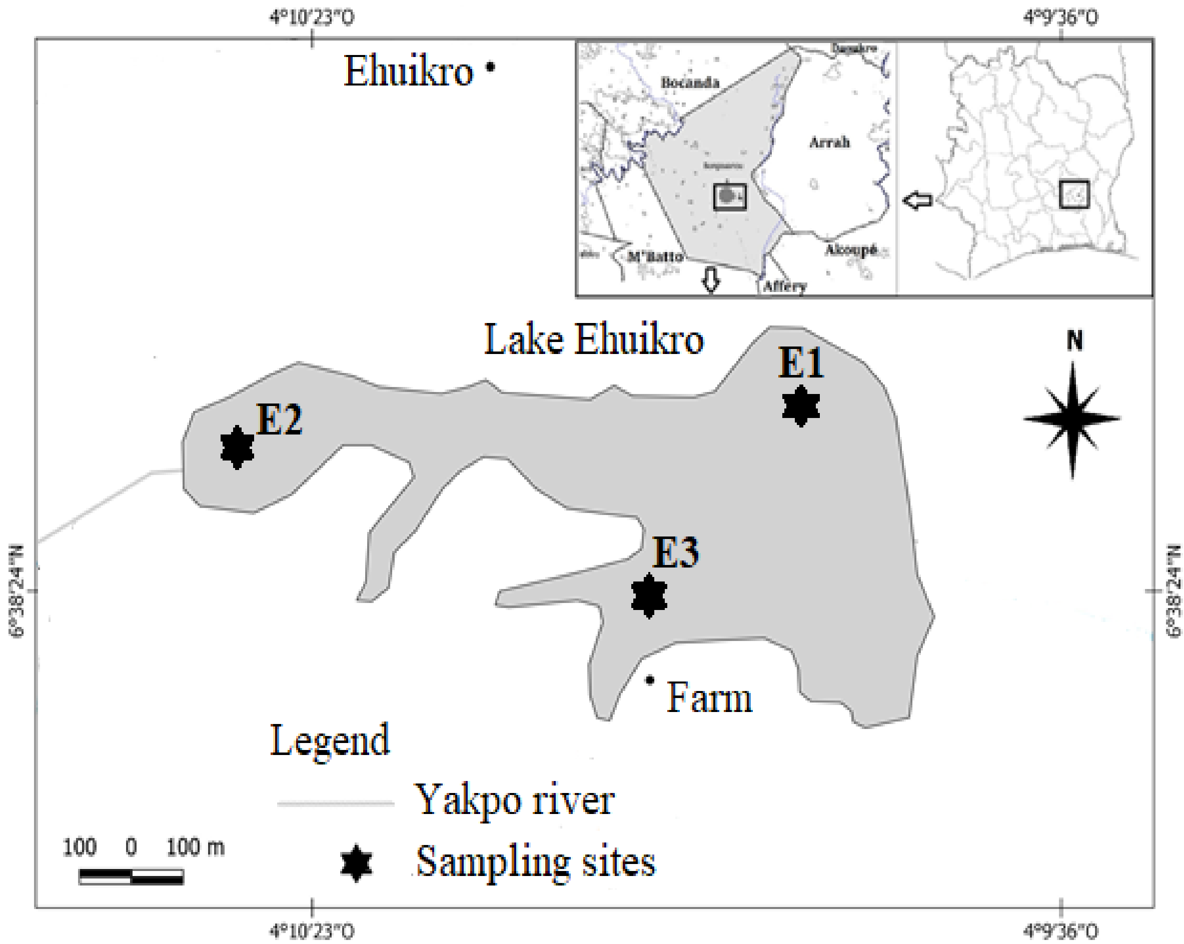

Figure 1. Map of Lake Ehuikro showing sampling sites (Bongouanou, Côte d'Ivoire).

rates of sensitive species (Amoatey and Baawain, 2019). Among these species, aquatic macroinvertebrates are an important part of freshwater biodiversity and their importance is widely known (Rosenberg and Resh, 1993; Barbour et al., 1999). They play an important role in the processing and cycling of nutrients as they belong to several specialized feeding groups such as shredders, filter feeders, deposit collectors, and predators (Tachet et al., 2010). They are influenced by habitat changes and are good indicators of environmental conditions (Macneil et al., 2002). Indeed, several works indicated that macroinvertebrates living in lake habitats show some morphological differences from those found in flowing water bodies (Williams et al., 2003).

In general, many supply water lakes have received near negligible attention in the benthic ecology research. Until date, few studies have been carried out to assess the biodiversity state of Lake Ehuikro (Kouadio et al., 2019). However, no studies have been carried out on the structure of macroinvertebrates assemblages. The objective of this study was to describe for the first time the diversity and the structure of macroinvertebrate communities in Lake Ehuikro.

MATERIALS AND METHODS

Study area

The Lake Ehuikro was built as a result of the construction of a dam in 1973 as part of the national hydraulic program on the Yakpo River in Bongouanou district (Figure 1). The Lake Ehuikro with an area of 733,455 m^2, is fed by Yakpo river and is supplied by precipitation run-off. Three sampling sites for this study were selected. The E1 site (6°38'34.00" N, 4°09' 54.60" W) located approximately 1 km from Ehuikro village receives discharges of wastewater from homes. Several large trees border this site and serves as a watering place for domestic animals and a place of various uses (washing vehicles, baptism) for population. Many plantations of cassava, cocoa, rubber trees and a hog farm border E2 site (6° 38' 31.20" N, 4°10' 27.40" W) located at the mouth of the Yakpo River. The E3 site (6°38'23.20" N, 4°10' 01.30" W) located at South of the lake and is surrounded by several poultry farms and many other food and industrial crops. Aquatic plants were observed near the banks on water surface in all stations.

Physico-chemical analysis

Measurements of the physico-chemical parameters of Lake were carried out monthly between May 2017 and April 2018. Temperature (Temp), dissolved oxygen (DO), Conductivity and pH were measured *in situ* using a multiparameter SX 713 Model. Transparency and water depth by with a Secchi disc and a graduated stick were measured, respectively following Lee et al. (2015). Water samples were collected only once at the surface in 500 mL polyethylene bottles and stored in a coolbox at 4°C. In the laboratory, orthophosphates (PO_4^{3-}) and nitrates (NO_3^-) were determined by colorimetry using HACH DR/2800 spectrophotometer. The proportion of aquatic macrophytes in each station was visually assessed.

Sampling and identification of Macroinvertebrates

Macroinvertebrates were sampled monthly at the same time as the abiotic variables using a Van Veen grab, 1 m long and 14 cm in diameter as described by Elliott and Drake (2006). In each sampling station, ten random replicate samples were taken from various habitats, for a total area of 0.5 m^2. Mud obtained was first examined, all large (visible) invertebrates removed with forceps and put in specimen bottles containing 5% formalin. All Macroinvertebrates found on the plant surface were removed using a dip net. In the laboratory, the mud was washed through a 500 µm sieve and all Macroinvertebrates picked from the sieve. Subjective methods were used to assess substrate texture and the amount of plant debris (PD) present after sorting the benthic organisms from each sample according to Atobatele and Ugwumba (2010). Macroinvertebrates were identified to generic level under a stereomicroscope according to Belleg (1981), Dejoux et al. (1981) and Tachet et al. (2010) and counted at the Laboratory.

Data analysis

Environmental variables

The environmental variable at each collection site were subjected to principal components analysis (PCA). For each variable, these measures were transformed by the function log (x+1) in the statistical analyses.

Macroinvertebrates metrics and indices

Macroinvertebrates sampled with the grab and dip net were combined for data analysis. Three indices were calculated to analyze the community structure: the diversity index of Shannon and Wiener (H'), the Pielou index of Equitability (J), the Density (D) calculated from the taxonomic richness (S, number of taxa found at each sampling site) and the numerical abundance (A, number of individuals in a taxa, in 12 sampling units) of macroinvertebrates. These indices informed on the distribution of individuals within the taxa to compare the diversity of the communities among the sampling stations (Dajoz, 2000). To assess the differences of the physico-chemical values and diversity indices between the different sampling sites was applied non-parametric analyses of variance (Kruskal–Wallis test, $p<0.05$). Application of Jaccard quotient gave a comparison in the faunal similarity between stations (Magurran, 1988). The rank frequency diagram (RFD) were used to monitor the demographic structure of the macrofauna in order to visualize the spatial evolution of the invertebrate population (Frontier, 1976).

Relationships between benthic community and environmental parameters

The Spearman correlation coefficient ($p<0.05$) to determine the relation between physico-chemical variables and biological variables was performed (Bilounga et al., 2020). Only specimens with a total abundance greater than 2% were included in the analysis.

Multivariate analyses of benthic macroinvertebrates community

A similarity matrix between samples was constructed using the Bray- Curtis similarity coefficient (Field et al., 1982). In addition, non-metric multidimensional scaling (NMDS) analysis were used as exploratory tools to identify the stations with similar macro-invertebrate communities. Analysis of similarity (ANOSIM) was then used to detect significant differences ($p<0.05$) between these groups (Clarke and Warwick, 1994). In this analysis, four variables were used: S, A, H' and J. Numerical abundance variables of Macroinvertebrates were log-transformed to diminish the influence of dominant and rare taxa (Suriano et al., 2013) and only taxa with an abundance greater than 2% were included in the analysis. The similarity percentage routine (SIMPER) was calculated to determine the specific importance of each taxon in each group (Clarke, 1993).

Table 1. Mean values (±SD) of environmental variables and substrate composition of Lake Ehuikro (Bongouanou, Côte d'Ivoire).

Parameters	E1	E2	E3	Lake
Temp (°C)	28.17±0.94	27.78±1.38	28.04±0.83	28.00±1.04
pH	7.59±0.41	7.42±0.42	7.71±0.66	7.57±0.50
Cond. (uS/cm)	278.33±43.27	274.45±58.97	278.07±47.48	277.01±47.95
DO (mg/l)	4.58±1.64	4.95±2.39	4.94±2.43	4.82±2.08
Transp (m)	0.54±0.11	0.58±0.11	0.56±0.12	0.56±0.11
Depth (m)	3.93±0.97	2.98±0.67	2.92±0.85	3.30±0.94
PO_4^{3-} (mg/l)	0.03±0.01	0.02±0.01	0.02±0.01	0.02±0.01
NO_3^- (mg/l)	0.01±0.01	0.01±0.01	0.02±0.01	0.01±0.01
Sand (%)	0	0	67	–
SGM (%)	0	68	0	–
GMM (%)	82	0	0	–
PD (%)	18	32	33	–
Macrophyte (%)	16	30	34	–

Temp, Temperature; **Cond,** conductivity; **DO,** dissolved oxygen; **Transp,** transparency; **SGM,** sand-gravel mixture; **GMM,** gravel-mud mixture; **PD,** plant debris.

All univariate, multivariate techniques and the diversity indices calculation were undertaken using the Palaeontological statistics (Past 3.21) Software (Hammer et al., 2001).

RESULTS

Physico-chemical parameters

The spatial variation of physico-chemical variables and the substrate composition were presented in Table 1. The mean temperature is 28.00±1.04°C and it varied from 27.78±1.38 to 28.17±0.94°C between sampling sites. The mean values of pH, conductivity, dissolved oxygen and transparency were 7.57±0.50, 277.01±47.95 µS/cm, 4.82±2.08 mg/l, 0.56±0.11 m, respectively and the spatial variation of these parameters had shown little change from one site to another. The station E1 was the deepest of all stations (3.93 ± 0.97m). The values of phosphate and nitrate levels were low and varied between 0.01 ± 0.01 and 0.03±0.01 mg/l. Phosphate level was higher in E1 station while the nitrate level was higher in E3. Except for the water depth was different significantly between E1 and E3 stations (Kruskall-Wallis, $p<0.05$), all other parameters don't vary significantly among sampling sites ($p>0.05$).

The lake substrate is dominated by sand (S), sand-gravel mixture (SGM), gravel-mud mixture (GMM) and plant debris. The stations E1, E2 and E3 were dominated by GMM (82%), SGM (68%) and sand (67%), respectively. The percentage of plant debris was higher in E2 and E3 stations and the comparison showed significant differences between E1-E2 and E1-E3 (Kruskall-Wallis, $p<0.05$). The proportion of aquatic macrophytes was estimated at 16%, 30% and 34% at stations E1, E2 and E3, respectively.

The physico-chemical parameters were incorporated into the PCA. The first principal component (PC1), explaining 52.19% of the total variability, was negatively associated with water depth and GMM substrate (Table 2). The PC2 (47.80% of the total variability) was positively correlated with the following variables: GMM, sandy substrate (sand), plant debris and MAC. In general, there is a clear pattern of separation of these three sampling sites according to the substrate type (Figure 2). The E1 station was strongly correlated to GMM while E2 and E3 were correlated to SGM and sand, respectively. Other abiotic variables such as water depth, plant debris and macrophytes showed a low correlation with the sampling stations.

Macroinvertebrates assemblages structure

Fifty-two taxa belonging to four phyla and thirty-two families were recorded: one Arachnida (1.92%), three Annelids (5.77%), nine Mollusca (17.31%) and thirty-nine Insecta (75%) (Table 3). Among the families, Hydrophilidae, Cordulidae and Chironomidae were the most dominant. With regard to macroinvertebrate abundances, a total of 3285 individuals were collected, including 2190 Insects (66.67%), 708 Mollusca (21.55%), 384 Annelida (11.69%) and 3 Arachnida (0.09%). In the E1 site, 1339 individuals were recorded and this site dominated by five taxa: *Tubifex* sp. (27.63%), *Baetis* sp. (13.74%), *M. tuberculata* (10,31%), *B. pfeifferi* (9,71%)

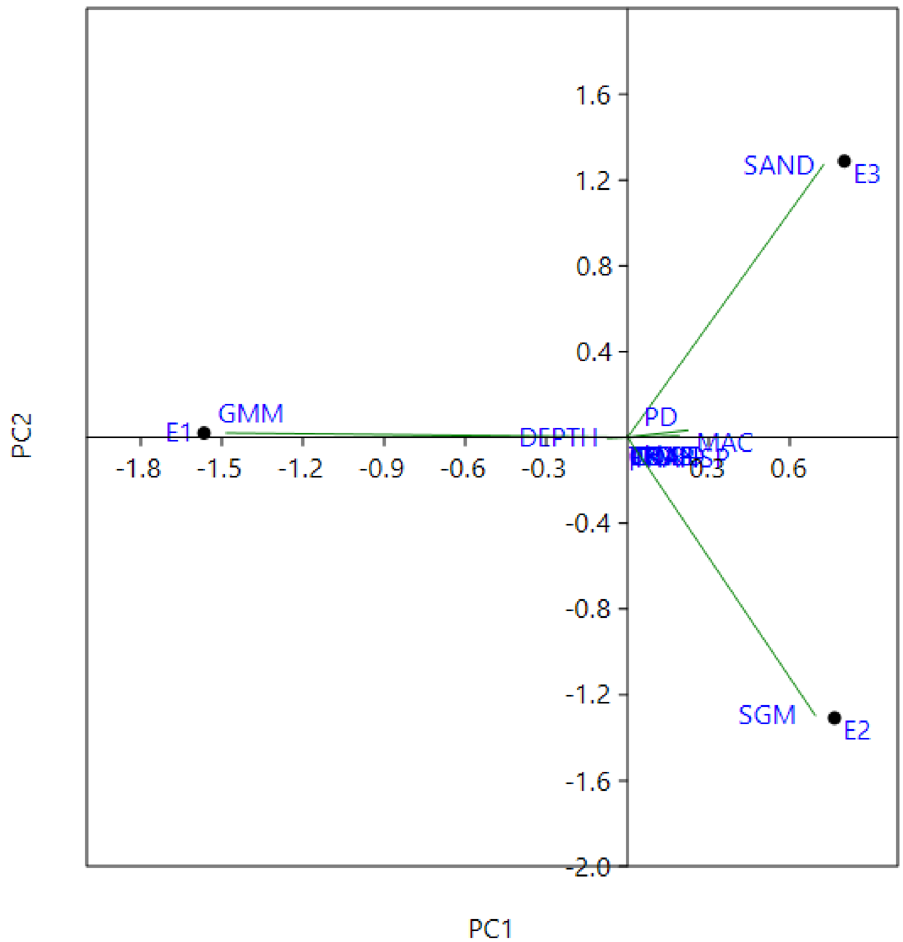

Figure 2. PCA biplot of environmental variables (conductivity, pH, water Temp, DO, phosphate, nitrate, transparency, depth, GMM, SGM, sand, PD and MAC) from 3 sampling stations of Lake Ehuikro.

Table 2. Results of principal components analysis of environmental parameters data from 3 sampling sites of Lake Ehuikro.

Variables	PC 1	PC 2
Temp	-0.00163	0.00152
pH	-0.00049	0.00567
Conductivity	-0.00135	0.00220
DO	0.01170	-0.00044
Transp	0.00353	-0.00218
Depth	-0.04099	-0.00196
PO43-	-0.00180	0.00002
NO3-	0.00093	0.00163
Sand	0.39901	0.70016
SGM	0.38213	-0.7136
GMM	-0.81666	0.01149
Plant debris	0.10485	0.00351
Macrophyte	0.12251	0.01857

Table 3. Taxonomic list, relative abundance (A, percentage of total number of individuals sampled) and density (D, ind/m^2) of aquatic macroinvertebrates sampled in Lake Ehuikro.

Phyla / Family	Taxa	E1		E2		E3		Lake	
		D1	A1	D2	A2	D3	A3	A	D
ANNELIDS		**61.7**	**27.6**	–	–	**2.3**	**1.4**	**11.7**	**21.3**
Tubificidae	*Tubifex* sp.	61.67	27.63	–	–	1.67	0.99	11.57	21.11
Glossiphoniidae	*Hemiclepsis marginata*	–	–	–	–	0.33	0.20	0.06	0.11
Lumbricidae	*Lumbricus* sp.	–	–	–	–	0.33	0.20	0.06	0.11
MOLLUSCA		**53.3**	**23.9**	**29.5**	**18.9**	**35.2**	**20.9**	**21.6**	**39.3**
Bulinidae	*Bulinus forskalii*	0.33	0.15	–	–	–	–	0.06	0.11
	Bulinus truncatus	–	–	0.67	0.43	5.17	3.07	1.07	1.94
Pilidae	*Lanites varicus*	7.17	3.21	7.67	4.90	7.33	4.36	4.05	7.38
	Lanites libycus	–	–	5	3.20	–	–	0.91	1.67
	Lanites sp.	1.17	0.52	2.67	1.70	–	–	0.70	1.28
Thiaridae	*Melanoides tuberculata*	23	10.31	–	–	2.67	1.59	4.69	8.56
Lymnaeidae	*Lymnae natalensis*	–	–	–	–	5.5	3.27	1.01	1.83
Physidae	*Physa marmorata*	–	–	8.83	5.65	1.5	0.89	1.89	3.44
Planorbidae	*Biomphalaria pfeifferi*	21.67	9.71	4.67	2.98	13	7.74	7.19	13.11
ARACHNIDA		–	–	–	–	**0.5**	**0.30**	**0.09**	**0.17**
Hydrachnidae	*Hydrachna globosa*	–	–	–	–	0.5	0.30	0.09	0.17
INSECTS		**108.2**	**48.5**	**126.9**	**81.1**	**130.1**	**77.4**	**66.7**	**121.6**
Ephemeroptera									
Baetidae	*Baetis* sp.	30.67	13.74	44.67	28.57	33.33	19.84	19.85	36.22
Odonata									
Coenagrionidae	*Ischnura* sp.	5.33	2.39	6.5	4.16	2.5	1.49	2.62	4.78
	Pseudagrion punctum	1.83	0.82	3.5	2.24	–	–	0.97	1.78
	Coeriagrion tenellum	–	–	–	–	0.5	0.30	0.09	0.17
Corduliidae	*Epitheca bimaculata*	0.5	0.23	–	–	0.5	0.30	0.18	0.33
	Somatochlora sp.	1.5	0.67	2.5	1.60	0.5	0.30	0.82	1.5
	Cordulia aenea	–	–	1.5	0.96	–	–	0.27	0.5
	Oxygastra curtisii	–	–	3.67	2.35	–	–	0.67	1.22
Libellulidae	*Brachythemis leucosticta*	1.5	0.67	–	–	2.67	1.59	0.76	1.39
	Orthetrum sp.	–	–	5	3.20	–	–	0.91	1.67
Heteroptera									
Belostomatidae	*Diplonychus* sp.	–	–	2.833	1.81	5.83	3.47	1.58	2.89
	Belostoma sp.	0.17	0.08	–	–	–	–	0.03	0.06
Nepidae	*Ranatra linearis*	1.17	0.52	0.833	0.53	0.5	0.30	0.46	0.83
Notonectidae	*Anisops* sp.	–	–	2.5	1.60	7.67	4.56	1.86	3.39
Pleidae	*plea* sp.	1.17	0.52	3.83	2.45	0.83	0.49	1.07	1.94
Naucoridae	*Naucoris* sp.	1.33	0.60	2.33	1.49	0.33	0.20	0.73	1.33
	Macrocoris flavicolis	2.17	0.97	0.67	0.43	3.17	1.88	1.10	2.00
Gerridae	*Gerris* sp.	–	–	–	–	0.5	0.30	0.09	0.17
Mesoveliidae	*Mesovelia* sp.	1.17	0.52	–	–	0.33	0.20	0.27	0.5
Lepidoptera									
Crambidae	*Parapoynx* sp.	1	0.45	1.33	0.85	–	–	0.43	0.77
Coleoptera									
Corixidae	*Micronecta scutellaris*	6.83	3.06	2.17	1.38	13.17	7.84	4.05	7.39
Dytiscidae	*Laccophilus* sp.	3.17	1.42	1.83	1.17	3.17	1.88	1.49	2.72
	Laccophilus luctuosus	–	–	–	–	0.33	0.20	0.06	0.11
	Hydrovatus sp.	1.5	0.67	1	0.64	3.17	1.88	1.04	1.89
Hydrophilidae	*Amphiops* sp.	1.83	0.82	1.17	0.75	3.33	1.98	1.16	2.11

Table 1. Contd.

	Helochares sp.	9.33	4.18	2.5	1.60	8	4.76	3.62	6.61
	Laccobius sp.	–	–	3.67	2.34	4.67	2.78	1.52	2.78
	Hydrobius sp.	1	0.45	–	–	–	–	0.18	0.33
	Coelostoma sp.	–	–	3.5	2.24	1.67	0.99	0.94	1.72
Noteridae	*Noterus* sp.	10	4.48	4.67	2.99	12	7.14	4.87	8.89
Diptera									
Culicidae	*Culex* sp.	–	–	–	–	0.67	0.40	0.12	0.22
Stratiomyidae	*Odontomyia* sp..	4	1.79	0.67	0.43	4.33	2.60	1.64	3.00
Ceratopogonidae	*Bezzia* sp.	1.17	0.52	–	–	–	–	0.21	0.39
Syrphidae	*Eristalis* sp.	0.33	0.15	–	–	–	–	0.06	0.11
Chaoboridae	*Chaoborus* sp.	0.83	0.38	0.67	0.43	1.33	0.79	0.52	0.94
Chironomidae	*Chironomus formosipennis*	4.5	2.02	1.67	1.07	1.17	0.69	1.34	2.44
	Nilodorum fractilobus	2.17	0.97	6.5	4.16	2.67	1.59	2.07	3.78
	Polypedilum sp.	11.83	5.30	15.17	9.70	11.17	6.65	6.97	12.72
	Corynoneura sp.	0.17	0.08	–	–	–	–	0.03	0.05

Underlined numbers represent phyla values.

Table 4. Metrics and diversity indices of aquatic macroinvertebrates in Lake Ehuikro.

Metrics	E1	E2	E3	Lake
Taxonomic richness	34	33	39	52
Number of individuals	1339	938	1008	3285
Relative abundance (%)	40.76	28.55	30.69	100
Density (ind/m^2)	74	52	56	61
Shannon and Wiener (H')	2.59	2.86	3.02	3.10
Equitability (J)	0.73	0.82	0.82	0.79

and *Polypedilum* sp. (5.30%) (Table 2). The E2 site contains 938 individuals and *Baetis* sp. was the most represented taxa with 28.57% relative abundance. Both taxa *Polypedilum* sp. (9.70%) and *Physa marmorata* (5.65%) also dominated the assemblage of this site. In the E3 site, 1008 individuals were counted and five taxa were most abundant: *Baetis* sp. (19.84%), *Micronecta scutellaris* (7.84%), *B. pfeifferi* (7.74%), *Noterus* sp. (7.14%) and *Polypedilum* sp. (6.65%).

There were 11 most abundant taxa (relative abundance greater than 2%) belonging 10 families: *Baetis* sp. (19.85), *Tubifex* sp. (11.57), *B. pfeifferi* (7.19), *Polypedilum* sp. (6.97), *Noterus* sp. (4.87), *M. tuberculata* (4.69), *Lanites varicus* (4.05), *M. scutellaris* (4.05), *Helochares* sp., *Ischnura* sp. and *Nilodorum fractilobus* (2.07). The twelve rarest taxa collected in a single station were: *Hemiclepsis marginata* (0.06), *Lumbricus* sp. (0.06), *Bulinus forskalii* (0.06), *Hydrachna globosa* (0.09), *Coeriagrion tenellum* (0.09), *Belostoma* sp. (0.03), *Gerris* sp. (0.09), *Laccophilus luctuosus* (0.06), *Hydrobius* sp. (0.18), *Culex* sp. (0.12), *Eristalis* sp. (0.06), *Corynoneura* sp. (0.03).

The taxonomic richness is higher in the station E3 (39) than E1 (33) and E2 (33) (Table 4). However, the relative abundance is higher in E1 (40.76%) and lower in E2 (28.55%). The mean density of Macroinvertebrates was 61 ind/m^2 and was higher in station E1 (74 ind/m^2). Shannon and Weaver index (H') of the lake was 3.10 bits/ind. and varied between 2.59 (E1) and 3.02 bits/ind (E3). Similarly, the Equitability index was higher in E2 and E3 stations (0.82). The comparison of taxonomic richness and abundance between three stations showed no significant differences (Kruskall-Wallis, $p>0.05$).

The degree of similarity among benthic Macroinvertebrates fauna showed a high close similarity between the stations E1 and E2 (68.65%), E1 and E3 (68.49%), E2 and E3 (72.22%).

In addition, no significant difference was observed between the different stations of the lake ($p>0.05$). The RFD of three sampling sites (Figure 3) have a completely convex curve showing a stand at the maturation stage

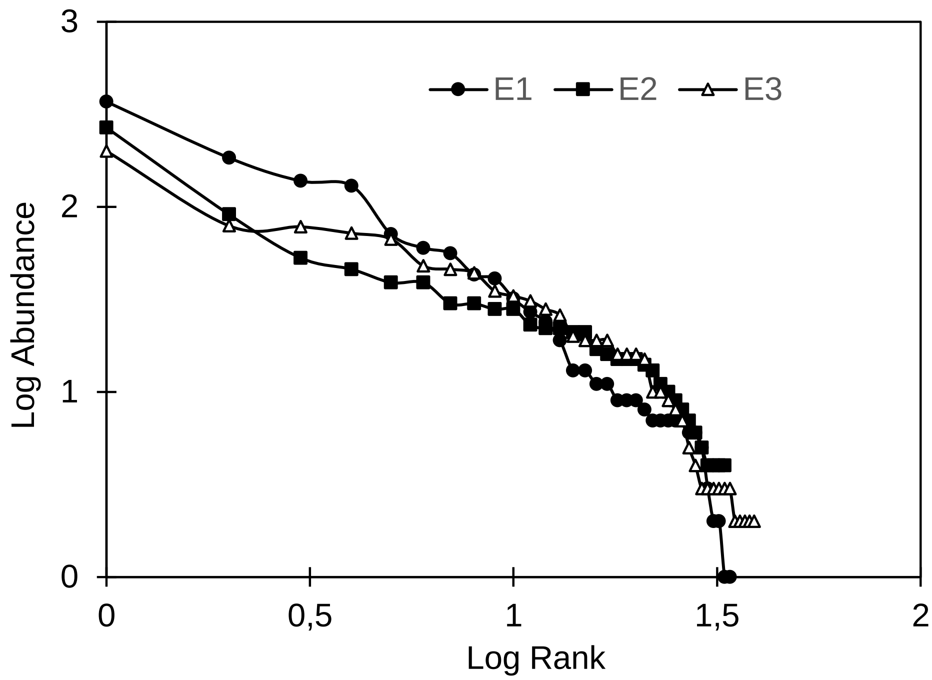

Figure 3. RFD of macroinvertebrate stands at three sampling sites of Lake Ehuikro.

Table 5. Spearman's correlation coefficient between the physico-chemical variables and macroinvertebrate species in Lake Ehuikro.

Taxa	Cond	pH	Temp	DO	PO_4^{3-}	NO_3^-	Transp	Depth	Sand	GMM	SGM	PD	AM
Tubifex sp.	0.37	-0.33	-0.04	-0.45	0.11	-0.52	**0.70***	**-0.76***	**0.67***	**0.80***	0.10	-0.13	0.60
B. pfeifferi	-0.60	0.30	-0.23	0.09	0.18	0.55	**-0.88***	**0.90***	**-0.86**	**-0.69***	-0.21	0.18	**-0.88***
L. varicus	0.11	-0.23	-0.25	-0.2	-0.04	-0.02	-0.15	0.50	-0.27	-0.05	-0.15	-0.09	-0.42
M. tuberculata	-0.46	0.20	**-0.75***	-0.12	0.14	0.12	**-0.70***	**0.70***	-0.62	-0.26	-0.6	0.51	**-0.76***
M. scutellaris	-0.19	-0.15	0.53	0.04	-0.02	0.33	0.14	-0.16	-0.14	-0.10	0.44	-0.45	0.20
Helochares sp.	0.04	-0.17	-0.20	**-0.70***	-0.49	-0.41	0.63	-0.26	0.39	0.30	0.09	-0.17	0.20
Noterus sp.	0.27	-0.08	0.19	-0.36	-0.39	-0.20	**0.76***	-0.49	0.47	0.25	0.15	-0.14	0.52
N. fractilobus	-0.04	0.19	-0.31	-0.42	-0.14	0.11	-0.25	**0.69***	-0.34	-0.32	-0.06	-0.06	**-0.71***
Polypedilum sp.	0.42	0.63	0.25	0.35	0.05	0.45	-0.02	0.08	-0.2	-0.26	-0.07	0.18	-0.05
Baetis sp.	-0.18	-0.17	0.15	-0.23	-0.61	-0.15	0.46	-0.20	0.24	-0.08	0.22	-0.22	0.30
Ischnura sp.	0.32	-0.33	0.60	-0.04	-0.12	-0.28	0.48	-0.43	0.64	0.20	**0.71***	-0.66	0.46

Cond, Conductivity; **Temp,** temperature; **DO,** dissolved oxygen; **Transp,** transparency; **GMM,** gravel-mud mixture; **SGM,** sand-gravel mixture; **PD,** plant debris; **AM,** aquatic macrophyte.
Values in bold and followed by an asterisk (*) indicated significant differences ($p<0.05$).

(stage 2) which is characterized by the presence of many taxa with high frequencies.

Relationship between environmental variables and Macroinvertebrates

Spearman correlation between five macro-invertebrate taxa and some abiotic variables showed significant correlations (Table 5). *Tubifex* sp. showed a positive correlation with transparency ($r = 0.70$; $p = 0.042$) and GMM ($r = 0.80$; $p = 0.013$) and a negative correlation with water depth ($r = -0.76$; $p = 0.023$). *B. pfeifferi* showed positive correlation with depth ($r = 0.90$; $p = 0.002$) and negative correlation with transparency ($r = -0.88$; $p = 0.003$), sand ($r = -0.86$; $p = 0.006$) and aquatic MAC ($r = -0.88$; $p = 0.002$). Moreover, the correlations between *M. tuberculata* and Temp ($r = -0.75$; $P = 0.028$), transparency

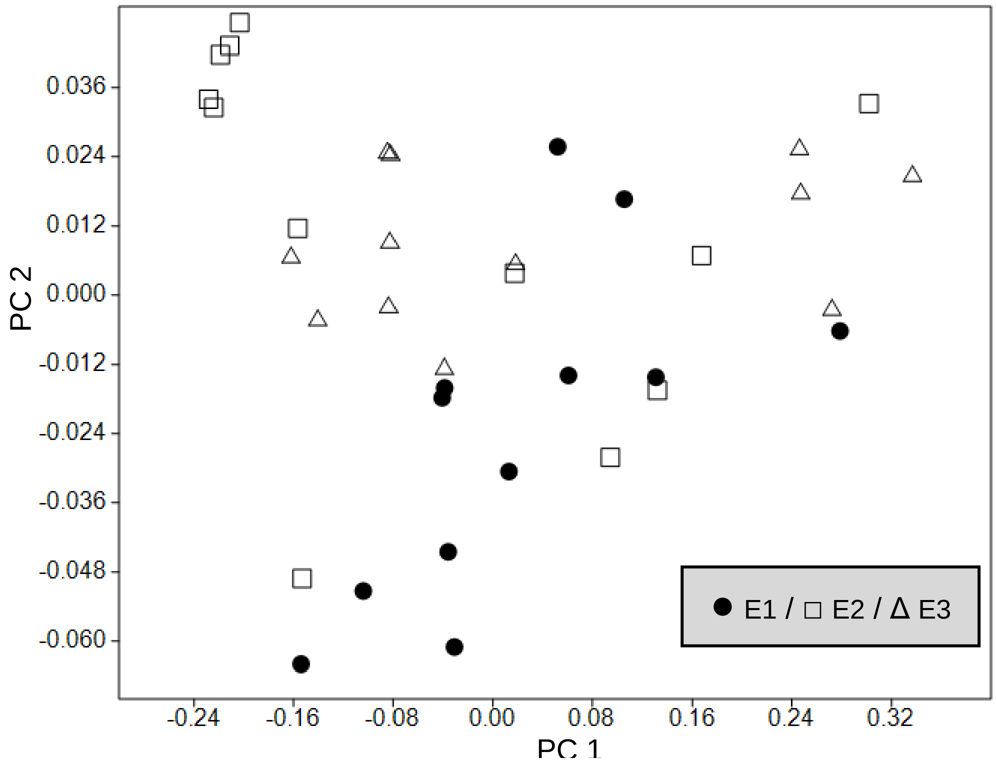

Figure 4. NMDS ordination, derived from the Bray Curtis similarity matrix of benthic Macroinvertebrates taxa in three stations of lake Ehuikro.

(r = -0.70; p = 0.047), depth (r = -0.70; p = 0.047) and AM (r = -0.76; p = 0.023) were significant. *Noterus* sp. and *N. fractilobus* showed significant correlation with transparency, depth and macrophytes (Table 4).

The separation of E1, E2 and E3 stations by substrate type does not appear to be confirmed by the ordination with NMDS of Macroinvertebrates data (Figure 4). An ANOSIM was performed to test for statistical differences in species composition between the pairs of stations E1, E2 and E3. A value of R = 0.160 supported the results of the classification and ordination of the data and indicated significant differences in species composition between E1 and E2 stations (p = 0.029). The other pairs of comparisons (E1-E3 and E2-E3) do not show significant differences.

The SIMPER was applied to identify those species that contribute most to the observed differences between E1 and E2 samples (Table 6). Only seven species were more abundant in the E1 group of samples, while 13 species were more abundant in the E2 sample. The taxa *Tubifex* sp., *M. tuberculata* and *B. pfeifferi* were the best indicator species for samples taken in the first station and accounted for 30.70% of the observed differences. The second station was characterized by relatively higher abundances of *P. marmorata*, *Orthetrum* sp., *Lanites libycus*, *Oxygastra curtisii*, *Laccobius* sp., *Coelostoma* sp. and *Bastis* sp. which together accounted for 51.15% of the observed differences between the two groups of samples.

The calculation of several univariate indices for the species densities of both samples E1 and E2 reflected some observed differences between the Macro-invertebrates assemblages. The average density of species was higher in the first station than the second. The diversity index H 'and Equitability J were higher in station E2 than E1. However, only Equitability showed significant differences (Kruskall-Wallis, p < 0.05).

DISCUSSION

The aquatic Macroinvertebrates structure showed fifty-two taxa in Lake Ehuikro. This taxonomic richness was diverse, composed of annelids, gastropods, molluscs, arachnids and insects and it was higher compared to several lakes. For example, Lake Sokotè located in Bongouanou city is home to thirty-five taxa (Motchié et al., 2020). Indeed, the intensity of human pressures on these lakes could justify the difference of specific richness. The Lake Ehuikro, located more than 2 km from the city, receives a low amount of domestic and industrial effluents unlike Lake Sokotè. Likewise, Olomukoro and Ovojie (2015) sampled only 46 Macroinvertebrates species

Table 6. Results of the SIMPER analyses for the dissimilarity of the species abundance between E1 and E2 station of the Lake Ehuikro. Overall average dissimilarity = 34,32.

Taxa	Mean abundance		Contribution (%)	Cumulative contribution (%)
	E1	E2		
Tubifex sp.	2.57	0	14.70	14.70
M. tuberculata	2.14	0	12.26	26.96
P. marmorata	0	1.73	9.91	36.87
Orthetrum sp.	0	1.49	8.53	45.40
L. libycus	0	1.49	8.53	53.93
O. curtisii	0	1.36	7.79	61.72
Laccobius sp.	0	1.36	7.79	69.51
Coelostoma sp.	0	1.34	7.67	77.18
B. pfeifferi	2.12	1.46	3.74	80.92
Helochares sp.	1.76	1.20	3.15	84.07
Plea sp.	0.90	1.38	2.73	86.80
M. scutellaris	1.62	1.15	2.73	89.53
N. fractilobus	1.15	1.60	2.61	92.14
C. formosipennis	1.45	1.04	2.32	94.46
Noterus sp.	1.79	1.46	1.85	96.31
P. punctum	1.08	1.34	1.51	97.82
Baetis sp.	2.27	2.43	0.93	98.75
Polypedilum sp.	1.86	1.96	0.61	99.36
Ischnura sp.	1.52	1.60	0.48	99.84
L. varicus	1.64	1.67	0.16	100

in Lake Obazuwa located in the area with the highest human activity (Benin City). These results corroborated several studies that have indicated that human activities have a significant impact on Macroinvertebrates diversity due to modification or habitats destruction (Okano et al., 2018; Amoatey and Baawain, 2019).

Among the organisms collected from the lake, Ephemeroptera was the most abundant (19.85%) and sampled in all stations. Indeed, the abundance of *Baetis* sp. larvae can be linked to the high proportion of aquatic macrophytes in E2 (30%) and E3 (34%) stations which represent their preferred habitat (Buffagni and Gomba, 1996). Furthermore, macrophytes increase niche space, provide higher food quality and cover from predators (Thomaz and Da Cunha, 2010). The three species *Biomphalaria pfeifferi* (7.19%), *M. tuberculata* (4.69%) and *L. varicus* (4.05%) represented the most abundant molluscs. They were sampled at all stations except *M. tuberculata* absent at station E2. Several reasons can justify the abundance of gastropods: they have a longer life cycle; they also have the ability to hide in the substrate and escape predators (Everett, 2000). Some authors have reported parthenogenetic reproduction in *M. tuberculata* (Berry and Kadri, 2009; Quirós-Rodríguez et al., 2018) and its potential spread to several habitats. In Lake Ehuikro, *B. pfefferi* and *M. tuberculata* were positively correlated with water depth and negatively with transparency. Thus, their high density in station E1 with great depth and low transparency can be justified by the substrate texture (gravel-mud mixture) and organic matter abundance, probably related to human disturbances and the leaves of trees falling into the lake. The three Coleoptera *M. scutellaris*, *Noterus* sp. and *Helochares* sp. were also collected in all stations and accounted for 12.54% of total abundance. Density of Coleoptera was higher in station E3 (50 ind./m2 against 13 and 15 ind./m2 in stations E1 and E2, respectively) and only *Noterus* sp. showed a significant correlation with water transparency. Several studies have shown that species composition of aquatic Coleoptera communities is affected by various environmental factors such as microhabitat, vegetation structure and water chemistry (Fairchild et al., 2003; Nilsson et al., 1994; Nilsson and Soderberg, 1996; Bloechl et al., 2010). In the present study, the abundance of macrophytes and water quality appear to be responsible for the proliferation of these organisms.

Tubifex sp. (Annelid) also showed a relatively high abundance (11.57%) in Lake Ehuikro. These species were positively correlated with transparency, sand, gravel-mud mixture and negatively correlated with water depth. According to Lafont (1984), the abundance of oligochaetes is an indication of enrichment of the environment in organic matter. Indeed, the entrance of materials from human activities such as agriculture and domestic effluents will accumulate in greater depth areas, which may justify their high density in station E1. In addition, Martins et al. (2008) indicated that the physical characteristics of the substrate are responsible for the distribution and the abundance of species within Tubificinae subfamily. Our results support the work of Atobatele and Ugwumba (2010) in Aiba reservoir where *Tubifex* sp. showed a preference for muddy, coarse sandy and gravelly substrate. Chironomidae larvae had a relative abundance of 9.04% and composed of four species, and the most dominant is *Polypedilum* sp. These species are generally known to be collectors and usually confined in the bottom mud, where they feed on plant debris and associated microorganisms. Thus they contribute in the general process of decomposition and in remobilization of nutrients into the water column (Hansen et al., 1998; Lencioni et al., 2018). The main characteristic of Chironomidae is to colonize extremely diversified habitats, which generally makes them more dominant among insects in natural and man-made aquatic ecosystems (Płóciennik et al., 2016). Among the abundant taxa, only *Tubifex* sp., *B. pfeifferi*, *M. tuberculata*, *Noterus* sp. and *N. fractilobus* showed significant correlations with the environmental variables. This indicates that the other species are not dependent on environmental parameters or otherwise, they are more tolerant species (Ndaruga et al., 2004; Cai et al., 2012; Scirocco et al., 2019).

In this study, the results of the PCA showed that the substrate type was the determining factor in the characterization of the sampling sites, the influence of other abiotic parameters being low. Station E1, E2 and E3 were dominated by gravel-mud substrate, sand-gravel mixture and only of sand, respectively. In general, the type of sediment is very characteristic of lake environments (Thompson et al., 2017). Similar observations were observed in Lake Buyo where stations with gravel dominated substrates formed a group that was quite distinct from those consisting mainly of sand (N’Dri et al., 2020).

Our results showed a separation between the community structure taken in E1 station and E2. The E2 samples showed greater diversity and a more equitable distribution of taxa. These findings could be well correlated with the sediments which offer different habitats depending on the species (Thompson et al., 2017). Station E1 is home to few abundant species such as *Tubifex* sp. and *M. tuberculata* while the E2 samples are composed of several species. This would be linked to Yakpo River which carries runoff charged with sand and silt and causing siltation of the Lake bed (Poleto and Beier, 2012). This impedes colonization of organisms that depend on a hard substrate, resulting in the exclusion of certain taxonomic groups such as *P. marmorata*, *L. libycus*, *Laccobius* sp. Diversity indices (H’ and J) obtained in the present study was generally high in the Lake Ehuikro with relatively similar values recorded in the sampling stations, indicating more diversified and equal distribution of Macroinvertebrates. The highest similarity index (more than 68% similarity) indicates the same environmental condition of these sites. The high diversity of the lake can be attributed to the low disturbance of the lake by human activities as compared to other tropical lakes which are affected by agricultural activities and pollution (Furey et al., 2006; Motchié et al., 2020). This high diversity can also reflect the good water quality for aquatic life. The results of the diversity index are in line with the RFD which showed a maturation phase of characterized by maximum diversity (Foto et al., 2013), resulting in higher H’ and J indices. Indeed, according to Staub et al. (1970), a Shannon-Weaver diversity index greater than 3 indicates an oligosaprobic ecosystem characterized by a low amount of organic matter. Likewise, the abundance of some taxa can provide indications of the water quality. Several authors have indicated that Ephemeroptera (*Baetis* sp.) which were abundant in Lake Ehuikro can tolerate a light organic pollution (Alhejoj et al., 2014). These results seem to be confirmed by Motchié et al. (2020) that have found the abundance of pollution tolerant taxa (*M. tuberculata* and Chironomidae) and a low diversity of Macroinvertebrates in Lake Sokotè which presents a eutrophic state. Furthermore, the values of the physico-chemical parameters seem to confirm the low abundance of organic matter. Low values of nitrate, phosphate and conductivity recorded throughout the study period could indicate a low mineralization of water (Alhejoj et al., 2014).

Conclusion

The present study revealed a relatively high diversity of aquatic Macroinvertebrates, a high relative abundance of Ephemeroptera and optimal values of physico-chemical parameters, indicating the moderately polluted conditions. The environmental variables that influence the distribution of benthic fauna were transparency and depth, sand, muddy and gravel mixture substrate and aquatic macrophytes. Our result could provide valuable information that could be used to establish biotic integrity indices based on aquatic Macroinvertebrates to monitor the human disturbance effect on water quality in Lake.

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