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Research Article

Composition and Structure of the Ichthyological Population of Urban and Peripheral Lakes of the City of Yamoussoukro (Central Ivory Coast)

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Abstract - *The present study aims to evaluate the diversity of fish populations in urban and peripheral lakes of the city of Yamoussoukro. This study was carried out on 8 lakes (5 urban and 3 peripheral) during 08 sampling campaigns between December 2022 and February 2024. The collection of fish from experimental fishing was carried out using gill nets, creels and hawks. The ichthyofauna inventory made it possible to identify 18 species of fish divided into 9 families and 5 orders. Fish populations are more diverse in the peripheral lakes (16 species) especially in lake 4 (16 species) than in the urban lakes (7 species). The frequencies of occurrence of ichthyofauna show that Oreochromis niloticus and Coptodon zilii are the species most encountered in the lakes. Analysis of the diversity of fish populations in the reserve shows that fish populations are less diverse, stable and balanced.*

Keywords - *Fish populations, Urban lakes, Peripheral lakes, Yamoussoukro.*

I. INTRODUCTION

Today, global fish consumption has exceeded the average threshold of 20 kg per year per capita, double the average consumption level of the 1960s (FAO, 2016). In sub-Saharan Africa, fish covers on average 22% of animal protein intake (Efolé, 2011). In Côte d'Ivoire, this food represents the main source of animal proteins consumed, i.e. nearly 15 kg/inhabitant/year (FAO, 2008). Thus, the growing interest in aquaculture results from the decline in natural reserves of fishery resources, caused by the strong pressure exerted on fishing to cover ever-increasing consumption needs, in relation to the increase in population (Naylor et al., 2000; Pauly et al., 2002). This is the case of the lakes in the town of Yamoussoukro which are subject to strong anthropogenic pressures. This concerns the location of industries, intensive agriculture and illegal fishing practiced. One of the consequences of these human actions in the lakes is the pollution of the waters of these lakes due to the increased input of fertilizers and pesticides (OIPR, 2015).

This pollution leads to its enrichment in suspended matter and chemicals of all kinds. This situation is perceptible by the proliferation of aquatic plants and algae (Halle et al., 2006). The impacts of these anthropogenic activities are likely to negatively influence the ecological quality of the waters of these lakes and the degradation of the natural habitats of aquatic biological communities, particularly ichthyofauna (Gourène et al., 1999). However, knowledge of the state of fish populations in urban and peripheral lakes is a major concern. Thus, the present study aims to determine the ichthyological diversity of urban and peripheral lakes of the city of Yamoussoukro.

II. MATERIALS AND METHODS

A. Study Environment

The study was carried out in the lakes of the town of Yamoussoukro. Yamoussoukro is a town in central Côte d'Ivoire (Figure 1). It has been the political capital of the country since 1983. Located between latitudes 6°48 North and longitudes 5°17 West, it is the capital of the Department and the Lakes Region. Yamoussoukro is

located 206 km from Abidjan, the economic capital. The city of Yamoussoukro has 340,234 inhabitants over an area of 3500 km^2. It is the sixth most populous city in Côte d'Ivoire after Abidjan (5,616,633 inhabitants), Bouaké (832,371 inhabitants), Korhogo (440,926 inhabitants), Daloa (421,879 inhabitants) and San-Pedro (390,654 inhabitants) (RGPH, 2021).

The city of Yamoussoukro belongs to the transitional humid tropical regime characterized by two (2) major seasons, notably the dry season which extends from November to February and the rainy season from March to October with the greatest precipitation in September (N'guessan et al., 2014). The dense and branched hydrographic network of the Yamoussoukro district is mainly made up of the Bandama River and its tributaries, as well as the N'Zi and Kan rivers. On the Bandama River, the Kossou hydroelectric dam and numerous small hydro-agricultural dams on the N'Zi and Kan rivers were built (Ouattara, 2015).

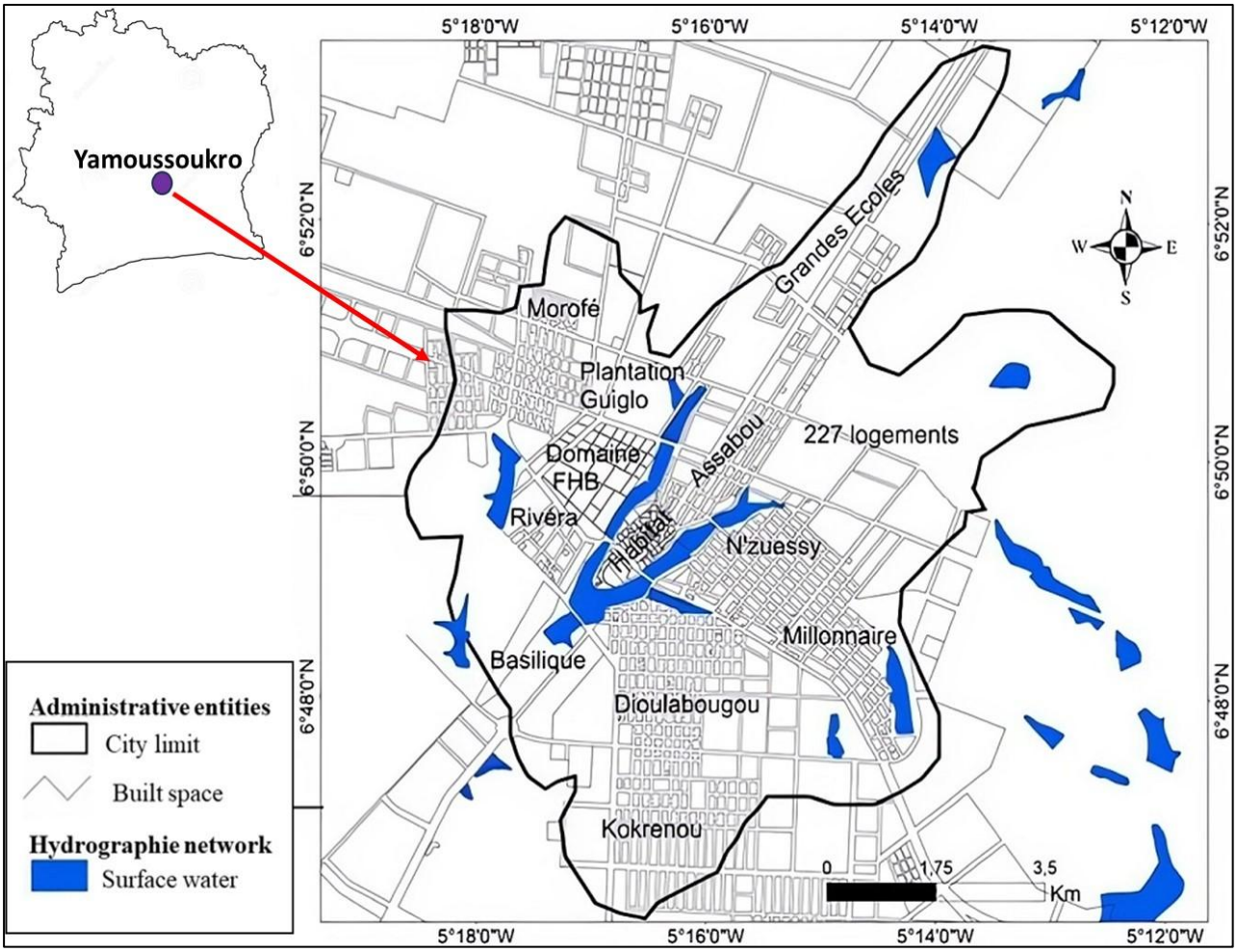

Figure 1. Presentation of the City of Yamoussoukro

B. Choice of Sampling Lakes

The choice of sampling lakes was made based on their accessibility, their proximity to sources of pollution (cattle breeding, intensive agriculture, fishing, etc.), land use, surrounding activities, fishing activity and their degrees of anthropization. In total, eight (8) lakes were defined, including six (6) located in the center of the city and three (3) on the outskirts. These are lake 1 (lake Guiglo), lake 6 (lake petit Bouaké), lake 5 (lake Hôpital), lakes 8 (lake Agip) and lake 9 (lake Fanon), all located in the center of the city. On the outskirts of town we have Lake 10 (Millionnaire Lake), Lake 3 and Lake 4. The study took place over eight (08) seasonal campaigns between December 2022 and February 2024 at a bimonthly rate (one campaign every two months). Thus, four (4) sampling campaigns were carried out including four (4) in the dry season (December 2022, February 2023, December 2023 and February 2024) and four (4) in the rainy season (April 2023, June 2023, August 2023 and October 2023) following the two climatic seasons which prevail in the study area.

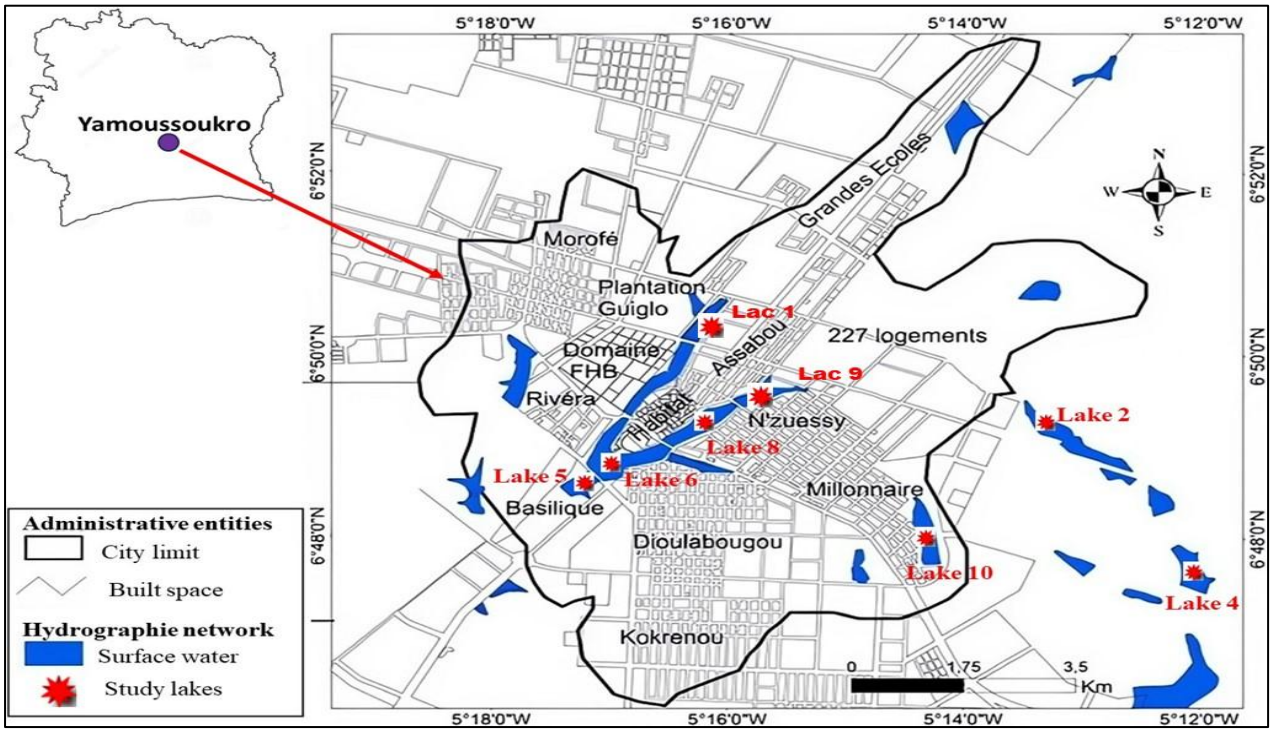

Figure 2. Presentation of the Lakes Sampled in the Town of Yamoussoukro

Table 1. Description of Sampling Lakes

	Lakes	Coordinates	Description and anthropogenic activities
Urban lakes	Lake 1	6°50'12'' N 5°16'23'' W	Located to the east of the city near the presidency. On the right and left banks of this lake, we observe market gardens and large trees. It receives waste from nearby market gardeners and serves as a place for dumping garbage and other waste.
	Lake 5	6°48'40'' N 5°16'10'' W	Largest lake in the system, receiving water from lake 6. Presence of washerwomen and vehicles using detergents. Presence of cattle and poultry farms, scrubland, homes and market gardeners.
	Lake 6	6°48'41'' N 5°17'9'' W	Receptacle of the system located below Lake 5 and adjacent to livestock parks and the presence of market gardeners.
	Lake 8	6°49' 08'' N 6°16' 22'' W	Concentration on the edges of tourist activities (restaurants, train stations, hotels) from which it receives wastewater with the presence of market gardeners
	Lake 9	6°49'20'' N 5°16'01'' W	Bordered by hotel complexes and restaurants on the right bank and market gardens on the left bank. Receptacle for wastewater from urban areas and waste emanating from activities developed on its banks
Peripheral lakes	Lake 2	6°50'35'' N 5°14'44'' W	Located in uninhabited areas with the presence of market gardeners
	Lake 4	6°47'35'' N 5°12'9'' W	Located in uninhabited areas with the presence of market gardeners
	Lake 10	6°48'23'' N 5°14'35'' W	Located in uninhabited areas with the presence of market gardeners

C. Sampling Methods

The fish fauna samples come from experimental fishing. The gillnets and bamboo traps are set between 4 p.m. and 5 p.m. and taken up the next day between 6 a.m. and 7 a.m., for night fishing. They are rested between 7 a.m. and 8 a.m. then released between 3 p.m. and 4 p.m., for daytime fishing. Furthermore, the cast net was also used to capture fish. It is thrown by hand from a canoe or on the banks of lakes and then brought back by pulling on the pick-up rope. The identification of these collected specimens is carried out at the specific level using the keys proposed by Paugy et al. (2003a and b) and Froese and Pauly (2012 and 2014).

III. DATA ANALYSIS

For the analysis of the diversity of fish populations, various indices were used :

- Specific richness (Rs) which makes it possible to determine the total number of various species of fish collected at a station (Ramade, 1994).
- The frequency of occurrence (F) provides information on the environmental preferences (habitat) of a given species (Dajoz, 2000). It is obtained according to the formula F = (Fi x 100) / Ft.

With: Fi = number of surveys containing species i and Ft = number of surveys carried out.

Depending on the value of F, the following classifications are adopted:

1. 80% ≤ F ≤ 100% : Very frequent species,
2. 60% ≤ F ≤ 79% : Frequent species,
3. 40%≤ F ≤ 59% : Frequent species,
4. 20% ≤ F ≤ 39% : Incidental species,
5. 0%≤ F ≤ 20% : Accidental species.

- Jaccard's similarity index (J) was used to evaluate the specific similarities of two sites (Jaccard, 1908). It has the formula : J = j / (a + b – j). With : J = number of species common to the two sites, a = the number of taxa specific to site 1, b = the number of taxa specific to site 2. Two groups are similar if J > 0.5 and dissimilar if J <0.5.
- The Shannon diversity index (H') made it possible to quantify the diversity of populations (Shannon et al., 1963). Its equation is as follows: H = - Σpi*log2pi. With: pi represents the relative abundance of species i in the sample (pi = ni/N).
- The Piélou equitability index (E) reflects the degree of balance of fish populations (Dajoz, 2000). Its equation is as follows: J = H'/log 2 S. With: S = number of species observed.

IV. RESULTS

A. Specific Composition of the Ichthyofauna

Table II presents the distribution of fish species captured in urban and peripheral lakes of the city of Yamoussoukro. In total, 18 species of fish distributed between 9 families and 5 orders were collected. These are the orders Characiformes, Osteoglossiformes, Perciformes, Siluriformes and Lepidosireniformes. Among these orders, the order Perciformes with 03 families and 10 species is the most diverse. In this order the Cichlidae family is the richest in species (08 species).

They are followed by the order of Siluriformes, which has 02 families and 4 species and that of Osteoglossiformes with 02 families and 2 species. The orders least rich in species are those of Charaformes and Lepidosireniformes, each grouping 01 family and 01 species. The distribution of fish species according to the lakes surveyed indicates that lake 4, with 16 species, is the most diverse. It is followed by lake 10 with 13 species. On the other hand, lakes 5, 8 and 9, with 03 species each, are the least diverse. The analysis of ichthyofauna occurrences shows that Oreochromis niloticus is constant in all the lakes sampled. The occurrences of the itchyofauna of the urban lakes of Yamoussoukro are presented in Table III. Lake 2 records the highest proportion of constant species (90.90%). It is followed by lake 9 with 66.67%. However, the low proportion of this category (33.33%) is noted on lake 8. Accessory species are more represented (66.67%) at lakes 5 and 8 and less represented (9.09%) on lake 2. As for accidental species, they record their greatest proportion (33.33%) on lakes 5 and 9. On the other hand, these species are less abundant (7.69%) in lake 10.

Table 2. Spatial Distribution of the Ichthyofauna of Urban and Peripheral Lakes of the City of Yamoussoukro

				Urban lakes					Peripheral lakes		
Orders	**Families**	**Species**	**Codes**	**Lake 1**	**Lake 5**	**Lake 6**	**Lake 8**	**Lake 9**	**Lake 2**	**Lake 4**	**Lake 10**
Characiformes	Hepsetidae	*Hepsetus odoe*	Hod	-	-	-	-	-	***	***	***
Ostéoglossiformes	Mormyridae	*Marcusenius senegalensis*	Mse	-	-	-	-	-	-	*	-
	Ostéoglossidae	*Heterotis niloticus*	Hni	-	-	**	-	-	-	*	*
Perciformes	Channidae	*Parachanna obscura*	Pob	-	-	-	-	-	***	***	***
	Anabantidae	*Ctenopoma petherici*	Cpe	-	-	-	-	-	-	*	-
	Cichlidae	*Coptodon guineensis*	Cgu	-	-	-	-	-	***	***	***
		Coptodon hybride	Chy	-	-	-	-	-	***	***	***
		Coptodon zillii	Czi	**	***	***	**	*	***	***	***
		Hemichromis fasciatus	Hfa	**	-	-	**	***	-	-	-
		Hemichromis bimaculatus	Hbi	-	-	-	-	-	-	*	***
		Oreochromis niloticus	Oni	***	***	***	***	***	***	***	***
		Sarotherodon galilaeus	Sga	***	-	-	-	-	***	***	***
		Sarotherodon melanotheron	Sme	*	-	-	-	-	-	-	-
Siluriformes	Clariidae	*Clarias anguillaris*	Can	-	*	*	-	-	***	***	***
		Clarias gariepinus	Cga	-	-	-	-	-	***	**	***
	Claroteidae	*Chrysichthys maurus*	Cma	-	-	-	-	-	**	**	**
		Chrysichthys nigrodigitatus	Cni	-	-	-	-	-	***	***	***
Lepidosireniformes	Protopteridae	*Protopterus annectens*	Pan	-	-	-	-	-	-	*	-
5	**9**	**18**		**5**	**3**	**4**	**3**	**3**	**11**	**16**	**13**

* = Accidental species ; ** = Incidental species; *** = Constant species ; - = absence

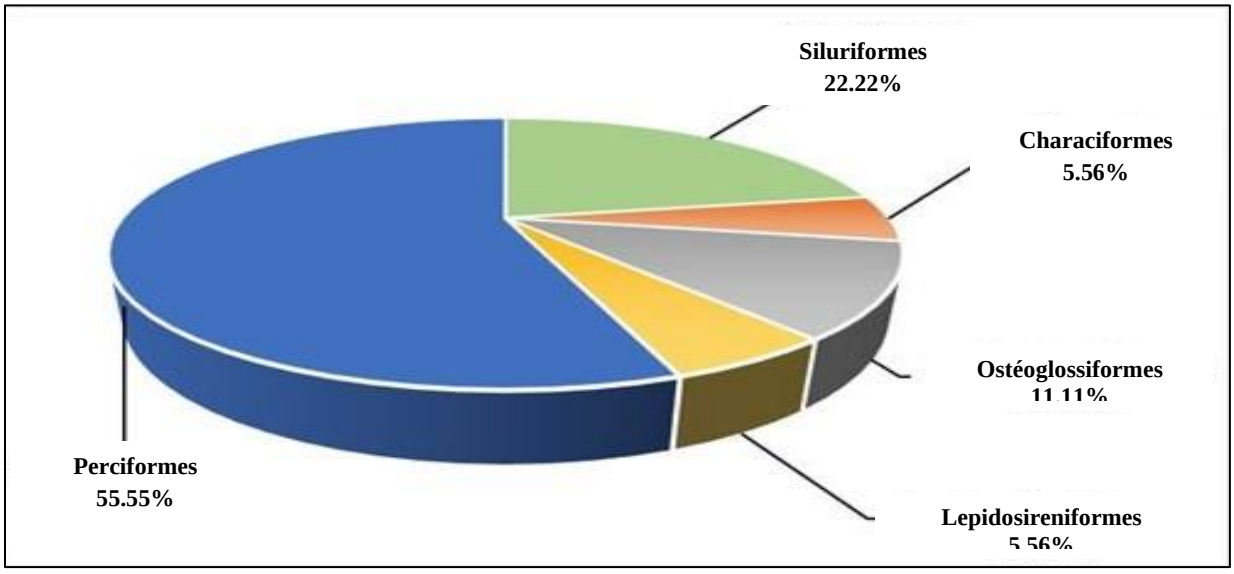

Figure 3. Relative Importance of Orders of Fish Caught

Table 3. Percentages of Categories of Fish Species Defined on the Basis of their Occurrences

		Urban lakes				Peripheral lakes		
Occurrences (%)	Lac 1	Lac 5	Lac 6	Lac 8	Lac 9	Lac 2	Lac 4	Lac 10
Constants	40	-	50	33,33	66,67	90,90	56,25	53,85
Accessories	40	66,67	25	66,67	-	09,09	12,25	38,46
Accidental	20	33,33	25	-	-	-	31,25	07,69

B. Specific Similarities between Lakes

The specific Similarities between lakes highlighted by the values of the Jaccard similarity index (J) calculated from the specific composition of the stations are presented in Table IV. For all the lakes, the values of the Jaccard similarity index between the fish communities of the lakes taken two by two vary between 1 and 86.67%. Also, peripheral lakes are more similar than urban lakes. The Jaccard index is higher (86.67%) between lake 4 and lake 10, all located on the periphery. They are followed respectively by lakes 4 and 2 (73.3%) and lakes 2 and 10 (71.4%), also located on the periphery. However, the smallest value of the Jaccard index is obtained between urban lakes 8 and 9.

Table 4. Results of the Jaccard Similarity Test Expressed as a Percentage of Species Common to the Lakes Taken Two by Two in the Different Urban and Peripheral Lakes of the City of Yamoussoukro

	Lake 1	Lake 5	Lake 6	Lake 8	Lake 9	Lake 2	Lake 4
Lake 5	28,6						
Lake 6	28,6	60					
Lake 8	60	40	40				
Lake 9	33,3	40	40	1			
Lake 2	23,1	36,4	25	16,67	16,67		
Lake 4	17,7	21,4	18,75	12,5	12,5	73,3	
Lake 10	12,5	26,7	21,43	14,29	14,29	71,4	86,66

Jaccard similarity test results greater than or equal to 50% are in bold.

C. Analysis of the Diversity of the Ichthyological Population

a. Spatial and Seasonal Variations of the Shannon Index (H')

Figure 4 presents the spatial and seasonal variations of the Shannon index of the ichthyological populations of urban and peripheral lakes of the city of Yamoussoukro. The fish populations are less diverse (0.18 bits) in urban lake 5 and more diverse (2.4 bits) in peripheral lake 4. The values of the Shannon index present significant differences between the lakes (tests of Kruskal-Wallis and Mann-Whitney, $p < 0.05$). At the seasonal level, fish populations are less diverse (2.4 bits) during the rainy season and more diverse (1.38 bits) during the dry season. The median values of the Shannon index differ significantly between the two climatic seasons in the reserve (Mann-Whitney test, $p < 0.05$).

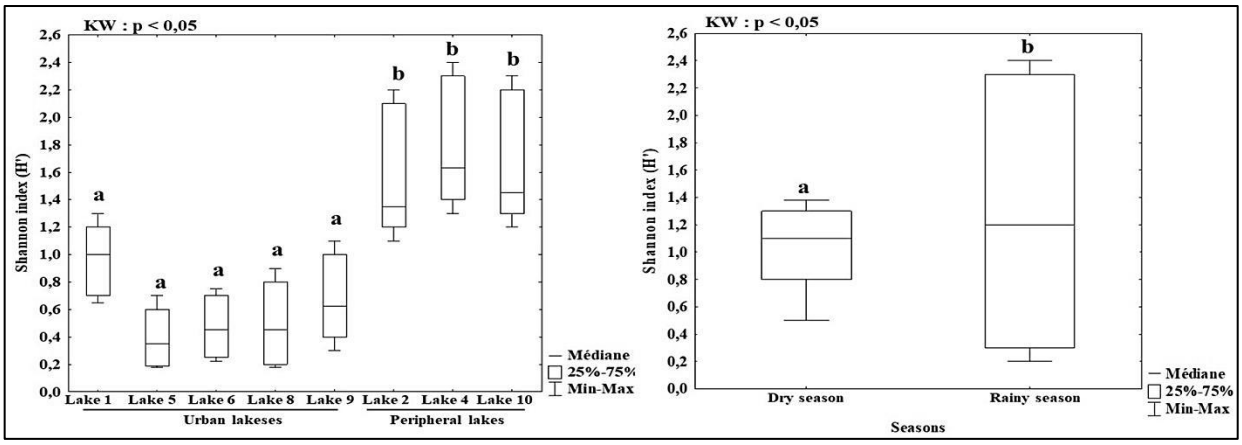

Figure 4. Spatial and Seasonal Variations in the Shannon Diversity Index of Fish Populations in Urban and Peripheral Lakes of Yamoussoukro

a and b reveal that there are significant variations between the median values of the Shannon index between lakes, p = significance threshold

b. Spatial and Seasonal Variations of the Equity Index (E)

Figure 5 indicates the spatial and seasonal variations of the equitability index of fish populations in urban and peripheral lakes of the city of Yamoussoukro. The fish populations are less stable and balanced (0.2 bit) in urban lake 5. On the other hand, they are more stable and balanced (0.98 bit) in the peripheral lake 4. At the seasonal level, the fish populations are less stable and balanced (0.6 bit) during the dry season and more diversified during the rainy season (1 bit). The median values of the Shannon index differ significantly between the two climatic seasons in urban and peripheral lakes (Mann-Whitney test, $p < 0.05$).

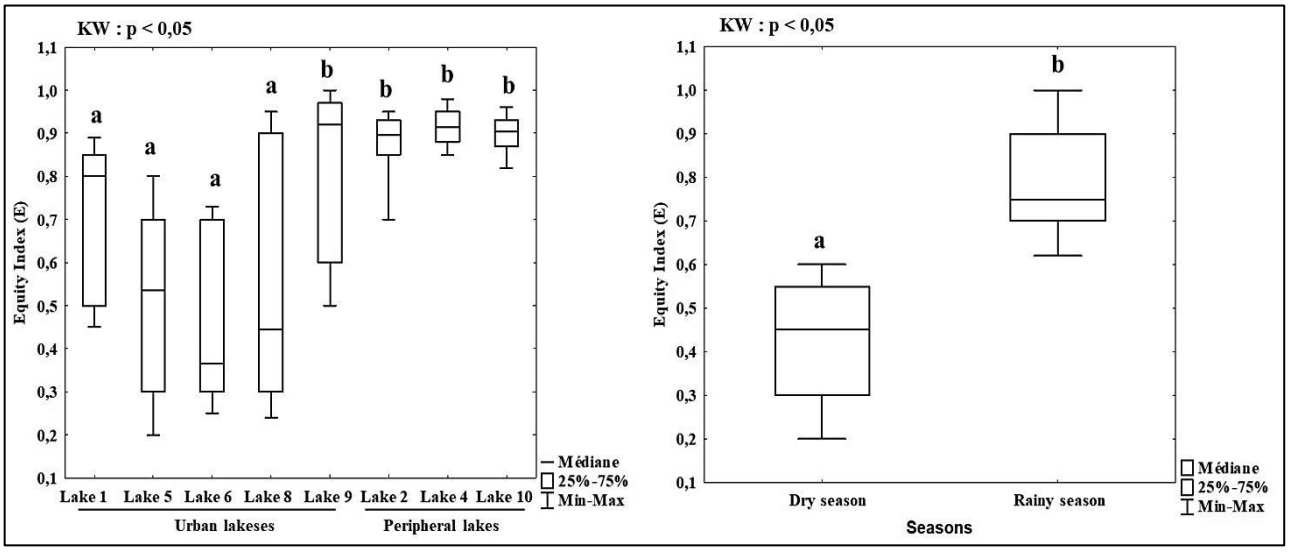

Figure 5. Spatial and Seasonal Variations in the Equitability Diversity Index of Fish Populations in the Urban and Peripheral Lakes of Yamoussoukro

a and b reveal that there are significant variations between the median values of the equitability index between lakes, p = significance threshold

V. DISCUSSION

The specific composition (18 species) of the ichthyofauna collected in the urban and peripheral lakes of the city of Yamoussoukro is lower than those reported by Konan et al. (2015), who inventoried 36 species in Lake Kossou. This difference in number of species would be linked to the extent of the lake and the fact that it is located in a rural area, therefore less exposed to anthropization. Furthermore, anthropogenic activities have led to habitat degradation and pollution of lake water, leading to the disappearance of fish species. The distribution of species richness according to the orders indicates that the Perciformes (10 species) are the most diverse. In this order the Cichlidae family (8 species) is the richest in species. This result corroborates that of Koné et al., (2003), who showed that the creation of lakes is often accompanied by the colonization of Cichlidae species. According to Greenwood (1981), the Cichlidae is one of the most diverse families of fish in all the basins in the world. This family exploits almost all the food resources available in aquatic environments (Lowe-Mcconnell, 1987). This plasticity would allow them to adapt to a large number of ecological niches. The analysis relating to the frequencies of occurrence of fish species indicates that Oreochromis niloticus is very frequently encountered in all lakes. This result shows that these species would be able to live in different types of biotopes and would have a large margin of tolerance with respect to various environmental factors (Yao et al., 2005). The result relating to the organization of fish populations in urban and peripheral lakes of the city of Yamoussoukro indicates values between 0.18 and 2.4 bits, for the Shannon index and between 0.2 and 1, for the fairness. This reflects that the fish populations of the urban and peripheral lakes of the city of Yamoussoukro are relatively undiversified. However, they are stable and balanced in peripheral lakes. This observation would result from the impacts of the intensity of anthropogenic activities observed in the lakes.

VI. CONCLUSION

This study made it possible to evaluate the diversity of fish populations in urban and peripheral lakes of the city of Yamoussoukro. The inventory made it possible to identify 18 species of fish divided between 9 families and 5 orders. Tilapia zillii and Oreochromis niloticus were encountered in all sampled lakes. Regarding the frequencies of occurrence of ichthyofauna, Oreochromis niloticus is very frequently encountered in all lakes. The diversity analysis shows that fish populations are less diverse, however, they are more stable and balanced on the outskirts of the city. Given the low diversity of the fish fauna in the urban and peripheral lakes of the city of Yamoussoukro, monitoring the fish fauna of these lakes and rationalizing anthropogenic activities will make it possible to better control the various impacts of pollution.

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