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Influence of mining on the ecological quality of the cavally river (Western Cote D'ivoire)

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Abstract

The aim of this study is to assess the ecological quality of a section of the river Cavally through physico-chemical variables. These parameters were measured seasonally in situ between April 2015 and May 2017. At each sampling station, water temperature, conductivity, TDS, dissolved oxygen and pH were measured twice a day. The results obtained show that the spatial variation in physico-chemical parameters showed a significant difference between the mean values obtained upstream, in the mining area and downstream (Kruskall-Wallis ; $p < 0.05$; ANOVA ; $p < 0.05$). Overall, stream substrate varied from station to station. The mining zone was not positively correlated with any species. It is characterised by high water temperature and depth. The downstream zone, on the other hand, has high values for conductivity and canopy but is positively correlated with a number of species, notably *Hepsetus odoe*, *Petrocephalus pellegrini* and *Heterobranchus longifilis*.

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Introduction

Essential for life, freshwater plays a central role in the development of human civilizations because aquatic and terrestrial ecosystems do not function independently of each other (Omernick and Bailey, 1997). However, human influences on aquatic biotope and its biocenosis are very diverse. According to Ibarra (2004), water and soil use are based on the four main human activities that can impact hydrosystems. Changes in the morphology of rivers, their physico-chemical properties and different uses have consequences on water quantity and quality (Cooper *et al.*, 1998). Aquatic biodiversity is threatened by anthropogenic activities mainly agriculture and mining that have intensified in recent years, especially in the Cavally basin and especially in the Ivorian part of its upper course at the level of the locality of Ity (Kamagaté, 2019). Among aquatic resources, fish are highly vulnerable to chemicals used in gold panning (Sanogo *et al.*, 2012). Indeed, several rivers including the river Cavally (Zouan-hounien) are impacted by this activity.

The distribution of freshwater fish is subject to many influences. These influences are ecological in relation to the effects of anthropogenic activities (disappearance of specific habitats, species extinction, hybridization, etc.) (Kamelan, 2014; Kouassi *et al.*, 2017).

Many research works (Konan *et al.*, 2007; Aboua, 2012) have been conducted on the impact of agricultural and industrial activities and on fish populations in Côte d'Ivoire but very few concerned the impact of mining activities. The objective of this study is (1) to evaluate the impact of mining on the ecological quality of this portion of the Cavally River through the physico-chemical variables and (2) their influences on the organization of the ichthyological settlement.

Material and methods

Study environment

With a length of 700 km, this river covers a watershed of 28,800 km2 (Koffi, 2017). To have a more global vision of the water quality in the study area, three sampling areas were chosen on the upper and middle course of the Cavally River according to the intensity of anthropogenic pressures, habitat diversity, the hydrological regime and the canopy. Accessibility of areas to sampling equipment and crews was also considered. Fourteen stations were selected for this study in the Cavally River (Fig. 1). These stations are divided into three sectors as follows:

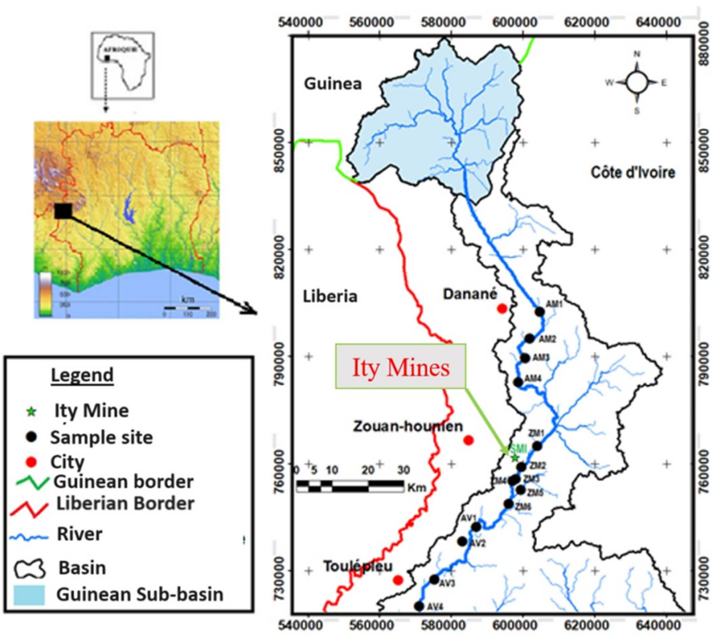


Fig. 1. Location of study area and sampling stations on the Cavally River (Côte d'Ivoire)

The first sampling area is located upstream of the Ity mining area and consists of four stations.

The second sampling area is located in the Ity mining area with six stations. Finally, the third sampling area is located downstream of the Ity mining area with four sampling stations.

All these areas are more related to the Sudanese regime than to the Baouléen regime because they have only two well individualized seasons. The dry season is however quite short (November to February), while the rainy season extends from March to October with a peak of precipitation in September (Kouassi *et al.*, 2017; Brou, 2019).

Equipment for measuring physico-chemical parameters

pH, dissolved oxygen (mg/L), electrical conductivity (µS/cm), dissolved solids (mg/L), water and air temperature (°C) were measured using a multi-parameter (HQ40d). Water transparency was evaluated in cm with a Secchi disc. The depth and width of the river, expressed in m, were measured by means of a graduated rope. Water sampling for cyanide and nutrient salts was performed using a 1-litre Niskin bottle. The sediment was collected using a Van Veen tipper in the Cavally River.

Measurement of environmental variables

Physico-chemical variables

Physico-chemical parameters were measured seasonally in situ between April 2015 and May 2017. At each sampling station, the temperature, the conductivity, the TDS, the dissolved oxygen level and the pH of the water were measured twice a day, between 7 am and 8 am and between 12 pm and 1 pm. For this purpose, after connecting the probes of the multi-parameter previously calibrated, he was energized and his probes were immersed in water. The value of each parameter is displayed after selecting the desired function. The transparency of the water was measured by total immersion followed by a gradual rise of the Secchi disc. Transparency is the distance at which the disc becomes visible again. This parameter was measured under the same conditions and by the same operator between 10:00 and 15:00. Water samples for the determination of nutrient salts and cyanide were stored in 1000 ml and 500 ml polyethylene bottles and then packaged in a cooler at 4°C before transport to the laboratory. Nitrate was determined according to ISO 7890-3 of December 1988 and orthophosphate according to NF ISO 6878 of April 2005. Heavy metals (mercury, arsenic) and total cyanide were determined by atomic absorption spectrometry.

Fish sampling

The fishery was conducted using gillnets. To do this, the nets were set between 5 pm – 6 pm and picked up the next day starting at 7 am for night fishing and then picked up again between 2 pm -3 pm for day fishing. In shallow and edge areas of the section, net fishing was conducted for approximately 30 minutes by two operators in the dry season. Taxonomic identification was carried out in the field by combining the identification keys proposed by Paugy *et al.* (2003) and Sonnenberg and Busch (2009).

Statistical treatments

Kruskal-Wallis, Mann-Whitney Test and Analysis of Variance (ANOVA) tests were used to compare spatial variations of physico-chemical and hydromorphological parameters (upstream, mining and downstream) to the significance threshold of 0.05. The t-test was used to compare two averages for seasonal variations in physico-chemical parameters. The canonical correspondence analysis (CCA) highlighted the main environmental factors influencing the distribution of fish.

Results

Environmental characteristics of the cavally river

Spatial variation of physico-chemical parameters

Variations in physico-chemical parameters are shown in Fig. 2. The water temperature ranged from 22.5 (downstream) to 28.7°C (mining area) (Fig. 2A). The variation of the temperature according to the zones, showed a significant difference between the upstream and the mining zone (Kruskall-Wallis; $p < 0.05$), but no significant difference between these two zones and the downstream (Kruskall-Wallis; $p > 0.05$).

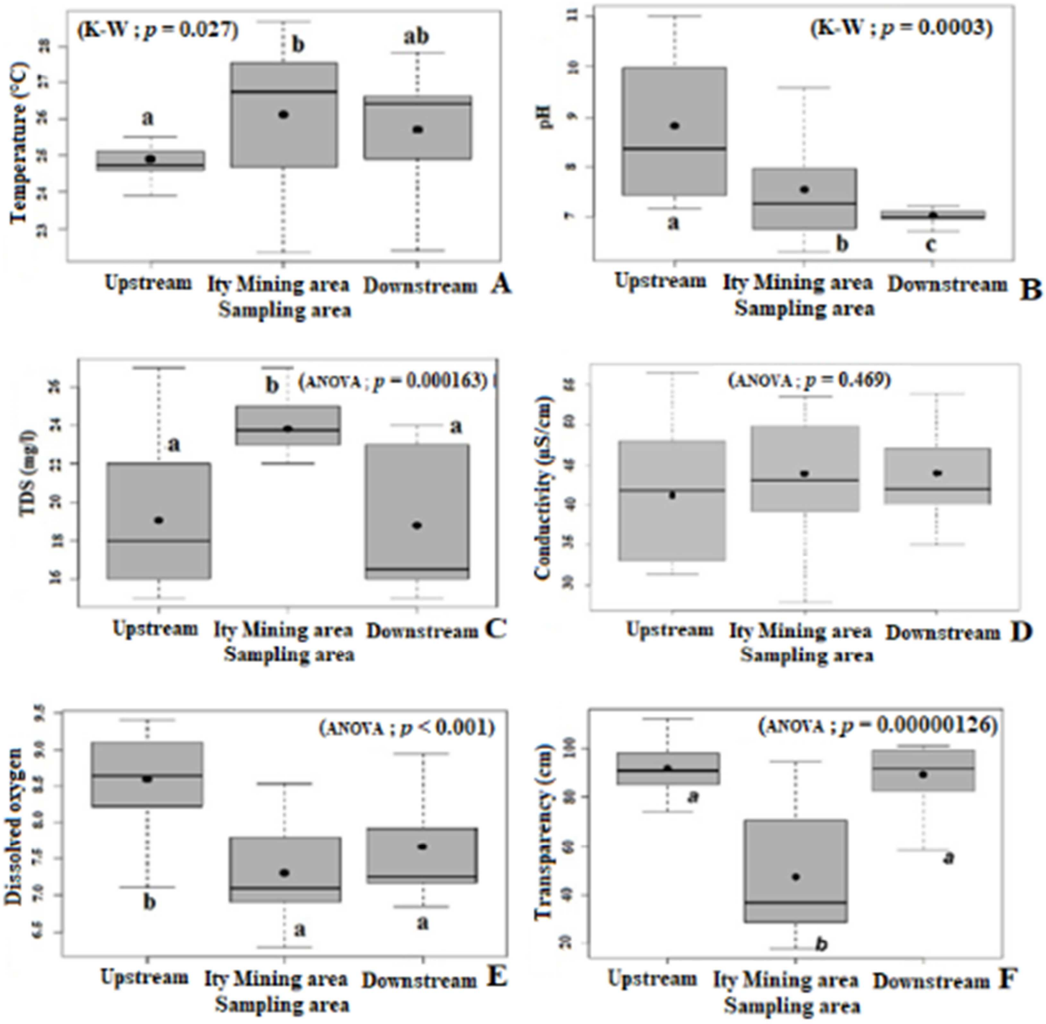


Fig. 2. Spatial variation of physico-chemical parameters measured between April 2015 and May 2017 in the Cavally River

The pH in the study area ranged from 6.31 (mining area) to 11.01 (upstream) (Fig. 2B). Analyses of this parameter by sampling area showed a significant difference between upstream, mining area and downstream (Kruskall-Wallis; $p < 0.05$).

Dissolved solids (TDS) ranged from 15 to 27 mg/L, with an average value of 20.50 ± 2.93 mg/L. The highest mean TDS was recorded in the mining area (23.82 ± 1.5 mg/L). The lowest mean value of this variable was obtained downstream (18.8 ± 3.7 mg/L) (Fig. 2C). For this parameter, no significant difference was observed between upstream and downstream (ANOVA; $p > 0.05$), but a significant difference was noted between these two zones and the mining zone (ANOVA; $p < 0.05$).

Water conductivity varied from 28 to 56.5 µS/cm with an average value of 43.05 7.07 µS/cm for all the areas surveyed. The mining area (43.92 ± 6.6 µS/cm) has the highest average conductivity value and the lowest value was measured upstream (41.23 ± 8.6 µS/cm) (Fig. 2D). These values showed no significant difference between the studied areas (ANOVA; $p > 0.05$). The minimum and maximum dissolved oxygen levels were 6.28 mg/L and 9.41 mg/L, respectively, with a mean dissolved oxygen level of 7.85 0.70 mg/L. The highest mean dissolved oxygen level was recorded upstream (8.59 0.69 mg/L). The lowest mean value of this parameter was recorded in the mining zone (7.31 ± 0.63 mg/L) (Fig. 2E). The comparison of dissolved oxygen values between study areas showed no significant difference between the mining area and the downstream (ANOVA; $p > 0.05$), but a significant difference appeared between these two areas and the upstream (ANOVA; $p < 0.05$).

Water transparency values ranged from 20 to 112 cm. The average value is 75.95 cm. The highest value was measured upstream (91.76 cm). It is lower in the mining area (47.47 cm) (Fig. 2F). Comparison of these values showed no significant difference between upstream and downstream (ANOVA; $p > 0.05$), but a difference between these two zones and the mining zone (ANOVA; $p < 0.05$).

Spatial variation of heavy metals, total cyanide and nutrient salts

The mean levels of mercury, arsenic and total cyanide are reported in Table 1. The mean values of nitrate and orthophosphate are 1.12 mg/L and 0.10 mg/L, respectively. Table 2 presents the values of these upstream nutrients, mining and downstream.

Table 1. Mercury, arsenic and total cyanide levels measured between April 2015 and May 2017 in the Cavally River

Sampling area	Mercury (mg/Kg)	Arsenic (mg/Kg)	Cyanide total (mg/L)
Upstream	$0.793.10^{-3}$	1.42	< 0.001
Ity mining area	$5.75.10^{-3}$	30.9	< 0.001
Downstream	$1.37.10^{-3}$	3.22	< 0.001

Table 2. Nutrient salt concentrations measured in Cavally areas studied from April 2015 to May 2017.

Sampling area	Nitrates (mg/L)	Ortophosphates (mg/L)
Upstream	1.35	0.08
Ity mining area	0.98	0.11
Downstream	1.04	0.11

Seasonal variation of physico-chemical parameters

The mean values of conductivity, temperature, dissolved solids, dissolved oxygen, transparency and pH measured in the dry and rain seasons are presented in Table 3.

Table 3. Seasonal variation in physico-chemical parameters measured between April 2015 and May 2017 in the Cavally River

	Upstream			Ity mining area			Downstream		
	SP	SS	p	SP	SS	p	SP	SS	p
Cond	33.11±1,49	49.82±5.45	0.0018*	40.88 ± 3.60	52.7±0.62	< 0.001*	41.58±4,58	51.38 ± 2.37	0.004*
T_xO_2	8.61±0,25	7.37±0.24	0.003*	7.74 ± 0.30	7.02±0.06	< 0.001*	8.16±0,70	7.15 ± 0.08	0.0163*
pH	8.64±0,29	7.75±0.15	< 0.001*	7.3 ± 0.30	6.9±0.3	0.011*	7.12± 0,15	6.85 ± 0.23	0.059 ^{ns}
Temp	24.95±0,29	25.71±0.15	< 0.001*	24.66 ± 0.78	27.24±0.7	< 0.001*	25.92±1,21	25.41 ± 2.34	0.65 ^{ns}
TDS	16.42±0,97	21.8±0.83	< 0.001*	20.64 ±1.90	25±1.4	< 0.001*	18.16±3,4	24.75 ± 1.5	0.007*
Trsp	85.71±9,1	81±7.31	0.36 ^{ns}	94.10 ±7.67	30.17±8.4	< 0.001*	95.5±3,8	42.87 ± 4.7	< 0.001*

* : test- t significant ; ns : test- t not significant ; Cond : Conductivity ; TxO2 : Dissolved oxygen pH : potentiel d'hydrogène ; Temp : Température, TDS : Dissolved solids ; Trsp : Transparency ; SP: rainy season; SS: dry season.

Disturbance of the environmental characteristics of the cavally river by illegal gold mining activity

Fig. 3 shows the disturbance of the riverbed caused by underground gold panning. Indeed, the intensive and uncontrolled dredging in the bed of the stream causes the obstruction of the stream by uprooted trees on the banks, the increase of suspended matter, changing the morphology of the bottom of the stream by establishing shoals and depressions, widening the stream bed in places, reducing draught in places and destroying vegetation on the banks.

Specific richness of the ichthyofauna of the cavally river

Spatial variation of ichthyofauna

The distribution of fish species in the three considered sectors of our Cavally River study area indicates 71 species in the upstream sector, 52 species in the mining zone and 66 species in the downstream sector (Table 4).

The variation of the specific richness according to the sampling sectors showed no significant difference between the upstream and downstream sectors (Mann–Whitney test; $p > 0.05$).

However, a significant difference was observed between these two sectors and the mining area (Mann–Whitney test; $p < 0.05$).

A: Obstruction of the watercourse by uprooted trees on the banks, B & E: Increase in suspended solids (water becomes very turbid), C: Modification of the morphology of the watercourse bottom, C &D: Reduction in draught in places and widening of the watercourse bed in places, F: dredger in navigation on the Cavally river.

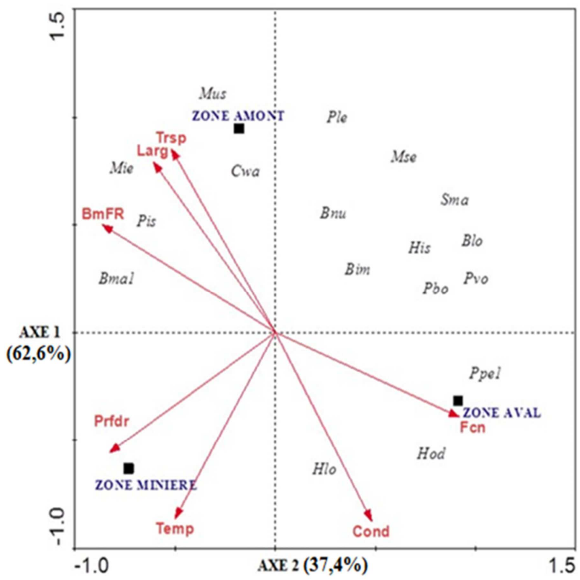
Fig. 3. Photos illustrating the modification of the environmental characteristics of the Cavally River by the scale of illegal gold-panning activity.

Seasonal variation of ichthyofauna

In the upstream and downstream zones, the variation in species richness was non-significant from one season to another (Mann–Whitney test; $p > 0.05$). The specific richness of the mining area varied significantly from season to season (Mann–Whitney test; $p < 0.05$).

Influence of environmental parameters on the organisation of fish populations

The results of the Canonical Correspondence Analysis (CCA) (Fig. 4) showed that the correlation between environmental factors and fish species is mainly explained by the first two axes (100% of cumulative variance for species data). Canopy closure, deadwood-foliage-root, stream depth, stream width, transparency, temperature and water conductivity best explain the distribution of ichtyofauna in the upper and middle Cavally River. The factor axis 1 clearly separates the mining area from the downstream. The mining area would not be positively correlated to any species. This zone, located in the negative part of axis 1, is characterized by high values of the temperature and the depth of the watercourse. The downstream zone is marked by high conductivity and canopy values but is positively correlated with a number of species including *Hepsetus odoe*, *Petrocephalus pellegrini* and *Heterobranchus longifilis*. Ordination in CCA according to factor axis 2 clearly separates the areas impacted by gold panning (mining and downstream areas) from that not impacted by this activity (upstream area).



Bm FR: dead wood-leaves-roots, Fcn: canopy closure, Larg: stream width, Trsp: stream transparency, Prfdr: stream depth, Temp: stream temperature, Cond: stream conductivity.

Fig. 4. Canonical correspondence analysis (CCA) applied to physicochemical parameters and fish species caught in the Cavally River from April 2015 to May 2017.

Table 4. Distribution of fish species caught in the Cavally River from April 2015 to May 2017

Families	Species	Codes	Sampling area		
		Codes	Upstream	Ity mining area	Downstream
Polypteridae	*Polypterus palmas*	Ppa	+	+	+
Clupeidae	*Pellonula leonensis**	Ple	+	+	+
	*Pellonula vorax**	Pvo	+	+	+
Arapaimidae	*Heterotis niloticus*	Hni	+	+	+
Notopteridae	*Papyrochranus afer*	Paf	+	+	+
Mormyridae	*Mormyrus tapirus*	Mta	+		
	Mormyrus rume	Mru	+	+	+
	Marcusenius senegalensis	Mse	+	+	+
	Marcusenius furcidens	Mfu	+	+	+
	Marcusenius ussheri	Mus	+	+	+
	Mormyrops breviceps	Mbr	+	+	+
	Mormyrops anguilloides	Man	+	+	+
	Brienomyrus brachyistius	Bbr	+	+	
	Petrocephalus pellegrini	Ppe1	+	+	+
	Petrocephalus bovei	Pbo	+	+	+
	Hippopotamyrus pictus	Hpi	+	+	+
	Pollimyrus isidori	Pis	+	+	+
Hepsetidae	*Hepsetus odoe*	Hod	+	+	+
	Hepsetus occidentalis	Hoc			+
Alestidae	*Brycinus longipinnis*	Blo	+	+	+
	Brycinus derhami	Bde	+	+	+
	Brycinus nurse	Bnu	+	+	+
	Brycinus imberi	Bim	+	+	+
	Brycinus macrolepidotus	Bma1	+	+	+
	Micralestes occidentalis	Moc	+	+	+
	Micralestes eburneensis	Meb	+	+	+
Distichodontidae	*Nannocharax fasciatus*	Nfa	+	+	+
Cyprinidae	*Raiamas senegalensis*	Rse	+	+	+
	Raiamas nigeriensis	Rni	+	+	+
	Labeo coubie	Lco	+	+	+
	Labeo parvus	Lpa1	+		
	Labeobarbus parawaldroni	Lpa2	+		+
	Enteromius leonnensis	Lwu	+		
	Labeobarbus wurtzi	Ele	+	+	+
	Enteromius trispilos	Etr	+	+	+
	Enteromius macrops	Ema	+	+	+
	Enteromius ablabes	Eab	+	+	+
	Enteromius chlorotaenia	Ech	+	+	+
	Enteromius bigornei	Ebi	+		+
	Enteromius inaequalis	Ein	+		+
Claroteridae	*Chrysichthys maurus*	Cma	+	+	+
	Chrysichthys teugelsi	Cte	+		+
	Chrysichthys auratus	Cau	+		
	Chrysichthys sp.	Cjo	+		+
	Chrysichthys nigrodigitatus	Cni	+	+	+
Schilbeidae	*Parailia pelucida*	Ppe2	+		+
	Schilbe mandibularis	Sma	+	+	+
Clariidae	*Heterobranchus longifilis*	Hlo	+	+	+
	Heterobranchus isopterus	His	+	+	+
	Clarias anguillaris	Can	+	+	+
	Clarias salae	Csa	+		+
	Clarias ebriensis	Ceb	+	+	+
	Clarias laeviceps	Cla	+	+	
Malapteruridae	*Malapterurus punctatus*	Mpu	+	+	+
Poeciliidae	*Aplocheilichthys spilauchen*	Asp	+	+	+
Nothobranchiidae	*Epiplatys olbrechtsi*	Eol	+	+	+
	Epiplatys hildegardae	Ehi	+		
	Scriptaphyosemion schmitti	Ssc			+
Channidae	*Parachanna obscura*	Pob	+	+	+
Cichlidae	*Chromidotilapia cavalliensis*	Cca	+		+
	Thysochromis ansorgii	Tan	+		
	Chromidotilapia guntheri	Cgu	+	+	+
	Hemichromis fasciatus	Hfa	+	+	+

	Hemichromis bimaculatus	Hbi	+	+	+
	Pelmatolapia mariae	Tma			+
	Tilapia brevimanus	Tbr	+		
	Coptodon walteri	Cwa	+	+	+
	Coptodon zillii	Czi	+	+	+
	*Coptodon guineensis**	Cgu	+	+	+
	*Oreochromis niloticus***	Oni	+	+	+
	*Sarotherodon melanotheron**	Sme			+
	Sarotherodon tournieri	Sto	+		+
	Sarotherodon caudomarginatus	Sca	+		+
Anabantidae	*Ctenopoma kingsleyae*	Cki	+		+
Mastacembelidae	*Mastacembelus nigromarginatus*	Mni	+		+
		Total			
19	75		71	52	66

The upstream zone in the positive part of this axis is characterized by high values of width, transparency and a large amount of deadwood-foliage-roots in the stream bed. It has been observed in this area, a larger number of species with high abundance such as *Micralestes eburneensis*, *Brycinus macrolepidotus*, *Coptodon walteri*, *Pollimyrus isidori* and *Marcusenius ussheri*.

Discussion

The average temperature values of the areas surveyed on the Cavally River (24.91 1.50°C to 26.13 0.94°C) could be explained by the intensity of precipitation and the duration of the rainy season (8 months/ 12 months) in this region. These results confirm the claim of Lemoalle (2006) that, in intertropical Africa, average water temperatures are most often above 20°C. However, an increase in average temperature is observed in the mining area. It could be explained by the gold panning activity that destroys the banks of the Cavally River and significantly modifies the canopy, as well as the hydromorphology of the stream. Indeed, according to Lery (2009), the factors that influence water temperature in aquatic ecosystems are latitude, degree of insolation, substrate composition, precipitation, wind and vegetation cover.

Mean dissolved oxygen values obtained in this study (7.31 ± 0.63 mg/L and 8.59 ± 0.69 mg/L) are lower than those obtained (9.8 mg/L) in the coastal rivers of south-eastern Côte d'Ivoire (Edia, 2008). In addition, dissolved oxygen levels are higher during the rainy season than in the dry season. This would be due to the fact that, the current causes a mixing of water masses, promotes the dissolution of air gases in water (Barendregt and Bio, 2003). The low levels of dissolved oxygen in the mining area are believed to be due to the abundance of suspended matter, high temperature and low water flow speed. The intense artisanal gold panning activity limits the penetration of light and therefore the photosynthetic activity following the resuspension of sediments in the bed of the Cavally. According to N'da (2015), the higher the temperature, the lower the solubility of oxygen. The combination of these factors, namely temperature and water agitation, would explain the relatively high levels of dissolved oxygen in the rainy season (low temperature and high speed) compared to the dry season (high temperature and low speed). Variations in this parameter between the mining area and downstream may indicate that the downstream stream is influenced by anthropogenic activities in the mining area. The mean pH (7.79 ± 0.83) indicates a low alkalinity of the Cavally waters in the study area. The average pH value (8.82 ± 1.5) of upstream water would be explained by low mineralization. The pH observed in the dry season in the mining zone (6.9 ± 0.3) and downstream (6.85 ± 0.23) could be explained by the high mineralization of the Cavally waters and acid drainage following the intensity of the gold panning. According to Earthworks (2018), gold and other metals are often found in rocks containing sulphide minerals.

The average conductivity obtained (43.05 ± 7.07 µS/cm) reflects the low mineralization of Cavally waters in the studied part. This value is much lower than those observed (107.05 and 112.00 µS/cm) respectively by Kouamé (2010) and Gbalo (2019) in

Sassandra. Conductivity values are higher during the dry season than during the rainy period. This increase could be justified by the concentration effect due to high water evaporation (Ouéda, 2009) and also the dilution phenomenon (Bengen *et al.*, 1992). TDS changes in proportion to conductivity.

The values of transparency (47.47 to 91.76 cm) are higher in the rainy season than in the dry season. The low transparency obtained during the dry season in the mining area could be explained by dredging the riverbed and washing the ore by artisanal gold mining. This activity results in a high concentration of solids and suspended solids resulting in more turbid and unfit water for consumption in the mining area and downstream. According to Ouedraogo (2010) gold panning contributes to soil and water pollution by waste oils from crusher and motor pump engines and chemicals leading to a loss of biodiversity.

The nitrate (1.12 mg/L) and orthophosphate (0.10 mg/l) values obtained are below the standards (nitrates < 50 mg/L; orthophosphate < 5 mg/L) defined by WHO (2008). Moreover, Rodier *et al.* (1996) indicate that phosphate levels above 0.5 mg/l should be considered as an index of pollution. The results of this study are well below the threshold values defined by these authors. In the mining area, mercury values are above this WHO guide value (Hg < 0.001 mg/Kg). For arsenic, all values (1.42 mg/Kg and 30.9 mg/Kg) are well above the WHO guideline for surface water (< 0.01 mg/Kg). These relatively high values in the Cavally River are justified by the fact that the analyses were conducted on sediments collected from the stream bed and not from the water column. Indeed, since the 1940s and 1950s, there has been intense gold mining activity in the study area (Papon, 1973). Since the establishment of the mining industry in this area in the 1990s, clandestine gold mining has developed using methods of exploitation using chemicals (Ettien, 2005). For total cyanide, the values recorded are well below WHO standards (0.7 mg/l).

The ordination in CCA made it possible to clearly separate the affected areas (mining areas) by gold panning from that which is not. The impacted areas are characterized by a low specific richness or even an absence of downstream species. While the upstream area not impacted contains almost all species. The distribution of fish species in the Cavally River is mainly influenced by the nature of the substrate (dead wood, foliage), physico-chemical parameters (temperature and conductivity), hydromorphological parameters (depth, transparency, width) and the canopy. Analysis of the correlation between ichtyofauna diversity and environmental characteristics showed that width, transparency, deadwood, leaves and roots are the environmental parameters that influence species diversity and abundance upstream. This area provides a source of food for the fish that live there, protects them from predators and represents breeding habitats for certain fish species (Aboua *et al.*, 2012).

The significant modification of the depth of the stream by the dredges of underground miners and the destruction of the banks of the stream could justify the influence of depth and temperature on the distribution of species in this area. CCA showed that canopy and conductivity significantly influence the species Hepsetus odoe, Petrocephalus pellegrini and Heterobranchus longifilis downstream of the Cavally River. The negative influence of the conductivity would be due to the mining of Ity's mining company and clandestine gold panning. No significant species were found to be indicative of the mining area. This could be explained by the profound modification of this study area in the face of the extent of gold panning (5 to 10 dredge/km).

Conclusion

Concerning the evaluation of the ecological quality, the analysis of the physico-chemical parameters of the Cavally River showed that the temperature of the prospected areas is low and varies little. The average conductivity obtained is high in the mining zone and the downstream zone is marked by low transparency and low dissolved oxygen.

For nutrient salts, the nitrate and orthophosphate values recorded are below the detection limit. At the seasonal level, the dry season is marked by an imbalance of physico-chemical parameters that negatively influences the diversity of ichtyofauna. Gold panning is therefore harmful to the environment. Given the potential risks of bioaccumulation, additional studies on the transfer of these heavy metals in the different links of the food chain and the health of the population must be carried out.

References

Aboua BRD. 2012. Développement d'un indice d'intégrité biotique piscicole pour la préservation de la biodiversité du fleuve Bandama. Thèse de Doctorat, UFR Biosciences, Université Félix Houphouët Boigny, Abidjan, Côte d'Ivoire, 227p.

Aboua BRD, Kouamélan EP, 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(8),** 1-19.

Barendregt A, Bio AMF. 2003. Relevant variables to predict macrophyte communities in running waters. Ecological Modelling **160,** 205-217.

Bengen D, Lim P, Beland A. 1992. Qualité des eaux de trois bras morts de la Garonne : variabilité spatio-temporelle. Revue des Sciences de l'Eau **5,** 131-156.

Brou LA. 2019. Modélisation de la dynamique hydrologique du fleuve Cavally sous influence de fortes pressions anthropiques dans la zone de Zouan-hounien (Côte d'Ivoire). Thèse de Doctorat, UFR Environnement, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire, 178p.

Cooper S, Diehl S, Kratz K, Sarnelle O. 1998. Implications of scale for patterns and processes in stream ecology. Australian Journal of Ecology **23,** 27-40.

Earthworks FS. 2018. Hardrock Mining and Acid Mine Drainage. http://www.earthworksaction.org/pubs/FS_AMD.pdf

Edia OE. 2008. Diversité taxonomique et structure des peuplements de l'entomofaune des rivières côtières Soumié, Eholié, Ehania, Noé (Sud-est, Côte d'Ivoire). Thèse de Doctorat, UFR des Sciences et Gestion de l'Environnement, Université d'Abobo-Adjamé, Abidjan, Côte d'Ivoire, 152 p.

Ettien DZ. 2005. Etude d'évaluation de l'impact des exploitations minières sur l'environnement et les populations en Afrique de l'ouest : cas de la mine d'or d'Ity dans la région semi-montagneuse de l'ouest de la Côte d'Ivoire. Apport du système d'informations géographique (SIG) et de la Télédétection. Thèse de Doctorat, UFR STRM, Université Félix Houphouët Boigny, Abidjan, Côte d'Ivoire, 163p.

Gbalo BMB. 2019. Diversité et statut de conservation de l'ichtyofaune du lac de Buyo à Guessabo (Bassin du fleuve Sassandra) au Centre-Ouest de la Côte d'Ivoire. Mémoire de Master de Biodiversité et Gestion Durable des Ecosystèmes Option: Gestion et Conservation de la faune sauvage, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire, 47p.

Ibarra AA. 2004. Les peuplements de poissons comme outil pour la gestion de la qualité environnementale du réseau hydrographique de la Garonne. Thèse de Doctorat, Institut National Polytechnique de Toulouse, Toulouse, France, 133p.

Kamagaté EAI. 2019. Diversité et dynamique des macroinvertébrés benthiques : outil d'évaluation de la qualité des eaux du bassin supérieur du fleuve Cavally sous influence d'activités minières (Ouest, Côte d'Ivoire). Thèse de Doctorat, UFR Environnement, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire, 214p.

Kamelan TM. 2014. Peuplement ichtyologique de quelques hydrosystèmes de l'espace Taï (Côte d'Ivoire). Thèse de Doctorat, UFR Biosciences, Université de Cocody, Abidjan, Côte d'Ivoire, 277p.

Koffi B. 2017. Dimensionnement du canal de dérivation du fleuve Cavally à l'aide d'un modèle hydraulique 1D. Master Génie de l'environnement et de l'eau, UFR Environnement, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire, 50p.

Konan KF, Ouattara A, Ouattara M, Gourène G. 2007. Weight-length relationship of 57 fish species. Ribarstvo **65(2),** 49-60.

Kouamé KA. 2010. Diversité biologique et habitudes alimentaires de quelques espèces de poissons dans le cours inférieur du bassin du fleuve Sassandra (Côte d'Ivoire). Thèse de Doctorat, UFR Biosciences, Université Cocody-Abidjan, Abidjan, Côte d'Ivoire, 219p.

Kouassi KL, Konan KF, Konan KS. 2017. Etat des lieux du fleuve Cavally dans le département de Zouan-Hounien (Ouest Côte d'Ivoire): Aperçu de la géomorphologie, l'hydrologie, l'hydrochimie et l'hydrobiologie. Rapport d'étude – SMI-ENDEAVOR MINING / UJLOG, Daloa, Côte d'Ivoire, 58p.

Lemoalle J. 2006. La diversité des milieux aquatiques. In: Les poissons des eaux continentales africaines: Diversité, écologie, utilisation par l'homme. Lévêque C, Paugy D. (Eds). IRD. Paris: 11-30.

Lery S. 2009. Mesures en continu des températures sur quelques rivières des pays de la Loire. Rapport DIREN, 16p. Willis D.W. (Eds). American Fisheries Society, Bethesda, Maryland, USA: 83-120.

N'da AS. 2015. Biodiversité, structure du peuplement ichtyologique et relations trophiques d'un bassin du nord de la Côte d'Ivoire : cas de la rivière bagoé. Thèse de Doctorat, UFR Biosciences, Université de Cocody, Abidjan, Côte d'Ivoire, 220p.

Omernick JM, Bailey RG. 1997. Distinguishing between watersheds and ecoregions. Journal of the American Water Resources Association **33,** 935-949.

OMS. 2008. Guidelines for Drinking-water Quality, Third edition, incorporating the first and second Addenda, Recommendations, Geneva, Volume 1, 515 p.

Ouéda A. 2009. Zooplancton et alimentation des poissons des lacs artificiels de Bagré et Loumbila (Burkina Faso). Thèse de Doctorat, Université de Ouagadougou, Ouagadougou, Burkina Faso, 156p.

Ouedraogo AH. 2010. L'impact de l'exploitation artisanale de l'or (orpaillage) sur la santé et l'environnement: Cas de l'utilisation du mercure dans l'exploitation artisanale de l'or et l'évaluation des impacts sur la santé et l'environnement au Burkina Faso. Mediaterre. Consulté le 05-08-2019. https://www.mediaterre.org/membres/Aboubakar.

Papon A. 1973. Géologie et minéralisation du Sud-Ouest de la Côte d'Ivoire : Synthèse des travaux de l'opération SASCA 1962-1968. Mémoire du BRGM **80**, 285p.

Paugy D, Lévêque C, Teugels GG. 2003. Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome 1. IRD (Paris), MNHN (Paris), MRAC (Tervuren), 457p.

Rodier J, Bazin C, Chanbon P, Broutin JP, Champsaur H, Rodi L. 1996. L'Analyse de l'eau : aux Naturelles, Eaux Résiduaires et Eaux de Mer. Dunod, Paris, 1383 p.

Sanogo Y, Traoré D, Samaké F, Koné A. 2012. Les communautés ichtyologiques de la rivière Baoulé dans le bassin du fleuve Niger au Mali. Tropicultura **30(2),** 65-71.

Sonnenberg R, Busch E. 2009. Description of a new genus and two new species of killifish (Cyprinodontiformes: Nothobranchiidae) from West Africa, with a discussion of the taxonomic status of Aphyosemion maeseni Poll, 1941. Zootaxa **2294,** 1-22.