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Diversity and conservation status of fish fauna from Cavally river in its catchment area under the influence of Gold mining activities (Côte d'Ivoire)

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Abstract
The present study was conducted from august 2014 to July 2016 in order to assess fish diversity and its conservation status in Cavally river in an area of intensive mining activities. A total of 76 species were recorded including 8 orders, 20 families and 37 genera. Twenty (20) species were registered for the first time in this river. Characiformes appeared to be the most prolific order in fish population. Among the species sampled, 3 species (*Micralestes eburneensis, Chromidotilapia cavalliensis* and *Coptodon walteri*) were endemic to the Cavally River. Fish diversity was higher in upstream area of the zone of intensive mining activities. According to fish conservation status, 52 species were Least Concern (LC), 7 species were Near Threaten (NT), 12 species were Not Evaluated (NE), 4 are Vulnerable and only one species was Data Deficient.

Keywords: Cavally, ichthyofauna, diversity, West Africa

Introduction
Rivers play a vital role in conservation of biodiversity, the functioning of organisms and the cycles of organic matter. Freshwater is also essential for life and plays a central role in the development of human civilizations, as aquatic and terrestrial ecosystems do not operate independently one another [1].

However, rivers are strongly influenced by their location, and even more so, human activities, which alter the nature of soils and hydrological channels. That inevitably affects this land-water interface [2]. Indeed, human influences on aquatic biocœnosis are very diverse. But four main activities, according to [3], can be considered: fishing, use of water, land use and the introduction of aquatic aliens' species. All of these changes in land and water use have direct effects on aquatic biocœnosis [2-4].

Knowing African fish fauna has long been of interest to scientists, however, African fish fauna awareness is recent and is an area insufficiently explored [5]. A scientific approach of different management strategies of biodiversity conservation is essential to back up an optimum exploitation [6-7-8-9]. Among aquatic resources, fish is an entity that is highly vulnerable to the pollution that agricultural inputs can produce especially pesticides and chemicals used in mining and gold panning [10]. Cavally river is one of the least known and least studied rivers in Côte d'Ivoire. Only some researches have been done on systematic, biogeographical and ecological aspects of Cavally fishes [11-12-13]. Therefore, it is important to update the Cavally fishery resource data as this river is actually subjected to high and acute disturbance due to mining activities in its main bed [14]. Indeed sections of the Cavally river suffers from strong anthropogenic pressure mostly related to gold mining. This intensive gold mining activity by using motorized equipment in the river bed has led to water pollution, destabilization of riverbanks, destruction of the forest gallery, disruption of ecosystem functioning, modification of the substrate, high noise levels and high concentration of suspended solids [15]. Thus, the present study aims at updating knowledge on Cavally river ichthyofauna and also the conservation status of its species.

Materials and Methods

Study area

The Cavally runs from Guinea, north of the Nimba Mountains, at an altitude of 600m. 700 km long, its bed serves as border between Liberia and Côte d’Ivoire in its middle and lower course. About 15,000 km2 of its catchment area is in Côte d'Ivoire. Samplings have been implemented around an area highly influenced by mining activities. Eight (8) sampling sites were taken in account for this study (Table 1). These sites were distributed upon three zones (Figure 1) based on the intensity of anthropogenic pressures (proximity with mining activities sites of Ity Mining Platform). These sites were grouped according to the upstream-downstream gradient around the Gold Mining Platform as following:

- Upstream: the stations were Teapleu Cavally (A2) and Lièpleu (A3);
- Gold Mining Platform area. The concerned stations are the stations of Walter (D4), Dahapleu (D5), Glai (D6) and Sokloaleu (D8);
- Downstream of the Gold Mining platform: The stations are Gueiossepleu (B1) and Glareu (B2).

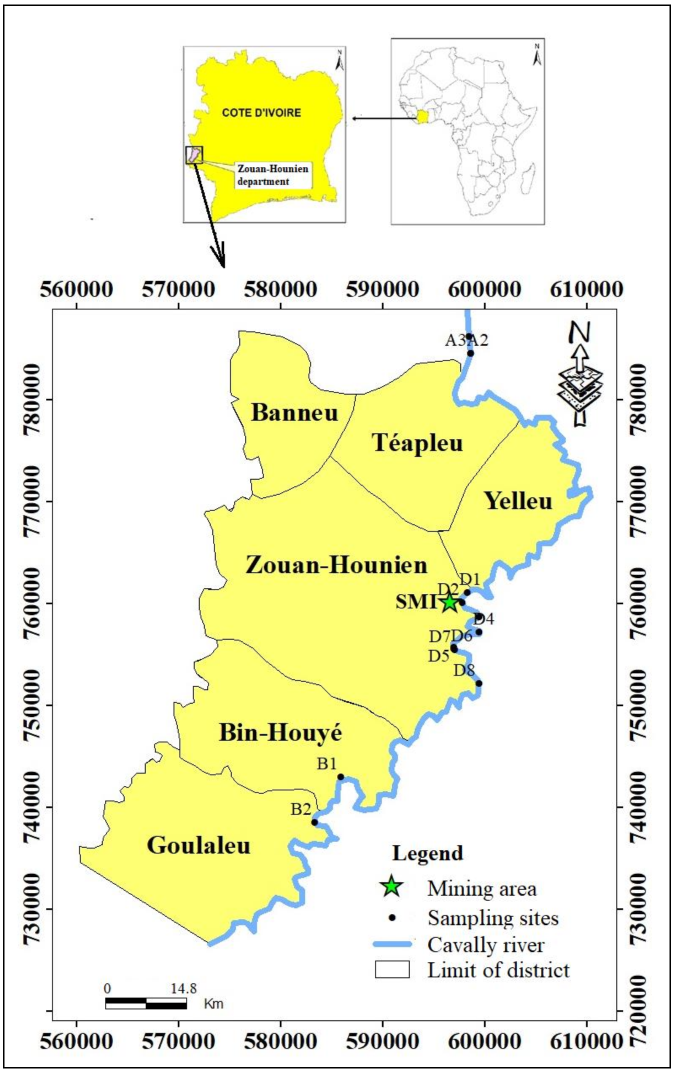

Fig 1: Map showing the study area of the Cavally river, and different sampling sites

Table 1: Geographic coordinates of sampling Stations on Cavally river

Stations Names	Longitudinal zonation	Latitude	Longitude
Téapleu Cavally (A2)	upstream	N0598469	W 0786150
Liépleu (A3)	upstream	N0598635	W0784543
Walter (D4)	Ity Mining area	N 0599444	W 0760655
Daapleu (D5)	Ity Mining area	N 0600256	W 0758421
Glai (D6)	Ity Mining area	N 0598006	W 0755776
Sokloaleu (D8)	Ity Mining area	N 0597611	W 0752074
Gueiossepleu (B1)	downstream	N 0587006	W 0742170
Glareu (B2)	downstream	N 0583094	W 0738210

Sampling surveys

Fish samplings were carried out monthly between august 2014 and July 2016 using two sets of 9 gillnets (bar mesh sizes 10, 12, 15, 20, 25, 30, 35, 40mm), each measuring 30m long with 2 or 2.5m deep. Fish collected were identified to species level following several regional identification books [16-17-18-19-20-21]. Data from the commercial catch were taken in account and used only for the qualitative analysis of the fish population.

Data analysis

Quantitative analyses were conducted using data from the experimental catches. Thus, the following indices have been used to characterize fish fauna. The *Frequency of occurrence (F)* reflects the number of samples where a species is met in relation to the total number of samples [22]. It quantifies the degree of ubiquity of different species and is calculated as follows: $F = (Si/St)x100$, where *Si* is number of samples where species *i* was observed and *St* is the total number of samples. Then, the following classification [23] was used for the characterization of species according to their frequency in samples:

- when F is between 80 to 100%, the species is qualified to be very frequent (VFS);
- 60 to 79%: Frequent species (FS);
- 40 to 59%: fairly frequent species (FFS);
- 20 to 39%: Accessory species (AS);
- 10 to 19%: Accidental species (ACS);
- Less than 10%: Very rare species (VRS).

The *Shannon –Wiener index (H’)* was used to quantify the heterogeneity of the biodiversity of the sites studied. It is independent of sample size and takes into account the relative abundance of each species [24]. This index makes it possible to characterize the population and gives an unbiased estimation of the population by measuring the degree of organization of a stand [25]. In natural environments, it generally varies between 0.5 for low diversity and 4.5 for high diversity [26]. It is calculated as follows, $H' = - \Sigma ((Ni / N) \times \log2 (Ni / N))$, where Ni is the number of individuals of a species, *i* ranging from 1 to S. N represents the total number of individuals in the sample. S is the species richness.

The *Evenness (E)* or Equitability is a measure of the relative abundance of different species. Equitability (E) varies between 0 and 1. It is equal to 0 when only one species dominates and 1 when all species have the same abundance. It is measured according to the following formula [27-28], E = H'/log2 S, where H' is the Shannon –Wiener index and S is the species richness.

The Global conservation status of fish was updated through Fishbase [21] and IUCN Red List [29]. The scientific names of fishes were validated through Catalog of fish [20] database.

Results

Fish community composition

A total of 3173 individuals belonging to 76 species were recorded. These species were grouped in 8 orders, 20 families and 37 genera. Species richness according to longitudinal zonation revealed 71 species registered upstream, 52 species in the mining area and 66 species downstream (Table 2). Order of Perciformes was dominant with 17 species (22.37% of the total species) followed by Osteoglossiformes and Siluriformes with 14 each (18.42%), Cypriniformes 13 (17.11%), Characiformes 11 (14.47%), Cyprinodontiformes 4 (5.26%), Clupeiformes 2 (2.63%) and Polypteriformes 1 (1.32%).

The families with the highest number of species were Cichlidae with 14 species, followed by Mormyridae (12 species). The families of Notopteridae, Polypteridae, Arapaimidae, Distichodontidae, Malapteruridae, Poecilidae, Notobranchidae and the Chanidae were the less prolific with only 1species (Table 2). Species occurrence revealed 8 Very frequent species, 4 species were Frequent, 10 species were Fairly frequent, 13 species were Accessory species, 18 species were Accidental species and 23 species were Very rare. Among all the species, the most frequent were *Micralestes eburneensis* (100%) and *Schilbe mandibularis* (100%). The more rare species were *Tilapia brevimanus* (1.81%), *Epiplatys hildegarde* (1.81%) and *Scriptaphyosemion schmitti* (1.81%).

According to the sampling area (Figure 2), in the upstream of the mining zone, the dominant families in the catches were Alestidae (50.76%) and Mormyridae (16.88%). But in the zone of intensive gold mining activities and downstream area, fish species from families of Alestidae and Schilbeidae were dominant in the catches.

Conservation status

Fish conservation status according to IUCN indicated that 52 species are least concerned (LC), 7 species are near threatened (NT), 12 species are not evaluated (NE), 4 species are vulnerable and one species was data deficient.

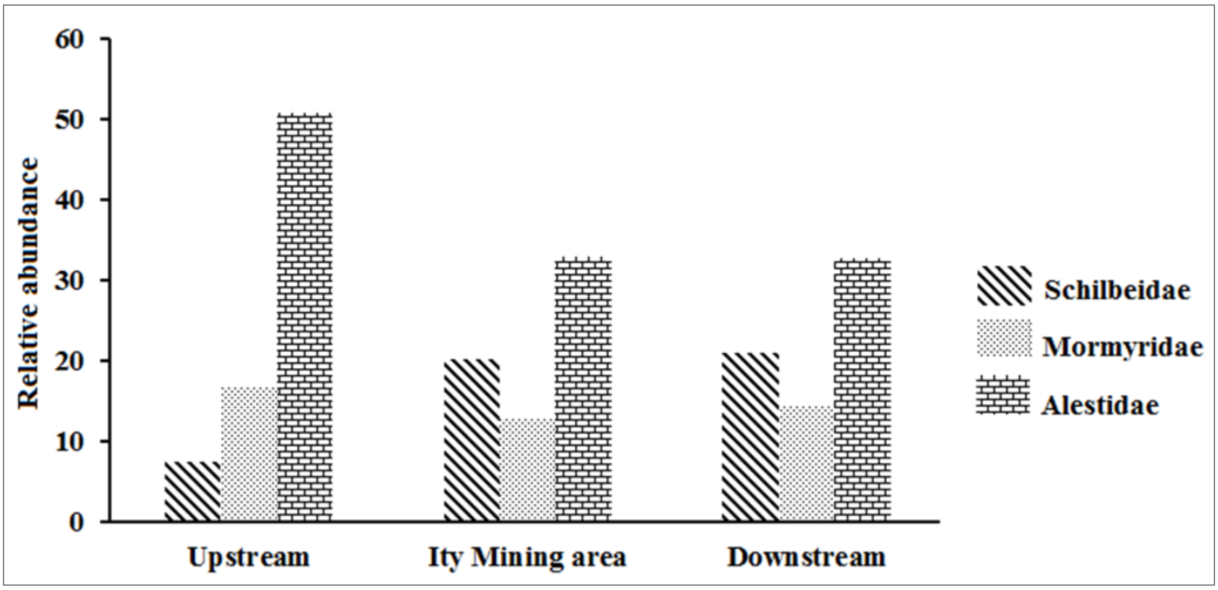

Figure 2: Relative abundance of fishes according to dominant families in the Cavally river

Near-threatened species (*Micralestes eburneensis*, and *Coptodon walteri*) are very frequent according to the upstream-down gradient in the Cavally region of Zouan - Hounien. Three Near-threatened species (*Marcusenius furcidens*, *Raiamas nigeriensis* and *Malapterurus punctatus*) have been found accidentally in the upper course of the Cavally. One Near-threatened species (*Labeobarbus parawaldroni*) has proved to be an accessory species and another near-threatened species (*Enteromius bigornei*) has been found to be very rare. One vulnerable species (*Brycinus derhami*) had been found in all three zones. However, three (3) vulnerable species, *Epiplatys hildegarde, Scriptaphyosemion schmittti* and *Chromidotilapia cavalliensis* were observed only in the upstream and downstream area.

Furthermore in this part of Cavally river, eleven (11) species had their conservation status not yet evaluated. These were *Pellonula leonensis*, *Mormyrus rume, Petrocephalus bovei, Pollimyrus isidori, Hepsetus occidentalis, Clarias laeviceps, Parachanna obscura, Coptodon zillii, Orecochromis niloticus, Sarotherodon melanotheron and Sarotherodon tournieri*).

Table 2: Distribution, occurrence and the conservation status IUCN of fishes' species collected in different sampling area of the Cavally river

Orders	Families	Species	upstream	Ity Mining area	downstream	PO	Frequency characteristic	Conservation status (IUCN)
Polypteriformes	Polypteridae	*Polypterus palmas* Ayres, 1850	+	+	+	25.45	AS	LC
Clupeiformes	Clupeidae	*pellonula leonensis**Boulenger, 1916	+	+	+	76.36	FS	NOT EVALUATED
		*pellonula vorax** Günther, 1868	+	+	+	47.27	FFS	LC
Osteoglossiformes	Arapaimidae	*Heterotis niloticus* (Cuvier, 1829)	+	+	+	14.54	ACS	LC
	Notopteridae	*Papyrochranus afer* Günther, 1868	+	+	+	27.27	EAC	LC
	Mormyridae	*Mormyrus tapirus* Pappenheim, 1905	+			3.63	VRS	LC
		*Mormyrus rume*Valenciennes, 1846	+	+	+	18.18	ACS	NOT EVALUATED
		Marcusenius senegalensis (Steindachner, 1870)	+	+	+	54.54	FFS	LC
		Marcusenius furcidens (Pellegrin, 1920)	+	+	+	12.72	ACS	NT
		Marcusenius ussheri (Günther, 1867)	+	+	+	47.27	FFS	LC
		Mormyrops breviceps Steindachner, 1895	+	+	+	14.54	ACS	LC
		Mormyrops anguilloides (Linnaeus, 1758)	+	+	+	16.36	ACS	LC
		Brienomyrus brachyistius (Gill, 1863)	+	+		10.90	ACS	LC
		Petrocephalus pellegrini Poll, 1941	+	+	+	47.27	FFS	LC
		Petrocephalus bovei (Valenciennes, 1846)	+	+	+	63.63	FS	NOT EVALUATED
		Hippopotamyrus pictus (Marcusen, 1864)	+	+	+	7.27	VRS	LC
		Pollimyrus isidori (Valenciennes, 1846)	+	+	+	50.90	FFS	NOT EVALUATED
Characiformes	Hepsetidae	*Hepsetus odoe* (Bloch, 1794)	+	+	+	63.63	FS	LC
		Hepsetus occidentalis Decru, Snoeks & Vreven, 2013			+	5.45	VRS	NOT EVALUATED
	Alestidae	*Brycinus longipinnis* (Günther, 1864)	+	+	+	87.27	VFS	LC
		Brycinus derhami Géry & Mahnert, 1977	+	+	+	43.63	FFS	VU
		Brycinus nurse (Rüppell, 1832)	+	+	+	83.63	VFS	LC
		Brycinus imberi (Peters, 1852)	+	+	+	98.18	VFS	LC
		Brycinus macrolepidotus Valenciennes, 1849	+	+	+	80	VFS	LC
		Micralestes occidentalis (Günther, 1899)	+	+	+	34.54	AS	LC
		Micralestes eburneensis Daget, 1964	+	+	+	100	VFS	NT
	Distichodontidae	*Nannocharax fasciatus* Günther, 1867	+	+	+	14.54	ACS	LC
Cypriniformes	Cyprinidae	*Raiamas senegalensis* (Steindachner, 1870)	+	+	+	18.18	ACS	LC
		Raiamas nigeriensis (Daget, 1959)	+	+	+	20	ACS	NT
		Labeo coubie Rüppell, 1832	+	+	+	25.45	AS	LC
		Labeo parvus Boulenger, 1902	+			3.63	VRS	LC
		Labeobarbus parawaldroni Lévêque, Thys van den Audenaerde et Traoré, 1987	+		+	27.27	AS	NT
		Enteromius leonnensis Boulenger, 1915	+			33.33	AS	LC
		Labeobarbus wurtzi Pellegrin, 1908	+	+	+	7.27	VRS	LC
		Enteromius trispilos (Bleeker, 1863)	+	+	+	25.45	AS	LC
		Enteromius macrops Boulenger, 1911	+	+	+	9.09	VRS	LC
		Enteromius ablabes (Bleeker, 1863)	+	+	+	45.45	FFS	LC
		Enteromius chlorotaenia (Boulenger,1911)	+	+	+	14.54	ACS	LC
		Enteromius bigornei lévêque, Teugels et Thys van den Audernaerde, 1988	+		+	9.09	VRS	NT

		Enteromius inaequalis Lévêque, Teugels et Thys van Audenaerde, 1988	+		+	3.63	VRS	DD
Siluriformes	Claroteridae	*Chrysichthys maurus* (Valenciennes, 1839)	+	+	+	23.63	AS	LC
		Chrysichthys teugelsi Risch, 1987	+		+	20	ACS	LC
		Chrysichthys auratus (Geoffroy Saint-Hilaire, 1808)	+			5.45	VRS	LC
		Chrysichthys johnelsi Daget, 1959	+		+	16.36	ACS	LC
		Chrysichthys nigrodigitatus (Lacépède, 1803)	+	+	+	34.54	AS	LC
	Schilbeidae	*Parailia pellucida* (Boulenger, 1901)	+		+	5.4	VRS	LC
		Schilbe mandibularis (Günther, 1867)	+	+	+	100	VFS	LC
	Claridae	*Heterobranchus longifilis* Valenciennes, 1840	+	+	+	81.81	VFS	LC
		Heterobranchus isopterus Bleeker, 1863	+	+	+	74.54	FS	LC
		Clarias anguillaris (Linnaeus, 1758)	+	+	+	30.90	AS	LC
		Clarias salae Hubrecht, 1881	+		+	18.18	ACS	LC
		Clarias ebriensis Pellegrin, 1920	+	+	+	16.36	ACS	LC
		Clarias laeviceps Gill, 1863	+	+		14.54	ACS	NOT EVALUATED
	Malapteruridae	*Malapterurus punctatus* Norris, 2002	+	+	+	10.90	ACS	NT
Cyprinodontiformes	Poeciliidae	*Aplocheilichthys spilauchen* Duméril, 1861	+	+	+	9.09	VRS	LC
	Epiplatyinae	*Epiplatys olbrechtsi* Poll, 1941	+	+	+	7.27	VRS	LC
		Epiplatys hildegarde Berkenkamp, 1978	+			1.81	VRS	VU
	Nothobranchiidae	*Scriptaphyosemion schmitti* (Romand, 1979)			+	1.81	VRS	VU
Perciformes	Channidae	*Parachanna obscura* (Günther, 1861)	+	+	+	29.09	AS	NOT EVALUATED
	Cichlidae	*Chromidotilapia cavalliensis* (Thys van den Audenaerde & Loiselle, 1971)	+		+	5.45	VRS	VU
		Thysochromis ansorgii (Boulenger, 1901)	+			5.45	VRS	LC
		Chromidotilapia guntheri (Sauvage, 1882)	+	+	+	16.36	ACS	LC
		Hemichromis fasciatus Peters, 1852	+	+	+	41.81	FFS	LC
		Hemichromis bimaculatus Gill, 1862	+	+	+	12.72	ACS	LC
		Tilapia mariae Boulenger, 1899			+	7.27	VRS	LC
		Tilapia brevimanus Boulenger, 1911	+			1.81	VRS	LC
		Coptodon walteri (Thys van den Audenaerde 1968)	+	+	+	83.63	VFS	NT
		Coptodon zillii (Gervais, 1848)	+	+	+	58.18	FFS	NOT EVALUATED
		Coptodon guineensis ***** (Bleeker in Günther, 1862)	+	+	+	16.36	ACS	LC
		*Oréochromis niloticus*** (Linnaeus, 1753)	+	+	+	52.72	FFS	NOT EVALUATED
		*Sarotherodon melanotheron** Rüppell, 1852			+	9.09	VRS	NOT EVALUATED
		Sarotherodon tournieri (Daget, 1954)	+		+	12.72	ACS	NOT EVALUATED
		Sarotherodon caudomarginatus (Boulenger, 1916)	+		+	12.72	ACS	LC
	Anabantidae	*Ctenopoma kingsleyae* Günther, 1896	+		+	7.27	VRS	LC
	Mastacembelidae	*Mastacembelus nigromarginatus* (Boulenger,1898)	+		+	5.45	VRS	LC
8	20	76	71	52	66			

*: Marine and/or brackish-water species; ** introduced species, DD: Data Deficient, LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: In Danger, FS: Frequent species, FFS: fairly frequent species, AS: Accessory species, ACS: Accidental species, VRS: Very rare species

Diversity index and evenness
The values of Shannon-Wiener index (H), and Evenness (E) are shown in table 3. The lower values of these indices were observed at the Mining area (H= 2.97, E= 0.52), then at the downstream (H= 3.29, E= 0.54) and the highest values at the upstream zone (H=3.35, E=0.55).

Table 3: Diversity index and Evenness values in the sampling zones near mining area in river Cavally.

Sampling zone	Diversity index (H')	Equitability (E)
Upstream area	3.35	0.55
Mining area	2.97	0.52
Downstream area	3.29	0.54

Discussion and Conclusion
The species richness recorded during the present study in Cavally river was 76 species. This value is higher than that registered by Daget & Iltis (1965) [11] who found 26 species, Teugels *et al*. (1988) [12] with 61 species, Paugy et.all. (1994) [13] with 72 species and Kamelan (2014) [30] with 36 species. Moreover, 20 species registered during the present study were encountered for the first time in Cavally river. These newly met species were *Pellonula vorax, Heterotis niloticus, Mormyrus tapirus, Marcusenius senegalensis, Marcusenius furcidens, Mormyrops breviceps, Brienomyrus brachyistius, Hippopotamyrus pictus, Pollimyrus isidori, Enteromius leonnensis, Enteromius macrops, Enteromius chlorotaenia, Chrysichthys auratus, Clarias anguillaris, Epiplatys hildegarde, Parachanna obscura, Thysochromis ansorgii,Coptodon mariae, Tilapia brevimanus* and *Sarotherodon melanotheron*. Several reasons could explain the differences observed in specific richness. Those could be sampling methods, the different habitats visited and the sampling periods [31-32-33-34].

The quantitative study of ichthyological data from Cavally shows that Alestidae (38.35%), Schilbeidae (16.51%) and Mormyridae (14.71%) constitute the most represented families in the section studied. Mormyridae are a family indicator of the ecological quality of water. This family is known to be very sensitive to any degradation in water quality [35-36]. But the relatively low abundance of Mormyridae compared to that found in Taï National Park [30] could indicate that Cavally's water quality is threatened by anthropogenic activities.

The organization of the ichthyological community of Cavally river in the section studied was analyzed through Shannon (H ') and equitability (E) indices. The equitability values in the different area were greater but closer to 0.5 and far from 1. Da Fonseca (1968) [38] reported that a stand with an equitability value close to 1 shows good organization. So the present results indicate that Cavally river fish populations in the studied areas are not in good and stable organization. Indeed, quantitative analysis of catches in the present study revealed a high dominance of Alestidae species. Thienemann (1954) [37] asserted that a balanced stand, is that in which there is not a taxon that largely dominates in numbers. Moreover, the mining zone (H'= 2.97, E = 0.52) showed the lowest values of these indices indicating that this site would relatively be less stable compared to upstream and downstream. Anthropogenic activities such as gold panning (use of dredge in the Cavally bed) and mining industry could be responsible of ecological disturbance. In Baoulé River, similar results were obtained in the Niger River catchment of Mali [10].

Relatively to the conservation status of fishes, 68.42% of species were recorded as Least Concern (LC) category. This result is very closer to that recorded in the River Dhonagoda [39].

Some fish species recorded in Cavally river were classed as threatened species, so the high pressure of mining activities in the Zouan-Hounien department, mostly in the Cavally river bed could be a driving force for extinction of Cavally's endemic and threatened species. These endemic species, *Micralestes eburneensis*, *Chromidotilapia cavalliensis* and *Coptodon walteri* were mentioned during previous studies [40-14]. Over decades, anthropogenic activities, would change natural ecosystems, deteriorate the quality of water and some habitats in this area [41] and lead probably to extinction of endemic species.

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