KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF WILDLIFE AND RANGE MANAGEMENT

ANURANS RESPONSE TO SMALL-SCALE MINING ACTIVITIES IN THE SUI RIVER FOREST RESERVE (SRFR), GHANA

ADU-TUTU PRINCE

MAY, 2017

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A THESIS SUBMITTED TO THE FACULTY OF RENEWABLE NATURAL RESOURCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIRMENT FOR THE AWARD OF A BACHELOR OF SCIENCE DEGREE IN NATURAL RESOURCES MANAGEMENT.

ADU-TUTU PRINCE

MAY, 2017

DEDICATION

I dedicate this dissertation to my parents, Mr Charles Agyei Kusi and Mrs Margaret Bofah and my siblings, Priscilla and Agnes Adu-Tutu. Also to all frog lovers and savers in Ghana and across the globe. We are a big family.

ABSTRACT

Amphibians (anurans, caecilians, and salamanders) play a critical role in the ecosystem. Their roles includes; bio-indicators of the environment and as both predators and prey species. Despite their importance, they are threatened more than both mammals and birds. Small-scale mining activities among other factors may be contributing to local amphibian declines but have so far been incompletely studied. This study therefore sought to assess anurans response to mining activities in the Sui River Forest Reserve. The study's objectives were (1) document anuran species and their conservation status in Sui River Forest Reserve; and (2) determine and compare the richness and abundance of anurans in small-scale mined (disturbed) and unmined (undisturbed) sites within the forest. A total of four standardized rectangular plots each of 200m × 100m were established. Visual encounter survey was employed to detect anurans within plots. Ninety-eight individuals of 16 anuran species belonging to nine families were recorded. Important results of this study was the discovery of two potential new species to science (*Conraua sp.* and *Phrynobatrachus sp.*). Species richness was higher in the unmined area (eight) as compare to the mined (five). Also the unmined area was more diverse compared to the mined area but this difference was not statistically significant. The abandoned pits in the mined area (mined-out pits) pose a threat to anurans species especially leaf-litter species which can be trapped and drowned leading to mortality of species and ultimately population declines. It is recommended that mined-out pits should be filled and enrichment planting should be embarked on those sites to restore the degraded area in the reserve to help save anuran species.

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My greatest thanks goes to my backbone which is my lovely family, Mr Charles Agyei Kusi and Mrs Margaret Bofah and my siblings: Priscilla and Agnes Adu-Tutu for your immense support through financial assistance, love and care for me. I pray God's abundant blessings for you. I would like to thank my counsellors: Rev. Richmond Nana Yaw Mensah, Rev. J. K. Appiah and Pastor Enoch Yeboah for praying and encouragements for me throughout these years. I express thanks to my roommate; Victor Agyei for helping in my data collection and proof-reading my work and AGSU members of Glorious Liberty Assemblies of God for your comments and prayers.

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AND TO GOD BE THE GLORY.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The class Amphibia (anurans, caecilians, and salamanders) are noticeable species of the world's vertebrate fauna. Amphibians are species with highly permeable skin and this feature makes them sensitive to the environment. A feature that also makes them good bio-indicators of environmental changes. There is a massive increment in the rate at which new species are being described (in recent years about 48.2% since 1985; Frost, 2016). Surely, more are to be discovered provided they are not eliminated by tropical deforestation.

There is a decline of the world's amphibian population (Beebee & Griffiths, 2005). It is estimated that, over 40% of biodiversity including amphibians will go extinct at an extinction rate over 200 times as compare to that of their natural background rate (Stuart *et al.*, 2004). Amphibians are more threatened than both mammals and birds (Stuart *et al*., 2004). For this reason, anurans have become a conservation concern than other group of vertebrate (Allentoft & O'Brien, 2010). Invasive species, disease and parasite, environmental pollution, exposure to ultra violet B, climate change, logging, and mining are diversity of factors contributing to the decline in amphibians (Alford & Richards, 1999) and this has amplified the need for scientific data on the diversity and abundance of anuran species.

Tropical forests support a high number of biodiversity but these forests are under serious threat due to the high rate of degradation. Over a decade now, the rate of loss of tropical forests has increased by 2,101 km^2 per year (Mugume *et al*., 2015). Chapman *et al*., (2013), explains that degradation is human induced. Human alteration of the environment is achieved through habitat modification, anthropogenically induced climate change, and atmospheric pollutants (Gardner, 2001).

In Ghana, small-scale mining defined herein as any single unit mining operation having an annual production of unprocessed material of 50,000 tonnes, or less as measured at the entrance of the mine (Aryee *et al*. 2003) is on the ascendency. The mining activities often leads to habitat loss, degradation and fragmentation of once continuous forest habitats. Despite its contribution to the country's foreign exchange earnings (Minerals Commission, 2015), it has destroyed the natural beauty of a lot of Ghana's forests (Ankomah, 2012). The proximate means by which this mining affects the environment is the pre-mining removal of vegetation cover, large excavation that degrades the soil and pollutes adjoining river systems. Apart from these direct obvious effects of mining, it may also directly lead to both direct and indirect mortality of wildlife species but this has so far not been investigated.

Amphibians are often attracted to dugout pits, because they hold water that may be suitable for breeding (Geigenbauer *et al*., 2014). However often times these waters are heavily contaminated or they are too deep and unsustainable for breeding. Amphibians of course may not be able to immediately distinguish between these water systems and the natural once which ultimately becomes an ecological trap leading to high mortalities in a phenomenon termed as 'ecological traps' (Battin, 2004).

Amphibians play an integral part in diverse ecological systems and their decline in the ecosystem can be catastrophic. They are for instance the highest of the vertebrate biomass (Gardner, 2001). They act as both predators and prey species playing a key role in trophic dynamics and so their absence can seriously disrupt the functioning of the rest of the ecological community. Looking at the importance of amphibians in the ecosystem and the rate of degradation of forest reserves in Ghana and the world as a whole, amphibian studies cannot be ignored since it can facilitate the management and conservation of amphibians in the reserve. Also it can serve as a stepping stone for other studies to be done including ecological studies of amphibians.

1.2 Problem Statement and Justification

Relatively, little is known on amphibians how particularly they respond to degradation in the eco-region of West Africa as compared to other vertebrate groups (Adum, 2014). Clearing of ground vegetation and digging out soil from the ground to get access to minerals have various effects on invertebrates which in turn affects the taxa that feed on them (Meijaard *et al*., 2004). Of course some species respond more sensitively to these changes than others and these suffer the most from such habitat alterations. Invertebrates, especially insects are consumed by anurans which are major consumers known as local top carnivores (Wake, 1991). There is scant lasting data on populations of amphibian in various areas which restricts our knowledge about their declines (Whitfield *et al*., 2007). This study provides insights into anurans response to small-scale mining activities in Ghana.

The decline of amphibians due to degradation calls for more research to be done to document the existing species particularly those that may be affected by ongoing degradation. Little is known about the impact of mining on anurans and the information acquired will serve as baseline to help future researchers embark on further researches on mined areas. When this study is carried out, the information gained will help the Forest Commission of Sefwi Wiawso District and the Wildlife Division to be specific on how to manage sustainably the Sui River Forest Reserve and other forests of Ghana and the world at large.

1.4 Aims and Objectives

1.4.1 Aim of the Study

The aim of this research is to improve our understanding of anurans responses to mining activities in the Afro-tropical forest ecosystem.

1.4.2 Specific Objectives

i. Document anuran species and their conservation status in Sui Reserve Forest Reserve.

ii. Determine and compare the richness and abundance of anurans in small-scale mined (disturbed) and unmined (undisturbed) forests.

1.5 Hypothesis

i. Species diversity of anurans in the unmined (undisturbed) forests will be significantly higher than in the small-scale mined (disturbed) forests.

ii. No forest specialist anuran species will be found in the mined area in the SRFR.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of Amphibians

Amphibians play very important roles in the ecosystem and thus have become of high conservation concern. They are species with highly permeable skin which absorbs chemicals and this feature makes them susceptible to environment changes. This delicate nature of the skin of amphibians classify them as bio-indicators of environmental stresses and their health is thought to be indicative of the health of the biosphere as a whole.

They serve as both predators and preys (Hocking & Abbitt, 2014). Tadpoles of amphibians help reduce eutrophication by feeding on the algae in water bodies (Kwapong, 2014). This clearly explains that they are not the just the first ones to die due to environmental changes but also they clean up the mess of our environment. Adult amphibians feed on large quantities of invertebrates including disease vectors like mosquitoes that transmit malaria which is fatal to humans. Amphibians are also preyed upon by a diverse array of animals including snakes, fishes, birds, monkeys and many others (Stuart *et al*., 2008). Thus their disappearance will disturbs the food chain and generate undesirable impact on the ecosystem.

Lastly, researches have shown that amphibians are vital resources in human medicine (Stuart *et al*., 2008; Baillie *et al.,* 2004). For instance three Australian frogs (*Litoria caerulea*, *L. chloris* and *L. genimaculata*) have skin secretions that inhibit the Human Immune Virus (HIV) (VanCompernolle *et al.,* 2009).

2.2 Global State of Amphibians

Globally, the world is facing an extinction crisis which the 2004 IUCN Red List contains 15,589 species threatened with extinction (Baillie *et al*., 2004). Amphibians are more threatened than both mammals and birds (Stuart *et al*., 2004). Global Species Assessment, 2004 lamented that about 32% of amphibians are threatened as against 12% of birds and 23% of mammals. As revealed by the first complete assessment of amphibians, they are likely to be the most threatened group of vertebrate. IUCN Red List reported that about one third of the 6,500 still existing amphibians species representing 1,856 species are threatened with extinction (Rödder *et al*., 2009; Stuart *et al*., 2004; Baillie *et al.*, 2004). Simply the most recent two decades there have been a disturbing number of eliminations, about 168 species are accepted to have become wiped out and no less than 2,469 (43%) more have population that are declining. Amphibians are not only the most threatened species of the vertebral group assessed but they are on the verge of extinction. Altogether, 21% of amphibians are Endangered as per the IUCN Red List, though the extents for mammals and birds are just 10% and 5% separately.

About 250 publications have been produced which all relates to the issue of amphibians declines in the world. All the publications are results from the first meeting held in the Canterbury, England consisting of a group of over 1400 from 60 countries across the world for the First World Congress of Herpetology ("Amphibians Extinction Crisis," n.d.). It was at this meeting that researchers reported the declines in the populations of their study of amphibians. This has birthed a new field of research into herpetology (Haddad, 2008). The decline of amphibians across the globe shows that a lot of things are happening and changes are taking place each and every passing second.

Habitat change (destruction and fragmentation), alien invasive species, over-exploitation and utilisation, emerging infectious diseases, pesticides and environmental toxins, global climate change (including UV) and synergistic effects are the diversity of factors contributing to the decline in amphibians globally (Stuart *et al*., 2004). These factors are interrelated and it makes it difficult to single out one of the causes of the factors. Amphibian biologists have articulated that habitat destruction has threatened amphibian species than any other factor that causes the decline of the species globally (Gardner, 2001).

For this reason, amphibians have become a conservation concern than any other group of vertebrate (Allentoft & O'Brien, 2010).

2.3 Factors Influencing Amphibian Decline

2.3.1 Habitat Loss, Fragmentation and Degradation

Degradation of habitats is a particular problem in certain parts of Africa though it happens all over the world. Throughout the world, a lot of people are worried about the rate at which our environment is being destroyed. From what people do, food chains and habitats which forms part of earth's biological systems as well as its physical systems such as water cycles and the ozone layer are being ruined. It takes many thousands of years for the thin crust of soil covering much of land to form which including human life, a great deal of life depends on it. It is very vulnerable and it becomes extremely difficult to put back once damaged.

People and wildlife suffers most from its consequences particularly when it comes to land degradation. The underlying structures of land are harmed including plants and animals which in extreme cases these living there are wiped out. Following the removal of forest covers, amphibians' response to these changes varies greatly. Whiles there is a rapid decline in the population of amphibians, others also undergo gradual depletion until they finally disappear from their geographic ranges (Gillespie & Hollis, 1996). Reduction in local populations and habitat fragmentation can result in decrease in genetic diversity which can lead to inbreeding and reduction in evolutionary potential for species to adapt to environmental changes such as global warming (Smith, 2001).

Numerous factors and a combination thereof, including anthropogenic activities such as deforestation, overgrazing, poor land management, fires, pollution, mining and neglect have resulted in degradation ("Land Degradation Assessment," n.d.). The subject of environmental degradation has become a matter of unease to all Ghanaians (Appiah, 2011).

2.3.2 Over-Harvesting

Amphibians are of no exemption of the exhaustion and extinction of both plant and animal species due to the unmanageable exploitation of natural resources (Meijaard *et al*., 2004). There is no paper which explicitly shows the natural history elements of reptiles and amphibians link with pet trade (Rodda & Tyrrell, 2008). There are also literatures that give details of figures import and export but neglect the account of species traded domestically and there is always some extraneous individuals trade internationally for food, medicine and leather (Rodda & Tyrrell, 2008). In spite of the fact that it is extremely hard to evaluate the quantity of amphibians collected for food, medicine and leather, the number is accepted to be noteworthy. Low cost to dealer, colourful appearance , ease of handling and non-secretive habits are the hypothesized reasons for the exploitation of amphibians (Rodda & Tyrrell, 2008). In many developing nations like Ghana, the harvest of amphibians is profoundly unregulated and is in this way a presumable giver to amphibian populace proficient decline.

2.3.3 Invasive Species

Researchers and conservationists generally acknowledge that there is a connection between species intrusions and extinction of species but there is no evidence supporting it (Gurevitch & Padilla, 2004). All arguments are based on speculation and observation. The argument of the link is based on the fact that the declines of native species frequently occur concurrently and in the same place as raid by non-native species (Gurevitch & Padilla, 2004). In spite of these arguments, Wilcove *et al*., 1998, pointed to the fact that after habitat loss, the next thing that is a threat to biological diversity is invasive species. Also Walker *et al*., (2015) added that the presence of invasive species that is their development and spread has huge effects on biodiversity in terms of both ecological and economic damages.

Recent studies now focus on the capacity of intrusive plants to change habitat structure or quality, by acting as ecosystem engineers as compared to past studies that focused on competition, prey and predation as interactions between invasive species and local species (Didham *et al.,* 2005). Wise *et al*., 2007, reported five species which are very invasive, dominating in Africa as of now and they include Nile tilapia (*Oreochromis niloticus*), Water hyacinth (*Eichhornia crassipes*), the larger grain borer (*Prostephanus truncatus*), Parthenium weed (*Parthenium hysterophorus*); and Triffid weed (*Chromolaena odorata*). Among the aforementioned species, Triffid weed (*Chromolaena odorata*) is of the most invasive species that has taken over all forest reserves in Ghana (Anning & Yeboah-Gyan, 2007). They serve as fuels when dried up and carry fires into forests and kills forest species. Invasive species may be ubiquitous but unless rare opportunities or empty niches are created as a results of bushfires, indiscriminate logging, surface mining especially in the forest zones, they cannot manifest.

Invasive species is well noted to be one of the causes of amphibian declines in Ghana and the world at large. Maerz *et al*., (2009) found out that, there was a reduction in leaf litter on the forest floor due the presence of non-native earthworm invasions, and the depletion of forest leaf litter is usually linked with declines in forest fauna, not excluding amphibians. Hence, several factors have been embroiled to clarify the effects of intrusive species on amphibians (Zimmermana *et al*., 2013;Diepenbrocka, 2013).

2.3.4 Habitat Pollution

Sparling *et al*., (2010) stated emphatically that habitat pollution play an analytical role in the decline of amphibians worldwide. There is a wide range of pollutants that affect amphibians causing their declines and they include fungicides, pesticides, fertilizers, herbicides, and numerous other pollutants (Blaustein *et al*., 2003; Sparling *et al*., 2010). Through direct applications, runoff from crops, forest applications or mines, urban and industrial sewage are the means through which the pollutants get into the habitats of amphibians. Amphibians' response to the pollutants quickly because of their delicate nature. The end is obviously mortality of the species. Several studies have reported the effects of pollutants on amphibians and they affect them in different ways because of the countless diversity of pollutants. Rowe *et al*., (1996), found a higher occurrence of oral deformities in the tadpoles of Bullfrog (*Rana catesbeiana*) in a coal ash presence areas as compared to areas without coal ash. Also, Hayes *et al*., (2002) demonstrated gonadal abnormalities in African clawed frogs (*Xenopus laevis*), when expose to relevant doses of atrazine. Though this harmful pollutant called atrazine is banned in Europe (Sass & Colangelo, 2006) but it is wildly used in certain parts of the whole world including Ghana. This calls for an alarm.

2.3.5 Other Factors

Baillie *et al.,* (2004), and Gibbons *et al*., (2000) have established that there are other causes of amphibians decline aside those already known and contributed to the 48% of amphibians which are threatened.

Diseases are increasingly recognised as threats to wildlife including amphibians. Viral, bacterial and fungal diseases have been reported as the major agents in the declines of many species. One of the emerging diseases is Chytridiomycosis which is caused by *Batrachochytrium dendrobatidis* (Kriger, 2006; Woodhams *et al*., 2003; Kilpatrick *et al*., 2010; Lips *et al.,* 2006).

Global change refers to human-induced alteration of the earth's atmosphere or biosphere. Climate change (Williams *et al.*, 2003) and increase in ultra violet radiation exposure (Blaustein *et al.*, 1996) are the two main changes affecting amphibian populations. An example of climate change is greenhouse effect (Carey *et al.,* 2003) and increases atmospheric temperature. In this century, there is bound to be an increase in average temperatures of between 1.4 ^{0}C and 5.8 ^{0}C coupled with huge increase atmospheric carbon dioxide (CO_2) concentrations and considerable changes in rainfall patterns (Houghton *et al*., 2001). The predictable effects of the adverse climatic conditions is insidious on the health of frogs, such as depression of immune function causing the frogs to become more susceptible to diseases. Furthermore, the change in the lower pond water levels will have more effects on frogs, exposing the embryos to more UV violet radiation from the sun causing them to be even more susceptible to fungal attacks (Carey *et al*., 2003).

2.4 Nature and State of Ghana's Forest

Ghana's forests forms part of the Upper Guinea forest (West Africa) which stretches from Senegal to Togo (Poorter *et al*., 2004) is ranked among the 25 biodiversity hotspots in the world (Hillers *et al.*, 2009). It is considered a region of high endemism with both reptiles and amphibians recording higher than other group of tetrapod (reptiles = 33% and amphibians = 77% versus mammals = 8% and birds = 18%) (Leaché *et al*., 2006). At the same time, Ghana's forests are under serious threats due to human population growth through forest fragmentation, degradation, infrastructure, conversion into agriculture lands, and mining activities (Hillers *et al*., 2009; Poorter *et al*., 2004). Due to anthropogenic activities, Ghana's forests is under serious threats leaving species in these forests vulnerable, not excluding amphibians. Therefore, if caution is not taken, some of the species might go extinct before we decide to explore them in details.

2.5 Anuran Studies in Ghana

Despite Ghana being part of the 25 biodiversity hotspots in the world, it has received little attention in terms of herpetological research (Leaché, 2005). Hughes, (1988) provided a checklist of 71 amphibians species as a preview of history of herpetological investigations in Ghana. Equally, the 2002-2004 Global Amphibian Assessment (GAA), by The World Conservation Union (IUCN)/Species Survival Commission, Conservation International Center of Applied Biodiversity Science and Nature Serve listed 71 amphibians' species for Ghana. On the other hand, after the work of (Schiøtz, 1964) conducted in 1964, only a few papers have been published and examples include; (Rödel *et al*., 2005; Rödel & Ernst 2004; Leaché, 2005). Recently, there has been concern for amphibians causing papers to be published including (Rojas-Ahumada *et al*., 2012; Singh *et al*., 2016; Ofori-Boateng *et al.,* 2013; Penner *et al.,* 2013; Mahama 2014)

It was believed that Ghana forests do have less diverse species as compared to other Upper Guinean forests like that of Côte d'Ivoire and Guinea but until recently. For the species recorded for Ghanaian amphibians documented species richness in the forests ranges from 10 to 20 species per site (Schiøtz, 1964) as compare to our neighbouring countries revealed 40 to 50 species richness (Rödel & Ernst, 2004). Nevertheless, recent studies has proven the above said statement to be wrong because they revealed that amphibians population of Ghana are not less diverse as compared to neighbouring countries. In a survey in the of south-western Ghana, Rödel & Ernst (2004) recorded 47 amphibians species. Also, during a research into the assessment of the amphibians in the forests of southern Ghana and western Togo, *(*Hillers *et al*., 2009) recorded 45 frog species. Hillers *et al.* (2009) shown that there is a high endemism in Ghana forests. However, with the exception of Leaché (2005), all surveys are done in wet and semi-deciduous forests neglecting fragmented areas and this limits our understanding of amphibians distribution in forests.

2.6 Small-Scale Mining in Ghana

2.6.1 Definition and Historical Overview of Small Scale Mining in Ghana

Aryee *et al*., (2003) defined small scale mining as ''mining by any method not involving substantial expenditure by an individual or group not exceeding nine (9) in number or by co-operative society made up of ten (10) or more persons''. The history of small scale mining in Ghana can be traced as far back as in the colonial era and alluvial gold and diamonds were the major precious minerals mined. The arrival of the Europeans brought about higher increment in the quest for gold in 1471. It was during this time that Ghana was named 'Gold Coast'. In the 19th century, however the British started commercial scale gold mining in Ghana (Tsikata, 1997). It was in 1989, that the Small Scale Gold Mining Law was enacted and came into legalised operation (Hilson, 2002; Minerals Commission, 2015). Hilson, (2002) stated emphatically that small scale mining do take place in regions where minerals are found near the surface of the earth crust and contained in a soil which is unconsolidated. In the extraction of the gold, simple tools like chisel and hammers are used. Amalgamation is the technique being employed in the extraction of minerals (Adiyahba, 2014; Mihaye, 2013 Aryee *et al.*, 2003). Small scale mining is popularly called 'Galamsey' in Ghana (Opoku-Antwi, 2012). Scale small mining is practiced alongside large scale mining in Ghana (Donkor *et al.*, 2006). Small scale mining comprises both the legal and illegal miners and the majority is the illegal miners (Adiyahba, 2014).

2.6.2 Impacts of Small Scale Mining in Ghana

The impact of the scale small mining ranges from the socio-economic to the environmental.

2.6.2.1 Socio-Economic Impact

Small scale mining contributes to the national economy of Ghana through foreign exchange and national mineral export (Offei–Aboagye *et al.*, 2004). It also contribute to household income by employing people and is estimated by the International Labour Organisation that, 13 million people are involved with Africa alone there are roughly three million people employed (Standing, 2010). These estimates excludes people who are not directly involved and they include family members, sellers of food and drink among others (Offei–Aboagye *et al.*, 2004). This contributes to poverty alleviation. On the contrary, the involvement of the youth in mining increases the reluctance to continuing their education (Andrews, 2015). Opoku-Antwi (2012), reported an incidence where young children between the ages of 12 – 16 were involved in the small scale mining in which put both their physical and socio-economic at risk in a long term run.

2.6.2.2 Environmental and Health Impact

Despite its contribution to the livelihood of people economically, there are environmental issues associated with it. The lithosphere, the hydrosphere and the atmosphere are the major states of environmental impacts of small scale mining (Aryee *et al*., 2003, cited in (Mihaye, 2013). The greatest impact of small scale mining is the lithosphere (Aryee *et al*., 2003). Land degradation is the primary impact of small scale mining (Mihaye, 2013; Adiyahba, 2014). Vegetation is cleared to get access to land for digging (Hilson, 2002) and this causes a global increase in atmospheric carbon dioxide due to the clearing because plants that will absorb the CO_2 are limited. The clearing od the vegetation also leaves the land bare and makes room for erosion to take place (Hilson, 2002). In addition, the pits dug are left uncovered and becomes the safety and health hazards of species including amphibians (Offei–Aboagye *et al.*, 2004). Also, the hydrosphere is also affected by small scale mining. Mercury used in the amalgamation (Aryee *et al*., 2003) pollute water bodies when being washed in to them as a results of rain pour. Several studies have reported similar situation and all focused on the impacts on water bodies. For example, in a study which assessed the environmental impacts of illegal mining operations in River Bonsa, (Kusi-Ampofo & Boachie-Yiadom, 2012) reported that the people leaving around no longer fetch from the river due to pollution and now depends on treated water from the Ghana Water Company Limited (GWCL). Amphibian species which aquatic are at risk due to the pollution of rivers.

Moreover, the atmosphere is also polluted as a result of mining. Offei–Aboagye *et al*., (2004) reported that during the process of amalgamation, there is a release of (methyl) mercury vapour and this affects breathing pattern of both humans and animals.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Site

The Sui River Forest Reserve (hereafter, Sui Forest) is located in the Upper Guinean Rainforest of Western Ghana. Geographically, the Reserve falls between latitudes 5^0 58' N and 6^0 38' N and longitudes 2^0 22' W and 2^0 56' W (Figure 3.1). It covers an area of 333.90 km^2, consisting of a long narrow band that follows the Bia-Tano watershed, south of Buaku which is a distance of 105 km^2. As one of the largest reserves in Ghana, and its vegetation zone is categorised as a Moist Semi-Deciduous (MSD) (Yeboah, 2013). Most of the trees are deciduous with the emergent trees in the reserve attaining an average height of 40 metres amidst the three storey structure it possess. The major soil type of the forest is the forest ochrosols and minor particles of granite are present in some areas (Yeboah, 2013). The Sui River Forest Reserve (SRFR) falls under Sefwi Wiawso Municipal Assembly and Sefwi Akontombra District Area (Political administration) and Wiawso Forest District (Forestry administration) of the Western region of Ghana. Part of SRFR is designated as a Globally Significant Biodiversity Area (GSBA), equivalent to IUCN's Category VI: a protected area designated mainly for conservation through management intervention (Adum, 2014). The reserve has an undulating topography with very steep slopes (Amoah, 2014). As a result most of these slopes being inaccessible to logging operations, vegetation there is less damaged. It is drained by the Sui River, Yoyo River and its numerous tributaries. The SRFR is surrounded by a lot of fringe communities including Yawkrom, Boodi, Aprutu, Sui, and Kwasiahakrom (Figure 3.1). Most parts of the reserve are under active logging (Adum, 2014).

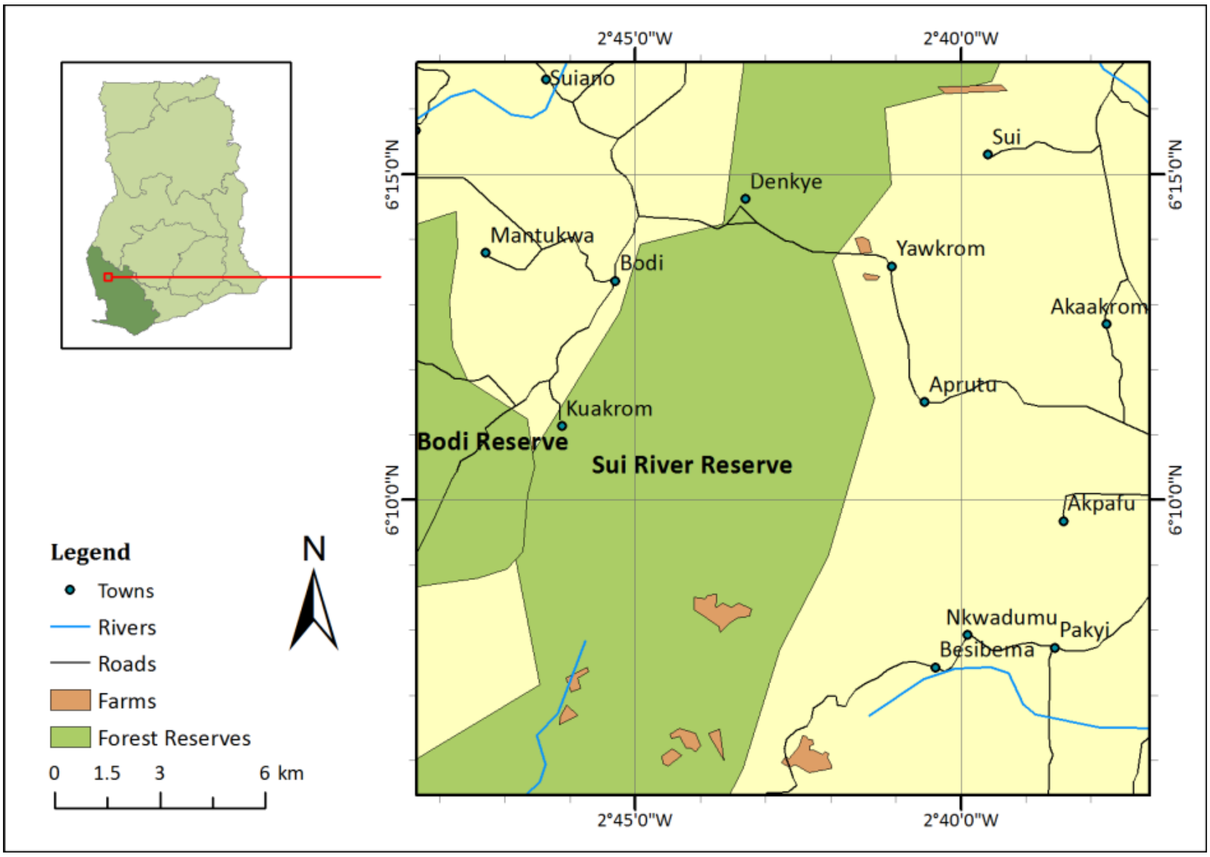

Figure 3.1: Map of Sui River Forest Reserve

3. 2 Study Design

A two day reconnaissance survey was conducted to familiarise with the area. The area under investigation was stratified into mined (disturbed) and unmined (undisturbed) forests. Undisturbed in this text refers to areas that do not have any signs of anthropogenic activities in terms of logging, charcoal burning and illegal mining activities or areas with three or less loggings per two hectares. A total of four (4) standardized square plots each of 200m × 100m were established. The plots had a Northern extension of 200 m and an Eastern or Western extension of 100 m depending on the orientation and direction of movement. The plots laid followed a stratified random design. The plots were laid using ranging poles, a compass and two coordinates within each plot were picked using a Global Positioning System (GPS) (GARMIN 64). The searches for anurans on each plot were carried out from 7:00am – 11:00am and 6:30pm - 9:30pm and it was a two-hour search.

3.3 Data Collection

Data was collected in July, August and December, 2016 over a period of 15 days. Visual Encounter Survey (VES) technique as described by (Rödel & Ernst, 2004) was used in data collection. Diurnal leaf-litter and nocturnal visual encounter surveys were the two main standard sampling methods used to investigate the presence of species at the mined and the unmined areas of SRFR. All possible anuran locations were searched including leaf litter, trees and other vegetation as well as bare ground and leaf litter. This was done by lifting cover objects (dead trees, rocks, and debris). Visually encountered anurans were captured, identified, photographed and released after searching time was completed in each of the plots. GPS was held in the hand so that it has a clear view of the sky with few or no obstructions and waited until the accuracy figure has stopped and drops no more. Coordinates were recorded by writing them down and marking them as a waypoint. The pits depth were measured by using an improvised straight stick which was lowered in to the pit. The point on the stick which touches the mouth of the pit was marked and the depth was measured using a tape measure on the improvised stick. A trained team of four individuals surveyed each of the plots for two hours and the search was replicated three times.

3.4 Data Analysis

With the aid of a 2007 Frog Guide prepared by Mark-Oliver Rödel species were identified on the field. The conservation status of the species were assessed on the IUCN Red List. Species richness the number of species present in a sample community, or taxonomic group. Shannon Wiener Index in Paleontological Statistics (PAST) version 3.0 was used to calculate the anuran species abundance, richness and diversity in both the mined and unmined forest types.

CHAPTER FOUR

4.0 RESULTS

4.1 Anuran species and their conservation status in SRFR

A total of 16 species were recorded, 10 species are listed as Least Concern whereas two are Threatened (Table 4.1). Two are Near Threatened: *Arthroleptis krokosua, Sclerophrys togoensis* Also, two of the species recorded are potentially new species to science: *Conraua sp, Phrynobatrachus sp.* (Figure 4.1 [d] and [e]). All degradation-tolerant species were recorded in the mined area except *Amnirana albolabris*, *Aubria subsigillata*, *Hyperolius concolor*, and *Sclerophrys regularis*. Also all forest specialist were recorded in the unmined forest except for *Sclerophrys togoensis* and *Amnirana occidentalis* (Table 4.1).

a) *Sclerophrys togoensis*

b) *Amnirana occidentalis*

c) *Arthroleptis krokosua*

d) *Conraua sp.*

e) *Phrynobatrachus sp.*

f) *Phrynobatrachus annulatus*

Figure 4.1: Some of the anuran species recorded in the Sui River Forest Reserve a) the dorsal view of the Near threatened *Sclerophrys togoensis* b) a typical habitat of the endangered *Amnirana occidentalis* c) Side view of a male Giant Squeaker Frog (*Arthroleptis krokosua*) d) and e) two potential new frogs (*Conraua sp.* and *Phrynobatrachus sp*. respectively) recorded during the study f) Ventral view Ringed River Frog (*Phrynobatrachus annulatus*).

Table 4.1 Checklist, Geographic Distribution, IUCN Red list categories, localities abundance of anurans observed in the different sampled sites.

Family	Species	Mined	Unmined	GD	HA	IUCN Red List
Arthroleptidae	*Arthroleptis krokosua*	0	1	UG/EG	FS	NT
	Arthroleptis sp.	11	25	UG	DT	LC
	Leptopelis spiritusnoctis	1	0	WA	DT	LC
Bufonidae	*Sclerophrys regularis*	0	3	A	DT	LC
	Sclerophrys togoensis	5	0	WA	FS	NT
Conrauidae	*Conraua sp.*	5	0	NE	NE	NE
Hyperoliidae	*Hyperolius concolor*	0	9	UG	DT	LC
	Afrixalus dorsalis	0	3	WA	DT	LC
Phrynobatrachidae	*Phrynobatrachus annulatus*	0	1	A	FS	EN
	Phrynobatrachus sp.	1	0	NE	NE	NE
Pipidae	*Xenopus tropicalis*	9	1	UG	DT	LC
Ptychadenidae	*Ptychadena aequiplicata*	0	5	WA	FS	LC
	Ptychadena longirostris	8	0	WA	DT	LC
Pyxicephalidae	*Aubria subsigillata*	0	2	WA	DT	LC
Ranidae	*Amnirana albolabris*	0	5	A	DT	LC
	Amnirana occidentalis	1	2	A	FS	EN

Geographic Distribution (DA): A = distributed also outside West Africa, EG = Endemic to Ghana, WA = only in West Africa, West of the Cross River, UG = endemic to the Upper Guinean forest zone (rainforest West of the Dahomey Gap); Habitat Association (HA): FS = Forest specialist; DT = Degradation-tolerant. IUCN Red list Category: EN = Endangered; VU = Vulnerable; NT = Near-Threatened, LC = Least Concern (Not threatened), NE = Not Evaluated

4.2. Species Richness and Abundance

A total of 98 individuals of 16 anuran species belong to nine families were recorded during the study (Table 4.1). Fifty-seven individuals (58.2%) were recorded in the unmined forest, while forty-one individuals (41.8%) were recorded in the mined forest. The *Arthroleptis spp* were the most dominant species in all forest types' whiles four species (*Arthroleptis krokosua, Leptopelis spiritusnoctis, Phrynobatrachus annulatus,* and *Phrynobatrachus sp.*) recorded the least number of individuals. Five species (*Leptopelis spiritusnoctis, Sclerophrys togoensis, Ptychadena longrirostris, Phrynobatrachus sp.* and *Conraua sp.)* of five families (Bufonidae, Arthroleptidae, Ptychadenidae, Phrynobatrachidae, and Conrauidae) were recorded exclusively in the mined forest. Eight species (Table 4.1) of seven families (Bufonidae, Ranidae, Arthroleptidae, Phrynobatrachidae, Hyperoliidae, Pyxicephalidae and Ptychadenidae) were recorded exclusively in the unmined forest. Three species (*Arthroleptis sp., Amnirana albolabris, and Xenopus tropicalis*) of three families (Arthroleptidae, Ranidae, and Pipidae) were also recorded in both forest types. The family Arthroleptidae had the highest number of individuals recorded, whiles two families (Pyxicephalidae and Phrynobatrachidae) recorded the lowest number of individuals.

4.2.2 Species diversity

There was no significant difference {p <0.05} in species diversity Shannon Wiener diversity index in the mined and unmined forest (Mined: H' = 1.79 and unmined forest: H' = 1.838; z = -0.72516, P = 0.46835; Table 4.4).

Table 4.2 Richness, individuals and Diversity comparison for mined forest and unmined forest

	Mined	Unmined
Species richness	8	11
Individuals	41	57
Shannon Wiener Index	1.79	1.838
Evenness_e^H/S	0.7484	0.5711

4.2.3 Species Turnover (Shared species and lost species)

Three species were found in both habitats. Five species were exclusive to the mined forest plots and as such were lost in unmined forest. Eight species were exclusive to the unmined forest plots and as such were lost in the mined forest plots.

CHAPTER FIVE

5.0 DISCUSSION

This study provides an insight into anurans response to mining activities in the SRFR. A total of 98 individuals of anurans belonging to 16 species of nine families were observed during this investigation (Table 4.1). Anurans recorded in the forest have been previously recorded from the reserve by (Adum, 2014). However, important results of this study was the discovery of two potential new species to science (*Conraua sp.* and *Phrynobatrachus sp.*). Other herpetological investigations in Ghanaian forests have reported new species and first country record (Rödel *et al*., 2005). Several species that according to literature occur in Sui River Forest Reserve were not recorded. Some of these species include *Cardioglossa occidentalis, Phrynobatrachus tokba*, *Phrynobatrachus latifrons* and *Phrynobatrachus alleni* (Adum, 2014).

The conservation status of anurans species recorded ranges from Unknown to Endangered. Out of the 16 species recorded, the conservation status two of them are not evaluated. Ten of them are listed on the IUCN Red List as Least Concern whiles two of the species recorded also fall under the Near Threatened category of the IUCN Red List. These are species are likely to be endangered in the near future. Two of the species recorded (*Amnirana occdentalis* and *Phrynobatrachus annulatus*) are of global concern and are listed as Endangered according to the IUCN Red List. Endangered species are those considered to be at brink of extinction, meaning their remnant population is so small that if care is not taken they could easily become extinct.

The anuran species recorded in SRFR consist of a unique mixture of savannah and forest anurans, ranging from species that require undisturbed primary rainforest such *Arthroleptis krokosua* to those requiring savannah habitats such as *Sclerophrys regularis* and *Hyperolius concolor*. Only five of the recorded anuran species are regarded as forest specialist.

Surprisingly, two forest specialists was recorded in the disturbed (mined area) (Table 4.1) and hence presumably tolerant to lower humidity. In addition, some disturbance tolerant were recorded in the unmined and this clearly indicates that SRFR has suffered from habitat degradation. Furthermore, only one species is endemic to Ghana; 25% endemic to the Upper Guinea Forest Zone, 37.5% of the species found were restricted to West of Africa whiles 25% ranges outside Africa (Table 4.1).

Rödel *et al.,* (2005) investigated the herpetofauna of four forests, designated as Globally Significant Biodiversity Areas in the Western Region, Ghana and recorded a total of 47 amphibian species. Hillers *et al*., (2007) recorded at least 43 frog species on the assessment of amphibians in the forests of southern Ghana. Adum (2014) also investigated the post-logging recovery of amphibian assemblages and habitat preferences of the Endangered Giant Squeaker frog (*Arthroleptis krokosua*) in Ghana's moist semi-deciduous forests recorded 24 anuran species. Conversely the species richness recorded for the forest zone of SRFR is very low when compared to these studies in Ghana that detected species between 24 – 47 species per forest. In contrast to the results of the above mentioned studies (Monney *et al.,* 2011), recorded 12 species of amphibians at the Kakum National Park in Ghana.

This study is in contrast with (Alvarez-Berríos *et al.,* 2016) who observed higher species in mined area than unmined area during a survey on the impacts of small-scale gold mining on birds and anurans near the Tambopata Natural Reserve in Peru. The differences in the two studies may be due to the differences in microclimates in the two ecological zones and the sampling techniques employed in both surveys. The lower numbers in both the richness and abundance of species in the mined area is probably due to the mined-out pits which pose as an ecological trap to the species. With the unmined site, the conditions were not significantly altered but the real treat in the mined site was the direct mortality due to the possible ecological trap of the pits. These pits up to or deeper than 200cm (Appendix 1) collected water all year round, which posed greater danger of trapping and "drowning" leaf-litter frogs such as the *Arthroleptis sp*. Anurans are attracted to these dugout pits which sometimes contain water for breeding. These waters becomes unstainable for them through drying up and they serve as ecological trap reducing reproductive success. The threat these pits pose is direct mortality of anuran species. The absence of disturbance sensitive species in the mined area could be because these species have been wiped out from such places due to the disturbance.

The limitation of the study however is that it was conducted over a short duration. Studies conducted over a long time could reveal subtle differences in the different habitat types. Again, the study did not collect data on forest structure, composition and microclimate which could have helped in teasing apart the proximate factors and presence or absence in the different habitats investigated. Notwithstanding these limitations, though small deep pits impact on amphibians can have catastrophic effects on population dynamics of anurans but has been less investigated.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusions

The conservation status of amphibian species in Sui River Forest Reserve varied greatly according to the IUCN Red List. Least Concern species had the highest percentage of individual species recorded. Two of the species recorded are of global concern. There was also two species as first time record and it is a clear indication that Western of Ghana is relatively diverse in species richness. Anuran species recorded were a mixture of both degradation-tolerant and forest specialist.

From the study, 98 individual species comprising of 16 species were recorded during the survey. The unmined recorded the highest number of species as compare to the mined. The unmined was slightly diverse than the mined but there was no significance difference between the sampling zones. The real threat was direct mortality and reduced reproductive success due to a possible ecological trap pose by the mined-out pits.

6.2 Recommendations

1. Reclamation should be done to restore the degraded part of the reserve to its original state through filling the pits with sand and enrichment planting.
2. Further surveys should be conducted in order to help locate the home ranges of the threatened species in the reserve.
3. Awareness creation should be done in the fringe communities to sensitize them on the need to protect the forest.

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APPENDICES

Appendix 1: Records of Abandoned Mine Pits at Sui River Forest Reserve

Pit ID#	Depth(cm)	Diameter(cm)	Amphibian Number	WL (cm)
1	214	100	0	0
2	262	120	0	0
3	186	121	0	0
4	300	110	0	0
5	270	111	0	0
6	379	133	0	0
7	313	116	0	0
8	420	120	0	0
9	336	126	0	0
10	334	116	0	0
11	248	190	0	0
12	304	162	0	0
13	100	74	0	0
14	127	97	0	0
15	177	109	0	0
16	291	118	0	0
17	104	107	0	0
18	198	155	0	0
19	161	127	0	0
20	174	123	0	0
21	237	107	0	27
22	113	125	0	0
23	179	113	0	0
24	279	109	1	21
25	311	107	0	55
26	173	102	0	0
27	143	117	0	0
28	159	123	0	0
29	178	125	0	0
30	166	117	0	0
31	126	117	0	0
32	152	112	0	0
33	151	96	0	0
34	125	97	0	3.5
35	124	337	0	0
36	73	175	0	0
37	91	434	0	0
38	97	135	0	0

39	125	121	0	0
40	62	113	0	0
41	132	109	0	0
42	238	113	0	0
43	315	164	9	42

Appendix 2: One of the several mine pits recorded in the mined area