

1 **Spatial and temporal variation of fish assemblage associated with aquatic macrophytes**  
2 **in three small lagoons of the South-eastern, Côte d'Ivoire**

3

4 **Abstract**

5 Aquatic plants play a crucial role in an aquatic ecosystem partly because these plant  
6 communities provide suitable habitats and food items to other aquatic organisms especially fish.  
7 The purpose of the present study was to examine spatial variation in fish assemblage structure  
8 associated with aquatic macrophytes in three small lagoons of Côte d'Ivoire. Fish were monthly  
9 sampled from September 2014 to August 2016 using traps, gill nets, harpoons and hawks. The  
10 abiotic parameters namely temperature, transparency, pH, total dissolved solids, conductivity,  
11 dissolved oxygen, ammonium-nitrogen, nitrate, nitrite and phosphate were recorded for the  
12 characterization of the water mass in the lagoons. Significant variation in water parameters was  
13 observed among the sampling lagoons, except for nitrite and ammonium-nitrogen. However,  
14 no significant difference was obtained between Kodjoboue and Hebe lagoons. A total of 42, 35  
15 and 37 species were recorded respectively in Ono, Kodjoboue and Hebe lagoons, with  
16 Perciformes (22 species), Siluriformes (8 species) and Osteoglossiformes (7 species) being the  
17 most diverse Orders. Habitats with highly amounts of macrophyte cover provide the optimal  
18 environment for many fish and hence, increase the taxonomic richness, abundance, diversity  
19 and equitability. The multivariate analysis showed that temperature, dissolved oxygen, nitrate,  
20 phosphate, pH and ammonium-nitrogen and macrophyte were key environmental variables and  
21 played important roles in determining species composition of fish assemblages.

22 **Keywords:** abundance, aquatic plants, diversity indices, fish, lagoons, Côte d'Ivoire

23

24

25 **Introduction**

26 Aquatic macrophytes play an important role in structuring fish assemblages [6 ; 20] by  
27 providing higher carrying capacity for food resources due to the availability of substrates for  
28 prey and higher productivity. They also increase the spatial complexity of the ecosystems,  
29 favouring the presence of numerous fish species [15 ; 23] and distribution of fish populations  
30 [19]. Their community assemblages can act as good indicators of the prevailing hydrological

31 regime and water quality in aquatic systems. However, high densities of aquatic plants can lead  
32 to physical and chemical restrictions, causing fish avoidance behaviour, especially hypoxia at  
33 night during the hot season [13]. It is expected that these positive and negative effects on fish  
34 can explain their horizontal distribution and diel movements in lentic habitats near stands of  
35 macrophytes. The degree of response to these conditions is variable depending on fish  
36 assemblage composition, dominant life strategies and ontogenetic stage.

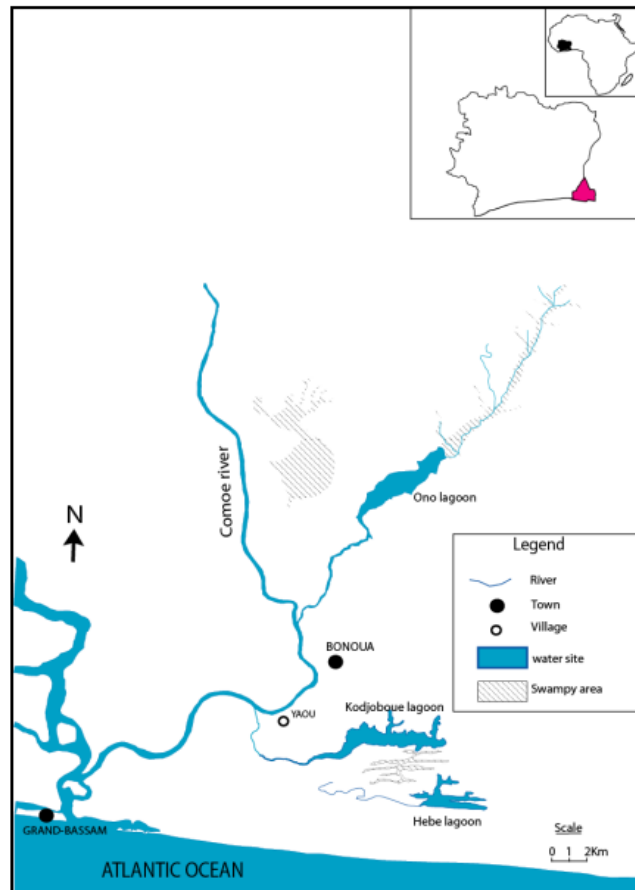
37 The role of macrophytes in the ecology of neotropical ichthyofauna is still not understood.  
38 There are some studies evaluating the effect of macrophytes coverage on fish assemblage  
39 structure [14 ; 21; 27]. In Côte d'Ivoire, no study addressing this topic has been conducted in  
40 marginal lagoons invaded by macrophytes. The present study aims to determine spatial and diel  
41 influence of macrophytes stands on fish assemblage and structure in Ono, Kodjoboue and Hebe  
42 lagoons of the South-eastern, Côte d'Ivoire.

## 43 **2. Materials and methods**

### 44 **2.1. Study area**

45 Ono lagoon (5°22'22"N and 3°33'53"W), Kodjoboue lagoon (5°14'11 "N and 3°35'9" W)  
46 and Hebe lagoon (5°12'14" N and 3°33'15" W) are three small lagoons of the Southeast of Ivory  
47 Coast (Figure 1). Their surfaces are respectively 400 ha, 423 ha and 244 ha. Because Ono  
48 lagoon is invaded by several habitat types such as emerged plants, free-floating macrophytes,  
49 floating leaf plants, submerged plants and white habitats, the exploitable surface is 162 ha. In  
50 the other lagoons, only the banks are occupied by macrophytes, with a pronounced degree of  
51 invasion in Kodjoboue lagoon. The main macrophytes are *Echinochloa pyramidalis*,  
52 *Eichhornia crassipes*, *Salvinia molesta*, *Pistia stratiotes* and *Hydrilla verticillata*. Hebe lagoon  
53 contains several species of mangroves such as *Rhizophora racemosa* (Rhizophoraceae),  
54 *Avicennia germinans* (Avicenniaceae) and *Conocarpus erectus*. These lagoons are irrigated by  
55 one or two small rivers and are connected in the downstream to Comoé River. This region has

56 an equatorial climate, including two rainy seasons (April-July and October-November) and two  
57 dry seasons (December-March and August-September). The permanent linkage with the Comoé  
58 river produces typical freshwater characteristics of these lagoons.



59  
60 **Figure 1:** Map showing the sampling areas.

## 61 2.2. Environmental parameters sampling and analysis methods

62 The abiotic parameters namely temperature, transparency, pH, total dissolved solids  
63 (TDS), conductivity and dissolved oxygen (DO) were recorded in *situ*. Water samples were  
64 taken stored in polyethylene bottles (500 mL) and kept at a temperature below 4°C for further  
65 determination of ammonium-nitrogen ( $\text{NH}_4^+$ ; mg/L), nitrate ( $\text{NO}_3^-$ ; mg/L), nitrite ( $\text{NO}_2^-$ ; mg/L)  
66 and phosphate ( $\text{PO}_4^{3-}$ ; mg/L). The samples were filtered through Whatman GF/C fibreglass  
67 filters and concentrations were determined using a spectrophotometer Model HACH DR 6000.

## 68 2.3. Fish sampling

69 In order to completely understand the effect of macrophytes on fish assemblages and  
70 determine their distribution characteristics, three lagoons were chosen following the occupation  
71 degree of macrophytes (Ono lagoon = 70%, Kodjoboue lagoon = 20% and Hebe lagoon = 2%).  
72 Fish were monthly sampled from September 2014 to August 2016 using traps, gill nets,  
73 harpoons and hawks. Specimens were systematically identified using the identification key of  
74 [22] and [16]. A sample of unknown fish were fixed in 10% formalin, placed in plastic bags  
75 and later transferred in 70% alcohol for further identification by specialists at the  
76 Oceanographic Research Center of Abidjan. Standard length of individuals was taken to the  
77 nearest 1 mm and body weight to the nearest 0.01 g using a Sartorius A200 S-F1 electronic  
78 balance.

#### 79 **2.4. Data analysis**

80 Fish composition, rarefied richness (S) and numerical abundance (N) were determined  
81 during the month in each lagoon. Species diversity was measured considering the Shannon-  
82 Wiener diversity index ( $H'$ ) and Evenness index (E). In order to determine the permanence of  
83 the species in the evaluated sectors, the ecological index of consistency was used and each  
84 species was classified as constant ( $C > 50$ ), incidental ( $25\% \leq C \leq 50\%$ ), or accidental ( $C <$   
85  $25\%$ ) [4].

#### 86 **2.5. Statistical Analysis**

87 The Shapiro-Wilk normality test for homoscedasticity were applied to the data, to  
88 determine whether the assumptions of the parametric and nonparametric analyses for the  
89 environmental variables (temperature, pH, DO, TDS, transparency,  $\text{NH}_4^+$ ,  $\text{NO}_3^-$  and  $\text{NO}_2^-$ ),  
90 abundance, species richness, diversity and evenness were satisfied. To compare the effects of  
91 macrophytes on fish assemblage characteristics within and between sampling sites when the  
92 data were normally distributed, an analysis of variance (ANOVA) was used.

### 93 **3. Results**

### 94 3.1. Environmental variables

95 The environmental variables of Ono, Kodjoboue and Hebe lagoons were presented in  
96 Table 1. Significant variation in water parameters was observed among the sampling lagoons  
97 (ANOVA test,  $p < 0.05$ ), except for nitrite and ammonium-nitrogen. However, no significant  
98 different (ANOVA test,  $p > 0.05$ ) was observed between Kodjoboue and Hebe lagoons for all  
99 parameters. For the parameters such as temperature, pH, DO, conductivity and TDS, the values  
100 were significantly higher in Hebe lagoon whereas the values were lower for the temperature,  
101 pH and DO in Ono lagoon and for conductivity and TDS in Kodjoboue lagoon. On the other  
102 hand, the values of transparency, nitrate and phosphate were lower in Hebe lagoon and higher  
103 in Ono lagoon.

104 **Table 1:** Average values (mean  $\pm$  SD) of the physical and chemical parameters in Ono,  
105 Kodjoboue and Hebe lagoons between September 2015 and August 2016.

Parameters	Ono lagoon	Kodjoboue lagoon	Hebe lagoon
Temperature ( $^{\circ}$ C)	$27.17 \pm 1.56^a$	$29.73 \pm 1.57^b$	$29.93 \pm 1.38^b$
Dissolved oxygen (mg/L)	$2.29 \pm 0.84^a$	$5.81 \pm 0.97^b$	$6.22 \pm 0.53^b$
pH	$6.32 \pm 0.49^a$	$6.29 \pm 0.58^a$	$6.67 \pm 0.45^b$
Conductivity ( $\mu$ S/cm)	$18.09 \pm 5.92^a$	$13.97 \pm 6.53^a$	$35.87 \pm 22.45^b$
TDS (mg/L)	$9.06 \pm 1.58^a$	$6.96 \pm 3.20^a$	$17.87 \pm 3.16^b$
Transparency (m)	$1.59 \pm 0.29^b$	$1.21 \pm 0.20^a$	$0.71 \pm 0.30^a$
Nitrate (mg/L)	$3.09 \pm 0.93^b$	$2.31 \pm 0.67^a$	$1.77 \pm 0.57^a$
Nitrite (mg/L)	$0.21 \pm 0.40^a$	$0.24 \pm 0.47^a$	$0.14 \pm 0.33^a$
Ammonium-nitrogen (mg/L)	$0.08 \pm 0.04^a$	$0.06 \pm 0.04^a$	$0.07 \pm 0.04^a$
Phosphate (mg/L)	$0.48 \pm 0.24^b$	$0.27 \pm 0.15^a$	$0.31 \pm 0.11^a$

106

### 107 3.2. Fish Assemblage Characteristics

108 The composition of fish population (species, genera, families and order) sampled during  
109 this study is shown in Table 2. Specific richness showed a spatial pattern where the greatest  
110 number of fish species were recorded in Ono lagoon (42 species) vs 35 species in Kodjoboue  
111 lagoon and 37 species in Hebe lagoon. The comparative analysis showed that six orders

112 (Perciformes, Siluriformes Osteoglossiformes, Characiformes, Cypriniformes, Clupeiformes)  
113 were common to all lagoons. The most diverse Order was that of Perciformes in Ono lagoon  
114 (10 families and 20 species), Kodjoboue lagoon (3 families and 11 species) and Hebe lagoon  
115 (3 families and 12 species). This was followed by Siluriformes and Osteoglossiformes with 4  
116 and 3 families, respectively, accounting for 5 and 4 species in Ono lagoon and 7 and 6 species  
117 in the other lagoons. The remaining orders presented one species by taxa and accounted for  
118 very low proportions of catches. Specially, all lagoons were dominated by Cichlids (10 species,  
119 23.81 % in Ono lagoon, 9 species, 25.71% in Kodjoboue lagoon and 12 species, 27.78% in  
120 Hebe lagoon). This family was followed by Alestidae (4 species, 9.52%), Mormyridae and  
121 Cyprinidae (3 species each, 7.14%) in Ono lagoon and by Clariidae, Alestidae and Mormyridae  
122 (4 species each) in Kodjoboue and Hebe lagoons.

123 The spatial consistency analysis indicated that 11 species (26.19%) and 7 species  
124 (16.67%) were considered constant and incidental respectively in Ono lagoon. The remaining  
125 24 species (57.14%) on the list were considered accidental. In Kodjoboue lagoon, 8 species  
126 (22.86%) were defined as constant, 10 species (28.57%) as incidental and a further 17 species  
127 (48.57%) as accidental (Table 2). In Hebe lagoon, 10 species (27.03%) were classified as  
128 constant, 8 species (21.62%) as incidental and 19 species (51.35%) as accidental.

129 **Table 2:** Taxonomic list of the fish fauna with percentage and occurrence class in the Ono, Kodjoboue and Hebe lagoons between September  
 130 2015 and August 2016. Oc. = occurrence, % Oc. = percentage of occurrence, Oc. class = occurrence class, + = sporadic, ++ = frequent, +++ =  
 131 very frequent, - = absent, Inc. = incidental, Acc. = accidental, C = constant.

Orders / Families	Species	Ono lagoon			Kodjoboue lagoon			Hebe lagoon		
		Oc.	%Oc.	Oc. class	Oc.	%Oc.	Oc. class	Oc.	%Oc.	Oc. class
<b>SILURIFORMES</b>										
CLARIIDAE	<i>Clarias ebriensis</i>	+	20.55	Acc	+	13.80	Acc	+	28.33	Inc
	<i>Heterobranchus longifilis</i>	-	-	-	+	22.46	Acc	+	26.66	Inc
	<i>Heterobranchus gariepinus</i>	-	-	-	+	18.66	Acc	+	25.67	Inc
	<i>Heterobranchus isopterus</i>	-	-	-	+	12.50	Acc	+	25.87	Inc
CLAROTEIDAE	<i>Chrysichthys maurus</i>	+	15.65	Acc	-	-	-	-	-	-
	<i>Chrysichthys nigrodigitatus</i>	+++	100	C	++	68.86	C	+	74.25	C
SCHILBEIDAE	<i>Schilbe mandibularis</i>	+	24.33	Acc	+	13.33	Acc	+	18.66	Acc
MALAPTERURIDAE	<i>Malapterurus electricus</i>	+	06.45	Acc	+	10.33	Acc	+	11.67	Acc
<b>MUGILIFORMES</b>										
MUGILIDAE	<i>Liza falcipinnis</i> *	+	16.66	Acc	-	-	-	-	-	-
<b>CHARACIFORMES</b>										
HEPSETIDAE	<i>Hepsetus odoe</i>	+	18.86	Acc	++	15.45	Acc	+	20.66	Acc
ALESTIDAE	<i>Brycinus imberi</i>	+	15.33	Acc	++	26.25	Inc	+	18.67	Acc
	<i>Brycinus macrolepidotus</i>	+	14.66	Acc	++	28.45	Inc	+	23.33	Acc
	<i>Brycinus nurse</i>	+	14.85	Acc	+	16.66	Acc	+	20.54	Acc
	<i>Brycinus longipinnis</i>	+	18.28	Acc	+	13.66	Acc	+	24.66	Acc
DISTICHODONTIDAE	<i>Distichodus rostratus</i>	+	10.33	Acc	-	-	-	-	-	-
<b>CYPRINIFORMES</b>										
CYPRINIDAE	<i>Enteromius ablaves</i>	+	19.25	Acc	+	12.25	Acc	+	16.67	Acc
	<i>Enteromius trispilos</i>	+	23.33	Acc	-	-	-	-	-	Acc
	<i>Enteromius eburneensis</i>	-	-	-	++	25.15	Inc	+	18.66	Acc
	<i>Labeo coubie</i>	++	26.77	Inc	+	15.66	Acc	+	19.66	Acc
<b>CLUPEIFORMES</b>										
CLUPEIDAE	<i>Pellonula leonensis</i>	++	25.33	Acc	+	20.66	Acc	+	15.67	Acc
<b>ELOPTIFORMES</b>										
ELOPTIDAE	<i>Elops lacerta</i>	++	25.33	Acc						
<b>PERCIFORMES</b>										

CHANNIDAE	<i>Parachanna obscura</i>	+++	81.50	C	++	45.26	Inc	++	51.67	C
GOBIIDAE	<i>Sicyopterus lagocephalus</i>	+	16.66	Acc	-	-		-	-	
POLYNEMIDAE	<i>Galeoides decadactylus</i>	+	15.67	Acc	-	-		-	-	
ANABANTIDAE	<i>Ctenopoma petherici</i>	++	26.66	Inc	+	19.67	Acc	+	23.33	Acc
HAEMULIDAE	<i>Pomadasys jubelini</i>	+	11.89	Acc	-	-		-	-	
SPHYRAENIDAE	<i>Sphyraena afra*</i>	+	06.67	Acc	-	-		-	-	
POLIMIDAE	<i>Polydactylus quadrifilis</i>	+	09.33	Acc	-	-		-	-	
MONODACTYLIDAE	<i>Monodactylus sebae</i>	+	07.66	Acc	-	-		-	-	
ELEOTRIDAE	<i>Eleotris senegalensis</i>	++	41.67	Inc	-	-		-	-	
	<i>Eleotris vittata</i>	++	25.67	Inc	-	-		-	-	
CICHLIDAE	<i>Hemichromis bimaculatus</i>	+++	68.50	C	++	41.25	Inc	++	45.66	C
	<i>Hemichromis fasciatus</i>	+++	74.56	C	++	48.89	Inc	++	55.3	C
	<i>Oreochromis niloticus**</i>	++	45.67	Inc	+	18.33	Acc	+	22.56	Acc
	<i>Sarotherodon melanotheron*</i>	+++	100	C	+++	100	C	+	100	C
	<i>Tilapia busumana</i>	++	30.28	Inc	-	-		-	-	
	<i>Coptodon guineensis*</i>	+++	98.26	C	+++	100	C	+++	100	C
	<i>Coptodon zillii</i>	+	27.33	Acc	+	17.66	Acc	++	36.86	Inc
	<i>Tylochromis jentinki*</i>	+++	86.66	C	+++	61.67	C	++	57.66	C
	<i>Pelmatolapia marie</i>	+	15.50	Acc	+	12.15	Acc	+	18.15	Acc
	<i>Chromidotilapia guntheri</i>	-	-	-	+	19.20	Acc	+	19.87	Acc
	Hybrid <i>Coptodon</i>	+++	100	C	+++	100	C	+++	100	C
	<i>Thysochromis ansorgii</i>	-	-	-	-	-		+	10.12	Acc
<b>OSTEOGLOSSIFORMES</b>										
NOTOPTERIDAE	<i>Papyrocranus afer</i>	+++	86.87	C	+++	64.66	C	+++	77.55	C
MORMYRIDAE	<i>Marcusenius furcidens</i>	+++	50.50	C	+++	54.66	C	++	51.21	C
	<i>Marcusenius ussheri</i>	++	48.67	Inc	++	45.55	Inc	++	48.67	Inc
	<i>Mormyrops anguilloides</i>	++	58.33	C	++	51.66	C	++	68.33	C
	<i>Marcusenius senegalensis</i>	-	-		++	41.33	Inc	++	47.50	Inc
	<i>Mormyrus rume</i>	-	-		++	38.66	Inc	++	41.67	Inc
OSTEOGLOSSIDAE	<i>Heterotis niloticus**</i>	+	20.33	Acc	++	36.67	Inc	+	23.33	Acc
<b>LEPDOSIRENIFORMES</b>										
PROTOPTERIDAE	<i>Protopterus annectens</i>	-	-		-	-		+	4.33	Acc
<b>9 orders / 25 families</b>	<b>51 species</b>	<b>42</b>			<b>35</b>				<b>37</b>	

### 133 3.3. Diversity indices

134 The Shannon Specific Diversity Index ( $H'$ ) and Equitability Index (E) showed a low  
135 spatial variability (ANOVA test,  $p > 0.05$ ) (Table 3). However, the recorded values were  
136 slightly higher in the Ono lagoon (4.5 bits/individual and 0.84 respectively) than that of  
137 Kodjoboue lagoon (4.45 bits/individual and 0.87 respectively) and Hebe lagoon (4.34 bits /  
138 individuals and 0.83 respectively).

139 **Table 3:** Diversity indices of Shannon and Equitability calculated for fish population of Ono,  
140 Kodjoboue and Hebe lagoons from September 2015 to August 2016.

Indices	Ono lagoon	Kodjoboue lagoon	Hebe lagoon
Shannon-Wiener index ( $H'$ )	4.50 <sup>a</sup>	4.45 <sup>a</sup>	4.34 <sup>a</sup>
Equitability (E)	0.84 <sup>a</sup>	0.87 <sup>a</sup>	0.83 <sup>a</sup>

142

### 143 3.4. Fish abundance

144 In this study, the abundance of fish populations varied significantly (ANOVA test,  $p <$   
145  $0.05$ ) according to lagoons from September 2015 to August 2016 (Table 4). A total of 4138,  
146 2630 and 2084 specimens were sampled respectively in Ono, Kodjoboue and Hebe lagoons. In  
147 general, Perciformes (48.11%), Osteoglossiformes (23.54%), Siluriformes (10.49%),  
148 Cypriniformes (7.66%) and Characiformes (7.62%) constituted the main orders in Ono lagoon.  
149 In Kodjoboue and Hebe lagoons, Perciformes was also the dominant order, accounting for  
150 respectively 58.95% and 56.65% of fish abundance, followed by Siluriformes (19.98% and  
151 16.53% respectively), Osteoglossiformes (9.32% and 16.07% respectively) and Characiformes  
152 (9.97% and 6.25% respectively). These orders represented of about 97.42%, 98.18% and  
153 99.00% of fish collected respectively in Ono, Kodjoboue and Hebe lagoons.

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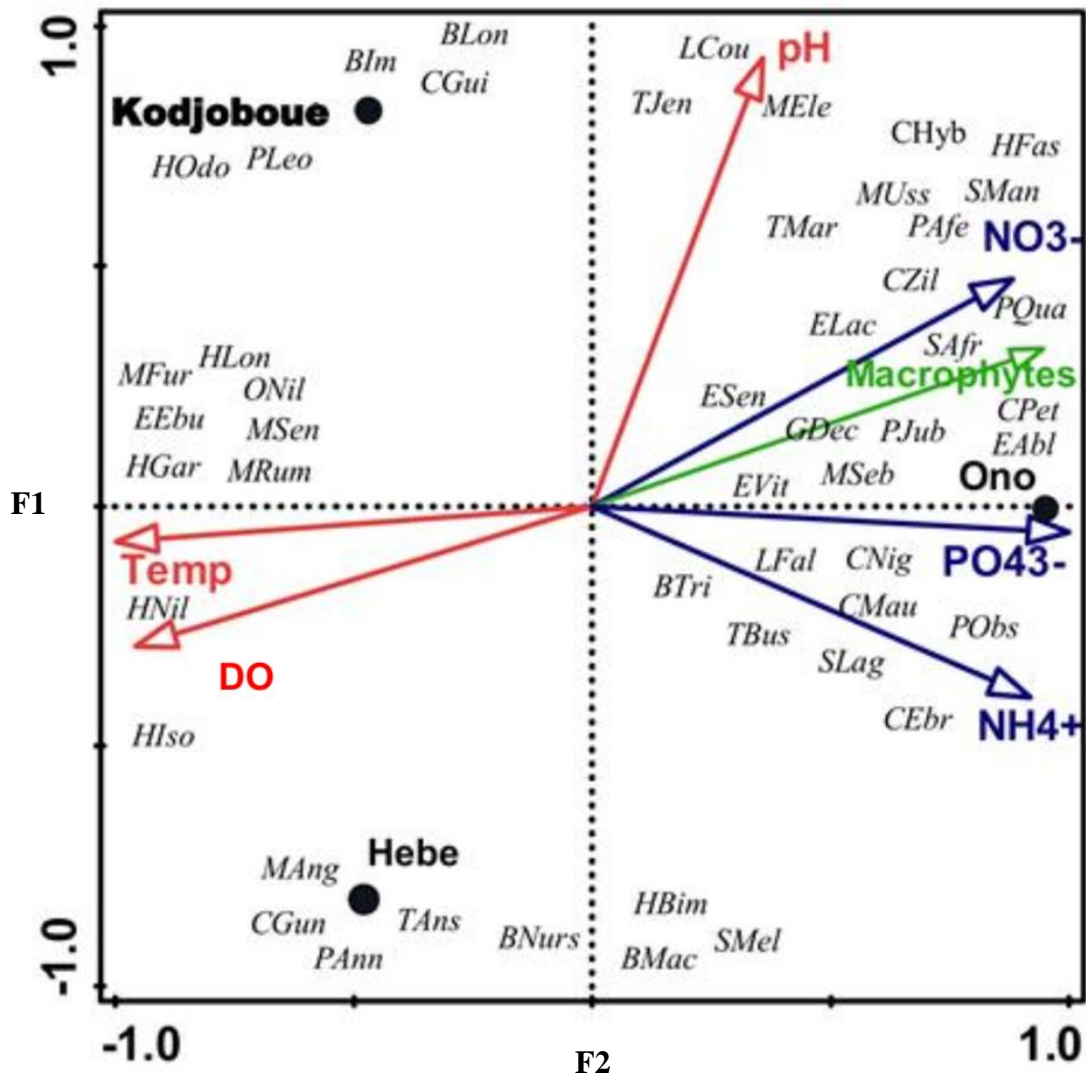
157 **Table 4:** Abundances of the mains fish Orders caught in Ono, Kodjoboue and Hebe lagoons  
 158 between September 2015 and August 2016.

<b>Orders</b>	<b>Ono lagoon</b>	<b>Kodjoboue lagoon</b>	<b>Hebe lagoon</b>
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
<b>Total</b>	<b>97.42</b>	<b>98.18</b>	<b>99.00</b>

159

### 160 **3.4. Factors influencing the distribution of species**

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



174

175 **Figure 2:** Graphical representation of Canonical redundancy analysis based on the abundance  
 176 fish assemblage of 50 fish species, environmental variables (Temp = water temperature, DO =  
 177 dissolved oxygen, pH,  $\text{NO}_3^-$  = nitrate,  $\text{PO}_4^{3-}$  = phosphate and  $\text{NH}_4^+$  = ammonium-nitrogen),  
 178 and lagoons (geometric figures) during the period-September 2015 to August 2016.

179 **4. Discussion**

180 Analysis of the physical and chemical parameters reveals that the parameters show  
 181 significant variation between lagoons sites, except for nitrite and ammonium-nitrogen.  
 182 Globally, the values of these parameters were higher in all lagoons due to aquatic macrophytes  
 183 and numerous human activities, namely the intensification of poultry and pig farm and the  
 184 organic fertilizer from industrial plantations. However, the value of temperature, pH and

185 dissolved oxygen were significantly lower in Ono lagoon than in the other lagoons. [9] reported  
186 that temperature plays an important role in the physical and chemical characteristics of lagoon  
187 environment, affecting the rate of CO<sub>2</sub> fixation by phytoplankton (primary productivity) and  
188 solubility of gases such as O<sub>2</sub>, CO<sub>2</sub> and NH<sub>4</sub><sup>+</sup> which on turn affect all aquatic organisms. The  
189 lowest values of oxygen levels may be due to the removal of free oxygen through respiration  
190 by, macrophytes, bacteria and animals as indicated by [25]. [3] noted that the dense mats of  
191 *Hydrilla verticillata* reduced water circulation and light penetration in water bodies and  
192 influenced dissolved oxygen concentrations. On the other hand, the value of nitrate, phosphate  
193 and ammonium-nitrogen were higher in Ono lagoon, indicating that this lagoon is most subject  
194 to anthropogenic pressures. In fact, its watershed is located in a zone which drain intensive  
195 agricultural activities using excessive application of chemical fertilizers and phytosanitary  
196 products. In addition, this lagoon is invaded by a multitude of macrophytes such as emergent  
197 plants, free-floating macrophytes, floating leafy plants, submerged plants and white habitats  
198 [5].

199 Fish assemblage structure seem to be influenced by both abiotic parameters and  
200 macrophytes cover. Fish assemblage responses were highlighted more in relation to the degree  
201 of macrophyte cover. The taxonomic richness, abundance, diversity and equitability decrease  
202 from areas most infested by macrophytes (Ono lagoon) to areas less infested (Hebe lagoon).  
203 Ono lagoon is heavily infested by several types of macrophytes, particularly *Eichhornia*  
204 *crassipes*, *Hydrilla vertillata* and *Echinochloa pyramidalis* whereas in the other lagoons, only  
205 the banks are infested by *E. pyramidalis*, with a pronounced degree of invasion in Kodjoboue  
206 lagoon. Numerous studies showed that vegetated sites contain higher fish densities as compared  
207 to unvegetated areas [2 ; 12]. In fact, vegetation is used as breeding sites for some species of  
208 fish, nurseries and important refuges for their juvenile since they provide minor shade, nesting  
209 and cover habitat for fishes [11]. Apparently, submerged vegetation (e.g. *H. vertillata*) is the

210 key factor in the distribution and habitat use of adult fish. It is known that the sites of the plant  
211 communities in water column and their morphology attract and influence the production of  
212 epiphytic invertebrates which then serve as prey for a variety of fishes especially Cyprinidae,  
213 Percidae and Cyprinodontidae [18 ; 12]. Although aquatic plants are a vital contributor in  
214 maintaining stability within water bodies, excessive plant growth reduces growth and condition  
215 of fish due to reduced foraging efficiency [7; 12]. For [8], the limited role of physicochemistry  
216 influencing fish distribution may be a common phenomenon, especially when macrophytes do  
217 not develop excessive coverage. In addition, all the orders encountered present almost the same  
218 distribution pattern in the three lagoons. However, Perciformes, Eloptiformes, Mugiliformes  
219 were frequently recorded in the Ono Lagoon having areas with high macrophyte complexity.

220 CCA results indicated that temperature, dissolved oxygen, nitrate, phosphate, pH and  
221 ammonium-nitrogen and macrophyte were key environmental variables and played important  
222 roles in determining species composition of fish assemblages. According to [10] and [1],  
223 oxygen concentration, predation and food availability are all influenced by macrophytes.  
224 Numerous authors predicted that higher structural complexity results in an increase in resource  
225 availability and variability, allowing the coexistence of a higher number of species in the same  
226 area [24 ; 26 ; 17].

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