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Spatial and Temporal Variation of Fish Assemblage Associated with Aquatic Macrophytes in Three Small Lagoons of the SOUTH-Eastern, Côte d'Ivoire

Kouadio Justin Konan [a*], Annigbé Justin Eyi [a], Konan N'Da [b] and Boua Célestin Atsé [a]

[a] Centre de Recherches Océanologiques, BP V 18 Abidjan, Côte d'Ivoire.
[b] UFR Sciences de la Nature, Université Nangui Abrogoua Abidjan, 02 BP 801 Abidjan 02, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aquatic plants play a crucial role in an aquatic ecosystem partly because these plant communities provide suitable habitats and food items to other aquatic organisms especially fish. The purpose of the present study was to examine spatial variation in fish assemblage structure associated with aquatic macrophytes in Ono, Kodjoboue and Hebe lagoons, three small lagoons of Côte d'Ivoire. Fish were monthly sampled from September 2014 to August 2016 using traps, gill nets, harpoons and hawks. The abiotic parameters namely temperature, transparency, pH, total dissolved solids, conductivity, dissolved oxygen, ammonium-nitrogen, nitrate, nitrite and phosphate were recorded for the characterization of the water mass in the lagoons. Significant variation in water parameters was observed among the sampling lagoons, except for nitrite and ammonium-nitrogen. However,

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**Corresponding author: E-mail: konankouadjustin@yahoo.fr, eyijustin3@gmail.com;*

no significant different was obtained between Kodjoboue and Hebe lagoons. A total of 42, 35 and 37 species were recorded respectively in Ono, Kodjoboue and Hebe lagoons, with Perciformes (22 species), Siluriformes (8 species) and Osteoglossiformes (7 species) being the most diverse Orders. Habitats with highly amounts of macrophyte cover provide the optimal environment for many fish and hence, increase the taxonomic richness, abundance, diversity and equitability. The multivariate analysis showed that temperature, dissolved oxygen, nitrate, phosphate, pH and ammonium-nitrogen and macrophyte were key environmental variables and played important roles in determining species composition of fish assemblages.

Keywords: Abundance; aquatic plants; Côte d'Ivoire; diversity indices; fish; lagoons.

1. INTRODUCTION

Aquatic macrophytes play an important role in structuring fish assemblages [1,2] by providing higher carrying capacity for food resources due to the availability of substrates for prey and higher productivity. They also increase the spatial complexity of the ecosystems, favouring the presence of numerous fish species [3,4] and distribution of fish populations [5]. "Their community assemblages can act as good indicators of the prevailing hydrological regime and water quality in aquatic systems. However, high densities of aquatic plants can lead to physical and chemical restrictions, causing fish avoidance behaviour, especially hypoxia at night during the hot season" [6]. "It is expected that these positive and negative effects on fish can explain their horizontal distribution and diel movements in lentic habitats near stands of macrophytes. The degree of response to these conditions is variable depending on fish assemblage composition, dominant life strategies and ontogenetic stage" [6].

"The role of macrophytes in the ecology of neotropical ichthyofauna is still not understood. There are some studies evaluating the effect of macrophytes coverage on fish assemblage structure" [7-9]. In Côte d'Ivoire, no study addressing this topic has been conducted in marginal lagoons invaded by macrophytes. These lagoons, which open directly or indirectly on to the Comoé River, have in recent years seen an increased proliferation of free-floating, emergent and submerged. The main macrophytes are *Echinochloa pyramidalis*, *Eichhornia crassipes*, *Salvinia molesta*, *Pistia stratiotes* and *Hydrilla verticillata*. The present study aims to determine spatial and diel influence of macrophytes stands on fish assemblage and structure as well as that of physico-chemical parameters in Ono, Kodjoboue and Hebe lagoons of the South-eastern, Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Study Area

Ono lagoon (5°22'22"N and 3°33'53"W), Kodjoboue lagoon (5°14'11 "N and 3°35'9" W) and Hebe lagoon (5°12'14" N and 3°33'15" W) are three small lagoons of the Southeast of Côte d'Ivoire (Fig. 1). Their surfaces are respectively 400 ha, 423 ha and 244 ha. Because Ono lagoon is invaded by several habitat types such as emerged plants, free-floating macrophytes, floating leaf plants, submerged plants and white habitats, the exploitable surface is 162 ha. In the other lagoons, only the banks are occupied by macrophytes, with a pronounced degree of invasion in Kodjoboue lagoon. The main macrophytes are *Echinochloa pyramidalis* (Hitchc. & Chase, 1917), *Eichhornia crassipes* (Solms, 1883), *Salvinia molesta* (Mitch, 1972), *Pistia stratiotes* (Linné, 1753). And *Hydrilla verticillata* (Royle, 1839**)**. Hebe lagoon contains several species of mangroves such as *Rhizophora racemosa* (Meyer, 1818) (Rhizophoraceae), *Avicennia germinans* (Linné, 1764), (Avicenniaceae) and *Conocarpus erectus* (Linné, 1753). These lagoons are irrigated by one or two small rivers and are connected in the downstream to Comoé River. This region has an equatorial climate, including two rainy seasons (April-July and October-November) and two dry seasons (December-March and August-September). The permanent linkage with the Comoé River produces typical freshwater characteristics of these lagoons.

2.2 Environmental Parameters Sampling and Analysis Methods

The abiotic parameters namely temperature, transparency, pH, total dissolved solids (TDS), conductivity and dissolved oxygen (DO) were recorded in *situ*. Water samples were taken stored in polyethylene bottles (500 mL) and kept at a temperature below 4°C for further determination of ammonium-nitrogen (NH_4^+; mg/L), nitrate (NO_3^-; mg/L), nitrite (NO_2^-; mg/L) and phosphate (PO_4^{3-}; mg/L). The samples were filtered through Whatman GF/C fibreglass filters and concentrations were determined using a spectrophotometer Model HACH DR 6000.

2.3 Fish Sampling

In order to completely understand the effect of macrophytes on fish assemblages and determine their distribution characteristics, three lagoons were chosen following the occupation degree of macrophytes (Ono lagoon = 70%, Kodjoboue lagoon = 20% and Hebe lagoon = 2%). Fish were monthly sampled from September 2014 to August 2016 using traps, gill nets, harpoons and hawks. Specimens were systematically identified using the identification key of Teugels et al. [10] and Paugy et al. [11]. A sample of unknown fish were fixed in 10% formalin, placed in plastic bags and later transferred in 70% alcohol for further identification by specialists at the Oceanographic Research Centre of Abidjan. Standard length of individuals was taken to the nearest 1 mm and body weight to the nearest 0.01 g using a Sartorius A200 S-F1 electronic balance.

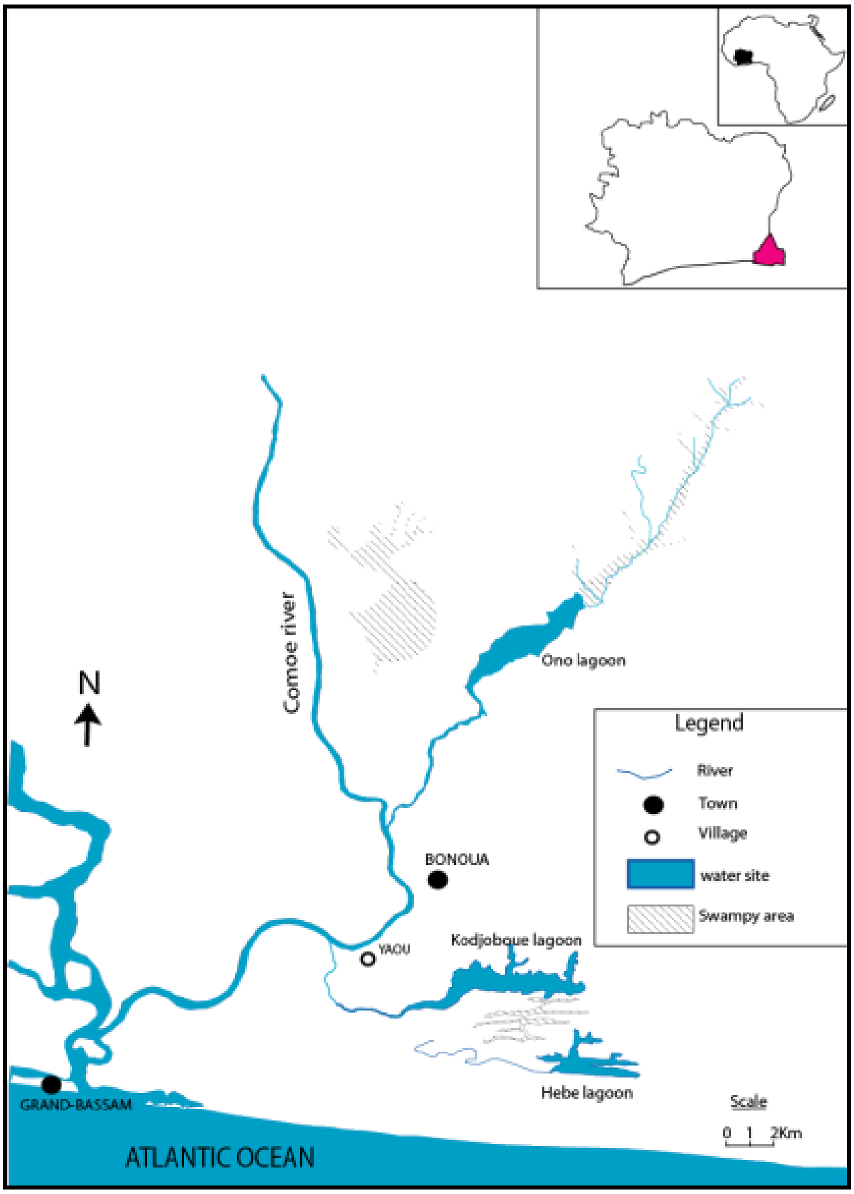

Fig. 1. Map showing the sampling areas

2.4 Data Analysis

Fish composition, rarefied richness (S) and numerical abundance (N) were determined during the month in each lagoon. Species diversity was measured considering the Shannon-Wiener diversity index (H') and Evenness index (E). In order to determine the permanence of the species in the evaluated sectors, the ecological index of consistency was used and each species was classified as constant (C > 50), incidental (25% ≤ C ≤ 50%), or accidental (C < 25%) [12]. Canonical Correspondence Analysis (CCA) was conducted to identify possible correlations between the distribution of ecological features (taxa, species) and environmental variables [13]. For this purpose, a species/lagoon matrix and a matrix (environmental variables/lagoons) are formed on the basis of the abundance of species in the lagoon.

2.5 Statistical Analysis

The Shapiro-Wilk normality test for homoscedasticity were applied to the data, to determine whether the assumptions of the parametric or nonparametric analyse for the environmental variables (temperature, pH, DO, TDS, transparency, NH_4^+, NO_3^- and NO_2^-), abundance, species richness, diversity and evenness were satisfied. To compare the effects of macrophytes on fish assemblage characteristics within and between sampling sites when the data were normally distributed, an analysis of variance (ANOVA) was used. The coverage rate was estimated using satellite data from the University Center for Research and Application in Remote Sensing. Macrophytes were collected manually. Samples of each macrophyte specimen (100g) were sent to the National Floristic Centre for identification according to the dichotomous keys for each species.

3. RESULTS

3.1 Fish Assemblage Characteristics

The composition of fish population (species, genera, families and orders) sampled during this study is shown in Table 1. Specific richness showed a spatial pattern where the greatest number of fish species were recorded in Ono lagoon (42 species) vs 35 species in Kodjoboue lagoon and 37 species in Hebe lagoon. The comparative analysis showed that six orders (Perciformes, Siluriformes Osteoglossiformes, Characiformes, Cypriniformes, Clupeiformes) were common to all lagoons. The most diverse Order was that of Perciformes in Ono lagoon (10 families and 20 species), Kodjoboue lagoon (3 families and 11 species) and Hebe lagoon (3 families and 12 species). This was followed by Siluriformes and Osteoglossiformes with 4 and 3 families, respectively, accounting for 5 and 4 species in Ono lagoon and 7 and 6 species in the other lagoons. The remaining orders presented one species by taxa and accounted for very low proportions of catches. Specially, all lagoons were dominated by Cichlids (10 species, 23.81 % in Ono lagoon, 9 species, 25.71% in Kodjoboue lagoon and 12 species, 27.78% in Hebe lagoon). This family was followed by Alestidae (4 species, 9.52%), Mormyridae and Cyprinidae (3 species each, 7.14%) in Ono lagoon and by Clariidae, Alestidae and Mormyridae (4 species each) in Kodjoboue and Hebe lagoons.

The spatial consistency analysis indicated that 11 species (26.19%) and 7 species (16.67%) were considered constant and incidental respectively in Ono lagoon. The remaining 24 species (57.14%) on the list were considered accidental. In Kodjoboue lagoon, 8 species (22.86%) were defined as constant, 10 species (28.57%) as incidental and a further 17 species (48.57%) as accidental (Table 2). In Hebe lagoon, 10 species (27.03%) were classified as constant, 8 species (21.62%) as incidental and 19 species (51.35%) as accidental.

3.2 Environmental Variables

The environmental variables of Ono, Kodjoboue and Hebe lagoons were presented in Table 2. Significant variation in water parameters was observed among the sampling lagoons (ANOVA test, $p < 0.05$), except for nitrite and ammonium-nitrogen. However, no significant different (ANOVA test, $p > 0.05$) was observed between Kodjoboue and Hebe lagoons for all parameters. For the parameters such as temperature, pH, DO, conductivity and TDS, the values were significantly higher in Hebe lagoon whereas the values were lower for the temperature, pH and DO in Ono lagoon and for conductivity and TDS in Kodjoboue lagoon. On the other hand, the values of transparency, nitrate and phosphate were lower in Hebe lagoon and higher in Ono lagoon.

Table 1. Taxonomic list of the fish fauna with percentage and occurrence class in the Ono, Kodjoboue and Hebe lagoons between September 2015 and August 2016

		Ono lagoon			Kodjoboue lagoon			Hebe lagoon		
Orders / Families	**Species**	**Oc.**	**%Oc.**	**Oc. class**	**Oc.**	**%Oc.**	**Oc. class**	**Oc.**	**%Oc.**	**Oc. class**
SILURIFORMES										
Clariidae	*Clarias ebriensis (Pellegrin, 1920)*	+	20.55	Acc	+	13.80	Acc	+	28.33	Inc
	Heterobranchus longifilis (Valenciennes, 1840)	-	-	-	+	22.46	Acc	+	26.66	Inc
	Heterobranchus gariepinus (Burchell, 1822)	-	-	-	+	18.66	Acc	+	25.67	Inc
	Heterobranchus isopterus (Bleeker, 1863)	-	-	-	+	12.50	Acc	+	25.87	Inc
Claroteidae	*Chrysichthys maurus (Valenciennes, 1840)*	+	15.65	Acc	-	-	-	-	-	
	Chrysichthys nigrodigitatus (Lacépède, 1803)	+++	100	C	+++	68.86	C	+	74.25	C
Schilbeidae	*Schilbe mandibularis (Günther, 1867)*	+	24.33	Acc	+	13.33	Acc	+	18.66	Acc
Malapteruridae	*Malapterurus electricus (Gmelin, 1789)*	+	06.45	Acc	+	10.33	Acc	+	11.67	Acc
Mugiliformes										
Mugilidae	*Liza falcipinnis (Valenciennes, 1836)*	+	16.66	Acc	-	-		-	-	
Characiformes										
Hepsetidae	*Hepsetus odoe (Bloch, 1794)*	+	18.86	Acc	++	15.45	Acc	+	20.66	Acc
Alestidae	*Brycinus imberi, Peters, 1852*	+	15.33	Acc	++	26.25	Inc	+	18.67	Acc
	Brycinus macrolepidotus, Valenciennes, 1849	+	14.66	Acc	++	28.45	Inc	+	23.33	Acc
	Brycinus nurse, Rüppel, 1832	+	14.85	Acc	+	16.66	Acc	+	20.54	Acc
	Brycinus longipinnis, Günther, 1864	+	18.28	Acc	+	13.66	Acc	+	24.66	Acc
Distichodontidae	*Distichodus rostratus (Günther, 1864)*	+	10.33	Acc	-	-		-	-	
Cypriniformes										
Cyprinidae	*Barbus ablabes (Bleeker, 1863)*	+	19.25	Acc	+	12.25	Acc	+	16.67	Acc
	Barbus trispilos (Bleeker, 1863)	+	23.33	Acc	-	-		-	-	Acc
	Barbus eburneensis (Poll, 1941)	-	-		++	25.15	Inc	+	18.66	Acc
	Labeo courbie (Rüppel, 1832)	++	26.77	Inc	+	15.66	Acc	+	19.66	Acc
Clupeiformes										
Clupeidae	*Pellonula leonensis (Boulenger, 1916)*	++	25.33	Acc	+	20.66	Acc	+	15.67	Acc
Eloptiformes										
Eloptidae	*Elops lacerta (Valenciennes, 1846)*	++	25.33	Acc						
Perciformes										
Channidae	*Parachanna obscura, Günther, 1861*	+++	81.50	C	++	45.26	Inc	++	51.67	C
Gobiidae	*Sicyopterus lagocephalus (Pallas, 1770)*	+	16.66	Acc	-	-		-	-	

		Ono lagoon			Kodjoboue lagoon			Hebe lagoon		
Orders / Families	**Species**	**Oc.**	**%Oc.**	**Oc. class**	**Oc.**	**%Oc.**	**Oc. class**	**Oc.**	**%Oc.**	**Oc. class**
Polynemidae	*Galeoides decadactylus (Bloch, 1795)*	+	15.67	Acc	-	-		-	-	
Anabantidae	*Ctenopoma petherici, Günther, 1864*	++	26.66	Inc	+	19.67	Acc	+	23.33	Acc
Haemulidae	*Pomadasys jubelini (Lacépède, 1802)*	+	11.89	Acc	-	-		-	-	
Sphyraenidae	*Sphyraena afra (Peters, 1844)*	+	06.67	Acc	-	-		-	-	
Polimidae	*Polydactylus quadrifilis (Cuvier, 1829)*	+	09.33	Acc	-	-		-	-	
Monodactylidae	*Monodactylus sebae (Cuvier, 1829)*	+	07.66	Acc	-	-		-	-	
Eleotridae	*Eleotris senegalensis (Steindachner, 1870)*	++	41.67	Inc	-	-		-	-	
	Eleotris vittata (Dumeril, 1858)	++	25.67	Inc	-	-		-	-	
Cichlidae	*Hemichromis bimaculatus (Gill, 1862)*	+++	68.50	C	++	41.25	Inc	++	45.66	C
	Hemichromis fasciatus (Peters, 1852)	+++	74.56	C	++	48.89	Inc	++	55.3	C
	Oreochromis niloticus (Linnaeus, 1758)	++	45.67	Inc	+	18.33	Acc	+	22.56	Acc
	Sarotherodon melanotheron, Rüppell, 1852	+++	100	C	+++	100	C	+	100	C
	Tilapia busumana (Günther, 1903)	++	30.28	Inc	-	-		-	-	
	Coptodon guineensis Bleeker, 1862	+++	98.26	C	+++	100	C	+++	100	C
	Coptodon zillii, Gervais, 1848	+	27.33	Acc	+	17.66	Acc	++	36.86	Inc
	Tylochromis jentinki Steindachner, 1895	+++	86.66	C	+++	61.67	C	++	57.66	C
	Tilapia marie, Vervoort, 1980	+	15.50	Acc	+	12.15	Acc	+	18.15	Acc
	Chromidotilapia guntheri (Sauvage, 1882)	-	-	-	+	19.20	Acc	+	19.87	Acc
	Coptodon hybride (C. guineensis×C. zillii)	+++	100	C	+++	100	C	+++	100	C
	Thysochromis ansorgii (Boulenger, 1901)	-	-	-	-	-	-	+	10.12	Acc
Osteoglossiformes										
Notopteridae	*Papyrocranus afer (Günther, 1868)*	+++	86.87	C	+++	64.66	C	+++	77.55	C
Mormyridae	*Marcusenius furcidens (Pellegrin, 1920)*	+++	50.50	C	+++	54.66	C	++	51.21	C
	Marcusenius ussheri (Günther, 1867)	++	48.67	Inc	++	45.55	Inc	++	48.67	Inc
	Mormyrops anguilloides (Linnaeus, 1758)	++	58.33	C	++	51.66	C	++	68.33	C
	Marcusenius senegalensis (Steindachner, 1870)	-	-		++	41.33	Inc	++	47.50	Inc
	Mormyrus rume (Valenciennes, 1870)	-	-		++	38.66	Inc	++	41.67	Inc
Osteoglossidae	*Heterotis niloticus (Cuvier, 1829)*	+	20.33	Acc	++	36.67	Inc	+	23.33	Acc
Lepdosireniformes										
Protopteridae	*Protopterus annectens (Owen, 1839)*	-	-		-	-		+	4.33	Acc
9 orders / 25 families	51 species	42				35				37

Oc. = occurrence, % Oc. = percentage of occurrence, Oc. class = occurrence class, + = sporadic, + + = frequent, + + + = very frequent, - = absent, Inc. = incidental, Acc. = accidental, C = constant.

3.3 Rarefied Wealth and Diversity Indices

Across the three lagoons, the number of taxa sampled during the study period was 51 species of all species. The fish fauna exploited in the Ono, Kodjoboue and Hebe lagoons consists of 42, 35 and 37 species respectively. The Shannon Specific Diversity Index (H') and Equitability Index (E) showed a low spatial variability (ANOVA test, $p > 0.05$) (Table 3). However, the recorded values were slightly higher in the Ono lagoon (4.5 bits/individual and 0.84 respectively) than that of Kodjoboue lagoon (4.45 bits/individual and 0.87 respectively) and Hebe lagoon (4.34 bits / individuals and 0.83, respectively).

3.4 Fish Abundance

In this study, the abundance of fish populations varied significantly (ANOVA test, $p < 0.05$) according to lagoons from September 2015 to August 2016 (Table 4). A total of 4138, 2630 and 2084 specimens were sampled respectively in Ono, Kodjoboue and Hebe lagoons. In general, Perciformes (48.11%), Osteoglossiformes (23.54%), Siluriformes (10.49%), Cypriniformes (7.66%) and Characiformes (7.62%) constituted the main orders in Ono lagoon. In Kodjoboue and Hebe lagoons, Perciformes was also the dominant order, accounting for respectively 58.95% and 56.65% of fish abundance, followed by Siluriformes (19.98% and 16.53% respectively), Osteoglossiformes (9.32% and 16.07% respectively) and Characiformes (9.97% and 6.25% respectively). These orders represented of about 97.42%, 98.18% and 99.00% of fish collected respectively in Ono, Kodjoboue and Hebe lagoons.

3.5 Factors Influencing the Distribution of Species

The results of the Canonical Correspondence Analysis (CCA) showed that the correlation between environmental variables and fish was mainly explained by the first two axes represented (90,98%) of total variance (Fig. 2). According to forward selection procedure and Monte Carlo permutation tests from CCA, several variables (macrophyte cover, temperature, DO, nitrate, phosphate, pH and ammonium-nitrogen) were significant in explaining patterns of occurrence and abundance of fish in the lagoons. The macrophytes, nitrate, ammonium-nitrogen and phosphate were positively correlated with the first axis whereas temperature and DO were negatively correlated with this axis. Concerning the second axis, it was positively correlated with pH. Ono lagoon was characterized by the abundance of macrophytes and high values of nitrate ammonia and phosphate and low values of temperature and dissolved oxygen. This lagoon was associated with the presence of numerous species belonged to Perciformes. On the other hand, Kodjoboue lagoon was characterized by high values of pH while Hebe lagoon was associated with low values of this parameter.

4. DISCUSSION

Analysis of the physical and chemical parameters reveals that the parameters show significant variation between lagoons sites, except for nitrite and ammonium-nitrogen. Globally, the values of these parameters were higher in all lagoons due to aquatic macrophytes and numerous human activities, namely the intensification of poultry and pig farm and the organic fertilizer from industrial plantations. However, the value of temperature, pH and dissolved oxygen were significantly lower in Ono lagoon than in the other lagoons. Gawad and Abdel-Aal [14] reported that "temperature plays an important role in the physical and chemical characteristics of lagoon environment, affecting the rate of CO_2 fixation by phytoplankton (primary productivity) and solubility of gases such as O_2, CO_2 and NH_4^+ which on turn affect all aquatic organisms". "The lowest values of oxygen levels may be due to the removal of free oxygen through respiration by, macrophytes, bacteria and animals as indicated" by Tohouri et al. [15]. Colon-Gaud [16] noted that the dense mats of *Hydrilla verticillata* (Royle, 1839**)**. reduced water circulation and light penetration in water bodies and influenced dissolved oxygen concentrations. On the other hand, the value of nitrate, phosphate and ammonium-nitrogen were higher in Ono lagoon, indicating that this lagoon is most subject to anthropogenic pressures. In fact, its watershed is located in a zone which drain intensive agricultural activities using excessive application of chemical fertilizers and phytosanitary products. In addition, this lagoon is invaded by a multitude of macrophytes such as emergent plants, free-floating macrophytes, floating leafy plants, submerged plants and white habitats [17].

Table 2, Average values (mean ± SD) of the physical and chemical parameters in Ono, Kodjoboue and Hebe lagoons between September 2015 and August 2016

Parameters	Ono lagoon	Kodjoboue lagoon	Hebe lagoon
Temperature (°C)	27.17 ± 1,56[a]	29.73 ± 1.57[b]	29.93 ± 1.38[b]
Dissolved oxygen (mg/L)	2.29 ± 0.84[a]	5.81 ± 0.97[b]	6.22 ± 0.53[b]
pH	6.32 ± 0.49[a]	6.29 ± 0.58[a]	6.67 ± 0.45[b]
Conductivity (µS/cm)	18.09 ± 5.92[a]	13.97 ± 6.53[a]	35.87 ± 22.45[b]
TDS (mg/L)	9.06 ± 1.58[a]	6.96 ± 3.20[a]	17.87 ± 3.16[b]
Transparency (m)	1.59 ± 0.29[b]	1.21 ± 0.20[a]	0.71 ± 0.30[a]
Nitrate (mg/L)	3.09 ± 0.93[b]	2.31 ± 0.67[a]	1.77 ± 0.57[a]
Nitrite (mg/L)	0.21 ± 0.40[a]	0.24 ± 0.47[a]	0.14 ± 0.33[a]
Ammonium-nitrogen (mg/L)	0.08 ± 0.04[a]	0.06 ± 0.04[a]	0.07 ± 0.04[a]
Phosphate (mg/L)	0.48 ± 0.24[b]	0.27 ± 0.15[a]	0.31 ± 0.11[a]

Table 3. Diversity indices of shannon and equitability calculated for fish population of Ono, Kodjoboue and Hebe lagoons from September 2015 to August 2016

Indices	Ono lagoon	Kodjoboue lagoon	Hebe lagoon
Shannon-Wiener index (H')	4.50[a]	4.45[a]	4.34[a]
Equitability (E)	0.84[a]	0.87[a]	0.83[a]

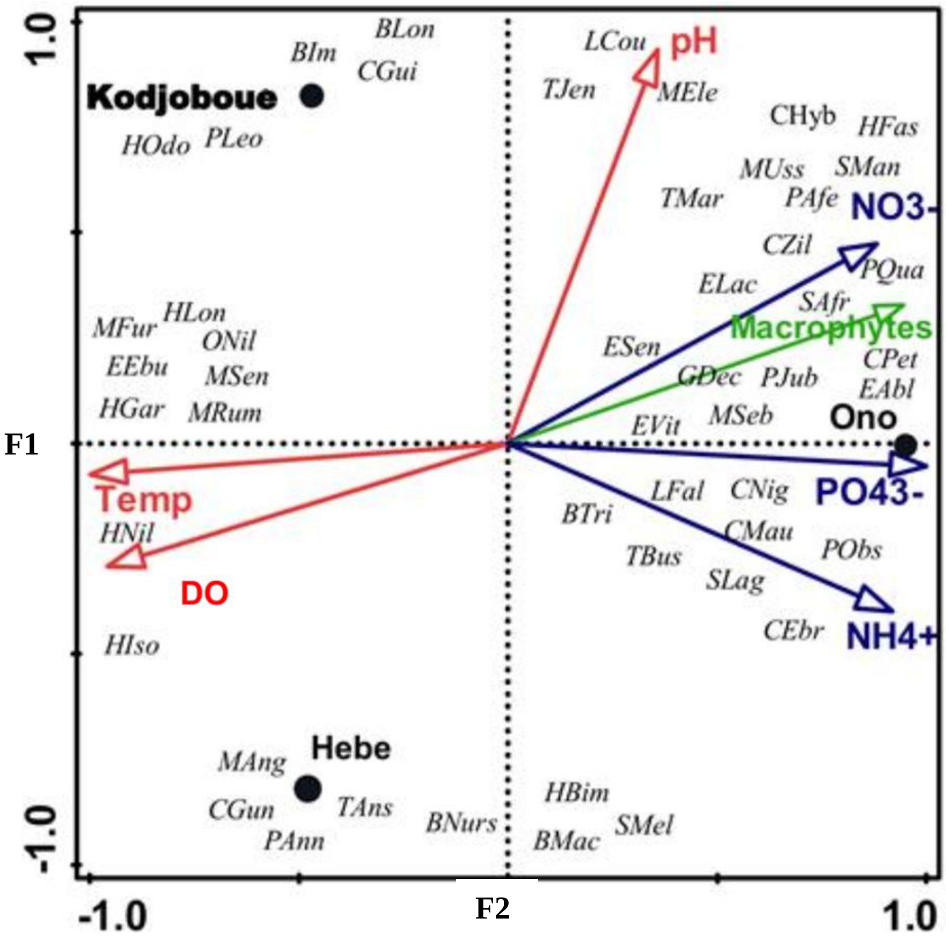

Fig. 2. Graphical representation of Canonical redundancy analysis based on the abundance fish assemblage of 50 fish species, environmental variables (Temp = water temperature, DO = dissolved oxygen, pH, NO_3^- = nitrate, PO_4^{3-} = phosphate and NH_4^+ = ammonium-nitrogen), and lagoons (geometric figures) during the period-September 2015 to August 2016

Table 4. Abundances of the mains fish orders caught in Ono, Kodjoboue and Hebe lagoons between September 2015 and August 2016

Orders	Ono lagoon	Kodjoboue lagoon	Hebe lagoon
Perciformes	48.11	58.95	56.65
Siluriformes	10.49	19.98	16.53
Osteoglossiformes	23.54	9.32	16.07
Characiformes	7.62	6.97	6.25
Total	97.42	98.18	99.00

Fish assemblage structure seem to be influenced by both abiotic parameters and macrophytes cover. Fish assemblage responses were highlighted more in relation to the degree of macrophyte cover. The taxonomic richness, abundance, diversity and equitability decrease from areas most infested by macrophytes (Ono lagoon) to areas less infested (Hebe lagoon). Ono lagoon is heavily infested by several types of macrophytes, particularly *Eichhornia crassipes* (Solms, 1883), *Hydrilla vertillata* (Royle, 1839) and *Echinochloa pyramidalis* (Hitchc. & Chase, 1917) whereas in the other lagoons, only the banks are infested by *E. pyramidalis*, with a pronounced degree of invasion in Kodjoboue lagoon. Numerous studies showed that vegetated sites contain higher fish densities as compared to unvegetated areas [18,19]. In fact, vegetation is used as breeding sites for some species of fish, nurseries and important refuges for their juvenile since they provide minor shade, nesting and cover habitat for fishes [20]. “Apparently, submerged vegetation (e.g. *H. vertillata*) is the key factor in the distribution and habitat use of adult fish. It is known that the sites of the plant communities in water column and their morphology attract and influence the production of epiphytic invertebrates which then serve as prey for a variety of fishes especially Cyprinidae, Percidae and Cyprinidontidae” [21,19]. “Although aquatic plants are a vital contributor in maintaining stability within water bodies, excessive plant growth reduces growth and condition of fish due to reduced foraging efficiency” [22,19]. For [23], the limited role of physicochemistry influencing fish distribution may be a common phenomenon, especially when macrophytes do not develop excessive coverage. In addition, all the orders encountered present almost the same distribution pattern in the three lagoons. However, Perciformes, Eloptiformes, Mugiliformes were frequently recorded in the Ono Lagoon having areas with high macrophyte complexity.

CCA results indicated that temperature, dissolved oxygen, nitrate, phosphate, pH and ammonium-nitrogen and macrophyte were key environmental variables and played important roles in determining species composition of fish assemblages. According to Miranda et al. [24] and Agostinho et al. [25], “oxygen concentration, predation and food availability are all influenced by macrophytes”. Numerous authors predicted that “higher structural complexity results in an increase in resource availability and variability, allowing the coexistence of a higher number of species in the same area” [26-28].

5. CONCLUSION

The inventory and distribution of taxa has made it possible to identify fifty-one species on all three hydrosystems. Fish assemblage structure seem to be influenced by abiotic parameters and macrophytes. Fish assemblage responses were highlighted more in relation to the degree of macrophyte cover.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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