SPECIES OF GENUS *BARBUS* AND ITS DISTRIBUTION IN THE IVORIAN HYDROSYSTEMS, WEST AFRICA

Ouanko Affoué Danielle Kouamé, Goore Bi Gouli, Kamelan Tanoh Marius*, Kouamé Kouakou Augustin, Bamba Mamadou, Kouamélan Essetchi Paul

UFR Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22
*Corresponding author: kamelan_marius@yahoo.fr / (+225) 01 10 59 44

ABSTRACT: Thirteen hydrosystems from Côte d'Ivoire were sampled between May 2000 to September 2002 and August 2004 to March 2006. A total of 8 species of *Barbus* have been identified in all the rivers studied. Among these species, *Barbus ablabes* was captured in all rivers investigated and constitutes the most abundant specie. Furthermore, 2 species were appeared only in one river. There are *B. tiekoroi* captured in Néro and *B. macinensis* in Bandana.The main factor influencing the *Barbus* species distribution in costal basins is the closure canopy. Nevertheless, in the other rivers, the distribution of *Barbus* species is influenced by pH, water temperature, width, depth, rocks and aquatic plants.
Keywords: Distribution, *Barbus* species, hydrosystems, Côte d'Ivoire, West Africa.

INTRODUCTION

Côte d'Ivoire is a West african country which has an important hydrographic network. This natural advantage gives it a high ecosystem diversity. These ecosystems support a significant animal and plant biodiversity including many of their economic functions that contribute to the development of Côte d'Ivoire. Among the fish fauna, the Cyprinidae are the most diversified family in Africa (Winfield et Nelson, 1991). These are primary fish exclusively dependent to freshwater environments (Roberts, 1975). In West Africa, this family is represented by 85 species belonging to nine genera (Paugy *et al.*, 2003): *Chelaethiops, Leptocypris, Raïamas, Garra, Labeo, Barboïdes, Prolabeo, Labeobarbus* and *Barbus*. *Barbus* is the most diversified genus in Africa. Several studies concerning *Barbus* (Lévêque, 1989; Lévêque and Guégan, 1990; Lévêque and Paugy, 1982; Teugels *et al.*, 1988; Paugy *et al.*, 2003a and b; Bamba, 2012) have been made in West Africa. Most of these works focus on inventory, systematic revision and distribution of species in the West African rivers. However, very few studies bring to light the link between environmental parameters and the distribution of *Barbus*. It is in this context that this work aimed to study the distribution of the small species of *Barbus* genus in Ivorian rivers in relation to their environmental components. These results will provide a basis for further work on the ecology of *Barbus* of West Africa.

MATERIAL AND METHODS
Study area
This study focused on three large basins (from the East to the West: Comoé, Bandama, Sassandra) and ten small coastal basins (Tanoe, Mé, Agnébi, Go, Boubo, Niouniourou, Brimé, San Pedro, Néro, Dodo) (see figure 1). A total of approximatively 400 samplings points were visited between May 2000 to September 2002 and August 2004 to March 2006. The characteristics of these hydrosystems are consigned in table 1.

Environment parameters
A total of 19 variables were used to describe environmental conditions at each sampling site. Six physical and chemical features were considered: pH (measured with a pH-meter WTW pH 330), temperature of water (measured in °C with a thermometer built into the pH-meter), dissolved oxygen (measured in mg/l with an oxymeter WTW DIGI 330), water transparency (measured to the nearest cm with a Secchi disk), conductivity and total dissolved solids (measured in μS/cm and mg/l, respectively, using a conduct meter WTW-LF 340).
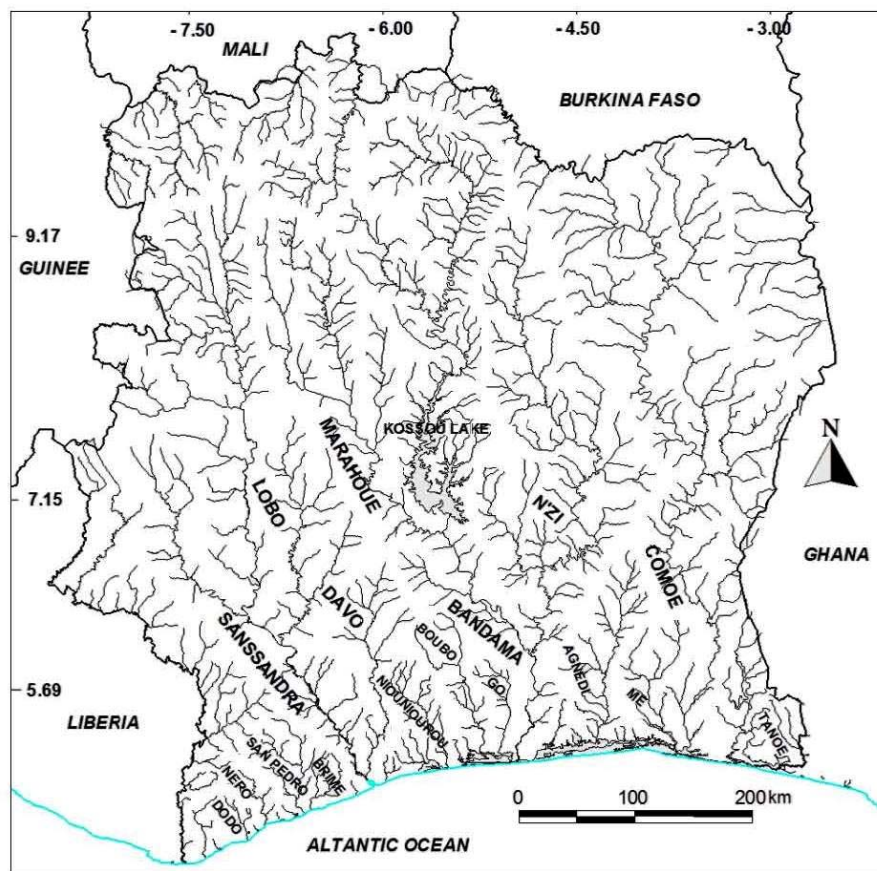
Figure 1: Hydrographic network of Côte d'Ivoire

Table 1: Hydrologic Characteristics of rivers sampling

Hydrosystems	Sources	Mouth	lenght	Watershed (Km²)
Dodo	Haute Dodo classified forest	Atlantic ocean	56	800
Néro	Taï National Park	Atlantic ocean	80	1300
San Pedro	Taï National Park	Atlantic ocean	112	3400
Brimé	Nounoua forest	Atlantic ocean	56	1200
Sassandra	Bela region; Guinée	Atlantic ocean	840	75000
Niouniourou	Nizoro region	Atlantic ocean	130	2100
Boubo	Zarebo	Tadio lagoon	130	5100
Gô	Zahéri	Tagba lagoon	100	2200
Bandama	Sirasso, Bondiali	Atlantic ocean	1050	97000
Tanoé	Techiman, Ghana	Ahy lagoon	620	16200
Agnebi	Agoua	Ebrié lagoon	200	8900
Mé	Besso forest, Adzopé	Potou lagoon	140	4300
Comoé	Fangora, Burkina	Atlantic ocean	1160	78 000

All these variables were measured *in situ* at 7 a.m and 12 a.m, at 30 cm depth, except for water transparency measured between 10 a.m and 3 p.m (MDDEP & CRE Laurentides, 2007). The habitat variables included are: current speed [measured in m/s timing the movement of plastic bottle 0.5l halffilled of water (Aboua *et al*., 2010)], depth (m), width (m), mean canopy closure and height (visually estimated and expressed in % and to the nearest m), aquatic plants (measured as % of stream surface overlain by this shelter category) and substrate type (mud, sand, clay, gravel, rock, mixed clay-mud and leaves-wood, measured as % of stream bottom surface overlain by each substrate type). These 19 environmental variables were used to interpret the variation in species at each sampling site according to Kamdem & Teugels (1997 and 1998).

Sampling

Fishes were collected with a fleet of 7 weighted monofilalement gill nets (bar mesh sizes 8, 10, 12, 15, 20, 25 and 30 mm), each measuring 30 m long by 1.5 m deep and a backpack electrofisher. Gill nets were set overnight (17–7 H) and during the following day (7–12 H). In each small tributary (maximum depths 1m), electrofishing was performed using a backpack electrofisher (Smith Root Inc., Model 12-B Pow), a generator delivering a pulsed continuous DC current (400–800V) via a hand-held anode, and a braided wire cathode. Power was supplied by a 24V rechargeable battery. A timer totalled shocking time in seconds. One operator and three assistants with dip-nets and buckets constituted the fishing team, all wearing rubber gloves and waders. Sampling was done by day and whilst moving upstream. At each site, the same catch effort (15min of fishing) was applied. All fishes collected were identified according to Lévêque *et al.* (1990, 1992) then update by Paugy *et al.* (2003a, b). Each specimen was measured to the nearest mm and weighted to the nearest 0.1 g.

Data analysis

The fish assemblage was described through taxonomic composition, spatial richness, and frequency of occurrence (FO). Frequency of occurrence is the percentage of samples in which each taxon occurred (Gbenyedji *et al.*, 2011). It was calculated to classify the fishes (Dajoz, 2000). Canonical Correspondence Analysis (CCA) using CANOCO 4.5 software was used to explore the principal patterns of fish distribution and their relation with the environmental variables. Significance tests for the general model relating assemblage structure to environmental variables were based on Monte Carlo permutation tests (1000 permutations, p 0.05). Environmental variables and fish data were log10 $(x + 1)$ transformed prior analysis.

RESULTS

Taxonomic composition and distribution

A total of 8 species of *Barbus* were collected in the 13 Ivoirian rivers: *Barbus ablabes, B. tiekoroi, B. macinencis, B. macrops, B. punctitaeniatus, B. sublineatus, B. trispilos, B. walkeri.* Among them, *B. ablabes* (100% of occurrence) was captured in all rivers investigated. The species *B. trispilos*, *B. macrops* and *B. punctitaeniatus* were frequently found in the majority of rivers with greater than 50% of occurrence. One specie (*B. sublineatus*) included 25% and 50% of occurrence was collected in four rivers (Bandama, Comoé, Mé and Sassandra). Furthermore, 3 species were appeared at least with 25% of occurrence. This is *B. macinensis* captured in Bandama, *B tiekoroi* in Néro and *B. walkeri* in Comoé and Néro.

Abundance

The relative abundance of species from different rivers is indicated in Table 2. Overall, *B. ablabes* (46%) is the most represented specie in all the rivers (n=6650) studied (Figure 2). This specie was followed by *B. trispilos* (21%), *B. macrops* (16%), *B. punctitaeniatus* (9%) and *B. sublineatus* (5%). Other species accounted for 3% of the total individuals captured in these rivers.

Table 2: List, abundance, richness and distribution of *Barbus* species in some Ivorian rivers. FO: Frequency of occurrence**; *B.:* Barbus**

	B ablabes	*B. macinensis*	*B. macrops*	*B. punctitaeniatus*	*B. sublineatus*	*B. tiekoroi*	*B. trispilos*	*B. walkeri*	Richness	Number of individuals
Agnébi	****		**	***			**		4	1106
Bandama	***	**	***	*	**				5	523
Boubo	****			**			***		3	518
Brimé	***		*	****					3	201
Comoé	***		***	*	***		***	*	6	1443
Dodo	****			**			***		3	167
Gô	****						**		2	141
Mé	***		*		*		***		3	1156
Néro	***		***	***		***	**	**	6	294
Niouniourou	****						***		2	53
Sassandra	***		***	**	**		***		5	613
San Pédro	****		***	***					3	197
Tanoé	***		*				****		3	238
F O	100	7,69	69,23	69,23	30,77	7,69	76,92	15,38	8	6650

:** less than 1%; *:** between 1% and 10%; *****:** between 11% and 50%; ******:** more than 50%
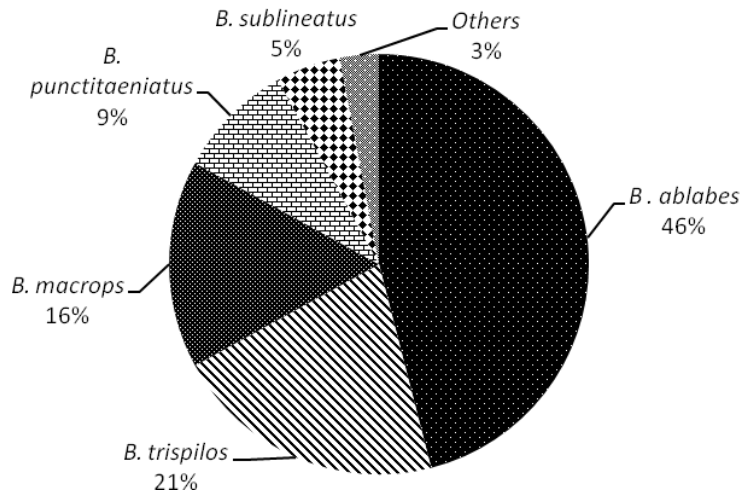
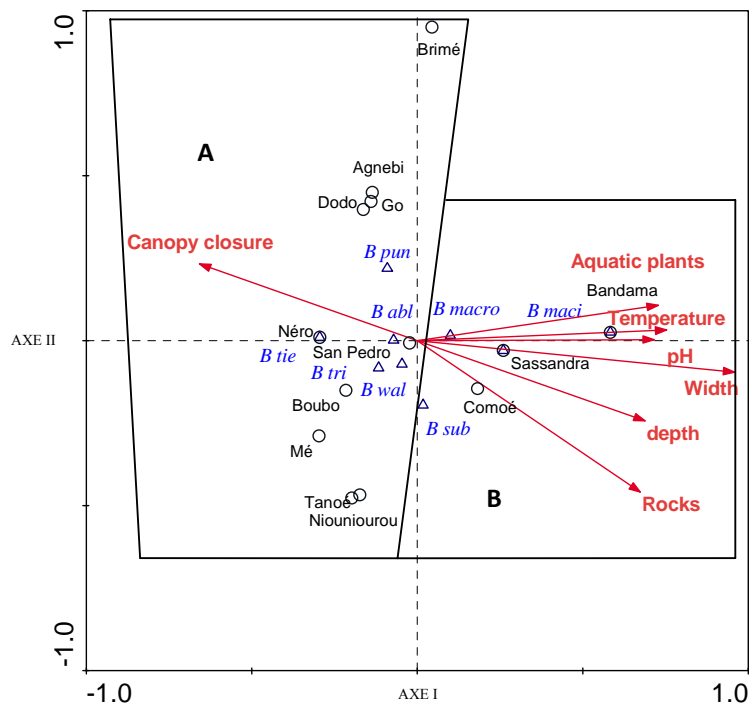**Figure 2: Numerical proportion of *Barbus* species in Ivorian rivers**

Figure 3: Canonical correspondence analysis (CCA) applied to environmental variables and to *Barbus* species collected by electrofisher. B pun: *Barbus punctitaeniatus*; **B abl:** *B. ablabes*; **B tie:** *B. tiekoroi* ; **B tri:** *B. trispilos* ; **B wal :** *B. walkeri* ; **B macro :** *B. macrops*; **B maci:** *B. macinensis*; **B sub:** *B. sublineatus*

Barbus species and environmental variables

The CCA showed the overall relationships between species distribution and environmental variables (Figure 3). Among the 19 environmental variables initially included in the analysis, only seven were significantly (p 0.05) related to assemblage structure and accounted for 53.52% of the variance explained by all the original variables: width (11.77%), water temperature (7.68%), closure canopy (7.51%), rocks (6.82%), water pH (6.65%), depth (6.61%) and aquatic plants (6.48%). Among the ordination axes extracted from the analysis, the first two axes (respectively eigenvalue $\lambda 1$ =0.27 and eigenvalue $\lambda 2$ = 0.24), explained 52% of the cumulative variance in the species data. Monte Carlo permutation attested that both axes were highly significant (p 0.008).

The axis 1 distinguishes two groups: the first group (A) comprising Bandama, Comoé and Sassandra rivers were positively correlated to width, depth, rocks, aquatic plants, pH and temperature. These rivers were associated to *B. macinensis*, *B. sublineatus* and *B. macrops* ; the second group (A) containing Brimé, Agnébi, Dodo, Gô, Néro, San Pedro, Boubo, Mé, Tanoé and Niouniourou were negatively correlated to canopy closure. These rivers were associated to *B. punctitaeniatus*, *B. ablabes*, *B. tiekoroi*, *B. trispilos* and *B. walkeri*.

DISCUSSION

The previous studies (Teugels *et al.*, 1988; Paugy *et al.*, 1994; Paugy *et al.*, 2003a and b) on *Barbus* species of Côte d'Ivoire reported that 17 species were sampled in all ivorian rivers. This work indicated 8 *Barbus* species. This difference could be due partly to the number of rivers prospected. Indeed, previous studies have covered 17 hydrosystems while our sampling covered 13 basins of Côte d'Ivoire with the exception of the Cavally , Tabou, middle and upper Sassandra, Bia, Nipoué and Bagoué basins because of the socio-political crisis in Côte d'Ivoire. This result could be also due to fishing gear and methods used, types of habitats sampled, the sampling period and the loss of species. The *Barbus* species are small in size, are mainly found in small tributaries and riffles (Kamdem and Teugels, 1998). These hydrosystems are unfortunately most sensitive to anthropogenic activities (Hugueny and Lévêque, 1999), which could adversely affect the habitats of species *Barbus*. These species will find other habitats less threatened that certainly our sample has not took into account. The distribution analysis showed that *B. ablabes* presents a large distribution across all the rivers visited followed respectively by *B. trispilos*, *B. macrops* and *B. punctitaeniatus*. This wide distribution of *Barbus ablabes* found his explanation for the sub-regional level. Indeed, *Barbus ablabes* is a widespread species in West Africa (Lévêque, 2003) as well as in the Lower Guinea (De Weirdt *et al.,* 2007). It is known from the Upper Reaches of the Senegal Basin and the Konkouré Basin (Guinea) in the western part of its distribution range West up to the Cross River (Nigeria/Cameroon) in the South East (Lévêque, 2003) and from the Cross River up to the Sanaga River in the northern part of the Lower Guinea (De Weirdt *et al.,* 2007). In addition to its ubiquitous character, *B. ablabes* is the most dominant of all species caught. This abundance is linked to his gregarious character and social as well as its omnivorous diet (Cecchi, 2007) which allows colonizing all types of aquatic environments. *Barbus tiekoroi, B. macinensis* and *B. walkeri* respectively captured in Nero, Bandama, Comoé and Nero rivers are considered accidental species. *B. tiekoroi* was known only from the Konkouré, Kolenté, and Little Scarcies basins in Guinea (Lévêque *et al.*, 1987; Lévêque 2003). This study provides the first report of *Barbus tiekoroi* in Ivorian rivers.

Entsua -Mensah and Lalèyê (2010) describe *Barbus walkeri* as a vulnerable species. The main threats posed to this fish species include effluents from mining activities in the upper reaches of coastal rivers. Also, the removal of vegetation due to mining activities and commercial timber felling in some of these areas cause increasing sediment loads, and its attendant problems to the life of the fish. *Barbus sublineatus* was reported by Paugy *et al.* (1994) in the Sassandra, Bandama Comoé Agnébi and Me rivers. This study indicates that this species was captured only in Comoé. It would be risky to assert that these species have disappeared from these rivers. However, the absence of this specie in these hydrosystems sampled both gill nets and electrofishing reflected an anthropogenic threat to this specie of *Barbus*. The canonical analysis indicates that the distribution of *B. macinencis, B. sublineatus* and *B. macrops* in Comoé Sassandra and Bandama is linked to environmental factors such as aquatic plants, temperature, width, depth, pH and rocks. These variables were highlighted by Hugueny (1990) in Niandan river from Guinea, Kouamelan *et al.* (2003) in the Boubo river and Yao (2006) Comoé river and Kamelan (2014) in rivers of Tai area. Vannote *et al.* (1980) reported that the depth and width are the habitat parameters which intervene directly on the structure and functioning of ichthyological communities. Bandama, Comoé and Sassandra are wider and deeper rivers of ivorian hydrosystems. Increasing the depth from upstream to downstream enable the installation of full water species and large size, which are mostly predators of *Barbus* species. Associated with increasing of depth, the width induces a diversification of habitats (Schlosser, 1982). These both habitat parameters offer a variety of habitats to these small fishes. These biotic benefits are exploited by *B. macinencis, B. sublineatus* and *B. macrops* in their survival strategy facing the threat of predators.

The canopy closure is the main common environmental variable which determines the distribution of *B. punctitaeniatus, B. ablabes, B. tiekoroi, B. walkeri* and *B. trispilos* in Brimé, Agnebi, Dodo, Gô, Néro, San Pedro, Boubo, Méné, Tanoé and Niouniourou. These coastal basins are located in the Ivorian forest areas. The canopy closure indicates the presence of riparian vegetation. Riparian vegetation plays a vital role in preserving the water quality of rivers is an important criterion for the survival of forest species such as *Barbus tiekoroi* and *B. walkeri*.

CONCLUSION

This study on Ivorian hydrosystems has enabled to identify the different species of genus *Barbus* and characterize its distribution in relation to the environmental variables. It emerges from this work that eight species of the genus *Barbus* are reported in the rivers studied. *Barbus ablabes* and *B. trispilos* are best represented of all species of genus *Barbus*. The distribution of species *Barbus* in coastal basins is mainly influenced by the canopy closure.

In large rivers, the distribution of species is influenced by the physico-chemical parameters (pH, water temperature, depth and width of rivers), the nature of the substrate (rocks) and aquatic plants. These results will be used for future work.

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