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Influence of the hydrological regime of lake buyo on fish community of three floodplains in the Tai national park (southwestern Côte d'Ivoire)

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Abstract

Floodplains play an important role in the ecological functioning of the areas on which they depend. These plains are also of socio-economic interest to the local population, particularly in terms of fishing activities. The fish fauna of three Lake Buyo floodplains (Néma, Libériakôbro and Gah) was studied in relation to the lake's hydrological regime. The aim of this study was to evaluate the influence of the hydrological seasons of Lake Buyo on the structure of the fauna considered. Sampling of fish community was carried out monthly during an annual cycle using experimental fishing. The structure of the fish community was analyzed by determining taxonomic composition, taxon abundances (Ar) and the Shannon-Weaver diversity (H') and Pielou equitability (E) index. Temporal dynamics of the studied parameters were analyzed according to three hydrological seasons: flood season, high water season and recession season. Results showed that total specific richness of ichthyofauna of the studied plains was 38 species, and the richness observed at the different hydrological seasons varied significantly ($p < 0.05$). The Cyprinidae family was dominant in the abundances recorded at all seasons ($48.34\% \leq Ar \leq 85.5\%$). It should be noted that the studied ichthyofauna exhibited relatively low diversity and equitability with reference to diversity index ($1.42 \leq H' \leq 1.46$ and $0.28 \leq E \leq 0.29$).

Keywords: Ichthyofauna; Taxonomic diversity; Abundance dynamics; Floodplains; Hydrological regime; Lake Buyo

1. Introduction

The building of hydroelectric dams is gaining increasing interest throughout the world for its development objectives. [1, 2]. In West Africa, and particularly in Côte d'Ivoire, the lake hydrosystems created upstream of these installations promote the development of inland fisheries [3, 4, 5] and thus contribute to improving the livelihood of local populations. However, the fishing practices employed to supply the growing need for protein sometimes represent a threat to aquatic biodiversity. These threats are reflected in a decline in fish stocks and the disappearance of some species from the main lakes, including Buyo [6, 7, 8]. The fact that Lake Buyo has partial protected status [9] means that there are good prospects for developing sustainable management plans for the fish stock, given the flood plains in its watershed [9, 10, 11]. Floodplains are environments of great biodiversity and are also the most productive zones of aquatic ecosystems [12, 13]. They offer a heterogeneity of habitats suitable for the various vital functions of fish in the regeneration of halieutic stocks [13]. Unfortunately, a decline in fish stocks had been observed in floodplain fisheries in recent decades, linked in particular to climate change and anthropogenic activities affecting the flow rate, intensity and duration of floods [12, 14]. This was the case of the floodplains of Lake Buyo, which were facing a reduction in their surface area and in the duration of their flooding, due to a drop in flooding from Lake Buyo [14]. In view of the various threats to these plains [6, 8, 11, 15], it was necessary to analyze their functioning, in particular by determining the

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dynamics of living communities. This study aimed to assess the influence of hydrological regime of Lake Buyo on the dynamics of fish community in three floodplains located in the Taï National Park. Specifically, the aim was to determine the variability of the specific richness and the diversity of fish community in relation to the hydrological regime of Buyo Lake.

2. Materials and methods

2.1. Study sites

Three floodplains of Lake Buyo (Néma, Libériakôbro and Gah), located in the Taï National Park (TNP), were selected as study sites (Figure 1). The geographical coordinates and surface areas of these plains are shown in Table 1. Important commercial fishing activities were carried out on these plains. Various fishing techniques were used according to the hydrological seasons of Lake Buyo [8, 16].

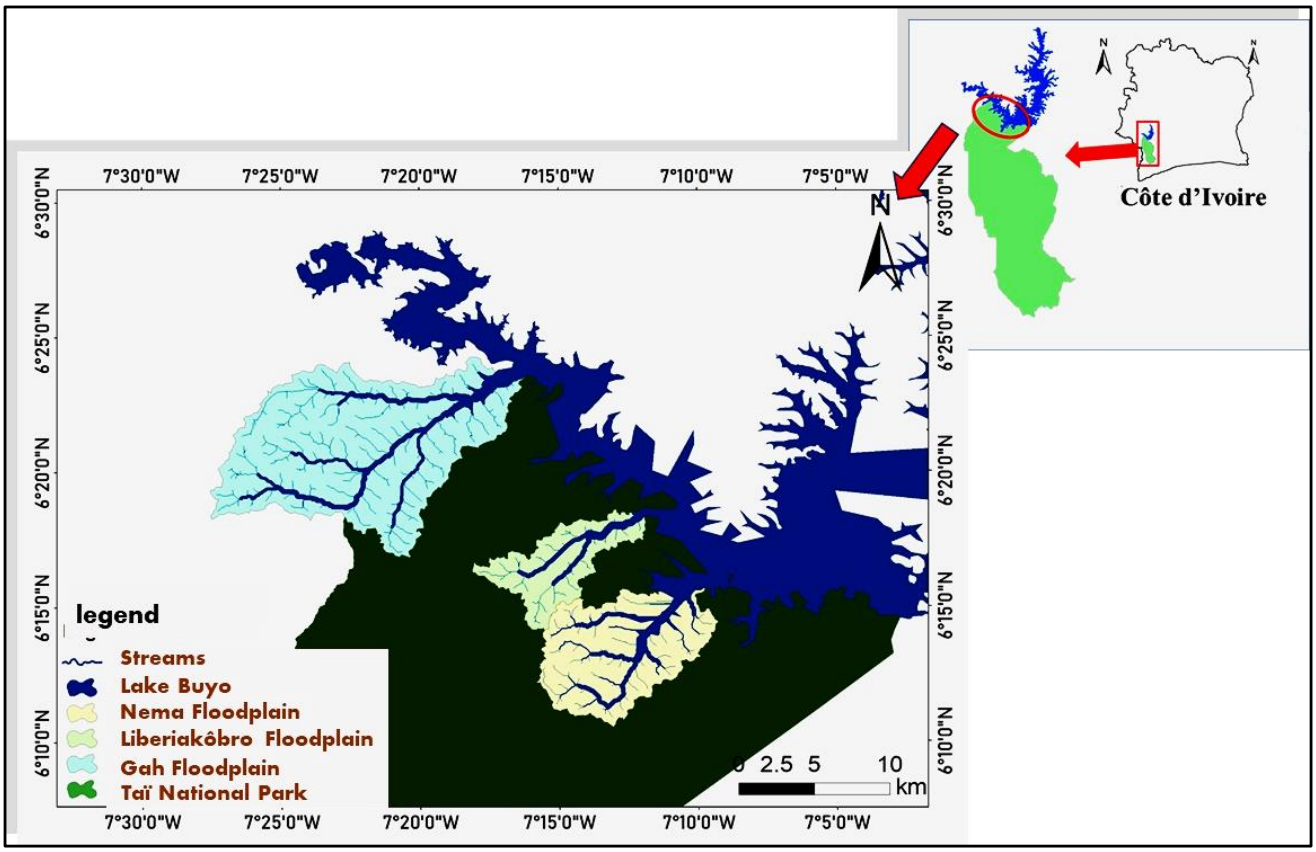


Figure 1 Location of the Néma, Libériakôbro and Gah floodplains, in the Taï National Park

Table 1 GPS coordinates and area of studied floodplains

Floodplains studied	Geographic coordinates	Area (Km²)
Néma	6°15 - 6°12 N & 7°15 – 7°12 W	74,54
Libériakobro	6°18 – 6°15 N & 7°18 – 7°12 W	36,72
Gah	6°24 – 6°18 N & 7°27 – 7°18 W	158,34

N: North; W: West

2.2. Data collection

Fish community of the studied floodplains was sampled monthly over an annual cycle (from April 2021 to March 2022). Sampling was based on experimental fishing. These were carried out using passive fishing gear (gillnets, creels) and active fishing gear (dip nets). Captured fish were identified and counted. Taxa were identified using keys suggested by reference documents [17].

2.3. Data analysis

Species richness was determined during each monthly sampling and the richness obtained was related to the corresponding hydrological season. The relative abundance (Ar) of families was determined according to the following equation [18] :

$$A_r(i) = \frac{n(i)}{N} x100$$

With Ar (i): relative abundance of family i; n (i): number of individuals of family i in the samples considered; N: total number of individuals in the samples considered.

The diversity index (Shannon-Weaver (H'), and Pielou equitability (E)) were calculated from the following equations [18, 19, 20, 21] :

$$H' = -\sum_{i=1}^{s} \left[\frac{n(i)}{N} log_2 \frac{n(i)}{N}\right]$$

$$E = \frac{H'}{log(s)}$$

With n (i): number of individuals of species i; N: total number of individuals; s: total number of species recorded.

The temporal analyses in this study were based on the hydrological seasons of Lake Buyo. These seasons were determined on the basis of monthly fluctuations in the water level of Lake Buyo in relation to its mean level [8, 22, 23]. Three hydrological seasons were thus defined, including a flood season (June to August), a high-water season (September to March) and a low-water season (April to May). The flood and deflooding seasons were observed during periods of low water (shoreline levels below the mean shoreline of Lake Buyo). They were coded FLS and FLS respectively. The high-water season is coded HWS. Taxa with a contribution of less than 3% of the abundances obtained were grouped together in the "other" taxa category during the analyses carried out.

A one-way analysis of variance (ANOVA) at the 5% significance level (p = 0.05) was performed on the seasonal variability of species richness and diversity indices (H' and E). A factorial correspondence analysis (FCA) was used to determine the affinities of fish families for each of the hydrological seasons of Lake Buyo. This affinity is reflected in the abundance of each family during the three hydrological seasons. Statistical analyses were carried out using PAST (Paleontological Statistics) software version 4.11.

3. Results

3.1. Taxonomic composition of floodplains ichthyofauna

A total of 38 fish species were inventoried in the three floodplains studied. These taxa were classified into 23 genera, 15 families and 8 orders. high-water season recorded the highest species richness (Rs=33 species) and the lowest in flood recession season (Rs=18 species). The Cichlidae family was the most diversified (6 species), followed by the Mormyridae (5 species) and Cyprinidae (5 species) as shown in Table 2.

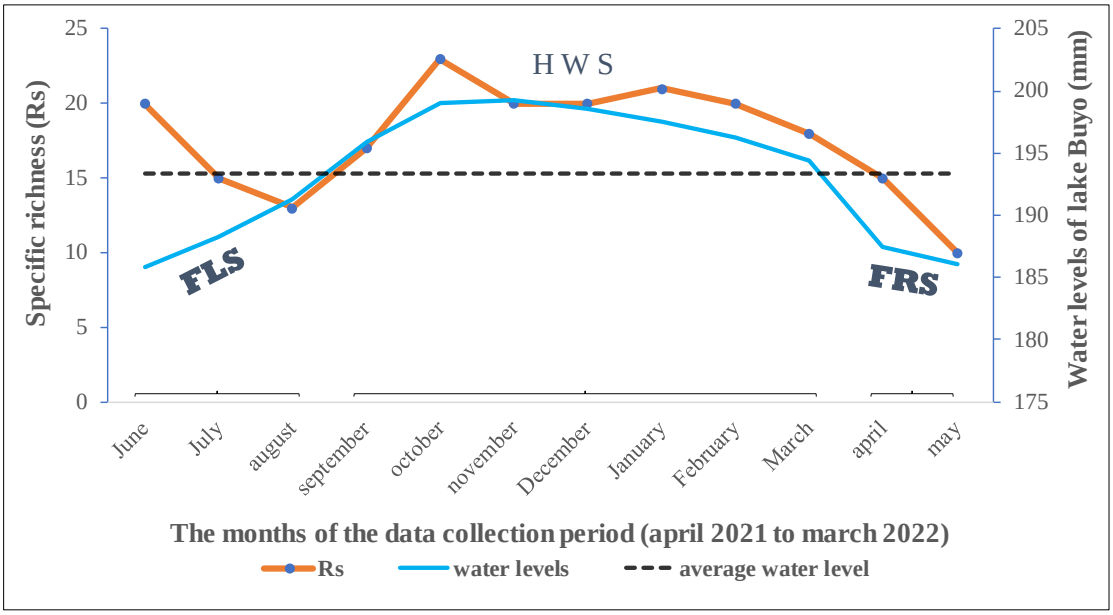
Table 2 Taxonomic composition of fish community in the Néma, Libériakôbro and Gah plains of Lake Buyo at different hydrological seasons

Orders	Families	Species	Flood season (FLS)	High-Water Season (HWS)	Flood recession season (FLS)
Characiformes	Alestidae	*Brycinus imberi**	-	+	-
		Brycinus longipinnis	+	+	+
		Brycinus macrolepidontus	+	+	+
		Brycinus nurse	+	+	+
	Distichodontidae	*Distichodus rostratus**	+	+	-
	Hepsetidae	*Hepsetus odoe**	-	+	-
Clupeiformes	Dorosomatidae	*Pellonula leonensis*	+	+	+
Cypriniformes	Cyprinidae	*Enteromius ablabes*	+	+	+
		Enteromius macrops	+	+	+
		*Enteromius trispilos**	-	+	-
		*Labeo coubie**	-	+	-
		*Labeo parvus**	+	-	-
Osteoglossiformes	Arapaïmidae	*Heterotis niloticus*	+	+	-
	Mormyridae	*Marcusenius senegalensis**	-	+	-
		*Marcusenius ussheri**	-	+	-
		Mormyrus rume	+	+	-
		*Petrocephalus bovei**	-	+	-
		Pollimyrus isidori	+	+	+
Perciformes	Centropomidae	*Lates niloticus*	+	+	+
Cichliformes	Cichlidae	*Coptodon zillii*	+	+	+
		Hemichromis bimaculatus	+	+	-
		Hemichromis fasciatus	+	+	+
		Oreochromis niloticus	+	+	+
		Sarotherodon galilaeus	+	+	-
		Sarotherodon melanotheron	-	+	+

Polypteriformes	Polypteridae	*Polypterus retropinnis**	-	+	-
Siluriformes	Clariidae	*Clarias anguilaris*	+	+	-
		Clarias gariepinus	+	+	+
		*Heterobrachus longifilis**	+	-	-
		Heterobranchus isopterus	-	+	+
	Claroteidae	*Chrysichtys johnelsis*	+	+	-
		*Chrysichtys maurus**	+	-	-
		Chrysichtys nigrodigitatus	+	+	+
	Malapteruridae	*Malapterurus electricus**	-	-	+
	Mochokidae	*Synodontis koensis*	+	+	+
		*Synodontis ponctifer**	+	-	-
	Schilbeidae	*Schilbe intermedius*	+	+	+
		Schilbe mandibularis	+	+	+
8	15	38	27	33	18

* : Fish species that occurred in a single hydrological season in the floodplains studied; FLS : flood seasons, HWS : high water season, FLS : flood recession season

3.2. Variations in species richness in relation to the hydrological regime of Lake Buyo



FLS : flood seasons, HWS : high water season, FLS : flood recession season

Figure 2 Seasonal variations in fish community species richness in the Néma, Libériakôbro and Gah plains of Lake Buyo

The seasonal dynamics of species richness showed a peak in October, one period of increase (August-October) and two periods of decrease (June-August and January-May) as shown in figure 2. The Rs averages obtained for the different

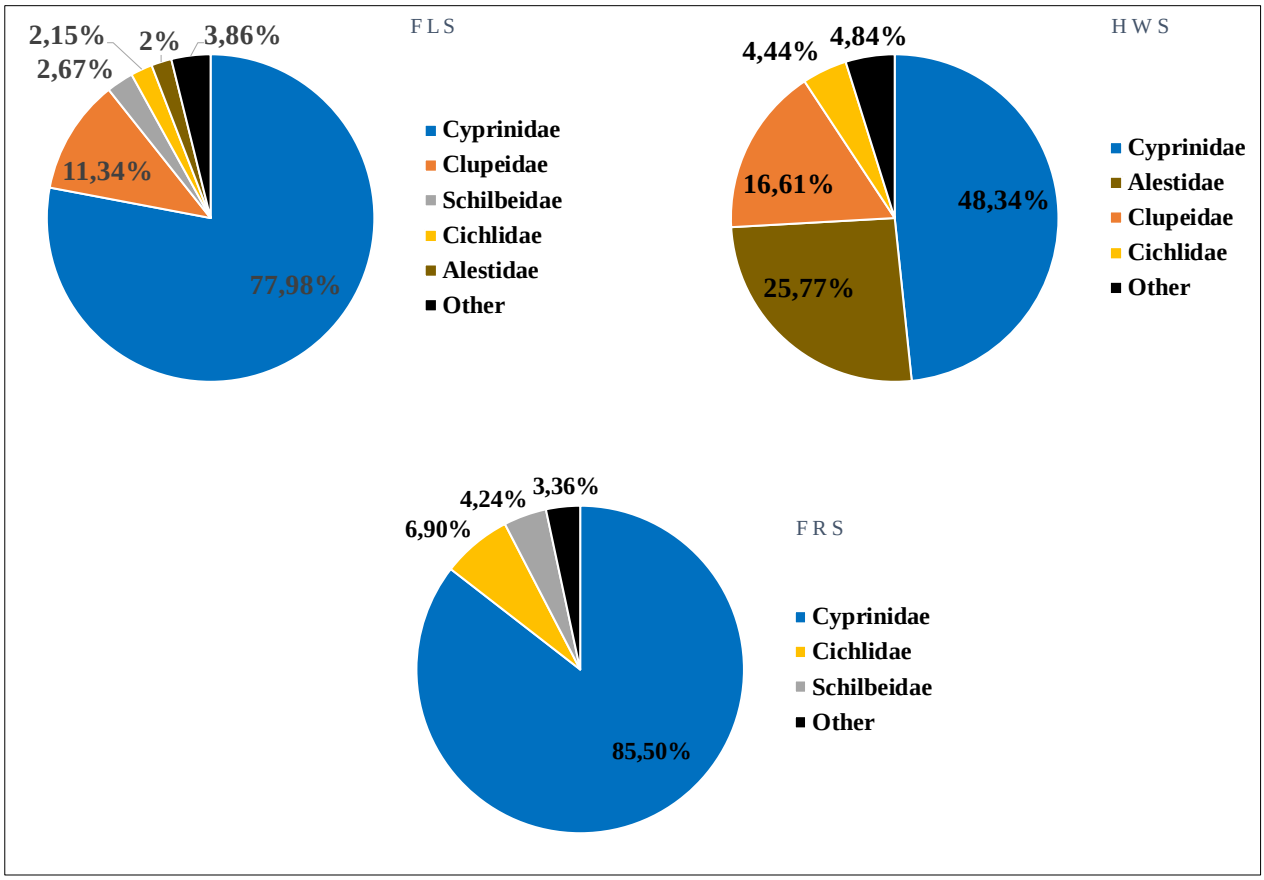
hydrological seasons were 16 ± 3.6 in Flond saeson, of 19.86 ± 1.95 in High-Water Season (HWS) and 12.5 ± 3.53 in Flood recession season (FLS) respectively (table 3). These averages were significantly different ($p < 0.05$).

Table 3 Shannon-Weaver diversity and Pielou equitability index for fish community on the Néma, Libériakôbro and Gah plains of Lake Buyo at different hydrological seasons

	Flood season (FLS)	**High-Water Season (HWS)**	**Flood recession season (FLS)**	**p (same)**
Mean of species richness	16 ± 3.6	19.86 ± 1.95	12.5 ± 3.53	0,014

3.3. Variations in families abundance in relation to the hydrological regime of Lake Buyo

A total of 10,356 fish specimens were sampled across the three plains studied. This overall abundance was divided down into 2,698 individuals (26.05%) in the flood season, 6,527 individuals (63.03%) in the high-water season and 1,131 individuals (10.92%) in the low-water season. The Cyprinidae family was the most represented in all the hydrological seasons considered, with a contribution ranging from 48.34% of abundances to 86%. This dominant species was followed by the Clupeidae (11.34%) in the flood season, the Alestidae (25.77%) in the high-water season and the Cichlidae (6.9%) in the low-water season (Figure 3).



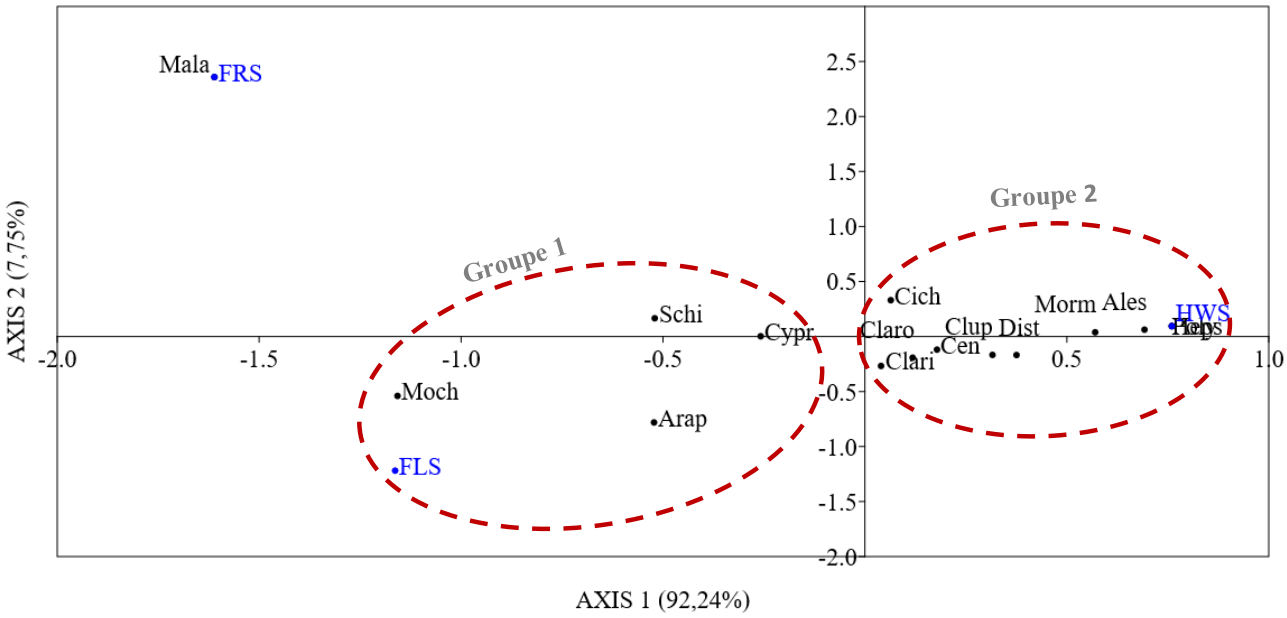
FLS : flood seasons, HWS : high water season, FLS : flood recession season

Figure 3 Contribution of families to the abundance of fish fauna in the Néma, Libériakôbro and Gah plains of Lake Buyo at different hydrological seasons

3.4. Classification of the ichthyofauna of studied plains in relation to their affinity with the hydrological seasons of Lake Buyo

The ordination of fish families on the two axes allowed us to identify two species assemblages (Figure 4). The first is associated with the flood season (FLS), which is negatively correlated with axis 1, while the second is associated with the high-water season (HWS), positively correlated with axis 1. Group 1 comprises the Mochokidae, Arapaïmidae,

Schilbeidae and Cyprinidae families. Group 2 includes the families Cichlidae, Clariidae, Claroteidae, Clupeidae, Centropomidae, Distichodontidae, Mormyridae, Alestidae, Hepsetudae and Polyteridae.



FLS : flood seasons, HWS : high water season, FLS : flood recession season; Ales : Alestidae ; Claro : Claroteidae ; Clari : Clariidae ; Dist : Distichodontidae ; Cypr : Cyprinidae ; Cich : Cichlidae ; Morm : Mormyridae ; Poly : Polypteridae ; Arap : Arapaïmidae ; Clup : Clupeidae ; Schi : Schilbeidae ; Moch : Mochokidae ; Heps : Hepsetidae ; Cen : Centropomidae ; Mala : Malapteruridae

Figure 4 Ordination of the 15 families of fish community of the Néma, Libériakôbro and Gah plains of Lake Buyo during the three hydrological seasons (FLS, HWS and FLS) according to the factorial axes 1 and 2 of the factorial correspondence analysis

3.5. Diversity of fish community in the studied plains

The Shannon-Weaver(H') and Pielou (E) index varied little over the three hydrological seasons studied (ANOVA, $p > 0.05$). The mean values recorded range from 1.35 ±0.17 to 1.61 ±0.41 for H' and from 0.26 ±0.08 to 0.33 ±0.14 for E (Table 4).

Table 4 Shannon-Weaver (H') and Pielou (E) equitability index for fish populations on the plains studied at different hydrological seasons in Lake Buyo

Diversity index	FLS	HWS	FLS	p (0,05)
Shannon (H' ; bits/ind)	1,42 ±0,23	1,61 ±0,41	1,35 ±0,17	0,58
Pielou (E)	0,27 ±0,09	0,26 ±0,08	0,33 ±0,14	0,73

FLS : flood seasons, HWS : high water season, FLS : flood recession season

4. Discussion

The inventory of fish fauna of the studied floodplains showed a richness of 38 species, including the species *Polypterus retropinnis*, newly observed in Lake Buyo and the aquatic ecosystems of the Taï National Park (TNP). This richness represented a significant proportion of the ichthyofauna of the areas on which the studied floodplains depend. Indeed, the recorded species richness represented 84.44% of the taxonomic richness of the Buyo Lake ichthyofauna, estimated at 45 species, and 57.57% of that of the TNP hydrosystems, estimated at 65 species [20]. The relatively high taxonomic richness of the fish fauna on the studied floodplains was thought to be a result of the colonization of species from surrounding areas, notably Lake Buyo, the N'Zo River and the TNP hydrosystems. The high diversity of floodplain ichthyofauna had also been reported by several authors [10, 24, 25, 26, 27, 28, 29]. The presence of the species *Polypterus retropinnis* in the studied floodplains increased the ichthyological richness of Lake Buyo to 46 species, and

that of the TNP hydrosystems to 66 species [30]. Seasonal dynamics of Rs indicated higher values in HWS, and these would be linked to intensified migrations during HWS [24, 25, 26, 31, 32, 33, 34, 35].

Seasonal dynamics of family abundances showed that Cyprinidae were dominant in all seasons considered. A predominance of this family was particularly observed during periods of high water (FLS) and low water (FLS). This observation was in accordance with the mode of colonization of floodplains as reported in previous studies [12, 22, 23, 28, 29]. Indeed, these studies reported that small species such as those of the Cyprinidae family were very abundant in floodplains during both flood and recession periods.

The relatively low diversity and equitability of the studied ichthyofauna was a consequence of the fact that the abundances recorded during the different hydrological seasons were dominated by one or two families, notably the Cyprinidae and the Alestidae. In fact, these families were represented by 9 species, including 6 species of Cyprinidae and 4 species of Alestidae, out of a total of 38 species for the whole ichthyological community. These 9 species therefore accounted for the great majority of observed abundances. The Shannon (H') and Pielou equitability (E) index obtained were therefore low.

5. Conclusion

This study showed that the taxonomic diversity of the ichthyofauna of the Néma, Libériakôbro and Gah floodplains represented a significant proportion (84.44%) of the ichthyofauna of Lake Buyo, on which they depended. The total species richness recorded was 38 species, and the richness observed in different hydrological seasons varied significantly. The high-water season presented the highest species richness (Rs = 33), while the low-water season exhibited the lowest (Rs= 18). The abundance of ichthyofauna was dominated by the Cyprinidae family at all seasons considered, with contributions ranging from 48.34% to 85.5%. Finally, the diversity index indicated that fish community on the studied plains was not very diversified or equilibrated.

Compliance with ethical standards

Acknowledgments

Data on rainfall in the study area and on water levels in Lake Buyo were essential for this study. The authors are very grateful to the Ivorian electricity company (CIE DPE/DUH-Buyo) for providing these data.

Disclosure of conflict of interest

The authors note that there are no conflicts of interest to declare for the data in this study.

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