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Effects of Small-Scale Mining Activities on Fisheries and Livelihoods in the Birim River in Atiwa District, Eastern Region of Ghana

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Abstract

The socioeconomic importance of small-scale mining in Ghana is of great interest to the country. It provides employment, supports the livelihood of poor rural areas, and also contributes to national income. Despite all these importance, it has a great influence on the surroundings, with surface and groundwater bodies being the most affected. The study was conducted to determine the effects of small-scale mining activities on fisheries and livelihoods along the Birim River in Atiwa District of Ghana, and also, to ascertain the nature of mining in the catchment and the current status of fisheries in the river. Data were collected with a help of open and closed ended questionnaire and fishers were sampled using purposive sampling method. Findings revealed that fishing activity was vibrant before 2010, but declined afterward. Respondents indicated that the number of fishers who went fishing daily before 2010 decreased drastically after 2010. Also, before 2010, most of the fishers (62%) used fishing nets compared to that after 2010. About 74% of respondents revealed that they could harvest at most 5 crates of fish a day before 2010, while about 38.6% of respondents indicated they could harvest 5 crates after 2010; thus 25 kg per day before 2010. It was revealed that 34% of respondents indicated they could make above $10 daily before 2010 as against 2% making $10 per day after 2010. About 90% of the respondents attributed their levels of harvest and average income per day to the effects of mining, with the reason being that miners wash their products in the river (52%), thus polluting the waterbody. Mining in water locally and commonly known as "changfan" was the main type of mining in the study area. From the findings, it is concluded that small-scale mining has detrimental effects on aquatic ecology and has resulted in the creation of deep pits which destroy gears, increasing the costs of gear repairs, fishing effort, and pollutes water (physical and chemical factors). Hence, it is recommended that there should be a ban on all small-scale mining in and around water bodies as this has detrimental effects on water quality and reduce fishing in the area.

Keywords: Pollution; small-scale mining; Birim River; Changfan; Atiwa; Ghana

Introduction

Many authors have deliberated on the socioeconomic importance of small-scale mining of minerals such as gold; employment (Hilson 2016), supports livelihoods of poor rural populations (Fisher et al. 2009), contributes to national income (Shen and Gunson 2006) through taxes, export earnings, and provision of raw materials for local industries (Bansah et al. 2018). Despite the significant socioeconomic roles that gold mining has played in Ghana, it has been ostracized by many citizens due to its substantial sources of heavy metal pollution of the environment on account of activities such as mineral exploitation, ore

transportation, smelting and refining, disposal of the tailings and wastewaters around mines (Essumang et al. 2007, Hanson et al. 2007, Obiri 2007, Singh et al. 2007). The impacts of gold mining in Ghana include land degradation, destruction of vegetation cover, waterlogged pits, pollution of aquatic environments with heavy metals (water pollution), among others. Notably, pollution of surface and groundwater bodies have particularly been experienced in gold mining communities in the country (Kuma and Younger 2004, Manu et al. 2004), the situation which prevails to date.

Ghana is among the luckiest countries worldwide that is gifted with rich natural resources such as gold. The wealth and strength of large ancient Ghanaian empires and cultures were due to the gold deposits which resulted in Ghana being named the 'Gold Coast' during the colonial exploration (Hilson 2001). The exploitation of gold in Ghana is in two folds; large-scale mining and small-scale mining. Large-scale mining encompasses the use of scientific methods and sophisticated machines whereas small-scale mining involves the use of simple tools in the recovery of gold from the land.

In southern Ghana, the Birim River is a tributary of "Pra" River, which is known to be a major source of water to the people of Anyinam and it has been noted for industrial, domestic, and agricultural purposes for the people living around and even beyond. It is noted for its gold and other mineral resources, and a major site for fishing activities. Birim River has been exposed to over-exploitation of these minerals through the activities of illegal small-scale miners, popularly referred to as "galamsey" which was derived from the English phrase, "gather them and sell" (Bansah et al. 2018). This has led to critical pollution problems such as heavy metal accumulation, high water turbidity, among others, raising concerns about its ability to alter the physico-chemical parameters in the water for fishing and domestic activities in the river (see Figure 1 for the current state of Birim River). Birim River as a freshwater body has been supporting fisheries activities for several decades but due to the recent activities of ''galamsey'', water quality parameters including pH, dissolved oxygen, temperature, conductivity, transparency, salinity, turbidity, nitrate and phosphate concentration been negatively affected, invariably affect fish productivity. Also, it has affected all the fishing activities; many fishers have stopped going to the river to hunt for fish, fish processors around the area do not get fish from the river as they used to and most farmers who were into aquaculture have stopped their aquaculture businesses (Bansah et al. 2018).

The present study was conducted to assess the influence of small-scale mining on fishing activities and water quality of the Birim River in the Atiwa District, Ghana. Specifically, the study determined the trends of mining and fishing in the catchment area, and the impacts of mining on fishing and water quality.

Figure 1: Recent state of the Birim River (Date: April, 2018).

Materials and Methods

Description of study area

The study was conducted in Birim River at Anyinam in the Atiwa District, Eastern Region of Ghana (Figures 2 and 3). Anyinam is one of the major towns in the Eastern Region where the Birim River passes. It is noted for supporting fishing activities and is a major site for mineral deposits. Anyinam lies in a wet-semi equatorial zone characterized by bi-modal rainfall season which reaches its maximum during the two peak periods of April-July and September-October. It was granted its District status by the legislative instrument (LI) 1784 in the year 2004. It is situated at the foot of the Atiwa range.

The annual rainfall is between 1250 mm and 1750 mm. The temperature ranges from 26 °C to 30 °C. Relative humidity ranges from 65%–75% and 75%–80% during the dry and rainy seasons, respectively. Anyinam lies between longitudes 0°3 west and 0°50 east and latitudes 6°10 north and 6°30 north. The demography of the Atiwa District is 110,622 and that of Anyinam is 21,567 according to the 2010 population and housing census (GSS 2010).

Birim River is a major source of water for the people of Anyinam which supports fishing and other domestic activities. The river takes its source from the Atiwa ridge, a mountain that is found in Kwaben in the Atiwa District (Figure 3). The Birim River is also noted to contain minerals like gold and others, at the same time it is a fishing community.

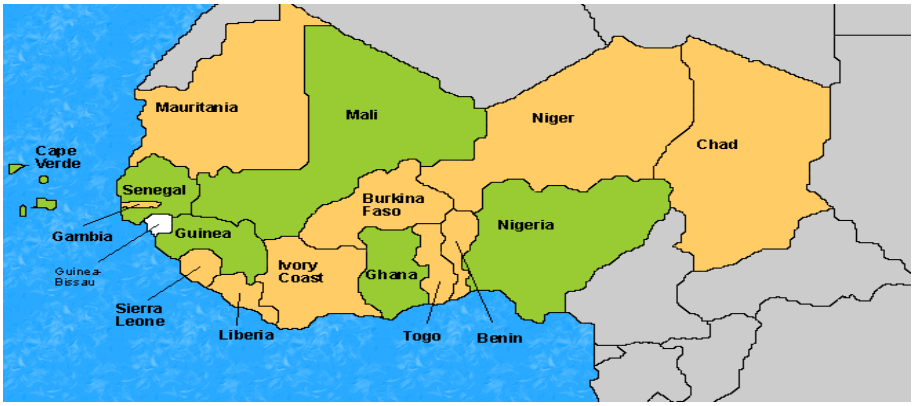

Figure 2: Map of Africa, indicating Ghana. Source: https://www.google.com.hk/imgres?imgurl=https://cdn.ghanaweb.com/imagelib/src/birim_river_state.jpg&imgrefurl=https://www.ghanaweb.com/GhanaHomePage/NewsArchive/The-current-state-of-Birim-River-as-a-result-of-illegal-mining-8848431&docid=UNZzoPRGX8GJ8M&tbnid=QPAIFZGXHSjFWM&vet=1&w=807&h=450&source=sh/x/im

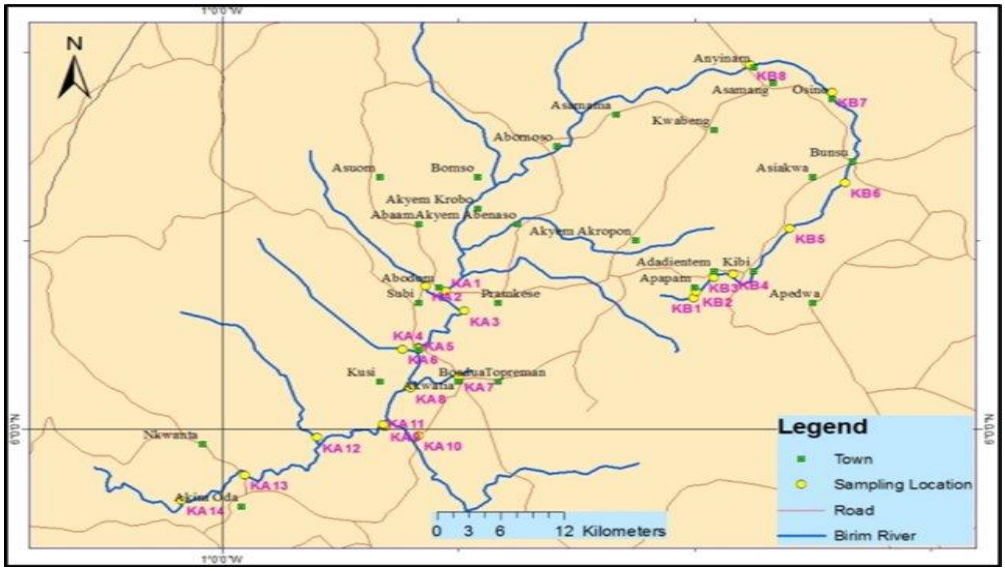

Figure 3: Map of Atiwa District showing Birim River distribution. Source: https://en.wikipedia.org/wiki/Atiwa_District#/media/File:Eastern_Ghana_districts.png

Data collection

Data collection was conducted by using open-ended and closed-ended questionnaires. The open-ended questions allowed the respondents to express their views, while the closed-ended questions gave the respondents opportunity to choose the option they highly agreed on from the list of options provided. The respondents were briefed about the objectives of the study and the various aims of the research thus, for academic purposes and policy recommendations. Confidentiality was assured during and after the interview. The respondents were allowed to indicate their names on the questionnaires. Moreover, the respondents were assured that information provided would be held undisclosed to another party.

Sampling methods

Purposive sampling was used to select fishers. The data was collected from October 2017-May 2018.

Data analysis

At the end of the data collection, the questionnaires were checked for completeness and internal consistency. Open-ended questions were recoded before analyzing. The data were entered into Statistical Package for Social Sciences (SPSS) programme (version 21) for analysis. Descriptive statistics were used to present the data. The data were also analyzed using Excel software version 2016.

Ethical issues

Appropriate permission from the community heads and other relevant authorities were obtained before carrying out the research.

Results

Socio-economic characteristics of fishers

The numeric information representation of the distribution of respondents by their demographic and socio-economic characteristics is indicated in Table 1.

Table 1: The numeric information representing the distribution of respondents by their demographic and socio-economic characteristics

Characteristics		Frequency	Percentage
Sex distribution	Male	45	90
	Female	5	10
Age distribution	20–29	4	8
	30–39	9	18
	40–49	12	24
	50–59	15	30
	60+	10	20
Education background	Basic school	9	18
	Junior secondary	29	58
	Senior secondary	12	24
	Tertiary	0	0
Socio economic characteristics	Agriculture	28	56
	Trading	10	20
	Fishing	22	22
	Any other	1	2
Number of years in fishing	1–10	19	38
	11–20	8	16
	21–30	12	24
	31+	11	22

Trends of fishing in Anyinam

Trends of fishers per day before and after 2010

The information on the number of fishers involved in fishing per day before and after 2010 according to the respondents is presented in Figure 4.

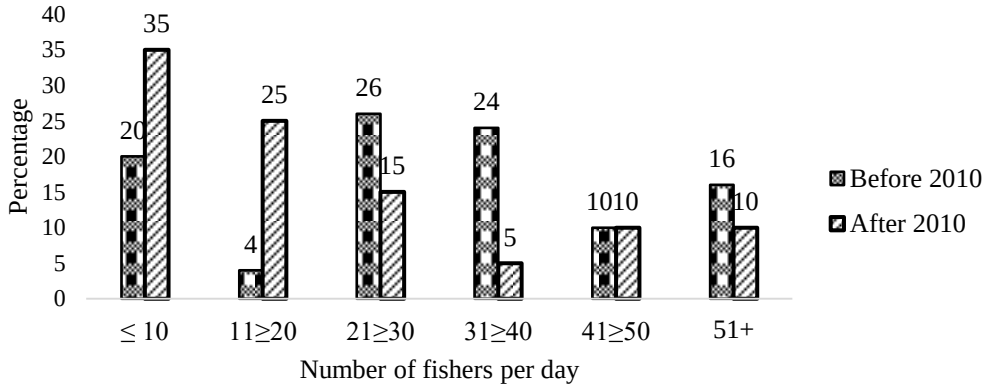

Figure 4: Number of fishers involved in fishing per day before and after 2010 in Anyinam.

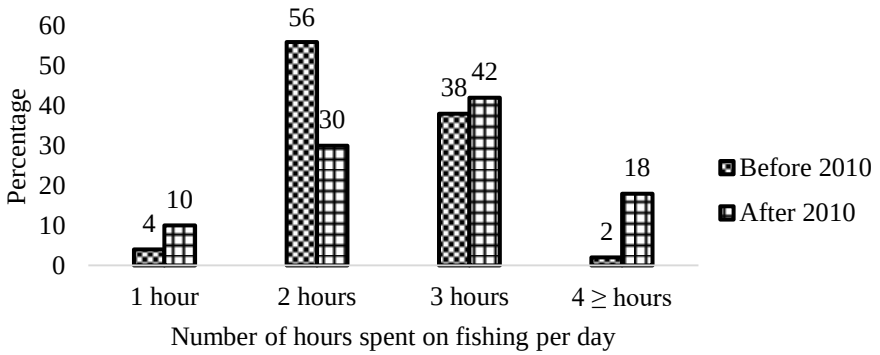

Figure 5: Number of hours spent in fishing on the Birim River in Anyinam.

Fishing hours before and after 2010

Figure 5 shows that majority of the fishers (56%) spent more than 2 hours on the river during fishing.

Types of fishing gears used before and after 2010

Figure 6 shows the types of fishing gears that were used before and after 2010 on the Birim River. About 68% of the fishers indicated they used hook and line fishing after 2010.

Size of fish caught before and after 2010

Before 2010, majority of fishers (93%) used to harvest fish of weight about 2 kg and above. However, a reverse trend was observed after 2010 when about 70% of fishers do not harvest the size they used to get, thus 2 kg and above as indicated in Figure 7.

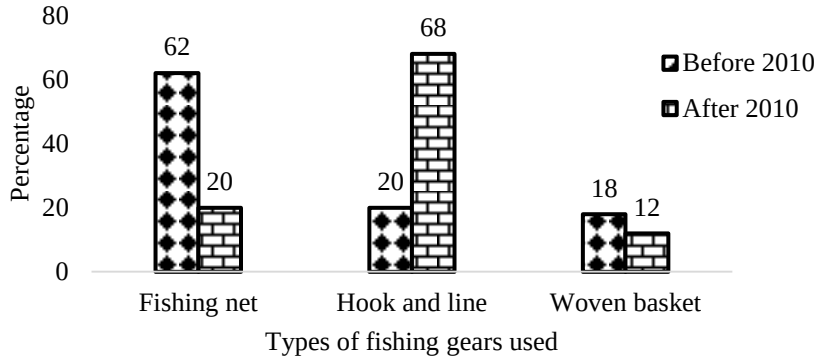

Figure 6: Responses to the types of gears used before and after 2010 in Anyinam.

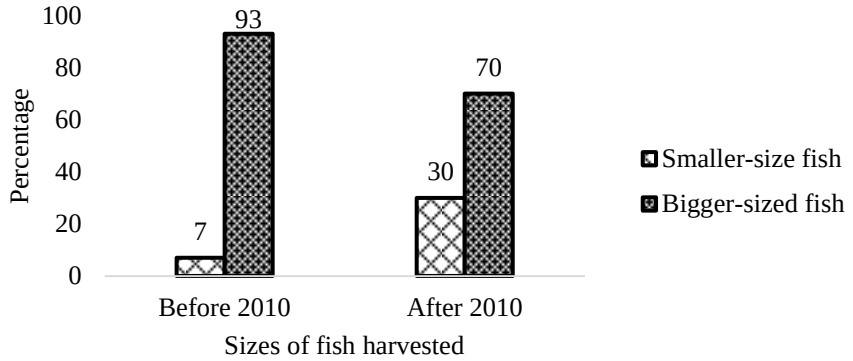

Figure 7: Sizes of fish caught before and after 2010 in Birim River at Anyinam.

Challenges of the fishers before and after 2010

Table 2, Figures 8 and 9 show the challenges faced by fishers in their operations. About 97.3% of fishers indicated that yes, they are facing challenges due to the activities of the mining which have resulted in intense pollution of the river as indicated in Figure 9.

Table 2: Information on whether fishers were facing any challenges before and after 2010

Response	Before 2010 (%)	After 2010 (%)
Yes	11.6	97.3
No	88.4	2.7
Total	**100**	**100**

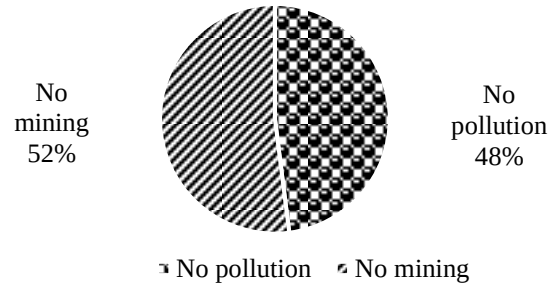

Figure 8: Reasons why before 2010, fishers were able to intense their fishing activities.

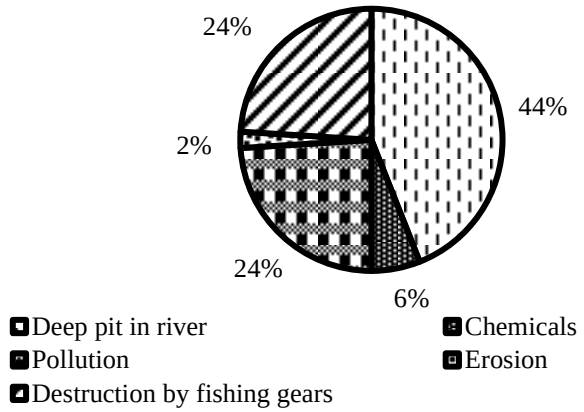

Figure 9: Kinds of challenges faced by fishers after 2010.

Factors causing the challenges of fishers after 2010

Information gathered from the respondents on the factors that caused the problems of fishers after 2010 revealed that, 30 of them (60%) referred to mining activities in the catchment, 3 of them (6%) said runoff from farms, 10 of them (20%) indicated that "changfan" is a factor causing the problems they are facing, 7 of them (14%) said pollution. See Figure 10.

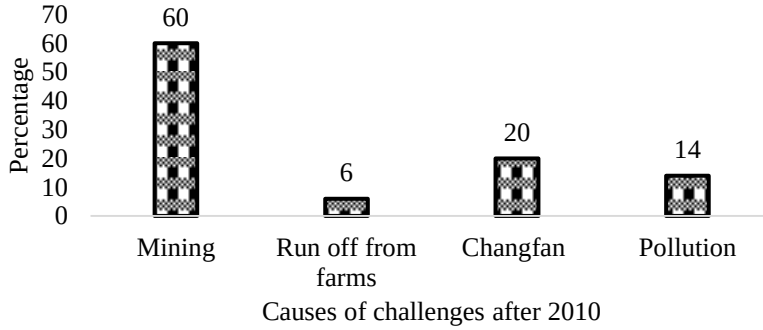

Figure 10: Factors causing the problems faced by fishers after 2010.

Levels of harvests before and after 2010 per day

Respondents were asked about their levels of harvests before and after 2010. Before 2010, 74% of them indicated they harvest less or equal to 2 crates of fish per day, and 26% of the respondents indicated they harvest 3-5 crates of fish per day. After 2010, 38.6% of the respondents indicated they harvest 3-5 crates of fish and 61.4% of them said they harvest less or equal to 2 crates as indicated in Table 3.

Table 3: Level (crates) of harvests per day before and after 2010

Responses	**Before 2010 (%)**	**After 2010 (%)**
3–5 crates	74	38.6
≤ 2 crates	26	61.4
Total	**100**	**100**

Average income per day before and after 2010

The results reveal that, before 2010, 5% of the respondents said they got less or equal to $ 3 per day, 36% of them said they got about $ 4–6 per day, 25% about $ 7–10 per day and 34% got above $ 10 per day.

However, after 2010, 60% of the respondents get less or equal to $ 3 per day, 24% about $ 4–6 per day, 14% about $ 7–10 per day and 2% got above 10 $ per day. See Table 4.

Table 4: Average income ($) per day before and after 2010

Average income	Before 2010 (%)	After 2010 (%)
≤ 3	5	60
4–6	36	24
7–10	25	14
> 10	34	2
Total	**100**	**100**

Attribution of the decline of average income per day after 2010 to mining activities

After assessing the average income of the fishers before and after 2010, a follow-up question was asked to know if the decline in the daily income was due to the effects of small-scale mining in the community. The responses of 45 (90%) respondents revealed that mining is the cause, while the remaining 5 (10%) of them said mining was not the cause as indicated in Figure 11.

The respondents who said yes to the follow-up question were further asked why they think the decline in the average daily income after 2010 was due to small-scale mining in the community. 52% of them indicated that miners wash their mined products in the river, 14% of them said those who mined close to the river redirect the canal back into the river after washing their mined product, 22% of them said they block the natural flow of the river and redirect the channel to a different place, and 12% of them said others as indicated in Figure 12.

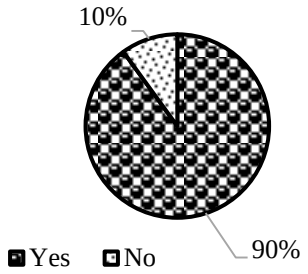

Figure 11: Attribution of the average level of income per day to the effects of mining after 2010.

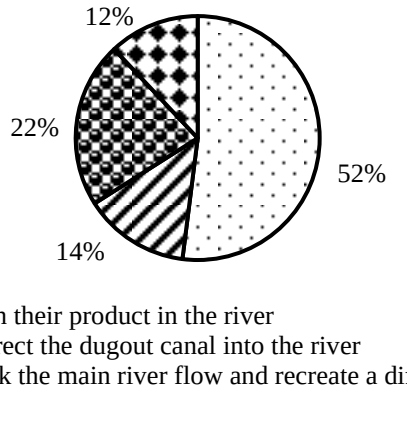

Figure 12: Reasons why respondents attribute the decline of their average income levels to mining.

Trends in marketing after 2010

The table below presents data on whether there was a ready market for harvested fish after 2010. 10 respondents said there was a ready market, 34 of them said there was no ready market for harvested fish, and 6 said they do not know representing 20%, 68%, and 12%, respectively as presented in Table 5.

Table 5: Market trends after 2010

Respondent	Frequency	Percentage (%)
Ready market	10	20
No ready market	34	68
Don't know	6	12
Total	**50**	**100**

Reasons for the trends in marketing after 2010

Figure 13 presents data on the reason for the trends of marketing. 22% of the respondents indicated that customers say harvested fish doesn't look appetizing, 20% of them said customers said harvested fish are full of chemicals, 28% of them said customers do not buy due to the fear of complicated health issues and 30% of them said fishes are of small sizes.

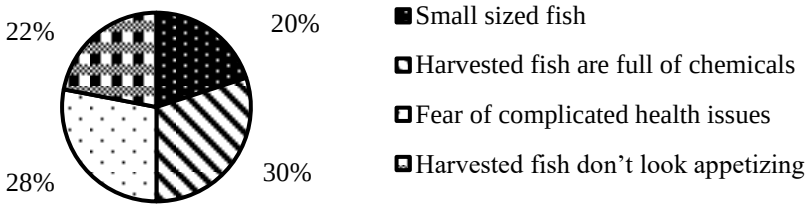

Figure 13: Reasons for the trends of marketing after 2010.

Factors causing the changes in livelihood

Table 6 presents data on the factors that cause a change in livelihood. 54% of the respondents indicated that they spent more money in buying other sources of protein, 22% of them said no fish to catch and 24% of them said they have stopped and ventured into different sources of income-earning business.

Table 6: Factors causing change in fishers livelihood

Respondent	Frequency	Percentage (%)
Spent more money in buying other sources of protein	27	54.0
No fishes to catch	11	22.0
Stopped fishing	12	24.0
Total	**50**	**100**

Trends of mining and its implications in Anyinam

Trends of mining in the catchment

Figure 14 presents the types of mining in and around the catchment in the Birim River. 18% respondents indicated "galamsey", 70% indicated "changfan" and 12% of the respondents indicated they did not know the type of mining.

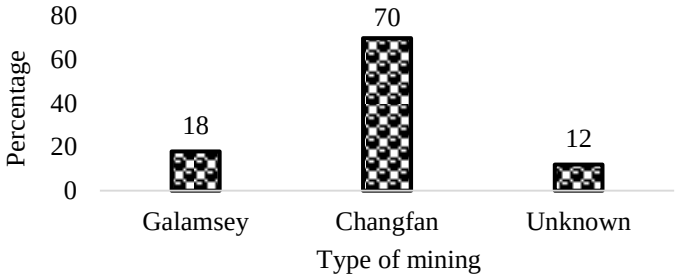

Figure 14: Perceived type of mining in and along the catchment at Anyinam.

Views of periods the mining have been in and around the catchment

Figure 15 presents information on the respondents' views concerning the duration of mining activities along the Birim basin. 88.9% of the respondents indicated that "galamsey" has been in the catchment for about 1–5 years, 11.1% of the respondents indicated that "galamsey" has been in the catchment for about 6–10 years, 97% of the respondents indicated that "changfan" has been in the catchment for about 1–5 years, 3% of the respondents said "changfan" has been in the catchment for about 6–10 years and 96% of the respondents indicated that the unknown types of mining has been in the catchment for about 1–5 years and 4% of the respondents indicated that the unknown types of mining have been in the catchment for about 6–10 years.

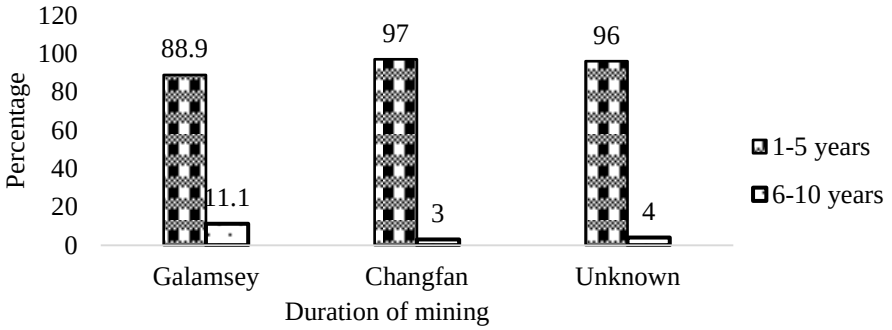

Figure 15: Mining duration (years) in the catchment area.

Types of machines used in mining

Figure 16 presents information on the type of machines used in mining in the catchment. 8%, of the respondents indicated that miners use bulldozers, 70% of the respondents indicated that miners use "changfan" in mining, 4% of the respondents indicated that miners use graders in mining and 18% of the respondents indicated that miners use excavators in mining.

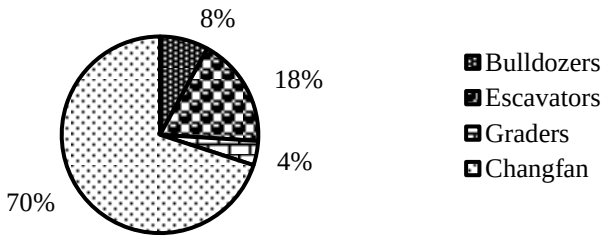

Figure 16: Types of mining machines in the catchment in Anyinam.

Implications of mining on fishing in the catchment area

Information received from the respondents on the perceptions of the implications of mining on fishing in the catchment area revealed that 94% of them think that mining has impacts on fishing in the community, while 6% indicated mining does not affect fishing as indicated in Figure 17.

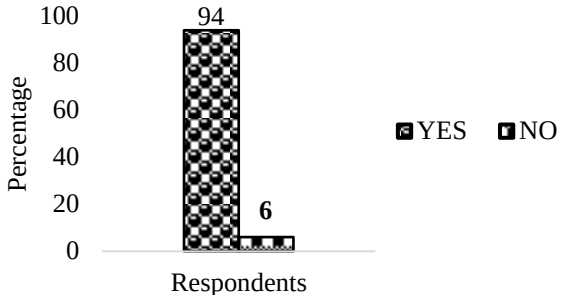

Figure 17: Responses on the implications of mining on fishing in the catchment area.

Some perceived implications of mining on fishing

Figure 18 describes the implications of mining on fishing. Respondents were asked to indicate some of the implications of mining on fishing and water quality. 40% of them indicated that pollution of the water body is an implication of mining on fishing, 14% indicated that destruction of fishing gear is also an implication of mining on fishing, 20% indicated that elimination of certain fish and other species is also an implication of mining on fishing and 26% of them said the creation of very deep pits in the river column is also a hindrance to fishing.

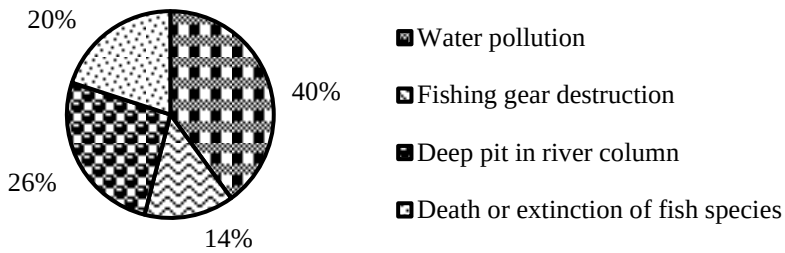

Figure 18: Some perceived implications of mining on fishing in Anyinam.

Discussion

The present study was conducted to assess the effects of small-scale mining on fishing activities and water quality of the Birim River in the Atiwa District of Ghana. Specifically, the study determined the trends of mining and fishing in the catchment area, and the impacts of mining on fishing and water quality.

Demographic and socio-economic characteristics

Fishing in the study area was a male-dominated activity. This may be attributed to the effort of physical energy required. None of the fishers fell below the age of 20, and by implication, older people generally stay in the villages and the younger people go to the cities to find work. This explains why 74% of the fishers were 40 years or more. About 18% of the fishers had basic school education. With regards to the number of years the respondents have been in the

fishing activity, 38% of them have been fishing for 1–10 years, meaning, the river is productive and support fishing in the area. The data also suggest that farming was the predominant alternative occupation aside fishing. The findings indicated that all the fishers had at least 1–10 years of experience in fishing. This implies that respondents may be well endowed with the necessary knowledge and skills in fishing. A similar study reported that fishing is a major source of both employment and animal protein for local river inhabitants (Almeida et al. 2001, Thurstan et al. 2010, Lotze et al. 2011).

Trends of fishing in Anyinam

The results show that 5% of fishers after 2010 went for fishing. This implies that there has been a reduction in fishers in the area and this could affect the output of fish caught per day in the catchment, thereby affecting the GDP of fisheries to the economy of Ghana. This may be due to the prevalence of mining and other factors. This is in line with reports which stated that river ecosystems all over the world are becoming heavily contaminated by anthropogenic activities, with negative effects on fish catches (Dudgeon et al. 2006, MEA 2005). It was also revealed that fishers spent more fishing hours after 2010. This may be due to the fact that before 2010 there was no mining distortion which destroyed gears and water visibility owing to pollution. Earlier workers reported that, pollution reduces the catchability of fish in a particular river body thereby increasing the fishing hours spent by fishermen (Myers and Worm 2003, Thurstan et al. 2010, Buchheister et al. 2013). It was also reported that a lot of fishers have changed the use of fishing nets to hooks and lines. The perceived change in the gear used in fishing may be attributed to indiscriminate mining activities. Some of the fishers exclaimed that their fishing nets get torn during fishing owing to the influence of the deep pits created as a result of mining in the rivers. Habitat characteristics including variable depth, complex woody structure, heterogeneous habitat, flow, and turbidity limit the effectiveness of fishing nets or gears (Thévenet and Statzner 1999). Moreover, the reduction in fishing nets after 2010 may be due to observed death associated with deep pits created by miners which prevent fishing in deeper parts of the river (FAO 2014).

The results of the study also indicated that fishers harvested bigger-sized fish (2 kg and above) of all the species of fish in the river like tilapia, catfish, freshwater shrimp before the commencement of the mining in the catchment although catfish are still in the water. This is because catfish are mud eaters and can grow and reproduce in a turbid environment (Friend et al. 2012). This may probably be due to the fact that some species of fish cannot survive in turbid waters due to mining activities. This is in line with a study which reported that the sizes of fish caught in the mined environment are decreasing and certain species that cannot thrive well in such polluted habitats are going extinct (Friend et al. 2012, Thorpe et al. 2009). According to Amarathunga and Fernando (2016), larger and bigger particles can clog and block the gills of fishes thereby impeding respiration and eventually kill them.

Reduction in quantity of fish catch following mining activities as revealed in this study generally affect fisher's level of catch and average income per day. This can be linked to mining due to the fact that, miners wash their products in the Birim River catchment, redirect their dugout canal back to the river and block the main river flow and recreate a different one. This confirms the findings of the study by Lake and Hinch (1999), who reported that mining pollutes nearby waters by increasing sedimentation and turbidity. Again, poor water quality causes physiological stress, death, and mortality in fishes, which can affect their growth (Lloyd 1987). It was also revealed that there was no ready market of fishes after 2010, with the reason that the fish have been affected with chemicals and people are scared to eat due to the fear of future complicated health issues. This is in line with earlier reports that mining pollutes water bodies with chemicals such as heavy metals that affect humans through the food chain (Jaishankar et al. 2014, Wongsasuluk et al. 2014).

Trends of mining and its implications in Anyinam

The findings indicated "changfan" as one of the mining types found along the catchment of Birim River, has been in use for about 5 years and it is the main equipment used in the area. "Changfan" is a machine that is used to mine in water. According to the respondents, "changfan" which is used to mine in waters is a cheaper form of mining machine as compared to excavators and other legal mining machines. This may be due to higher costs and the criteria to meet in getting a concession before one could proceed in mining and the high costs of treating wastewater. This confirms the findings of Adjei et al. (2012) that, rivers are endowed with gold deposits, which are also referred to as 'alluvial gold. These deposits are found in the majority of rivers in Ghana as in rivers Offin, Pra, Ankobra, Birim, Volta and Tano. It was also revealed that aside from the use of the "changfan", illegal mining on the land (galamsey) is the second most practised type of mining in the catchment area and has been in existence for about 5 years. The "galamsey" operators use excavators in mining. Reclaiming damaged lands caused by these two machines is very difficult due to the high costs involved, thus they leave the pits uncovered and wastewater untreated.

The majority of the respondents indicated that mining has implications on fishing and water quality. The creation of deep pits in the river, destruction of fishing gears, and pollution were among some of the implications of mining on fishing. This can also cause the death of fishermen. There has been a series of deaths of fishers in the Birim River due to the deep pits left after mining. The increasing sediments and turbidity in rivers affect the reproductive structure of the habitat which affects the reproductive cycles causing physiological stress of fish which increases their susceptibility to disease (FAO 2014). However, the above-listed implications are in line with the study conducted by Adjei et al. (2012), who stated that mining activities pollute nearby water resources due to their physical degrading nature, as well as the uses of chemicals and other harmful substances. Mining operations, whether small or large scale, usually require the use of water which affects the stability, physico-chemical parameters of water resources, even in the long term after the closure of the operations (Gardner et al. 2015). The use of chemicals like mercury and cyanide by miners also contributes enormously to the pollution of rivers and streams within these mining areas, thus posing threats to human existence and aquatic life (Varol 2011, Wongsasuluk et al. 2014). Pollution caused by miners leads to death and total elimination of fishes as it is reported in the study that, there has been a decline in fish catch and extinction of some species in the Birim River as a result of pollution due to mining. This is in line with a study conducted by Awudi (2002) who reported that mining pollutes water bodies thereby increasing the sediment load of the river and the turbidity level which can cause the death of certain fishes. Some researchers confirmed that the sizes of fish caught in the mined environment are decreasing, certain species that cannot thrive well in such polluted habitats are disappearing in the freshwater system (Thorpe et al. 2009, Friend et al. 2012).

Conclusion

The findings indicated creation of deep pits which destroy gears, increase the costs of gear repairs, fishing effort, and pollute water (physical and chemical factors). It was also revealed that fishers spend more hours in fishing and small-sized fish were mostly harvested after 2010. There was also no ready market for fish harvested from the mining catchment and the general average income of fishers per day was reduced according to the study. The creation of the deep pits because of the mining activities in the area has destroyed the habitats of the fishes in the river thereby contributing to loss of biodiversity. Therefore, further studies should be carried out on fish stock assessments to determine the status of the fishery for regular monitoring.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

References

Adjei S, Oladejo NK and Adetunde IA 2012 The impact and effect of illegal mining (galamsey) towards the socio-economic development of mining communities: A case study of Kenyasi in the Brong Ahafo Region Adjei Samuel1. *Int. J. Mod. Soc. Sci.* 1(1): 38–55.

Almeida OT, McGrath DG and Ruffino ML 2001 The commercial fisheries of the lower Amazon: an economic analysis. *Fish. Manag. Ecol.* 8(3): 253–269.

Amarathunga AD and Fernando RW 2016 Suspended sediment concentration and its impact on aquatic invertebrates in the Gin River, Sri Lanka. *J. Food Agric.* 9(1–2): 24–38.

Awudi GBK 2002 The role of foreign direct investment (FDI) in the mining sector of Ghana and the environment. *Conference on Foreign Direct Investment and the Environment, OECD, Paris*.

Bansah KJ, Dumakor-Dupey NK, Kansake BA, Assan E and Bekui P 2018 Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana. *J. Clean. Prod.* 202: 465–475.

Buchheister A, Bonzek C F, Gartland J and Latour RJ 2013 Patterns and drivers of the demersal fish community of Chesapeake Bay. *Mar. Ecol. Prog. Ser.* 481: 161–180.

Dudgeon D, Arthington AH, Gessner MO, Kawabata Z, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard A, Soto D and Stiassny MLJ 2006 Freshwater biodiversity: importance, threats, status, and conservation challenges. *Biol. Rev.* 81(2): 163–182.

Essumang D K, Dodoo D K, Obiri S and Yaney J Y 2007 Arsenic, cadmium, and mercury in cocoyam (Xanthosoma sagititolium) and watercocoyam (Colocasia esculenta) in Tarkwa a mining community. *Bull. Environ. Contamin. Toxicol.* 79(4): 377–379.

Fisher E, Mwaipopo R, Mutagwaba W, Nyange D and Yaron G 2009 The ladder that sends us to wealth: Artisanal mining and poverty reduction in Tanzania. *Resources Policy* 34(1–2): 32–38.

Food and Agriculture Organization (FAO) 2014 The State of World Fisheries and Aquaculture 2014: Opportunities and Challenges. Food & Agriculture Org.

Friend R, Arthur R and Keskinen M 2012 Songs of the doomed: the continuing neglect of capture fisheries in hydropower development in the Mekong. In *Contested Waterscapes in the Mekong Region* (pp. 329–354). Routledge.

Gardner A, Duff N, Ainuson K and Manteaw S 2015 Regulating Mining Water Use and Impacts in Ghana: Comparing Australian and Ghanaian Law for Reform Ideas. *International Mining for Development Centre Research Report*.

GSS (Ghana Statistical Service) 2010 Population and Housing Census.

Hanson R, Dodoo D K, Essumang DK, Blay J and Yankson K 2007 The effect of some selected pesticides on the growth and reproduction of freshwater Oreochromis niloticus, Chrysicthys nigrodigitatus, and Clarias gariepinus. *Bull. Environ. Contamin. Toxicol.* 79(5): 544–547.

Hilson G 2001 A contextual review of the Ghanaian small-scale mining industry. *Mining, Minerals and Sustainable Development* 76(September).

Hilson G 2016 Farming, small-scale mining and rural livelihoods in Sub-Saharan Africa: A critical overview. *The*

Extractive Industries and Society 3(2): 547–563.

Jaishankar M, Tseten T, Anbalagan N, Mathew BB and Beeregowda KN 2014 Toxicity, mechanism, and health effects of some heavy metals. *Interdiscip. Toxicol.* 7(2): 60.

Kuma JS and Younger PL 2004 Water quality trends in the Tarkwa gold-mining district, Ghana. *Bull. Eng. Geol. Environ.* 63(2): 119–132.

Lake RG and Hinch SG 1999 Acute effects of suspended sediment angularity on juvenile coho salmon (Oncorhynchus kisutch). *Can. J. Fish. Aquat. Sci.* 56(5), 862–867.

Lloyd DS 1987 Turbidity as a water quality standard for salmonid habitats in Alaska. *N. Am. J. Fish. Manag.* 7(1): 34–45.

Lotze HK, Coll M, Magera AM, Ward-Paige C and Airoldi L 2011 Recovery of marine animal populations and ecosystems. *Trends Ecol. Evol.* 26(11): 595–605.

Manu A, Twumasi YA and Coleman TL 2004 Application of remote sensing and GIS technologies to assess the impact of surface mining at Tarkwa, Ghana. *IGARSS 2004. 2004 IEEE International Geoscience and Remote Sensing Symposium, 1*.

MEA (Millennium Ecosystem Assessment) 2005 *Ecosystems and human well-being: Synthesis* (Vol. 5). Island Press Washington, DC.

Myers RA and Worm B 2003 Rapid worldwide depletion of predatory fish communities. *Nature* 423(6937): 280–283.

Obiri S 2007 Determination of heavy metals in water from boreholes in Dumasi in the Wassa West District of the western region of the Republic of Ghana. *Environ. Monit. Assess.* 130(1): 455–463.

Shen L and Gunson A J 2006 The role of artisanal and small-scale mining in China's economy. *J. Clean. Prod.* 14(3–4): 427–435.

Singh N, Koku JE and Balfors B 2007 Resolving water conflicts in mining areas of Ghana through public participation a communication perspective. *J. Creat. Commun.* 2(3): 361–382.

Thévenet A and Statzner B 1999 Linking fluvial fish community to physical habitat in large woody debris: sampling effort, accuracy, and precision. *Archiv Für Hydrobiologie* 57–77.

Thorpe A, van Anrooy R, Niyazov BN, Sarieva MK, Valbo-Jørgensen J and Millar A M 2009 The collapse of the fisheries sector in Kyrgyzstan: an analysis of its roots and its prospects for revival. *Communist and Post-Communist Studies* 42(1): 141–163.

Thurstan RH, Brockington S and Roberts C M 2010 The effects of 118 years of industrial fishing on UK bottom trawl fisheries. *Nat. Commun.* 1(1): 1–6.

Varol M 2011 Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques. *J. Hazard.Mater.* 195: 355–364.

Wongsasuluk P, Chotpantarat S, Siriwong W and Robson M 2014 Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environ. Geochem. Health* 36(1): 169–182.