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(Research Article)

Structure of the macro invertebrate population of Lake Buyo (Guessabo, west Côte d'Ivoire)

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Abstract

This study focused on the macroinvertebrate population in the upstream waters of Lake Buyo. Data collection was carried out in 4 stations (G1 to G4) from November 2017 to October 2018. Sampling involved both physical-chemical parameters and macro invertebrates. Physical and chemical parameters (temperature. dissolved oxygen. pH and conductivity) were measured in situ using a multi-parameter at each sampling campaign. Water samples were taken for the subsequent determination of nutrient salts (nitrate. phosphate. ammonium). Macro invertebrates were collected using a dip net and a sediment bucket. The physico-chemical characterization of Guessabo Bay showed that the abiotic parameters vary little from one station to another. The inventory of macro invertebrates in the water body yielded 98 taxa divided into 59 families. 16 orders and 07 classes belonging to insects. gastropods. bivalves. crustaceans. Arachnids and Oligochaetes. Insects were found to be the most diverse class. followed by the class of molluscs. The values of Shannon Weiner's diversity index and Pielou's equitability showed that the aquatic macroinvertebrate population of the lake is more or less diverse and balanced. which reflects good water quality. Jaccard's similarity index reveals a high degree of similarity between G1 and G3. The distribution of aquatic macro invertebrates in this lake is positively influenced by the environmental variable conductivity. nitrate. phosphate. ammonium. pH. dissolved oxygen and temperature.

Keywords: Macro invertebrates; Structure; Buyo Lake; Côte d'Ivoire

1. Introduction

Inland water ecosystems play a key role in the lives of many plant and animal species. including humans. and are interdependent with the surrounding environment [1]. They provide goods and services worth billions of dollars annually. Unfortunately. these ecosystems are exposed to numerous threats. mainly due to anthropogenic pressure. The hydrosystems of Côte d'Ivoire are not immune to this growing anthropogenic pressure. Indeed. for several years now. many water bodies have been developed in the Ivorian continental environment for the production of electricity and drinking water as well as for the development of agro-pastoral activities (irrigation and livestock breeding). These water bodies also constitute an enormous hydrological and hydrobiological potential that can contribute to reducing the deficit in animal protein of halieutic origin in Côte d'Ivoire [2, 3 and 4].

This is the case of the Sassandra River in western Côte d'Ivoire with the creation of the Buyo hydroelectric dam in 1980. The reservoir of the same name created by the dam has accentuated fishing activities. with the locality of Guessabo being the main landing site for catches in the Haut-Sassandra region. The intensity of anthropic activities (fishing.

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transport. agriculture. etc.) in this area is likely to disturb both the physico-chemical quality of the environment and the fauna component [5]. Thus. to better understand this state of affairs on the one hand. and on the other hand to fill the lack of information on macro invertebrates in order to propose an effective management. our study proposes as an objective. to know the population of macro invertebrates of the lake of Buyo at the level of the zone of Guessabo. Indeed. macro invertebrates represent an essential link in the trophic chains of freshwater ecosystems [6]. and are an important source of food for many species of fish. amphibians and birds [7, 8]. Moreover. macro invertebrates are recognised as good biological indicators of the health of aquatic ecosystems and can be used to develop biomonitoring tools for surface waters [9, 10, 1, 11].

2. Material and methods

2.1. Study area

Located in the west of Côte d'Ivoire (6° 44′ N. 6° 59′ W) on the Daloa - Duékoué axis. the subprefecture of Guessabo (Zoukougbeu department) is part of the Haut-Sassandra region. It is also a cross-border area between the regions of Haut Sassandra. Guémon and Tonkpi. This locality is located in the upstream zone of the Buyo hydroelectric dam lake built on the Sassandra River and put into service in 1980 and covers an area of 17 km^2. The climate in this locality is tropical and humid with two seasons. A rainy season from April to October and a dry season from November to March with an annual rainfall of about 2000 mm [12]. The sampling stations were chosen taking into account accessibility. permanence of water at all times of the year. diversity of aquatic habitats (stones. plant debris. branches and roots. etc.) and the surrounding environment. Thus. four sampling points (G1- G4) were selected on the lake.

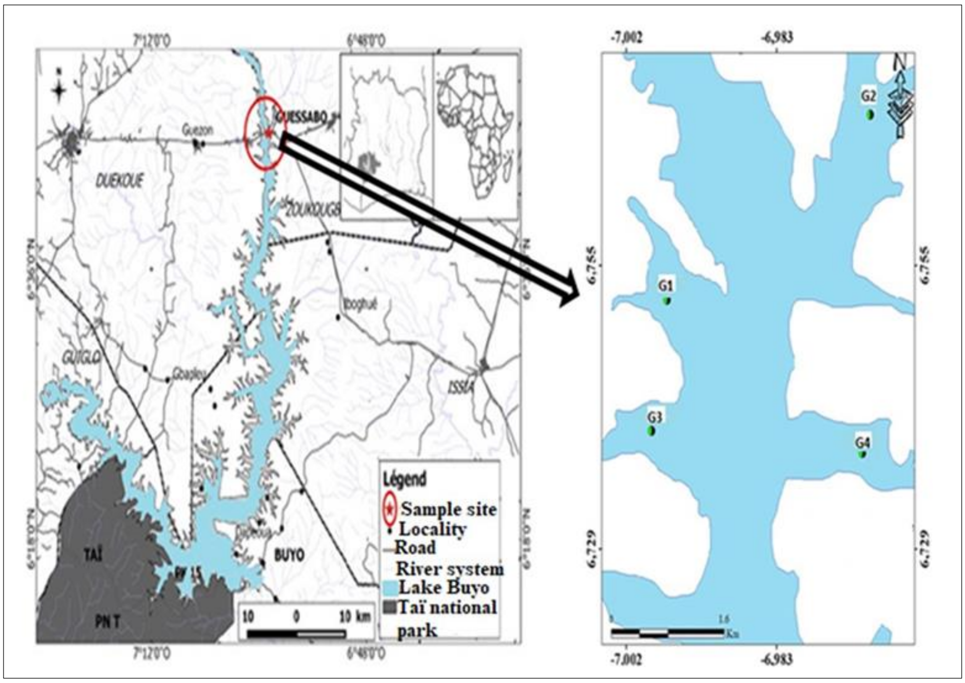


Figure 1 Location of the study area and location of the sampling station

2.2. Measurement of physico-chemical parameters

The main parameters (pH. temperature. conductivity. dissolved oxygen) were measured in situ at each station using a HANNA multi-parameter. In addition. water samples were taken and kept cool (± 4º C) in a cooler and then transported to the laboratory to measure the concentration of ions including phosphates (PO_4^{3-}), nitrates (NO_3^-) and ammonium (NH_4^+). Their determination was estimated according to standard norms (respectively AFNOR ISO 7890-3. ISO 6777.T 90015. T900-23) after filtration of the samples on Whatman filter paper with a porosity of 0.45 µm. The spectrophotometer (SHMADZU UV / visible 1700 pharma) was used for these analyses.

2.3. Sampling and identification of macro invertebrates

Aquatic macro invertebrates were collected monthly at each sampling station from November 2017 to October 2018. Sampling was done using a haze net (mesh size: 250 µm) and a Van veen type sediment bucket. Macro invertebrates from the native vegetation covering the lake shore and those living in the water column were collected using the mist net. The Van Veen bucket was used to sample macro invertebrates in the sediment. On leaving the water. the contents of the bucket and the net were washed through a 1 mm vacuum sieve. The sieve reject was stored in bottles and then fixed with 70% alcohol. The two samples (1 net and 1 per bucket) from each point and each campaign were pooled for analysis in the laboratory. In the laboratory. the samples were observed using a binocular magnifying glass. Specimens were sorted and identified to the lowest possible taxonomic level using a series of identification keys [13. 14. 15. 16. 17. 18 and 19].

2.4. Data analysis

Macroinvertebrate structure was described by taxonomic composition. rarefied richness. Shannon-Weiner index. Pielou regularity index. frequency of occurrence and Jaccard's similarity index (used to assess the similarity of macroinvertebrate communities between stations). Taxon richness was rarefied to eliminate any bias related to differences in abundance between samples [20, 21, 22]. Calculations were made using the lowest abundance (2 individuals for this study) found at all stations as the target number of individuals [23]. The frequency of occurrence (FO) was calculated at all sampling stations. The FO is the percentage of samples in which each taxon is present. It was calculated according to Dajoz (2000) [24] to give some information on the number of taxa frequently encountered in each station without any indication of their quantitative importance [25, 26].

The normality of the data was checked using the Shapiro test before conducting comparative analyses. and variations in physico-chemical parameters and diversity indices between stations were assessed using the Kruskal-Wallis and Mann-Whitney tests given that the distribution of the data follows an abnormal distribution ($P>0.05$)

A redundancy analysis (RDA) was performed to highlight the relationships between macroinvertebrate distribution and environmental variables. Macroinvertebrate taxa representing at least twenty-five percent of the occurrences were selected for this analysis.

Analyses were performed using the R. 4.0 and Canoco 4.5 software packages.

3. Results

3.1. Physico-chemical parameters of the water

The variations of the environmental variables measured in the stations of the lake are illustrated in Table 1. The parameters studied did not vary significantly except for pH. which showed a significant variation between the stations studied. The variation in dissolved oxygen was between 0.8 mg/L (G2) and 7.6 mg/L (G3). Temperature ranged from 22.6 °C (G2) to 29.37 °C (G3). Conductivity varied between 8 µS/cm (G1) and 55 µS/cm (G2). The pH values varied from 4.89 (G1) to 7.11 (G4). Phosphorus. nitrate and ammonium values ranged from 0.11 mg/L (G2) to 13.73 mg/L (G2). from 0.01 mg/L (G1) to 11.1 mg/L (G1) and from 0.048 mg/L (G3) to 0.872 mg/L (G1) respectively.

Table 1 Environmental variables measured at sampling stations in Lake Buyo (Côte d'Ivoire)

Parameters	**G1**			**G2**			**G3**			**G4**		
	Min	**Med**	**Max**	**Min**	**Med**	**Max**	**Min**	**Med**	**Max**	**Min**	**Med**	**Max**
Dissolved oxygen (mg/L)	1.3	4.6	6.79	0.8	4.7	6.65	1	4.51	7.6	1.1	4.7	6.7
Temperature (°C)	22.93	26.84	29.14	22.71	26.68	29.33	22.6	26.9	29.37	22.6	26.6	29.4
pH	4.89	5.48	6.11	5.37	5.865	6.34	5.66	5.96	6.93	5.54	5.845	7.11
Conductivity (µS/cm)	8	19	53	12	27.5	55	5.8	21	47	11	30	48
Nitrates (mg/L)	0.01	3.6	11.1	0.01	3.05	7.2	0.6	3.15	7.7	0.01	2.65	6.8
Ammonium (mg/L)	0.127	0.202	0.872	0.078	0.293	0.412	0.048	0.2	0.386	0.1	0.172	0.82
Phosphates (mg/L)	0.14	0.61	13.19	0.11	0.64	13.73	0.2	0.55	10.6	0.3	0.54	7.01

Min = minimum; Med = median; Max = maximum; G1-G4: sampling stations

3.2. Taxonomic composition

This study enabled 98 taxa to be recorded. divided into 59 families. 16 orders and 7 classes (Insects. Gastropods. Bivalves. Crustaceans. Arachnids and Oligochaetes) (Table 2). The Insects class grouped together 81 taxa. or 82% of the taxonomic richness of Lake Buyo. thus constituting the most diversified class. In this class. Hemiptera (25 taxa) are the best represented. followed by Coleoptera (24 taxa). Diptera (15 taxa) and Odonata (08 taxa). Ephemeroptera. Orthoptera and Lepidoptera are represented by 04. 02 and 03 taxa respectively. The class of Gastropods is composed of 08 taxa. or 8% of the taxonomic wealth. and the class of Arachnids. 4 taxa. or 4% of the latter. The classes of Achaetes. Oligochaetes and Bivalves are each represented by one taxon and the Crustacea class by two taxons.

The taxa collected at the different stations are grouped into three categories: constant taxa (***). accessory taxa (**) and accidental taxa (*). Accidental taxa dominated the macroinvertebrate community with a percentage of 55%. The proportion of constant taxa is estimated at 17% and that of accessory taxa is 38% (Table II).

Table 2 List of aquatic macroinvertebrate taxa collected in Lake Buyo surveyed from November 2017 to October 2018

Classes	Orders	Family	Taxa	Code	G1	G2	G3	G4
Crustacea	Conchostracans		Conchostracans	Conc	**	**	**	**
	Ostracods		Ostracods	Ostr	*	*		
Oligochaeta			Oligochaeta	Olig	**	**	*	**
Purchase	Hirudinidae	Hirudinidae	*Hirudo* sp.	Hisp	*		*	
Gastropods	Sorbeoconches	Thiaridae	*Melanoides tuberculata*	Metu	**	**	***	**
		Physidae	*Aphexa Waterloti*	Apwa		*	*	*
		Planorbidae	*Afrogyrus.* sp.	Afsp	**	**	**	**
			Gyraulus sp.	Gysp	*	*	**	*
			Bulinus sp.	Busp	**		**	
		Lymnaeidae	*Radix* sp.	Rasp	**	**	**	*
	Mesogasteropods	Bithyniidae	*Gabiella* sp.	Gasp	***	***	***	***
Bivalves	Veneroides	Sphaeriidae	*Sphaerium* sp.	Spsp			*	
	Unionoides	Unionidae	*Unio* sp.	Unsp	*	*	*	
Insects	Diptera	Chironomidae	*Cryptochironomus* sp.	Crysp	*			*
			Chironomus sp.	Chsp	***	***	*	***
			Cricotopus sp.	Crisp		*	*	
			Polypedilum sp.	Posp	**	**	***	**
		Ceratopogonidae	*Dasyhelea* sp.	Dasp		**	**	**
			Bezzia sp.	Besp	**	**	**	***
			Eristalis sp.	Ersp		*	*	
		Culicidae	*Aedes* sp.	Aesp	*		*	*
			Anopheles sp.	Ansp	*	*	*	
			Culex sp.	Cusp	**	**	**	**
			Mansonia sp.	Masp				*
		Tanypodinae	*Ablabesmyia* sp.	Absp	*	**	**	*

Classes	Orders	Family	Taxa	Code	G1	G2	G3	G4
		Tabanidae	*Tabanus* sp.	Tasp	*			*
		Stratiomuidae	*Odontomyia* sp.	Odsp	**	*	*	*
		Sciomyzidae	*Sepedon* sp.	Sciom	**		*	*
	Odonata	Gomphidae	*Ictinogomphus* sp.	Icsp	*	*	*	*
		Coenagrionidae	*Ceriagrion* sp.	Cesp	**	*	***	**
			Pseudagrion sp.	Pswa	***	**	***	***
		Libellulidae	*Trithemis* sp.	Trsp	***	**	**	*
			Brachythemis sp.	Brsp	**	*	**	**
			Hemicordulia sp.	Hesp	*	*	**	**
			Crocothemis sp.	Crsp	**	*	*	**
			Libellula sp.	Lisp	*		*	**
	Hemiptera	Belostomatidae	*Limnogeton hedenborgi*	Lihe		*	*	*
			Diplonychus sp.	Disp	***	**	***	**
			Appasus sp.	Apsp	**	**	**	***
			Abedus sp.	Absp	*	*	*	*
		Corixidae	*Micronecta scutellavis*	Misc	***	***	***	**
		Nepidae	*Laccotrephes* sp.	Lasp				*
		Aphelocheiridae	Aphelocheiridae	Aphe	*			
		Aphrophoridae	*Aphrodes* sp.	Aphsp	*	*	**	*
		Reduviidae	Reduviidae	Redu		*		*
		Cydnidae	*Sehirus* sp.	Sehsp	*		*	
		Leptopodidae	*Valleriola* sp.	Vasp				*
		Pentatomidae	*Dolycoris* sp.	Dosp				*
		Naucoridae	*Naucoris* sp.	Nasp	*	*	**	*
			Hydrometra sp.	Hydr			**	
		Veliidae	*Microvelia* sp.	Misp	**	**	**	***
		Notonectidae	*Anisops* sp.	Anisp	*	*	*	*
		Gerridae	*Eurymetra* sp.	Eusp	**	*	**	**
			Gerisella sp.	Gesp		*		*
			Neogerris sp.	Neosp	*	*	*	*
			Limnogonus sp.	Linsp	*	*	*	*
		Pleidae	*Plea Pulula*	Plpu	*	*	*	*
		Mesoveliidae	*Mesovelia* sp.	Mevi	*	**	**	*
		Ranatridae	*Ranatra* sp.	Ransp	**	**	***	**
	Coleoptera	Dytixidae	*Dineutus* sp.	Disp		*	*	**

Classes	Orders	Family	Taxa	Code	G1	G2	G3	G4
			Bidessus sp.	Bide				
			Hyphydrus sp.	Hypsp	*	*	**	**
			Hygrotus sp.	Hygsp				*
			Hydaticus sp.	Hidsp	*			*
			Hydrovatus sp.	Hydsp	*		*	*
			Dytiscus sp.	Dysp	*	*		
		Noteridae	*Hydrocanthus* sp.	Hydrsp			**	
		Lampyridae	Lampyridae	Lamp		*		
		Hydrophilidae	*Enochrus* sp.	Ensp	**	**	**	**
			Amphiops sp.	Amsp	**	*	**	*
			Hydrophilus sp.	Hypi				*
		Carabidae	Carabidae	Cara		*		
		Colymbenidae	*Agabus* sp.	Agsp			*	*
		Limnichidae	*Limnichoderus* sp.	Liisp	*			
		Scirtidae	*cyphon* sp.	Cysp	*	**	*	
		coccinellidae	*Harmonia axyridis*	Harax				*
			coccinellidae	Cocc	*		*	
			Chilocorus sp.	Chil				
		Curculionidae	*Neochetina* sp.	Nesp	**	**	***	**
			Bagous sp.	Basp	*			
		Hydrochidae	*Hydrochus* sp.	Hyosp	*		**	*
		Spercheidae	*Spercheus* sp.	Spesp	*		*	
		Staphylinidae	*Paederus* sp.	Pasp			*	*
		Elmidae	*Potamodytes* sp.	Posp				*
			Limnius sp.	Liusp	*		*	
	Ephemeroptera	Caenidae	Caenis sp.	Caesp	***	***	***	***
		Polymitarcyidae	*Povilla adusta*	Poad	*		*	
		Beatidae	*Cloeon* sp.	Cloesp	***	**	***	**
			Centroptilum sp.	Censp	***	**	**	**
	Orthoptera	Acrididae	*Acrida* sp.	Acsp	*	*	*	*
		Gryllidae	*Acheta* sp.	Achsp	*		*	
	Lepidoptera	Geométridae	Geométridae	Geom				*
		Crambidae	*Petrophila* sp.	Petsp	*	*		*
		Pyralidae	Pyralidae	Pyra	*		*	*
Arachnida	Trombidiforme	Hydrachnidiae	Hydrachnidiae	Hydra	**	***	**	***

Classes	Orders	Family	Taxa	Code	G1	G2	G3	G4
	Araneids	Lycosidae	*Trochosa spinipalpis*	Trosp	***	**	***	***
		Tetragnathidae	*Tetragnatha* sp.	Tetrsp	**	**	**	*
		Pisauridae	*Pisauridae*	Pisa	***	**	***	**
				98	72	62	74	73

* = accidental taxa; ** = incidental taxa; *** = constant taxa

3.3. Macro invertebrate structure in the lake stations

Figure 2 shows the variation of the different biological indices between stations. The rarefied richness varied between 2.92 and 8.12 at station G1. At station G2. this index varied from 2.38 to 7.98. The values of the rarefied richness are between 3.23 and 8.24 at station G3 and between 3.50 and 8.28 at station G4. Stations G3. G4 recorded the highest values of rarefied richness and station G2 the lowest value. This richness did not vary significantly between the stations studied (Kruskal-Wallis test. $p > 0.05$). As for the Shannon diversity index. the values fluctuated between 0.82 and 3.22 from station G2 to station G3. This index shows low variability (MannWhitney test. $p > 0.05$). Like the Shannon diversity index (Mann-Whitney test. $p > 0.05$) and rarefied richness (Kruskal-Wallis test. $p > 0.05$). equitability shows a fairly low intra-lake variation (Mann-Whitney test. $p > 0.05$). This variation is between 0.33 (G1) and 0.67 (G2).

Jaccard's similarity index varies between 0.65 (G1-G2-G4) and 0.79 (G1-G3). (Table x).

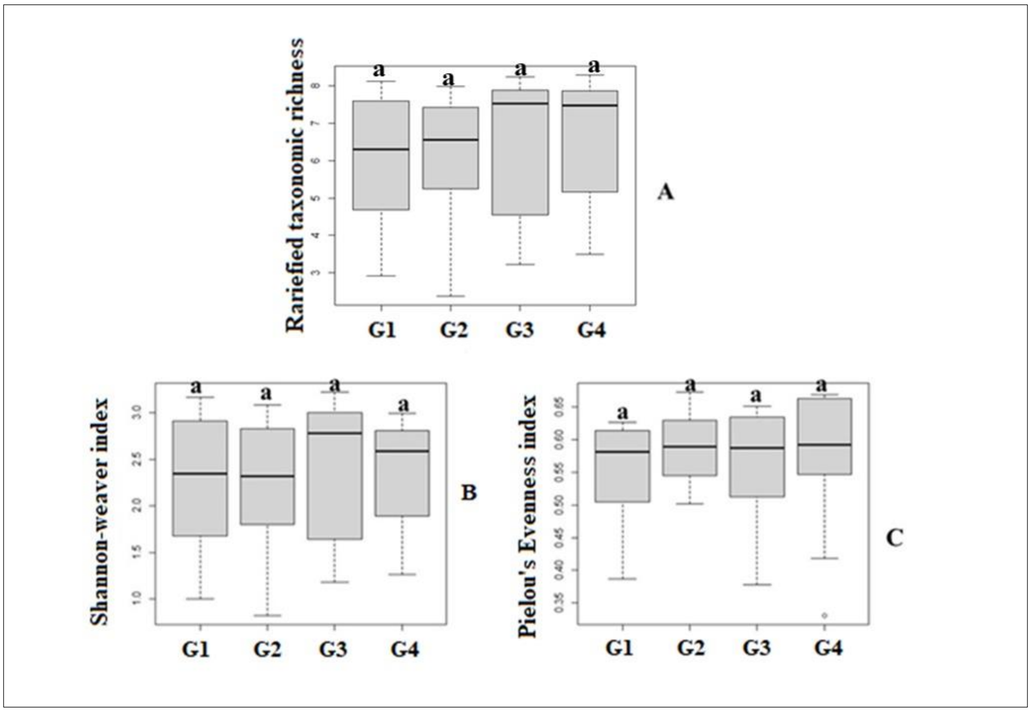


Figure 2 Variations in rarefied richness (A). Shannon diversity (B) and Piélou equitability (C) in Lake Buyo (Côte d'Ivoire)

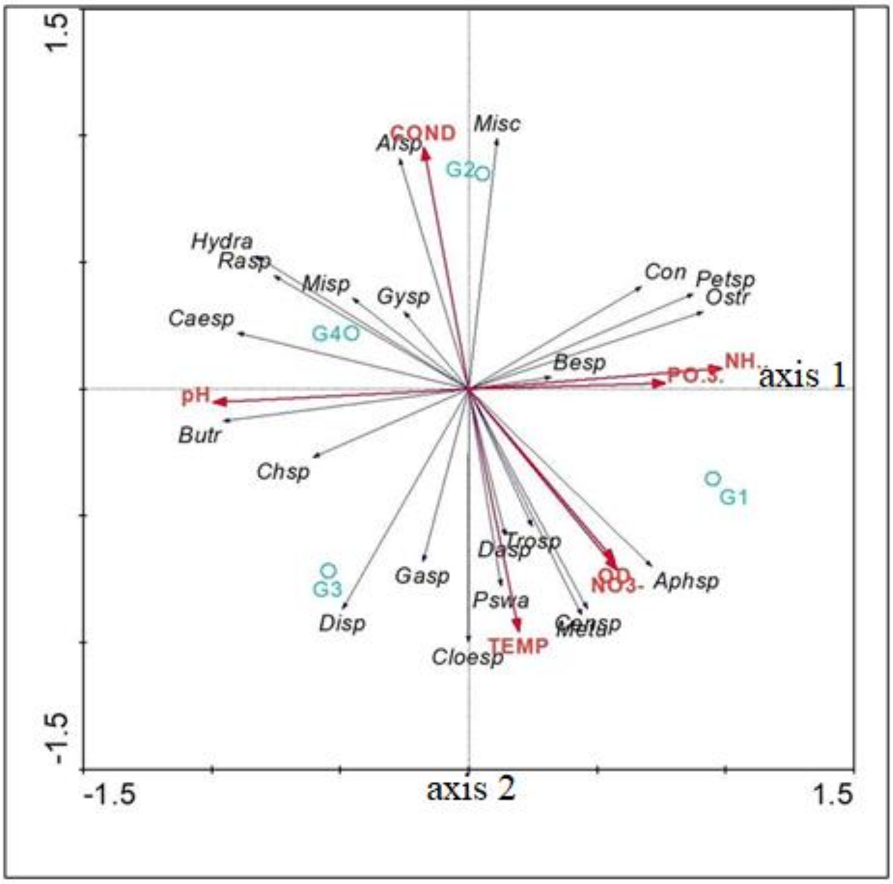
Table 3 Jaccard's similarity index of macroinvertebrate communities in Lake Buyo (Côte d'Ivoire)

Stations	G1	G2	G3	G4
G1		0.66	0.79	0.65
G2			0.70	0.65
G3				0.66
G4				

3.4. Influence of abiotic parameters on macroinvertebrate communities

Redundancy analysis (RDA) showed that the first two axes express 86% of the total variance. The first axis. which expresses 58% of the total inertia. is positively correlated with phosphate. ammonium. nitrite. nitrate and dissolved oxygen. On the other hand. pH is negatively correlated with this axis. The second axis. which accounts for 28% of the total inertia. is strongly and positively correlated with conductivity and negatively correlated with temperature. On axis 1 a positive association is observed between *Bezzia* sp. Ostracodes. *Petrophila* sp. and phosphate and ammonium while *Bulinus Tropicus*. *Chironomus* sp. are positively associated with pH.

On axis 2 *Micronecta scutellavis*. *Afrogyrus* sp. are positively associated with conductivity. In the same positive part of this axis *Cloeon* sp. *Pseudagrion wallani* and *Dasyhelea* sp. are positively associated with temperature. There is also a strong positive correlation between dissolved oxygen. nitrates and *melanoides tuberculata*. *Aphrodes* sp. *Centroptilum sp.* and *Trochosa spinipalpis*.



Disp = *Diplonychus* sp.; Gasp = *Gabiella*. sp; Cloesp = *Cloeon* sp; Metu = *Melanoides tuberculata*; Censp = *Centroptilum* sp; Aphsp = *Aphrodes* sp.; Dasp = *Dasyhelea* sp.; Trosp = *Trochosa spinipalpis*; Chsp = *Chironomus* sp.; Pswa = *Pseudagrion wallani*; Butr = *Bulinus Tropicus*; Besp = *Bezzia* sp. Ostr = Ostracodes; Petsp = *Petrophila* sp; Con = Conchostracans; Hydra = Hydrachnidiae; Rasp = *Radix* sp; Misc = *Micronecta scutellavis*; Misp = *Microvelia* sp.; Gysp = *Gyraulus* sp; Afsp = *Afrogyrus.* sp; Caesp = *Caenis* sp.; COND = Conductivity; NO3- = Nitrates; PO.3= Phosphates; NH. = Ammonium; TEMP = Temperature; DO = Dissolved oxygen; pH = Hydrogen potential. G1 to G4 = Sampling stations.

Figure 3 RDA ordination of dominant macroinvertebrate taxa and environmental parameters (November 2017 to October 2018) upstream of Lake Buyo (Côte d'Ivoire)

4. Discussion

The abiotic characterization of the lake showed that the parameters vary little from one station to another over the study period. This low spatial variability could be explained by the exchanges between the different sampling stations. Indeed. these exchanges would favour a constant communication between the stations. thus leading to their relative homogeneity from the physico-chemical point of view. as mentioned by [27]. The temperature measurements carried out in the lake indicate that the values varied from 22.6°C to 29.52°C. These data are consistent with Lemoalle's (1999) [28] assertion that in intertropical Africa. average temperatures are high and mostly above 20 °C.

The waters of Lake Buyo are relatively acidic (median pH value around 5.50). This acidity is linked to the production of CO_2 under the action of biological activities and rainfall [29]. Indeed. the hydration of CO_2 produces carbonic acid whose ionization releases H ions$^+$ which contribute to the acidity of the water [12].

The macroinvertebrate inventory identified 98 taxa belonging to 59 families. 16 orders and 07 classes. Insects constitute the most diverse class with 82% of the taxonomic richness. These results corroborate several studies that [30. 31. 32. 33. 34]. According to (2006) [35]. insects are the most diverse taxonomic group among aquatic macro invertebrates and for [36]. nearly 95% of the organisms present in the environment are insects. This class represents one of the most important groups of freshwater invertebrates. particularly because of their diversity [9].

The Shannon Weiner diversity index values ranged from 0.82 (G2) to 3.22 (G3). These results show that the aquatic macroinvertebrate population of the lake is more or less diverse. which could reflect the more or less stable conditions. The Pielou regularity index obtained varies between 0.33 (G1) and 0.67 (G2). These results show that the distribution of macroinvertebrate taxa is balanced in Lake Buyo. According to [37] and [38, 39]. habitat stability and biotic interactions could be important factors in the structure of macroinvertebrate communities. Macroinvertebrate communities were found to be much larger in stable sites compared to unstable sites. Our results are in line with these observations. Regarding rarefied richness. it shows that in the absence of any bias in the samples. G3 and G4 are the richest in taxa and therefore the least impacted. Jaccard's similarity index reveals a strong similarity between G1 and G3. This similarity between these two sites is explained by their proximity. which subjects them to almost identical conditions [40].

Redundancy analysis shows that environmental variables such as conductivity. nitrate. phosphate. ammonium. pH. dissolved oxygen and temperature significantly influence macroinvertebrate structure in Lake Buyo in a positive way. The results of this study corroborate those of other studies that have shown a positive correlation between macroinvertebrate structure and environmental variables. Indeed. macroinvertebrate densities are related to environmental parameters. In a similar study [41]. found the highest densities associated with high values of temperature. pH and conductivity.

5. Conclusion

This work has enabled an initial characterization of the macroinvertebrate population in the waters upstream of Lake Buyo. comprising 98 taxa belonging to insects. gastropods. bivalves. crustaceans. arachnids and oligochaetes. The macroinvertebrate community of this lake is dominated by insects. The distribution of aquatic macro invertebrates in this lake is positively influenced by the environmental variable conductivity. nitrates. phosphate. ammonium. pH. dissolved oxygen and temperature. The combination of the different indices studied revealed that the waters of Lake Buyo have a good ecological status.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare they have no competing interest.

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