

**POST-LOGGING RECOVERY OF AMPHIBIAN ASSEMBLAGES AND
HABITAT PREFERENCES OF THE ENDANGERED GIANT SQUEAKER
FROG (*Arthroleptis krokosua*) IN GHANA'S MOIST SEMI-DECIDUOUS
FORESTS**

KNUST

By

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**A Thesis submitted to the Department of Wildlife and Range Management,
Kwame Nkrumah University of Science and Technology
in partial fulfillment of the requirements for the degree of**

MASTER OF PHILOSOPHY

**Faculty of Renewable Natural Resources,
College of Agriculture and Natural Resources**

JULY, 2014

DEDICATION

I dedicate this thesis to all frog lovers and savers upon and below the face of Mother Earth. Together with you I am saving the frogs and promoting a society that respects and appreciates nature.

KNUST



ABSTRACT

Logging intensity and the area size continue to increase rapidly each year. As a result, there are indications that by the year 2050 nearly all tropical forests will be logged. However, to date there is a lack of quantitative information on the effectiveness of selective-logging practices in ameliorating impacts of logging on faunal communities. To assess post-logging effects on amphibian assemblages, we conducted a large-scale replicated field study in three Ghanaian selectively logged moist semi-deciduous forests at varying times after timber extraction. Specifically, we assessed whether the diversity, abundance, and assemblage composition of amphibians changed over time for forest-dependent species and those tolerant of forest disturbance. We sampled amphibians in Suhuma, Krokosua Hills and Sui River forest reserves in southwestern Ghana (total of 48 study plots, each 2 ha). We also investigated and herein we provide further data on the species' variability and habitat preferences of one of the world's rarest frogs, the Giant West African Squeaker Frog, *Arthroleptis krokosua*. In each forest, we established plots in undisturbed forest, recently logged forest, and forest logged 10 and 20 years previously. Logging intensity was constant across sites with 3 trees/ha removed. A total of 24 species, 8, 267 amphibians were collected including 14 specimens of *A. krokosua*, its highest abundance since discovery. Recently logged forests supported substantially more species than unlogged forests. Simultaneously Simpson's index decreased, with increased dominance of a few species. Over time following logging, increased richness of disturbance-tolerant species decreased until 10 years after logging when their composition was indistinguishable from unlogged forests. Simpson's index increased with time since logging and was indistinguishable from unlogged forest 20 years after logging. Forest specialists decreased after logging and recovered slowly. However, after 20 years amphibian assemblages had returned to a state indistinguishable from that of undisturbed forest in both abundance and composition. These results demonstrate that even with low-intensity logging (≤ 3 trees/ha) a minimum 20-year rotation of logging is required for effective conservation of amphibian assemblages in moist semi-deciduous forests. Furthermore, remnant patches of intact forests retained in the landscape and the presence of permanent brooks may aid in the effective recovery of amphibian assemblages. Further data on the breeding habitats and detailed population estimates of *A. krokosua* are also recommended in order to set up plans for the long-term conservation of the peculiar Ghanaian forest frog.

ACKNOWLEDGEMENT

A story is told of Little Mouse and his friend Elephant who decided to travel by foot to a far-off place in search of greener pastures. They had been walking for days and the more they did the farther it appeared their destination became. Eventually they came but upon a bridge they needed to cross before they would succeed. Little Mouse was totally tired. His good friend Elephant gave him a ride on the back. Every step taken quaked the bridge; at long last they were at the other side. “We shook that bridge, didn’t we?” Little Mouse asked. In crossing over my bridge I had to ride on the backs of the following organisations and personalities:

This project has been funded by Defra’s Darwin Initiative which draws on the wealth of biodiversity expertise within the UK to help protect and enhance biodiversity around the world. It received special assistance from the following people on the ZSL’s Wildlife Wood Project: Chris Ransom, Noelle Kumpel and Nico Dauphiné. In Ghana, research was supported by the Ghana Forestry Commission, Kwame Nkrumah University of Science and Technology, University of Ghana (especially Lars Holbeck and Nathaniel Annorbah), John Bitar and Co. Ltd., and Logs and Lumber Ltd. Additional funding for field work was provided respectively by Trobenbos Ghana and, BirdLife International in collaboration with Ghana Wildlife Society. I also thank the Cambridge Student Conference on Conservation Science, UK and Museum für Naturkunde, Germany for grants to prepare the thesis at the Universities of Nottingham, England and Humboldt, Berlin respectively.

My supervisor and foster-father, Professor William Oduro has supported my academic development since my undergraduate years. He coordinated the grant for this research. I thank him. I also thank Professor S. K. Oppong and Dr. Emmanuel Danquah, Senior Lecturers of the Department, for all their encouragement throughout my study. Dr Markus Eichhorn and PD Dr. Mark-Oliver Rödel have also served as both my advisors and promoters. To say the least, I am greatly indebted to them for my getting this far. I also thank Dr. Caleb Ofori-Boateng who first introduced me to the study of frogs. I would like to thank Johannes Penner for helping with the map for the study sites and, TBA-DRECA (especially Dr Rosie T.) for providing useful comments. I also appreciate the many scientists around the world who also provided useful comments at conferences, to mention here but a few: ATBC-SCB, Ausha Meeting, Tanzania; BES, Newcastle University, UK and SCCS, Cambridge University, UK.

My family deserves a big thank-you. I commend my kind and hardworking wife Cecilia Kaloo Songjei and our genius children, Ceberta Asewe and Markus Jnr, Akwo, for their prayers and support throughout this journey.

AND TO GOD BE THE GLORY.

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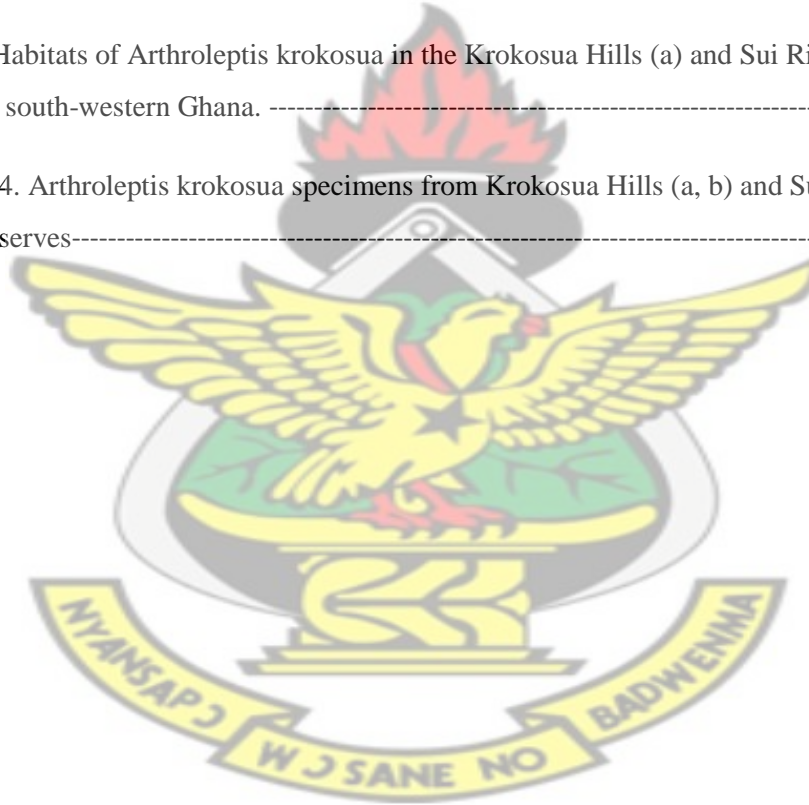
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CHAPTER ONE
INTRODUCTION

1.1. Background of the Study

Amphibian populations have been rapidly declining in Ghana (Hillers *et al.*, 2009), the rest of Africa and worldwide (Stuart *et al.*, 2004, 2008). For the last two decades, scenarios of these declines have been prevalently reported in the scientific literature and dominated round-table discussions at scientific conferences (Adum, 2011). Since the 1970's, at least 200 species have gone extinct and nearly half of the extant $\approx 7,000$ species are threatened with extinction. Amphibians are, thus, the most threatened vertebrate taxonomic group (Fig. 1.1), and their declines have indicated the Sixth Mass Extinction (Wake and Vredenburg, 2008).

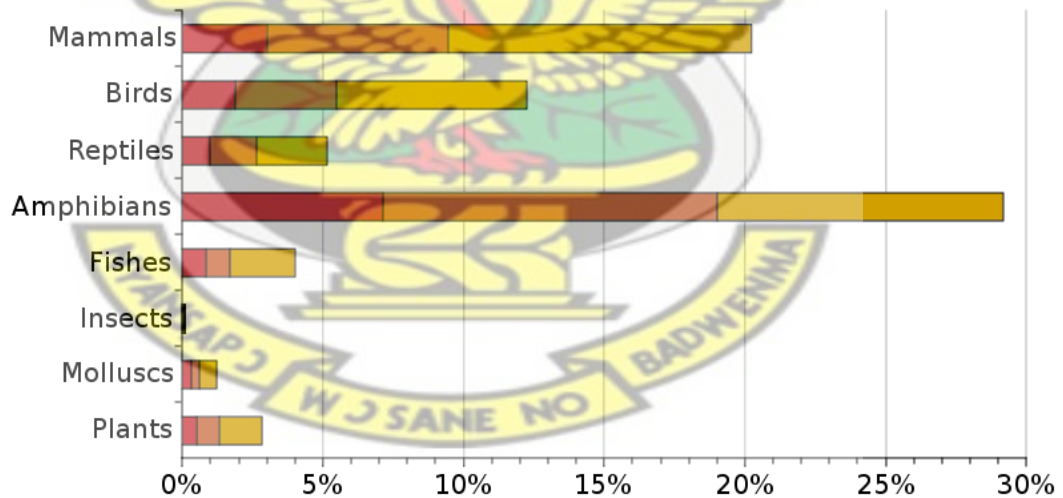


Fig.1.1. The percentage of amphibian species and other taxonomic groups which are listed as ■ critically endangered, ■ endangered, or ■ vulnerable on the 2007 IUCN Red List (IUCN_Red_List_2007.png).

Although factors responsible for the declines are complex as are often synergistic and interactive in nature, individual culprits include (1) habitat destruction and fragmentation (Cushman, 2006; Gallant *et al.*, 2007); (2) overexploitation for human consumption (Warkentin *et al.*, 2009; Mohnke *et al.*, 2010); (3) emerging wildlife diseases, especially chytridiomycosis, an infectious disease caused by the fungus *Batrachochytrium dendrobatidis* (Daszak *et al.*, 1999, 2000, 2003); (4) pollution (Carey and Bryant, 1995); (5) climate change (Carey and Alexander, 2003; Corn, 2005); (6) pesticides (Marco *et al.*, 1999); and (7) invasive species (Kats and Ferrer, 2003). Of all these factors, in tropical countries such as Ghana, habitat destruction particularly through logging is the main driver of forest degradation (Ernst *et al.*, 2006). Hence, studies on the impacts of logging on wildlife fauna and the ability of the fauna to recover following such logging disturbance are warranted.

Amphibians are sensitive to perturbations in both terrestrial and aquatic environments because of their dual life histories, highly specialized physiological adaptations, and specific microhabitat requirements (Wells, 2007). In addition, they are locally abundant in tropical forest ecosystems (Myers *et al.*, 2000) where they interact with a large range of other species in the local environment during their lifetime (Gardner, 2001; Gardner *et al.*, 2007). For instance, anurans play dual roles as both herbivores during larval stages and carnivores as adults, making them potentially suitable to monitor changes in both floristic and faunal community composition (Gardner, 2001; Gardner *et al.*, 2007). For these reasons amphibians are considered excellent bio-indicators and are widely used in biodiversity assessments and monitoring programmes.

In response to the urgent need of methods that are both reliable and cost-effective in improving wildlife management in commercially-logged forests in Ghana, the Zoological Society of London under its Wildlife Wood Project (WWP) in collaboration with the Kwame Nkrumah University of Science and Technology (KNUST) and other partners, conducted research to assess wildlife fauna as indicators of logging activities. This study formed part of that interdisciplinary project, which was funded by DEFRA's Darwin Initiative. From 2007 to 2009, and in collaboration with other partners Samartex Timber and Plywood Co. Ltd., John Bitar and Co. Ltd. (JCM), Logs and Lumber Ltd. (LLL), and University of Ghana, the WWP carried out surveys of mammals, birds and amphibians in selected commercially-logged forests in southwestern Ghana. On behalf of KNUST, my research focused on amphibians at LLL and JCM concessions within the study area.

The amphibians of the Upper Guinean Forest especially are taxonomically well known and comparatively easily accessible with a set of standardized methods (Raxworthy and Attuquayefio, 2000; Rödel and Ernst, 2004). Since the early 2000s, there has also been strong capacity built of both locals and foreigners in using the amphibian fauna as effective bio-indicator system (Raxworthy and Attuquayefio, 2000; Rödel and Agyei, 2002, 2003; Ernst and Rödel, 2004). Thus, it was expected of this study to provide a scientific foundation and contribute to coordinated efforts that would improve wildlife management in commercially-logged forests in Ghana. These results would contribute to providing a basis for understanding the current conservation status of wildlife, especially endemic and threatened taxa such as the Giant West African Squeaker Frog, *Arthroleptis krokosua*, known to be restricted exclusively to commercially-logged forests. Ultimately,

these results can be integrated into ongoing forest certification schemes as cost-effective and reliable means of monitoring and managing wildlife in Ghana's commercially-logged forests.

1.2. The Problem Statement and Justification of the Study

Compared to other vertebrate groups, amphibians have received relatively little attention on how they respond to logging in the West African eco-region. There has been considerable amount of work done on especially primates and other mammals (Oates, 1999; Oates *et al.*, 2000; Kormos *et al.*, 2003; McGraw, 2005; Buzzard and Parker, 2012; Ofori *et al.*, 2012), and birds (Waltert *et al.*, 2000; Beier *et al.*, 2002; Holbech, 2005; Weckstein *et al.*, 2009). These studies shed deeper insights into how the studied taxa respond to logging. But albeit few exceptions (Ernst *et al.* 2006; Hillers *et al.*, 2008; Ofori-Boateng *et al.*, 2012), which represent less than 1% of over 80 publications on the amphibian fauna, basic surveys and other descriptive studies are the most prevalent in the scientific literature (Hillers *et al.*, 2009). However, amphibians in the eco-region include proportionately more endemics than other vertebrate taxa (77% amphibians endemic compared to 33% of reptiles, 8% of mammals, and 18% of birds (Myers *et al.*, 2000). Amphibians are also the most threatened taxa locally; one out of three species is currently endangered (Hillers *et al.*, 2009). Therefore, there is both the need and urgency for more synecological studies to fully understand how species respond to logging to ensure their effective conservation in the long-term.

In terms of the recovery abilities of amphibian assemblages following logging, although there are a handful of such topical studies, these have been constrained by both methodological and statistical approaches. Studies mainly focused on changes in species diversity, and failed to account for times required for species assemblages to recover following logging (Ernst and Rödel, 2005; Ernst and Rödel, 2008). Commercially-logged forests in Ghana, like most tropical forests are selectively logged based on poly-cyclical logging regimes. Currently, the silvicultural system is a cutting cycle of 40 years, after having experienced four different felling-year cycles in less than half a century (Adam *et al.*, 2006). However, clearly most of these poly-cyclical logging regimes have been established without having adequate knowledge of the potential of species communities' resilience, even for commercially valuable timber species such as mahogany (Sodhi and Ehrlich, 2010). But such information especially about amphibian faunal recovery can be crucial for design and redesign of logging practices that are compatible with species dynamics (Sodhi and Ehrlich, 2010).

For instance, some amphibian species such as the Giant West African Squeaker Frog, *Arthroleptis krokosua* (Ernst *et al.*, 2008) are currently known to be restricted exclusively to logged forests. This species persists in only logged forests in south-western Ghana, i.e. amphibian assessments in other Ghanaian and eastern Ivorian forests failed to detect the species (Hillers *et al.*, 2009). Such species are most particularly vulnerable to extinction caused by habitat loss (Wright and Muller-Landau, 2006a; Sodhi and Ehrlich, 2010) and insight into their habitat preferences and recovery following logging disturbance is, thus, critical to ensuring their long-term persistence.

In addition, while patterns of amphibian assemblage composition have been analyzed, usually ecologically distinct groups were combined as a single entity, which treats all taxonomic species as equivalent. This practice can lead to obscured cause-and-effect relations because, for example, different amphibian groups have different responses to anthropogenic disturbance (Ernst and Rödel, 2005, 2006, 2008), which can lead to spurious results when combined in multi-community analyses (Jost *et al.*, 2011). In such studies, it is, therefore, important to treat particular amphibian groups separately to accurately detect trends in diversity metrics (Ernst and Rödel, 2008).

1.3. Objectives of the Study

The overarching goal of this research is to assess the ability of amphibian assemblages to recover in logged forests and to evaluate the efficacy of reduced-impact logging in maintaining such assemblages. Achieving this goal will provide the basis for understanding the scale of logging impacts on wildlife and the implications for sustainable forest management. More specifically, the study will:

1. Determine the effects of selective-logging on amphibian species abundance and diversity patterns.
2. Determine the times required for different amphibian assemblage compositions, forest-dependent versus non-forest dependent amphibian species to recover following selective-logging.
3. Assess the abundance and habitat preferences of the Giant West African Squeaker Frog, *Arthroleptis krokosua*.

1.4. Research Questions

1. Are there changes in amphibian species abundance and diversity patterns following selective-logging?
2. Are there differences in the times required for forest-dependent versus non-forest dependent amphibian assemblage compositions to recover following selective-logging?
3. What habitat types and vegetation characteristics favour the presence of the Giant West African Squeaker Frog, *Arthroleptis krokosua*?

1.5. Hypotheses

1. There are significant changes in amphibian species abundance and diversity patterns following selective-logging.
2. There are significant differences in the times required for forest-dependent versus non-forest dependent amphibian assemblage compositions to recover following selective-logging.
3. The Giant West African Squeaker Frog, *Arthroleptis krokosua* is restricted-range species.

1.6. Scope and Limitations of the Study

The field work of this study was carried out in 2009 within the tropical forest region of southwestern Ghana. We focused on the Suhuma, Krokosua Hills and Sui River Forest Reserves, where we sampled amphibians in a total area of 96 ha in all three forest reserves. We chose to study amphibians because they are sensitive to alterations of forest structure (Ernst and Rödel, 2005; Ernst *et al.*, 2006; Ofori-Boateng *et al.*, 2012). We simultaneously considered three different selectively-logged forests with a number of stands of known time since timber extraction, replicated both within and among concessions.

It is understandable that animals typically do not respond directly to human activity such as logging but to the changes in their environment caused by that activity. Unfortunately, we could not collect data on forest structure, composition and microclimate to accompany the amphibian sampling. However, we made some field notes, and have added a general description of these observations to the Methods. We have also provided citations of other papers that provide evidence that logging changes forest structure and micro-climate (Ernst and Rödel, 2005; Hillers *et al.*, 2008a) and how the three forests compare (Hall and Swaine, 1981; Hawthorne and Abu-Juam, 1995; Ernst *et al.*, 2008; Annorbah, 2011). Also, given the large changes expected in species composition, we could not predict potential effects of logging on overall amphibian abundance.

CHAPTER TWO

LITERATURE REVIEW

2.1. Tropical Logging and Biodiversity Conservation

It is estimated that of the remaining 9 million km² of primary forest worldwide 50,000–70,000 km² are logged annually, and the tropics alone contribute up to three-thirds. Timber harvest, both in logging intensity and the area size continue to increase rapidly each year. For instance, in Ghana, timber harvest increased from 270, 000 m³ in 1994 to 1, 200,000 m³ in 2003 (Bird *et al.*, 2006). As a result, there are indications that by the year 2050 nearly all tropical forests will be logged (Sodhi and Ehrlich, 2010). Already, even by the most conservative estimates, West Africa currently retains only about 1.5% of primary forest cover, and most of these surviving forests have also experienced some degree of logging (Norris *et al.*, 2010). Most of these West African forests and in other tropical countries such as those of Southern Asia (Edwards *et al.*, 2009, 2010, 2012; Berry *et al.*, 2010) are only now being repeatedly re-logged.

Tropical logged forests apart from being rich in high-value timber species for which reason they are over-exploited, are also biodiversity hotspots. Beier *et al.* (2002), and Holbech (2005) respectively reported serious declines of birds and in many cases absence of forest obligates in tropical logged forests. The most comprehensive available data on the status of West African primates (Kormos *et al.*, 2003) also implicated logging as a key cause of local or global extinctions of some species, for example, extinction of the Miss Waldron's red colobus monkey (*Procolobusbadius waldroni*) (Oates *et al.*, 2000).

Nonetheless, at the same time, in their review, Norris *et al.* (2010) assert that logged forests support a greater proportion of forest obligate species than any other modified land-use. Numerous studies have also revealed that generally species richness and composition of animal communities in logged forests are consistently comparable to unlogged forests (Edwards *et al.*, 2009, 2010, 2012; Gibson *et al.*, 2011; Putz *et al.*, 2012). Not surprisingly, even repeatedly logged forests retain much of their biodiversity (Edwards *et al.*, 2010). Therefore, it is not surprising that the new ecological paradigm shift [(proposed by Vandermeer and Perfecto (1997) and Gascon *et al.* (1999) respectively)] that re-directs conservation focus on these new forests is gaining much popularity.

2.2. Upper Guinean Forest: Amphibian Diversity and Threats

One of Africa's two major tropical lowland forest regions, the Upper Guinea Forest stretches from Ghana into Sierra Leone, and is among the 34 biodiversity hotspots in the world (Mittermeier *et al.*, 2004). The forests of southwestern Ghana (Rödel *et al.*, 2005a; Ernst *et al.*, 2008); southwestern Côte d'Ivoire and Mts. Nimba (Rödel *et al.*, 2004b; Hillers, 2008) particularly harbour exceptional levels of amphibian endemism and diversity (Fig. 2.1).

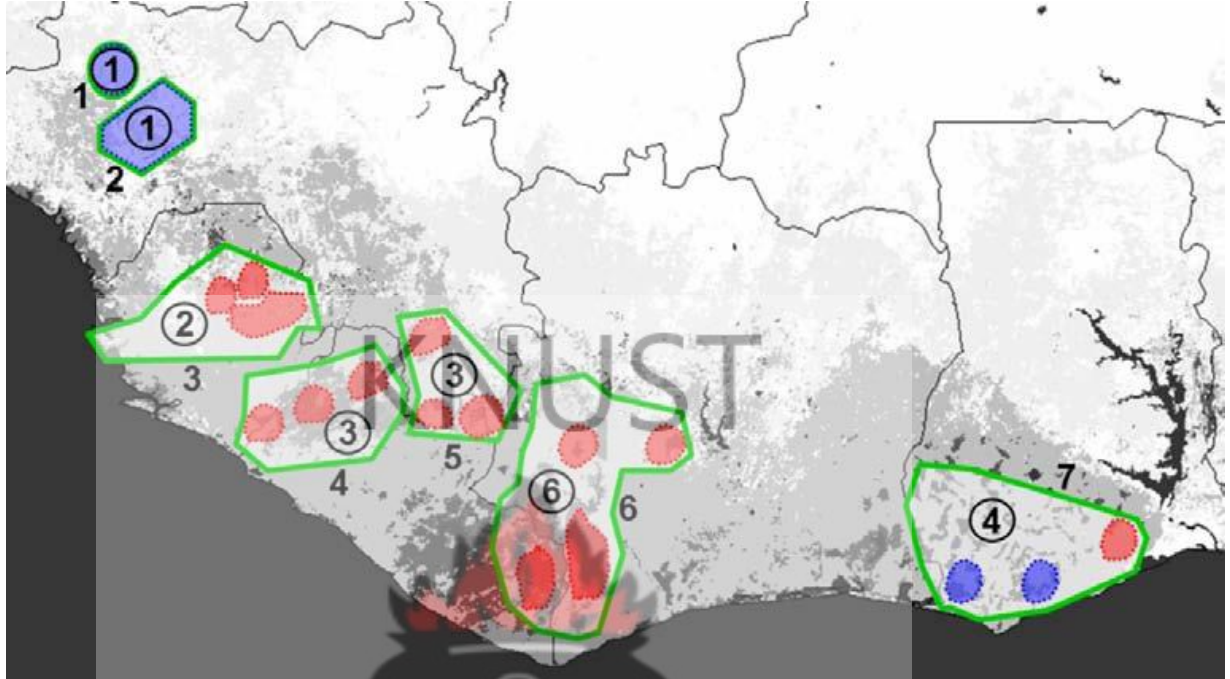


Fig. 2.1. Macro- and microrefugia in the Upper Guinean Forest zone in western Africa as revealed by the phylogeography of six *Phrynobatrachus* species.

Green areas = macrorefugia 1-7 (their numbers next to them); blue areas = Miocene (micro) refugia; red areas = Pleistocene microrefugia; numbers in circles = number of supporting species. (Source: Hillers, 2008).

In the eco-region, since the year 2000, nearly every amphibian survey has resulted in one discovery or another. Over 15 species new to science have been described (Rödel, 2000, 2007; Rödel *et al.*, 2002, 2003, 2004b, 2005b, 2009; Ernst *et al.*, 2008; Blackburn *et al.*, 2008, 2010; Hillers *et al.*, 2008b); there have been more than 10 first country records and new taxa (Rödel and Agyei, 2002, 2003; Rödel *et al.*, 2005b, 2009; Leache *et al.*, 2006;

Hillers *et al.*, 2008b; Hillers *et al.*, 2009; Ofori-Boateng unpubl. data) and many more species still await description (Boateng-Ofori unpubl. data; Rödel unpubl. data) or even discovery (Rödel *et al.*, 2008). But at the same time the amphibian fauna are threatened from high-level threats emanating from logging, forest fragmentation, forest conversion into plantations, and mining activities (Bakarr *et al.*, 2001; Poorter *et al.*, 2004; Ernst and Rödel, 2005; Ernst *et al.*, 2006; McCullough *et al.*, 2007; Hillers *et al.*, 2008a). In the past decade, deforestation rates proceeded at between 1.3% and 1.5% annually (Benhin and Barbier, 2004), labeling the region one of the worst in the world (ITTO, 2005). Nowadays, only $\approx 75\%$ of the eco-region's remaining forests are available for logging, and unfortunately these are poorly managed (Bakarr *et al.*, 2001; Poorter *et al.*, 2004; ITTO, 2006). Hence, it is not inapt to suggest that logging constitutes one of the most important potential threats to the eco-region's amphibians.

2.2.1. Effects of Logging on Amphibian Assemblages

Although data on the impacts of logging on West African amphibian fauna are under-represented, the few studies including incidental records may provide insights into the effects of logging on some amphibian community parameters.

Logging altered the composition of forest amphibian assemblages (Rödel *et al.*, 2005a; Rödel *et al.*, 2008; Ofori-Boateng *et al.*, 2012), including shifts in species composition whereby non-forest specialists dominated over forest specialists after logging (Hillers *et al.*, 2008a). In addition, functional diversity of forest species assemblages was found to be greatly reduced by logging activities through the loss of specific life history traits

(Ernst *et al.*, 2006). Furthermore, in logged areas Rödel and Agyei (2002) and Hillers *et al.* (2009) recorded 50% and 56.3% invasive species compared to 12.5% and 32% of forest specialists respectively. Rödel *et al.* (2005a) claim logging led to the establishment of these invasive (non-native) species within the forests reserves. These studies appear to follow global trends on the impacts of logging indicating that species that require the typical conditions of undisturbed forests decline after logging while the generalist frogs increase in abundance and species richness (Meijaard *et al.*, 2005).

However, since long-term studies are lacking in the region there have been controversies about some aspects of amphibian biodiversity loss following logging. For instance, Rödel and Ernst (2005) suspect that habitat degradation (mostly due to logging activities) might have caused the disappearance or even local extinction of some endangered and endemic species (e.g. *Hyperolius bobiriensis*, *H. torrentis* *Arthroleptis brevipes*, *Conraua derooi* and *Werneria africana*). But all these species were recorded in a later study (Hillers *et al.*, 2009), except *Werneria africana* and *Arthroleptis brevipes* (but see Segniagbeto *et al.*, 2007).

2.3. Recovery of Amphibian Assemblages Following Selective-Logging of Tropical Forests

Across tropical regions in general, to date there are relatively fewer studies that have examined recovery of amphibian assemblages; and majority of the very few studies have been biased toward other forms of secondary forests such as abandoned pastures (Herrera-Montes and Brokaw, 2010); cacao agroforests (Wanger *et al.*, 2009) and other human-modified land-uses (Furlani *et al.*, 2009) or a comparison of these with primary

forests (Vallan, 2002; Wanger *et al.*, 2010). These secondary forests are regrowing following complete clearance, while selectively-logged forests have had only a few trees of commercial interest removed. Thus, there are important differences between these two types of secondary forests during the regeneration phase which may affect the rate of faunal recovery (Bihn *et al.*, 2008).

But at least three studies have been specific about the time required for diversity or assemblages to recover to their former state following selective-logging. Fredericksen and Fredericksen (2004) and Vallan *et al.* (2004) concluded there was either no change or that communities recovered within 1-4 years following selective logging. In contrast, Ernst *et al.* (2006) found that recovery of amphibian communities in humid evergreen forests in Guyana, South America, and Ivory Coast, West Africa, did not occur even 30 years after selective logging ceased.

2.4. Notes on the Giant West African Squeaker Frog, *Arthroleptis krokosua*

Arthroleptis krokosua Ernst, Agyei and Rödel, 2008 is a morphologically distinct squeaker species. It has no apparent affiliations to any other West African member of the genus (Ernst *et al.*, 2008), but instead is most closely related to some Central African *Arthroleptis* (Blackburn *et al.*, 2010). It differs from all known West African *Arthroleptis* by its large size (> 40 mm snout-vent-length), colouration and other morphological characters, such as a very broad head (Fig. 2.3). Until now the species is only known from the type locality, the Krokosua Hills FR and only from the holotype (Ernst *et al.*, 2008). Other large *Arthroleptis* (larger than 35 mm SVL) are known from Central and

East Africa (Blackburn *et al.*, 2009). As *A. krokosua* might be locally endemic (to only logged forests), the long-term persistence of this species and the many other amphibians located in logged areas is dependent on the effects of logging activities.

2.5. Theoretical Framework: Ecological Disturbance Theory

Following the Ecological Disturbance Theory (EDT), otherwise called Intermediate Disturbance Theory (Lubchenco, 1978), species richness typically increases following disturbance as disturbance-tolerant species colonize the area. Species richness levels are however largely determined by the numbers of uncommon species and can disguise changes in the evenness of communities (Connell, 1978). This theory has important implications for amphibian assemblages following logging disturbance.

In general, logged forests comprise a partly open canopy and contain roads and trails used to transport logs. Because roads may act as conduits for disturbance-tolerant species, non-forest species turn to invade and establish in opened forest habitats (Meijaard *et al.*, 2005; Hillers *et al.*, 2008; Furlani *et al.*, 2009). Conversely, because recovering forests tend to resemble mature forests over time, the microclimatic conditions that once favoured disturbance-tolerant species diminish and make these species unable to cope with the change (Vallan, 2002), whereas forest-dependent species may recover.

CHAPTER THREE

STUDY AREA AND GENERAL METHODS

3.1. Study Sites

We focused my research work on three commercially-logged forest reserves in the tropical forest region of southwestern Ghana: Suhuma Forest Reserve (SFR), Krokosua Hills Forest Reserve (KHFR), and Sui River Forest Reserve (SRFR) (Fig. 3.1). All three reserves are of moist semi-deciduous forest type and have an undulating topography with steep slopes (Hawthorne and Abu-Juam, 1995). Annual rainfall is 1200–1800 mm (Hall and Swaine, 1981). There are two rainfall peaks, one between May and June and the other between September and October, and the dry season is from November to March. There are permanent brooks or streams that transverse across all the three forest reserves.

3.1.1. SFR: The SFR covers an area of 359 km² (Hawthorne and Abu-Juam, 1995). Large areas of the reserve have been logged (Hawthorne and Abu-Juam, 1995), and most parts are still under active logging. The canopy is discontinuous, usually reaching average heights of 43 m and 50-60 m. There are many areas with undulating topography with about 35% of slopes being steeper than 15% (Hawthorne and Abu-Juam, 1995). Vegetation on most of these slopes is less damaged as a result of being inaccessible to logging operations. The SFR had less degraded areas and disturbance as compared to KHFR and SRFR.

3.1.2. KHFR: The KHFR covers an area of 481.7 km. Trees in this type of forest become taller than those of other Ghanaian forest types; heights often exceeding 50-60 m. Upper canopy consists of deciduous species in varying proportions. Large areas of the reserve have been logged and are still being logged. Of all three reserves KHFR (and SRFR) had the highest levels of disturbance to vegetation. Such disturbed or degraded areas were characterized by highly compacted soil and secondary growth, often dominated by the invasive Siam weed (*Chromolaena odorata*) (Ernst *et al.*, 2008). The reserve consists of two forest blocks, the northern and southern ranges, separated by the Asempaneye-Kumasi road. The northern range which has relatively small human population and more distinctive topography is much more intact than the southern range (Magnuson, 2002). During the present study only the southern range of KHFR could be surveyed.

3.1.3. SRFR: The SRFR covers an area of 333.9 km², consisting of a long narrow band that follows the Bia-Tano watershed, south of Buaku. Most parts of the reserve are under active logging. Steep slopes with flat hill summits, usually underlain by bauxite, constitute the bulk of the reserve. Like KHFR, it recorded the highest levels of disturbance to vegetation. Such disturbed or degraded areas were also characterized highly by compacted soil and secondary growth, often dominated by *C. odorata*.

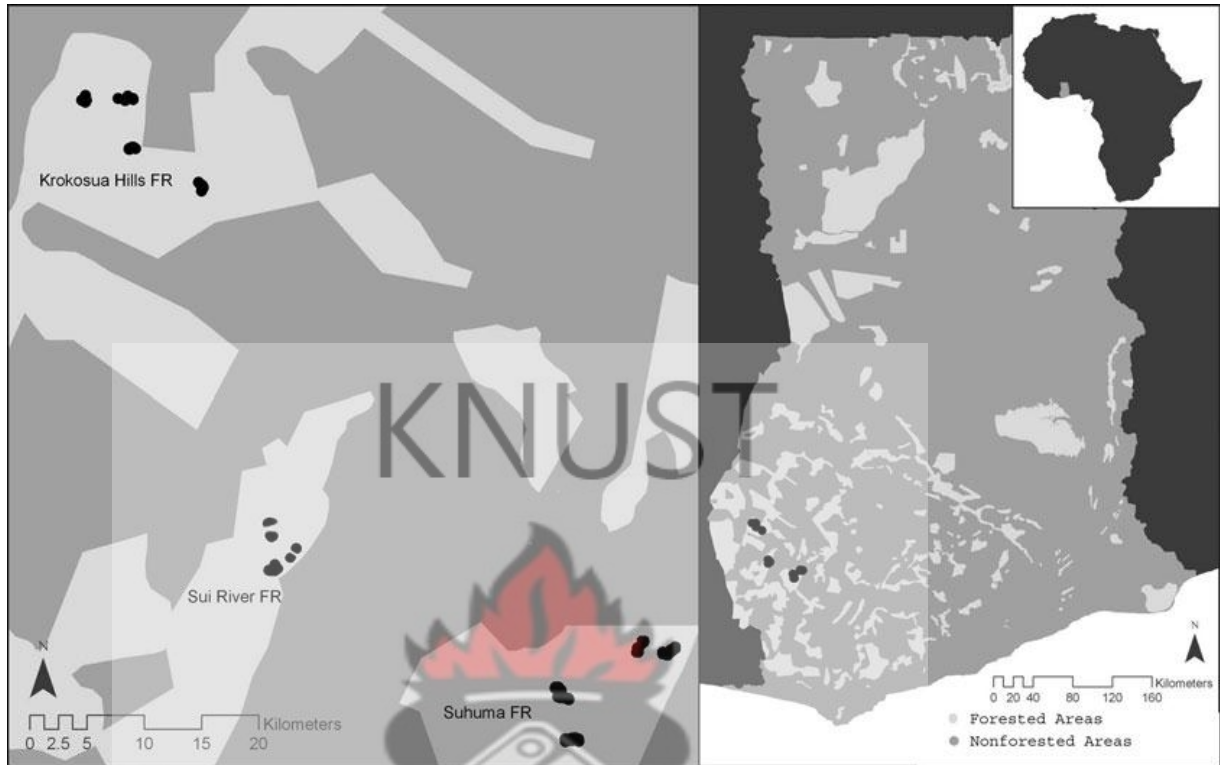


Fig. 3.1. Locations of study sites within Ghana (right map) and forest reserves (FR), Krokosua Hills, Sui River, and Suhuma.

The exact locations of amphibian sampling sites (dots) in these forests (left map).

3.2. Logging History

We obtained data on logging histories from the Ghana Forestry Commission. All three forests were subjected to similar felling strategies of selective logging, including recent slight modifications to reduced-impact logging. Logging intensity was constant across all sites with three trees/ha removed. A 40-year felling cycle has also been in force, at least within the 20 years preceding this study.

Logging concessions were subdivided into compartments within the confines of which selective-logging activities were carried out. Different compartments within a concession were logged in different years. The size of a standard compartment was 128 ha. We established sampling plots in 12 compartments on the basis of their logging histories. There were four compartments in each concession: recently logged (<2 years), with logging ongoing in neighboring areas; logged 10 (L10) or 20 years (L20) before the study; and unlogged (i.e., never commercially logged). Unlogged areas had all been allocated for future logging. We established four 2-ha plots randomly within each logging-history category and had 48 plots in the three forests. Thus, the study area in each forest was 32 ha (96 ha total). To minimize spatial autocorrelation, all plots were separated by at least 1.8 km (Ernst and Rödel, 2005; Hillers *et al.*, 2008a).

3.3. Sampling Methods

3.3.1. Amphibian Data

We surveyed amphibians during daylight from February through December 2009 in wet and dry seasons. Three people (myself GBA and two field assistants) visited each plot five times with a constant sampling intensity of three hours per visit for a total of 720 h of sampling. The average time between visits to plots was two months. We searched for amphibians by visually scanning the vegetation and ground and by lifting objects such as rocks, logs, and debris while listening for calls (Rödel and Ernst, 2004). Frogs that were seen were captured and sexed and their body lengths were measured.

To allow for evaluation of correct species determination in the field, we collected two individuals of each species, euthanized them in chlorobutanol solution, and preserved them in 75% ethanol. We deposited vouchers in the Wildlife Museum of the Kwame Nkrumah University of Science and Technology, Ghana, and in the Museum für Naturkunde, Berlin, Germany.

3.3.2 Species Classifications

We assigned each species to one of two broad habitat groups on the basis of Rödel and Ernst (2004), Ernst *et al.* (2006), Hillers *et al.* (2008a), Penner *et al.* (2011), Ofori-Boateng *et al.* (2012), and references cited in these publications. Forest specialists were species dependent on relatively undisturbed forest habitats. Non-forest specialists (henceforth disturbance tolerant) were defined as species that predominantly occur in savanna-like habitats but also colonize disturbed (opened) forest and farmbush (i.e., shrubby secondary growth).

3.4. Statistical Analyses

We calculated species' detectability to assess whether systematic variation in our ability to find particular species may have biased our results. For each species across all five visits to any single plot, we used a maximum-likelihood estimator (for details see Wintle *et al.*, 2004).

Three measures of diversity were calculated following the recommendations of Tuomisto (2010) and Hill (1973). We estimated species richness with the bias-corrected version of

the Chao1 estimator (Chao, 2005) and the exponential of Shannon's entropy (H) with the Horvitz–Thompson estimator and sample-coverage method (Chao and Shen, 2003). We calculated the inverse of Simpson's diversity (D) with a maximum-likelihood estimator (Magurran, 1988). Following Hill (1973), we interpreted $\exp(H)$ as equivalent to the number of common species and $1/D$ as the number of highly abundant species. We considered species richness to reflect the number of rare or uncommon species. These three estimates scale linearly and allow for direct statistical comparisons between assemblages (Hill, 1973). Because they reflect number equivalents, we regarded them as “true” diversity (Jost, 2006, 2007). Diversity statistics were calculated in SPADE (Chao and Shen, 2010). Statistics by site are presented in tables, whereas statistics per plot were used in comparative analyses.

We compared assemblage structures among logging regimes with nonmetric multidimensional scaling (NMDS) via the Bray–Curtis similarity index in CAP (Henderson and Seaby, 2007). All assemblage analyses were run for the whole community as well as separately for disturbance-tolerant and forest specialists, respectively. All other analyses were conducted in R 2.15.0 (R Development Core Team, 2012). We used multivariate analysis of variance (MANOVA) to test for variation in species composition between sites, with time since logging as a nested effect within sites. We used a posteriori contrasts to identify significant differences among logging histories or concessions. Statistical results are presented on the basis of minimum adequate models with grouping of factor levels where appropriate.

3.4.1 An Analysis of Similarity of Amphibian Assemblages

For comparative purposes, we conducted an analysis of similarities (ANOSIM) as a complement to the NMDS. This grouped samples according to the *a priori* hypothesis that they would differ among logging histories. ANOSIM calculates a test statistic R which scales from -1 to 1. An R of 1 signifies that the most similar samples are grouped together, whereas an R of 0 indicates that similarities among samples are completely mixed and unrelated to the grouping factor. Significance was assessed by comparison of the observed value of R against 1000 values generated via random permutations of the group assignment. Note that since it is not possible within an ANOSIM design to test for a nested effect of logging history within locations, there is expected to be a higher rate of Type 1 errors than the NMDS analysis.

3.5. Notes on the Giant West African Squeaker Frog, *Arthroleptis krokosua*

We assessed morphological characters of new specimens of *A. krokosua* by following Ernst *et al.* (2008). Characters taken in the field included snout-vent length (SVL in mm); structure of dorsal skin; snout shape in dorsal and lateral view, nares visible from above or not and dorsal and ventral colour pattern. We also identified the habitat types that harboured *A. krokosua* and characterised the habitats, focusing specifically on vegetation structure.

CHAPTER FOUR

RESULTS

4.1. General Amphibian Assemblage Data

We recorded 8,267 individuals of 24 anuran species (Tables 4.1, 4.2; Appendix A). Eleven were forest-dependent species, and 13 were disturbance-tolerant species. Three forest species: the Giant West African Squeaker Frog (*Arthroleptis krokosua*), Western long-fingered frog (*Cardioglossa occidentalis*), and snouted ridged frog (*Ptychadena longirostris*), were recorded only in logged areas. Other forest species recognized as threatened by IUCN, including Villier's puddle frog (*Phrynobatrachus villiersi*; vulnerable) and Ivory Coast frog (*Hylarana occidentalis*; endangered) were found in nearly equal numbers in both logged and unlogged forests (Appendix A).

In contrast, we recorded species that naturally occur in savanna, such as flat-backed toad (*Amietophrynus maculatus*), African toad (*Amietophrynus regularis*), African tiger frog (*Hoplobatrachus occipitalis*), and Accra puddle frog (*Phrynobatrachus latifrons*) only in logged forests. Detectability across species was on average 28%. Although there was significant variability among species in their detectability ($F_{23,127} = 15.4, p < 0.001$), there was no overall difference among sites ($F_{2,127} = 1.1, p = 0.336$) or logging histories nested within sites ($F_{9,127} = 1.1, p = 0.382$). No significant interactions among these main effects occurred, indicating that individual species were equally likely to be recorded in all sampling locations. Thus, we concluded our data on amphibian assemblages were unlikely to be systematically biased. Sampling was nearly complete for all sites as shown

by the close correspondence between observed and estimated species richness (Table 4.1).

Table 4.1. Characteristics of amphibian communities in unlogged or recently logged forests and 10 or 20 years post-logging in three concessions.

Time since logging^a	Location	<i>n</i>	<i>S</i>_{obs}	\hat{S} (CI)^b	<i>exp(H)</i> (CI)	<i>I/D</i> (CI)
Unlogged	Suhuma	7	10	11.0(10.1-24.0)	5.67 (2.95 - 8.39)	4.82(4. - 5.38)
Unlogged	Krokosua	692	11	11.0	5.92 (3.61 - 8.22)	4.69(4.19-5.19)
Unlogged	Sui	671	11	11.0	6.20 (3.82 - 8.57)	4.90(4.42- 5.38)
Recently logged	Suhuma	728	15	15.0	4.23 (3.88 - 4.79)	2.30(1.70- 2.91)
Recently logged	Krokosua	832	15	15.0	5.29 (4.80 - 5.78)	2.89(2.42- 3.35)
Recently logged	Sui	758	19	19.0	5.04 (2.82 - 7.27)	2.50(1.96- 3.04)
10 years	Suhuma	556	12	12.0	4.91 (4.42 - 5.39)	3.02(2.54- 3.50)
10 years	Krokosua	469	16	16.0	3.98 (3.48 - 4.48)	2.27(1.53- 3.00)
10 years	Sui	602	13	13.0	5.48 (4.97 - 5.99)	3.41(2.94- 3.88)
20 years	Suhuma	938	12	12.5(12.0-20.3)	6.14 (3.24 - 9.04)	5.31(4.74- 5.88)
20 years	Sui	8	14	14.0	6.49 (3.75 - 9.22)	5.16(4.63- 5.68)

^aKey: *n*, abundance, and *S*_{obs}, observed species richness, are for overall collections at each site; \hat{S} , estimated species richness; *exp(H)*, exponential of Shannon's entropy *H*;

1/D, inverse of Simpson's diversity index; CI, confidence interval. ^bConfidence intervals are intractable when $S_{obs} = \hat{S}$.

Overall, 8 (33%) species were either near-threatened or threatened according to their IUCN listing (Table 4.2). The list of threatened species excludes one potential threatened frog that has currently not been evaluated by the IUCN. Both the Suhuma and Sui River FRs recorded the highest number of threatened species of 8 (33%) while Krokosua Hills had the lowest number of 6 species (25%). In terms of the level of endemism, 11 (46%) species were endemic to UGF (forests west of the Dahomey Gap) and 6 (25%) were strictly restricted to West Africa, west of the Cross River. Only 7 (29%) species ranged outside West Africa.

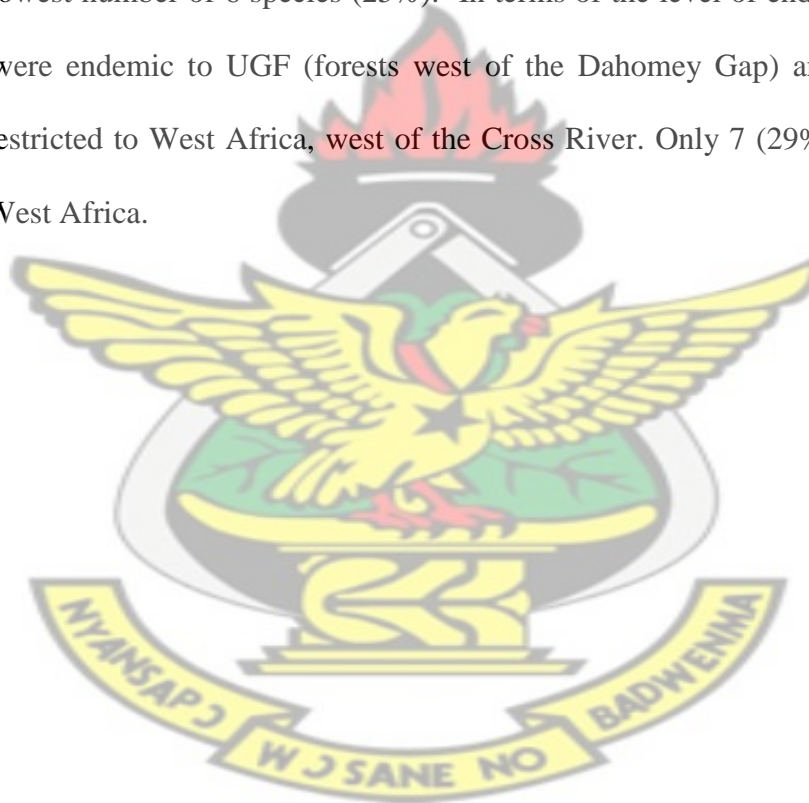


Table 4.2. Checklist, Geographic Distribution, IUCN Red list categories, and localities (of Threatened) amphibian species recorded at Suhuma, Krokosua Hills and Sui River, Forest Reserves in south-western Ghana

Species	Habitat Category	IUCN Category	Geog. Distrn
<i>Amietophrynus maculatus</i>	DT	LC	A
<i>Amietophrynus regularis</i>	DT	LC	A
<i>Amietophrynus togoensis</i>	FS	NT	WA
<i>Arthroleptis krokosua</i>	FS	EN	UG/EG
<i>Arthroleptis sp*</i>	DT		UG
<i>Cardioglossa occidentalis</i>	FS	NE (T)	UG
<i>Hoplobatrachus occipitalis</i>	DT	LC	WA
<i>Hylarana albolabris</i>	DT	LC	A
<i>Hylarana occidentalis</i>	FS	EN	A
<i>Hyperolius concolor</i>	DT	LC	UG
<i>Leptopelis spiritusnoctis</i>	DT	LC	WA
<i>Leptopelis occidentalis</i>	FS	NT	UG
<i>Phrynobatrachus tokba</i>	DT	LC	WA
<i>Phrynobatrachus latifrons</i>	DT	LC	UG
<i>Phrynobatrachus alleni</i>	FS	NT	UG
<i>Phrynobatrachus annulatus</i>	FS	EN	A
<i>Phrynobatrachus calcaratus</i>	DT		UG
<i>Phrynobatrachus liberiensis</i>	FS	NT	WA
<i>Phrynobatrachus plicatus</i>	FS		UG
<i>Phrynobatrachus villiersi</i>	FS	VU	UG
<i>Ptychadena aequiplicata</i>	FS		A
<i>Ptychadena bibroni</i>	DT	LC	A
<i>Ptychadena longirostris</i>	DT	LC	WA
<i>Ptychadena mascareniensis</i>	DT	LC	A
Totals: 24	DT=11, FS=13	EN=3, VU=1, NE=1, NT=4 LC: 11	A=7, EG=11, WA= 6

Geographic Distribution: 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: 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, (T) = Proposed threatened status, * Species complex.

4.2. Changes in Amphibian Assemblage Composition Following Selective-Logging

4.2.1. Abundance Patterns

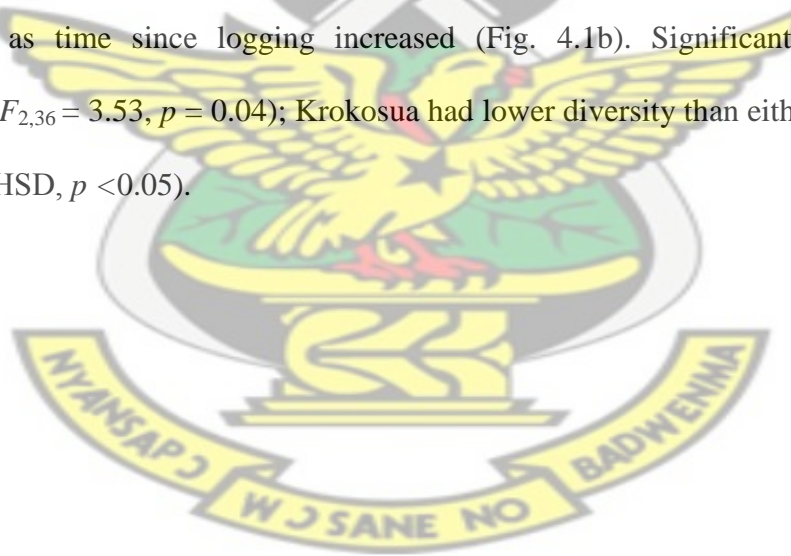
Overall abundance of amphibians was unaffected by logging ($F_{9,36} = 2.02, p = 0.07$) or concession ($F_{2,36} = 1.52, p = 0.23$). There were no overall differences in abundance of disturbance-tolerant species among concessions ($F_{2,36} = 2.00, p = 0.14$) or logging histories ($F_{9,36} = 0.06$ (Fig. 4.2c), although abundance of disturbance-tolerant species was substantially lower in sites logged 10 years previously than in recently logged sites. Abundance of forest-dependent amphibians differed significantly among concessions ($F_{2,36} = 12.66, p < 0.001$); Krokosua contained fewer individuals than Suhuma (Tukey's HSD, $p < 0.05$). There were also significant differences among logging treatments ($F_{9,36} = 13.36, p < 0.001$).

Abundance of forest-dependent species was significantly lower in recently logged forests and forests logged 10 years previously relative to abundance in forests logged 20 years previously or unlogged. There was an approximate two-fold increase in abundance of forest-dependent amphibians from 10 to 20 years post-logging (Fig. 4.1d).

4.2.2. Diversity Patterns

The observed species richness differed among sites with different logging histories ($F_{9,36} = 2.70, p = 0.02$). Recently logged forests contained a greater number of species (Fig. 4.1a). The observed species richness did not differ among concessions ($F_{2,36} = 0.54, p = 0.59$). Estimated species richness was slightly higher in recently logged forests, although the effect was not significant ($F_{9,36} = 2.04, p = 0.06$). Estimated species richness did not differ among concessions ($F_{2,36} = 0.46, p = 0.64$).

The exponent of Shannon entropy ($\exp[H]$) did not differ with time since logging ($F_{9,36} = 0.64, p = 0.76$) or among concessions ($F_{2,36} = 2.34, p = 0.11$). There were, however, significant differences in diversity between logged and unlogged sites as measured by the inverse of Simpson's index ($1/D$) ($F_{9,36} = 2.68, p = 0.02$). This measure of diversity increased as time since logging increased (Fig. 4.1b). Significant location effects occurred ($F_{2,36} = 3.53, p = 0.04$); Krokosua had lower diversity than either Suhuma or Sui (Tukey's HSD, $p < 0.05$).



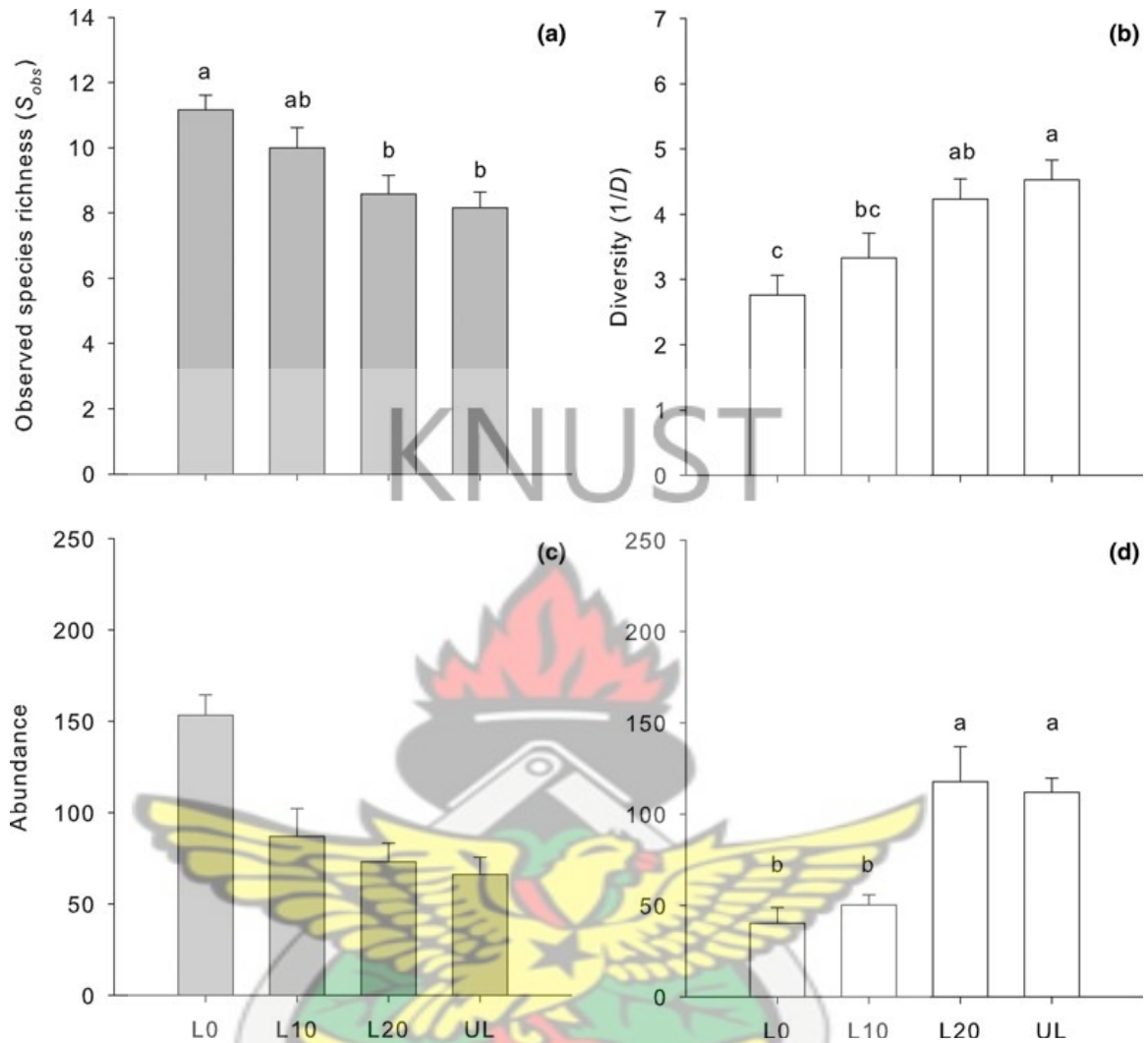


Fig.4.1. Characteristics of amphibian communities in forests that were logged recently (L0), logged 10 (L10), and 20 (L20) years previously, or unlogged (UL).

Mean (SE) (a) observed species richness (S_{obs}) per plot, (b) Simpson's diversity ($1/D$) per plot, and overall abundance of amphibian community fractions of either (c) disturbance-tolerant species or (d) forest-dependent species. Bars with different letters indicate significant differences (Tukey's HSD, $p < 0.05$).

4.2.3. Assemblage Analyses

The NMDS analyses of all amphibians extracted 2 main components (2D stress = 0.15). There were significant differences among the logging histories (MANOVA $F_{6, 39} = 3.61$, $p = 0.003$) (Fig. 4.2a), which suggests a gradient of recovery with time since logging increased. A posteriori contrasts indicated there was no difference in species composition between unlogged forests and forests surveyed 20 years after timber extraction. All other comparisons among logging histories were significant. There was no variation in overall amphibian composition among concessions ($F_{2,39} = 1.62$, $p = 0.18$).

The NMDS analyses for disturbance-tolerant species again extracted 2 components (2D stress = 0.14). Composition of disturbance-tolerant species differed significantly among logging histories ($F_{3,42} = 4.17$, $p = 0.001$; Fig. 4.2b), although in this case the effect was driven by a distinct assemblage occurring in recently logged forests. There was no variation in disturbance-tolerant species among recovering or intact forests. The pattern, therefore, suggests that this fraction of the assemblage reverted to baseline levels 10 years after logging (cf. Fig. 4.2c). There were no differences among concessions ($F_{2,42} = 1.33$, $p = 0.27$).

Assemblages of forest-dependent amphibians (NMDS 2D stress = 0.08) differed significantly among logging histories ($F_{2,44} = 7.14$, $p < 0.001$) (Fig. 4.2c) but did not differ significantly between recently logged forests and forests 10 years after logging or between unlogged forests and forests 20 years after logging.

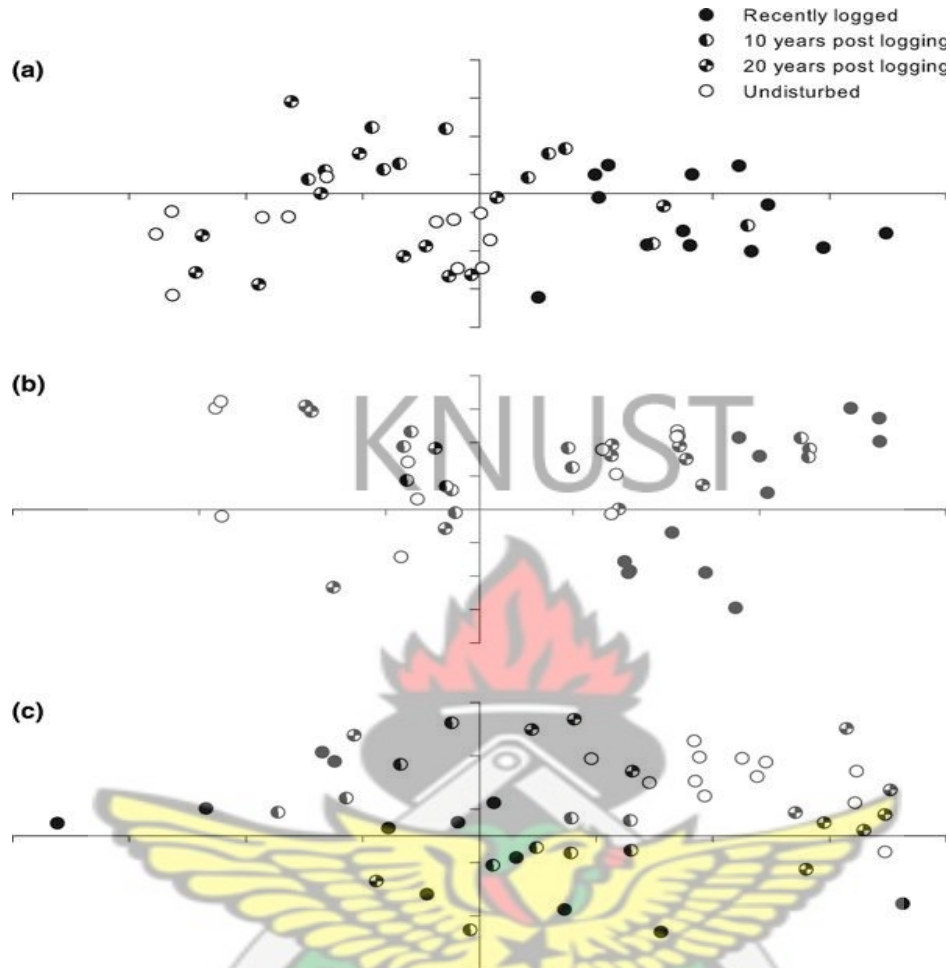


Fig.4.2. Nonmetric multidimensional scaling plots of amphibian communities for (a) all species combined, (b) disturbance-tolerant species, and (c) forest-dependent species.

4.2.3.1 An Analysis of Similarity of Assemblages

When analysing the full amphibian dataset, there was support for the grouping of samples by logging history ($R = 0.399$, $p = 0.001$). When assessing individual groups, there was no support for separating unlogged forests from those which had been logged 20 years previously ($R = 0.104$, $p = 0.063$). All other comparisons were significant ($p < 0.01$).

Those amphibian species identified as degradation-tolerant significantly varied among logging histories ($R = 0.185$, $p = 0.001$), with the recently-logged forest separated from recovering or unlogged sites ($p < 0.01$ for all comparisons), with no differences among the remaining groups. This implies that this component of the amphibian assemblage had recovered to its previous state after 10 years. Among forest-dependent amphibians there was once again significant support for grouping by logging history ($R = 0.357$, $p = 0.001$). In this case there was no difference between recently-logged forests and those which had been recovering for 10 years ($R = 0.035$, $p = 0.204$), but all other comparisons were significant ($p < 0.01$). The results obtained via ANOSIM are therefore qualitatively identical to those as shown in the NMDS, with the exception that the assemblage of forest-dependent amphibians has not completely recovered by 20 years to the same level as unlogged forests, though the trajectory remains in this direction. Given the propensity for a greater Type 1 error rate in this analysis, a more conservative interpretation is warranted.

Finally, in separate tests for grouping according to concession, for all amphibians combined there was significant overall support ($R = 0.060$, $p = 0.004$) driven largely by a difference between Krokosua and Suhuma ($R = 0.121$, $p = 0.018$). No other significant differences among concessions were detected. There were no differences between concessions in the composition of degradation-tolerant amphibian species ($R = -0.035$, $p = 1.000$). For forest dependent species, significant differences among concessions occurred ($R = 0.144$, $p = 0.001$), driven by separation between Krokosua and both Sui

River ($R = 0.204$, $p = 0.004$) and Suhuma ($R = 0.235$, $p = 0.002$). These results concur qualitatively with those shown through NMDS.

4.3. Notes on the Giant West African Squeaker Frog, *Arthroleptis krokosua*

A total of 14 *A. krokosua* were recorded ranging in size between 12-30 mm SVL, indicating that our specimens were juveniles and semi-adults. The largest individual was found on 20 July 2009 at an elevation of 349 m in KHFR (06°34.886' N, 002°48.626' W). This frog was the only one detected in KHFR and 13 mm smaller than the male holotype (SMNS 155; 43.3 mm SVL). In SRFR, 13 individuals were recorded ranging from 12-29 mm ($x = 19.8$ mm \pm 5.4 SD). Seven individuals (13-27 mm) were recorded on 9th August at two sites (five frogs at 06°12.680' N, 002°41.685' W; 477 m; two frogs at 06°14.907' N, 002°42.003' W; 447 m). Additional two frogs (22-23 mm) were detected at the latter site on 10th August. At another locality (06°14.915' N; 002°41.948' W; 439 m) we recorded one frog (29 mm) on 31st July and additional three on 1st August (12, 15 and 28 mm, respectively). There was no record of *A. krokosua* for SFR. Although this survey covered an eight-month period, all frogs were detected towards the end of July and beginning of August, which is the core rainy season.

The holotype originated from the northern range of the KHFR (6°35.970' N, 2°50.705' W). During the present investigations we investigated KHFR sites, which are approximately 30 km from the type locality and recorded only a single individual. This frog was detected in slightly disturbed secondary forest, believed to be logged over 20 years ago. The vegetation was characterized by partly large canopy gaps and thick

shrubby undergrowth (Fig. 4.3a). The frog was found close to a permanent brook in syntopy with disturbance-tolerant frog species (compare Ernst *et al.*, 2006), i.e. *Arthroleptis spp.*, *Phrynobatrachus calcaratus* (Peters, 1863) and *P. tokba* (Chabanaud, 1921). The majority of individuals (13) were recorded at SRFR within forest plots exploited 20 years ago. The SRFR sites in general and in particular those where we recorded *A. krokosua* were less disturbed than KHFR. Detecting a larger numbers of specimens in SRFR (by searching with comparable effort in all three forests), thus may indicate that this frog is a specialist of relatively undisturbed semi-deciduous forest, although it may tolerate some degree of habitat disturbance. The SRFR individuals were recorded in secondary forest with partly thick undergrowth, also very close to a brook along a steep slope (Fig. 4.3b). Syntopic frog species were *Phrynobatrachus annulatus* Perret, 1966 and *P. alleni* Parker, 1936 (which usually both occur in primary rain forest; Ernst *et al.*, 2006), as well as the disturbance-tolerant species complex of small *Arthroleptis*.

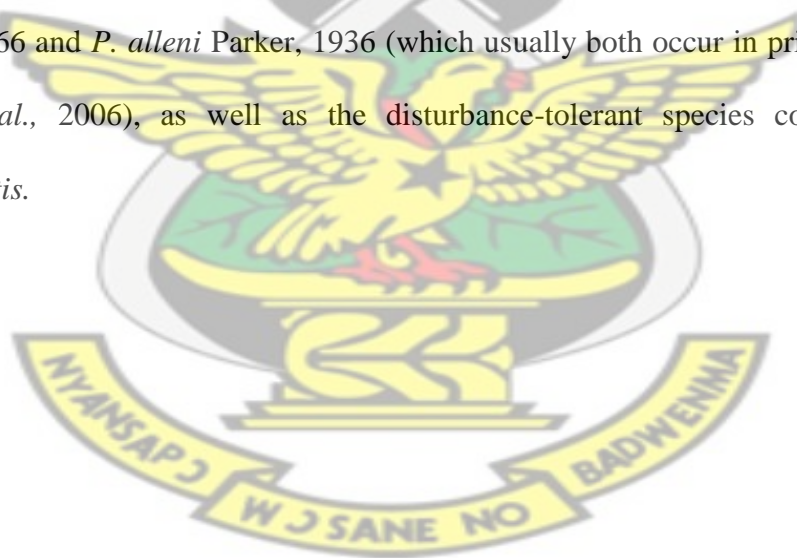




Fig. 4.3. Habitats of *Arthroleptis krokosua* in the Krokosua Hills (a) and Sui River (b) Forest Reserves, south-western Ghana.

The new specimens recorded in this study equal the holotype by having a sturdy and compact body, very broad head; nares located lateral on snout, hardly visible from above and closer to tip of snout than to anterior corner of eyes; snout rounded, only slightly oval; canthus rostralis rounded but distinct; loreal region slightly concave; round comparatively large tympanum; fingers and toes without webbing; terminal toe phalanges slightly expanded; no webbing of foot (in holotype description: foot webbing rudimental, almost absent); skin on dorsum, venter and legs usually smooth, the KHFR specimen with granular back skin (Fig. 4.4a). The dorsal colourations of the new records extend the known colour variability of this species. The frogs vary from light to dark brown. We found specimens having almost exactly the colour pattern of the holotype (Fig. 4.4b), i.e. lacking clearly marked patterns (although a pair of clearer patches is present posterior to scapular region), and frogs with a dark dorsal “hour-glass pattern” and very distinct black lateral spots, all dark markings are bordered by a sharp fine white line (Fig. 4.4a).

The region from the snout tip to the interorbital region usually carries a light triangle or the snout tip has the colour of the back and there is only a light interorbital band; the tympanum and its surroundings bear a dark patch; dark patches also always present on upper lip below eye; anterior and posterior to eye light beige or grey patches; flanks with distinct, few or many small to large black patches which are bordered by fine distinct white line; legs with distinct (Fig. 4.4a) or indistinct (Fig. 4.4c) dark banding on front and hind legs; the throat is dark brown to black and may carry a few white spots along the lower mandible; the dark pigmentation continues across chest and fades caudally; irregular white spots distributed across venter, starting at level of chest; the ventral part of the femur either irregularly marbled (Fig. 4.4c, d) or uniform light beige. Colour variation

seems to be not strictly linked to size, i.e. the largest frog recorded herein (Fig. 4.4a; from KHFR) and SRFR juveniles of less than 20 mm SVL differed most from the holotype by their distinct dorsal colouration. This pattern was missing in SRFR frogs > 20 mm (Fig.4.4c).

The diagnostic characters given by Ernst *et al.* (2008) to distinguish *A. krokosua* from other *Arthroleptis* still apply. From two recently described Central African species, *A. krokosua* can be easily distinguished by its very broad head and a uniform dark throat (*A. palava* Blackburn, Gvoždik and Leaché, 2010: throat mottled with white spots and light gular midline; *A. perreti* Blackburn, Gonwouo, Ernst and Rödel, 2009: white spots on throat), as well as larger size (SVL < 30 mm in *A. palava*) and the absence of large distinct white spots on posterior surface of thighs (present in *A. perreti*).

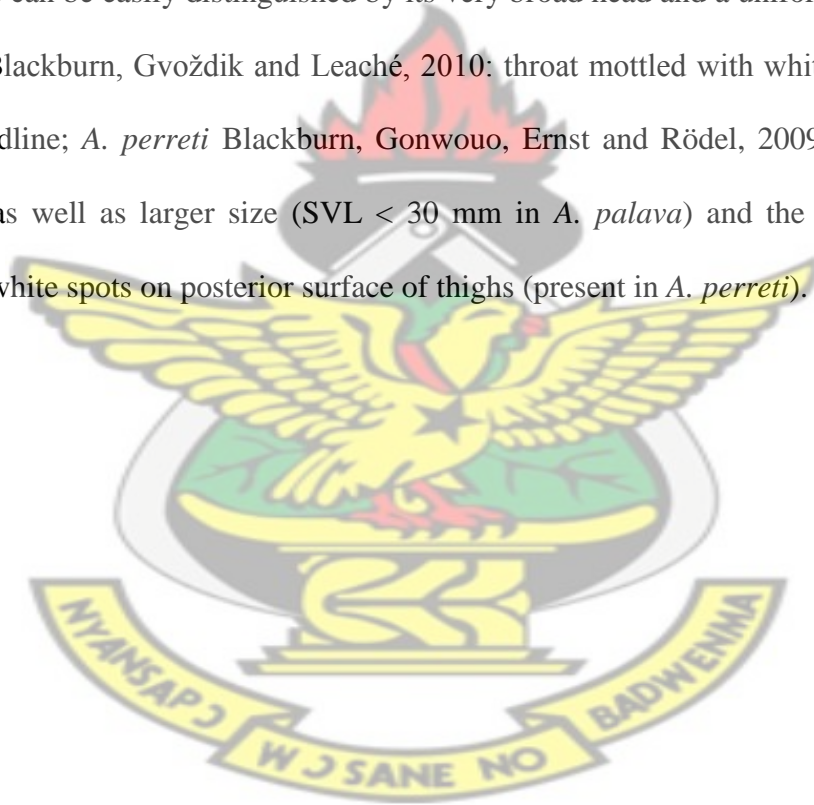




Figure. 4.4. *Arthroleptis krokosua* specimens from Krokosua Hills (a, b) and Sui River (c, d) Forest Reserves

CHAPTER FIVE

DISCUSSION

5.1. Changes in Amphibian Assemblage Composition Following Selective-Logging

The results provide insight into the recovery of amphibian assemblages following logging as we conducted sampling at known times since the most recent felling took place. We found that recovery occurred in two phases: an initial reduction in disturbance-tolerant species followed by eventual recovery of forest-dependent species.

Sites with different logging histories varied markedly in species richness, and the number of species in recently logged forests were substantially higher than in unlogged forests. This is mostly due to an influx of disturbance-tolerant species following the opening of the forests. Simpson's index of diversity, by contrast, increased with time since logging, which indicates that species richness and abundance relations returned to a pre-logging state 20 years after logging. When considered alongside the reduction in species richness and stability of Shannon's Index, this implies that within the community there was a reduction in the dominance of a small number of highly abundant species over time. Such a pattern is common across a wide range of taxonomic groups (Wright and Muller-Landau, 2006a) because disturbance enables colonization of species not normally found in intact forests and decreases the evenness of communities.

By splitting the assemblage into two groups with respect to forest specialization, we could discern how each group responded relative to the overall response to logging of the

entire anuran assemblage. Species characteristic of disturbed areas increased around 50% in overall abundance after logging, and the composition of this fraction of the community was markedly altered. It reverted to baseline levels 10 years after logging. Forest-dependent species were dramatically reduced in number after logging and this led to an approximately 3-fold numerical dominance by disturbance-tolerant species. The forest dependent species took longer to recover, but 20 years after logging their abundance and composition had returned to a state indistinguishable from that of undisturbed forest.

One explanation for the observed patterns is that the forest-dependent species remained present in logged forests, albeit in a community dominated by disturbance-tolerant species such as some toads (*A. maculatus*, *A. regularis*), puddle frogs (*Phrynobatrachus latifrons*, *Phrynobatrachus calcaratus*), tiger frogs (*H. occipitalis*), and ridged frogs (*Ptychadena bibroni*, *Ptychadena longistroris*). Vallan *et al.* (2004) also recorded a shift in species composition 4 years after logging in a tropical rainforest in eastern Madagascar; species characteristic of pristine forests were numerically dominated by species adapted to disturbed forests. A similar shift was observed in forest fragments older than 10 years in Tai National Park, Ivory Coast (Hillers *et al.*, 2008a), which is located within the same eco-region as our study site.

At all our logged sites, 3 trees/ha were removed, and this low level of removal may account for the effective recovery of amphibian assemblages within 20 years. In Guyana and Ivory Coast, amphibian assemblages did not recover to their former levels 30 years after logging when 19.5 trees/ha were removed or when an unknown number of trees

were removed, respectively (Ernst and Rödel, 2005; Ernst *et al.*, 2006). Such differences in recovery rates could result from differences in the ecological requirements of the frogs and the particular forest type (Ofori-Boateng *et al.*, 2012). The studies in Guyana and Ivory Coast considered entire frog assemblages (Ernst *et al.*, 2006) and took place in humid evergreen forests (Ernst and Rödel, 2005; Ernst *et al.*, 2006). Results of some studies in Southeast Asia, although conducted in intensively logged forests, were consistent with our results. Twenty years after logging at a removal level of approximately 41 trees/ha in twice-logged forests, sites harbored over 75% of dung beetle and bird species that occur in unlogged forests (Edwards *et al.*, 2010). In another study, where logging intensity was 27 trees/ha, 15 years after logging species richness and diversity of birds in a rehabilitated forest were similar to species richness and diversity in an unlogged forest, and they were higher in both these sites than in a forest left to recover through natural processes (Edwards *et al.*, 2009). Furthermore, species richness and diversity of 11 taxonomic groups of more than 2500 species, including amphibians, were comparable in logged forest and primary forest 19 years after logging (Berry *et al.*, 2010).

A growing body of evidence suggests that many species can persist after timber extraction (Gibson *et al.*, 2011; Edwards *et al.*, 2012; Putz *et al.*, 2012). Our results are consistent with this theory and provide evidence that selectively logged forests retain many of their species.

Furthermore, the recovery of the original assemblage occurred within 20 years, the average rotation time for these forests. Thus, current felling strategies seem compatible with the conservation of amphibian communities in West African semi-deciduous forests, at least when they are based on very low logging intensities (≤ 3 trees/ha). However, there is evidence that logging in Ghanaian forests on a 20-year rotation is not sustainable for timber production, and rotations exceeding 40 years are required (Hawthorne *et al.*, 2012). There is no information on the effects of successive harvesting on amphibians, and future surveys will be required to ensure that successive rotations do not have a cumulative impact. At present repeat harvesting has only occurred in a small proportion of Ghana's forests.

Another landscape feature that potentially aided in the recovery of amphibian assemblages is the small geographic distance between forests of different logging histories (including unlogged) (Lindenmayer *et al.*, 2012) and in particular the presence of permanent brooks that traverse both logged and unlogged forests. The species we recorded comprised a large subset of forest- and stream-dependent species and included the puddle frogs *Phrynobatrachus liberiensis*, *Phrynobatrachus alleni*, *Phrynobatrachus annulatus*, *Phrynobatrachus plicatus*, *P. villiersi*, and *H. occidentalis*. In addition, apart from squeaker frogs (*Arthroleptis* sp.), which currently is a species complex that cannot be distinguished, two stream dependent frogs, Peter's puddle frog (*Phrynobatrachus calcaratus*) and White-lipped Frog (*Hylarana albolabris*), were the most commonly recorded disturbance-tolerant species in both logged and unlogged areas. These two species require high humidity and often live close to rivers. Based on these observations

and those of other studies (Fredericksen and Fredericksen, 2004; Ficetola *et al.*, 2008), we suggest these brooks or streams facilitated migration of species between logged and unlogged forest. This facilitated movement may have enhanced the recovery of amphibian assemblages.

5.2. Notes on the Giant West African Squeaker Frog, *Arthroleptis krokosua*

Overall, only comparatively few *A. krokosua* (14 individuals during > 700 h of searching) have been recorded. Furthermore, the complete absence of adult frogs, in particular males in breeding activities, raises the question of where and when this species is breeding. However, as all *Arthroleptis* so far known, are direct developers (e.g. Guibé and Lamotte, 1958; Lamotte and Perret, 1963; Tapley, 2009), a minimum of soil humidity should be present to assure successful reproduction. The holotype was collected in November in 2002, reported to show any breeding activities (Ernst *et al.*, 2008). It thus so far remains not resolved where and when the species reproduces, neither has the advertisement call been heard. The species was absent from the third site, SFR, although habitats of this site did not vary from the other two sites examined. Hence, it is not known what habitat characteristics best explain the presence or absence of *A. krokosua*.

We assume that we either have not yet detected the breeding habitats of the species or have not recorded adult *A. krokosua* because they are well hidden during the day and only active at night. However, other species of the genus usually call during night and day (the latter in particular shortly after rain) and can be even more easily recorded in the leaf-litter during the day than during night.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

6.1.1. Changes in Amphibian Assemblage Composition Following Selective-Logging

Tropical forest managers, governments, and conservation biologist, those in Ghana in particular have been grappling with the issue of designing logging practices that are compatible with conservation and sustainable timber production. Of particular interest has been determining an optimum period that allows natural regeneration to occur after logging (Chapman, 2004; Sodhi and Ehrlich, 2010). Most logging rotations are established without prior knowledge of the resilience of forest communities (Sodhi and Ehrlich, 2010). Our results show that for effective management of amphibian assemblages in logged forests, concessions should be managed on a minimum 20-year rotation.

Loss of genetic diversity has also been reported in amphibian populations 3-9 years following logging (Curtis and Taylor, 2004). Nevertheless, our results show that, although sensitive to disturbance, forest-dependent frog species are able to recover if forests are left undisturbed at least over 20 years, and may be useful indicators of the resilience of amphibian communities (Rödel and Ernst, 2004; Rödel *et al.*, 2005a). That I (for details see Adum *et al.*, 2011) recorded the highest number of the endangered endemic forest species *A. krokosua* since its discovery further underscores the conservation value of logged forests for some forest species. These discoveries are

positive indications that logged forests can play a significant role in safeguarding the habitats of some forest species. Overall, there is hope for the future of conservation in West African forests that have been subjected to defaunation, especially in the last two decades. At least some portion of the surviving fauna can apparently recover when forests are subsequently left undisturbed. This therefore adds to the case for preserving logged forests alongside undisturbed forests.

KNUST

6.1.2. Abundance, Habitat Preferences and Species' Variability of the Endangered Ghanaian Giant Squeaker Frog, *Arthroleptis Krokosua*

Many forests in Ghana have been surveyed in recent years, without detecting the Ghanaian endangered and rare Squeaker Frog, *Arthroleptis krokosua*. The two forests where *A. Krokosua* occurs are approximately 30km apart and under severe threats. The reserves' vegetation has been severely disturbed resulting from past and current logging activities, fragmentation, farming and mining. Logging and farming might be the reason why over half of the Krokosua HFR amphibian fauna already consists of non-forest specialists.

6.2. Recommendations

6.2.1. Changes in Amphibian Assemblage Composition Following Selective-Logging

Parameters such as low logging intensity (≤ 3 trees/ ha), remnant patches of intact forests retained in the landscape, and presence of permanent brooks should be considered

because they may aid in the recovery of amphibian assemblages. Because there is a shift toward habitat generalists during the first 10 years following logging, this period should be considered critical for the protection of forest specialists because any additional ecological threats could delay the recovery of species. However, there is the need for further studies to investigate the recovery of species genetic diversity following logging.

KNUST

6.2.2. Abundance, Habitat Preferences and Species' Variability of the Endangered

Ghanaian Giant Squeaker Frog, *Arthroleptis Krokosua*

All the localities of the distinct Ghanaian endangered and rare Squeaker Frog, *Arthroleptis Krokosua* need to be protected from logging activities by for instance setting the habitats aside during logging operations. This may be the most effective way to safeguard the endangered squeaker frog's habitats and avoid a perceived imminent extinction. Further data on the breeding habitats and detailed population estimates are urgently required in order to set up plans for the long-term conservation of this peculiar Ghanaian forest frog.

REFERENCES

- Adam, K. A., M. A. Pinard, and M. D. Swaine. 2006. Nine decades of regulating timber harvest from forest reserves and the status of residual forests in Ghana. *International Forestry Review* 8:280-296.
- Adum G. 2011. SAVE THE FROGS! Ghana - Powering Africa's Environmental Revolution. *FrogLog*. Vol. 99, <http://www.amphibians.org/blog/2011/11/17/froglog-99>.
- Adum, G. B., C. Ofori-Boateng, W. Oduro, and M.-O. Rödel. 2011. Rediscovery of the Giant West African Squeaker, *Arthroleptis krokosua* Ernst, Agyei & Rödel, 2008 (Amphibia: Anura: Arthroleptidae) in two forests of south-western Ghana with observations on the species' variability and habitat preferences. *Zootaxa* 2744:34–38.
- Annorbah, N. N. D. 2009. Implications of selective logging for avifaunal species in a moist semi-Deciduous forest of Ghana. MPhil Thesis. University of Ghana, Legon.
- Bakarr, M., B. Bailey, D. Byler, R. Hams, S. Olivieri and M. Omland (eds.). 2001. From the forest to the sea: Biodiversity connections from Guinea to Togo, Conservation Priority-Setting workshop, December 1999. Washington D. C., Conservation International, 78 pp.
- Beier, P., M. Van Drielen, and B. O. Kankam. 2002. Avifaunal collapse in West African forest fragments. *Conservation Biology* 16:1097-111.
- Benhin, J. K. A., and E. B. Barbier. 2004. Structural Adjustment Programme, deforestation and biodiversity loss in Ghana. *Environment and Resources Economic* 27, pp. 337-366.

- Berry, N. J., O. L. Philips, S. L. Lewis, J. K. Hill, D. P. Edwards, C. V. Khen, N. A. Tawatao, M. Maryati, R. C. Ong, and K. C. Hamer. 2010. The high value of logged tropical forests: lessons from northern Borneo. *Biodiversity and Conservation* 19:985–997.
- Bihn, J. H., M. Verhaagh, R. Brandl. 2008. Ecological stoichiometry along a gradient of forest succession: bait preferences of litter ants. *Biotropica* 40:597-599.
- Bird, N., T. Fomete, and G. Birikorang. 2006. Ghana's experience in timber verification system design. VERIFOR Country Case Study No.1. Overseas Development Institute (ODI), London, United Kingdom. 12p.
- Blackburn, D. C., J. Kosuch, A. Schmitz, M. Burger, P. Wagner, L. N. Gonwouo, A. Hillers, and M. -O. Rödel. 2008. A new species of *Cardioglossa* (Anura: Arthroleptidae) from the Upper Guinean forests of West Africa. *Copeia* 2008:603-612.
- Blackburn, D. C., L. N. Gonwouo, R. Ernst, and M. -O. Rödel. 2009. A new squeaker frog (Arthroleptidae: *Arthroleptis*) from the Cameroon volcanic line with re-descriptions of *Arthroleptis adolfifriederici* Nieden, 1911 “1910” and *A. variabilis* Matschie, 1893. *Breviora*, 515:1–22.
- Blackburn, D. C., V. Gvoždik, and, A. D. Leaché. 2010. A new squeaker frog (Arthroleptidae: *Arthroleptis*) from the mountains of Cameroon and Nigeria. *Herpetologica* 66:335–348.
- Buzzard, Paul J., and Atingah John A. Parker. "Surveys from the Subri River Forest Reserve, Ghana." *African Primates* 7.2 (2012): Pp-175.
- Carey, C., and C. J. Bryant. 1995. Possible interrelations among environmental toxicants, amphibian development, and decline of amphibian populations. *Environmental Health Perspective* 103:13-17.

- Carey, C., and M. A. Alexander. 2003. Climate change and amphibian declines: is there a link? *Diversity and Distribution* 9:111-121.
- Chao, A. 2005. Species estimation and applications. 2nd edition. *Encyclopedia of statistical sciences*. Wiley, New York.
- Chao, A., and T. J. Shen. 2003. Nonparametric estimation of Shannon's index of diversity when there are unseen species in sample. *Environmental and Ecological Statistics* 10:429-443.
- Chao, A., and T. J. Shen. 2010. SPADE (species prediction and diversity estimation). National Tsing Hua University, Taiwan. Available from <http://chao.stat.nthu.edu.tw> (accessed May 2012).
- Chapman, C. A., and L. J. Chapman. 2004. Unfavorable successional pathways and the conservation value of logged tropical forest. *Biodiversity and Conservation* 13:2089-2105.
- Connell, J. H. 1978. Diversity in tropical rain forests and coral reefs. *Science* 199:1302-1310.
- Corn, P. S. 2005. Climate change and amphibians. *Animal Biodiversity Conservation* 28:59-67.
- Curtis, J. M. R., and E. B. Taylor. 2004. The genetic structure of coastal giant salamanders (*Dicamptodon tenebrosus*) in a managed forest. *Biological Conservation* 115:45-54.
- Cushman, S. A. 2006. Effects of habitat loss and fragmentation on amphibians: a review and prospectus. *Biological Conservation* 128:231-240.

- Daszak, P. 2000. Emerging infectious diseases of wildlife—threats to biodiversity and human health .*Science* 287:1756-1756.
- Daszak, P., A. A. Cunningham, and A. D. Hyatt. 2003. Infectious disease and amphibian population declines. *Diversity and Distribution*9:141-150.
- Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. *Emerging Infectious Diseases* 5:735–748.
- Edwards, D. P., P. Woodcock, F. A. Edwards, T. H. Larsen, W. W. Hsu, S. Benedick, and D. S. Wilcove. 2012. Reduced-impact logging and biodiversity conservation: a case study from Borneo. *Ecological Applications* 22:561–571.
- Edwards, D. P., F. A. Ansell, A. H. Ahmad, R. Nilus, and K. C. Hamer. 2009. The value of rehabilitating logged rainforest for birds. *Conservation Biology* 23:1628–1633.
- Edwards, D. P., T. D. Larsen, F. A. Ansell, W. W. Hsu, M. A. Derhe, K. C. Hamer, and D. S. Wilcove. 2010. Degraded lands worth protecting: the biological importance of Southern Asia’s repeatedly logged forests. *Proceedings of the Royal Society B* 278:82–90.
- Ernst, R., A. C. Agyei, and M.-O. Rödel. 2008. A new giant species of *Arthroleptis* (amphibia :anura :arthroleptidae) from the Krokosua Hills forest reserve, southwestern Ghana. *Zootaxa* 1697:58-68.
- Ernst, R., and M. -O. Rödel. 2005. Anthropogenically induced changes of predictability in tropical anuran assemblages. *Ecology* 86:3111–3118.
- Ernst, R., and M. -O. Rödel. 2006. Community assembly and structure of tropical leaf-litter anurans. *Ecotropica*12:113–129.

- Ernst, R., and M. -O. Rödel. 2008. Patterns of community composition in two tropical tree frog assemblages: separating spatial structure and environmental effects in disturbed and undisturbed forests. *Journal of Tropical Ecology* 24:111–120.
- Ernst, R., K. E. Linsenmair, and M.-O. Rödel. 2006. Diversity erosion beyond the species level: dramatic loss of functional diversity after selective logging in two tropical amphibian communities. *Biological Conservation* 133:143–155.
- Ficetola, G. F., D. Furlani, G. Colombo, and F. De Bernardi. 2008. Assessing the value of secondary forest for amphibians: *Eleutherodactylus* frogs in a gradient of forest alteration. *Biodiversity and Conservation* 17:2185–2195.
- Fredericksen, N. J., and T. S. Fredericksen. 2004. Impacts of selective logging on amphibians in a Bolivian tropical humid forest. *Forest Ecology and Management* 191:275–282.
- Furlani, D., G. F. Ficetola, G. Colombo, M. Ugurlucan, and F. De Bernardi. 2009. Deforestation and the structure of frog communities in the Humedale Terraba-Sierpe, Costa Rica. *Zoological Science* 26:197–202.
- Gallant, A. L., R. W. Klaver, G. S. Casper, and M. J. Lannoo. 2007. Global rates of habitat loss and implications for amphibian conservation. *Copeia* 4:967-979.
- Gardner, T. 2001. Declining amphibian populations: a global phenomenon in conservation biology. *Animal Biodiversity and Conservation* 242: 25–44.
- Gardner, T. A., J. Barlow, and C. A. Peres. 2007. Paradox, presumption and pitfalls in conservation biology: the importance of habitat change for amphibians and reptiles. *Biological Conservation* 138:166-179.

- Gascon, C., E. T. Lovejoy, O. R. J. Bierregaard, J. R. Malcolm, H. L. Vasconcelos, W. F. Laurance, B. Zimmerman, M. Tocher, and S. Borges. 1999. Matrix habitat and species richness in tropical forest remnants. *Biological Conservation* 91:223–229.
- Gibson, L., T. M. Lee, L. P. Koh, B. W. Brook, T. A. Gardner, J. Barlow, C. A. Peres, C. J. A. Bradshaw, W. F. Laurance, T. E. Lovejoy, and N. S. Sodhi. 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* 478:378-383.
- Guibé, J., and M. Lamotte. 1958. Morphologie et reproduction par développement direct d'un anoure du Mont Nimba, *Arthrolepti scrusculum* Angel. *Bulletin du Musée National d'Histoire Naturelle, 2e Sér.*, 30:1–133.
- Hall, J. B., and M. D. Swaine. 1981. Distribution and ecology of vascular plants in a tropical rain forest: forest vegetation in Ghana. *Geobotany. Volume 1.* Junk Publishers, The Hague, Netherlands.
- Hawthorne, W. D., D. Sheil, V. K. Agyeman, M. Abu-Juam, and C. A. M. Marshall. 2012. Logging scars in Ghanaian high forest: towards improved models for sustainable production. *Forest Ecology and Management* 271:27–36.
- Hawthorne, W. D., and M. Abu-Juam. 1995. Forest protection in Ghana, with particular reference to vegetation and plant species. *International Union for Conservation of Nature*, Cambridge, United Kingdom.
- Henderson, P. A., and R. M. H. Seaby. 2007. *Community analysis package 4.0.* Pisces Conservation, Lymington, United Kingdom.
- Herrera-Montes, A., and N. Brokaw. 2010. Conservation value of tropical secondary forest: A herpetofaunal perspective. *Biological Conservation* 143:1414–1422.

- Hill, M. O. 1973. Diversity and evenness: a unifying notation and its consequences. *Ecology* 54:427–431.
- Hillers, A. 2008. West African forest frogs. Ecology, evolution, and conservation. PhD thesis, University of Amsterdam, the Netherlands.
- Hillers, A., B. Zimkusand, M. -O. Rödel. 2008b. A new species of *Phrynobatrachus* (Amphibia: Anura: Phrynobatrachidae) from northwestern Guinea, West Africa. *Zootaxa* 1815:43-50.
- Hillers, A., C. O. Boateng, G. H. Segniagbeto, A. C. Agyei, and M. -O. Rödel. 2009. Assessment of the amphibians in the forests of southern Ghana and western Togo. *Zoosystematics and Evolution* 85:127–141.
- Hillers, A., M. Veith, and M.-O. Rödel. 2008a. Effects of forest fragmentation and habitat degradation on West African leaf-litter frogs. *Conservation Biology* 22:762–772.
- Holbech, L. H. 2005. The implications of selective logging and forest fragmentation for the conservation of avian diversity in evergreen forests of south-west Ghana. *Bird Conservation International* 15:27–52.
- IUCN Red List of Threatened Species. 2007. (<http://www.iucnredlist.org/>).
- Jost, L. 2006. Entropy and diversity. *Oikos* 113:363–375.
- Jost, L. 2007. Partitioning diversity into independent alpha and beta components. *Ecology* 88:2427–2439.
- Jost, L., A. Chao, and R. L. Chazdon. 2011. Compositional similarity and β (beta) diversity. Pages 66–84 in A. E. Magurran and B. J. McGill, editors. *Biological diversity: frontiers in measurement and assessment*. Oxford University Press, Oxford, United Kingdom.

- Kats, L. B., and R. P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. *Diversity and Distribution* 9:99-110.
- Kormos R., C. Boesch, M. I. Bakarr, and T. M. Butynski (eds.). 2003. West African chimpanzees. Status survey and conservation action plan. Gland, Switzerland and Cambridge: IUCN.
- Lamotte, M., and J. -L. Perret. 1963. Contribution à l'étude des batraciens de l'OuestAfricain XV.– Le développement direct de l'espèce *Arthroleptis poecilonotus* Peters. *Bulletin de l'Institute fondamentale Afrique noire, Sér. A:277–284.*
- Laurance, W. F. 1999. Reflections on the tropical deforestation crisis. *Biological Conservation* 91:109–117.
- Leaché, A. D., M. -O. Rödel, C. W. Linkem, R. E. Diaz, A. Hillers, and M. K. Fujita. 2006. Biodiversity in a forest island: reptiles and amphibians of the West African Togo Hills. *Amphibian and Reptile Conservation* 4:22-45.
- Lindenmayer, D. B., J. F. Franklin, A. Lothmus, S. C. Baker, J. Bauhus, W. Beese, A. Brodie, B. Kiehl, J. Kouki, G. Martínez Pastur, C. Messier, M. Neyland, B. Palik, A. Sverdrup-Thygeson, J. Volney, A. Wayne, and L. Gustafsson. 2012. A major shift to the retention approach for forestry can help resolve some global forest sustainability issues. *Conservation Letters*: DOI:10.1111/j.1755-263X.2012.00257.x.
- Lubchenco, J. 1978. Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities. *The American Naturalist* 112:23-39.

- Magnuson, L. E. 2002. Distribution and habitat use of the Roloway guenon (*Cercopithecus diana roloway*) in Ghana, West Africa. Master's thesis, Natural Resources: Wildlife Management, Humboldt State University, 68 pp.
- Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey.
- Marco, A., C. Quilchano, and A. R. Blaustein. 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific northwest, USA. *Environmental Toxicology Chemistry* 18:2836-2839.
- McCullough, J., L. E. Alonso, P. Naskrecki, H. E. Wright, and, Y. Osei-Owusu. 2007. A rapid biological assessment of the Atewa Range Forest Reserve, eastern Ghana. *RAP Bulletin of Biological Assessment*, 47, Conservation International, Arlington, VA.
- McGraw, W.S. 2005. Update on the search for Miss Waldron's red colobus monkey. *International Journal of Primatology* 26, 605–619.
- Meijaard, E., D. Sheil, R. Nasi, D. Augeri, B. Rosenbaum, D. Iskandar, T. Setyawati, M. Lammertink, I. Rachmatika, A. Wong, T. Soehartono, S. Stanley, and T. O'Brien. 2005. Life after logging: reconciling wildlife conservation and production forestry in Indonesian Borneo. Center for International Forestry Research, Bogor, Indonesia.
- Mittermeier, R. A., P. R. Gil, M. Hoffmann, J. Pilgrim, T. Brooks, C. G. Mittermeier, J. Lamoreux, and G. A. B. da Fonesca (eds.): Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions, Conservation International and CEMEX, Washington, D. C. 392 pp.
- Myers N, R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403:853–858.

- Norris, K., A. Asase, B. Collen, J. Gockowksi, J. Mason, B. Phalan, and A. Wade. 2010. Biodiversity in a forest-agriculture mosaic—the changing face of West African rainforests. *Biological Conservation* 143:2341–2350.
- Oates J. F. 1999. Myth and reality in the rainforest: how conservation strategies are failing in West Africa. University of California Press, Berkeley, xxviii+310pp.
- Oates, J. F., M. Abedi-Lartey, McGrawWAS, T. T. Struhsaker, and G. H Whitesides. 2000. Extinction of a West African red colobus monkey. *Conservation Biology* 14:1526–1532.
- Ofori-Boateng, C., W. Oduro, S. K. Opong, G. B. Adum, A. Hillers, K. Norris, and M.-O. Rödel. 2012. Differences in the effects of selective logging on amphibian assemblages in three West African forest types. *Biotropica* DOI:10.1111/j.1744-7429.2012.00887.x.
- Penner, J., M. Wegmann, A. Hillers, M. Schmidt, and M.-O.Rödel. 2011. A hotspot revisited – a biogeographical analysis of West African amphibians. *Diversity and Distributions* 17:1077–1088.
- Poorter, L., F. Bongers, and R. H. M. J. Lemmens. 2004. West African Forests: Introduction. In: Poorter, L., F. Bongers, F. N. Kouame and W.D. Hawthorne: Biodiversity of West African Forests: an ecological atlas of woody plant species. CABI Publishing, Cambridge, Massachusetts, 521 pp.
- R Development Core Team. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.
- Raxworthy, C. J., and D. K. Attuquayefio. 2000. Herpetofaunal communities at Muni Lagoon in Ghana. – *Biodiversity and Conservation* 9: 501-510.

- Rödel M. O., and A. C. Agyei. 2002. Herpetological Survey in Volta Region, Eastern Ghana. Biocenter of the University AmHubland in Würzburg, Germany. Available at: www.cepf.net/xp/cepf/static/pdfs/Voltasurvey.pdf.
- Rödel, M. -O. 2007. The identity of *Hylambates hylodes* Boulenger, 1906 and description of a new small species of *Leptopelis* from West Africa. *Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe* 83:90-100.
- Rödel, M. -O., and A. C. Agyei. 2003. Amphibians of the Togo-Volta highlands, eastern Ghana. *Salamandra* 39:207-234.
- Rödel, M. -O., and R. Ernst. 2004. Measuring and monitoring amphibian diversity in tropical forests. An evaluation of methods with recommendations for standardization. *Ecotropica* 10:1-14.
- Rödel, M. -O., C. O. Boateng, J. Penner, and A. Hillers. 2009. A new cryptic *Phrynobatrachus* species (Amphibia: Anura: Phrynobatrachidae) from Ghana, West Africa. *Zootaxa* 1970:52-62.
- Rödel, M. -O., J. Kosuch, M. Veith, and R. Ernst. 2003. First record of the genus *Acanthixalus* Laurent, 1944 from the Upper Guinean rain forest, West Africa, with the description of a new species. *Journal of Herpetology* 37:43-52.
- Rödel, M. -O., J. Kosuch, N. G., Kouamé, R. Ernst, and M. Veith. 2005b. *Phrynobatrachus alticola* Guibé and Lamotte, 1961 is a junior synonym of *Phrynobatrachus tokba* (Chabanaud, 1921). *African Journal of Herpetology* 54:93-98.
- Rödel, M. -O., P. J. Adeba, R. Ernst, A. Hillers, S. G. A. Nago, J. Penner, and M. Wegmann. 2008. Threatened islands of amphibian diversity in West Africa. In: Stuart, S. N., M. Hoffmann, J. S. Chanson, N. A. Cox, R. J. Berridge, P. Ramani, and B. E. Young (eds.): *Threatened amphibians of the world*. Lynx Edicions in

- association with IUCN-The World Conservation Union, Conservation International and NatuServe, pp. 62-63.
- Rödel, M. -O., T. U. Grafe, V. H. W. Rudolf, and R. Ernst. 2002. A review of West African spotted *Kassina*, including a description of *Kassina schioetzi* sp.nov. (Amphibia: Anura: Hyperoliidae). *Copeia* 2002:800-814.
- Rödel, M. -O., V. H. W. Rudolf, S. Frohschammer, and K. E. Linsenmair. 2004a. Life history of a West African tree-hole breeding frog, *Phrynobatrachus guineensis* Guibé, and Lamotte, 1961 (Amphibia: Anura: Petropedetidae). –pp. 31-44 In: Lehtinen, R.M. (ed.): Ecology and evolution of phytotelm-breeding anurans, Miscellaneous Publications of the Museum of Zoology, University of Michigan, Ann Arbor, No. 193, 73 pp.
- Rödel, M.-O., M. A. Bangoura, and W. Böhme. 2004b. The amphibians of southeastern Republic of Guinea (Amphibia: Gymnophiona, Anura). *Herpetozoa*, 17:99-118.
- Rödel, M.-O., M. Gil, A. C. Agyei, A. D. Leaché, R. E. Diaz, M. K. Fujita, and R. Ernst. 2005a. The amphibians of the forested parts of south-western Ghana. *Salamandra*, 41:107–127.
- Segniagbeto, G. H., J. E., Bowessidjaou, A. Dubois, and, A. Ohler. 2007. Les amphibiens du Togo: état actuel des connaissances. *Alytes* 24:72-90. In: Hillers, A. 2008. West African forest frogs. Ecology, evolution, and conservation. PhD thesis, University of Amsterdam, the Netherlands.
- Sodhi, N. S., and P. R. Ehrlich. 2010. Conservation biology for all. Oxford University Press, Oxford, United Kingdom.
- Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306:1783-1786.

- Stuart, S., M. Hoffman, J. Chanson, N. Cox, R. Berridge, P. Ramani, and B. Young. 2008. *Threatened amphibians of the World*. Lynx Editions, Barcelona.
- Tapley, B. 2009. Notes on the captive husbandry and breeding of the shovel-footed squeaker, *Arthroleptis stenodactylus* (Pfeffer 1893). *The Herpetological Bulletin* 110:38–41.
- Tuomisto, H. 2010. A consistent terminology for quantifying species diversity? Yes, it does exist. *Oecologia* 164:853–860.
- Vallan, D. 2002. Effects of anthropogenic environmental changes on amphibian diversity in the rainforests of eastern Madagascar. *Journal of Tropical Ecology* 18:7–742.
- Vallan, D., F. Andreone, and V. H. Raherisoa. 2004. Does selective wood exploitation affect amphibian diversity? The case of An'Ala, a tropical rainforest in eastern Madagascar. *Oryx* 38:410–417.
- Wake, D. B., and V. T. Vredenburg. 2008. Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of National Academy of Science, USA*, 105: 11466-11473.
- Waltert, M. 2000. Diversity and structure of a bird community in a logged forest in south-east Côte d'Ivoire (Doctoral dissertation, Ph. D. dissertation. Universität Göttingen, Göttingen, Germany).
- Wanger, T. C., A. Saro, D. T. Iskandar, B. W. Brook, N. Sodhi, Y. Clough, and T. Tschardtke. 2009. Conservation value of cacao agroforestry for amphibians and reptiles in Southeast Asia: combining correlative models with follow-up field experiments. *Journal of Applied Ecology* 46:823-832.

- Wanger, T. C., D. T. Iskandar, I. Motzke, B. W. Brook, N. S. Sodhi, Y. Clough, and T. Tschardtke. 2010. Effects of land-use change on community composition of tropical amphibians and reptiles in Sulawesi, Indonesia. *Conservation Biology* 25:795–802.
- Warkentin, I. G., D. Bickford, N. S. Sodhi, and C. J. A. Bradshaw. 2009. Eating frogs to extinction. *Conservation Biology* 23:1056–1059.
- Weckstein, J. D., B. D. Marks, R. G. Moyle, K. P. Johnson, M. J. Meyer, J. Braimah, J. Opong, and J. Amponsah. Birds recorded from surveys in Ghana's Central and Brong-Ahafo regions.
- Wells, K.D. (ed). 2007. *The ecology and behaviour of amphibians*. University of Chicago Press, Chicago, Illinois, USA.
- Wintle, B. A., M. A. McCarthy, K. M. Parris, and M. A. Burgman. 2004. Precision and bias of methods for estimating point survey detection probabilities. *Ecological Applications* 14:703–712.
- Wright, S. J., and H. C. Muller-Landau. 2006a. The future of tropical forest species. *Biotropica* 38:287–301.
- Wright, S. J., and H. C. Muller-Landau. 2006b. The uncertain future of tropical forest species. *Biotropica* 38:443-445.

APPENDICES

Species	Date	Visit number	Plot	Treatment	Site
	30/5/2009	1	1	Unlogged	Suhuma
	06/02/2009	2	1	Unlogged	Suhuma
	22/6/2009	3	1	Unlogged	Suhuma
	29/9/2009	4	1	Unlogged	Suhuma
	12/11/2009	5	1	Unlogged	Suhuma
	30/5/2009	1	2	Unlogged	Suhuma
	06/02/2009	2	2	Unlogged	Suhuma
	22/6/2009	3	2	Unlogged	Suhuma
	29/9/2009	4	2	Unlogged	Suhuma
	12/11/2009	5	2	Unlogged	Suhuma
	30/5/2009	1	3	Unlogged	Suhuma
	06/02/2009	2	3	Unlogged	Suhuma
	22/6/2009	3	3	Unlogged	Suhuma
	29/9/2009	4	3	Unlogged	Suhuma
	12/11/2009	5	3	Unlogged	Suhuma
	30/5/2009	1	4	Unlogged	Suhuma
	06/02/2009	2	4	Unlogged	Suhuma
	22/6/2009	3	4	Unlogged	Suhuma
	29/9/2009	4	4	Unlogged	Suhuma
	12/11/2009	5	4	Unlogged	Suhuma
	30/5/2009	1	4	Unlogged	Suhuma
	06/02/2009	2	4	Unlogged	Suhuma
	22/6/2009	3	4	Unlogged	Suhuma
	29/9/2009	4	4	Unlogged	Suhuma
	12/11/2009	5	4	Unlogged	Suhuma
Amietophrynus maculatus		0	0	0	0
Amietophrynus regularis		0	0	0	0
Amietophrynus togoensis		6	0	0	0
Arthroleptis krokosua		0	0	0	0
Arthroleptis sp*		7	8	18	5
Cardioglossa occidentalis		0	0	0	0
Hoplobatrachus occipitalis		0	0	0	0
Hylarana albolabris		0	0	0	0
Hylarana occidentalis		0	0	1	0
Hyperilous concolor		0	0	0	0
Leptopelis spiritusnoctis		0	0	0	0
Leptopelis occidentalis		0	0	0	0
Phrynobatrachus tokba		0	0	0	0
Phrynobatrachus latifrons		0	0	0	0
Phrynobatrachus alleni		2	5	13	7
Phrynobatrachus annulatus		0	0	3	12
Phrynobatrachus calcaratus		0	3	0	2
Phrynobatrachus liberiensis		6	11	8	3
Phrynobatrachus plicatus		6	2	14	9
Phrynobatrachus villiersi		0	0	1	0
Ptychadena aequiplicata		1	6	0	0
Ptychadena bibroni		0	0	0	0
Ptychadena longirostris		0	0	0	0
Ptychadena mascareniensis		0	0	0	0

Species	Date	Visit number	Plot	Treatment	Site
	06/01/2009	1	1	L10	Suhuma
	06/03/2009	2	1	L10	Suhuma
	25/6/2009	3	1	L10	Suhuma
	10/02/2009	4	1	L10	Suhuma
	13/12/2009	5	1	L10	Suhuma
	06/01/2009	1	2	L10	Suhuma
	06/03/2009	2	2	L10	Suhuma
	25/6/2009	3	2	L10	Suhuma
	10/02/2009	4	2	L10	Suhuma
	13/12/2009	5	2	L10	Suhuma
	06/01/2009	1	3	L10	Suhuma
	06/03/2009	2	3	L10	Suhuma
	25/6/2009	3	3	L10	Suhuma
	10/02/2009	4	3	L10	Suhuma
	13/12/2009	5	3	L10	Suhuma
	06/01/2009	1	4	L10	Suhuma
	06/03/2009	2	4	L10	Suhuma
	25/6/2009	3	4	L10	Suhuma
	10/02/2009	4	4	L10	Suhuma
	13/12/2009	5	4	L10	Suhuma
	06/01/2009	1	4	L10	Suhuma
	06/03/2009	2	4	L10	Suhuma
	25/6/2009	3	4	L10	Suhuma
	10/02/2009	4	4	L10	Suhuma
	13/12/2009	5	4	L10	Suhuma
Amietophrynus maculatus		0	0	0	0
Amietophrynus regularis		0	0	0	0
Amietophrynus togoensis		1	0	2	0
Arthroleptis krokosua		0	0	0	0
Arthroleptis sp*		9	3	9	1
Cardioglossa occidentalis		0	0	0	0
Hoplobatrachus occipitalis		0	0	0	0
Hylarana albolabris		1	0	0	0
Hylarana occidentalis		0	0	0	0
Hyperilous concolor		0	0	0	0
Leptopelis spiritusnoctis		0	0	0	0
Leptopelis occidentalis		0	0	0	0
Phrynobatrachus tokba		0	0	0	0
Phrynobatrachus latifrons		0	0	0	0
Phrynobatrachus alleni		3	1	5	2
Phrynobatrachus annulatus		5	2	7	3
Phrynobatrachus calcaratus		0	0	0	0
Phrynobatrachus liberiensis		0	0	1	0
Phrynobatrachus plicatus		5	2	7	0
Phrynobatrachus villiersi		0	0	0	0
Ptychadena aequiplicata		3	2	0	0
Ptychadena bibroni		0	0	0	0
Ptychadena longirostris		0	0	0	0
Ptychadena mascareniensis		0	0	0	0

Species	31/5/2009	06/02/2009	24/6/2009	30/9/2009	18/11/2009	31/5/2009	06/02/2009	24/6/2009	30/9/2009	18/11/2009	31/5/2009	06/02/2009	24/6/2009	30/9/2009	18/11/2009	31/5/2009	06/02/2009	24/6/2009	30/9/2009	18/11/2009
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20	L20
	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma	Suhuma
Amietophrynus maculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus regularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus togoensis	5	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Arthroleptis krokosua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis sp*	13	0	0	8	21	31	12	6	6	23	23	7	2	29	41	4	3	4	2	15
Cardioglossa occidentalis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hoplobatrachus occipitalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylarana albolabris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylarana occidentalis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyperilous concolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptopelis spiritusnoctis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptopelis occidentalis	0	0	0	0	0	3	0	2	1	0	2	0	0	0	0	0	0	0	0	0
Phrynobatrachus tokba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus latifrons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus alleni	10	16	7	13	3	5	12	0	2	6	12	6	6	3	3	24	12	11	3	7
Phrynobatrachus annulatus	0	28	1	19	9	9	11	2	3	5	23	2	16	2	6	1	9	20	3	1
Phrynobatrachus calcaratus	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Phrynobatrachus liberiensis	0	2	27	1	2	0	2	0	0	0	0	1	3	0	0	0	1	5	0	0
Phrynobatrachus plicatus	16	2	2	0	0	12	8	11	4	15	25	12	5	17	8	16	3	18	9	12
Phrynobatrachus villiersi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena aequiplicata	2	11	0	2	6	11	3	0	0	0	11	5	1	4	6	6	17	2	3	1
Ptychadena bibroni	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena mascareniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Date	Plot number	Treatment	Site	06/02/2009	06/04/2009	23/6/2009	10/02/2009	12/12/2009	06/02/2009	06/04/2009	23/6/2009	10/02/2009	12/12/2009	06/02/2009	06/04/2009	23/6/2009	10/02/2009	12/12/2009	06/02/2009	06/04/2009	23/6/2009	10/02/2009	12/12/2009	
Amietophrynus maculatus	06/02/2009	1	RL	Suhuma	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Amietophrynus regularis	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Amietophrynus togoensis	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis krokosua	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis sp*	06/02/2009	1	RL	Suhuma	12	7	17	9	25	21	12	19	7	28	52	18	23	33	61	30	24	19	13	41	0
Cardioglossa occidentalis	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hoplobatrachus occipitalis	06/02/2009	1	RL	Suhuma	0	2	0	3	3	0	0	4	0	6	0	0	0	0	2	0	0	0	0	0	0
Hylarana albolabris	06/02/2009	1	RL	Suhuma	4	1	1	0	2	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	3
Hylarana occidentalis	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyperilous concolor	06/02/2009	1	RL	Suhuma	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Leptopelis spiritusnoctis	06/02/2009	1	RL	Suhuma	2	1	2	0	5	1	0	5	1	0	2	0	0	0	0	0	0	1	0	0	0
Leptopelis occidentalis	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Phrynobatrachus tokba	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus latifrons	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus alleni	06/02/2009	1	RL	Suhuma	3	0	4	1	1	2	2	8	1	0	0	0	3	0	0	0	0	4	1	0	0
Phrynobatrachus annulatus	06/02/2009	1	RL	Suhuma	1	2	6	2	1	3	0	4	1	2	0	5	10	3	2	2	0	6	0	0	0
Phrynobatrachus calcaratus	06/02/2009	1	RL	Suhuma	0	0	0	0	3	2	3	0	0	4	0	0	0	0	0	2	0	1	0	3	0
Phrynobatrachus liberiensis	06/02/2009	1	RL	Suhuma	0	0	2	1	0	0	0	0	0	0	6	0	0	2	1	0	0	2	0	0	0
Phrynobatrachus plicatus	06/02/2009	1	RL	Suhuma	1	3	5	2	0	0	6	4	2	2	2	0	0	2	4	5	2	8	2	3	0
Phrynobatrachus villiersi	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena aequiplicata	06/02/2009	1	RL	Suhuma	0	0	1	0	0	0	0	2	0	0	1	0	7	0	0	0	0	0	0	0	0
Ptychadena bibroni	06/02/2009	1	RL	Suhuma	2	1	0	1	3	2	0	0	0	0	1	0	1	0	3	0	0	0	0	0	0
Ptychadena longirostris	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena mascareniensis	06/02/2009	1	RL	Suhuma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Date	Plot number	Treatment	Site
	24/6/2009	1	Unlogged	Krokosua
	26/6/2009	2	Unlogged	Krokosua
	23/7/2009	3	Unlogged	Krokosua
	10/05/2009	4	Unlogged	Krokosua
	14/12/2009	5	Unlogged	Krokosua
	24/6/2009	1	Unlogged	Krokosua
	26/6/2009	2	Unlogged	Krokosua
	23/7/2009	3	Unlogged	Krokosua
	10/05/2009	4	Unlogged	Krokosua
	14/12/2009	5	Unlogged	Krokosua
	24/6/2009	1	Unlogged	Krokosua
	26/6/2009	2	Unlogged	Krokosua
	23/7/2009	3	Unlogged	Krokosua
	10/05/2009	4	Unlogged	Krokosua
	14/12/2009	5	Unlogged	Krokosua
	24/6/2009	1	Unlogged	Krokosua
	26/6/2009	2	Unlogged	Krokosua
	23/7/2009	3	Unlogged	Krokosua
	10/05/2009	4	Unlogged	Krokosua
	14/12/2009	5	Unlogged	Krokosua
	24/6/2009	1	Unlogged	Krokosua
	26/6/2009	2	Unlogged	Krokosua
	23/7/2009	3	Unlogged	Krokosua
	10/05/2009	4	Unlogged	Krokosua
	14/12/2009	5	Unlogged	Krokosua
	24/6/2009	1	Unlogged	Krokosua
	26/6/2009	2	Unlogged	Krokosua
	23/7/2009	3	Unlogged	Krokosua
	10/05/2009	4	Unlogged	Krokosua
	14/12/2009	5	Unlogged	Krokosua
Amietophrynus maculatus		0		0
Amietophrynus regularis		0		0
Amietophrynus togoensis		0		0
Arthroleptis krokosua		0		0
Arthroleptis sp*		8		3
Cardioglossa occidentalis		0		0
Hoplobatrachus occipitalis		0		0
Hylarana albolabris		2		4
Hylarana occidentalis		0		0
Hyperilous concolor		0		0
Leptopelis spiritusnoctis		0		0
Leptopelis occidentalis		0		0
Phrynobatrachus tokba		0		0
Phrynobatrachus latifrons		0		0
Phrynobatrachus alleni		6		5
Phrynobatrachus annulatus		3		7
Phrynobatrachus calcaratus		0		0
Phrynobatrachus liberiensis		1		1
Phrynobatrachus plicatus		0		0
Phrynobatrachus villiersi		0		0
Ptychadena aequiplicata		4		3
Ptychadena bibroni		0		0
Ptychadena longirostris		0		0
Ptychadena mascareniensis		0		0

Species	Date	Plot number	Treatment	Site																			
	26/6/2009	1	L10	Krokosua																			
	28/6/2009	2	L10	Krokosua																			
	22/6/2009	3	L10	Krokosua																			
	10/06/2009	4	L10	Krokosua																			
	15/12/2009	5	L10	Krokosua																			
	26/6/2009	2	L10	Krokosua																			
	28/6/2009	2	L10	Krokosua																			
	22/6/2009	3	L10	Krokosua																			
	10/06/2009	4	L10	Krokosua																			
	15/12/2009	5	L10	Krokosua																			
	26/6/2009	3	L10	Krokosua																			
	28/6/2009	3	L10	Krokosua																			
	22/6/2009	3	L10	Krokosua																			
	10/06/2009	3	L10	Krokosua																			
	15/12/2009	3	L10	Krokosua																			
	26/6/2009	4	L10	Krokosua																			
	28/6/2009	4	L10	Krokosua																			
	22/6/2009	4	L10	Krokosua																			
	10/06/2009	4	L10	Krokosua																			
	15/12/2009	4	L10	Krokosua																			
	26/6/2009	5	L10	Krokosua																			
	28/6/2009	5	L10	Krokosua																			
	22/6/2009	5	L10	Krokosua																			
	10/06/2009	5	L10	Krokosua																			
	15/12/2009	5	L10	Krokosua																			
Amietophrynus maculatus	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
Amietophrynus regularis	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus togoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Arthroleptis krokosua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis sp*	4	4	3	7	20	9	2	8	9	15	39	30	17	23	45	8	10	13	11	25			
Cardioglossa occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hoplobatrachus occipitalis	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylarana albolabris	0	0	1	0	0	0	0	2	0	0	2	1	5	2	1	0	0	0	0	0	0	0	0
Hylarana occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyperilous concolor	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Leptopelis spiritusnoctis	0	0	0	0	1	0	0	0	1	1	0	0	0	2	1	0	0	0	0	0	0	0	0
Leptopelis occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus tokba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus latifrons	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus alleni	6	2	3	0	0	5	3	0	0	0	6	2	8	1	3	0	0	5	0	0	0	0	0
Phrynobatrachus annulatus	11	2	7	0	0	8	2	5	0	0	1	1	6	0	2	6	1	4	2	0	0	0	0
Phrynobatrachus calcaratus	0	0	0	2	0	0	0	0	2	3	0	0	2	0	0	0	0	0	0	0	0	1	0
Phrynobatrachus liberiensis	0	0	1	0	0	0	0	1	0	0	0	0	4	2	0	0	0	1	1	0	0	0	0
Phrynobatrachus plicatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus villiersi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena aequiplicata	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena bibroni	0	0	0	0	2	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0
Ptychadena longirostris	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena mascareniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Date	Visit number	Plot	Treatment	Site
25/6/2009	1	1	L20	Krokosua
27/6/2009	2	1	L20	Krokosua
20/7/2009	3	1	L20	Krokosua
10/05/2009	4	1	L20	Krokosua
16/12/2009	5	1	L20	Krokosua
25/6/2009	1	2	L20	Krokosua
27/6/2009	2	2	L20	Krokosua
20/7/2009	3	2	L20	Krokosua
10/05/2009	4	2	L20	Krokosua
16/12/2009	5	2	L20	Krokosua
25/6/2009	1	3	L20	Krokosua
27/6/2009	2	3	L20	Krokosua
20/7/2009	3	3	L20	Krokosua
10/05/2009	4	3	L20	Krokosua
16/12/2009	5	3	L20	Krokosua
25/6/2009	1	4	L20	Krokosua
27/6/2009	2	4	L20	Krokosua
20/7/2009	3	4	L20	Krokosua
10/05/2009	4	4	L20	Krokosua
16/12/2009	5	4	L20	Krokosua

Species

Amietophrynus maculatus	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus regularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus togoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis krokosua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis sp*	2	4	13	3	20	8	12	10	21	27	28	19	13	11	31	6	2	6	3	11
Cardioglossa occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hoplobatrachus occipitalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylarana albolabris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylarana occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyperilous concolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptopelis spiritusnoctis	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptopelis occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus tokba	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Phrynobatrachus latifrons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus alleni	3	2	11	1	3	9	10	3	1	2	0	0	0	0	0	2	1	9	1	0
Phrynobatrachus annulatus	8	1	11	4	3	5	3	17	0	5	1	7	11	1	0	1	2	3	1	1
Phrynobatrachus calcaratus	1	0	0	3	6	0	0	0	0	0	0	1	3	4	16	0	0	0	0	0
Phrynobatrachus liberiensis	0	0	2	0	0	0	0	2	0	0	0	0	4	0	0	0	0	6	0	0
Phrynobatrachus plicatus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phrynobatrachus villiersi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena aequiplicata	0	0	1	0	0	0	0	3	0	0	0	0	6	2	0	0	0	0	0	0
Ptychadena bibroni	0	0	0	1	2	0	0	0	0	2	2	0	0	0	2	0	0	0	0	1
Ptychadena longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptychadena mascareniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Date	Visit number	Plot	Treatment	Site
Amietophrynus maculatus	27/6/2009	1	1	RL	Krokosua
Amietophrynus regularis	29/6/2009	2	1	RL	Krokosua
Amietophrynus togoensis	21/6/2009	3	1	RL	Krokosua
Arthroleptis krokosua	10-Jun	4	1	RL	Krokosua
Arthroleptis sp*	15/12/2009	5	1	RL	Krokosua
Cardioglossa occidentalis	27/6/2009	1	2	RL	Krokosua
Hoplobatrachus occipitalis	29/6/2009	2	2	RL	Krokosua
Hylarana albolabris	21/6/2009	3	2	RL	Krokosua
Hylarana occidentalis	10-Jun	4	2	RL	Krokosua
Hyperilous concolor	15/12/2009	5	2	RL	Krokosua
Leptopelis spiritusnoctis	27/6/2009	1	3	RL	Krokosua
Leptopelis occidentalis	29/6/2009	2	3	RL	Krokosua
Phrynobatrachus tokba	21/6/2009	3	3	RL	Krokosua
Phrynobatrachus latifrons	10-Jun	4	3	RL	Krokosua
Phrynobatrachus alleni	15/12/2009	5	3	RL	Krokosua
Phrynobatrachus annulatus	27/6/2009	1	3	RL	Krokosua
Phrynobatrachus calcaratus	29/6/2009	2	3	RL	Krokosua
Phrynobatrachus liberiensis	21/6/2009	3	3	RL	Krokosua
Phrynobatrachus plicatus	10-Jun	4	3	RL	Krokosua
Phrynobatrachus villiersi	15/12/2009	5	3	RL	Krokosua
Ptychadena aequiplicata	27/6/2009	1	4	RL	Krokosua
Ptychadena bibroni	29/6/2009	2	4	RL	Krokosua
Ptychadena longirostris	21/6/2009	3	4	RL	Krokosua
Ptychadena mascareniensis	10-Jun	4	4	RL	Krokosua
	15/12/2009	5	4	RL	Krokosua

	Date	Plot Visit number	Treatment	Site
	30/7/2009	1	Unlogged	Sui
	08/09/2009	2	Unlogged	Sui
	13/8/2009	3	Unlogged	Sui
	17/11/2009	4	Unlogged	Sui
	18/12/2009	5	Unlogged	Sui
	30/7/2009	1	Unlogged	Sui
	08/09/2009	2	Unlogged	Sui
	13/8/2009	3	Unlogged	Sui
	17/11/2009	4	Unlogged	Sui
	18/12/2009	5	Unlogged	Sui
	30/7/2009	3	Unlogged	Sui
	08/09/2009	3	Unlogged	Sui
	13/8/2009	3	Unlogged	Sui
	17/11/2009	3	Unlogged	Sui
	18/12/2009	3	Unlogged	Sui
	30/7/2009	4	Unlogged	Sui
	08/09/2009	4	Unlogged	Sui
	13/8/2009	4	Unlogged	Sui
	17/11/2009	4	Unlogged	Sui

Species

Amietophrynus maculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus regularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amietophrynus togoensis	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	2	0
Arthroleptis krokosua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthroleptis sp*	6	10	2	3	18	11	15	9	8	33	21	2	20	19	37	2	6	11	1	
Cardioglossa occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Hoplobatrachus occipitalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Hylarana albolabris	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	
Hylarana occidentalis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Hyperilous concolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Leptopelis spiritusnoctis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Leptopelis occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Phrynobatrachus tokba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Phrynobatrachus latifrons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Phrynobatrachus alleni	2	3	12	6	4	4	0	16	7	3	5	2	23	3	9	8	7	2	7	
Phrynobatrachus annulatus	2	4	9	2	3	1	1	1	9	2	0	0	16	3	4	7	11	5	0	
Phrynobatrachus calcaratus	4	6	8	1	2	0	2	14	0	1	0	0	0	0	1	2	5	2		
Phrynobatrachus liberiensis	2	1	4	1	0	3	0	10	0	0	0	2	15	0	0	0	3	10	0	
Phrynobatrachus plicatus	9	3	12	5	2	0	0	13	1	0	1	2	15	3	4	7	3	0	6	
Phrynobatrachus villiersi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Ptychadena aequiplicata	0	2	5	0	0	0	3	4	0	0	0	0	5	0	0	0	0	0	0	
Ptychadena bibroni	0	0	0	0	0	0	0	6	0	0	0	0	0	1	0	0	0	0	0	
Ptychadena longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Ptychadena mascareniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

	Site	Treatment	Plot	Visit	Date	Species	31/7/2009	08/01/2009	08/09/2009	08/10/2009	17/12/2009	31/7/2009	08/01/2009	08/09/2009	08/10/2009	17/12/2009	31/7/2009	08/01/2009	08/09/2009	08/10/2009	17/12/2009	31/7/2009	08/01/2009	08/09/2009	08/10/2009	17/12/2009	
	Sui	L20	1	1	31/7/2009	Amietophrynus maculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Sui	L20	1	2	08/01/2009	Amietophrynus regularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Sui	L20	1	3	08/09/2009	Amietophrynus togoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Sui	L20	1	4	08/10/2009	Arthroleptis krokosua	0	0	5	0	0	0	0	0	2	2	0	0	3	0	0	0	1	0	0	0	0
	Sui	L20	1	5	17/12/2009	Arthroleptis sp*	4	2	14	3	19	3	12	20	2	41	23	8	6	23	42	8	2	12	2	4	
	Sui	L20	2	1	31/7/2009	Cardioglossa occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	2	2	08/01/2009	Hoplobatrachus occipitalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	2	3	08/09/2009	Hylarana albolabris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	2	4	08/10/2009	Hylarana occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	3	1	31/7/2009	Hyperilous concolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	3	2	08/01/2009	Leptopelis spiritusnoctis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
	Sui	L20	3	3	08/09/2009	Leptopelis occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	3	4	08/10/2009	Phrynobatrachus tokba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	4	1	31/7/2009	Phrynobatrachus latifrons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	4	2	08/01/2009	Phrynobatrachus alleni	1	3	8	2	6	6	2	10	4	3	1	2	7	12	8	3	2	5	2	1	
	Sui	L20	4	3	08/09/2009	Phrynobatrachus annulatus	1	0	16	2	8	3	5	7	11	4	5	4	10	1	0	2	3	5	0	1	
	Sui	L20	4	4	08/10/2009	Phrynobatrachus calcaratus	2	0	0	0	0	6	5	11	1	2	3	2	5	0	2	0	11	4	5	1	
	Sui	L20	5	1	31/7/2009	Phrynobatrachus liberiensis	0	0	0	0	2	0	1	1	0	0	0	0	3	1	0	2	0	3	1	0	
	Sui	L20	5	2	08/01/2009	Phrynobatrachus plicatus	0	3	6	2	9	4	8	3	12	23	7	13	10	5	32	13	1	6	31	14	
	Sui	L20	5	3	08/09/2009	Phrynobatrachus villiersi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
	Sui	L20	5	4	08/10/2009	Ptychadena aequiplicata	0	0	0	0	1	4	6	21	2	1	7	0	19	5	9	2	0	7	3	9	
	Sui	L20	4	1	31/7/2009	Ptychadena bibroni	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
	Sui	L20	4	2	08/01/2009	Ptychadena longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sui	L20	4	3	08/09/2009	Ptychadena mascareniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

