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Research Article

CONTRIBUTION OF TAÏ NATIONAL PARK IN THE PRESERVATION OF FISH DIVERSITY IN SASSANDRA RIVER BASIN (CÔTE D'IVOIRE, WEST AFRICA)

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ABSTRACT

The effective management of protected areas requires a deep knowledge of the natural resources they contain.Although several rivers flow through the Taï National Park, very few detailed survey on fish diversity has been conducted so far in this Park.As a matter of fact, the present study is the first to investigate the ichtyofauna of the segment of Sassandra River which is under strict protection.Samplings were carried out on three different sites respectively on January 2012, November 2012 and September 2013. In total, 45 species distributed in 6 orders and 13 families were collected. Five species (*Clariasebriensis, Malapterurus barbatus, M. beninensis, M. minjiriya and M. tanoensis*) were reported for the first time from Sassandra basin. The richness and diversity indices were significantly different from upstream to downstream ($p<0.05$). In contrast, the evenness (E) was not significantly different both study areas. Zakoue area which account for less than 1% of Sassandra river area contains more than 45 % of total species fishes. These results indicate that Tai National Park plays an important role in the conservation of aquatic biodiversity of Sassandra basin.

INTRODUCTION

The freshwater ecosystems are of great socio-economic interest for mankind despite the small area they occupy in the surface of the earth. Unfortunately, the freshwater biodiversity, particularly in African tropical rainforests is seriously threatened by harmful anthropogenic actions. These threats are mainly related to dam-constructions on the rivers, intensive fishing, introduction of new species, the use of chemicals in agriculture, the pollution and industrial deforestation. This latter human activity causes pretty serious damages especially on the ecological quality of aquatic systems and their biocoenosis.

The alteration of ecological functions in ecosystems considerably affects the human uses of these aquatic systems. From that standpoint, freshwater ecosystems are of particular concern (Gleick 2003). Currently, the access to water resources to meet human needs both qualitatively and quantitatively is now considered as a prerequisite to human development (Baron *et al*. 2002; Gleick 2003).

After years of political and socio-economic crisis, Côte d'Ivoire is going through a process of transformations. During these armed conflicts, the biodiversity declined significantly in some parts of the country. As a result, many protected areas and protected forests have been degraded through poaching, gold panning and clearing land for agricultural considerations. The Taï National Park (TNP) in the Southwest of Côte d'Ivoire ranks among the protected areas of Côte d'Ivoire. Classified as Biosphere Reserve and World Heritage Site by UNESCO, the TNP is the last unspoiled ecosystem of primary forests under protection in West Africa. The park as such is the guarantor of a stable microclimate for agricultural production (cocoa, coffee, palm oil and rubber) of the surrounding zone. Unfortunately, the misuse of the soil has significantly increased coupled with the agro-industrial activities in neighboring area of the Tai National Park. These factors have strongly degraded the forest ecosystem of western Côte d'Ivoire. Several rivers flow in the Taï national Park such as Zakoue River, a tributary of the Sassandra River located in the East side of park.A hydroelectric dam has been built in the main course, resulting in the creation of Buyo Lake. This lakegenerated significanteconomic activities relatedto fishingin this hydrosystem (Aloko-N'Guessan 2001). Furthermore,

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Kouamé*et al*. (2008) have brought to light the impact of industrial pollution in the preservation of fish biodiversity in the Sassandra River. The present paper seeks to investigate the community-level patterns of fish in a tributary of Sassandra River and to assess the contribution of TNP in the preservation of fish biodiversity in Sassandra River.

MATERIALS AND METHODS

Study area

The Sassandra River basin originates from the Bela region in Guinea Conakry and flows down into the Atlantic Ocean in Côte d'Ivoire, near to the city of Sassandra.

It is 840 km long and encompasses a catchment area of 75000 km^2, with an average annual discharge estimated at 513 m/s (Traoré 1996; Lemoalle 1999). Zakoue River is the only tributary of the Sassandra River which irrigates the Taï National Park (Figure 1). It is 30 km long with a catchment area of 218 km^2 (Kamelan 2014). The Zakoue River is the only anthropogenic river in TNP. The survey includes three stations. The first station (Sa1) is located on the upper course of the Zakoue River. This station is located near the ADK village where human activities (washing, bathing) are performed upstream of the sampling station. The second station (Sa2) is located on the lower course of the Zakoue River. This segment of the Zakoue is located nearby the village of people evicted from Lake Buyo area (V1).

Table 1 Fish species collected in the Zakoue River basin in January 2012, November 2012 and September 2013

Orders	Families	Species	Zakoue river		Buyo lake
			Upstream	Downstream	
Osteoglossiform	Arapaimidae	*Heterotisniloticus*			+
	Mormyridae	*Marcuseniussenegalensis*	+	+	+
		Marcuseniussusheri	+	+	+
		Mormyropsanguilloides			+
		Mormyrusrume	+	+	+
		Petrocephalusbovei	+	+	
		Pollimyrusisidoris	+		
Characiform	Alestidae				
		Brycinusimberi	+		
		Brycinuslongipinnis	+		
		Brycinusmacrolepidotus	+		+
		Brycinus nurse	+		+
		Micralesteselongatus	+		
		Micralestesoccidentalis	+		
	Hepsetidae	*Hepsetusodoe*	+		
	Distichodontidae	*Distichodontusrostratus*			+
		Nannocharaxfasciatus	+		
Cypriniform	Cyprinidae	*Barbusablabes*	+		
		Barbusmacrops	+		
		Barbustrispilos	+		
		Labeoparvus	+		
Siluriform	Claroteidae				
		Chrysichtysnigrodigitatus	+		+
	Schilbeidae	*Schilbe intermedius*	+	+	
		Schilbemandibularis	+	+	+
	Clariidae	*Clariasanguillaris*	+		+
		Clariasbuettikoferi	+		
		Clariasebriensis	+		
		Heterobranchusisopterus	+	+	
		Heterobranchuslongifilis	+		
	Malapteruridae	*Malapteruruselectricus*	+		
		Malapterurus barbatus	+		+
		Malapterurusbeninensis	+		
		Malapterurusminjiriya	+		
		Malapterurustanoensis	+		
	Mochokidae	*Synodontiskoensis*	+	+	+
		Synodontis punctatus			+
Cyprinodontiform	Notobranchidae	*Epiplatysolbrechtsi*	+		
		Poropanchaxnormani	+		
Perciform	Channidae	*Parachannaobscura*	+		
	Centropomidae	*Latesniloticus*			+
	Chichlidae	*Chromidotilapiaguntheri*	+		+
		Hemichromisbimaculatus	+	+	
		Hemichromisfasciatus	+		+
		Orechromisniloticus	+		+
		Sarotherodongallilaeus	+		+
		Coptodonzillii	+		+
6 orders	13 families	45 species	40	9	17

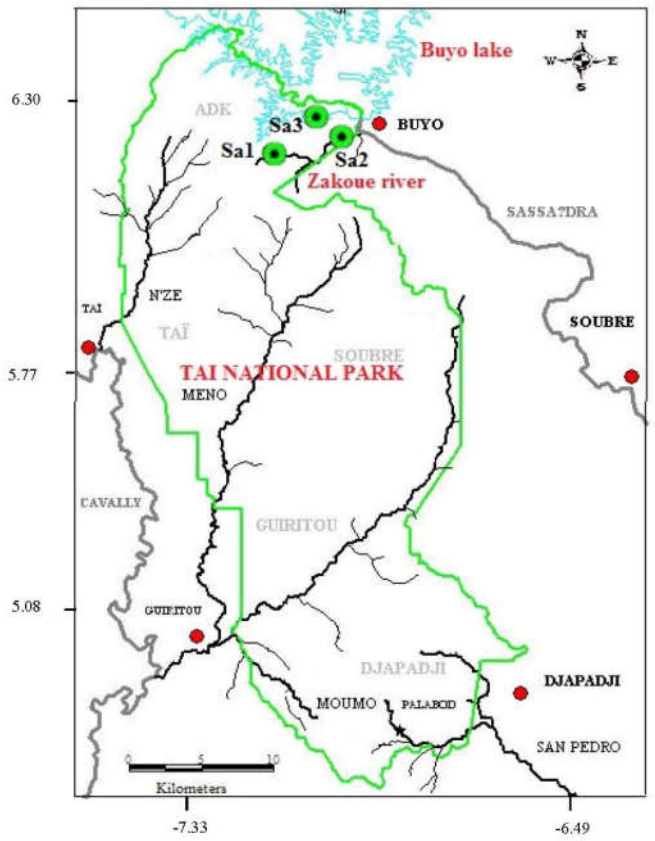

Fig 1 Map of the Zakoue River Basin with indication of the sampling sites

The river therefore crosses several cocoa plantations, including those belonging to local residents. Riparian vegetation consists of scattered trees bush. The last station (Sa3) encompasses the portion of Buyo Lake located on the edges of TNP.At this station, there is a camp of fishermen who live on the fish fauna and perform this activity under the supervision of the management of the fishery. The three stations were sampled in January 2012, November 2012 and September 2013.

Fish sampling

Fishes were collected with a fleet of 8 weighted monofilament gillnets (bar mesh sizes 10, 12, 14, 20, 25, 30, 35 and 40), 16hoop netsand a hand net. Each gillnet measures 30 m long by 1.5 m deep. Gilnets and hoop nets are usually set in the afternoon at 5 p.m, visited the following day in the morning at 7 a.m and 12 a.m to remove the fishes captured. The fishes were identified according to Paugy *et al.* (2003a; 2003b) identification keys and were counted per species.

Data analysis

Ichthyofauna structure was described through taxonomic composition and spatio-temporal richness. Ichthyofauna diversity was studied through taxonomic abundance, Shannon-Weaver diversity index (*H'*) and equitability index (*E*), Berger-Parker's dominance (*d*), Simpson index (*D*). Beta diversity index (β_H) was used to assess the differentiation between sampling areas. Beta diversity (β_H) measures the change in the diversity of species from one environment to another. β_H generally ranges from 0 (complete similarity) to 1 (complete dissimilarity). A high beta diversity index indicates a low level of similarity, while a low beta diversity index shows a high level of similarity (Legendre and De Caceres 2013). With α-diversity, β-diversity measures total diversity, or the biotic heterogeneity of a specific area (Wilson and Shmida 1984).

$\beta_H = 2c/S_1 + S_2$

S1 = total number of species in the first community, S2 = total number of species in the second community, and c = number of species common to both communities.

All statistical analyses were carried out by the software Paleontological Statistic (PAST) version 2.15 (Hammer *et al.* 2001).

RESULTS

Richness and distribution

A total of 45 fish species, belonging to 13 families distributed in 6 orders were collected in the sampling sites (Table 1). One introduced species (*Oreochromisniloticus*) was captured in this river. Siluriform (33.33%) was the most diversified group, represented by 5 families and 15 species (Figure 2); followed respectively by Characiform (20%), Perciform (17.18%), Osteoglossiform (15.56%), Cypriniform (8.89%) and Cyprinodontiform (4.44%).

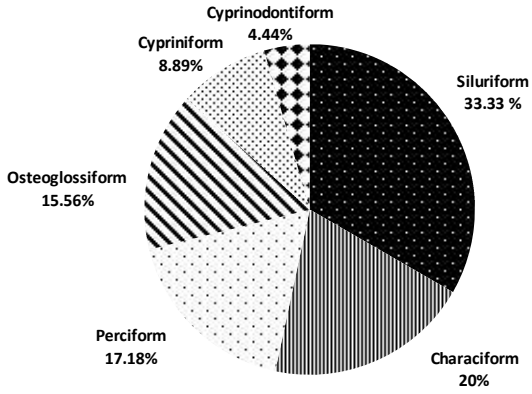

Fig 2 Proportion in number of families collected in Zakoue bassin

Among the families collected, Cichlidae (15.56%), Alestidae (13.33%), Mormyridae (13.33%); Clariidae (11.11%), Malapteruridae (11.11%) as well as Cyprinidae (8.89%) are largely represented. The other families (26.67%) were poorly represented with less than four species (Figure 3). Species richness varied contrary to gradient in Zakoue river (Figure 4) The upstream, with 40 species, was richer than the downstream and lake Buyo area (9 and 17 respectively).

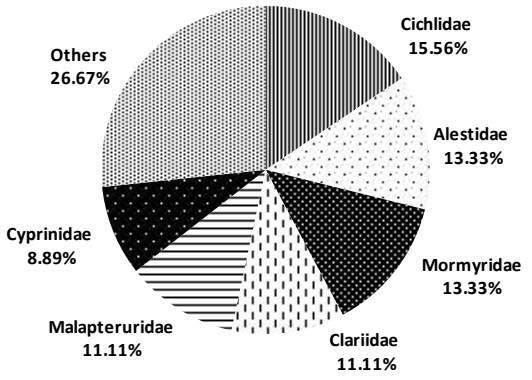

Fig 3 Proportion in number of species collected in Zakoue bassin

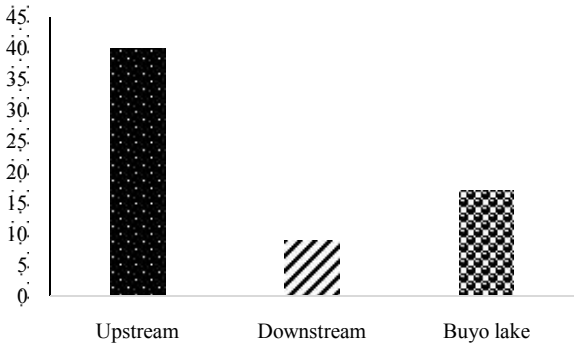

Fig 4 Spatial variation of species richness from Zakoue River

Five species (*Marcuseniussenegalensis, Marcuseniussussheri, Mormyrusrume, Schilbemandibularis, Synodontiskoensis*) were very common and appeared in every sampling station (Table 1). Five species (*Heterotisniloticus, Mormyropsanguilloides, Distichodontusrostratus, Synodontispunctifer, Latesniloticus*) were caught only in lake Buyo while twenty-seven species were restricted to the Zakoue river. The others species were caught in the lake as well as in the river.

Abundance and diversity

In the whole Zakoue River, Characiform (43.25%), Osteoglossiform (22.26%), Siluriform (19.93%) were respectively the main families dominating this river (Figure 5).

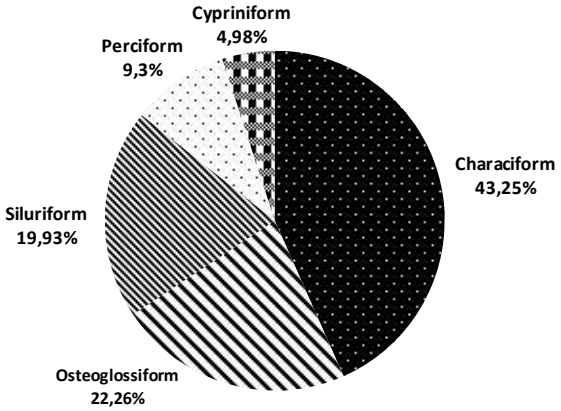

Fig 5 Numerical abundance of main orders collected in the Zakoue basin.

Alestidae (42.52%) and Mormyridae (22.26%) represented more than half of the fish caught in Zakoue River, followed by Clariidae (8.64%), Schilbeidae (7.31%) and Cichlidae (7.31%). The others families (11.95%) represented less than 5% (Figure 6).

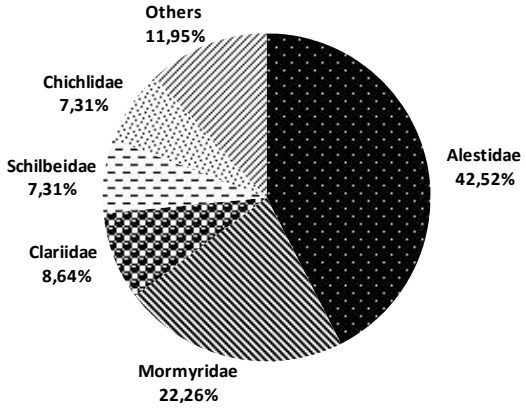

Fig 6 Numerical abundance of main families collected in the Hana basin

Brycinus nurse (19.27%) was the most dominant species in Zakoue River, which accounted for 20.10% of the fishes sampled. The next most abundant species were *Brycinusimberi* (15.95%), *Marcuseniussussheri* (8.31%), *Marcuseniussenegalensis* (6.64%), *Schilbemandibularis* (5.98%), *Clariasbuettikoferi* (5.98%), *Brycinusmacrolepidotus* (5.65%) (Figure 7).

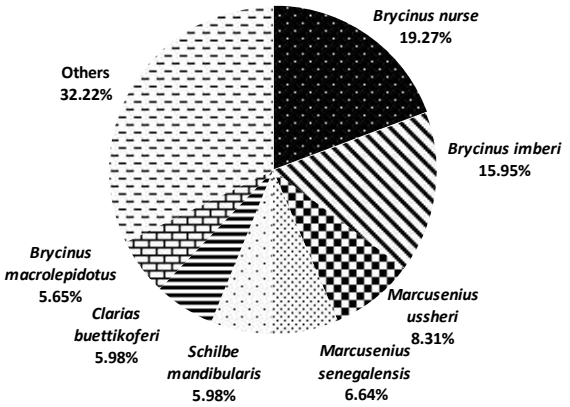

Fig 7 Numerical abundance of main species collected in the Hana basin.

Overall, the richness and diversity indices were significantly different from upstream to downstream ($p< 0.05$). In contrast; the evenness (E) was not significantly different in both study segment. Species richness was significantly higher in upstream compared to downstream. In the same way, Shannon-Weaver diversity index (H') and Simpson index (D) were significantly higher in the upstream compared to downstream whereas the Berger-Pearker diversity index (d) was significantly higher in downstream compared to upstream. The beta diversity index calculated, along longitudinal gradient; is much high (0.65) between the upper and down courses (Table 2).

Table 2 Results of diversity tests of fish assemblage collected in the Zakoue River basin in January 2012, November 2012 and September 2013

	Upstream	Downstream	Compare
Richness (R)	40	9	0.001
Shannon diversity H'	2.85	1.73	0.001
Eveness (E)	0.43	0.62	0.792
Dominance (Dm)	0.09	0.24	0.001
Berger-Pearker diversity (d)	0.21	0.43	0.002
Simpson index (D)	0.9	0.75	0.001
Beta diversity (βH)		0.63	

DISCUSSION

This study reports for the first time the list of species from the portion of the Sassandrabasinunder strictprotection in the Taï National Park. During the present survey, a total of 45 freshwater fish species were identified in the Sassandra Basin, among which 40 species in Zakoue River only; versus 96 species previously recorded by previous studies (Daget and Iltis 1965; Teugels *et al*. 1988; Paugy *et al*. 1994; Kouamé *et al*. 2008). This result is very relevant for the preservation of fish biodiversity in the Sassandra River basin. Indeed, the Zakoue basin which represents less than 1% of entire Sassandra basin, contains more than 45% of species richness of the whole Sassandra basin. The studies ofKouamé*et al*. (2008)which depictthe negative impact of the Buyo hydroelectricdam, the pressure of excessive fishing, household and industrial pollution on fish species communities in the segment of Sassandra River outside the Taï National Park, corroborate

ourresults. Five species, *Clariasebriensis, Malapterurus barbatus, M. beninensis, M. minjiriya and M. tanoensis,* were reported for the first time in the Sassandra basin. Thereby, the number of identified species in the Sassandra basin has now gone up from 96 (Daget and Iltis 1965; Teugels *et al*. 1988; Paugy *et al*. 1994; Kouamé *et al*. 2008) to 101 species. The investigations undertaken between1965 and2008 by previous works haveindicateda single species of Malapteruridae (*Malapteruruselectricus)*. Four species pertaining to this family were reported in the park. The impactof human activitiesisprobably highlightedin the effort to preserve Malapteruridae. Indeed, these species are benthic fishes. Their absence from the vicinity of the park is due to the aftermaths of agriculture, gold mining, urbanization and deforestation which cause increasing sediment loads, and its attendant problems to the life of these fishes. These observations are confirmed by Lalèyè *et al*. (2010a; 2010b) in Liberia and Nigeria. *Clariasebriensis*is a West African catfish (Chikou *et al*. 2007). This species was generally common in lagoons andlower reachesof rivers basin from Dodo in Côte d'Ivoire to Southeast Nigeria (Entsua-Mensah and lalèyè 2010). This Clariidae was absent from the segment of Sassandra basin outside the park and was found in the upper reaches of Zakoue river. Ezenwaji (2002) came up with the same result in Anambra River where *Clariasebriensis* were more abundant and frequent in the forest floodplain ponds than in other habitats. The presence of this species within the forest area relates to not only to its diet dominated by fish and insects (Ezenwaji 2002) but also fishing pressure on the edges of the park.

Five species (*Marcuseniussenegalensis, Marcuseniussussheri, Mormyrusrume, Schilbemandibularis, Synodontiskoensis*) have a widedistributionacross the Sassandrabasin. Thesefish specieshave a commondietdominated byaquatic and terrestrialinsects (Entsuah-Mensah et Lalèyè 2010; Kouamélan 1999; Kouamélan *et al*. 1998; Yao *et al*. 2010).

Siluriform was the order with the highest number of families and species in Zakoue river unlike patterns of fish assemblage in Ivorian rivers [Gô (Koné *et al*. 2003a), San Pedro (Koné *et al*. 2003b), Comoé (Yao *et al*. 2005), Tanoé and Bia (Konan, 2006), Mé (Kouadio *et al*. 2006), Sassandra (Kouamé *et al*. 2008), Bandama (Aboua *et al*. 2010), Brimé-Méné-Nounoua complex river (Kamelan *et al*. 2013a) and Dodo (Kamelan *et al*. 2013b)] where Perciform was the most common order with the most number of families and species. According to Kamelan *et al*. (2014), the Zakoue River belonging to the Liberian-Guinean sector from the West Guinean region characterized by a dense rainforest. The majority of Siluriform, which are benthic species, were recorded in Taï National Park where the ecological conditions suit their biology. Moreover, most Ivorian rivers were strongly influenced by human activities (fishing, agricultural and industrial pollution) while the rivers located inside the Taï National Parkare safe from these human activities. *Brycinus nurse* was the most abundant species in Zakoue River. This relates to the feeding habit of this Characidae. Indeed, *B. nurse* was a euryphagous species, feeding on various kinds of food resources available in its natural habitat (Saliu 2001). This non-specific feeding habit easily explains the abundance de *B. nurse* in Zakoue River.

The upstream showed a higher value of species richness and diversity than the downstream in the Zakoue River with a relative stability (more 70 %) of fish assemblage in both areas. Unlike the upstream inside TNP, the lower downstream fish diversity relates to the anthropogenic impact arising from farming activities carried out in the edges of the Park. The increase in species richness in the upstream over the downstream was observed by Sanogo *et al*. (2012) in the Baoulé River in Bamako. This is a proof of an inversion of longitudinal distribution of fish species in Zakoue River. According to Hugueny and Lévêque (2006), the increase in species richness and fish diversity in upstream could be explained by some abundance well-preserved habitats in that Zakoue River segment.

The results of the beta diversity index for both segments of Zakoue River indicated significant differences in the species composition pattern from upstream to downstream. The analysis showed a heterogeneous and dissimilarly ichtyofauna in different areas of this river. The upstream ichtyofauna contains six orders (Osteoglossiform, Characiform, Cypriniform, Siluriform, Cyprinodontiform and Perciform) while the downstream recorded three orders (Characiform, Siluriform and Perciform). Besides, eight families (Osteoglossidae, Alestidae, Heseptidae, Cyprinidae, Claroteidae, Malapteridae, Notobranchiidae and Channidae) were not found in downstream unlike the upstream ichtyofauna. This result underlines the impact of anthropogenic activities by surrounding residents on fish biodiversity.

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