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Comparative analysis of fish assemblages in three mining areas (Diamond, Gold and Manganese) of Ivory Coast (West Africa)

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Abstract
This study described the fish population in three mining areas. The fish fauna was sampled during eight surveys from November 2017 to January 2019 with two fishing gears (Gill nets and dip nets). A total of 53 species was inventoried in the 3 zones, 38 species in TORTIYA (Diamond area), 28 species in LAUZOUA (Manganese area) and 27 species in HIRE (Gold area). The proportion of constant species is relatively higher at all sites (36 – 62.5%). Invertivores dominated fish communities on all prospected stations. Rarefied richness and Shannon-Weaver index are significantly (kruskal- Wallis test; $p < 0.05$) higher at TORTIYA comparatively to HIRE and LAUZOUA. As for the Pielou's evenness index, it does not vary significantly ($p > 0.05$) between areas. Similarity analyses (ANOSIM) showed that the composition of the fish assemblage did not change significantly ($p > 0.05$) in the locality of TORTIYA. At the localities of HIRE and LAUZOUA the compositions change significantly ($p < 0.05$).

Keywords: Fish diversity, distribution, mining areas, Côte d'Ivoire, West Africa

1. Introduction

In Côte d'Ivoire, one of the main development axes defined by the government is the developing mining area. So many authorizations of mining exploitation are given to several companies. The performance of the current operation is 12 tons of gold and approximately 400,000 tons of manganese annually. As for diamond production, it is estimated at 300,000 carats, made artisanally. Even more, the populations are interested by traditional mining exploitation. HIRE and TORTIYA are of the cities where many people there to exploit this gold and diamond to get money. Such activities generate pollution of environment in general and surface water in particular.

Most of the studies carried out these mining areas concerned the physico-chemical quality of the water [1-4]). No study has evaluated the ecosystem health based on fish assemblages. Yet freshwater fish represent an important component of the aquatic ecosystem and are highly valued for their economic, social and aesthetic importance [5]. In addition, fish are already involved in environmental policies as biodiversity and ecological quality indicators [6] and they have been used successfully conservation evaluations [7] and assessments of ecologically acceptable water regime management [8]. The study of diversity and abundance among species has been commonly used as an indicator of biotic integrity in different types of ecosystems [9, 10]. Some studies have used the diversity and structure of communities (plants and/or animals) to demonstrate the effect of exposure to a certain pollutant such as pest-control substances, metals, herbicides, chemical wastes, residual water discharge [11- 14].

This study, carried out for the first time, aims to describe the fish population of the different mining areas through diversity, spatial distribution, occurrence and abundance, in order to improve the management and conservation of the fish resources of the mining areas.

2. Materials and Methods

2.1. Study area

This study was conducted in three mining areas: TORTIYA, HIRE and LAUZOUA. TORTIYA is a diamondiferous area, located on a hill in the Hambol region (Côte d'Ivoire).

The geographical coordinates of this locality are 8 ° 46'0 "N and 5 ° 40'60" W [15]. Artisanal mining is practiced in this area. HIRE city, situated between 05 ° 18'000 and 05 ° 16'500 W, and between 06 ° 12'200 and 06 ° 10'500 N, belongs to the region of Lôh-Djiboua [2]. In HIRE area, the artisanal and industrial activities of gold are practiced. LAUZOUA is located in the Lôh-Djiboua region in the south of Côte d'Ivoire. The area is located at the former "Mokta" mine at coordinates 05 ° 20'06.5" N and 05 ° 23'00.9 "W [16]. An industrial manganese exploitation is conducted in this zone.

2.2. Sampling sites

The choice of sampling sites (Figure 1) was guided by water permanence, accessibility to any period and extent of degradation of sites by mining activities and other human activities. Two (2) streams were selected respectively at HIRE (Gbloh and Tchindegri,) and LAUZOUA (Dougodou and N'Têkô). In TORTIYA zone, on stream (Bou) has been chosen. Site characteristics are summarized in Table 1.

2.3. Data Collection

The fish fauna was sampled from November 2017 to January 2019. The sampling concerned exclusively experimental fishing. Gill nets of different meshes (9, 10, 15, 20, 26, 30, 35, 40 and 45 mm) and dip nets (25 cm in diameter and 2 mm in mesh size) were used. In each sampling site, gill nets are usually set in the afternoon at 17.00 visited the following day in the morning at 7.00. Fish analysis began with the identification and enumeration of specimens that make up the samples. The identification of taxa was made using the keys proposed by Paugy *et al.* (2003ab) [17, 18], and systematic reviews available at *www.fishbase.org.*

2.4. Data analysis

In this study, the results of dip net will be only used for inventory quality. For the quantitative comparisons, only fish caught in gill nets will be taken into account.

Diversity indices based on data from gill nets were calculated to describe the assemblages for fishes across the different sampling areas. Species diversity was assessed using four different indices viz., species richness, rarefied richness, Shannon–Wiener index (*H'*) (Shannon and Weaver 1949), species evenness or equitability index (*J*) (Pielou 1969). Taxa richness was rarefied to eliminate any bias related to differences in abundances between samples [19, 20]. Calculations were performed using the lowest abundance (1 individual for this study) found in all sites as the target number of individuals [21]. Non-parametric tests of Kruskal-Wallis and Man-Whitney (p<0.05), were used to compare diversity indices across areas. Before performing the comparison test, the normality of data was checked by Shapiro test (P > 0.05). The analysis was performed with STATISTICA 7.1.

The percentage of occurrence or frequency F (%) is the percentage of samples in which each taxon occurred. It was calculated according to Dajoz (2000) [22], to gives some information on the number of taxa frequently met in each site without any indication on their quantitative importance [23, 24].

The classification of species according to frequency F (%) is as follows: Constant species (F > 50 %), Accessory species (25 % < F < 50 %), Accidental species (F < 25 %).

The adult feeding habits of all collected species were drawn from the literature (available on request) at the genera or species level when available. Each species was assigned into trophic groups as Herbivorous, Invertivorous, Omnivorous, Piscivorous, and Phytophagous based on its principal adult food as indicated by the literature [25, 26] supplemented with information available on http://www.fishbase.org. Species trophic composition was calculated as the proportion richness (i.e., the number of species in each trophic group divided by the total number of species).

The similarity of fish assemblages and relationships among sampling stations were mapped by ordination using non-parametric multidimensional scaling (nMDS) based on Bray-Curtis similarity indices. Significance testing and pairwise comparisons among different stations were examined using analysis of similarities (ANOSIM). Species contributions to dissimilarity (similarity) between sites were determined by using similarity percentages (SIMPER). nMDS, SIMPER, ANOSIM analyses were conducted using the software Paleontological Statistic (PAST) version 2.15.

3. Results and Discussion

3.1. Results

3.1.1. Species composition and occurrence of fish

A total of 53 fish species belonging to 8 orders, 19 families were captured (Table 2). Among them, two introduced species (*Heterotis niloticus* and *Oreochromis niloticus*) and one hybrid (*Coptodon guineensis* x *Coptodon zillii)* were collected. The Perciformes and Siluriformes, each representing at least 8 species per area, are the orders that contain the largest number of families and species in the three zones. The most diverse families in the TORTIYA and HIRE areas are Cichlidae (7 and 5 species respectively) and Cyprinidae (6 and 4 species respectively). On the other hand, in the LAUZOUA area, the most diverse families are Mormyridae (4 species) and Clariidae (3 species). Fourteen species (*Brycinus longipinnis, Chromidotilapia guntheri, Chrysichtys nigrodigitatus, Clarias anguillaris, Coptodon hybride, Ctenopoma kingsleyae, Ctenopoma petherici, Enteromius ablabes, Hepsetus odoe, Parachana obscura, Petrocephalus bovei, Schibe intermedius, Schilbe mandibularis, Synodontis schall*) were common to the three mining areas. Twelve species were only collected in TORTIYA: *Brycinus imberi, Brycinus macrolepidetus, Brycinus nurse, Heterobranchus longifilis, Heterotis niloticus, Labeo parvus, Labeo senegalensis, Pellonula leonensis, Raimas senegalensis, Sarotherodon galilaeus, Synodontis bastiani and Synodontis punctifer*. Only 6 species were specific in the area of gold mining (HIRE). There are *Brienomyrus brachyistius, Enteromius trispilos, Enteromius hypsolepis, Epiplatys dageti, Amphilius atesuensis* and *Protopterus annectens*. In the area of manganese mining (LAUZOUA), 7 species (*Papyrocranus afer, Clarias buettikoferi, Coptodon guineennis, Distichodus rostratus, Eleotris senegalensis, Marcusenius senegalensis and Thysochromis ansorgii)* were only caught.

The area of diamond mining contains more species with 38 species (25 species at Bou1 and 37 at Bou2). The specific richness is substantially equal in manganese (28) and gold (27) areas mining. In this manganese area, 25 species were identified in Dougodou1 station, 14 at Dougodou2 and 8 at N'teko. Concerning gold areas, 23 species were recorded in Gbloh1 station, 13 in Gbloh2 and 12 in Tchindegri.

The Table 3, shows a high proportion in favour of the constant species on all the stations of the three mining surfaces. At TORTIYA, 48 and 40.54% respectively are recorded at the Bou1 and Bou2 stations. In HIRE, 43.47%

were recorded in Gbloh1, 38.46% in Gbloh2 and 58.34% in Tchindegri. Regarding LAUZOUA, 36%, 42.86% and 62.5% are respectively recorded at Dougodou1, Dougodou2 and N'teko stations. There was an absence of accessory species at the N'teko station.

3.1.2. Trophic Structure of Fish Composition

The Figure 2 shows the relative abundance of different trophic groups of fish caught in the three mining areas. The group of Invertivores dominates the catches on all the stations prospected with the exception of Bou2 where Piscivores (38.5%) are more abundant. An absence of omnivorous species was found at Tchindegri station (TC) at HIRE. Concerning the LAUZOUA zone, there is an absence of Herbivorous and Phytophagous species in N'teko (NT), and Phytophagous species in Dougodou2.

3.1.3. Diversity Indices

The Rarefied richness, Shannon-Weiner Diversity (H') Index and Pielou's Evenness Index (J') were calculated for each sample to determine fish structure in of the mining surfaces. The Figure (3A) shows the variation of rarefied richness of the different mining areas. This richness varies from 4.62 to 7.63 (TORTIYA). At HIRE, the rarefied richness oscillates between 2 and 7. Concerning LAUZOUA, it is between 2 and 7.61. The kruskal- Wallis test showed a significant difference ($p < 0.05$) in the rarefied richness between TORTIYA and the two other localities (HIRE and LAUZOUA). Figure 3B showed that the Shannon-Weiner index is significantly (kruskal- Wallis test; $p < 0.05$) higher at TORTIYA (2.27) and the lowest diversity value was recorded at LAUZOUA (1.40). Regarding the Pielou's evenness index, it varied from 0.35 (LAUZOUA) to 0.69 (HIRE). The test of Kruskal-Wallis showed that there is no significant difference between its three localities (Figure 3C).

3.1.4. Compositional similarity

In the TORTIYA area, the sampling sites (Bou1 and Bou2) are not clearly separated in the NMDS biplot (stress = 0.11) (Figure 4). The ANOSIM result showed that there is no significant change in the composition of the fish community between Bou1 and Bou2 (global R ANOSIM = 0.053, P-value = 0.2061, Table 4). According to the SIMPER analysis, the main species responsible for the homogeneity and similitude between Bou1 and Bou2 are characterized by the dominance of *Schilbe intermedius, Brycinus nurse, Pollimyrus isidori, Labeo senegalensis* and *Synodontis schall* (Table 5).

Concerning the HIRE area, the NMDS graphical representation (stress = 0.13) (Figure 4) and the ANOSIM analysis noted that the compositions of the fish communities are clearly separated and significantly different between the Gbloh1 and Gbloh2 stations (global R ANOSIM = 0.5324, P - value = 0.0002; Table 4), Gbloh1 and Tchindegri (global R ANOSIM = 0.774, P-value = 0.0002; Table 4), Gbloh2 and Tchindegri (global R ANOSIM = 0.8262, P-value = 0.0002; Table 4). The species responsible for this separation according to the SIMPER analysis are characterized by the dominance of *Enteromius abables, Coptodon zillii* and *Schilbe intermedius* between the Gbloh1 and Gbloh2 stations; *Chromidotilapia guntheri, Petrocephalus bovei, and Enteromius abables* between the Gbloh1 and Tchindegri stations; *Chromidotilapia guntheri* and *Petrocephalus bovei* between Gbloh2 and Tchindegri stations (Table 5).

At LAUZOUA, the Dougodou1 and Dougodou2 stations are slightly separated in the NMDS biplot (stress = 0.14) (Figure 4). These two stations (Dougodou1 and Dougodou2) showing low (0.24) R-values, suggesting low dissimilarity between their ichthyofaunas (Table 4). The species responsible for this low dissimilarity are dominated by *Brycinus longipinnis* and *Synodontis schall* (Table 5). On the other hand, the stations Dougodou1 and N'teko, and Dougodou2 and N'teko appear separated. ANOSIM analysis have shown that fish assemblages between Dougodou1 and N'teko, and Dougodou2 and N'teko stations are significantly different (Table 4). The species that contributed to SIMPER separations are dominated by *Synodontis schall*, *Brycinus longipinnis, Ctenopoma kingsleyae* and *Thysochromis ansorgii* at Dougodou1 and N'teko; *Synodontis schall, Ctenopoma kingsleyae, Thysochromis ansorgii* and *Brycinus longipinnis* between Dougodou2 and N'teko (Table 5).

3.2. Discussion

Our results revealed that Perciformes and Siluriformes exhibit greater taxonomic diversity in the three mining areas. The dominance of these groups is common to several Ivorian basins: Gô [27], Boubo [28], San Pedro [29], Niouniourou [30], Comoé [31], Sassandra [32] and Bandama [33]. Regarding the main families, Cichlidae (7 and 5 species respectively) and Cyprinidae (6 and 4 species respectively) dominate catches in TORTIYA and HIRE. On the other hand, in the LAUZOUA area, the most diverse families are Mormyridae (4 species) and Clariidae (3 species). These observations could be compared to those of other authors who mentioned that the four families are very abundant in Côte d'Ivoire Rivers [27, 29, 32, 33, 34].

Fifty-three (53) species were identified in this study; 38 species in the TORTIYA zone, 28 in the LAUZOUA zones and 27 species respectively in HIRE area. Rarefied richness and Shannon-Weaver index are significantly (kruskal- Wallis test; $p < 0.05$) higher at TORTIYA comparatively to HIRE and LAUZOUA. As for the Pielou's evenness index, it does not vary significantly ($p > 0.05$) between areas. This high level of richness in TORTIYA would be related to the width of the river on the one hand or the other to environmental conditions such as the quality of the water, the availability of food. According to Lévêque et Paugy (2006), Aboua *et al.* (2010) [35, 33], the specific richness of an environment reflects its capacity of reception which is all the greater as the number of ecological niches is high. In general, large rivers have more fish species than smaller ones and there was a strong correlation between the volume of the discharge and the number of species in African rivers [36]. Estimates of the discharge are not always available, and the area of the drainage basin has been used in its place [37]. These relationships have been explained by the suggestion that large rivers (i.e. those with large drainage basins) provide a greater diversity of habitats [38].

14 species (*Brycinus longipinnis, Chromidotilapia guntheri, Chrysichthys nigrodigitatus, Clarias anguillaris, Coptodon guineensis X Coptodon zillii, Ctenopoma kingsleyae, Ctenopoma petherici, Enteromius ababes, Hepsetus odoe, Parachanna obscura, Petrocephalus bovei, Schibe intermedius, Schilbe mandibularis, Synodontis schall*) were common to the three mining areas. According to N'Zi *et al.* (2015) [39], these species have cosmopolitan distribution, and relatively high environmental tolerance, some of them possess accessory air-breathing organs.

As far as the occurrence is concerned, the results showed a high proportion in favour of the constant species on all the stations of the three mining surfaces. This would be explained by the fact that its environments would offer a better living condition more favourable to the species encountered during our sampling periods. The adaptation of certain species to environmental conditions is a factor that catalyzes the diversity of species encountered. In fact, according to [40], the ichthyological communities of African watercourses are very rich because many species adapt to the unfavourable conditions, notably to the contraction of their habitat.

Our results showed a high abundance of invertivorous species on all the stations of the different mining zones. These results are contrary to several studies. These studies state that the invertivore metric measures the lower trophic levels. Because invertebrates are sensitive to mining activities [41, 42], decreases in this metric with mines may suggest an effect from habitat degradation or food availability, potentially resulting from mining. Other studies have shown that trophic guilds change longitudinally [43] and with increasing degradation, such that species with specialized diets (e.g., carnivores, invertivores, herbivores) decrease, while those fish with generalized diets (i.e., omnivores) increase [6, 44]. These situations could demonstrate that our sampling stations would provide favourable feeding conditions for this trophic group. Or this group would be adapted to another mode of feeding.

The ANOSIM result showed that there is no significant change in the composition of the fish community between Bou1 and Bou2 (global R ANOSIM = 0.053, P-value = 0.2061). According to the SIMPER analysis, the main species responsible for the homogeneity and similitude between Bou1 and Bou2 are characterized by the dominance of *Schilbe intermedius, Brycinus nurse, Pollimyrus isidori, Labeo senegalensis* and *Synodontis schall*. This homogeneity recorded at the TORTIYA stations could be explained by the fact that these stations share the same environmental conditions which would be more favourable to their life cycle, reproduction or feeding.

Concerning HIRE area (global R ANOSIM = 0.7016, P -value = 0.0001) and LAUZOUA (global R ANOSIM = 0.4894, P -value = 0.0001), we observed a change in fish composition. These changes would be due to disparity of the stations on the one hand and on other hand to the various anthropogenic activities (agricultural and mining activities) that take place around the stations. According to Moustafa et El-sayed (2014) [45], all these activities affect the physicochemical characteristics of the water, sediments and biological components, thus negatively affecting the quality and quantity of fish stocks. For Mohite et Samant (2103) [46], habitat fragmentation is considered to be responsible for change in local biodiversity of the river, in recent years there are increasing reports of pollution causing massive fish kill, soil erosion and siltation, and agriculture expansion in the catchment area. River valley projects together with deforestation, mining, and changing agriculture patterns. Activities are responsible for degradation of riparian habitats. Developmental activities affect species survival by causing abrasion, clogging gills, and smothering fish eggs, algae and benthic invertebrates [47, 48]. These disturbances also reduce canopy cover and hence increase luminosity and water temperature, but also reduce the input of litter and woody debris [49]. Such environmental changes are known to affect the structure and the composition of fish communities [50, 49].

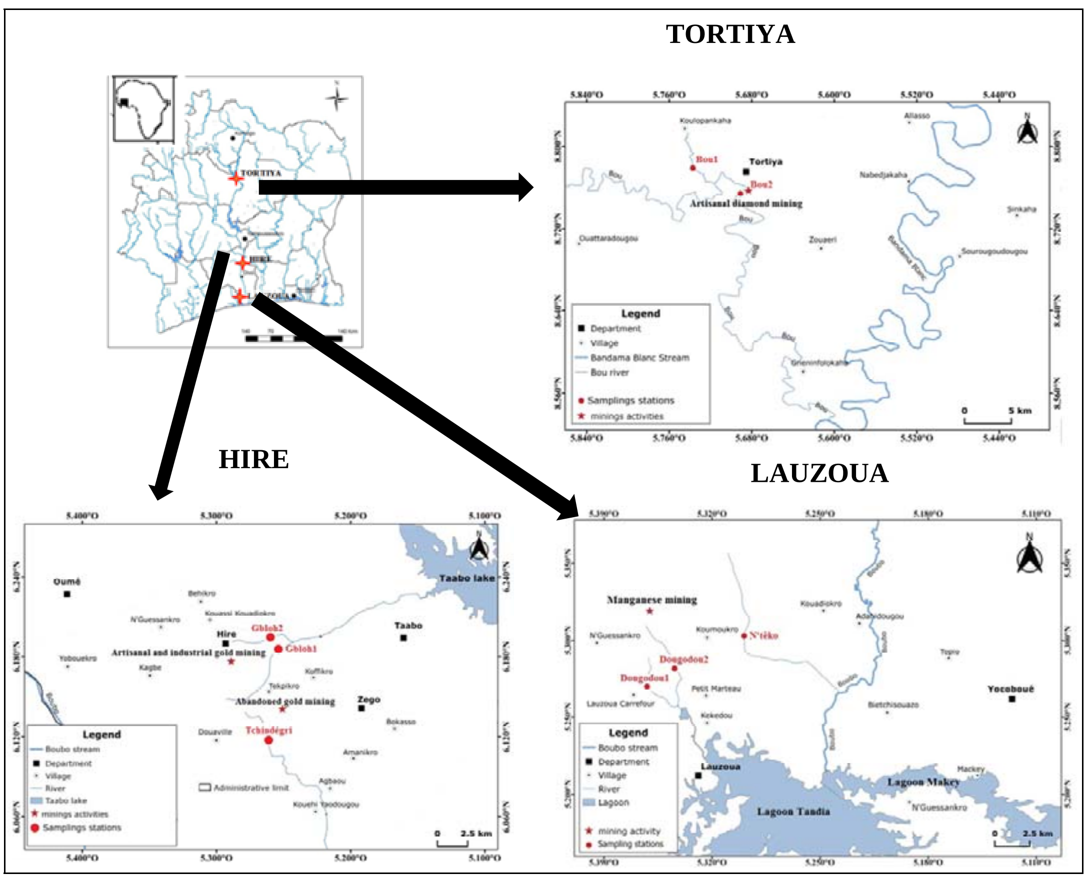

Fig 1: Study area showing the different stations of the three zones

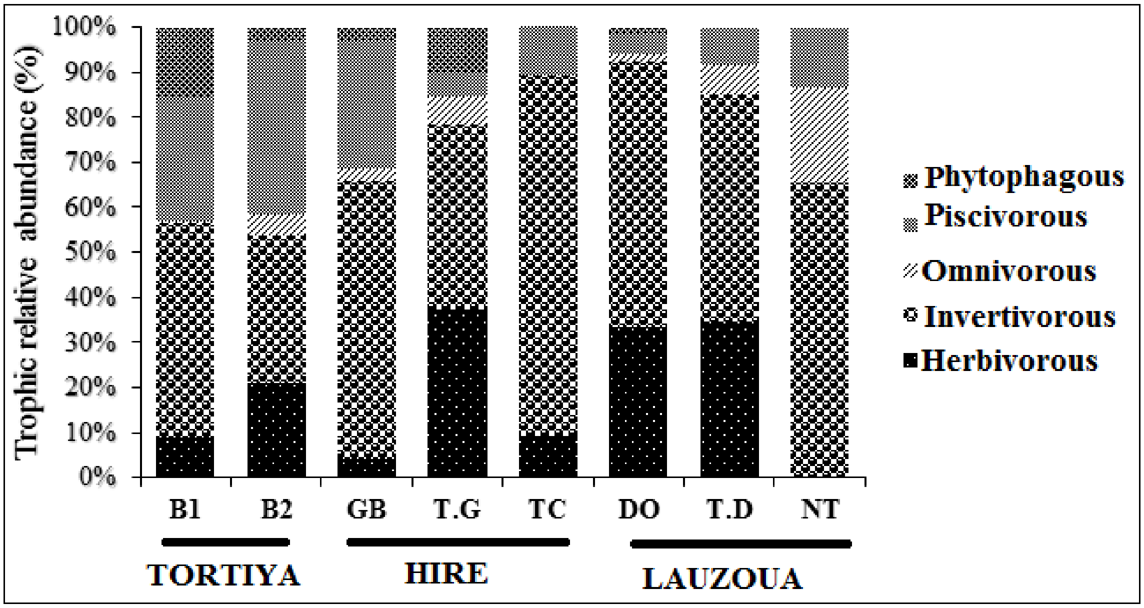

Fig 2: Trophic relative abundance of the fish caught in the three the mining areas

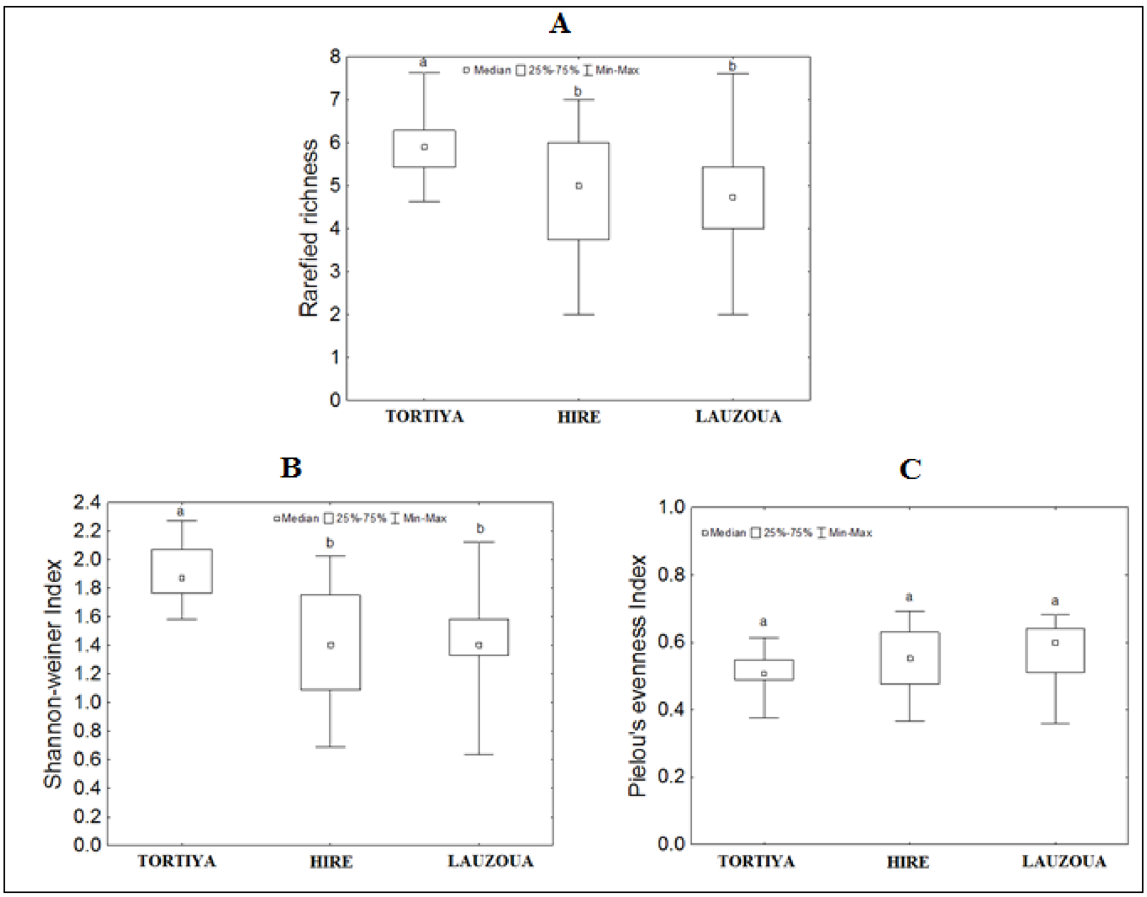

Fig 3: Spatial variation of the diversity indices of fish communities in the three mining areas: A= Rarified richness; B= Shannon-Weiner; C= Pielou's Evenness; The median values having a letter in common (a, b) does not differ significantly (Kruskal-Wallis Test; p > 0,05)

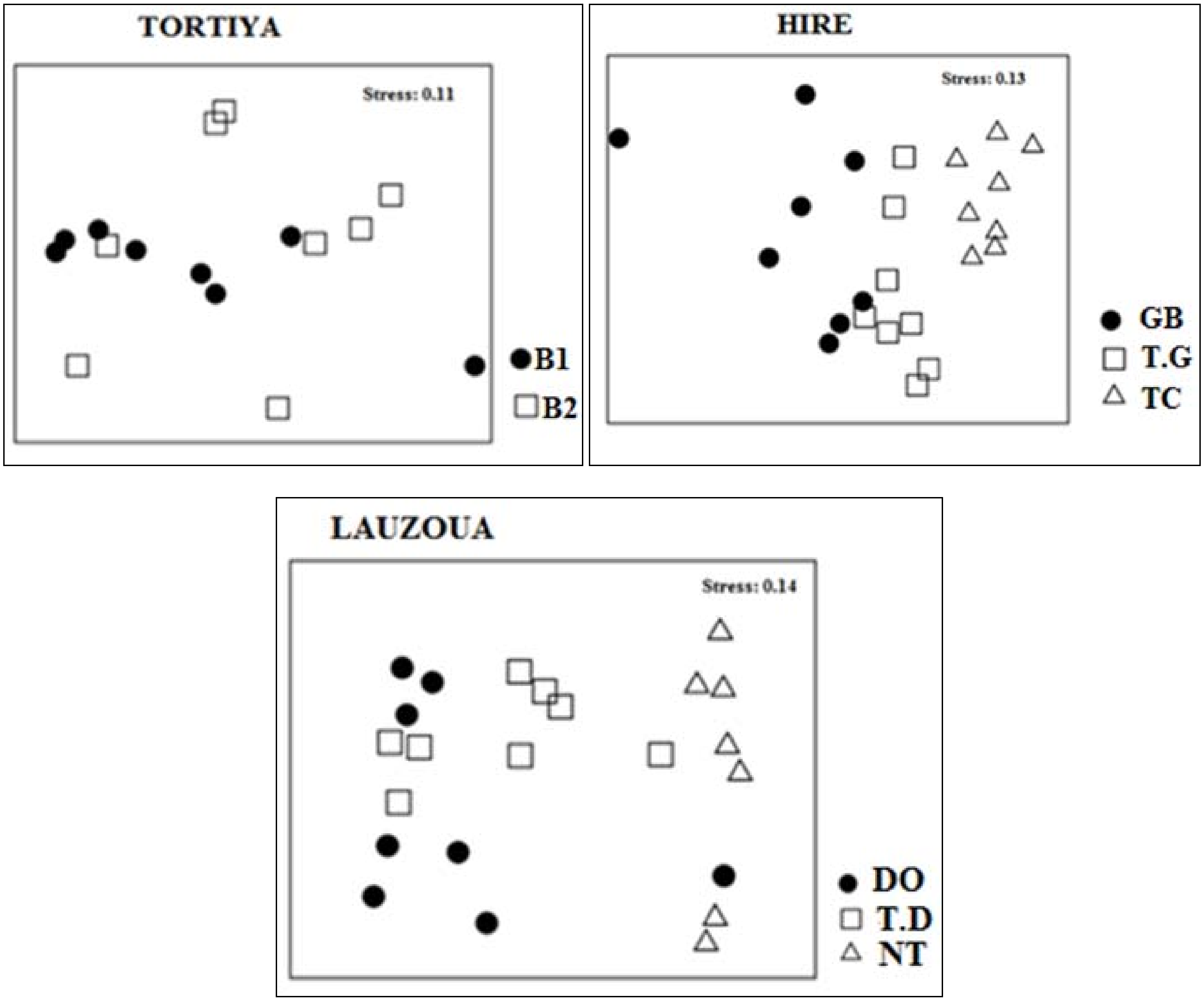

Fig 4: Non-parametric multidimensional scaling (nMDS) ordinations of fish assemblage structure in the three mining areas

Table 1: Geographical location and characteristics of study areas

				Geographic coordinates (UTM)			
Localities	**Streams**	**Stations**	**Code**	**X**	**Y**	**Altitude (m)**	**Land occupation**
TORTIYA (Diamond area)	BOU	Bou1	B1	200619	970058	300	Cashew plantation, food, fishing, no mining activity
		Bou2	B2	387252	595637	343	Diamond mining, fishing, washing cars and beef
HIRE (Gold area)	GBLOH	Gbloh1	GB	250551	684486	191	Artisanal and industrial gold activities, food
		Gbloh2	T.G	249927	685437	168	Gold industry, teak, food and cocoa plantations
	TCHINDEGRI	Tchindegri	TC	200615	970060	189	Abandoned gold mining activity, cocoa plantations
LAUZOUA (Manganse area)	DOUGODOU	Dougodou1	DO	238101	582993	4	Manganese mining, cocoa plantations, village
		Dougodou2	T.D	240225	584411	1	Manganese mining, food and cocoa plantations, village
	N'TEKO	N'teko	NT	245176	546616	4	No mining activity, cocoa plantations

Table 2: List, occurrence and distribution of fish species sampled in three mining areas captured using gill nets and dip nets[1]: Piv = Piscivorous; Inv = Invertivorous; Her= Herbivorous; Phy= Phytophagous; Pis= Piscivorous B1 = Bou1; B2 = Bou2; GB= Gbloh1 ; TG = Gbloh2; TC =Tchindegi; DO=Dougodou1; T.D= Dougodou2; NT= N'teko * = Accidental species; **= Accessory species; ***= Constant species

				Tortiya		Hire			Lauzoua		
Orders	**Families**	**Species**	**Trophic Groups**	**B1**	**B2**	**Gb**	**T.G**	**Tc**	**Do**	**T.D**	**NT**
Lepidosireniformes	Protopteridae	*Protopterus annectens*	Piv			***	**				
Polypteriformes	Polypteridae	*Polypterus endlicheri*	Piv	*					*		
Osteoglossiformes	Notopteridae	*Papyrocranus afer*	Inv						***	**	
	Osteoglossidae	*Heterotis niloticus*	Inv	**	***						
	Mormyridae	*Brienomyrus brachyistius*	Inv					*			
		Marcusenius senegalensis	Inv						**		
		Marcusenius ussheri	Inv	**	**				***		

				Tortiya		Hire			Lauzoua		
Orders	**Families**	**Species**	**Trophic groups**	**B1**	**B2**	**GB**	**T.G**	**TC**	**DO**	**T.D**	**NT**
		Mormyrus rume	Inv	**	**				*		
		Petrocephalus bovei	Inv	***	***			***	*		
		Pollimyrus isidori	Inv	**	**	*					
Characiformes	Alestidae	*Brycinus longipinnis*	Inv	***	***	***			***	***	**
		Brycinus macrolepidetus	Her		*						
		Brycinus nurse	Inv	***	***						
		Brycinus imberi	Her		**						
	Distichodontidae	*Distichodus rostratus*	Her						*		
	Hepsetidae	*Hepsetus odoe*	Piv	***	**	**			***	***	***
Clupeiformes	Clupeidae	*Pellonula leonensis*	Inv	**	**						
Cypriniformes	Cyprinidae	*Enteromius ablabes*	Inv	*	*	***	**	**	*	**	
		Enteromius trispilos	Inv			**	**				
		Enteromius hypsolepis	Inv			*					
		Enteromius macrops	Inv	**	**	*					
		Labeo coubie	Phy		***				**		
		Labeo parvus	Phy		**						
		Labeo senegalensis	Phy	***	**						
		Raimas senegalensis	Inv		*						
Cyprinodontiformes	Nothobranchiidae	*Epiplatys dageti*[1]	Inv					***			
Siluriformes	Claroteidae	*Auchenoglanis occidentalis*	Inv		*	*					
		Chrysichtys maurus	Inv		*				*		
		Chrysichtys nigrodigitatus	Inv	**	***	*			***	***	
	Clariidae	*Clarias anguillaris*	Omn	**	***	***	***		*	***	***
		Clarias buettikoferi	Omn						**		**
		Clarias gariepinnis	Omn			*				*	
		Heterobranchus isopterus	Inv			***	**		***	*	***
		Heterobranchus longifilis	Piv	**	**						
Siluriformes	Schilbeidae	*Schilbe intermedius*	Piv	***	***	***			***	**	
		Schilbe mandibularis	Her		*	*			**		
	Mochokidae	*Synodontis bastiani*	Inv	**	**						
		Synodontis punctifer	Her		***						
		Synodontis schall	Her	***	***	*			***	***	
	Amphillidae	*Amphilius atesuensis*	undefined					***			
Perciformes	Cichlidae	*Chromidotilapia guntheri*	Inv		***			***	***	***	
		Coptodon guineennis	Her						**		
		Coptodon guineennis x Coptodon zillii	Her		**		*		**		
		Coptodon zillii	Her	***	***	**	***	***			
		Hemichromis bimaculatus	Inv	***	***	***	***	*			
		Hemichromis fasciatus	Piv	***	***	***	**	***			
		Oreochromis niloticus	Phy	***	***	***	***	*			
		Sarotherodon galilaeus	Phy	***	**						
		Thysochromis ansorgii	Inv								***
	Anabantidae	*Ctenopoma kingsleyae*	Inv		*	**	*		**	*	***
		Ctenopoma petherici	Inv		*	***	***	**	*	**	**
	Eleotridae	*Eleotris senegalensis*	Inv							*	
	Channidae	*Parachanna obscura*	Piv	**	**	**	*	***	**		
8	19	53		25	37	23	13	12	25	14	8

Table 3: Proportion in number of constant, accessory and accidental species found in the rivers of TORTIYA, HIRE and LAUZOUA areas: B1 = Bou1; B2 = Bou2; GB= Gbloh1; T.G = Gbloh2; TC =Tchindegri; DO=Dougodou1; T.D= Dougodou1; NT= N'têko

	Tortiya			Hire			Lauzoua	
	B1	B2	GB	T.G	TC	DO	T. D	NT
Constant species (%)	48	40.54	43.47	38.46	58.34	36	42.86	62.5
Accessory species (%)	44	37.83	21.73	38.46	16.66	32	28.57	37.5
Accidental species (%)	8	21.62	34.8	23.08	25	32	28.57	0

Table 4: Statistic results of ANOSIM and their significance levels ($P<0.05$) for pairwise comparisons of fish assemblage structure among the three localities

Localities	Comparaison	R	p
Tortiya	Global	0.05301	0.2061
	B1 v B2	0.05301	0.2061
Hire	Global	0.7016	0.0001
	GB v T.G	0.5324	0.0002
	GB v TC	0.774	0.0002
	T.G v TC	0.8262	0.0002
Lauzoua	Global	0.4894	0.0001
	DO v T.D	0.2405	0.0138
	DO v NT	0.652	0.0016
	T.D v NT	0.6039	0.0002

Table 5: Similarity Analysis Result (SIMPER) showing the percentage of contribution (% Contrib.) and the cumulative percentage (Cum.%; 50% threshold) of the main species to the dissimilarity between the different stations of the mining areas: A. D = Average dissimilarity

Localities	Stations	A. D	Species	Contrib. %	Cum. %
Tortya	B1 V B2	73.13	*Schilbe intermedius*	18.24	18.24
			Brycinus nurse	9.41	27.65
			Pollimyrus isidori	8.318	35.97
			Labeo senegalensis	8.12	44.09
			Synodontis schall	7.832	51.92
Hire	GB VT.B	84.97	*Enteromius abables*	19.65	19.65
			Coptodon zillii	16.51	36.16
			Schilbe intermedius	13.59	49.75
	GB V TC	90.77	*Chromidotilapia guntheri*	28.58	28.58
			Petrocephalus bovei	16.21	44.78
			Enteromius abables	12.54	57.32
	T.G V TC	81.98	*Chromidotilapia guntheri*	38.14	38.14
			Petrocephalus bovei	20.45	58.59
Lauzoua	DO V T. D	76.75	*Brycinus longipinnis*	24.27	24.27
			Synodontis schall	23.42	47.68
	DO V NT	91.13	*Synodontis schall*	20.19	20.19
			Brycinus longipinnis	16.91	37.1
			Ctenopoma kingsleyae	10.28	47.38
			Thysochromis ansorgii	8.869	56.25
	T.D V NT	85.9	*Synodontis schall*	14.58	14.58
			Ctenopoma kingsleyae	13.83	28.4
			Thysochromis ansorgii	11.8	40.2
			Brycinus longipinnis	10.22	50.42

4. Conclusion

This study described the fish population in three mining areas. A total of 53 fish species belonging to 8 orders, 19 families were captured. 14 species were common to the three mining. The results showed a high proportion in favour of the constant species on all the stations of the three mining surfaces. Invertivores dominated fish communities on all prospected stations. Diversity indices (Rarefied richness and Shannon-Weaver index significantly (kruskal- Wallis test; $p<0.05$)) are higher at TORTIYA comparatively to HIRE and LAUZOUA. As for the Pielou's evenness index, it does not vary significantly ($p>$ 0.05) between areas. Similarity analyses (ANOSIM) showed that the composition of the fish assemblage did not change significantly ($p>$ 0.05) in the locality of TORTIYA. At the localities of HIRE and LAUZOUA the compositions change significantly ($p<$ 0.05). This study will contribute to the management and conservation of the fish resources of the mining areas.

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