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Research Article

BENTHIC MACROINVERTEBRATES IN FISH SPAWNING GROUNDS, DIVERSITY AND SPATIAL DISTRIBUTION, BUYO LAKE DAM (CÔTE D'IVOIRE)

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ABSTRACT

This work focuses on the diversity and spatial distribution of benthic macroinvertebrates in the ichthyological spawning grounds of Lake Buyo. Sampling took place from June 2018 to May 2019 on 11 spawning grounds using a Van Veen grab, a dip net and a dip net. A total of 19,940 individuals grouped into 28 Families, 13 Orders, 6 Classes and 4 Branches were identified. The most abundant Families with a percentage higher than 20 in the study area are Thiaridae (63.33%) and Chironomidae (22.88%). The Insects class is the most diversified with 17 families followed by Gastropods with 8 families. The values of the Shannon-Weaver indices and the Pielou equitability calculated are low, which reflects a low taxonomic diversity and an imbalance in the spatial distribution of benthic macroinvertebrates in the different ichthyological spawning grounds.

Keywords: Benthic macroinvertebrates, Taxonomic diversity, Buyo Lake, Cote d'Ivoire.

INTRODUCTION

For fish, the most crucial moment of their life cycle is certainly the breeding season, but also the time of foraging. To do so, the fish needs water, food and suitable sites to reproduce. These breeding sites or areas also called spawning grounds are places where females lay their eggs and where males sprinkle them with sperm (Désy, 2005 and Anonymous, 2021). For these reproductive activities, fish, like any other animal, need energy. This energy is provided by the food consumption. The food search is therefore an essential activity for these organisms.

Surface freshwaters are environments that host a very rich and diverse fauna including different trophic levels despite their low importance in volume (Tachet *et al.*, 2010). In this trophic edifice, fish whose trophic level is higher than that of benthic macroinvertebrates, consume them in addition to the living organisms they produce from the transformation of organic material (Moisan & Pelletier, 2013). Benthic macroinvertebrates are organisms visible to the naked eye. They live at the water-sediment interface and at the bottom of streams, rivers, lakes or marshes. They are mainly composed of Worms, Crustaceans, Mollusks and Insects (Moisan, 2010). In addition to being part of the fish diet, benthic macroinvertebrates also play an important ecosystem role. They include many decomposer, filter feeder, predator, herbivore, omnivore and detritivore species and are also bioindicators of stream health. In view of their high importance and the role they play in aquatic ecosystems, these organisms have been the subject of several studies in Côte d'Ivoire. These include, among others, those of Diomandé & Gourène, (2005) in the fluvio-lacustrine hydrosystem of the Bia; Kouamé, (2010) in the lower Sassandra River; Simmou, (2017) in four coastal rivers and a lagoon complex in the southeast; Tapé, (2020) in macroinvertebrate responses to the degradation of the ecological quality of artificial urban lakes in Yamoussokro and Motchié, (2021) for the assessment of lake water quality in the department of Bongouanou.

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Present study aimed to update benthic macroinvertebrates faunal in Côte d'Ivoire and first database on spatial distribution in the ichthyological spawning grounds of Buyo Lake. The objectives were to highlight the importance of benthic macroinvertebrates during the reproduction periods of fish and to define the determinisms of the choice of spawning areas for different species of fish based on benthic macroinvertebrates

MATERIALS AND METHODS

Study area and sampling stations

Lake Buyo is a hydroelectric dam located in the South West of Côte d'Ivoire, between latitudes 06°14' and 07°03' N and longitudes 06°54' and 07°31' W (OIPR, 2006; Kouamé, 2010). Built in 1980 on the Sassandra River basin downstream from the confluence of the Sassandra and N'zo rivers, this dam generated an artificial lake of 900 km^2 and about 8.4 billion m^3 of water after its impoundment (Anonymous 2, 2020). Our study area is the part of Lake Buyo located in the Taï National Park (TNP). This area is characterized by a primary forest and the only authorized activity is fishing.

Eleven (11) stations were defined and investigated. These sites were characterized by the existence of ichthyological spawning grounds (Figure 1).

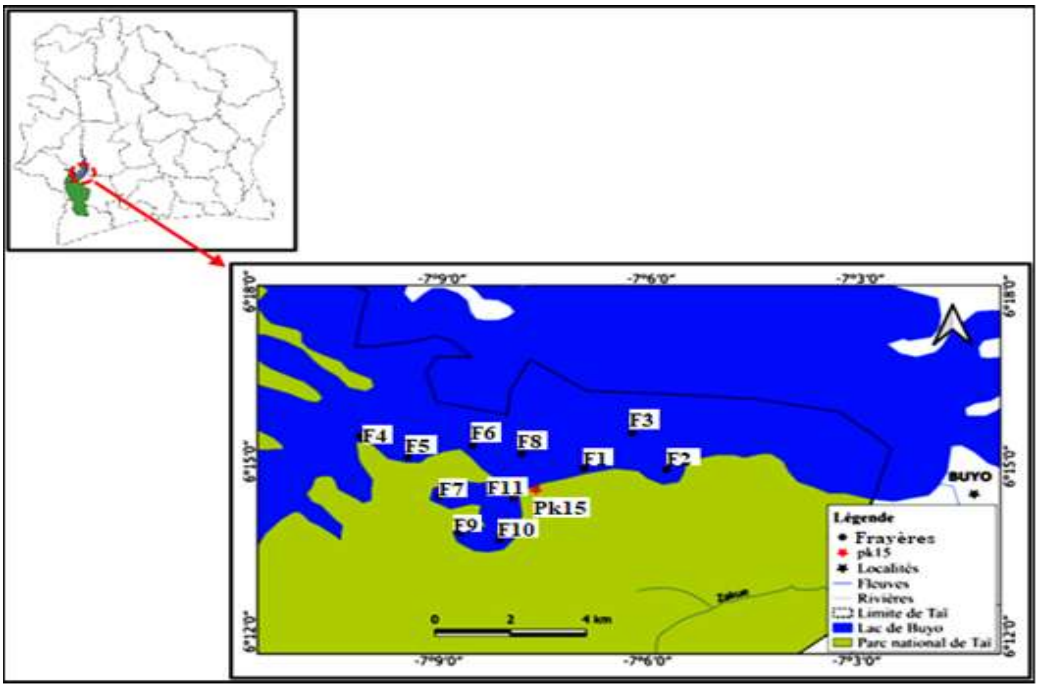

Figure 1. Lake Buyo fish spawning ground sampling site from June 2018 to May 2019.

Data sampling and analysis: Collection and identification of benthic macroinvertebrates

Benthic macroinvertebrate sampling was conducted monthly from June 2018 through May 2019 using a Van Veen bucket and a dip net. Samples collected were rinsed with water on a 1 mm mesh void sieve to remove branches, stems, and silt. Organisms were then sorted in situ and preserved in pillboxes that contained 5% formaldehyde. In laboratory, organisms were observed under a binocular magnifying glass model sorted and grouped by similarity. Identification of macroinvertebrates was done at the lowest possible taxonomic level using the keys of Belleg (1981) for Molluscs; Déjoux *et al*., (1981); Diomandé *et al*., (2000); De Moor *et al*., (2003) and Tachet *et al*., (2003) for Annelids, Arthropods and Platyhelminthes.

Data processing

Absolute abundance (Aa)

Abundance is an important parameter used to determine the number of individuals of a taxonomic group in a given sample on a specified area. It has been expressed by the following formula:

$$\mathbf{a = Nombre\ d'invidus\ d'un\ taxon}$$

Occurrence Frequency (OF)

The occurrence frequency (OF) of taxa is the ratio of the number of spawning sites where the taxon (Pi) is present to the total number of spawning sites surveyed (P).

$$\%\mathbf{FO} = \frac{\mathbf{Pi}}{\mathbf{P}} \times \mathbf{100}$$

The classification of Djakou and Thanon (1988) was chosen for the present study. Taxa " very frequent" have OF ≥ 50%; taxa " frequent" have 25% ≤ OF < 50% and taxa " rare" OF < 25%.

Shannon-Weaver diversity index (H)

This index is used to evaluate the degree of organization of the settlement (Amanieu & Lassere, 1982) and is related to the probability that two individuals drawn at random from the set of individuals belong to the same taxonomic group.

$$\mathbf{H = -\sum_{i=1}^{i=s} pi \times \log pi}$$

Where pi = probability of capture of species i (i ranging from 1 to s) and s = total number of species.

Pielou equitability index (E)

Equitability index is the ratio of true diversity to maximum diversity. It is closely related to the Shannon-Weaver index (H).

$$\mathbf{E = \frac{H}{\log_2 S}}$$

Analysis of variance (ANOVA)

Analysis of variance (Anova) was used to evaluate the degree of variability of biotic parameters in relation to spawning sites. Before the choice of the test, the normality and homogeneity tests were performed on the variables. The significance level of the probability value of these tests was $p > 0.05$.

RESULTS AND DISCUSSION

In all the spawning grounds surveyed, 19,940 individuals of benthic macroinvertebrates were recorded. These individuals are divided into 6 classes, 13 orders, 28 families and 33 taxa (Table I). The global analysis of the whole population shows that Gastropods class is the most abundant with 13619 individuals or 68.30% of the total abundance. It is followed by Insect with 5792 individuals or 29.05% (Figure 2). As for the total diversity, Insects has the highest proportion (64%) followed by Gastropods (24%) and Arachnids, Branchiopods, Clitellates, Turbellariates classes each represent 3% of the total abundance of macroinvertebrates in the spawning grounds surveyed (Figure 3).

Table 1. Faunistic composition and occurrence of benthic macroinvertebrates sampled at different spawning grounds in Buyo Lake from June 2018 to May 2019.

Class	Ordres	Famillies	Taxa	Ichthyological spawning grounds sites											Occurrence Frequency (%OF)
				F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	
Clitellata	Tubificida	Naididae	*Branchiodrilus hortensis*	*											9,1
Arachnida	Hydracarina	Hydrachanidae	*Hydracariens* sp	*	*		*	*	*	*	*	*	*	*	90,9
Branchiopoda	Spinacaudata	Limnadiidae	*Limnadia lenticularis*		*		*	*	*	*		*	*	*	72,7
Insecta	Coleoptera	Gyrinidae	Gyrinus sp											*	9,1
		Cerambycidae	Cerambycidae											*	9,1
	Diptera	Ceratopogonidae	Ceratopogonidae							*			*		18,2
		Chaoboridae	*Chaoborus* sp	*								*			9,1
		Chironomidae	*Chironomus* sp	*	*	*	*	*	*	*	*	*	*	*	100
			Polypedilu									*			9,1

			m sp												
	Ephemeroptera	Baetidae	*Beatis* sp		*							*			18,2
		Caenidae	*Caenis latipennis*	*	*		*	*	*	*		*	*	*	81,8
		Ephemerellidae	Ephemerellidae										*		9,1
		Leptophleibiidae	*Thraulus bellus*											*	9,1
			Undetermined										*		9,1
		Polymitarcyidae	*Ephoron virgo*			*	*		*	*			*	*	54,5
		Potomanthidae	*Potamanthus luteus*	*	*		*	*	*	*		*	*	*	81,8
	Hemiptera	Belostomatidae	*Lethocerus americanus*	*	*		*	*	*	*		*	*	*	81,8
		Gerridae	*Gerris lacustris*		*			*	*	*	*	*	*		63,6
		Nepidae	*Ranatra linearis*		*			*	*	*		*	*	*	63,6
	Odonates	Coenagrionidae	*Ceriagrion tenellum*	*	*		*	*	*	*		*	*	*	81,8
			Erythromma pro parte		*		*	*	*	*		*		*	63,6
			Ischnura sp							*		*	*	*	36,4
		Corduliidae	*Epitheca bimaculata*	*	*	*	*	*	*	*		*	*	*	90,9
		Libellulidae	*Trithemis annulata*	*	*		*	*	*	*		*	*	*	81,8
Gastropods	Littorinimorpha	Bithyniidae	*Bithynia tentaculata*	*	*		*	*	*	*	*			*	72,7
	Basommatophora	Bulinidae	*Bulinus truncatus*	*	*		*	*	*	*		*	*	*	81,8
		Physidae	*Physa* sp										*		9,1
		Planorbidae	*Biomphalaria pfeifferi*	*	*		*	*	*	*		*	*	*	81,8
	Caenogastropoda	Lithoglyphidae	*Lithoglyphus naticoides*		*										9,1
		Lymnaeidae	*Myxas glutinosa*	*	*										18,2
		Thiaridae	*Melanoides tuberculata*	*	*	*	*	*	*	*	*		*	*	90,9
	Hygrophila	Lymnaeidae	*Omphiscola* sp		*		*							*	27,3
Turbellaria	Tricladida	Planariidae	*Planaria torva*									*	*		18,2
6	13	28	33	15	20	4	16	16	17	19	5	19	21	21	

The occurrence of benthic macroinvertebrates in the ichthyological spawning grounds (Cf. Table I) shows that 18 taxa (FO > 50% of total richness), were very frequent, 2 taxa (25 < FO < 50%) were frequent and 15 taxa (FO < 25% of total richness) were rare. Spawning grounds F10 and F11 had the highest taxa richness (21 taxa) and the lowest taxa richness (4 taxa) was observed in spawning ground F3 (Figure 4). Taxonomic richness showed

significant variations between the different spawning grounds (ANOVA test, $p < 0.05$). These differences were observed between spawning ground F3 (Tukey test, $p = 0.0003$) and the other spawning grounds, and between spawning ground F8 (Tukey test, $p = 0.0001$) and the other spawning grounds. No significant difference was observed between spawning grounds F3 and F8. Concerning numerical abundance of benthic macroinvertebrates (Figure 5), highest value was recorded at spawning ground F4 (5973 individuals) and lowest value was noted at spawning ground F3 (46 individuals). Significant difference was observed between spawning grounds (ANOVA test, $p < 0.05$). These differences are observed between spawning grounds F4 and F3 on the one hand (Tukey test, $p = 0.01$) and between spawning grounds F4 and F8 on the other hand (Tukey test, $p = 0.01$).

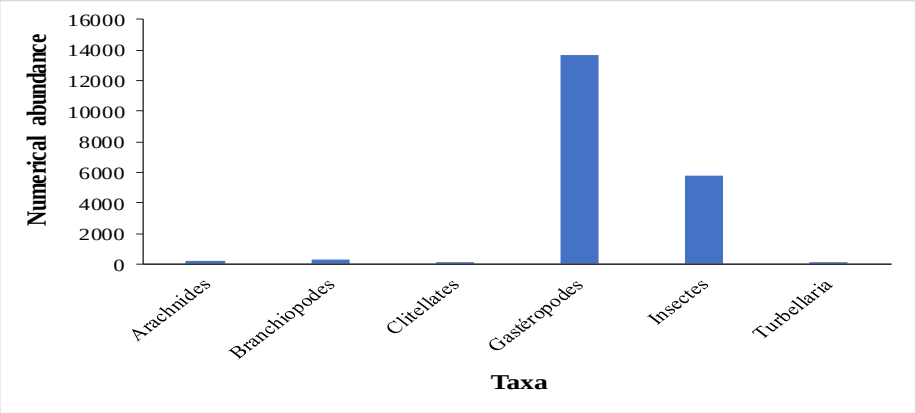

Figure 2. Abundance of benthic macroinvertebrate taxa recorded at Lake Buyo fish spawning grounds from June 2018 to May 2019.

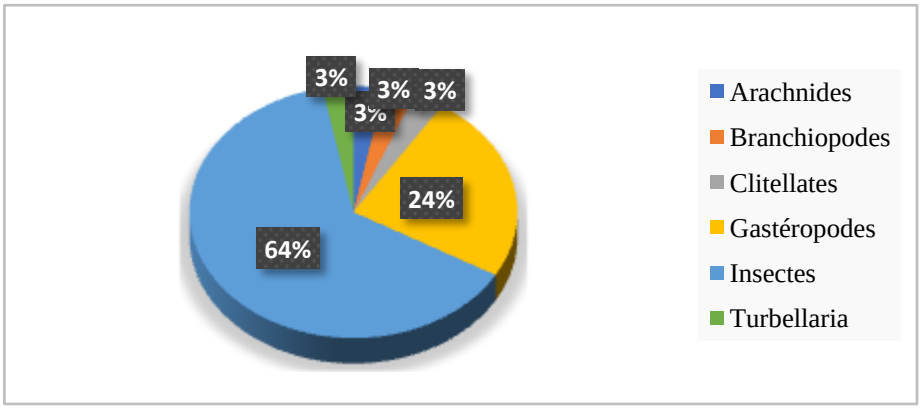

Figure 3. Diversity of benthic macroinvertebrate taxa recorded at Buyo Lake fish spawning grounds from June 2018 to May 2019.

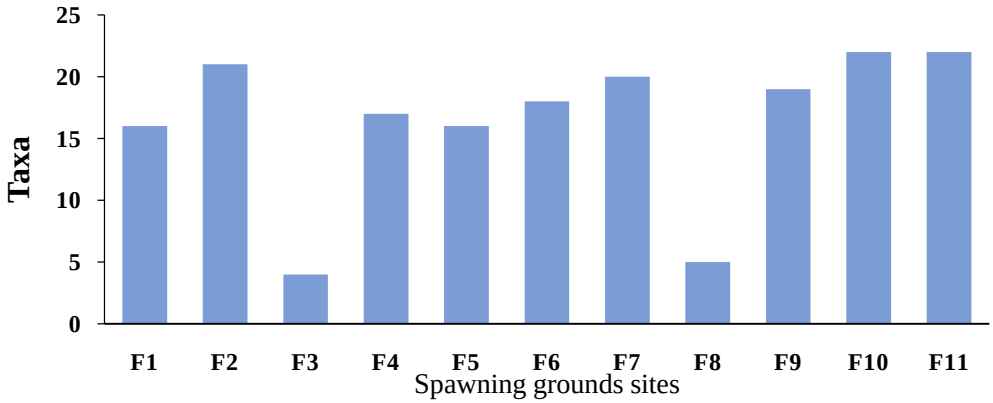

Figure 4. Spatial variation in taxonomic richness of benthic macroinvertebrates sampled at Buyo Lake fish spawning grounds from June 2018 to May 2019.

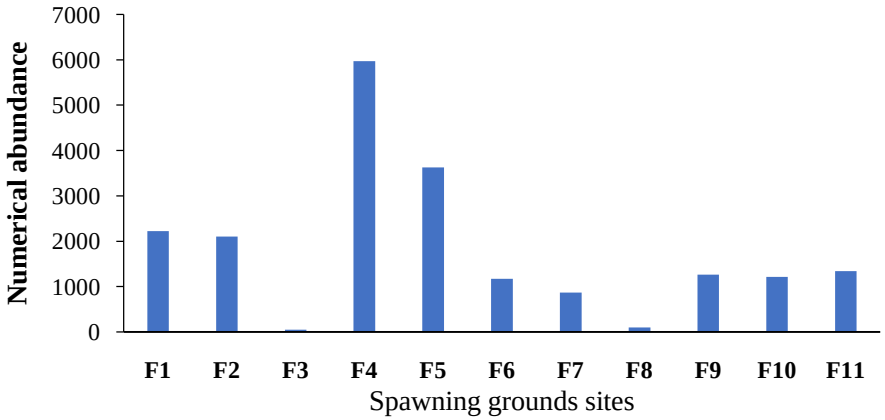

Figure 5. Spatial variation in numerical abundance of benthic macroinvertebrates collected from ichthyological spawning grounds in Buyo Lake from June 2018 to May 2019.

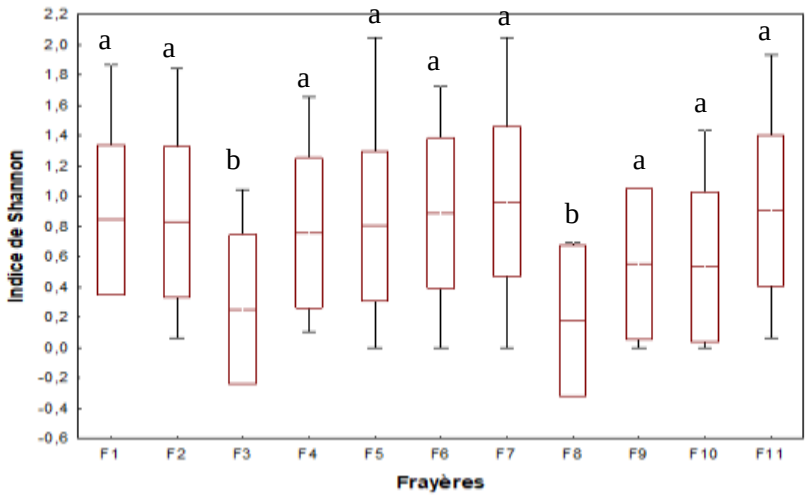

Figure 6. Spatial variation in Shannon-Weaver diversity index of ichthyological spawning grounds in Buyo Lake from June 2018 to May 2019: median values with a letter (a or b) in common do not differ significantly (Anova test, p>0.05).

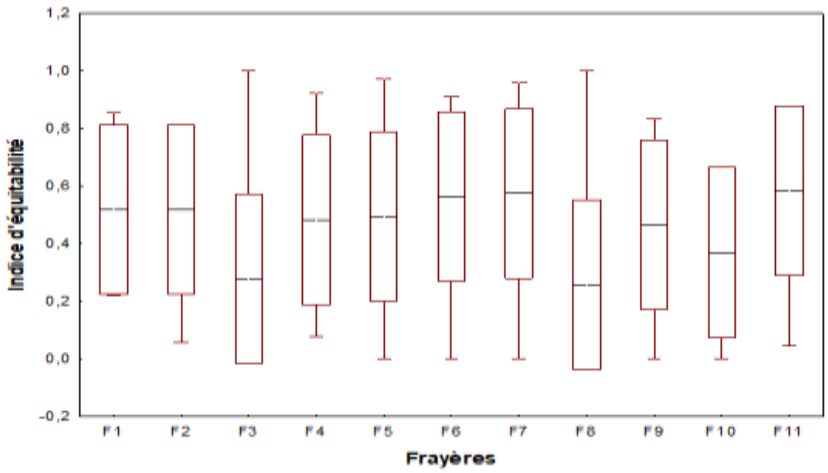

Figure 7. Spatial variation in the equitability diversity index of fish spawning grounds in Buyo Lake from June 2018 to May 2019.

Figures 6 and 7 show the spatial variations of the Shannon-Weaver diversity and Pielou equitability indices. The recorded Shannon index values ranged from 0 to 2.048 bits/ind. The maximum value was noted in spawning area F5 and minimum value was observed in Figure 3 and F8. Significant differences were observed between spawning areas F1, F2, F6, F7, F11 and F8 on one hand and between spawning areas F7, F11 and fifure F3 on other hand (Tukey test, p = 0.0004). According equitability, index maximum value (1 bits/ind) was obtained in spawning grounds F3 and F8 and the lowest value (0 bits/ind) was recorded in spawning grounds F3 and F8, respectively. ANOVA test showed no significant difference (Anova, p = 0.0691) between the different ichthyological spawning grounds.

The study of benthic macroinvertebrates from the ichthyological spawning grounds of Buyo Lake revealed 19,940 individuals grouped into 35 taxa belonging to 6 classes, 13 orders and 28 families. Numerical abundance of taxa observed was largely superior to that of Kouamé (2010) in the same environment (2498 individuals) and to those of Motchié (2021) in lakes Sokotè (3465 individuals) and Ehuikro (143 individuals) in the department of Bongouanou in Côte d'Ivoire However, this abundance is lower than that obtained by Tapé (2020) (22072 individuals) in artificial lakes of Yamoussoukro, Côte d'Ivoire. This difference in species richness compared to the study of Kouamé (2010) in the same environment could be explained by the equipment used, the sampling period and the number of sampled sites surveyed. Indeed, this author used only the Ekman bucket for his sampling and had only two sites on Buyo Lake. Analysis of benthic macroinvertebrate fauna of the ichthyological spawning grounds showed that Gastropods were the most abundant organisms in the population. These observations were similar to those made by Kouamé (2010). The high presence of gastropods could be explained by the fluctuating water level of the lake, which regularly floods the riparian vegetation, resulting in an enrichment of the environment with nutrients during their decomposition. Also, the high presence of nutrients leads to the proliferation of algae and macrophytes which constitutes an important food source for many gastropods (Strong et al., 2008 and Kaboré et al., 2016). The high density of the species *Melania tuberculata* observed in the captures could be attributed to the fact that this species tolerates numerous variations of abiotic parameters. Insects represent the most diverse group in the study area. These results corroborate those of Kouamé (2010), Sanogo et al. (2014) and Tapé (2020) respectively in Buyo lake, three basins of the Volta basin and in the artificial lakes of Yamoussoukro.

This predominance of insect diversity is linked to their ubiquity and adaptability (Gagnon and Pedneau, 2006). Among insects, Chironomidae family were the most abundant with an occurrence of 100%. This high numerical importance of Chironomidae would be related to their continuous reproduction throughout the year as highlighted by Dejoux et al. (1981). The abundance of Chironomidae could also be related to the combined effect of high temperatures and abundant food in the environment. The highest taxonomic richness observed in spawning grounds F10 and F11 would be due to the proximity of these areas to the fishermen's camp. This proximity would favor a diversification of food sources for these organisms. Evaluation of the level of organization of benthic macroinvertebrate population was carried out using Shannon Weaver diversity indices and the corresponding equitability. The high peak values of these indices (2.048 bits and 1 bit respectively) observed in the surveyed ichthyological spawning grounds indicated that benthic macroinvertebrate community in spawning areas is very low in diversity and poorly organized. Our observations corroborate those of Abahi et al. (2018) (1.23 bits and 0.53 bits, respectively) in the upper Ouémé River, Benin.

CONCLUSION

This study focused on the benthic macroinvertebrates of the ichthyological spawning grounds of Buyo Lake showed that Gastropods and Insects are the most abundant and diversified groups. The families Thiaridae and Chironomidae dominate the population. The Chironomidae are present in all the ichthyological spawning grounds. The spawning grounds located near human living areas have the highest specific abundance and are the most diversified.

ACKNOWLEDGMENT

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