



RESEARCH ARTICLE

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DIVERSITY AND CONSERVATION STATUS OF THE ICTHYOFAUNA OF THE HAUT-BANDAMA FLORA AND FAUNA RESERVE, (CÔTE D'IVOIRE)

BOUSSOU K. Charles^{1*}, YOBOUE A. Nicole¹, KOUAME K. Martin¹, KRESSOU Armand¹, BENE K. Jean Claude¹, KONAN K. Félix¹, OUATTARA Mamadou² and GOURENE Germain²

¹Departement of Environment, Jean Lorougnon Guédé University, POB 150 Daloa, Côte d'Ivoire

²Aquaculture&FisheriesDepartment, Nangui Abrogoua University, POB 801, Abidjan 02, Côte d'Ivoire

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ABSTRACT

The present study was carried out in the Reserve of Fauna and Flora of Haut-Bandama in order to provide data on fish diversity and conservation status in this reserve subjected to high anthropization. For this purpose, experimental samplings were conducted using sets of gillnets, traps and dip nets from February to April 2017. As results, 31 fish species belonging to 17 families and 8 orders have been identified. The most prolific orders were Perciformes with 4 families and 9 species followed by Characiformes counting 3 families and 6 species. Cichlid fishes were more numerous with 6 species followed by families of Alestidae and Mormyridae. The most abundant species in the catches were *Brycinus macrolepidotus* (38%), *Brycinus simberi* (31%), *Chromidotilapia guntheri* (14%) and *Oreochromis niloticus* (7%). The diversity index of Shannon-Wiener was 2.8 and the evenness 0.54. These indices values were lesser than those registered before anthropogenic aggression. The conservation status of 5 species (16%) was Not Evaluated against 26 species that had the status of Least Concerned (LC) and they represented 84% of the fish community.

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INTRODUCTION

For many people in the world, fish fauna is source of income and also animal protein (Horemans, 1998; Ticheler, 2000). Moreover, fish have an ecological value, being biological indicators for surface water' quality (Whitfield and Elliot 2002, Harrison and Whitfield 2004.). They also present a cultural, educational and didactic value (Groombridge, 1992). However, the abusive exploitation of the world's fish resource has caused a significant erosion of the biodiversity of fish populations (Compagnon, 2005). In this context of degradation, protected areas (national parks and nature reserves) remain the suitable places for the preservation and protection of nature, as well as endangered species. In Côte d'Ivoire there are thirteen protected areas, comprising eight national parks and five reserves, some of them are classified as world biosphere reserves (Comoé and Taï). The Reserve of Fauna and Flora of Haut-Bandama, located in the north-central

of the country, is facing, as most of the protected areas, several malfunctions such as lack of monitoring means and qualified workforce, an inadequate and non-effective legislation and an inefficient management leading to a strong anthropization. Indeed, this reserve created since 1973 (OIPR, 2019) ceased to be under government control for more than a decade due to the military-political crisis in Côte d'Ivoire in years 2000. As a consequence, the reserve has been under diverse aggression. The watershed of this river in this reserve is undergoing significant human activities such as fraudulent gold panning and agricultural settlements (Carreti and Loyer, 2012; Dabalen and Paul, 2014) and also fishery pressure (Anonyme, 1999). The Haut-Bandama fauna and flora Reserve is crossed from north to south by the White Bandama River. Thus, this zone supposed to be a refuge area for aquatic and terrestrial fauna does not seem to be one anymore. However, studies on the fish fauna diversity and equilibrium of the hydrosystems of this reserve had been conducted before this period of disturbance (Daget and Iltis, 1965; De Merona, 1981). The present study was conducted in order to get a real idea of the impact of the degradation of this protected area on the integrity

*Corresponding author: BOUSSOU K. Charles,
Departement of Environment, Jean Lorougnon Guédé University, POB 150
Daloa, Côte d'Ivoire

of fish communities, based on an inventory of current fish fauna, its diversity and equilibrium.

MATERIAL AND METHODS

Study area and sampling sites: Covering an area of 123,000 hectares, the Haut-Bandama fauna and flora Reserve lies on both sides of White Bandama River in the central northern part of Côte d'Ivoire. It is located between 8° 10' 25.3" and 8° 38' 25.01" N and between 5° 12' 14.1" and 5° 37' 55.3" W (OIPR, 2015). The Haut-Bandama fauna and flora Reserve is crossed from north to south by the White Bandama River. Inside the reserve, several tributaries in both sides join the river's main course. The reserve occupies 3.5 % of the White Bandama watershed (Bouché, 1996). A total of six (6) sampling sites were surveyed, including four in the main course of White Bandama and two on small tributaries of the river in the reserve. According the longitudinal gradient of the river, one station (BandamaTortya) was chosen in the upstream area, two (BandamaSinain and Nakara) in the median area and three (BandamaTabakoro, BandamaYayakaha and Nambion) in the downstream part of the reserve (Fig. 1). Factors that have been taken into account in the selection of sampling sites are hydrological zonation, water permanence and site accessibility.

Fish sampling and identification: Fish samplings were carried out from February to April 2017 using two sets of 9 gillnets (bar mesh sizes 10, 12, 15, 20, 25, 30, 35, 40mm), each measuring 30m long with 2 and 2.5m deep. Traps and dip nets were also used for fishing. Fish collected were identified to species level following Paugy *et al.* (2003a & b), Decruet *al.* (2012), Sonnenberg & Busch (2009), Eschmeyer (2018) and Froese & Pauly (2018). In the purpose to complete the list of species really present, catches of fishermen encountered in or around the reserve were examined and species were identified. In addition, regular visits were made on five fish markets nearby the reserve where freshwater fish caught in the reserve were available.

Data analysis

Specific richness: The species richness (Rs) of the fish population corresponds to the total number of fish species harvested at the different sites in the reserve (Palleret *al.*, 2011). A large number of species increase species diversity. However, this method depends on the size of the samples and does not consider the relative abundance of the different species.

Shannon –Wiener index (H') of biodiversity: The Shannon diversity index (H') is used to highlight the number of species in a given community. Taking into account both species richness and species diversity, it measures the degree of organization of a stand (Amanieu and Lasserre 1982, Krebs 1989, Dajoz 2000). This index, according to Ramade (1994), is well suited to communities' comparison because it is relatively independent of sample size. It was calculated according to the equation:

$$H' = - \sum ((Ni / N) \times \log_2 (Ni / N))$$

Ni: number of individuals of a species, i ranging from 1 to S (total number of species).

N: total number of individuals in the sample

S: species richness

In natural environments, it generally varies between 0.5 (for low diversity) and 4.5 (for high diversity) (Trouilhé, 2002).

Evenness (E): Evenness is a measure of the relative abundance of different species in a community. Evenness (E) varies between 0 and 1 (Hill, 1973). It is equal to 0 when only one species dominates and 1 when all species have the same abundance, which is measured using the following formula:

$$E = H' / \log_2 S$$

where: H' = Shannon –Wiener index

E= Evenness

S= Species richness

Fish conservation status: The vulnerability, the geographical scope and the conservation status of the fish species collected during this study were determined respectively according to the link www.fishbase.de (Froese&Pauly, 2018) and the classification of the International Union for the Conservation of Nature (IUCN, 2018).

RESULTS

Fish community composition: A total of 31 fish species belonging to 17 families and 8 orders have been identified and registered (Table 1). The most prolific orders are Perciformes with 4 families and 9 species also Characiformes counting 3 families and 6 species. Cichlid fishes were more numerous with 6 species followed by families of Alestidae and Mormyridae with 4 species each. The less prolific families were Distichodontidae, Hepsetidae, protopteridae, Arapaimidae, Channidae, Anabantidae, Latidae, Polypteridae, Mochokidae, Clariidae and Schilbeidae that were monospecific. According to upstream-downstream gradient, fish species richness was higher in river middle course (17 species) and downstream area (16 species) than in the upstream course (7 species). Six (6) species were found all along the river basin in the reserve. They were *Brycinusimberi*, *Brycinusmacrolepidotus*, *Chromidotilapiaguntheri*, *Hemichromisfasciatus*, *Oreochromisniloticus* and *Clariasanguillaris*. All the fish species caught in the river tributaries through experimental fishing were met on the local markets or as subsistence catch apart from two species that were *Auchenoglanisoccidentalis* and *Schilbemandibularis*. On the other hand, 11 species were found only with subsistence or fraudulent fishermen or on the markets namely *Polypterusendlicherii*, *Parachannaobscura*, *Coptodonguineensis*, *Coptodonzillii*, *Hemichromisbimaculatus*, *Marcuseniusseagalensis*, *Mormyropsanguilloides*, *Mormyrusrume*, *Protopterusannectens*, *Enteromiusmacrops* and *Pellonulaleonensis*.

Relative abundance of species: The relative abundances of the different species along the upstream-downstream gradient of the reserve are shown in Figure 2. In the upstream of the reserve, the most abundant species in the catches was *Brycinusmacrolepidotus* (38%). It was followed by *Brycinusimberi* (31%), *Chromidotilapiaguntheri* (14%) and *Oreochromisniloticus* (7%). The other species gathered (n = 3) represented only 10% of the catches. In the middle course of the reserve, the most common species were *Brycinusimberi* and *Brycinusmacrolepidotus* (12% each), *Labeoparvus* (9%) and *Hydrocynusforskalii* (7%). In the downstream area, the most prevalent species in the samplings was *Brycinusimberi* (25%). It was followed by *Brycinusmacrolepidotus* (17%), followed by *Hemichromisfasciatus* and *Labeoparvus* with (7% each). The remaining species represented 44% of the specimens caught.

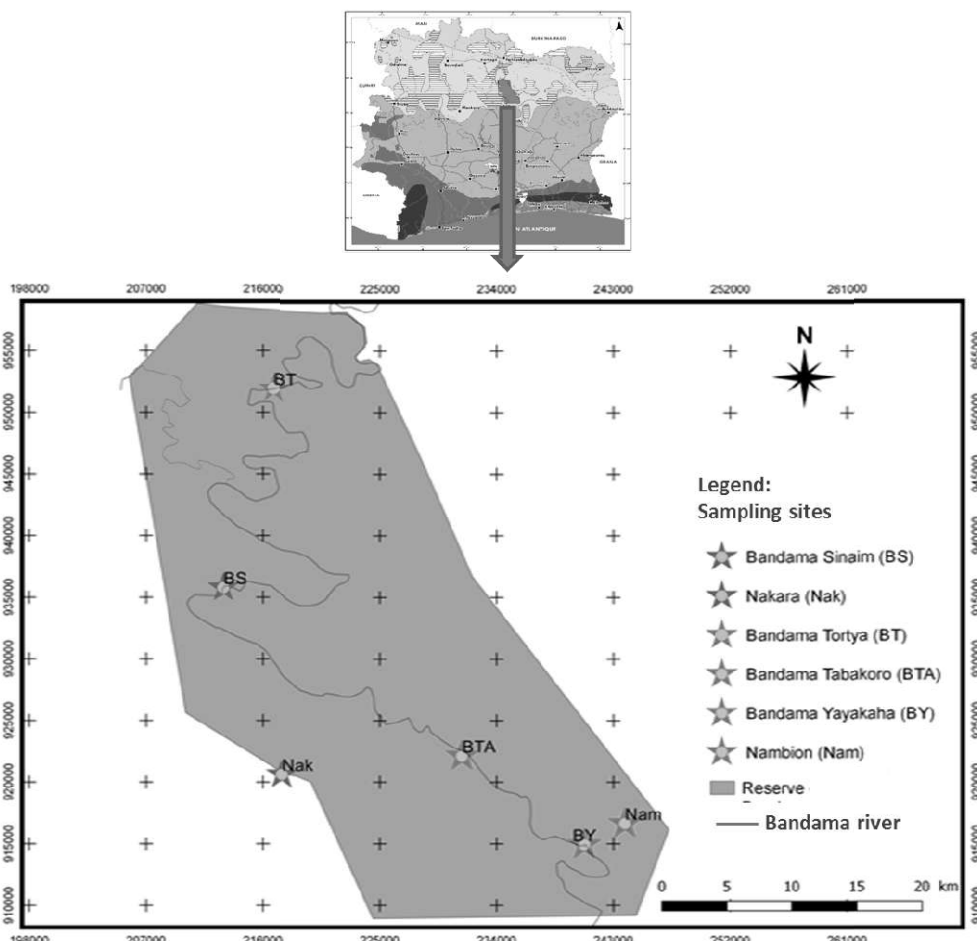


Figure 1. Location of Haut-Bandama fauna and flora Reserve in Côte d'Ivoire and sampling sites

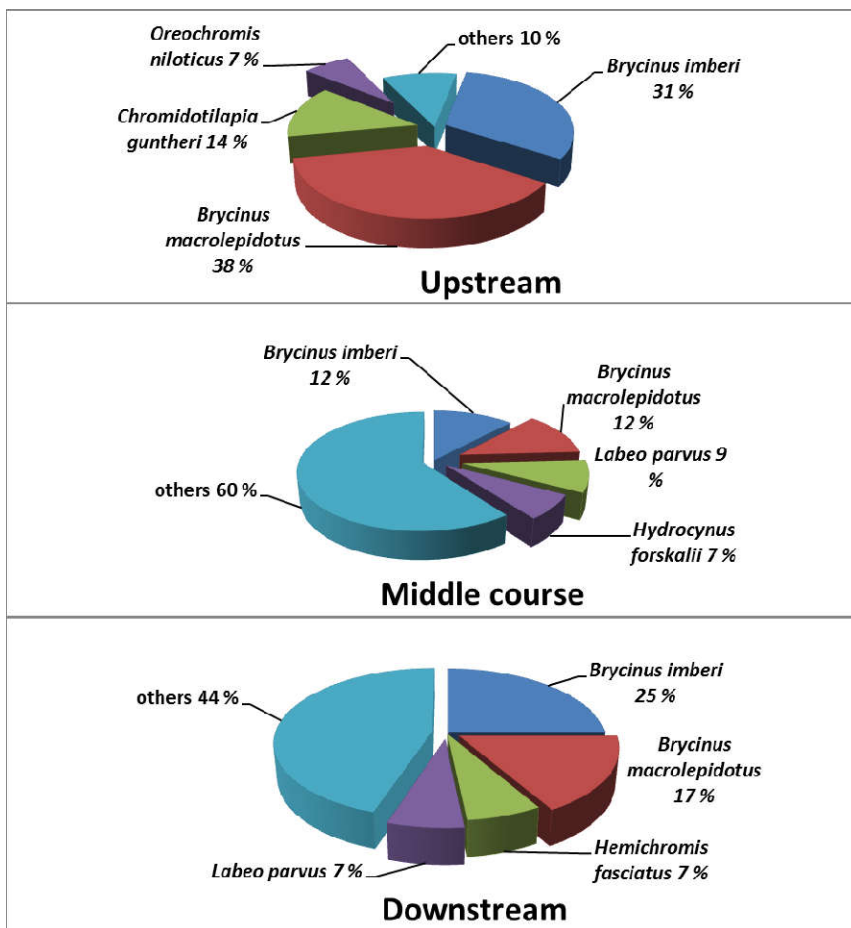


Figure 2. Relative abundances of fish species according to the downstream upstream gradient of the Haut-Bandama Flora and Fauna Reserve

Table 1. List of fish species registered in Bandamariver and its tributaries in the Haut-Bandama Flora and Fauna Reserve (Côte d'Ivoire)

Orders	Families	Species	Experimental fishing			Subsistence or fraudulent fishing	Vernacular names
			Downstream area	Middle course	Upstream area		
Characiformes	Alestidae	<i>Brycinusimber</i>	+	+	+	+	Couléni
		<i>Brycinusmacrolepidotus</i>	+	+	+	+	Koro
		<i>Hydrocynusforskahlii</i>		+	+	+	Wouroudjéguè
		<i>Alestes baremoze</i>	+			+	Sardine
	Distichodontidae	<i>Distichodusrostratus</i>		+		+	Galia
	Hepsetidae	<i>Hepsetusodo</i>	+	+		+	Wouroudjéguè
Clupeiformes	Clupeidae	<i>Pellonulaleonensis</i>				+	Mimi lago
Cypriniformes	Cyprinidae	<i>Labeoparvus</i>	+	+		+	Bama
		<i>Enteromiusmacrops</i>				+	Zarani
Lepidosireniiformes	Protopteridae	<i>Protopterusannectens</i>				+	Wono
Osteoglossiformes	Mormyridae	<i>Petrocephalusbovei</i>	+	+		+	Nana
		<i>Marcuseniusseagalensis</i>				+	Nana
		<i>Mormyropsanguilloides</i>				+	Sonana
		<i>Mormyrusrume</i>				+	Nana
	Arapaimidae	<i>Heterotisniloticus</i>		+		+	Fana
Perciformes	Cichlidae	<i>Chromidotilapiaguntheri</i>	+	+	+	+	Thébéni
		<i>Hemichromisbimaculatus</i>				+	Thébéni
		<i>Hemichromisfasciatus</i>	+	+	+	+	Thébéni
		<i>Coptodonzillii</i>				+	Thébéni
		<i>Oreochromisniloticus</i>	+	+	+	+	Thébéni
		<i>Coptodonguineensis</i>				+	Thébéni
	Channidae	<i>Parachannaobscura</i>				+	Sinogodjéguè
	Anabantidae	<i>Ctenopomapetherici</i>	+	+		+	Thébénifiman
	Latidae	<i>Latesniloticus</i>	+	+		+	Salé
Polypteriformes	Polypteridae	<i>Polypterusendlicherii</i>				+	Cracachia
Siluriformes	Mochokidae	<i>Synodontisbastiani</i>		+		+	N'godoro
	Claroteidae	<i>Chrysichthysmaurus</i>	+	+		+	Machoiron vrai
		<i>Chrysichthysnigrodigitatus</i>	+			+	Machoiron
		<i>Auchenoglanisoccidentalis</i>	+				
	Clariidae	<i>Clarias anguillaris</i>	+	+	+	+	Manogo
	Schilbeidae	<i>Schilbemandibularis</i>	+	+			
8	17	31	16	17	7	29	

Table 2. Values of the diversity index (H') and evenness (E) of fish community in the hydrosystems of Haut-Bandama Fauna and Flora Reserve (North, Côte d'Ivoire)

River considered portion	Shannon-Wiener Index (H')	Evenness (E)
Upstream	1.54	0.55
Middle course	2.85	0.70
Downstream	2.42	0.61
All the sampling area	2.80	0.54

Table 3. Conservation status, vulnerability and trophic organisation of fish community in the hydrosystems of Haut-Bandama Fauna and Flora Reserve (North, Côte d'Ivoire)

Species	Conservation status	Vulnerability	Trophiclevel	Trophic group
<i>Latesniloticus</i>	Least Concerned (LC)	Moderate to highvulnerability (47 %)	4.5	High-level carnivores
<i>Hepsetusodoe</i>	Least Concerned (LC)	Lowvulnerability (16%).	4.1	
<i>Hydrocynusforskahlil</i>	Least Concerned (LC)	Moderatevulnerability (39%)	4.0	
<i>Hemichromisbimaculatus</i>	Least Concerned (LC)	Lowvulnerability (19%)	3.9	Mid-level carnivores
<i>Protopterusannectens</i>	Least Concerned (LC)	Moderatevulnerability (42 %)	3.8	
<i>Mormyropsanguilloides</i>	Least Concerned (LC)	Moderate to highvulnerability (47%)	3.8	
<i>Polypterusendlicherii</i>	Not Evaluated	Moderate to highvulnerability (48 %)	3.8	
<i>Parachannaobscura</i>	Not Evaluated	Moderate to highvulnerability (47 %)	3.4	
<i>Clarias anguillaris</i>	Least Concerned (LC)	Moderate to highvulnerability (54 %)	3.4	
<i>Schilbemandibularis</i>	Least Concerned (LC)	Moderate to highvulnerability (52%)	3.4	
<i>Brycinusimberi</i>	Least Concerned (LC)	Lowvulnerability (10 %)	3.3	
<i>Pellonulaleonensis</i>	Least Concerned (LC)	Lowvulnerability (10%)	3.3	
<i>Petrocephalusbovei</i>	Not Evaluated	Lowvulnerability (13 %)	3.3	
<i>Marcuseniussenegalensis</i>	Least Concerned (LC)	Moderatevulnerability (35 %)	3.2	Omnivores-herbivores-detritivores
<i>Hemichromisfasciatus</i>	Least Concerned (LC)	Lowvulnerability (14%)	3.2	
<i>Ctenopomapetherici</i>	Least Concerned (LC)	Low to moderatevulnerability (31 %)	3.2	
<i>Chrysichthysnigrodigitatus</i>	Least Concerned (LC)	High vulnerability (60 %)	3.2	
<i>Alestes baremoze</i>	Least Concerned (LC)	Lowvulnerability (22 %)	3.1	
<i>Enteromiusmacrops</i>	Least Concerned (LC)	Low to moderatevulnerability (33%)	3.0	
<i>Synodontisbastiani</i>	Least Concerned (LC)	Low to moderatevulnerability (25 %)	2.9	
<i>Auchenoglanisoccidentalis</i>	Least Concerned (LC)	Moderatevulnerability (38 %)	2.9	
<i>Brycinusmacrolepidotus</i>	Least Concerned (LC)	Low to moderatevulnerability (31%)	2.8	
<i>Coptodonguineensis</i>	Least Concerned (LC)	Lowvulnerability (19 %)	2.8	
<i>Heterotisniloticus</i>	Least Concerned (LC)	Moderate to highvulnerability (55 %)	2.7	
<i>Chrysichthysmaurus</i>	Least Concerned (LC)	Moderate to highvulnerability (46%)	2.7	
<i>Distichodusrostratus</i>	Least Concerned (LC)	Moderate to highvulnerability (52 %)	2.6	
<i>Chromidotilapiaguntheri</i>	Least Concerned (LC)	Lowvulnerability (25 %)	2.6	
<i>Mormyrusrume</i>	Not Evaluated	High vulnerability (63%)	2.5	
<i>Coptodonzillii</i>	Not Evaluated	Low to moderatevulnerability (27 %)	2.5	
<i>Labeoparvus</i>	Least Concerned (LC)	Moderate to highvulnerability (51%)	2.0	
<i>Oreochromisniloticus</i>	Least Concerned (LC)	Low to moderatevulnerability (30 %)	2.0	

In subsistence and fraudulent catches, the most encountered and abundant fish species (Fig. 3) were *Oreochromisniloticus* (26 %), *Heterotisniloticus*(20 %), *Synodontisbastiani* (18 %), *Clariasanguillaris* (15%), *Latesniloticus* (13%) and *Chrysichthysnigrodigitatus* (8%).

Fish diversity index and evenness: The values of the diversity index (H') and evenness of fish populations calculated in the different sectors according to the longitudinal gradient of the Haut-Bandama fauna and flora Reserve are presented in table 2. The highest diversity index (2.85) and evenness (0.70) were obtained in middle course and the lowest values of these indices (H'=1.54 and E= 0.55) were registered in the upstream of the reserve. In the overall hydrosystem, the diversity index was 2.8 and the evenness 0.54.

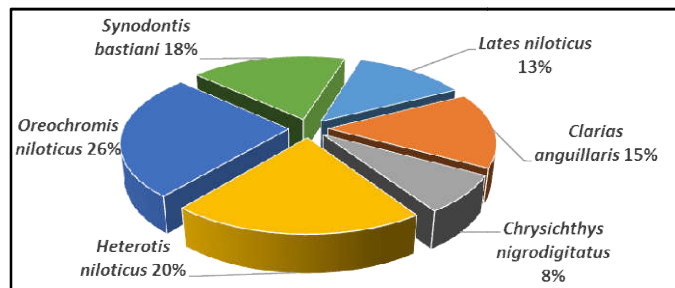


Figure 3. Relative abundance of main fish species from subsistence and fraudulent fishing in the Haut-Bandama Flora and Fauna Reserve

Fish vulnerability and conservation status: According to their conservation status, the fish species collected during this study could be grouped into two statuses, not Evaluated status and of Least Concern (LC) status (Table 3).

Then, among the 31 species collected, the conservation status of five (5) of them was not yet evaluated (16%). The remaining 26 species had the status of Least Concerned (LC) and they represented 84% of the fish community. The vulnerability of these species according to IUCN, 2018 is showed five (5) categories: low vulnerability, low to moderate vulnerability, moderate vulnerability, moderate to high vulnerability and high vulnerability. Two species were found to be highly vulnerable (*Chrysichthysnigrodigitatus* and *Mormyrusrume*), ten (10) were designated to have moderate to high vulnerability, four (4) were with moderate vulnerability, six (6) were low to moderate vulnerability and nine (9) were with low vulnerability. According to the trophic structure of consumers (Table 3 and Figure 4), the mid-level carnivores species were more numerous (16 species) followed by omnivores-herbivores-detritivores species (12 species) and high-level carnivores (3 species).

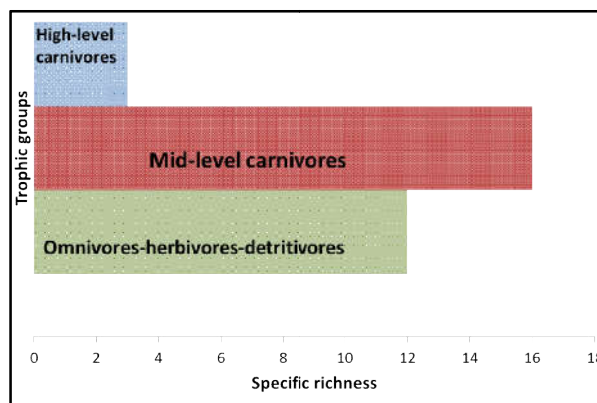


Figure 4. Specific richness of the different trophic groups of fish community in the hydrosystems of Haut-Bandama Fauna and Flora Reserve (Côte d'Ivoire)

DISCUSSION AND CONCLUSION

The inventory of fish fauna in the hydro systems of the Haut-Bandama Fauna and Flora Reserve has permitted to identify 31 species from 8 orders and 17 families. This specific richness is lower than that registered by Aboua *et al.* (2015) who inventoried 47 species of fish in the same area, not only in the reserve, but in the part of the river Bandama before the lake Kossou also called White Bandama. So the difference in fish richness could be justified by the differences in fishing methods used, the habitat types sampled, the areas surveyed, the fishing effort and the sampling period (Kouamélan *et al.*, 2003). Indeed, Aboua *et al.* (2015) used different gears, including an electric fishing gear, which is not very selective. The analysis of fish community composition revealed that this reserve is dominated mostly by Perciformes, Siluriformes and Characiformes. The same observations have been made in other rivers and watersheds in Côte d'Ivoire (Paugy *et al.*, 1994, Yao *et al.*, 2005 and Kouamélan *et al.*, 2008). At the fish family level, the most prolific in this reserve were Cichlid fishes with 6 species followed by Alestidae and Mormyridae, each counting for four (4) species. However, the investigations made by Aboua *et al.* (2015) in this part of river Bandama basin showed that Schilbeidae, Alestidae and Cichlidae dominated the community. At the specific level, the most frequently encountered species in everywhere in the reserve were *Brycinusimberi*, *Brycinusmacrolepidotus*, *Chromidotilapiaguntheri*, *Hemichromisfasciatus*, *Oreochromisniloticus* and *Clariasanguillaris*. Meanwhile, according to Mérona (1981), this area of Bandama basin is dominated by *Schilbemystus*, *Brycinuslongipinnis* and *Hepsetusakawo*. The species richness varies according to the upstream-downstream gradient of the reserve. It was higher in river middle course (17 species) and downstream area (16 species) than in the upstream course (7 species).

The relative weakness of the upstream species richness is due to the fact that in this sector only one station was retained and only in the riverbed while in the other sectors, there were more than one station and some were located in the tributaries. In addition, the median and downstream areas were characterized by spatial heterogeneity of riparian vegetation. According to Didier (1997), environmental heterogeneity ensures a higher species richness than that likely to be encountered under homogeneous environmental conditions. With regard to the general degree of organization of the reserve's ichthyological stand, the values of the Shannon index ($H' = 1.54$ to 2.85) and equitability ($E = 0.55$ to 0.70) were in the same trends than that reported in the Haut-Bandama River by Aboua *et al.* (2015) which were respectively 2.87 and 0.74 . Moreover, these authors found that these values of diversity were the smallest alongside all the course of Bandamariver. However, in this reserve before anthropogenic pressure, De Mérona (1981) studies registered diversity values evolving between 2.40 and 3.27 . And equitability ranged from 0.58 to 0.78 . Thus, the actual relatively low values of these indices confirm that aquatic media in this reserve under anthropogenic aggression are seriously disturbed. Indeed, a reserve is basically a sanctuary, a refuge area for species and therefore should have a higher diversity of species and a more balanced settlement organization. A general definition of "disturbance" has been given by Pickett and White (1985) and modified by Reshet *et al.* (1988): "any relatively discrete event in time that is characterised by a frequency, intensity, and severity outside a predictable range, and that disrupts ecosystems, community, or

population structure, and changes resources or the physical environment". Regarding the conservation status of fish community, all the species encountered were of a status not yet evaluated or least concerned. Their vulnerability oscillates between low vulnerability and high vulnerability. Species of interest for conservation would certainly have already disappeared due to the pressure exerted on the hydrosystems of the reserve. Relatively to trophic organization of consumers, these studies revealed that mid-level carnivorous were more abundant in terms of species richness compared to omnivores-herbivores-detritivores group. However, in freshwater ecosystems, fish assemblages in tropical river food webs are characterized by high taxonomic diversity, diverse foraging modes, omnivory, and an abundance of detritivores (Jepsen and Winemiller, 2002). But as in the present study, numerical abundance has not been taken in account for trophic level investigations, the dominance of trophic groups could not be determined objectively. On the other hand, according to de Bernardi and Giussani (1990), in freshwater ecosystems the trophic structures of consumers are probably determined on the basis of available food. In conclusion, the present study shows that the anthropogenic disturbance in the reserve has not led to a severe shift in the fish fauna composition but rather a decrease in the fish community equilibrium. No threatened fishes have been registered during this study in the reserve. Thus some measures (workforce training, legislative and facilities) are required to minimize or annihilate totally anthropogenic disturbance in this reserve.

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