JFLS | 2018 | Vol 3(2) | Pp 9-13

Research Article

Biological evaluation of the water quality of Haut Bandama Reserve (Côte d'Ivoire)

Aboua Benié Rose Danielle* Konan N'Goran Léonce, Berté Siaka, Kouamélan Essetchi Paul

Hydrobiology Laboratory, UFR Biosciences, University Felix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire

ISSN: 2456-6268

ARTICLE INFO
Received: 18 September 2018
Accepted: 13 November 2018
Available online: 01 December 2018

KEYWORDS
Biotic Integrity
Haut Bandama Reserve
Bandama River
Côte d'Ivoire

***CORRESPONDENCE**
abouabrd@yahoo.fr

ABSTRACT

Water quality of Haut Bandama Reserve was assessed by analyzing the composition of fish communities following the eviction of the populations living in the reserve. The sampling took place during the months of February and November 2017 using a battery of gillnets. 589 fish specimen belonging to 7 orders, 14 families, 25 genera and 33 species was collected. The study of the fish assemblage structure showed that the Cichlidae family was qualitatively most varied with seven species. The application of the fish index of biotic integrity (F-IBI) allowed that the water quality of the stations inside the reserve is excellent (ST3) to medium (S1, S2, S4, S7) and low (S5) than one located outside the reserve (S6) which describes us very poor".

INTRODUCTION

Freshwater ecosystems account for less than 1% of the land but provide many goods and services, whether to agriculture, industry, communities or households (WWF, 2002). However, these streams are strongly influenced by the geology, vegetation and physiography of the valley in which they are located, and more, by human activities, which alter the nature of soils and hydrologic routes, inevitably affect this land-water interface (Schlosser, 1991).

In Côte d'Ivoire, the Bandama River, like some streams, show signs of eutrophication characterized by the presence of invasive plants, by the use of fertilizers and pesticides near large plantations and discharges from factories (Halle and Bruzon, 2006). Works conducted by Aboua et al. (2012) on the assessment of water quality on the Basin of the Bandama River based on fish revealed that some stretches of basin were poor quality. Despite this large area of study, there is no data on the water quality of the Bandama River inside Haut Bandama Reserve, between Marabadiassa and Niakaramadougou localities. This reserve, which become patrimony of the Ivorian State since March 21,1973 (OIPR, 2006), was exploited by the surrounding population until 2013, the date on which a policy of resumption of this patrimony was started by the Ivorian government following a program of eviction of the villagers. However, according to Camargo et al. (2004), increased urbanization, forest exploitation and the use of agricultural inputs in modern agriculture influenced at various levels the hydrosystems. This causes an accumulation of nutrients in the rivers, responsible for their pollution. Therefore, it has been important to assess the water quality of Bandama in the Haut Bandama Reserve, in order to measure the impact of human activities in this part of the river, and to strengthen the conservation and enhancement of the hydrosystem of this reserve.

The objective of this study is to use fish assemblages as biological indicators to quantify the state of health of the Bandama River stretch in the Haut Bandama Reserve.

MATERIALS AND METHODS

Study area

The reserve of fauna and flora of Haut Bandama is located between longitudes West 8°40' and 8°20' and latitudes North 5°30' and 5°20' (Fig. 1). This reserve was established by Decree No. 73-113 of 21 March 1973 and covers an area of 123 000 ha (Kpan, 2015). The Haut Bandama Reserve is located between the departments of Katiola and Niankaradougou. It is limited in the North by the sub-prefectures of Marandallah, Niakaramandougou and Fronan, in the South by Bodokro, in the East by Katiola prefecture and in the West by Téningboué (Kpan, 2015). The vegetation is composed of savanna dotted with big trees (Aboua, 2012).

The sampling stations in this study were located on the main channel. Seven sites were sampling: Djiminisso (S1),

Yayakaha (S2), Oulékaha (S3), Zouahiry (S4), Agakro (S5), Bananeraie (S6) and Sirikikaha (S7) (Figure 1). Runoff from agricultural activities (banana, sugar) as well as smaller municipalities (Marabadiassa, Fronan, Niakara, Tortiya) and neighboring villages, and artisanal gold mining activities in the Tortiya locality were discharged in the main course of the river in the reserve of Haut Bandama. The study zone was sampled during the months of February and November 2017.

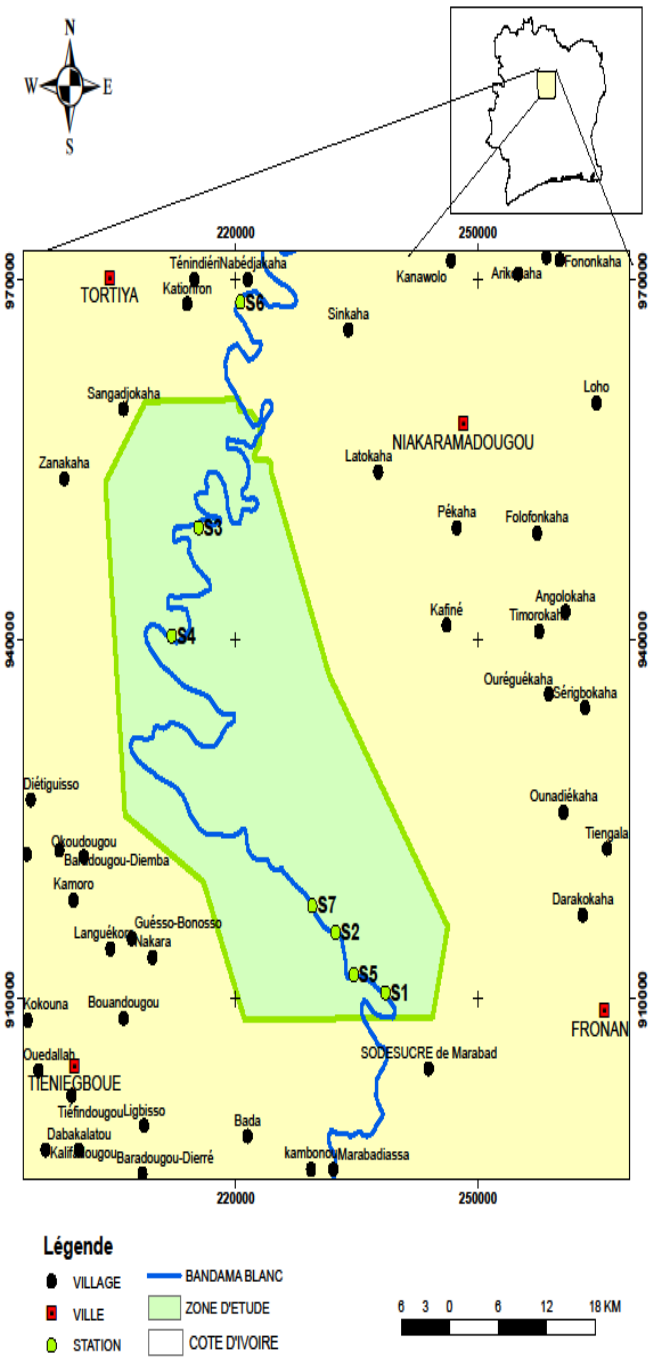

Fig. 1: Geographical location of Haut Bandama Reserve and the different sampling stations

Environmental variables

Local physical variables were noted (Table 1), as follow: the channel width, the channel depth, the flow velocity, and substrate type. Distance from source was measuring using a digital plannimeter from topographic maps. They were based on Aboua et al. (2012) method. The average value of each variables was computed.

Fish sampling

Fish assemblages were sampling following a standardized sampling protocol. A battery of nine gill-nets with mesh sizes of 8, 10, 14, 15, 18, 20, 25, 30 and 40 mm were used. Each net measure 30 m long by 1.5 m deep. Gill-nets were set parallel to the bank at 1.5 m depth during high and low water periods. Net were set overnight (5.00 p.m. - 7.00 a.m.) and during the follow day (7.00 a.m. - 12.00 p.m.).

Selection of fish assemblage metrics and index development

Many fish assemblage descriptors were considered as possible index metrics. Each of them are biological indicators. However, fish assemblage metrics included in the study of the reserve of Haut Bandama river quality were chosen based on pre-existing fish IBI study in Bandama river. The metrics were selected as metrics for inclusion in the final index as follow: number of native species, biomass of natives, number of benthic Siluriform species, number of Cichlid species, percentage of individual invertivores and percentage of individual herbivores (Aboua et al., 2012). Biological descriptors and environmental variables were transformed to achieve a normal distribution as much as possible (Table 1 and 2). We computed multilinear regressions between fish assemblage descriptors and environmental variables. To reduce the cases of co-linearity (Oberdorff et al., 1995), we used a forward stepwise selection of the environmental variables combined with a ridge regression. We used the standardized residuals as scores. The final index score at each station is the sum of the standardized residuals of the metrics. The biotic integrity classes suggested by Karr et al. (1986) were selected. However, the index values associated with each of the classes on the Bandama River Basin by Aboua (2012) were chosen (Table 3) for the interpretation of the index in the Haut Bandama Reserve. All statistical analyses were performed with the software STATISTICA 7.1.

Table 1: Environmental variables considered for index development

Variables	Code	Descr-iption	Rang	Transfor-mation
Flow velocity	VEL	m/s	0.1 - 0.33	Cos (x)
Depth	DEP	m	0.4 - 1	Log10 (x)
Distance from source	DS	km	393 - 559	aucune
Width	WID	m	16 - 50	Aucune
Sand	SAN	%	05 - 25	Cos (x)
Rock	ROC	%	0 - 45	Cos (x)
Dead woods, leaves, roots	WLR	%	15 - 55	Cos (x)
Gravel	GRA	%	0 - 25	Cos (x)
Clay-mud	CM	%	05 - 25	Cos (x)

Table 2: Fish assemblage descriptors tested for relationships with environmental variables

Metrics	Code	Transfo-rmation
Nombre des espèces Natives	NEN	Cos (x)
Biomasse des Natives	BN	Rand (x)
Nombre des espèces benthiques Siluriformes	NEBS	Cos (x)
Nombre des espèces de Cichlidae	NEC	Cos (x)
Pourcentage des individus Invertivores	INV	Cos (x)
Pourcentage des individus Hertivores	HER	Cos (x)

RESULTS AND DISCUSSION

Structure of fish assemblages

A total of 589 fish were collected in the all sampling sites of Haut Bandama Reserve (Table 4). These fish are grouped into 7 orders, 14 families, 25 genera and 33 species. The most qualitatively represented orders are Siluriformes with four families (28.57% of inventoried families) and eight species (24.24% of inventoried species) and Perciformes with three families (21.42%) and nine species (27.27%). %) including the Cichlidae family with seven species. The species *Brycinus macrolepidotus*, *Labeo coubie* and *Chrysichthys nigrodigitatus* were collected in all visited stations (occurrence = 100%). The highest species diversity, H '= 2.89, was obtained at Oulekaha (S3) with an avenness E = 0.87 for 23 fish species.

Fish-Index of biotic integrity (F-IBI)

The residuals of the biological variables obtained after the multiple stepwise linear regression were summed by station to give the final Fish-Index of biotique integrity (F-IBI) (Table 5). The index reaches its highest value at Oulekaha station (S3) (5.26), described as "excellent" and its smallest value at Bananeraie station (S6) (-6.25) qualified as "very poor".

The Djiminisso (S1), Yayakaha (S2), Zouahiry (S4), and Sirikikaha (S7) stations are of "medium" water quality with values between]-1.66 ; 1.33]. The Agakro station (S5) with an index of -1.87 has a quality water " poor ".

The ichthyological population of the Haut Bandama Reserve sampled in February and November 2017 counted 33 species. This number is lower than that found by Aboua et al. (2012) and Traoré (1996). Many species were not caught during our samplings. This could be related, of course, to several causes such as sampling methods, different aquatic ecosystems, habitats visited, sampling periods, etc. (Gourène et al., 1999 ; Kouamélan et al., 2003 ; Yao et al., 2005), but in this study, the low specific richness noted is particularly due to the small dimension of the catchment area (Haut Bandama Reserve) with 1230 km^2 against the watershed area of the Bandama river with 97500 km^2.

The qualitative inventory of this study allowed that Perciformes and Siluriformes are the most important orders in families and species. These results were also observed by Aboua et al. (2012) in the Bandama River, Yao et al. (2005) in the Comoé River and Kouamé et al. (2008) in the Sassandra River. According to Lévêque and Paugy (1999), this important presence of these orders in watercourses was due to a high fertility (more than 150 000 eggs per kg of female) among the families of these orders.

Furthermore, the water quality of the Haut Bandama Reserve has been evaluated using the Fish-Index of Biotic Integrity (F-IBI). The index of biotic integrity is a multimetric index that studies the fish communities present in the watercourse to assess the state of health of the ecosystem, to measure its response to the physicochemical changes produced by the hydrological changes and possibly, to conclude on his sensitivity.

This index, applied in the Haut Bandam Reserve, showed that the Bananeraie station (S6) is the most degraded (IIB-P = -6.25). This result could be justified by the fact that, this station is much influenced by human activities. Located outside the reserve and inside a banana plantation, it has not been the subject of eviction of villagers. In addition, this station receives runoff from workers households of banana plantation but mainly, runoff water containing pesticides used for the maintenance of banana plantations and effluents from the artisanal activities of the Tortiya gold mine. This demonstrated the presence of organic and chemical pollution at this station. This station, also, recorded the lowest species richness (n = 12). Which would be a consequence of the different disturbances noted. The studies of Bode *et al.* (2002) were also emphasized.

The calculated index showed that the Oulekaha station (S3) was qualified as "excellent". This quality of water could be explained by a low influence of anthropic pressures. Indeed, this station is located in the part of the reserve where the eviction of the villagers was almost effective. This has been resulted to the ecological level by a high specific richness (n = 23). This station was the most diversified of the all stations sampled in the reserve with a Shannon index and evenness respectively equal to 2.89 and 0.87. The increase in the index of biotic integrity in this station has also resulted, among other things, in a good organization of the trophic level. Indeed, the relative abundance of specialized diet species is higher in this station with 75% of piscivore species found, as well as 75% of herbivores, 69.23% of invertivores and 50% of phytoplanktivores. This station also recorded the presence of benthic species, nearly half of the species collected in this station (47.82%), thus giving evidence to an environment in restoration. Indeed, benthic ecosystems are permanent indicators of the state of the environment because, they integrate local ecological characteristics and are subject to natural fluctuations or generated by human activities (Barnay, 2005).

Other stations that are "medium" or "poor" quality still show signs of disturbance due to the presence of certain riparian populations who carry out agricultural activities on these sites.

Table 3: Interpretation of Index of biotic integrity based on fish (Aboua, 2012)

Index class	Excellent	Good	Medium	Poor	Very poor
Index value	] 3.69 ; + ∞ [	] 1.33 ; 3.69]	] -1.66 ; 1.33]	] -5.91 ; -1.66]	] - ∞ ; -5.91]

Table 4: Distribution of fish species sampled in the Haut Bandama Reserve in February and November 2017.

				STATIONS						
ORDERS	FAMILIES	SPECIES	Ecology Aboua et al. (2012)	S1	S2	S3	S4	S5	S6	S7
Polypteriformes	Polypteridae	*Polypterus endlicheri*	Pis, Ben	*		*				
Clupeiformes	Clupeidae	*Pellonula leonensis*	Inv, Pel						*	*
Osteoglossiformes	Mormyridae	*Marcusenius senegalensis*	Inv, Ben		*		*	*		
		Marcusenius ussheri	Inv, Ben	*						
		Mormyrops anguilloïdes	Pis, Ben				*			
		Mormyrus rume	Inv, Ben			*	*			
		Petrocephalus bovei	Inv, Ben		*	*	*	*		
Characiformes	Hepsetidae	*Hepsetus odoe*	Pis, Ben	*						
	Alestidae	*Brycinus imberi*	Her, Ben						*	*
		Brycinus macrolepidotus	Her, Pel	*	*	*	*	*	*	*
		Brycinus nurse	Inv, Pel			*		*		
		Hydrocynus forskalii	Pis, Pel		*	*				*
	Distichodontidae	*Distichodus rostrarus*	Her, Ben	*		*	*			*
Cypriniformes	Cyprinidae	*Barbus macrops*	Inv, Benpel		*	*			*	
		Labeo coubie	Phy, Benpel	*	*	*	*	*	*	*
		Raiamas senegalensis	Inv, Ben	*				*	*	*
Siluriformes	Claroteidae	*Auchenoglanis occidentalis*	Inv, Ben	*	*	*				
		Chrysichthys nigrodigitatus	Inv, Ben	*	*	*	*	*	*	*
	Schilbeidae	*Schilbe intermedius*	Pis, Pel	*	*	*		*	*	
		Schilbe mandibularis	Her, Ben		*	*		*	*	*
	Clariidae	*Heterobronchus longifilis*	Pis, Ben	*		*		*		
	Mochokidae	*Synodontis bastiani*	Inv, Benpel			*	*	*		
		Synodontis punctifer	Her, Benpel			*		*		
		Synodontis schall	Her, Benpel		*	*		*	*	
Perciformes	Latidae	*Lates niloticus*	Pis, Ben		*	*				*
	Cichlidae	*Chromidotilapia guntheri*	Inv, Benpel	*	*	*			*	
		Hemichromis fasciatus	Pis, Benpel	*	*	*			*	
		Oreochromis niloticus	Phy, Ben	*					*	
		Sarotherodon galilaeus	Phy, Ben			*	*	*	*	
		Sarotherodon melanotheron	Phy, Ben				*			
		Coptodon guineensis	Her, Benpel							*
		Coptodon zillii	Her, Ben	*	*	*	*		*	*
	Anabantidae	*Ctenopoma petherici*	Inv, Benpel	*		*	*		*	
7	14	33		16	15	23	13	14	16	12

Pis = piscivore ; Inv= invertivore ; Her= herbivore ; Phy= phytoplanktivore ; Ben= benthic ; Benpel= Benthopelagic; Pel= pelagic.

Table 5: Scores (standard residuals) per station of metrics and values and classes of the index (NEN = number of native species; BN = biomass of natives; NEBS = number of benthic Siluriform species; NEC = number of Cichlid species, INV = percentage of individual invertivores; HER = percentage of individual herbivores)

STATION	NEN	BN	NEBS	NEC	INV	HER	F-IBI	Water quality
S1	0,12498	-0,78594	-0,108654	-0,32102	-0,105716	0,777918	**-0,42**	Medium
S2	0,00361	0,16035	-0,108654	0,69216	0,356000	-0,484431	**0,62**	Medium
S3	-3,48851	3,95541	0,748039	2,20453	-0,285751	2,130235	**5,26**	Excellent
S4	0,54840	-0,21923	-0,422078	0,12870	0,015594	0,113889	**0,16**	Medium
S5	-0,68060	0,02785	-0,108654	-0,44519	-0,564540	-0,101145	**-1,87**	Poor
S6	5,02983	-2,17225	0,866304	-8,53648	-0,940127	-0,500796	**-6,25**	Very poor
S7	-0,23884	-0,18955	0,246182	-0,24618	-0,026955	-0,374588	**-0,83**	Medium

CONCLUSION

This work allowed to study the fish population of the Bandama River within the Haut Bandama Reserve and assessed the quality of this aquatic environment from fish. Seven stations were sampled. 33 species of fish were recorded in the Haut Bandama Reserve. The S3 station (Oulékaha) was the most diversified and the best organized (n = 23 ; H'= 2.89 ; E = 0.87). The calcul of the fish index of biotic integrity was described this station as "excellent", in contrast to the 'very poor' S6 station (Bananeraie) which received the waste water discharges from the banana plantation and those from the artisanal mining activities of the Tortiya gold mine.

ACKNOWLEDGEMENTS

The authors thank the researchers, students and technical staff who took part in the data-gathering. They are very grateful to the "Office Ivoirien des Parcs et Réserves", to Captain N'DRIN N'Drin Ehie, Chief of the Haut Bandama Wildlife Reserve for their assistance and cooperation. We also thank Mr Aka Simon, the professional fisherman for providing us fish.

REFERENCES

Aboua B.R.D. 2012. Développement d'un indice d'intégrité biotique piscicole pour la préservation de la biodiversité du fleuve Bandama. Thèse de Doctorat à l'Université de Cocody- Abidjan, Cote d'Ivoire, 278p.

Aboua B.R.D., Kouamélan E.P., N'Douba V. 2012. Development of a fish-based index of biotic integrity (FIBI) to assess the quality of Bandama River in Côte d'Ivoire. *Knowledge and Management of Aquatic Ecosystems*, 404 (08): 1-19.

Barnay A.S. 2005. *Avant-Projet Sommaire du futur réseau de surveillance DCE (domaine benthique) - District côtier Seine-Normandie*, IFREMER, DYNECO-BENTHOS, LERN, 115p.

Bode R.W., Novak M.A., Abele L.E., Heitzman D.L., Smith A.J. 2002. Quality Assurance Work Plan for Biological Stream Monitoring in New York State, Albany (New York), Stream Biomonitoring Unit Bureau of Water Assessment and Management Division of Water, NYS Department of Environmental Conservation, 41p.

Camargo J.A., Alonso A., De La Puente M. 2004. Multimetric assessment of nutrient enrichment in impounded rivers based on benthic macroinvertebrates. *Environmental Monitoring and Publishers*, 96: 233-249.

Gourène G., Teugels G.G., Huguen B., Thys Van Den Audenaerde D.E. 1999. Evaluation et conservation de la diversité ichtyologique d'un bassin ouest-africain après la construction d'un barrage. *Cybium*, 23: 147-160.

Halle B., Bruzon V. 2006. Profil environnemental de la Côte d'Ivoire. Rapport final. Consortium AGRIFOR consult. 127p.

Karr J.R., Fausch K.D., Angermeier P.L., Yant P.R., Schlosser I.J. 1986. Assessing biological integrity in running waters. A method and its rationale. *Illinois Natural History Survey*, Special Publication 5: 1–28.

Kouamé K.A., Yao S.S., Gooré Bi G., Kouamélan E.P., N'Douba V., Kouassi N.J. 2008. Influential environmental gradients and patterns of fish assemblages in a West African basin. *Hydrobiologia*, 603: 159-169.

Kouamélan E.P., Teugels G.G., N'Douba V., Gooré Bi G., Koné T., 2003. Fish diversity and its relationships with environmental variables in a West African basin. *Hydrobiologia*, 505: 139-146.

Kpan N.V. 2015. Dynamique spatio-temporelle de la réserve du Haut Bandama en Côte d'Ivoire. Université Alassane Ouattara (Bouaké, Côte d'Ivoire). 13p.

Lévêque C., Paugy D. 1999. Les poissons des eaux continentales africaines: Diversité, écologie, utilisation par l'homme. Éditions IRD, Paris, France, 521p.

Oberdorff T., Guégan J.-F., Hugueny B. 1995. Global scale patterns of fish species richness in rivers. *Ecography*, 18: 345–352.

OIPR. 2006. Plan d'aménagement et de gestion du Parc National de Taï, 110p.

Schlosser I.J. 1991. Stream fish ecology: a landscape perspective. *Bioscience*, 41: 704-712

Traoré K. 1996. État des connaissances sur les pêcheries continentales ivoiriennes. (Rapport de consultation Avril 1996). Projet F.A.O. TCP/ IVC/ 4553. 135p.

WWF. 2002. Pour une gestion raisonnée des ressources en eau. WWF, Gland, 8 p.

Yao S.S., Kouamélan E.P., Koné T., N'Douba V., Gooré BI G., Ollevier F., Thys Van DEN AUDENAERDE D.F.E. 2005. Fish communities along environmental gradients within the Comoé River basin, Côte d'Ivoire. *African Journal of Aquatic Science*, 30 (2): 185-194.