ICHTHYOLOGIC DIVERSITY OF BANDAMA RIVER BASIN (CÔTE D'IVOIRE): AN UPDATE AND ENVIRONMENTAL INFLUENCES ON FISH DISTRIBUTION

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Abstract

The inventory and distribution of fish assemblages of Bandama River were studied from October 2008 to September 2009. Fish samples were collected in three areas (upper, middle and lower catchment) using a back pack electrofisher and two batteries of gill-nets with mesh sizes between 8 and 80 mm. A total of 64 sites were visited and 83 fish species belonging to 11 orders, 30 families and 51 genera were identified. We counted 13 marine and/or brackish-water species and 70 freshwater species. Among them, two introduced species (*Heterotis niloticus* and *Oreochromis niloticus*) and one hybrid form (*Tilapia zillii* x *T. guineensis*) were found. Characiformes order, mainly represented by Alestidae family and *Brycinus longipinnis* species, are the most abundant. Studies comparing biodiversity of families used species richness and abundance, showed that families of Cichlidae and Cyprinidae (16% of species each), Mormyridae (11% of species) and Alestidae (10% of species) werethe most abundant.

The influence of environmental parameters such us width, dissolved oxygen, turbidity, depth, canopy closure, mixed sand-gravel and aquatic plants on the distribution of fish population has been highlighted by a redundancy analysis (RDA) coupled with Monte Carlo test 499 permutations.

Keywords: Fish diversity, Species distribution, Environmental parameters influence, Freshwater ecosystems, Bandama River, Côte d'Ivoire

Introduction

The freshwater ecosystems are essential for key economic sectors such as domestic activities, industry, fishing and tourism. It is also of a vital importance for nature because these ecosystems shelter an abundant plant and animal biodiversity. But this richness is threatened by increasing pressure from human activities (e.g. intensive fishing, introduction of exotic species, deforestation, construction of dams for agriculture and hydroelectricity, use of ichthyotoxin, discharges of households agriculture, and industry) (Moyle and Leidy, 1992; Traoré, 1996; Kamdem Toham and Teugels, 1999). These activities also lead to the reduction of spawning areas and food sources (Hugueny, 1990). Therefore a good policy development for the utilization and conservation of aquatic ecosystems should be informed by knowledge of fish populations and their habitat.

In Côte d'Ivoire, ichthyofauna has been well studied. Previous works have allowed the compilation of faunal lists for most basins (Daget and Iltis 1965, Teugels et al. 1988, Paugy et al. 1994). But all the research on the Bandama River is one of the few multi-disciplinary approaches (Lévêque et al. 1983) owing to the program of ecological monitoring of aquatic areas led by Orstom hydrobiology laboratory of Bouaké beginning in 1974. More than 100 species of fish have been collected from this River (Mérona 1981; Teugels et al., 1988; Traoré 1996). Mérona (1981) found a relatively homogenous population when describing the ichthyological zonation of the basin with a clearly defined upper, middle and lower course fish communities. However, taxonomic revisions, improving fish sampling methods, loss of specific habitats, extinction of species and introduction of species, have occurred in the past 30 years. In addition, increasing human development, the construction of two hydroelectric dams (Kossou in 1972 and Taabo in 1980) and many others small dams for agricultural use in the upstream have caused great changes in the aquatic environment.

Therefore, the current study aimed to describe the fish community in Bandama River, its specific composition and its distribution along up and downstream on the one hand, and the influences of environmental factors on the other hand.

Material and methods

Study area

The Bandama River is located entirely within Côte d'Ivoire between 3°50′ and 7°00′W and 5°00′ and 10°20′ N. It is 1050 km long and drains a catchment area of97 500 km^2 (Figure 1). The river rises in the north of the country, between Korhogo and Boundiali, and enters the sea at Grand-Lahou lagoon. On the main course of the Bandama River, two hydroelectric dams, Kossou (drainage area: 900 km^2) and Taabo (drainage area: 69 km^2), were build (Traoré, 1996; Kouassi, 2007). The man-made lakes Kossou (drainage area: 900 km^2) and Taabo (drainage area: 69 km^2) originated from the building of a hydroelectric dam on the main course of the Bandama River (Traoré, 1996; Kouassi, 2007). Its two main tributaries are N'Zi on the left bank (725 km in length) and Marahoué on the right bank (550 km in length). The general characteristics of watershed areas described by Lévêque et al. (1983) indicate that the streams flow through different vegetation and climate zones (area of Sudan and Guinea) and hydrological regimes (tropical regime transition, equatorial regime transition attenuated, and equatorial regime transition) from north to south. The description of the physico-chemical characteristic has been done by Lévêque et al. (1983).

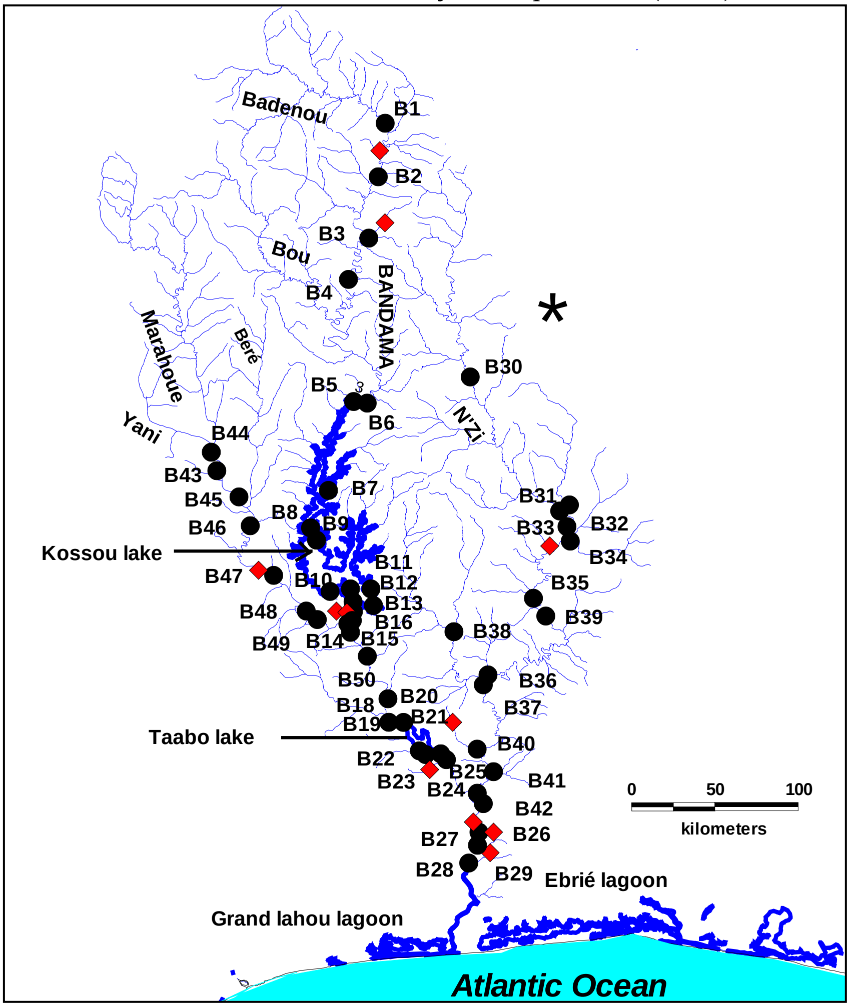

Figure 1: Position of sampling sites within the Bandama River (Côte d'Ivoire); ● = gill netting sites, ◆= electrofishing sites

According to ecological features of the river, three zones were distinguished along the upstream-downstream gradient. The upper stream is up on Kossou Lake. The middle course is characterized by the running waters (N'Zi River, Marahoué Rivers and Bandama fluvial course) and the lentic waters (Kossou and Taabo Lakes). The lower stream is under Taabo Lake (Figure 1).

Fish sampling

Fish were collected during 12 sampling campaigns from October 2008 to September 2009. A total of 64 sites were sampled in the Bandama River using two gears. Fifty sites were sampled with a battery of 19 gill-nets (mesh sizes 8, 10, 12, 14, 15, 18, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75 and 80 mm). Among them, 29 sites were in the main channel (B1-B29) and 21 in the major tributaries N'Zi (B30-B42) and Marahoué (B43-B50). In each sampling site, nets were set between 5.00 pm and 7.00 am for night fishing and between 7.00 am and 12.00 am for the day fishing. A backpack electrofisher (Smith-Root Inc. Model 12 Pow) was used in shallow waters in the tributaries. Electrofishing was done into 14 sites. At each site, electrofishing was done with the same sampling effort (15 min of fishing). Fish specimens were identified according to Paugy et al. (2003a, 2003b) and Decru et al. (2012), measured to the nearest mm and weighed to the nearest 0.1 g with a top loading Satorius balance (model BP 310S) and counted.

Environmental parameters

Prior to fish sampling, physico-chemical parameters such as water turbidity (cm) was measured using a Secchi disc; depth (m) with a ballasted rope ; current velocity ($m.s^{-1}$) with a propeller-driven current meter; electrical conductivity ($\mu S.cm^{-1}$), a total dissolved solids or TDS ($mg.l^{-1}$) and salinity (‰) were measured with a multi-parameter WTW-LF 340; the value of dissolved oxygen ($mg.l^{-1}$) with an oxymeter WTW DIGI 330; pH and temperature (°C) with a pH-meter WTW- pH 330 coupled with a thermometer. All these parameters were measured between 7.00 am to 9:00 am, and between 12:00 am and 1:00 pm. The mean canopy closure was expressed in %. Aquatic plants and substrate type (sand, gravel, mud, rock, clay and leaves-wood-roots) were measured as % of stream bottom surface overlain by the plants and each substrate type.

Data Treatment and Statistical Analysis

In this study, the results of electrofishing will be only used for inventory quality. For the quantitative comparisons, only fish caught in gill nets will be taken into account.

Principal Components Analysis (PCA), based on physical and chemical parameters, and samples sites, were used to evaluate if the samples sites are grouping according the ecological zones.

Diversity indices based on data from gill nets were calculated to describe the assemblages for fishes across the different sampling areas. The Shannon-Weiner's diversity (*H'*), Jaccard similarity index (*J'*) and a nonparametric test Kruskal-Wallis (H) at $p<0.05$, were used to compare diversity indices across areas.

The relationship between the environmental parameters and the fish communities was investigated by means of Redundancy Analysis (RDA) (Ter Braak, 1995). A series of RDA with forward a selection of environmental variables and unrestricted Monte Carlo permutation tests (499 iterations) was used to select variables explaining variation in fish species data. Because rare species can have a strong effect on the position of samples in multivariate space (Ter Braak, 1995), we only included species that occurred at ≥ 3% of the total abundance. In addition, species abundances were $\log_{10}(x+1)$ transformed prior to analysis to reduce the influence of the most common species (Ter Braak and Smilauer, 2002). Environmental and fish data were examined using CANOCO (Canonical Community Ordination) version 4.5.

Results

Species composition

The composition of the icthyofauna of the Bandama River (species, genera, families) collected during this study is shown in Table 1. A total of 83 fish species belonging to 11 orders, 30 families and 51 genera were captured. Thirteen marine and/or brackish-water species (*Elops lacerta, Pellonula leonensis, Caranx hippos, Trachinotus teraia, Gerres melanopterus, Sarotherodon galilaeus, S. melanotheron, Tilapia mariae, Tylochromis jentinki, Liza falcipinnis, Polydactylus quadrifilis, Awaous lateristriga* and *Eleotris vittata*), two introduced species (*Heterotis niloticus* and *Oreochromis niloticus*) and one hybrid (*Tilapia guineensis* x *T. zillii* were collected. Eight species were newly reported (*Epiplatys etzeli, Barbus guildi, Micralestes elongatus, Gerres melanopterus, Caranx hippos, Trachinotus teraia, Liza falcipinnis* and *Eleotris vittata*).

In Bandama River, Characiformes with 10 % of families and 14 % of species were the most abundant order (37 % of individuals). Followed by Siluriformes (20 % of families and 18 % of species) represented by 19 % of fish, Osteoglossiformes (10 % of families and 13 %of species) amount to 12 % of total fish and Perciformes (33 % of families and 28 % of species) with 11 % of fish caught. Among families, Alestidae with 10 % of species were the most abundant (35 % of fish sampled).

Table 1: Fish species collected in the Bandama Basin between October 2008 and September 2009; + = recorded, 1 = fishes with marine and/or brackish water affinities, 2 = introduced species, 3 = hybrid species, MAR = affluent Marahoué, MC = main course of Bandama River without Lakes species, TAA = Lake of Taabo, KOS = Lake of Kossou

Orders	Families	Species	Upper course	Middle course					Lower course
				N'ZI	MAR	MC	TAA	KOS	
Lepidosireniformes	Protopteridae	*Protopterus annectens*		+					
Polypteriformes	Polypteridae	*Polypterus endlicheri*	+	+	+	+			
Elopiformes	Elopidae	*Elops lacerta*[1]							+
Clupeiformes	Clupeidae	*Pellonula leonensis*	+	+	+	+	+	+	+
Osteoglossiformes	Osteoglossidae	*Heterotis niloticus*[2]	+	+		+	+	+	
	Notopteridae	*Papyrocranus afer*		+		+		+	+
	Mormyridae	*Marcusenius furcidens*		+	+	+			
		Marcusenius senegalensis	+	+	+	+	+	+	+
		Marcusenius ussheri	+	+	+	+	+	+	+
		Marcusenius sp.							+
		Mormyrops anguilloides	+	+	+	+		+	+
		Mormyrus rume	+	+	+	+			+
		Mormyrus hasselquistii		+					
		Pollimyrus isidori	+	+	+	+	+	+	
		Petrocephalus bovei	+	+	+	+	+	+	+
Characiformes	Hepsetidae	*Hepsetus odoe*	+	+	+	+			+
	Alestidae	*Alestes baremoze*	+	+	+	+			+
		Brycinus imberi	+	+	+	+		+	+
		Brycinus longipinnis	+	+	+	+	+	+	+
		Brycinus macrolepidotus	+	+	+	+	+	+	+
		Brycinus nurse		+	+	+			+
		Hydrocynus forskalii	+	+	+	+	+		+
		Micralestes elongatus			+				
		Micralestes occidentalis	+	+					
	Distichodontidae	*Distichodus rostratus*	+	+	+	+	+		+
		Nannocharax fasciatus	+	+					
		Noelebies unifasciatus	+	+	+				
Cypriniformes	Cyprinidae	*Barbus ablabes*	+	+	+	+	+	+	+

		Barbus guildi		+					
		Barbus macrops	+	+	+	+	+	+	
		Barbus punctitaeniatus			+				
		Barbus macinensis	+						
		Barbus perince		+					
		Barbus sublineatus	+	+	+	+		+	
		Barbus trispilos				+			
		Barbus sp.					+		
		Labeo coubie	+	+	+	+	+	+	+
		Labeo parvus	+	+	+	+	+		+
		Labeo sp.				+			
		Raiamas senegalensis	+	+	+	+			

Table 1: (continued)

Orders	Families	Species	Upper course	Middle course					Lower course
				N'ZI	MAR	MC	TAA	KOS	
Siluriformes	Claroteidae	*Auchenoglanis occidentalis*	+	+	+	+	+	+	+
		Chrysichthys maurus		+	+	+	+	+	+
		Chrysichthys nigrodigitatus	+	+	+	+	+	+	+
	Schilbeidae	*Paraillia pelucida*	+	+		+	+	+	+
		Schilbe intermedius	+	+		+	+	+	
		Schilbe mandibularis	+	+	+	+	+	+	+
	Amphiliidae	*Amphilius atesuensis*				+			
	Clariidae	*Clarias anguillaris*	+	+	+	+	+	+	
		Clarias buettikoferi		+					
		Heterobranchus isopterus	+	+		+			
		Heterobranchus longifilis	+	+	+	+	+		
	Malapteruridae	*Malapterurus electricus*	+	+		+		+	+
	Mochokidae	*Synodontis bastiani*	+	+	+	+	+	+	+
		Synodontis punctifer	+	+	+	+	+	+	+
		Synodontis schall	+	+	+	+	+		+
Cyprinodontiformes	Poeciliidae	*Rhexipanchax schioetzi*		+					
	Notobranchiidae	*Epiplatys chaperi*				+			+
		Epiplatys dageti		+					
		Epiplatys etzeli				+			+
Perciformes	Channidae	*Parachanna obscura*		+	+	+	+		+
	Latidae	*Lates niloticus*	+	+	+	+		+	+
	Carangidae	*Caranx hippos*[1]							+
		Trachinotus teraia[1]		+					+
	Gerreidae	*Gerres melanopterus*[1]							+
	Cichlidae	*Chromidotilapia guntheri*	+	+	+	+	+	+	+
		Hemichromis bimaculatus	+	+	+	+	+	+	+
		Hemichromis fasciatus	+	+	+	+	+	+	+
		Oreochromis niloticus[2]	+	+	+	+	+	+	

		Sarotherodon galilaeus[1]	+	+	+	+	+	+	+
		Sarotherodon melanotheron[1]		+		+		+	
		Thysochromis ansorgii				+			+
		Tilapia guineensis × *Tilapia zillii*[3]		+	+	+	+	+	
		Tilapia guineensis		+			+	+	+
		Tilapia mariae[1]				+		+	+
		Tilapia zillii	+	+	+	+	+	+	+
		Tilapia sp.							+
		Tylochromis jentinki[1]							+
	Mugilidae	*Liza falcipinnis*[1]							+
	Polynemidae	*Polydactylus quadrifilis*[1]							+
	Gobiidae	*Awaous lateristriga*[1]				+			+
	Eleotridae	*Eleotris vittata*[1]							+
	Anabantidae	*Ctenopoma petherici*	+	+	+	+	+	+	+
Synbranchiformes	Mastacembelidae	*Mastacembelus nigromarginatus*	+	+	+	+			
11	**30**	**83**	**47**	**62**	**46**	**58**	**36**	**37**	**51**

They were followed by Mormyridae (11 % of species) with 12 % of fish caught, Cichlidae (16 % of species) and Schilbeidae (4 % of species) with 10 % of fish sampled respectively. Based on the percentage of occurrence, 10 species species were the most represented in Bandama River: *Chrysichthys nigrodigitatus* (71.87 %), *B. longipinnis* and *Schilbe mandibularis* (67.18 % each), *B. macrolepidotus* (65.62 %), *Hemichromis facsiatus* (62.5 %), *B. imberi* (59.37 %), *Marcusenius ussheri* and *Petrocephalus bovei* (56.25 % each), *Chromidotilapia guntheri* (54.68 %) and *T. zillii* (51.56 %).

Species distribution

Along upstream and downstream gradient

Fish communities structures along the upstream-downstream gradient were showed by the Table 1. The middle course contains more species with 73 species. In this area, the tributaries N'Zi have 62 species; Marahoué, 46 species and Bandama fluvial course, 58 species. The upper and lower courses contain respectively 47 and 51 species. Seventeen (17) species were common to the three areas. *Barbus macinensis* was only collected in upper course. In middle course, *Protopterus annectens*, *Mormyrus hasselquistii*, *Barbus perince*, *B. guildi*, *Epiplatys dageti*, *Rhexipanchax schioetzi*, *Clarias buettikoferi* and the marine/brackish *Trachinotus teraia* species were caught solely in the N'Zi River. *Barbus punctitaeniatus* and *Micralestes elongatus* were caught in Marahoué; and, *Barbus trispilos*, *Amphilius atesuensis*, *Epiplatys chaperi* and *E. etzeli* were caught in small tributaries of middle course. Nine (9) species (*Elops lacerta*, *Marcusenius* sp., *Caranx hippos*, *Gerres melanopterus*, *Tilapia* sp., *Tylochromis jentinki*, *Liza falcipinnis*, *Polydactylus quadrifilis* and *Eleotris vittata*) were only caught in lower course. Sampling sites of the lower course were characterized by the presence of important marine and/or brackish water species.

In the upper catchment (Table 2), species assemblages were dominated by *S. intermedius* (18%) and *B. imberi* (12%). Alestidae (27%), Schilbeidae (26%) and Cichlidae (13%) were the dominant families. In the middle course (Table 2), N'Zi River was dominated by *S. mandibularis* (13%), *S. intermedius* (9%) and *Alestes baremoze* (14%) species whereas Alestidae (37%) and Schilbeidae (24%) were the dominant families. In Marahoué River, the dominant species were *C. nigrodigitatus* (14%), *P. bovei* (12%) and *B. imberi* (10%). Alestidae (29%), Mormyridae (16%) and Claroteidae (15%) were the dominant families. The dominant species in the Bandama fluvial course in the middle area were *B. longipinnis* (55%) and *P. bovei* (8%). Alestidae (64%) and Mormyridae (11%) were the dominant families. The lentic areas Kossou and Taabo were characterized by the presence of more Cyprinidae (31% to Kossou Lake and 15% to Taabo Lake), Cichlidae (31% to Kossou Lake and 15% to Taabo Lake) and Mormyridae (31% to Kossou Lake and 15% to Taabo Lake). In the Kossou Lake, the dominant species were *B. macrops* (30%) and *P. bovei* (12%). Taabo lake, were dominated by *Hemichromis bimaculatus* (10%) and *H. fasciatus* (14%). The lower catchment (Table 2) assemblages were represented by *Alestes baremoze* (17%), *Pellonula leonensis* (17%) and *C. nigrodigitatus* (11%) species. The Alestidae (27%), Clupeidae (17%) and Claroteidae (11%) were the most abundant families.

Table 2: Numerical proportions of the principal fish families and fish species caught (2008-2009) using gill-nets in the Bandama River

Zonation	**Stream**	**Families**	**Proportions (%)**	**Species**	**Proportions (%)**
Upper course	Main channel of Bandama	Schilbeidae	26	*Schilbe intermedius*	18
				Schilbe mandibularis	8
		Alestidae	27	*Brycinus imberi*	12
				Brycinus macrolepidotus	6
		Cichlidae	13	*Hemichromis fasciatus*	5
		Clupeidae	6	*Pellonula leonensis*	6
Middle course	N'Zi	Schilbeidae	24	*Schilbe intermedius*	9
				Schilbe mandibularis	13
		Alestidae	37	*Alestes baremoze*	14
				Brycinus imberi	6
				Brycinus macrolepidotus	6
	Marahoué	Mormyri	16	*Petrocephalus bovei*	12

		dae			
		Cichlidae	17	*Tilapia zillii*	6
		Claroteidae	15	*Chrysichthys nigrodigitatus*	14
		Alestidae	29	*Brycinus imberi*	10
	Main channel of Bandama	Schilbeidae	6	*Schilbe mandibularis*	5
		Mormyridae	11	*Petrocephalus bovei*	8
		Clupeidae	5	*Pellonula leonensis*	5
		Alestidae	64	*Brycinus imberi*	5
				Brycinus longipinnis	55
	Lake of Kossou	Cyprinidae	31	*Barbus macrops*	30
		Cichlidae	20	*g. Hemichromis*	13
		Mormyridae	17	*Petrocephalus bovei*	12
		Clupeidae	9	*Pellonula leonensis*	9
		Claroteidae	9	*Chrysichthys nigrodigitatus*	9
	Lake of Taabo	Cichlidae	26	*Hemichromis bimaculatus*	10
				Hemichromis fasciatus	14
		Mormyridae	20	*Petrocephalus bovei*	19
		Cyprinidae	15	*g. Barbus*	11
Lower course	Main channel of Bandama	Mormyridae	12	*Petrocephalus bovei*	6
		Alestidae	27	*Alestes baremoze*	17
		Scilbeidae	5	*Schilbe mandibularis*	5
		Clupeidae	17	*Pellonula leonensis*	17
		Claroteidae	11	*Chrysichthys nigrodigitatus*	11

The Jaccard index calculated between the sampling areas showed important similarities between upper course and N'Zi River (0.71),upper course and Marahoué River (0.73), lower course and Marahoué River (0.70), N'Zi River and Bandama main course (0.74), and Marahoué River and Bandama main course (0.70).The lowest similarities were identified between lower course and upper course (0.45), lower course and N'Zi River (0.48), lower course and Kossou Lake (0.47) and, lower course and Taabo Lake(0.45).

The maximum of Shannon diversity index based on fish biomass was observed in the lower course (*H'*= 3.18), N'Zi (*H'*=3.19) and Marahoué (*H'*=3.04). The lowest values was observed in the upper course (*H'*=2.97), in

Bandama main course (*H'*=2.88) and in Lakes areas (Kossou, *H'*=2.75; Taabo, *H'*=2.64). Shannon index calculated with fish abundance showed that the index is high in the N'Zi (*H'*=3.13) and low in the Bandama main course (*H'*=1.95). The Kruskal-Wallis test ($p>0.05$) indicated that there are no significant differences in species richness between the different study areas.

According to environmental abiotic parameters

The principal component analysis (PCA) realized showed two different areas: sampling sites in rivers and sampling sites in lakes (Figure 2a).

Redundancy analysis coupled to Monte Carlo test (499 permutations) in water courses (Figure 2b) indicated seven environmental variables accounting for 53.77% of the variance explained by the variables in the whole: width (10.32%), dissolved oxygen (8.78%), turbidity (8.16%), depth (7.08%), canopy closure (6.93%), mixed sand-gravel (6.31%) and aquatic plants (6.16%).

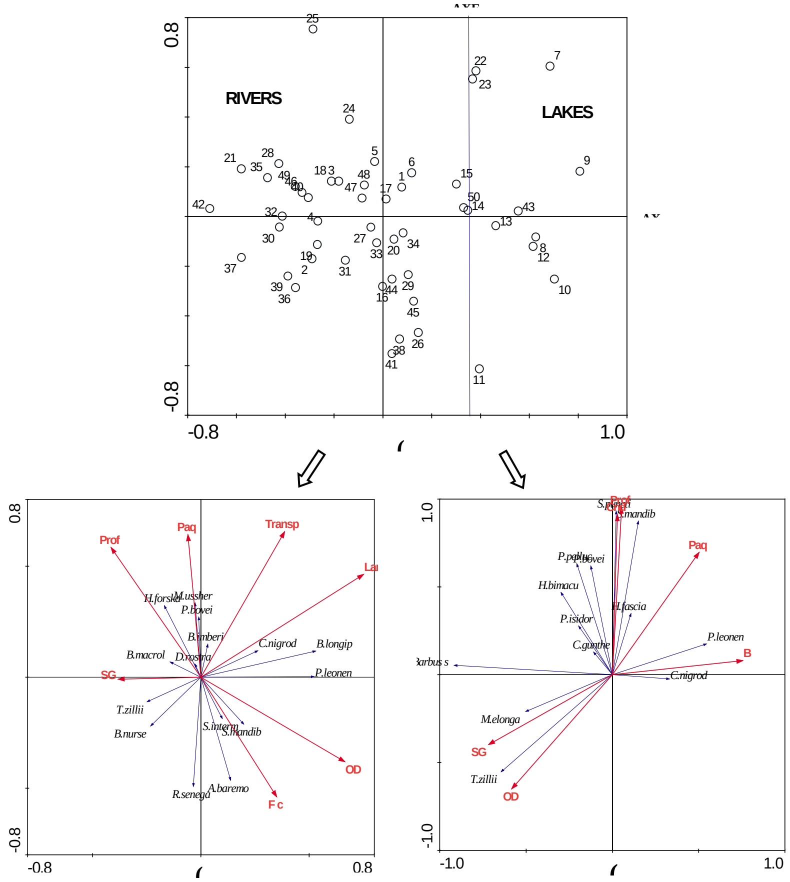

Figure 2: Redundancy analysis applied to the environmental variables and to the fish taxa of the gill-net sampling sites on the Bandama Basin. (**a**) Sampling sites; ordination between environmental variables and fish in rivers (**b**) and in lakes (**c**). Prof = depth, Transp = transparency, Paq = aquatic plants, Larg = width, Cnd = conductivity, SG = mixed sand-gravel, OD = dissolved oxygen, Fc = canopy closure, B = mud. Fish taxa: H.forskalii = *Hydrocynus forskalii*, M.ussheri = *Marcusenius ussheri*, P.bovei = *Petrocephalus bovei,* B.imberi = *Brycinus imberi,* B.macrol = *Brycinus macrolepidotus*, B.longip = *Brycinus longipinnis*, D.rostra = *Distichodus rostratus*, C.nigrod = *Chrysichthys nigrodigitatus*, P.leonen = *Pellonula leonensis*, S.interm = *Schilbe intermedius,* S.mandib = *Schilbe mandibularis,* A.baremo = *Alestes baremoze*, R.senega = *Raiamas senegalensis*, Barbus s = *Barbus* sp., S.punctif = *Synodontis punctifer*, P.pelluc = *Parailia pellucida,* H.bimacu = *Hemichromis bimaculatus*, H.fascia = *Hemichromis fasciatus*, P.isidor = *Pollimyrus isidori,* C.gunther = *Chromidotilapia guntheri,* M.elonga = *Micralestes elongates.*

Schilbe intermedius, S. mandibularis, Raiamas senegalensis and *Alestes baremoze* were associated to high dissolved oxygen and an important canopy closure. *Hydrocynus forskalii, Marcusenius ussheri, Petrocephalus bovei, Distichodus rostratus, Brycinus imberi*and *B. macrolepidotus*, were characterized by depth and the presence of aquatic plants. The substrate composed of mixed sand-gravel was associated with *B. macrolepidotus*, *B. nurse* and *T. zillii*. The width and turbidity influenced *C. nigrodigitatus*, *B. longipinnis* and *P. leonensis* distribution.

In the lakes Kossou and Taabo, Redundancy Analysis (Figure 2c) showed, six environmental variables accounting for 50.99 % of the cumulated variance of all variables: dissolved oxygen (9.62 %), aquatic plants (9.38 %), depth (8.87 %), conductivity, (7.76 %), mixed sand-gravel (7.94 %) and mud (6.43 %). Redundancy analysis computed indicated that the relative abundance of *Micralestes elongatus* and *T. zillii* were favored by the presence of mixed sand-gravel and the rate of high dissolved oxygen. Otherwise, a massive presence of aquatic plants and mud, the relative abundance of *M. elongatus* and *T. zillii* decreases. The mud had good effects on the *P. leonensis* species and *C. nigrodigitatus*. However, the opposite effect was observed for the small Barbus. Also, depth, conductivity and aquatic plants had a large influence on the *Synodontis punctifer*, *S. mandibularis* and *Hemichromis fasciatus* species. The fish assemblages composed by *Parailia pellucida*, *P. bovei*, *H. bimaculatus*, *Pollimyrus isidori* and *C. guntheri* were less influenced by the conductivity and the depth.

Discussion

The current study indicated lower species richness (83 species) in the Bandama River comparatively those found (96 species) by Teugels et al. (1988). However, three freshwater species (*Epiplatys etzeli*, *Barbus guildi* and *Micralestes elongatus*) and five marine species (*Gerres melanopterus, Caranx hippos*, *Trachinotus teraia*, *Liza falcipinnis* and *Eleotris vittata*) were reported for the first time in the Bandama River. This difference could be related to the sampling procedure, the types of habitats, sampling periods, species loss probably due to environmental alteration by human activities (Gourène et al., 1999; Kouamélan et al., 2003) and to the systematic revisions. Moreover, studies doing in Guyanne by Mérona (2005) showed that the dam building led important dysfunctioning of the environment, mainly on the fish assemblage's diversity. Indeed, they are highlighted a significant decrease of fish diversity in downstream of the dam. Qualitative and quantitative analysis showed that Perciformes, Siluriformes, Osteoglossiformes and Characiformes orders contain the most families and species in the Bandama River. The same observations are made in main Rivers of Côte d'Ivoire by Yao et al. (2005) and Kouamé et al. (2008) and on others basins by Paugy et al. (1994). For Lévêque et al. (1991) these basins are in the same ichthyological province, i.e. the Nilo-Sudanian regionand have the same characteristics.

The abundant of *Brycinus longipinnis* in the fish population in Bandama River particularly in downstream of man-made Lakes could be explained by the fact the release of water from the lakes extends the flood period, benefiting the reproduction of this species. Paugy and Lévêque (1999) indicated that most tropical species are physiologically prepared for spawning during flood periods. In addition, *B. longipinnis* was omnivorous and ate food drained by rainwater, mainly insects which fall in the water during the flood periods (Dietoa et al., 2007). A modified hydraulic regime with a long frequency and flood time, increase their opportunity to feed and lead an increase of their population.

The lower catchment, despite the presence of marine and/or brackish water species, was dominated by *Alestes baremoze, Pellonula leonensis, Chrysichthys nigrodigitatus* whereas Mérona (1981) mentioned the abundance of *B. longipinnis, Schilbe intermedius, Synodontiss chall* and *Hepsetus akawo*. The upper course was characterized by the dominance of *S. intermedius* and *B. imberi* in contrast to *S. mystus, B. longipinnis* and *H. akawo* noted by Mérona (1981). The middle course was subdivided in two parts: the lotic water and the lentic water. The lotic waters were characterized by *S. mandibularis, B. imberi, A. baremoze*, *Petrocephalus bovei, C. nigrodigitatus* and important *B. longipinnis*. This study showed that *B. longipinnis*, *B. imberi* and *P. bovei* species were abundant instead of *B.*

nurse, *B. macrolepidotus* and *Hydrocynus forskalii* noted by Mérona (1981) in fluvial course of Bandama River. The lentic waters were showed an assemblage dominated by the species *Hemichromis fasciatus*, *P. bovei* and g. *Barbus* in the Kossou and Taabo lakes. However, the *A. baremoze* and *S. mandibularis* species are well represented in both Lakes. These observations are similar to those found by Welcomme (1986) in African and Asian man-made lakes where after building, pelagic species "boom".

The species richness in the Bandama River showed an irregular distribution. This richness was high and very varied in the middle course comparatively to the upper and lower courses. On the one hand, the habitat diversity could be one of the main causes of this irregularity distribution. Indeed, the middle part of Bandama contains lentic and lotic aquatic systems due to the Kossou and Taabo Lakes. And, on the other hand, this suggests some disturbance and an irregular distribution in fish community structure in the upper and lower reaches. The extensive use of toxic products (lead, sodium cyanide, mercury) in gold mining of the upper catchment (Halle and Bruzon, 2006) and pesticides (Caodalam®, Thiodan®, Miridan®, Basudine®, Califan® and Furadan®) in the agricultural areas (coffee, cocoa, banana, rubber tree and palm tree plantations)of the lower catchment (Balk and Koeman, 1984, Calamari, 1985) could contribute to these changes. This result is corroborated with those from studies carried out in other Ivorian areas by Kouamélan et al. (2003) and Yao et al. (2005). The majority of Jaccard indices calculated is greater than 0.5, meaning that half the species is common to the different sectors studied. The Kruskal-Wallis test ($p > 0.05$) indicated that there were no significant differences in fish assemblages along the Bandama River. These analyses showed that a large portion of the stream has a relatively homogeneous ichtyofauna characterized by the dominance of Alestidae, Schilbeidae, Cichlidae, Mormyridae, Clupeidae and Cyprinidae families. This supports the findings of Lévêque et al. (1983) for the Bandama River, and those of Sydenham (1977) for the Ogun River in Nigeria.

The environmental variables best describing the fish assemblages in the Bandama River were substrate, riparian vegetation, aquatic plants, physico-chemical parameters and habitat quality. Depending on the type of water, certain fish species do not seem to have the same response to the environmental conditions. In this study, we noted that *S. intermedius*, *S. mandibularis*, *Raiamas senegalensis* and *A. baremoze* were abundant when the increase of dissolved oxygen and canopy closure were important. These species like the running water and are qualified as rheophilic species by Lalèyè et al. (2004). The importance of substrate in determining fish assemblage composition has been documented by Gorman and Karr (1978). We noted that *B. macrolepidotus*, *B. nurse* species and *Tilapia zillii* liked substrate composed of mixed sand-gravel. *C. nigrodigitatus*, *B. longipinnis* and *P. leonensis* are widely influenced by the river width. In West Africa, Hugueny (1989) found a significant relationship between the river size and the number of species in the Niandan River (upper Niger). Also, the influence of water depth and conductivity on species distribution was noted by Da Costa et al. (2000) and Kouamélan et al. (2003). According to these authors, total dissolved solids, conductivity and depth are some of the most discriminating factors in the Agnéby and Bia Rivers, and in Ayamé man-made lake (Côte d'Ivoire).

Conclusion

Like in most of the tropical rivers of Africa, ichtyofauna of the Bandama River is diverse, although the fish assemblage is relatively homogeneous in the three parts of basin (upper, middle and lower catchment). *Brycinus longipinnis* species accounts for more than 21% of the total abundance. The man-made lakes (of Kossou and Taabo) built on the main course of the Bandama River and the environmental factors influenced fish species distribution. Among these environmental factors, four (dissolved oxygen, depth, aquatic plants and mixed sand-gravel) are commune to the lakes and rivers. Moreover, two are specific to the lakes (conductivity and mud) and three to the rivers (turbidity, canopy closure and width).

Acknowledgement

We are grateful to the research group directed by Pr. Kouamélan and Mr Aka Simon, the fisherman, for the collect of the data on the study area. We also think all the staff of the Hydrobiology Laboratory of Félix Houphouët-Boigny University (Côte d'Ivoire) for their invaluable help and advice. This study was financed thanks to the partnership between Hydrobiology Laboratory of Félix Houphouët-Boigny and the *Swiss Center for Scientific Research* (CSRS), through PASRES (*Strategic Support Programme for Scientific Research*) in the project entitledDevelopment of fish index of biotic integrity for the preservation of Bandama River biodiversity(Côte d'Ivoire). This study was also supported by the Swiss government.

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