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Fish distribution pattern and environmental influence in the Bandama River estuary (West Africa)

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Abstract
The structure and distribution of the fish population were investigated from March 2019 to February 2020 in relation to environmental variables in the Bandama River estuary. Overall, the estuary showed environmental homogeneity outside of the conductivity and width of the study area. A total of 52 species of fish were recorded, belonging to 48 genera, 28 families and 12 orders. This ichthyofauna was composed of 24 native freshwater species, 27 brackish and marine species and a hybrid (Coptodon guineensis x Coptodon zillii). The species defined a distribution according to their ecological category in the Bandama estuary. Redundancy analysis (ARD) indicated that salinity and bed width are the main variables that influence the fish species distribution in the Bandama River estuary.

Keywords: Fish assemblage, diversity, ecological categories, fresh and marine water

1. Introduction
The Bandama River is one of the main rivers of Côte d'Ivoire. Entirely located in Côte d'Ivoire, it originates in northern Côte d'Ivoire at an altitude of 480 m between the towns of Korhogo and Boundiali (Aboua *et al.*, 2010) [2] and enters the Grand-Lahou lagoon at sea level. This estuary is a real source of subsistence for the riparian populations, as fishing is the main and traditional economic activity of this population (Wognin *et al.*, 2007) [31]. Ochok (2017) [22] indicates that 20% of the national fisheries production comes from the lagoon-estuary zone of Grand-Lahou. Although estuaries provide a hostile environment due to changes in salinity, many species from fish have found them to be very advantageous areas in which they spawn, develop and grow early in life ; productivity tends to be high (Abdul *et al.*, 2016) [1]. In addition, the Bandama River estuary forms the natural boundary between the Azagny National Park and the rural area of Grand-Lahou. It is one of the main hydrosystems that irrigate the Azagny National Park. A Ramsar site, this protected area plays an essential role in the preservation of biodiversity. Despite the ecological importance of the Bandama estuary, the structure of the fish population in relation to environmental variables is very poorly known. Most studies on fish fauna have focused on the freshwater zone of the Bandama River. These studies mainly concern the specific composition and ecology of fish (Paugy and Lévêque, 1977 ; Mérona, 1981 ; Berté, 2009 and Aboua *et al.*, 2010) [23, 21, 2, 7]. The only data available on the Bandama estuary mainly concern the environmental and geomorphological variability of the estuary. The present study carried out as part of a research project entitled "State of conservation of the aquatic biodiversity of the Azagny National Park" aims to fill this gap in order to contribute to a better management of the fisheries resources of the Bandama estuary. This work focuses mainly on the characteristics of the estuary's physico-chemical environment, the analysis of the fish population structure and the ecological determinism of the distribution of species in the Bandama River estuary zone.

2. Material and Methods
2.1 Study area
The estuarine area of the Bandama river is located in Grand-Lahou, between 5°17 - 5°90 North latitude and 4°47 - 4°57 West longitude. At the outlet, the Bandama river joins to the east with the Ebrié lagoon, through the Azagny canal. It is connected in the west to the Grand Lahou Lagoon.

The Grand-Lahou pass is the only sea outlet for the lagoon system, the Bandama river and the Boubo river. This estuarine zone of the Bandama river constitutes the natural limit with the Azagny National Park and the urban zone of Grand-Lahou. Surveys occurred at 3 sampling sites (Ba1, Ba2 and Ba3) following a longitudinal pattern (Figure 1).

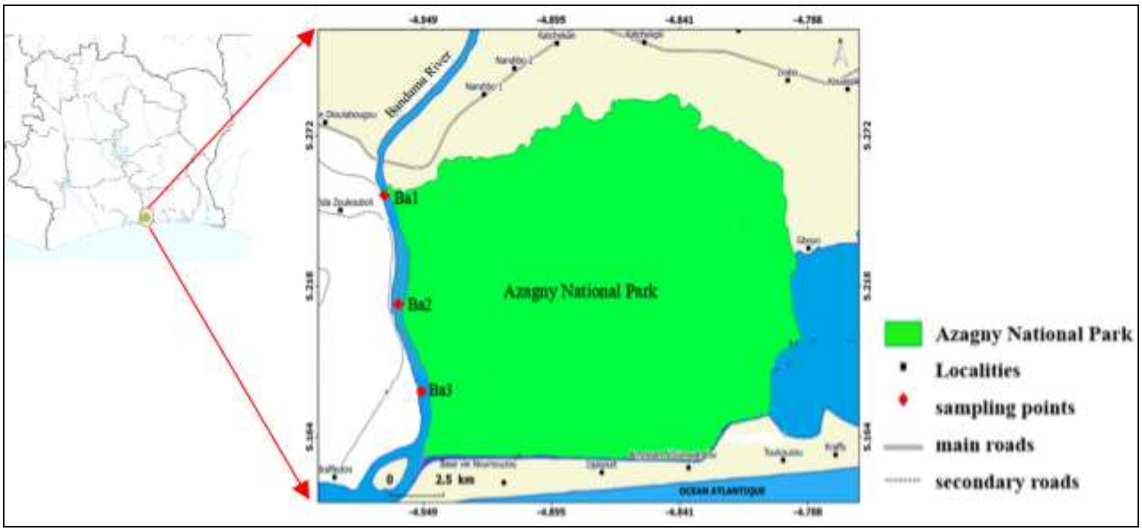

Fig 1: Map showing the different fish sampling points in the Bandama River estuary.

2.2 Data collection

The physicochemical parameters (Water temperature, pH, salinity, dissolved oxygen, conductivity, total dissolved solids) were determined monthly from march 2019 to february 2020 by using a multiparameter $AQUA_{Red}$ Aquameter. A Secchi disc (20 cm diameter) was used to measure the water transparency. The habitat variables included width, depth, current velocity (measured by observing the horizontal displacement of a float over a calibrated distance according to McMahon *et al*., 1996) [20], mean canopy closure and height (visually estimated, expressed in% to the nearest m), aquatic plants (measured as% of stream bottom surface overlain by this shelter category) and substrate type (sand, gravel, mud, rock, mixed clay-mud and leaves-wood, measured as% of stream bottom surface covered by each substrate type).

Fish samples were collected at three sites (Ba1, Ba2 and Ba3) of distinct ecological characteristics. Only a type of gear (gill net) was used in the capture of both juvenile and adult fish. Fishes were collected with a fleet of 6 weighted monofilalement gill nets (bar meshnsizes 10, 25, 30, 35, 40, 50 mm and 90 mm), each measuring 30 m long by 2.5 m deep. Nets were set overnight (17–7 H) and during the following day (7–12 H). All fishes collected were identified following paugy *et al.* (2003 a et b) [24, 25]. Species were classified according to threat of extinction from IUCN Red List Categories and their ecological categories. The ecological classification proposed by Fishbase was used in this study. This method classified species on several ecological categories according to their degree of euryhalinity and the characteristics of their bioecological cycle in different estuarine environments.

2.3 Data analysis

Descriptive analysis was applied to data in order to highlight the central tendency (mean, minimum and maximum) and variation (standard deviation) of physicochemical variables. Kolmogorov–Smirnov test for normality at $\alpha = 0.05$ showed that water variables data were normally distributed, and these were subjected to one-way ANOVA.

Fish community structure was analysed using three univariate indices (Shannon and Wiener diversity index and Pielou's evenness index) to express the degree of uniformity in the distribution of individuals among taxa in the study area (Imoobe and Adeyinka, 2009) [12]. Student's test at $\alpha = 0.05$ was carried out to verify the significance of the variation of the different indices.

Frequency of occurrence is the percentage of samples in which each taxon occurred (Gbenyedji *et al*., 2011) [13]

$$F = \frac{Si}{St} \times 100$$

Where Si: number of stations where species i was captured and St: total number of stations examined. The classification of Djakou and Thanon (1988) [12] was used for this study. It is established as follows: 80% ≤ F <100%: very frequent species; 60% ≤ F <79%: Frequent species; 40% ≤ F <59%: fairly frequent species; 20% ≤ F <39%: Ancillary species; F <20%: accidental species. Factorial Correspondence Analysis (FCA) was carried out using fish abundance indices to investigate the pattern of species assemblage among ecological categories. Relationships between fish species composition and environmental factors were calculated by Redundancy analysis (ARD) using CANOCO 4.5 software.

3. Results

3.1 Environmental variables

The principal results of environmental parameters of the Bandama estuarine area is shown in Table 1. The analysis of variance (ANOVA) showed no significant difference ($P > 0.05$) in the environmental parameters of the three sites in the study area outside the electric conductivity where a significant difference was found among the stations Ba1 and Ba3 ($F = 3.42$, $P < 0.05$). The estuarine maximum electrical conductivity value recorded in this study was 537.17 µS/cm in Ba3 and the minimum was 483.83 µs/cm in Ba1. Temperature varied from 29.39(Ba3) to 27.86 (Ba1). Regarding the pH, the water of Bandama estuarine area was acid with low variation of pH [6.20 (Ba2) –6.41 (Ba3)]. Concerning the current velocity, the lower mean value (0.025

m S-1) was observed at Ba2 and the lower mean value (0.042 m S-1) recorded to Ba1. The highest dissolved oxygen value (6.62 mg l-1 ; 91.53%) was found in Ba1, and the lowest values were observed in Ba2 (5.70 mg l-1 ; 72.40%). Water depth varied from 2.11 m (Ba1) to 1.84 m (Ba3).

Table 1: General characteristics of physicochemical variables in Bandama River estuary.

Stations	Descriptives	T°C	pH	OD (mg/l)	Satur (%)	Cond* (µS/cm)	Salinity (‰)	Current (m S^{-1})	Width* (m)	Depth (m)
BA1	Min	26,18	4,01	5,42	17.6	0,60	0,02	0,010	400	0,94
	Max	31,00	8,83	7,70	110	104,70	50,00	0,070	420	3,80
	Mean	27,86	6,31	6,62	91.53	70,94 **(3)**	11,86	0,042	410 **(3)**	2,11
	SD	1,61	1,23	0,74	23.35	32,99	16,82	0,023	8.48	0,97
BA2	Min	27,30	4,38	4,20	17.9	6,26	0,02	0,005	412	1,00
	Max	30,90	7,63	7,90	98.2	695,00	62,00	0,058	432	2,76
	Mean	28,85	6,20	5,70	72.40	134,26	15,29	0,025	424 **(3)**	2,02
	SD	1,22	0,99	1,12	27.23	180,15	24,42	0,016	9.24	0,54
BA3	Min	26,80	4,75	5,30	75.4	52,00	0,02	0,001	450	1,21
	Max	32,30	7,60	7,60	122	1563,00	62,00	0,082	600	2,87
	Mean	29,39	6,41	6,57	81.97	400,60 **(1)**	16,76	0,036	507.5 **(1,2)**	1,84
	SD	1,75	0,81	0,66	13.62	536,90	26,14	0,025	9.43	0,50

Moy = average ; Min = minimum ; Max = maximum ; Med = median ; SD = Standard deviation ; Oxygen saturation

3.2 Taxonomic composition and distribution

A total of 950 individuals belonging to 52 fish species, 48 genera, 28 families and 12 orders were collected in the all sampling sites (Table II). This ichtyofauna were comprising 24 native freshwater species, 7 brackish water species, 20 brackish and marine water species and on hybrid (Coptodon guineensis x Coptodon zillii). The most diversified order was Perciforms with 18 species (34.61% of species), followed by Siluriforms with 9 species (17.31%), Characiforms with 7 species (13.46%) and Osteoglossiforms with 7 species (9.61%). These four orders were represented 75% of all species from estuarine area of Bandama River. Among the families sampled, Cichlidae (15.38% of species), Alestidae (9,61%) and Mormyridae (7,69%) were largely represented. Two (2) near threatened species (*Cynoglossus monodi* and *Cynoglossus senegalensis*) and one threatened species (*Brycinus nurse*) were caught.

The distribution of species according to ecological categories indicated a decrease in native freshwater species from station B1 to B3. This observation is contrary to that of brackish and marine water species whose number of species decreased from Ba3 to Ba1 (Figure 2a). The distribution analysis of species with marine and / or estuarine affinity revealed that 70% of these species are quite common in the area and 30% of these species (*Pellonula vorax, Enneacampus ansorgii, Coptodon zillii, Lutjanus agennes, Lutjanus dentatu, Citharichthys stampfli, Cynoglossus monodi*) have an occurrence of less than 40%. Concerning freshwater species, more than 60% of these species are quite frequent while less than 40% (*Marcusenius ussheri, Alestes dentex, Brycinus nurse, Schilbe intermedius, Heterobranchus longifilis, Synodontis punctifer, Malapterurus electricus, Monopterus boueti, Parachanna obscura*) have an occurrence of less than 40%.

The Factorial Correspondence Analysis (FCA) carried out on the ecological categories abundance of species table showed that the 1-2 factorial plane explained 100% of the total inertia (98.29% for axis 1 and 1.71% for axis 2). Therefore, results obtained from the first two axes were plotted. The projection of these ecological categories on the factorial plan 1-2 shows that these ecological categories were clearly distinct (Figure 2b). The first group (Freshwater species) was associated with Ba1 (Figure 2b). The second group consisted of the brackish and/or marines species in Ba2 and Ba3.

3.3 Abundance and diversity

Fish community (Table II) comparisons based on the relative abundance of fish orders showed that in the Bandama estuary, the dominant order was Perciforms (25.26% of the total number of fishes sampled in this catchment area), followed by Siluriforms (23.26%) and Characiforms (22.21%).

The most abundant families were Distichodontidae (17.16%), Cichlidae (13.89%), Claroteidae (10.95%) and Schilbeidae (10.95%). In terms of specie, *Distichodus rostratus* (17.16%) was the most represented, followed by *Schilbe mandibularis* (10.84%) and *Chrysichthys nigrodigitatus* (7.58%).

Indices of diversity and species richness are presented in Table III. Ba 1 was the most diverse site (H' = 3.03) and Ba3 was the least (H' = 2.99). Ba3 was also the richest with 39 species, while there were 37 species for Ba2 which was the least species-rich site. Fish species were more evenly distributed at Ba2 (Evenness = 0.84), while the Fish community in Ba1 and Ba3 were least uniform (evenness = 0.82). The diversity test indicated that the diversity indices were similar across sites ($p > 0.05$).

Table 2: Fish population at sampling stations in the Bandama River estuary. LC = Least Concern ; DD = Data Deficient ; NE = Not evaluated ; NT = Near threatened ; EN = Endangered ; M = Marine ; B = Brackish ; F = Freshwater.

N°	Species	Surround	Conservation status	Ba1	Ba2	Ba3	F%
Order : Elopiforms ; Family : Elopidae							
1	*Elops lacerta* Valenciennes, 1847	M, B, F	LC	+	+	+	100
Clupeiforms ; Clupeidae							
2	*Pellonula leonensis* Boulenger, 1916	M, B, F	LC	+	+	+	100
3	*Pellonula vorax* Günther, 1868	M, B, F	LC	+			33,3
4	*Ethmalosa fimbriata* (Bowdich, 1825)	M, B, F	LC	+	+		66,7
Osteoglossiforms ; Notopteridae							
5	*Papyrocranus afer* (Günther, 1868)	F	LC	+	+	+	100

	Osteoglossiforms ; Mormyridae						
6	*Marcusenius ussheri* (Günther, 1867)	F	LC	+		+	66,7
7	*Mormyrus rume* Valenciennes, 1847	F	NE	+	+	+	100
8	*Mormyrops anguiloides* (Linnaeus, 1758)	F	LC	+	+	+	100
9	*Petrocephalus bovei* (Valenciennes, 1847)	F	NE	+	+		66,7
	Characiforms ; Hepsetidae						
10	*Hepsetus odoe* (Bloch, 1794)	F	LC	+	+	+	100
	Characiforms ; Alestidae						
11	*Alestes dentex* (Linnaeus, 1758)	F	LC	+			33,3
12	*Brycinus longipinnis* (Günther, 1864)	B, F	LC	+		+	66,7
13	*Brycinus nurse* (Rüppell, 1832)	F	EN		+		33,3
14	*Brycinus macrolepidotus* Valenciennes, 1850	B, F	LC		+	+	66,7
15	*Hydrocynus forskahlii* (Cuvier, 1819)	F	LC	+		+	66,7
	Characiforms ; Distichodontidae						
16	*Distichodus rostratus* Günther, 1864	F	LC	+	+	+	100
	Cypriniforms ; Cyprinidae						
17	*Labeo coubie* Rüppell, 1832	F	DD	+	+	+	100
	Siluriforms ; Claroteidae						
18	*Chrysichthys maurus* (Valenciennes, 1840)	F	LC	+	+	+	100
19	*Chrysichthys nigrodigitatus* (Lacepède, 1803)	F	DD	+	+	+	100
	Siluriforms ; Schilbeidae						
20	*Schilbe intermedius* Rüppell, 1832	F	LC			+	33,3
21	*Schilbe mandibularis* (Günther, 1867)	F	LC	+	+	+	100
	Siluriforms ; Clariidae						
22	*Clarias anguillaris* (Linnaeus, 1758)	F	LC	+	+	+	100
23	*Heterobranchus longifilis* Valenciennes, 1840	F	LC		+		33,3
	Siluriforms ; Schilbeidae						
24	*Synodontis punctifer* Daget, 1964	F	LC	+			33,3
25	*Synodontis schall* (Bloch & Schneider, 1801)	F	LC	+	+	+	100
	Siluriforms ; Malapterururidae						
26	*Malapterurus electricus* (Gmelin, 1789)	F	LC		+		33,3
	Syngnathiforms ; Syngnathidae						
27	*Enneacampus kaupi* (Bleeker, 1863)	B, F	LC	+	+		66,7
28	*Enneacampus ansorgii* (Boulenger, 1910)	B, F	LC			+	33,3
	Symbranchiforms ; Synbranchidae						
29	*Monopterus boueti* (Pellegrin, 1922)	F	LC	+			33,3
	Perciforms ; Gerreidae						
30	*Eucinostomus melanopterus* (Bleeker, 1863)	M, B, F	LC		+	+	66,7
	Perciforms ; Cichlidae						
31	*Chromidotilapia guntheri* (Sauvage, 1882)	F	LC	+	+		66,8
32	*Hemichromis fasciatus* Peters, 1857	F	LC	+	+	+	100
33	*Coptodon hybride = Tilapia guineensis X Tilapia zillii*	-	LC	+	+	+	100
34	*Coptodon guineensis* (Günther, 1862)	M, B, F	LC		+	+	66,7
35	*Coptodon zillii* (Gervais, 1848)	B, F	NE			+	33,3
36	*Sarotherodon melanotheron* Rüppell, 1852	M, B, F	NE	+	+	+	100
37	*Tylochromis jentinki* (Steindachner, 1894)	B, F	LC	+	+	+	100
38	*Pelmatolapia mariae* (Boulenger, 1899)	B, F	LC	+	+	+	100
	Perciforms ; Haemulidae						
39	*Pomadasys jubelini* (Cuvier, 1830)	M, B, F	LC	+	+	+	100
	Perciforms ; Lutjanidae						
40	*Lutjanus agennes* Bleeker, 1863	M, B	LC			+	33,3
41	*Lutjanus dentatus* (Duméril, 1861)	M, B	DD			+	33,3
42	*Lutjanus goreensis* (Valencienne, 1830)	M, B, F	DD			+	33,3
	Perciforms ; Monodactylidae						
43	*Monodactylus sebae* (Cuvier, 1829)	M, B, F	NE	+	+	+	100
	Perciforms ; Polynemidae						
44	*Polydactylus quadrifilis* (Cuvier, 1829)	M, B, F	LC	+	+	+	100
	Perciforms ; Carangidae						
45	*Trachinotus teraia* Cuvier, 1832	M, B, F	LC	+	+	+	100
	Perciforms ; Channidae						
46	*Parachanna obscura* (Günther, 1861)	F	NE	+			33,3
	Perciforms ; Sciaenidae						
47	*Pseudotolithus elongatus* (Bowdich, 1825)	M, B	LC	+	+	+	100
	Mugilliforms ; Mugilidae						
48	*Liza falcipinnis* (Valenciennes, 1836)	M, B, F	DD	+	+	+	100
	Gobiiforms ; Gobiidae						
49	*Awaous lateristriga* (Duméril, 1861)	M, B, F	LC	+	+	+	100
	Pleuronectiforms ; Paralichthydae						

50	*Citharichthys stampflii* (Steindachner, 1894)	M, B, F	LC	+			33,3
	Pleuronectiforms ; Synoglossidae						
51	*Cynoglossus monodi* Chabanaud, 1949	M, B	NT		+		33,3
52	*Cynoglossus senegalensis* (Kaup, 1858)	M, B	NT		+	+	66,7

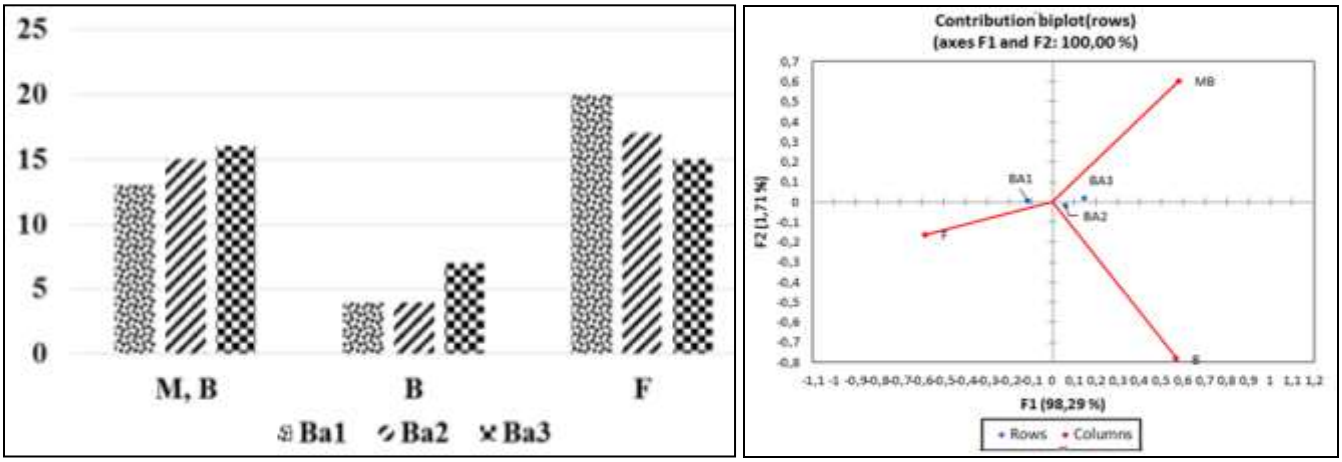

Fig 2: Distribution of species by station in the PNA area according to their ecological categories.

Table 3: Shannon and Weaver index (H ') and Equitability (E) of the ichthyological population of the Bandama River estuary

Indices		Ba1	Ba2	Ba3	Bandama
Abundance		438	312	199	950
Richness		38	37	39	53
Shannon et Weaver (H')		3,01	3,03	2,99	3,17
Equitability (E)		0,82	0,84	0,82	0,80
Diversity test		**Ba1-Ba2**	**Ba1-Ba3**	**Ba2-Ba3**	
	t-test	-0,32	0,12	0,37	
	df	689,03	370,83	397,39	
	p-value	0,74	0,70	0,89	

3.4 Patterns of species composition in relation to environmental variables

Redundancy analysis (RDA) between the fish community structure and environmental parameters are presented in Figure 3. Among the ordination axes extracted from the analysis, the first two axes (with, respectively, eigenvalue $\lambda 1 = 61.6\%$ and eigenvalue $\lambda 2 = 38.4\%$), explained 100% of the cumulative variance in the species data. Among the 17 environmental variables initially included in the analysis, only seven were significantly ($P < 0.05$) related to assemblage structure and accounted for 56.86% of the variance explained by all the original variables : width (9.39%), salinity (9.39%), conductivity (8.27%), gravel (7.58%), plant residus (7.58%), depth (7.36%) and total dissolved (7.26%). Monte Carlo permutation attested that both axes were significant ($P < 0.05$). Therefore our interpretation will be limited to these two axes which displayed three groups of sampling sites : Group 1 was representative the upstream of estuary sampling site (Ba1) having a minimal salinity and conductivity. The fish species correlated positivility with axis I to these variables were *Synodontis punctifer, Pellonula vorax, Pellonula leonensis, Parachanna obscura, Alestes dentex, Hemichromis fasciatus, Chrysichthys nigrodigitatus, Citharichthys stampflii, Brycinus longipinnis, Marcusenius ussheri, Hydrocynus forskahlii, Schilbe mandibularis, Ethmalosa fimbriata, Chrysichthys maurus, Elops lacerta, Polydactylus quadrifilis, Petrocephalus bovei, Labeo coubie, Hepsetus odoe, Mormyrops anguiloides, Distichodus rostratus, Clarias anguillaris, Pomadasys jubelini, Enneacampus kaupi, Tylochromis jentinki, Awaous lateristriga, Coptodon hybride, Chromidotilapia guntheri, Papyrocranus afer, Monodactylus sebae.* Group 2 has the sampling sites in downstream of estuary (Ba2 and Ba3) correlated negativility with axis I. This area was associated to a high level of salinity and width. The second axis showed a fish assemblage (*Brycinus nurse, Mormyrus rume, Heterobranchus longifilis, Trachinotus teraia, Malapterurus electricus, Cynoglossus monodi, Brycinus macrolepidotus, Chromidotilapia guntheri, Synodontis schall, Pseudotolithus elongatus*) associated positively to sampling site Ba2 and was characterised by a high mean (%) of plant residus and and higher total dissolved. The site Ba3 was distinguished by a high mean (%) of gravels and higher conductivity value and correlated negativility with axis II. This site was highly associated with *Lutjanus agennes, Lutjanus dentatus, Coptodon zillii, Enneacampus ansorgii, Schilbe intermedius, Pelmatolapia mariae*, Cynoglossus senegalensis, *Eucinostomus melanopterus* and *Sarotherodon melanotheron.*

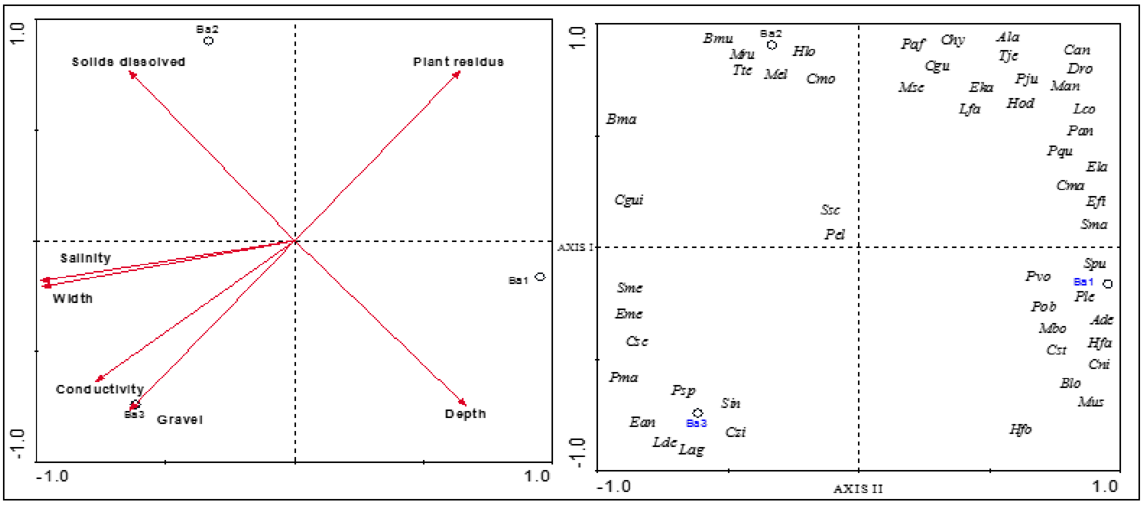

Fig 3 : Correlations between fish species and environmental variables in the Bandama River estuary.

4. Discussion

Salinity of the present work was varied from 11.86 ‰ to 16.76 ‰ for all stations throughout the study period. This result confirms the estuarine status of the study area from Bandama River. Indeed, McErlean *et al*. (1973) [19] stated that salinity of an estuary ranged between 0.50 and 35 ‰ and Ahammad (2004) [4] showed the salinity ranged between 14.43 and 25.92 ‰. In addition, Ketchum (1983) [14] defines an estuary as a body of water in which river water mixes with and measurably dilutes seawater. According to Georges *et al*. (2012)[11], estuarine environment are subjected to varied change in physicochemical properties due to continuous mixing of fresh water with marine water. Thus, salinity of the estuarine zone of the Bandama River is controlled by freshwater inflows from the Bandama River upstream, direct precipitations and high tides through the Grand-Lahou pass. The temperature, the dissolved oxygen, the pH and the salinity of the waters of the Bandama estuarine zone have a homogeneous distribution (Anova, $P > 0.05$) in all measuring stations. This homogeneity of temperature and pH could be explained by the shallow depth of this estuary which favors the mixing of surface and bottom water. This finding seems to be a particularity of tropical estuaries because low spatial variabilities in temperature and pH have also been observed in estuarine waters (Kouassi *et al*., 2005 ; Konan *et al*., 2008) [16, 15]. The dissolved oxygen of Bandama estuary varies between 5.70 and 6.62 mg/l with an oxygenation rate close to saturation. This could be explained by the movements of the tide, which generates a continuous agitation of the water mass and consequently an enrichment of the dissolved phase. These highest dissolved oxygen values would be related to direct influences from oxygenated marine waters. The electrical conductivity and the width of the estuarine zone of the Bandama River showed a significant variation. This large variation in conductivity (70 to 400µS / cm) could be explained both by the distance from marine influences and by the dilution by freshwater inputs.

A total of 52 fish species were recorded during the study period versus more than 107 species previously recorded by Paugy *et al*. (1994) [26], Traoré (1996) [29]. Recent works of Aboua *et al*. (2012) [3] reported 70 species of Bandama River. Among them, 10 species (*Enneacampus ansorgii*, *Monodactylus sebae*, *Ethmalosa fimbriata*, *Pomadasys jubelini*, *Pseudotolithus elongatus*, *Citharichthys stampflii*, *cynoglossus senegalensis*, *Cynoglossus monodi*, *Eucinostomus melanopterus* and *Lutjanus dentatus*) were reported for the first time in this area. Among the species previously found by authors cited above recorded, 31 species (*Heterotis niloticus ; Marcusenius furcidens ; Marcusenius senegalensis ; Pollimyrus isidori ; Alestes baremoze ; Brycinus imberi ;Micralestes occidentalis ;Nannocharax fasciatus ; Noelebies unifasciatus ;Barbus ablabes ; Barbus macrops ; Barbus macinensis ; Barbus sublineatus ; Barbus trispilos ; Labeo parvus ; Raiamas senegalensis ; Amphilius atesuensis ; Parailia pellucida ; Heterobranchus isopterus ; Synodontis bastiani ;Epiplatys chaperi ; Epiplatys etzeli ; Lates niloticus ; Caranx hippos ; Gerres melanopterus ; Hemichromis bimaculatus ; Oreochromis niloticus ; Thysochromis ansorgii ; Eleotris vittata ; Ctenopoma petherici ; mastacembelus nigromarginatus)* were not recorded during our sampling. The absence of these species did not justify their extinction in this area but were probably due to three reasons. Firstly, the use of several fishing gears (mono and multifilament nets, drift nets, electric fishing and ichthyotoxin fishing) during ORSTOM studies on the Bandama basin as part of the onchocerciasis program. During this current study, only a type of gear (gill net) was used for fishing of both juvenile and adult fish. The second reason is linked to the estuarine environment of the study area. Indeed, the estuaries are characterized by a 'buffer zone' sharing some characteristics of both the river and sea, but identical to neither (Reid and Wood, 1976) [27]. Thus estuarine environments are areas with high seasonal variability in salinity levels, thus favouring the presence of euryhaline species which adapt to these saline fluctuations (Diouf, 1996) [8]. Therefore, the absence of freshwater species is probably explained by the fact that they can only tolerate minimal variations and low amplitudes of salinity in the aquatic environment (Albaret, 2006) [5]. According to Diouf (1996) [8], the most essential adaptation required by fishes to enter estuaries is an ability to adjust to changing salinity regimes. A key to the poor penetration of estuarine waters by freshwater taxa is an inability to develop chloride cells in gill filament epithelia, as well as a lack of other osmoregulatory adaptations present in euryhaline fishes. Thirdly, we could mention the number of stations prospected (3 sites) on the Bandama River. The prospecting of tributaries (primary, secondary, tertiary, etc.) has not been considered compared to the work of Albaret *et al.* (1978) [5], Maslin-Leny and Mérona (1978) [18], and Aboua *et al.* (2010) [2]. This could explain the absence of Mormyridae, Syngnathidae, Cyprinidae, Alestidae, Nothobranchiidae, Poeciliidae.

Although the current study area is very small, less than 10% of the total surface area of the Bandama river, the current results showed a large number of species composition compared to previous researches. These previous data indicated more than 100 species and which covered more than 80% of the upper course of the Bandama river basin. This result of the current study, which gave a preliminary overview of the fish assemblage of the Bandama estuary, revealed a great richness of marine and / or estuarine species (27 species). Estuarine environments provide nursery habitat for a number of marine and freshwater species : marine fishes that recruit into estuaries from the sea, and the freshwater fishes needing to migrate from freshwater into the brackish reaches of estuaries in order to breed and for successful larval development to take place. This could enable the increase in the number of species in this area of the Bandama River.

This observation is confirmed by the redundancy analysis which revealed a clear discrimination in the distribution of species according to their ecological category under the effect of salinity and the width of the Bandama River estuary. Winemiller and Leslie (1992) [30] showed that environmental variables relating to salinity and habitat size were important in the structuring of the assemblages. The environmental salinity on fishes typically found in fresh water. Salinity can change the amount of energy available for growth of fishes by altering the energetic cost of ionic and osmotic regulation (Altinok et Grizzle, 2001) [6]. In the present study, a concentration of marine and/or estuarine species is observed in the area surrounding lagoon waters characterised by high conductivity. The presence of these mostly marine and/or estuarine species can be justified by their great capacity to adapt to salinity fluctuations (Albaret, 2006) [5]. Adaptation to sea water in euryhaline teleosts is thought to involve the development of ion secretion pathways in the mitochondria-rich cells of the gill epithelium under the influence of cortisol, growth hormone and insulin-like growth factors (Jacob and Taylor, 1983; Mancera and McCormick, 1998) [13, 17]. Furthermore, most of the freshwater species are more observed in the upper part of the estuary area characterised by low conductivity.

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