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Fish Community Assemblages of Mining-Impacted Freshwaters at Prestea, Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OOA and MJTA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NOP managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study evaluated the fish community assemblage in the sections of the Subri river, the Ankobra river, and the "galamsey" pond within the Prestea community as impacted by alluvial mining activities. Gill nets of length 10 m and mesh size 1.27 cm were used to trap fish of average length 25.25 cm whilst cane baskets were used to trap fish of average width 10.40 cm using the catch and recapture method. All the 46 fish samples identified belong to 10 genera and 5 families. The Chichlidae was the dominant family, accounting for 60% of the total families observed. With an *H'* index of 1.57 the Subri river had the most fish diversity in comparison with the Ankobra river and the "galamsey" pond, which had 1.21 and 0.71, respectively. Similarly, the Subri river had a more complex fish community structure than the Ankobra and "galamsey" pond. The dominant species, *Oreochromis niloticus*, has not yet been evaluated by the IUCN, but the least dominated *Brienomyrus brachyistus* could be regarded as "least concern". Notwithstanding, these fish are essential for food by the local communities. There is a possibility that the alluvial mining might have influenced the complexities of fish species communities. Thus conservation efforts must be promoted to sustain fish communities and overall freshwater ecosystem health.

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1. INTRODUCTION

It has been estimated that freshwater makes up only a tiny fraction (0.01%) of the World's water resources and approximately 0.8% of the Earth's surface. Notwithstanding, this small fraction of global water supports at least 6% (100 000 species) of the total 1.8 million described species [1]. Hence, freshwater conservation and management are critical to the interests of all humans, nations and governments. However, human activities have impacted mainly on freshwater ecosystems leading to declining in biodiversity and overall water quality. According to the Millennium Ecosystem Assessment report [2], about 20% of the world's 10,000 freshwater fish species are listed as threatened, endangered, or extinct over the last few decades due in part to anthropogenic activities. The decline in fish populations is attributed to water pollution, overexploitation, destruction or degradation of habitat or water quality, flow modifications and invasion by exotic species [1,3,4] as well as land-use changes [5,6].

Globally, fish provide 20% of animal protein to about three billion individuals [7]. Fishing is a significant trade in Ghana, which supports and provides a livelihood for over 2.0 million individuals [8]. In 2012 the fishing industry in Ghana contributed approximately 1.8 percent of the country's Gross Domestic Product (GDP) [9] and currently about 4.5 percent of GDP [10]. Despite these invaluable contributions of the sector to the economy and livelihood of communities, the water resources in the country have been under increasing threat from pollution in recent times due to rapid population growth culminating into increasing demand for the establishment of human settlements many of which lack appropriate sanitary facilities [11]. Additionally, the rising spate of illegal gold mining ("galamsey") has worsened the problem of water pollution and destruction of aquatic life in mining communities. Typically in ''galamsey'' operations, the ore-bearing rocks are ground, and the gold extraction is done by chemicals such as cyanide and mercury with the waste being washed directly into nearby water bodies or discharged into rivers.

These disturbances coupled with the rising demand for fish and other resources from the increasingly impoverished population in mining catchment communities have contributed significantly to widespread deterioration of waterbodies and fish depletion. Thus the protection and judicious utilisation of freshwater ecosystems need to be given critical attention to maintaining not only their ecological integrity but also their sustainable production of fish for current and future generations.

River Ankobra is one of the major rivers in Prestea, Ghana. The Ankobra river drains rivers such as Asesere and Subri. Most of these rivers in Prestea serve as a primary source of fish caught by anglers and local folks within the various communities. Aside from fishing, the rivers provide domestic water supply to neighboring communities in Prestea. Yet, the anthropogenic activities within the rivers' catchment have been affecting the rivers severely thereby impairing on their capacity to provide the requisite services to the local community. Alluvial mining is one of the primary sources of pollution to the freshwater bodies at Prestea. Land cover change has affected the productive yield of fish due to the effluent discharge of slurry with high cyanide and arsenic content into neighboring rivers such as Subri, Asesere and Ankobra [12]. Typically, fish species find it uncomfortable to reside in such polluted waterbodies. The International Union for Conservation of Nature (IUCN) has listed 31% of freshwater species as highly vulnerable to extinction [13]. Disturbances of riparian vegetation along river banks render fish deficient of energy and nutrient [14].

Conservative and sustainable management of ecologically diverse fish communities are eminent objectives of contemporary management of the aquatic landscape. However, little attention has been given to the rate of fish diversity decline at Prestea. Detailed assessment on fish diversity in Prestea would generate the awareness on the need to conserve fish species. Additionally, dominant and threatened species would easily be traced if this detailed analysis were generated. The specific objectives were: (i) to identify fish species of Ankobra river, Subri river, and "galamsey" pond, and (ii) to compare the diversities and communities of fish species of the respective waterbodies as affected by alluvial mining.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study was carried out at Prestea in the Prestea-Huni Valley District of the Western Region of Ghana (Fig. 1). The study area is located at Latitudes 5°00’ N and 5°40’ N and Longitudes 1°45’ W and 2°10’ W. It shares boundaries on the North with Wassa- Amenfi East District, and on the West with Axim Municipal Assembly. A range of hills that run in the Northeast - Southwest direction dominate the landscape. These hills are aligned with the primary gold-bearing ores, and, therefore, accommodate the majority of ore extraction activities. The area is drained by the Ankobra river and its tributaries, including Asesere (which is used for domestic purposes by the Bondaye village), and Subri. These rivers ultimately flow into the Ankobra river, which is the primary drainage of the Bogoso/ Prestea mining area [15]. The climatic condition of the project area is hot and humid. The mean annual rainfall is about 1803.7 mm, ranging from 984 to 2,414 mm. The area is characterised by seasonal weather patterns, which involve double wet season from April to June and October to November, and a main dry season from December to February [15]. The mean annual temperature is 26°C with the daily maximum temperature reaching 28°C to 30°C. The annual humidity is 86% and ranges from 70 to 90%. It is highest in August-September and lowest in January and February. Some prevailing winds in the area are in the south-west and northeast directions. The daily measurements since 2001 show that daily changes influence the wind direction. It is southwards in the mornings and then northwards in the afternoon (Attuah, personal communications 11.09.2016).

2.2 Site Selection

Three waterbodies were purposively selected for the study. They included Subri river, Ankobra river, and a “galamsey” pond. The study was conducted along the sections of these waterbodies within Prestea, of the Western Region of Ghana. The Subri river has been slightly disturbed by the activities of the alluvial mining activities. The abandoned “galamsey” pond had been left for a long time. The water from the pond flows gently into another pond before it finally gets to river Ankobra. The Ankobra River, which had been turned into “galamsey” site, was assessed. Due to the colour of the waterbodies, the water sources were deemed degraded to the extent that they may impact on fish species because they were no more conducive for habitation (Plates 1 and 2). The locations were georeferenced and recorded in the field notebook (Table 1).

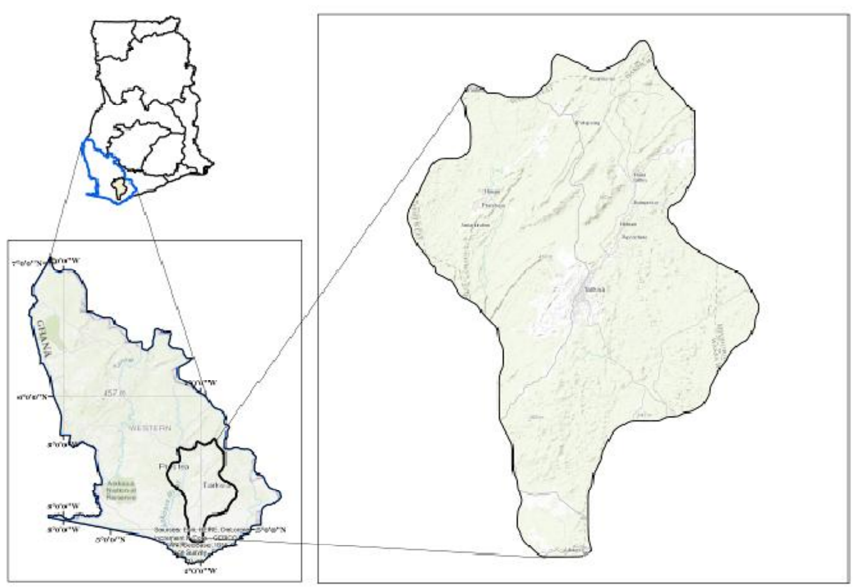

Fig. 1. Map of Ghana, showing Prestea, the study area

Plate 1. The meandering nature of Subri River

Plate 2. Surface view of Ankobra River

Table 1. GPS location of the study sites

Sites	GPS Location		
	SITE I	SITE II	SITE III
Subri river	N05º96'79.5 E06º00'25.7	N05º96'80.4 E06º00'35.3	N05º96'83.4 E06º00'35.9
Ankobra river	N05º97'60.1 E06º01'23.7	N05º97'58.4 E06º01'27.4	N05º97'58.9 E06º01'27.0
"Galamsey" pond	N05º97'23.6 E06º00'78.8	N05º97'21.4 E06º00'78.6	N05º97'20.7 E06º00'76.0

2.3 Data Collection

In all, three fish sites were selected randomly for the fish assemblage study. Each site had three subplots, which represents three replicates for each site. Thus, nine replicates were used for the study. The attribute and location data of each site has been described in Table 1. The catch and recapture method were used in conducting the fish survey. Four-gill nets of length 10m with a mesh size of 1.27 cm were used. In addition eight (8) basket traps were used. At each selected section of the waterbody, a gill net and two cane basket traps were inserted. The nets were kept in place for a 24-hour period on each day before each of the nets and traps were checked to collect fish species. The fish caught were identified, labeled, counted, and carefully released back into their respective waterbodies. Primarily, the fish species were identified in collaboration with local fishmonger and where difficulties were encountered in species identification, pictures of major parts of the fish were taken, which aided in their identification. Samples and scientific names of fish species were recorded. The study spanned four months from September to December.

Additionally, the quality characteristics of the rivers were ascertained. Generally, the quality of the waterbodies flowed the order; Subri>Ankobra> "galamsey" pond. Parameters such as pH, dissolved oxygen (DO), total dissolved solids (TSS), temperature, and turbidity were used. The pH and dissolved oxygen concentrations within the "galamsey" pond at 6.40 and 6.37 mg/g, respectively were lower than that of the Subri and Ankobra rivers. Not only was the TSS in the pond water greater than that of Subri and Ankobra, but also the level of TSS was about nine (9) times higher than the WHO recommended level of 1000 mg/l.

2.4 Data Analysis

The analyses were performed using the Minitab software (v17) and Microsoft Excel (MS 2016 suite). Species richness for each fish sites was computed and the total number of genus and families were assessed. The abundance and the

Table 2. Water quality characteristics of sampled water bodies

Parameters	Unit	Water bodies			WHO
		Subri river	Ankobra river	"Galamsey" pond	
pH	-	6.61±0.34	6.49±0.36	6.40±0.03	6.5- 8.5
Dissolved oxygen	mg/g	11.80±1.13	12.87±1.86	6.37±5.75	7.5
Total dissolved solids	mg/l	75.21±19.40	71.00±13.98	9496±268.40	1000
Temperature	°C	14.07±2.65	13.66±3.62	24.52±0.14	22 – 29
Turbidity	NTU	16.41±4.84	19.00±5.43	43.68±2.64	5

diversity of fish species were quantified using the Shannon-Wiener species diversity (equation 1) and the Pielou's Evenness (equation 2). The diversities and evenness of the sites were compared.

$$H' = -\sum P_i \ln P_i \quad (1)$$

$$J = \frac{H'}{H'_{max}} \quad (2)$$

Where:

Pi is the proportion of individuals of *i*th species expressed as a proportion of total cover and Ln equals the Log base n [16].

3. RESULTS AND DISCUSSION

Fish assemblages are recognized as sensitive indicators of habitat degradation, environmental contamination, and overall ecosystem health [17]. Table 3 summarises the species of fish, their respective families, and IUCN classification. Overall, 46 fish samples were identified. The samples belong to 10 species and 5 families of fish species. Surprisingly, the 6,197 fish specimens surveyed by Dankwa et al. [18] belong to four species and four families. Cichlidae, the most dominant family had 27 members and 6 different species, which represented 58.7% of the total fish collected. Mormyridae family was the least dominant family. The least dominant family is attributed to overfishing and other anthropogenic pressures producing impacts of unprecedented intensity and frequency on the freshwater ecosystems, causing changes in biodiversity [19]. The first three most dominant fish species recorded were *Oreochromis niloticus*, *Clarias gariepinus*, and *Coptodon zillii*. They constituted approximately 33 percent, 15 percent, and 11 percent of the total individuals recorded at the study sites. However, the least dominant species, *Brienomyrus brachyistus*, was approximately 2% of the total individuals collected. In addition, all the species identified are native to Ghana.

The most dominant species (*O. niloticus*), mostly known as Nile Tilapia, have an ex-situ conservation status in Ghana [20]. Nile tilapia is a tropical species that prefer to live in shallow water, and mostly the preferred temperature ranges from 31 to 36°C. The species is an omnivorous grazer that feeds on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus and bacterial films associated with detritus [21]. The Nile tilapia can filter feed by entrapping suspended particles, including phytoplankton and bacteria, on mucous in the buccal cavity, although its main source of nutrition is obtained by surface grazing on Periphyton mats, particularly ponds [21].

The extinction status of fish and the potential threats to humans were distinguished. *Oreochromis niloticus* was the most dominant fish species of the study sites, recording about 15 species in total. Although not yet evaluated, according to the IUCN Red List classification, the species is a potential pest to human [22]. The least dominant species, *Brienomyrus brachyistus*, had only one individual. Although it was the least dominant species at our study site, according to IUCN Red List, the species is of less concern and no specific threats to human is known. Overall, 60% of the species collected were of "least concern", whereas the Red list status of 30% of the species has not been evaluated. The "least concerned" species have been categorized and evaluated by the IUCN but they do not qualify to belong to any other category [23]. Only *Sarotherodon occidentalis* (*n* = 3) was classified as IUCN "Near Threatened" species. Factors such as drought, deforestation, overfishing and dam construction have been reported to threaten the *S. occidentalis* [24]. Overall, 60% of the species recorded were classified as least concerned, whereas 30% and 10% were "not evaluated" and "near threatened", respectively (Fig. 2).

A significant proportion (72.7%) of the fish collected from the Ankobra river was *Oreochromis niloticus.* The majority (21.1%) of the fish collected from Subri river were *Clarias gariepinus*. Additionally, a significant proportion (15.2%) of *Coptodon zillii* and *Oreochromis niloticus* were also present. However, only two individuals of *Pelmatochromis buettikoferi,* and *Sarotherodon galilaeus,* which represents 6.1% of all the fish collected from the Subri river. Only two species of *Oreochromis niloticus* were identified in the 'galamsey' pond.

The structure of the fish communities within the respective rivers was assessed by using the Shannon diversity and Pielou's evenness. It was also useful for comparing and prioritising among fish sites [25]. The Subri river recorded the highest Shannon Wiener diversity index and Simpson's index of diversity of 1.567 and 0.961, respectively making it is more diverse in term of species community complexities compared to Ankobra river and "galamsey" pond. Diversity indices gave a quantitative view of the diversity of fish species and thus provided information essential for understanding community's numerical structure [26]. The lower diversities in the Ankobra river and the galamsey pond may be attributable to the slow flow of water as induced by excessive contaminants such as turbidity that makes these contaminants stay longer and thereby influences heavily on fish species assemblages. This could be reasons accounting for the disparities in assemblage characteristics of the three waterbodies studied. Moreover, Okyere et al. [27] posit that a good environmental condition reflects a higher richness and diversities of fish within the Whi Estuary of Ghana. Additionally, Dufrene and Pierre [28] have emphasized that the contamination of water environment causes fish habitat degradation and ultimately alter fish community assemblages.

The impact of soil quality on species richness was expressed with a Pearson Moment Correlation. The results are summarised in Table 3. Overall, the variation in fish richness is highly expressed in the variation in the pH, dissolved oxygen (DO), total suspended solids (TSS), temperature, and turbidity at coefficients of 0.988, 0.610, -0.723, -0.701, and -0.781 respectively (Table 4).

In as much as this study provides insights into the possible influence of alluvial mining on fish community characteristics, there are some limitations which might have introduced some uncertainties into the outcome. First, the study spanned four months which comprised three wet months in the minor rainy season and December, the beginning of the dry season. This could have contributed to the smaller number of fish samples. Further follow-up studies should assess the influence of seasons on the variation fish communities as this could affect the physicochemical parameters of the different waterbodied, and increase the duration of the study.

Table 3. Fish species identified at study area

Scientific name	Families	Status	Subri river	"Galamsey" pond	Ankobra river	Total
Atya gabonensis	Atyidae	Native	3	-	-	3 (6.5%)
Brienomyrus brachyistus	Mormyridae	Native	-	-	1	1 (2.2%)
Clarias gariepinus	Clariidae	Native	7	-	-	7 (15.2%)
Coptodon zillii	Cichlidae	Native	5	-	-	5 (10.9%)
Micralestes elongatus	Alestidae	Native	3	-	-	3 (6.5%)
Oreochromis niloticus	Cichlidae	Native	5	2	8	15 (32.6%)
Pelmatochromis buettikoferi	Cichlidae	Native	2	-	1	3 (6.5%)
Sarotherodon galilaeus	Cichlidae	Native	2	-	1	3 (6.5%)
Sarotherodon occidentalis	Cichlidae	Native	3	-	-	3 (6.5%)
Tilapia louka	Cichlidae	Native	3	-	-	3 (6.5%)
Richness			**33**	**2**	**11**	**46**
Shannon Diversity (H')			**1.567**	**0.707**	**1.206**	
Evenness			**0.961**	**0.000**	**0.639**	

LC = Least Concern; NE = Not Evaluated; NT = Near Threatened. References: a De Grave and Moeleatto [29]; b Laleye and Moelanta [30]; c Freyhof et al. [31]; d Dunz and Schiewen [32]; e Paugy and Schaefer [33]; f Trewavas [22]; g Entsua-Mensah [34]; h Awaiss et al. [35]; Bousso and Laleye [36]; j Laleye [23]

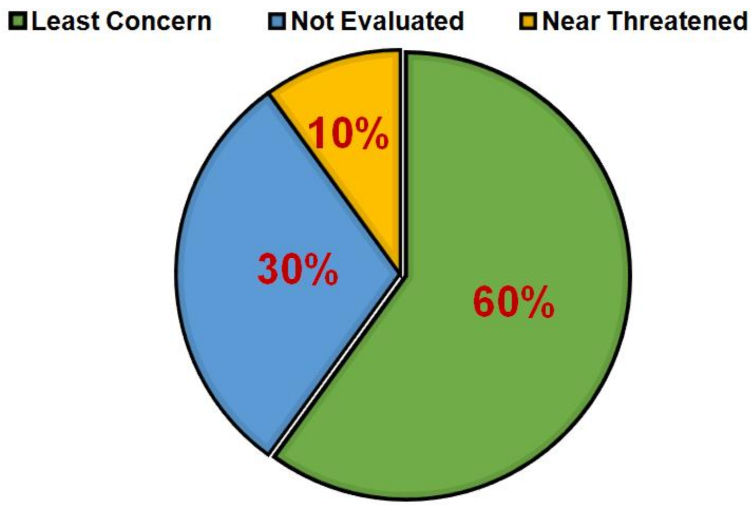

Fig. 2. The IUCN status of the fish species sampled

Table 4. Relationship between richness and physical characteristics of waterbodies

	Richness	pH	DO	TSS	Temp	Turbidity
Richness	1.000					
pH	0.988	1.000				
DO	0.610	0.725	1.000			
TSS	-0.723	-0.822	0.988	1.000		
Temp	-0.701	-0.803	-0.993	0.999	1.000	
Turbidity	-0.781	-0.868	-0.973	0.993	0.996	1.000

4. CONCLUSION

The study evaluated the diversity of fish species in three rivers at Prestea as impacted by alluvial mining activities. The fish species identified during the study belong to 10 genera and 5 families. The Cichlidae was the most dominant fish family with the highest species richness. The *Oreochromis niloticus* was the most dominant species whereas *Brienomyrus brachyistus* was the least dominant species. Most of the fish sampled were classified as “least concern” and “not evaluated” by the IUCN Red List categorization. However, the *Sarotherodon occidentalis* had been listed as “near threatened” by the IUCN. The community of fish was more complex in the Subri river, compared to river Ankobra and the “galamsey” pond. The conservation of fresh waterbodies in mining communities must be promoted to sustain fish communities and overall ecosystem health. In order to implement conservation measures, further studies that include landscape and/or water quality analysis and their implication on fish community structure should be undertaken.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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