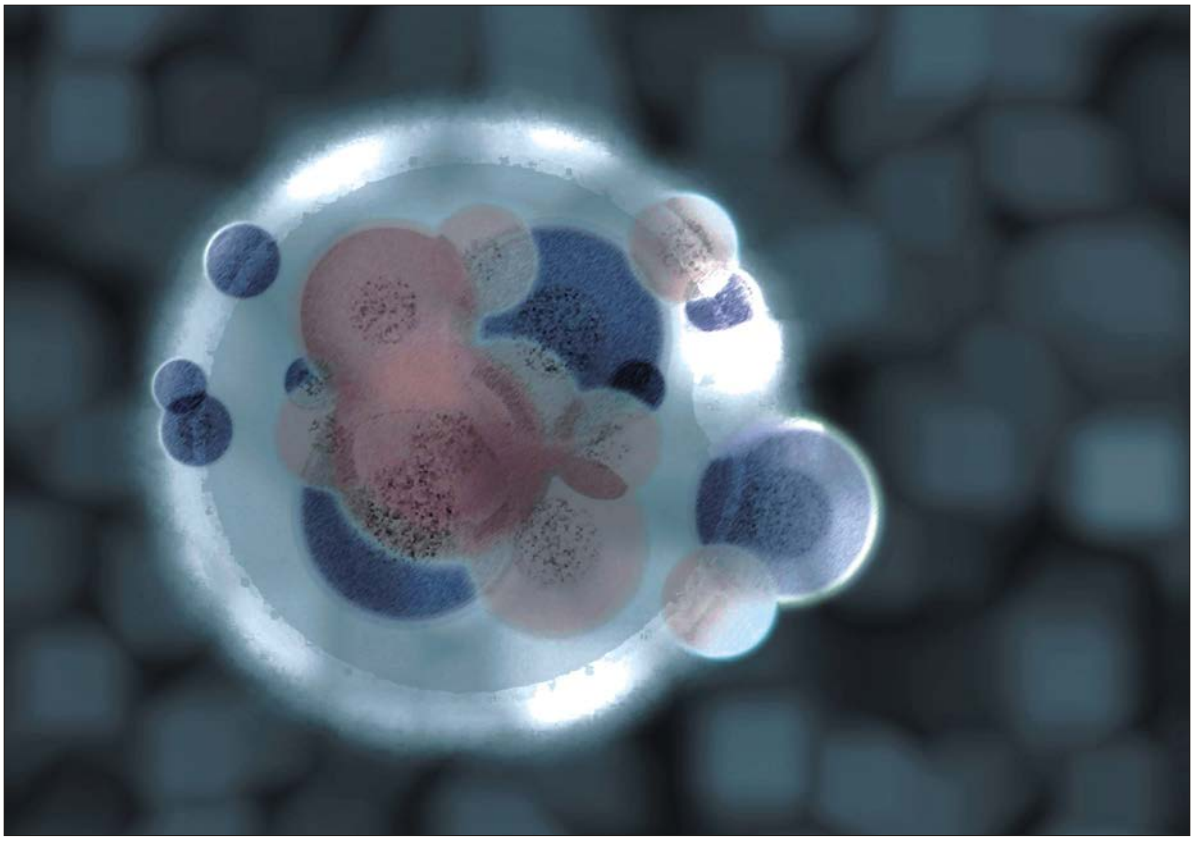

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Update of Fish Biodiversity and Impact of Human Activities on the Community Structure, Mé River (Ivory Coast)

[1]N.F. Kouadio, [1]E.P. Kouamélan, [1]V. N'Douba, [1]T. Koné, [2]J. Snoecks and [3]F. Ollevier
[1]Laboratoire d'Hydrobiologie, U.F.R. Biosciences, Université de Cocody,
22 B.P. 582 Abidjan 22, Côte d'Ivoire
[2]Royal Museum for Central Africa, Ichthyology Laboratory, B-3080 Tervuren, Belgium
[3]Laboratory for Comparative Anatomy and Biodiversity, Katholieke Universiteit Leuven,
Ch De Bériotstraat 32, B-3000 Leuven, Belgium

Abstract: Fish community structure in relation with environmental variables was studied in the Mé River (Ivory Coast, West Africa). Fifty-four freshwater fish species belonging to 35 genera and 20 families were listed. Eight of these species were reported for the first time in this river, whereas fifteen species reported earlier were not found in the present sampling campaign. Fourteen species are found exclusively in the upstream versus three species for the lower stream. Thirty-seven species are common to both sampling areas. The present findings are opposed to the tendency for species composition to increase from the source to the mouth of the river, which is probably due to a major human activity: the exploitation of a gravel pit. Among fish families sampled, Cyprinidae and Alestidae are more abundant, respectively in the upper and lower courses. Significant correlation between species distribution and environmental variables was found. Aquatic plants, canopy closure, conductivity, dissolved oxygen, mixed deadwoods-leaves-rocks, temperature and width are the main environmental variables influencing fish distribution in the Mé River.

Key words: Freshwater fish, distribution, environmental variables, Mé River, Ivory Coast

INTRODUCTION

The main goal of fish communities ecology is to understand the mechanisms and the processes responsible for differences and similarities between the fish assemblages (Angermeir and Karr, 1983). Many studies showed a good correlation between the number of fish species and river sizes. In rivers, it was noted that the main factors usually selected to define the microhabitat of fishes are: depth, substrate type and velocity (Baker and Ross, 1981; Gorman and Karr, 1978; Hugueny, 1990; Kamdem Toham and Teugels, 1998; Kouamélan *et al*., 2003; Moreau and Legendre, 1979; Paugy and Roberts, 1990; Pielou, 1984). Physical conditions and chemical composition of rivers in Ivory Coast were studied by Iltis and Lévêque (1982) within the framework of a monitoring program of the aquatic environments subjected to weekly insecticide spreading (OMS program). Other works showed the increase of species richness from upstream to downstream (Angermeir and Karr, 1983; Balon and Stewart, 1983; Belliard *et al*., 1997). Hugues and Larsens (1988) highlighted the differences between fish assemblages of areas having different environmental characteristics inside the same geographical surface. According to Hugueny *et al*. (1996) and Gourene *et al*. (1999), few of this kind of studies were undertaken in African coastal basins. In Ivory Coast, earlier studies on fish communities were limited mainly to the taxonomic and biological aspects (Koné and Teugels, 1999; Kouamélan, 1999; Kouamélan *et al*., 2000; N'Douba, 2000), except for some works on the dynamics of communities (Daget *et al*., 1973), on the structure of the ichthyologic communities (Merona, 1981) or on the relations between the environmental variables and fish assemblages (Da Costa *et al*., 2000; Kouamélan *et al*., 2003; Yao *et al*., 2005).

As part of a multidisciplinary study entitled characterization, use and conservation of freshwater fish biodiversity in Ivory Coast, fish diversity in the Mé River was studied, its spatial distribution was discussed, the main environmental variables that were associated to species assemblage were determined and the disruptive effect of human activities was highlighted.

MATERIALS AND METHODS

Study area: Fish samples were collected in the Mé River, a coastal basin of Ivory Coast. With a main-channel total length of 140 km (Fig. 1), it encompasses a catchments

Corresponding Author: N.F. Kouadio, Université de Cocody, UFR Biosciences, Laboratoire d' Hydrobiologie, 22 BP 582 Abidjan 22 (RCI), West Africa Tel: (225) 07631634 Fax: (225) 22440412

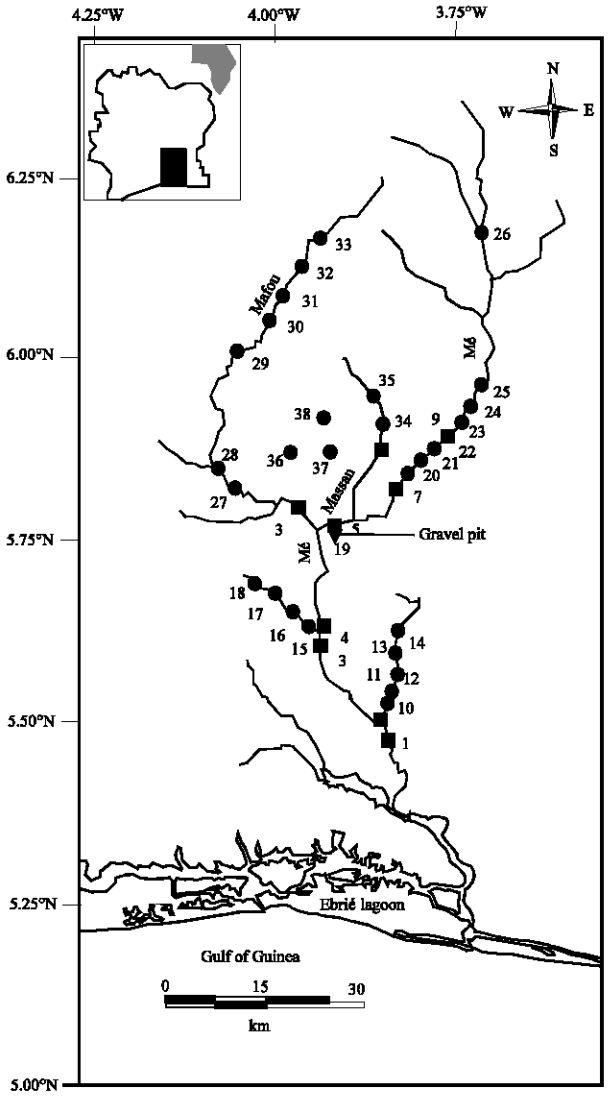

Fig. 1: Map of the Mé River (Ivory Coast) and location of sampling sites: ■ = gill-nets sites, ● = electrofishing sites, ▼ = gravel pit

area of 4300 km^2 (Avenard *et al.*, 1971). The Mé River takes its source in the Bosso listed forest in the North-East of Adzopé (Girard *et al.*, 1971). It receives four tributaries while crossing several listed forests, before reaching the Potou Lagoon (Avenard *et al.*, 1971). A gravel pit is exploited before the mouth of the second tributary Mafou. As a plain river, the Mé River has a very weak slope (0.78 m km^{-1}). Its average flow is about 50 m^3 s^{-1}. Two rising periods (June-July and October-November) and two low water levels (December-March and August-September) were noted.

Fish sampling: Thirty-eight sampling sites were explored along the Mé River from June to December 2000. Two fishing methods were used. In the main channel and the important tributaries (sites 1 to 4 of the lower course and 5 to 9 of the upper course), a fleet of gill-nets each measuring 30 m long and 2.5 m deep with meshes size 8, 10, 12, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 80 and 90 mm were used to collect fish samples. At each of these sampling sites, gill-nets were set overnight (17:00 to 7:00) and during the following day (7:00 to 13:00). Each of these sites was sampled four times corresponding to the wet (June and October) and dry season (August and December). In the other sites, less than one meter depth (sites 10 to 18 of the lower course and 19 to 38 of the upper course), sampling was performed during the day using an electrofisher device (Smith-Root Inc, Model

Backpack 12 Pow), each of them being sampled twice in dry season (August and December). Electrofishing was accomplished by wading and applying the same catch effort (15 min fishing) each time in each site. All fishes sampled were measured to the nearest mm, weighed to the nearest 0.1 g and identified following Lévêque *et al.* (1990, 1992) and Paugy *et al.* (2003a, b).

Measurement of environmental variables: Twenty-one environmental variables were considered for each sampling site. The following physical and chemical variables were measured: pH (with a pH-meter WTW-pH 330), temperature of water (in °C) and the dissolved oxygen (%) using an oxymeter WTW OXI 330, conductivity (μS cm^{-1}) and total dissolved solids (mg L^{-1}) measured with a conductimeter WTW-LF 340 and water transparency (cm) using a Secchi disc. These variables were measured at 50 cm depth, at 7:00 and 12:00 in the gill-nets sampled sites, except for water transparency. In electrofishing sites, these environmental factors were measured before fishing occurred.

The following parameters were measured to characterize the habitat (Kamdem Toham and Teugels, 1998): depth and width (measured to nearest cm), velocity (measured at surface in each sampling site in m s^{-1}), mean canopy closure (visually estimated in three spot and expressed in %), aquatic plants (expressed in percent of the surface of the site covered by the aquatic plants) and substrate type (measured as percent of stream bottom surface covered by this substrate type at each sample site). Eight substrates types were identified: Sand (S), Sand-gravel (SG), Gravel (G), Mud (M), Rock (R), Large Rocks (LR), Mixture Clay-mud (CM) and Deadwoods-leaves-rocks (LWR).

For each site, water samples were taken before fishing and kept cold for measurement of the following chemical compounds (expressed in mg L^{-1}) using a spectrophotometer, model DR/2000: ammonia (NH_3), calcium (Ca^{2+}).

Statistical analysis: Cluster analysis, a multivariate technique often employed to classify objects according to a distance or similarity measure (Digby and Kempton, 1987) was applied to group different sampling sites in clusters based on their fish assemblage. In this study, the analysis was performed using Euclidean distance and Ward method (Pielou, 1984).

Canonical Correspondence Analysis (CCA) (Ter Braak and Smilauer, 1998) was used to examine the possible correlations between the environmental variables and fish assemblages.

As only a few sites were sampled with gill-nets, statistical analysis was restricted to electrofishing samples. Therefore, two matrices covering 29 sampling sites were constituted for this analysis: (1) numerical abundance of species and (2) environmental variables. The Monte Carlo tests (with 199 permutations) were used to select the adequate environmental factors explaining variation in fish species data. Environmental and fish data have been standardized (Underwood, 1997) using $\log_{10}$ (x+1) transformation prior the analysis. The analysis was performed with the software CANOCO (Canonical Community Ordination; version 6.0).

This analysis results in two diagrams that simultaneously display the similarities between the sampling sites, based on their fish assemblages and the relationship between the environmental variables and the species numerical abundance (Godinho *et al.*, 1998).

RESULTS

Species composition: Fifty-four freshwater fish species belonging to 20 families and 35 genera were sampled during the present study (Table 1).

Among fish families sampled, Mormyridae (n = 8 species) is the most represented, followed by Alestidae, Cyprinidae, Clariidae (n = 6 species each one), Aplocheilidae (n = 5 species), Cichlidae (n = 4 species) and Schilbeidae (n = 3 species) (Table 1).

In the whole Mé River, Cyprinidae represented 34.76% of the total number of fishes, followed by Alestidae (18.02%), Aplocheilidae (11.38%), Schilbeidae (9.98%) and Cichlidae (5.57%). Each of the other families (Amphiliidae, Anabantidae, Channidae, Clariidae, Claroteide, Distichodontidae, Gobiiade, Eleotridae, Hepsetidae, Malapteruridae, Mastacembelidae, Mormyridae, Nandidae, Notopteridae, Poeciliidae, Polynemidae) represented less than 5% (Table 2).

In the present study, eight freshwater species (*Clarias anguillaris* (Linnaeus, 1758); *Clarias ebriensis* Pellegrin, 1920; *Clarias gariepinus* (Burchell,1822); *Epiplatys chaperi scheljuzhkoi* Poll, 1953; *Epiplatys etzeli* Berkenkamp, 1975; *Fundulopanchax walkeri* (Boulenger, 1901); *Malapterurus electricus* (Gmelin, 1789); *Micralestes elongates* Daget, 1957), one brackish water fish (*Polydactylus quadrifilis* (Cuvier, 1829)) and one hybrid (*Tilapia guineensis* (Bleeker *in* Günther, 1862) *x Tilapia zillii* (Gervais, 1848) were reported for the first time in the Mé River.

Distribution: At 205 Euclidean distance, two groups of sampling sites could be distinguished from the dendrogram (Fig. 2). The first of these (A) included

Table 1: List of freshwater fish species sampled in the Mé River (Ivory Coast) in June, August, October and December 2000; * = presence of species

				Upper course	
Families	Species	Abbreviations	Lower course	Above the gravel pit	Mafou River
Notopteridae	*Papyrochranus afer*	Paf	*	*	
Mormyridae	*Brienomyrus brachyistius*	Bbra	*	*	
	Marcusenius senegaleusis	Msen	*		
	Marcusenius ussheri	Muss	*	*	*
	Mormyrops anguilloides	Mang	*		
	Mormyrus hasselquistii	Mhas		*	*
	Mormyrus rume	Mru	*	*	
	Petrocephalus bovei	Pbov	*	*	*
	Pollimyrus isidori	Pisi	*	*	
Hepsetidae	*Hepsetus odoe*	Hod	*	*	*
Alestidae	*Brycinus imberi*	Bim	*	*	*
	Brycinus longipinnis	Blon	*	*	*
	Brycinus macrolepidotus	Bma	*	*	*
	Brycinus nurse	Bnu	*	*	
	Micralestes elongatus	Mel	*	*	
	Micralestes occidentalis	Moc	*	*	*
Distichodontidae	*Nannocharax fasciatus*	Nfas	*	*	
	Neolebias unifasciatus	Nun	*	*	*
Cyprinidae	*Barbus ablabes*	Bab	*	*	*
	Barbus macrops	Bmac	*		
	Barbus sublineatus	Bsub	*	*	
	Barbus trispilos	Btr	*	*	*
	Labeo parvus	Lpar		*	
	Raiamas nigerieusis	Rnig		*	
Claroteidae	*Chrysichthys maurus*	Cma	*	*	*
	Chrysichthys nigrodigitatus	Cni	*	*	
Schilbeidae	*Parailia pellucida*	Ppel	*	*	*
	Schilbe intermedius	Sint	*	*	
	Schilbe mandibularis	Sman	*	*	*
Amphiliidae	*Amphilius atesneusis*	At	*	*	*
Clariidae	*Clarias anguillaris*	Can	*	*	
	Clarias bnettikoferi	Cbu		*	*
	Clarias ebrieusis	Cebr		*	
	Clarias gariepinus	Cgar			*
	Heterobranchus isopterus	His	*	*	*
	Heterobranchus longifilis	Hlo	*		*
Malapteruridae	*Malapterurus electricus*	Melec		*	
Poeciliidae	*Poropanchax rancurelli*	Pran	*	*	*
	Aplocheilichthys spilauchen	Aspi	*	*	
Aplocheilidae	*Epiplatys chaperi chaperi*	Ech	*	*	
	Epiplatys chaperi sheljuzhkoi	Ecsc		*	*
	Epiplatys dageti dageti	Edd			*
	Epiplatys etzeli	Eet		*	
	Fundulopanchax walkeri	Fwal		*	
Channidae	*Parachanna obscura*	Pob	*	*	*
Nandidae	*Afronandus sheljuzhkoi*	Ash		*	
Cichlidae	*Chromidotilapia guntheri*	Cgu	*	*	*
	Hemichromis fasciatus	Hfa	*	*	*
	Tilapia guineeusis	Tgui	*	*	
	Tilapia zillii	Tzil	*	*	
Gobiidae	*Awaous lateristriga*	Alat			*
Eleotridae	*Kribia nana*	Kna		*	
Anabantidae	*Ctenopoma petherici*	Cpe	*	*	*
Mastacembelidae	*Mastacembelus nigromarginatus*	Mnig	*	*	
Total number of freshwater fish species		54	40	47	27

sampling sites of the upper catchments above the gravel pit (sites 19-21; 23-25; 34; 35 and 38). The second group (B) gathered sampling sites from the lower course of the Mé River (sites 10-18), as well as those located on the main tributary Mafou River (sites 27-33; 36). At 70 Euclidean distance, sampling sites of group B could be discreetly separated into two subgroups: sampling sites from the main tributary Mafou River and those located in the lower course of the Mé River.

Three freshwater fish species (*Marcusenius senegalensis* (Steindachner, 1870); *Mormyrops anguilloides* (Linnaeus, 1758); *Barbus macrops* Boulenger, 1911) were found only in the lower course versus 14 species in the whole upper course, whereas 37

Table 2: Relative numerical abundance (%) of the dominant families of fish caught in the whole Mé River (Ivory Coast) and in the lower and upper courses using electrofishing

Families	Mé River	Lower course	Upper course
Alestidae	**18.02**	**35.03**	**11.58**
Amphiliidae	2.38	3.90	1.81
Anabantidae	0.69	0.98	0.57
Aplocheilidae	**11.38**	**6.07**	**13.39**
Channidae	0.33	0.43	0.29
Cichlidae	5.57	4.23	6.08
Clariidae	2.11	1.30	2.42
Claroteidae	0.48	0.87	0.33
Clupeidae	1.10	1.95	0.78
Cyprinidae	**34.76**	**15.18**	**42.18**
Distichodontidae	3.96	1.19	5.01
Eleotridae	1.16	0.65	1.36
Gobiidae	0.15	0.00	0.21
Hepsetidae	0.83	1.63	0.53
Malapteruridae	0.03	0.00	0.04
Mastacembelidae	0.63	0.11	0.82
Mormyridae	3.75	3.15	3.98
Nandidae	0.03	0.00	0.04
Notopteridae	0.39	0.76	0.25
Poeciliidae	2.23	1.74	2.42
Polynemidae	0.03	0.11	0.00
Schilbeidae	**9.98**	**20.72**	**5.91**

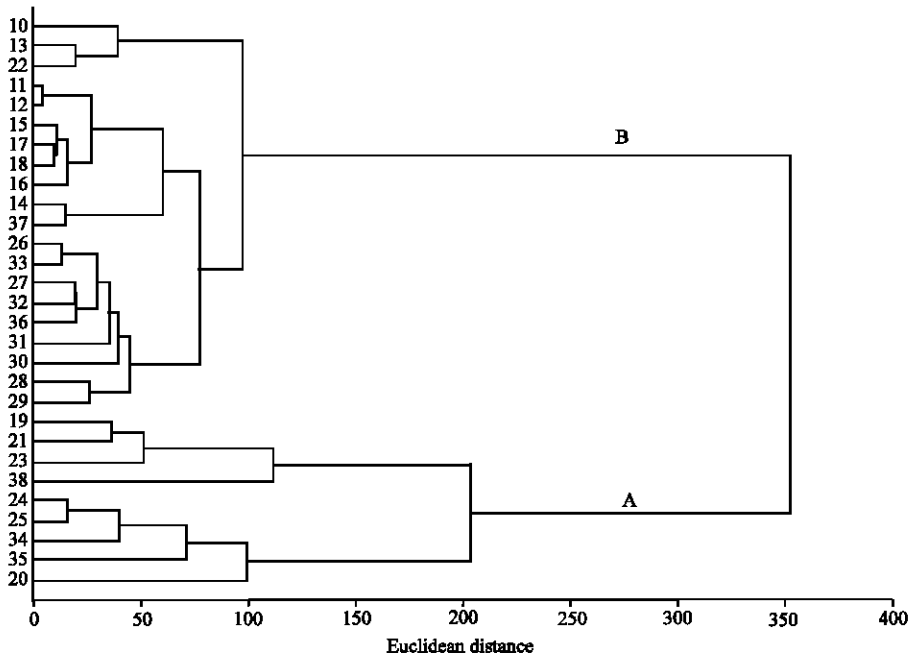

Fig. 2: Cluster dendrogram summarising similarities in fish assemblages between the different sites (10 to 38) sampled using electrofishing in the Mé River (Ivory Coast): A = upper course above the gravel pit, B = lower course and upper course in the main tributary Mafou

species were common to both courses (Table 1). Eight species from the upper course (*Labeo parvus* Boulenger, 1902; *Raiamas nigeriensis* (Daget, 1959); *C. ebriensis*; *M. electricus*; *E. etzeli*; *F. walkeri*; *Afronandus scheljuzhkoi* (Meinken, 1954); *Kribia nana* (Boulenger, 1901)) were captured only above the gravel pit against three species (*C. gariepinus*, *Epiplatys dageti dageti* Poll, 1953; *Awaous lateristriga* (Duméril, 1861) in the tributary Mafou River.

In the Mé River, Cyprinidae (42.18%) and Alestidae (35.03%) are the most numerically abundant families, respectively in the upper course and in the lower

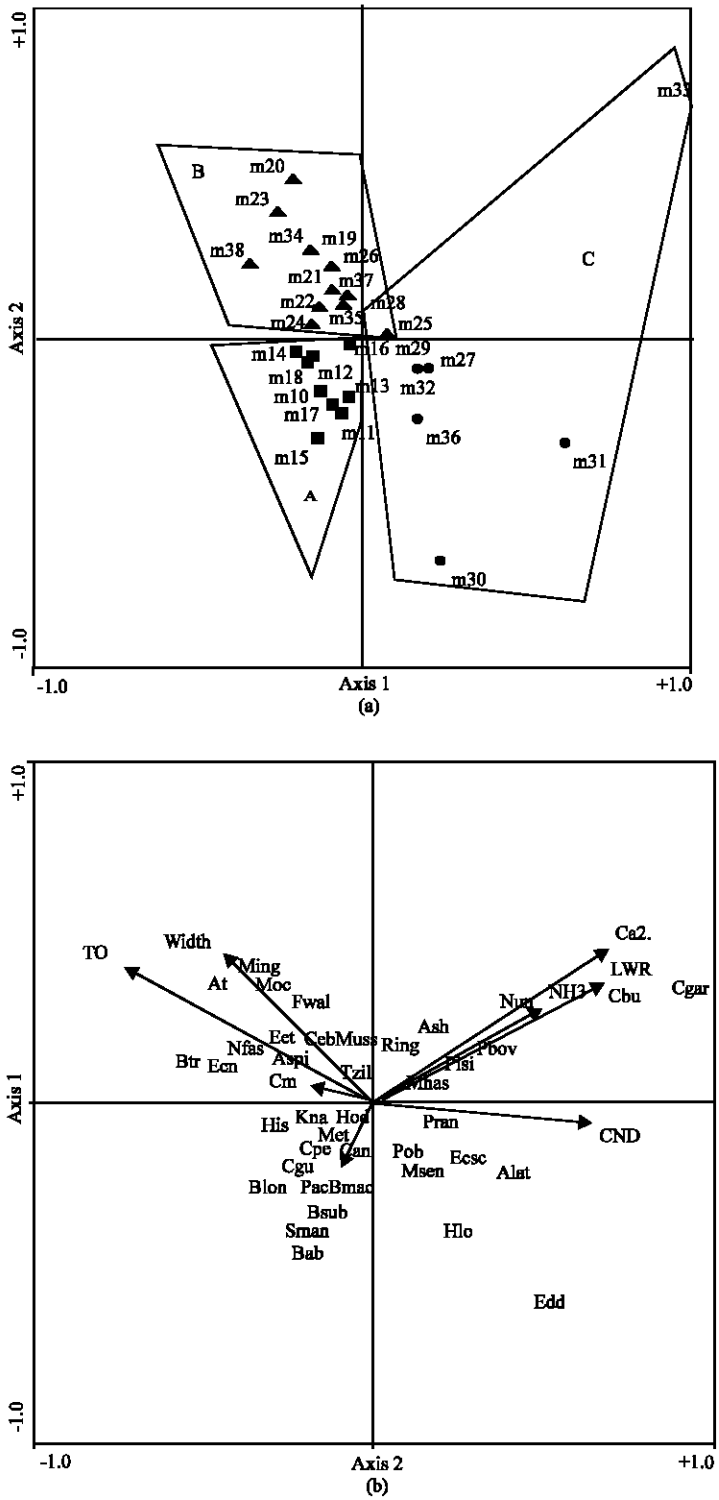

Fig. 3: Canonical correspondence analysis showing correlation between species composition and the environmental variables in the Mé River (Ivory Coast). (a): similarities between sampling sites; (b): relationship between environmental variables and species numerical abundance. Abbreviations: LWR = mixed deadwoods, leaves and rocks; Ca = calcium; Cm = canopy closure; CND = conductivity; HN3 = ammonia; Paq = aquatic plants; TO = Dissolved Oxygen

course (Table 2). These two families are dominated, respectively by *Barbus ablabes* Bleeker, 1863 and *Brycinus longipinnis* (Günther, 1864). They are followed respectively by Aplocheilidae (13.39%) and Schilbeidae (20.72%). Then come Alestidae (11.58%) in the upper course and Cyprinidae (15.18%) in the lower course.

Fish communities and environmental variables: Canonical correspondences analysis computed (Fig. 3) indicated that the first two axes express 50.6% of the cumulated variance. Forward selection and Monte Carlo permutation (199 iteration) attest that the contribution of axis 1 and 2 in data arrangement is significant ($p = 0.005$). Consequently, only these two axes were considered for data analysis. This test also allowed to select eight environmental variables accounting for 56.77% of the variance explained by 22 variables: oxygen (7.46%), deadwood-leaves-rocks (7.19%), conductivity (6.72%), width (5.98%), calcium (5.77%), ammonia (5.29%), aquatic plants (4.97%) and canopy closure (4.87%). These variables have significant ($p<0.05$) influence on the distribution of fish species.

Three groups of sampling sites are distinguished in relation to both CCA axes 1 and 2 (Fig. 3):

Group A represents sampling sites of the lower course (m10-m18) and is negatively correlated with both axes 1 and 2. The main fish species found in this area are *Barbus sublineatus* Daget, 1954; *B. longipinnis*; *Chromidotilapia guntheri* (Sauvage, 1882); *Schilbe mandibularis* (Günther, 1867) and *Hepsetus odoe* (Bloch, 1794). Sampling sites in the lower course are characterized by low aquatic plants.

Group B (m19-m26; m34; m35; m37; m38) included sampling sites above the gravel pit and is positively correlated with axis 2 and negatively correlated with axis 1. This area is distinguished by fish assemblage including *Mastacembelus nigromarginatus* Boulenger, 1898; *Amphilius atesuensis* Boulenger, 1904; *Aplocheilichthys spilauchen* (Duméril, 1861); *Barbus trispilos* Bleeker, 1863 and *Nannocharax fasciatus* Günther, 1867 and by high dissolved oxygen rates and width above the gravel pit.

Group C (m27-m33; m36) including sampling sites of the main tributary (Mafou River) of the Mé River is positively correlated with axis 1. It included the following fish species: *A. sheljuzhkoi*; *A. lateristriga*; *Clarias buettikoferi* Steindachner, 1894; *C. gariepinus*; *E. dageti dageti*; *Petrocephalus bovei* (Valenciennes, 1846); *Pollimyrus isidori* (Valenciennes, 1846); *M. senegalensis* and *Heterobranchus longifilis* Valenciennes, 1840. Sites in this area are characterized by high conductivity, calcium, mixed leaves-wood-rock and low dissolved oxygen.

DISCUSSION

Earlier works on fish communities (Teugels *et al.*, 1988) of the Mé River listed more freshwater species (n = 65) than species list showed by the present study. Also, fifteen species previously reported (*Archiaphyosemion maeseni* (Poll, 194); *Archiaphyosemion petersi* (Sauvage, 1882); *Poropanchax normani* (Ahl, 1928); *Rhexipanchax schioetzi* (Scheel, 1968); *Citharinus eburneensis* Daget, 1961; *Epiplatys bifasciatus* (Steindachner, 1881); *Epiplatys spilargyreius* (Duméril, 1861); *Labeo coubie* Rüppel, 1862; *Nematogobius maindroni* (Sauvage, 1880); *Pellonula vorax* Günther, 1868; *Polypterus endlicheri* Heckel, 1849; *Synodontis bastiani* Daget, 1948; *Tilapia mariae* Boulenger, 1899; *Thysochromis ansorgii* (Boulenger, 1901); *Tylochromis jentinki* (Steindachner, 1895)) were not found in the present sampling campaign. However, the present work listed for the first time eight freshwater species. Among these species two (*C. gariepinus* and *T. zillii*) were introduced respectively in 1973 and 1957 in Ivory Coast for fish farming (Welcomme, 1988). The number of freshwater fish species now announced in the Mé River is seventy-three.

These different results can be explained as noted Kouamélan *et al.* (2003) by fishing methods used, type of habitats sampled, sampling periods, species loss probably due to environmental alteration by human activities, the introduction of new species. According to Daget (1988), introduction of new fish species can have such a tiny influence on the pre-existent settlement. These new species could act by simple predation, by modifying the zone, making it also unfavourable or not with certain species or by exerting a food or space competition with the other species. According to Moreau *et al.* (1988), the introduced species can act by hybridization with a close species; it may be the case of the introduced species *T. zillii*, which could give the hybrid *Tilapia* by hybridization with *T. guineensis*.

Unlike the traditional observation according to which species richness increases from the upstream to the downstream (Ibarra and Stewart, 1989; Kamdem Toham and Teugels, 1998; Paugy and Bénech, 1989), this richness decreases in Mé River. This result corroborated with those from studies carried out in other Ivorian areas. In Côte d'Ivoire, Kouamélan *et al.* (2003) observed an

irregular distribution of fishes, when following the upper-lower gradient of the main channel of the Boubo River and Yao *et al.* (2005) found more species in upper Comoe basin than in the downstream. In both cases, it is due to human activities as in the case of this study. Apart from the listed forests crossed by Mé River, vegetation is a mosaic of cultures and secondary forests with cultures predominance. However, the element likely influence most directly upper-lower gradient could be the presence of a gravel pit. In fact, beside site 20, water is used to wash gravels extracted from the pit. This site corresponds to the limit of the zonation in Mé River.

Overall 54 freshwater species were collected in the Mé River basin. This list increases substantially if we include the 4 species (*Pellonula leonensis* Boulenger, 1916; *Polydactylus quadrifilis* (Cuvier, 1829); and *Sierrathrissa leonensis* Thys van den Audenaerde, 1969 in downstream and *Sarotherodon melanotheron* Rüppel, 1852 in both upper and lower courses) entering the brackish water (Albaret, 1994) and often occurring in freshwater making a total of 58 species. The presence of these species in Mé River may be explained by their euryhalinity.

In the present study, Cyprinidae and Alestidae are the most abundant fish families. These results are similar to those found in the Agnébi River by Kouadio (2001). According to Paugy and Roberts (1990), Alestidae are very widely distributed in intertropical Africa, with 30 species belonging to 10 genera in Western Africa.

The environmental variables most tightly linked with fish assemblages in the Mé River are oxygen, conductivity, canopy closure and width. These result corroborated with those from studies carried out in other tropical areas.

According to Da Costa *et al.* (2000), Total Dissolved Solids (TDS) and the conductivity (CND) are some of the most discriminating factors in the Agnébi and the Bia rivers (Ivory Coast). Hugueny (1990) noted a positive correlation between the width of the catchments area and the species richness of the Niandan River (Upper Niger). Kouamélan *et al.* (2003) noted also the influence of width, deadwood-leaves-rocks, canopy closure and oxygen on fish distribution in the Boubo River.

According to Hugueny (1990), only few Cichlidae, Clariidae and Aplocheilidae are found in low oxygen and velocityless rivers. This corroborates the presence of *C. gariepinus*, *C. buettikoferi*, *H. longifilis* and *E. dageti dageti* in the sites of Mafou.

In the Ntem River in Cameroon, Kamdem Toham and Teugels (1998) found a preference of some *Barbus* species for the high dissolved oxygen. Indeed, the large canopy closure (cm) seems to justify the presence of *B. ablabes* in some sites. Such result is highlighted in the Boubo River by Kouamélan *et al.* (2003).

However, certain fish species do not seem to have the same response to the environmental conditions according to the aquatic ecosystem. The distribution of the fish species would be thus a resultant of the individual and simultaneous actions of the various factors of the river.

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