DISTRIBUTION AND FEEDING ECOLOGY OF AMPHIBIAN (ANURAN) SPECIES IN KIMBOZA FOREST RESERVE IN MOROGORO DISTRICT, MOROGORO REGION, TANZANIA

ASHA KAMUNGU

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ECOSYSTEM SCIENCE AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2018

ABSTRACT

An assessment of the distribution and feeding ecology of amphibian (anuran) species of Kimboza Forest Reserve, Tanzania was conducted between March 2017 and April 2017. Visual encounter survey and capture methods were used to study the distribution of anurans. Captured animals were degutted and their gut contents were used in the study of feeding ecology. A total of 13 species of amphibian belonging to 7 families of order anuran were found to exist in Kimboza forest. The highest occurrence of anurans (70%) was recorded in areas where forest border with farms and along Kimboza forest streams. The study showed that there was no significant variation of occurrence of anurans among different habitats in Kimboza forest (Q=11; DF =6; P=0.096). On the other hand, about 462 prey items belonging to 10 food groups were found in the guts of 93 captured anurans and the most abundant food groups were Isoptera and Hymenoptera while Coleoptera were the most frequent. There were no significant differences in the anurans' diet (composition, diversity and preferences) among different habitats of the forest (along boundaries and within the forest) but significant differences were found between the upper fragment and the lower fragment of the forest. The similarities of diets of anurans in different habitats along forest boundaries and within the forest were due to the fact that most of anurans were generalist predators. The study provides a preliminary estimation of the actual diet of anurans and establishes a general distribution pattern for these species in Kimboza forest. These findings are important for understanding and management of anurans in Kimboza Forest Reserve. Further studies focused on dry season and nocturnal species are recommended so as to come up with a complete description of the distribution and feeding ecology of anuran species of Kimboza Forest Reserve.

DECLARATION

I, ASHA KAMUNGU, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor is being concurrently submitted to any other institution.

…………………………………. ………………………………….
Asha Kamungu   Date

(MSc. Candidate)

The above declaration is confirmed by:

…………………………………. ………………………………….
Dr. N. E. J. Mbije   Date
(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

I would to like to express my gratitude to the many people and institutions whose support made this dissertation possible.

First, I want to warmly thank my supervisor, Dr. N. E. J. Mbije, very much for his patience, friendly mode, constructive criticisms and support in all phases of this study but also for his inspiration and encouragement towards my better scientific future.

Many thanks should go to the District Forest Manager of Morogoro Mr. S. K. Nyabange for grating me permit to do research in Kimboza Forest Reserve. Special thanks to Kimboza Forest Reserve guard, Mr. Jeremiah Y. Paul for his facilitation and support during field work.

I am thankful to my field assistants, Ali Salum, Rama Mitiku and Ansifrid Mkongoja for their hard work and tolerance during data collection. Further, I am very greatfully to Dr. Ngalason of University of Dar es Salaam for assisting me in identification of amphibian species.

I also appreciate Prof. R. L. Mwamakimbulah for his valuable advice and support to making this dissertation possible. I am grateful to Mr. Imani Kambindu holder of Bachelor of Science in Applied Statistics of Mzumbe University for his assistance on data analysis and constructive advice on data interpretation.

Finally, I would like to thank very much The Almighty God who gave me strength and the ability to complete this work but also to give deep appreciation to my family, my father

DEDICATION

This dissertation is dedicated to:

i.   My beloved parents, Hamisi Twaibu Kamungu and Caroline Mwalivalila who funded this study and for their unfailing love.

ii.   My brothers, Hamisi Kamungu, Hasani Kamungu and my sister Sofia Kamungu for their support and affectionate love.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

DFP   Degree of Food Preferences

EAMCEF   Eastern Arc Mountains Conservation Endowment Fund

GIS   Geographical Information System

h   Hours

HIV   Human Immunodeficiency Virus

IUCN   International Unoin for Conservation of Nature

Km   Kilometer

LFF   along the forest and farm border in the lower segment of the forest

LFI   interior of the forest in lower segment of the forest

LFRS   along the forest border with road and along Kimboza stream in lower

                 segment of the forest

m   Meter

mm   Millimeter

MNRT   Ministry of Natural Resource and Tourism

SUA   Sokoine University of Agriculture

UFF   along the forest and farm border in the upper segment of the forest

UFI   interior of the forest in the upper segment

UFR   along the forest and road border in the upper segment of the forest

UFS   along the Kimboza streams in the upper segment of the forest

UV-B   Ultra Violet B

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Amphibians are mostly considered to be generalist predators (Pough *et al.,* 2004). Some species have a narrow diet or even specialise on certain prey categories. For example a number of species of Microhylids and Dendrobatids, have specialised on eating ants and termites (Hirai and Matsui, 2000; Solé *et al.,* 2002). Nevertheless, within the generalist specialist continuum, there are several species that have highly varied diets, but with concentrated consumption of a few prey categories (Siqueira *et al*., 2006; Lima *et al.,* 2010).

The differences in diet composition are probably due to variation of habitats abundance and diversity of prey (Sousa and Avila, 2015). The type and quality of habitat tend to influence the distribution and feeding preferences in anurans (Ferenti *et al.,* 2010). For instance, anthropogenic disturbance of habitat can lead to variation in composition and abundance of resources, and as a result some species may adjust their diets. Generalist species are a good example of such species as they have the ability to adjust their diets to the more available resources in order to improve their energy uptake and fitness (Gray and Smith, 2005; Williams *et al.,* 2006; Falico *et al*., 2012). However, the highly specialised species or those with specific and fixed trophic requirements have greater difficulties of coping with environmental alterations which usually cause changes to prey availability (Williams *et al.,* 2006).

Amphibians (anurans) are distributed in different forest types and in different microhabitats. There are many factors that influence the differences in the distribution of

anuran species in their habitats. For example, diet was found to be one of the factors by Allmon (1991) who observed that the distribution patterns of forest leaf litter anurans was linked to prey availability. Further, there are other factors which are reported to influence the differences of distribution of anuran species in the same habitat including environmental structure (Menin *et al*., 2005), differential utilisation of microhabitat and foraging strategy (França *et al*., 2004).

Amphibians are an abundant and diverse component of many terrestrial and freshwater ecosystems where they play critical roles in food webs often linking terrestrial and aquatic ecosystems (Pradhan *et al*., 2014). The rapid and ongoing reduction of amphibians' species richness worldwide has added urgency for dedicated efforts to understand the ecological roles that they play within ecosystems (Connelly *et al.,* 2011). Threats to amphibians are particularly evident in the coastal region of Tanzania, where forests continue to decline as a consequence of expanding populations and proximity to urban areas (Barratt *et al.,* 2014). Feeding can be an important parameter for the understanding of anuran life history, population fluctuations, the impact of habitat modification on those populations especially for species that inhabit endangered areas, and as an indicator of the quality of the environment in which the amphibians live (Santos *et al*., 2004 ; Kovacs *et al.,* 2007).

1.2 Problem Statement and Justification of the Study

Amphibian population is steadily declining where by it is approximated that 97 percent of the existing species are found in protected areas (Milligan *et al.,* 2014). The main reasons for the population decline include habitat loss and degradation (Milligan *et al.,* 2014). Yet, amphibians have not been given appropriate attention with regard to their ecological roles in ecosystems to where they exist (Valencia-Aguilar *et al.,* 2013). This, among many

reasons, is brought about by low level of understanding regarding the roles that amphibians play in ecosystems (Bickford *et al.,* 2010; Hocking and Babbitt, 2014). A good example is in Kimboza forest reserve where there is poor information on amphibians due to little attention with regard to their important ecological roles (Bayliss, 1994; Clarke and Dickinson, 1995). None of the studies conducted so far have involved the understanding of distribution, dietary composition and feeding preferences of anurans.

Although a few studies exist, Kimboza forest reserve is known to harbor high diversity of amphibians. However, the home ranges and foraging habitats for these species are threatened by increased anthropogenic disturbances resulting from illegal agriculture activities in the forest area, timbers and pole harvesting carried out by people in the villages surrounding the forest (Kacholi, 2013). Since, amphibians are important components in trophic cascades of ecosystems, their vanishing may bring crucial effects on ecosystem functioning (Mohneke and Rödel, 2009). Accordingly, besides available basic ecological and biological data on amphibians, studies on feeding ecology can help to open up abundant but hidden ecological information which can be used to estimate the effects of loss of amphibians on ecosystem functioning (Duffy, 2002; Whiles *et al.* 2006). Furthermore, information on amphibian distribution is essential in understand where species occur and to be able to determine sound conservation strategies of the species (Dodd and Smith, 2003). Therefore, this study was aimed at unveiling the distribution and feeding ecology of Amphibians of Kimboza forest reserve. Besides being the first of its kind in Tanzania for the class, the information about predation competition and trophic cascades is of great use in furthering understanding of amphibian ecology.

1.3 Objectives of the Study

1.3.1 Overall objective

The overall aim of the study was to describe the distribution and feeding ecology of amphibian (anuran) species in Kimboza Forest Reserve.

1.3.2 Specific objectives

The specific objectives of the study were:

i. To examine the distribution of anurans in different habitats across Kimboza Forest Reserve.

ii. To analyze the anuran dietary composition.

iii. To examine the anuran dietary diversity.

iv. To assess the influence of habitat on the feeding preferences of anuran species in Kimboza forest Reserve.

1.3.3 Research questions

To realize the specific objectives, the study was guided by these questions:

i. How are anurans species distributed across different habitats along boundaries and within Kimboza forest?

ii. What is the food composition of anuran species in Kimboza forest?

iii. How diverse is the food composition of anuran species in Kimboza forest?

iv. How do different habitats along boundaries and within the forest influence the feeding preference of anuran species in Kimboza forest?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Amphibians

Amphibians can be defined as quadrupedal vertebrates having two occipital condyles on the skull and no more than one sacral vertebrate with glandular skin that lacks the epidermal structures (scales, feathers, and hairs) (Duellman and Treub, 1986). They are generally known as tetrapods with aquatic larvae and terrestrial adults, although amphibians may have other life histories. Further life histories of amphibians include permanently aquatic or strictly terrestrial and lack of aquatic larvae. Amphibian species with strictly terrestrial life occur in majority of salamander and caecilians species, but also in more than a thousand frogs. These members lay eggs on land which develop directly into miniatures of adult. Furthermore, some of frogs transfer eggs to male vocal sacs, or to pouches in the skin of the back of female, or even to the stomach of females to avoid use of aquatic habitat. On the other hand, some members of amphibian are live-bearers, giving birth to metamorphosed young that have been nourished during development in the reproductive tract of the female (Whittaker *et al.*, 2013).

There are over 7000 species of amphibian worldwide. Over 6 800 species of amphibians are placed in three orders Anura (the frogs and toads), Caudata (salamanders), and Gymnophiona (caecilians). Among all the three groups, anurans comprise most of the amphibians containing over 6000 species. Salamanders and caecilians contain more than 600 species and nearly 200 species, respectively (Amphibian Web, 2017). In general, anurans are defined as tailless amphibians with elongated hind limbs having the most distinctive features which are concentrated at the rear end of the animal the fused post sacral vertebrate which form a single bone (the urostyle, or cocoyx). This distinctive

feature gives anurans their characteristic squatting reciprocation calls for receptive female in response to male advertisements (Duellman and Treub; 1986 Beebee, 1996). Furthermore, anurans are able to jump because of their very short and stiffened trunk with relatively elongated legs and feet, although some species walk, hop, or burrow.

On the other hand, majority of salamanders have the structure of a generalised tetrapod with four legs, a relatively short but flexible trunk, and a tail. Some are exceptionally elongated with very small limbs or only forelimbs. Salamanders can be very large about 1.5m in size. In contrast, caecilians do not possess limbs and their eyes are covered by skin or bone. Caecilians have high numbers of trunk vertebrae and are very elongated, but they either lack entirely or have an exceedingly short tail (Whittaker *et al.*, 2013).

Amphibians comprise a diverse component in both aquatic and terrestrial ecosystems. They are normally important components of communities and food webs. In some ecosystems, amphibians are the dominant predators, both in terms of numbers and total biomass. Adult amphibians are effective predators (Whittaker *et al.*, 2013).

2.2 Distribution of Anurans

Anurans are distributed in different forest types and in different microhabitats. Some of them live in specialised niches that are created by the seasons, climate and life zones. These niches influence anurans abundance and distribution over the different forest types (Savage, 2002; Wells, 2007). Allmon (1991) found that distribution patterns of forest leaf litter anurans are associated with prey availability. Therefore, knowledge on feeding ecology of coexisting anuran species contributes to the understanding of the organisation of the respective communities (Juncá and Eterovick, 2007).

However, diet is not the only factor that influences the differences in distribution among sympatric species. There are other factors like, differences in foraging strategy (França *et al*., 2004), differential utilisation of microhabitat (França *et al*., 2004; Dure and Kehr, 2004), and environmental structure (Menin *et al*., 2005). Interaction of these factors determines the coexistence among species in amphibian communities (Narváez *et al.,* 2014). For instance, amphibian distributions at a breeding pond are influenced by pond hydroperiod (Collins and Wilbur, 1979), type and amount of vegetation surrounding the breeding site (Skelly *et al.,* 1999), presence of fish and/or other predators (Semlitsch, 2000) and water chemistry (Hecnar and M'Closkey, 1996).

Furthermore, amphibian species have different habitat preferences. For instance, many amphibian species are known to have specific non-breeding habitat preferences. Eastern gray treefrogs and spring peepers are the good examples of such species since they spend the majority of their lives in forests or wooded wetlands after the breeding season (Harding, 1997). Other species may be less specific in their habitat requirements in and near breeding sites like the American toad and green frog (Price *et al*., 2005).

Again, Carr and Fahrig (2001) found that infrastructure and other anthropogenic characteristics also influence anuran distributions. For instance, habitat fragmentation caused by roads can reduce amphibian abundance and isolate populations by impeding amphibian movements across landscapes. Also, urbanisation contributes to the complete loss of habitat which can eventually lead to local population extinction. On the other hand, Price *et al.* (2005) found that some of the anurans species may use drainage ditches and other habitat modifications to serve as dispersal corridors or to replace natural wetlands in agricultural landscapes (Reh and Seitz, 1990). In general, the investigation of amphibian

distribution and status is necessary to understand where species occur and to determine if declines have taken place or are in progress (Dodd and Smith, 2003).

2.3 Feeding Ecology

Feeding ecology is defined as the processes which determine general diet. However, feeding ecology and foraging behavior which is defined as that which is required to stalk, catch, manipulate and eat prey are arbitrary as the processes covered by each of term are not mutually exclusive. There are significant areas of overlap between the two terms (Carss, 1995). Feeding is a fundamental function of any organism. Feeding provide mean of understanding organism connection to the environmental resources, and to determine its relation to the environment. Consequently, feeding is an essential indicator of the position of a species in an ecosystem as it is the primary link between an animal and its environment (Kenett and Tory, 1996). Studies on feeding of sensitive animals like anurans are capable of providing much information about the stage of habitat degradation (Ferenti *et al.,* 2010). Furthermore, characterisations of feeding provide means for understanding different biological aspects such as: the ecological organisation in communities and assemblages (Arroyo *et al.,* 2008), the phylogenetic relationships among species (Grant *et al.*, 2006), and their behavior and physiology (Lima and Magnuson, 1998).

There are various factors influencing the feeding habits in amphibians, such as seasonal abundance of food (Toft, 1980), ecological tolerances, and morphological constraints (Pough *et al.*, 2004). Several anurans have evolved adaptations related to feeding mode (Meyers *et al.*, 2004). Among the most interesting of these are the alkaloid-containing anurans in families: Dendrobatidae (various genera) and Bufonidae (*Melanophryniscus*), and the Madagascan Mantellidae (*Mantella*). Alkaloids play a role in defense from predators (Daly *et al.*, 1987). Saporito *et al*. (2007) found that specialization on ants and

termites by some dendrobatid species is related with production of toxic alkaloids found in their skins.

Traditionally, amphibian feeding ecology analysis has been carried out based on taxonomic identification of gut contents (López *et al*., 2005). Amphibians have been classified as active or passive ("sit and wait") foragers, and specialist, intermediate or generalist predators depending on relative proportions of the different type of prey found in their gastrointestinal tracts (López *et al*., 2003). Toft (1981) found that sit-and-wait species consume a few large preys, while active foraging species consume small, highly mobile prey. Moreover, individuals may use different foraging strategies as a response to fluctuations in prey abundance (Duellman and Trueb, 1994).

Toft (1981) further explained that there are two adaptive pick of anuran species foraging strategies that is sit and wait (broad niche species) and active foragers (narrow niche species) meaning anurans using sit and wait strategy had broad niche while those with active foraging strategy had narrow niche. Evidence shows that species with a tendency towards active foraging are partially independent of the aquatic environment, while those showing a tendency for the sit and wait strategy have higher dependence on aquatic or semi-aquatic environments (Haddad and Prado, 2005).

The type of foraging and trophic niche could be also related to structural differences in habitat heterogeneity. Areas with waters sources tend to have higher structural heterogeneity compared with dry areas (Méndez-Narváez *et al.,* 2014). Therefore, anurans feeding on water sources are expected to have greater availability of prey items compared to dry areas, because of the positive correlation between heterogeneity and diversity of arthropods (Tews *et al*., 2004), and thus they can exhibit a sit and wait strategy and abroad

trophic niche. Meanwhile, those on grasslands, where is characterised by low diversity of invertebrate and the dominance of ants (Kamura *et al*., 2007), should be active for detection and capturing (Dure and Kehr, 2004).

2.4 The Dietary Composition of Anuran Species

The diet of anurans reveals thier source of energy for growth maintenance, and reproduction but it also indicates part of their ecological roles (Zug *et al*., 2001). Diets of anuran species depend on factors, such as morphological constraints associated to life-history stage, size, specialisation, foraging mode, diet plasticity, presence or absence of competitors and changes in resource availability due to habitat alterations by humans (Lima *et al*., 2010). Traditionally anurans are described as generalist predators, with opportunistic foraging behavior (Duellman and Trueb, 1986) and this is because almost all of them have low level of discrimination in feeding (Stebbins and Cohen, 1997).

The diet of adult anurans consists mainly of invertebrates (Anderson *et al.*, 1999). However, small vertebrates, such as fish, rodents, birds, reptiles and amphibians may occasionally be consumed by larger amphibian species (Duellman and Trueb, 1986; Beebee, 1996) and cannibalism may also occur (Jordan *et al.,* 2004). Some species are also found to rarely feed on plant materials and other non moving food items (Santos *et al.,* 2004). Kovács *et al.* (2007) found that increase of the feeding intensity result to rise of accidental ingestion of vegetal fragments.

Anurans do not wholly lack food preferences (Stebbins and Cohen, 1997). There are some of species with narrow diet or even specialise on certain prey items. Specialisation in diet is frequently linked with morphological, physiological, and behavioral characteristics that facilitate location, identification, capture, ingestion, and digestion of prey items (Solé and

Rödder, 2009). Some of anuran species have specialized in eating ants and termites. Evidence shows that specialization on ants and termites by some dendrobatid species is related with production of toxic alkaloids found in their skins (Saporito *et al.,* 2007).

Anuran diet varies and these differences in diet composition are probably due to variation in abundance and prey diversity of an area (Sousa and Avila, 2015). For instance anurans occupying different habitats may have variation on the prey items they eat. Therefore on this basis, data on diet composition can support both ecological and behavioural studies (Fabricante and Nuñeza, 2012). On the other hand, species using the same habitats in the area may consume similar food (Nuneza *et al.,* 2012). The diet of anuran may vary due to time and space variations (Quiroga *et al*., 2011). Accordingly, dietary descriptions of anurans from different localities are important. Studies concerning the diet of adult amphibians have been conducted for various species in almost all regions of the world, although studies on African anurans are comparatively rare (Hirschfeld and Rödel, 2011).

2.5 The Dietary Diversity of Anuran Species

The habitat morphology is reflected by the food eaten by anurans. For instance, areas with water sources tend to have higher structural heterogeneity compared to dry areas (Méndez-Narváez *et al.,* 2014), and therefore anurans feeding on the water source areas are expected to have greater availability of prey items than anurans in dry areas.

The habitat quality and local arthropod diversity affects the source of food for anurans (Daly *et al*., 2008). Ferenti *et al.* (2010) established that the highest diversity values of the feeding occur in habitats where the percentage abundance of terrestrial and aquatic prey was close. Further, the diversity of food groups tends to vary with season, and for instance slightly increase of diversity usually occurs in wet seasons. Generally, the food diversity

of anurans can be an indicator of the quality of the environment in which the amphibians live (Kovács *et al*., 2007).

2.6 The Influence of the Habitat on the Feeding Preferences of Anuran Species

Habitat has a strong impact on the feeding preferences of anuran species which include food composition and frequency, size and volume of prey (Plistli *et al.,* 2016). Martin (1998) found that the initial phase of the development of previous changes within a population is influenced locally by microhabitats. The environmental changes that take place in habitats may result to decrease or increase of prey number in habitats depending on whether the changes are either unfavorable or favorable for preys. These changes of either decrease or increase of prey in habitat will in turn affect the predatory anurans. As a result, the diet composition of anuran species may vary according to the prey items available in a specific habitat (Maneyro and da Rosa, 2004). For example, the diet composition varies between natural and anthropogenic habitats (Solé and Rödder, 2009). Again, the rate of feeding activity of anurans is usually determined by changes happening in the microhabitat. For instance, the variation of feeding intensity of anurans is a result of either modification of the environmental conditions or because of the anthropogenic effect upon the habitats (Kovacs *et al*., 2007; Covaciu- Marcov *et al*., 2010).

The similarity of the food consumed by anuran species is the result of species occupying the same habitats in the area (Nuneza *et al.,* 2012), meaning that the similarity of the habitat morphology is reflected by the food consumed by anurans. Furthermore, the type of foraging and trophic niche of anurans could be related to structural differences in habitat heterogeneity (Méndez-Narváez *et al.,* 2014). This is because feeding behavior of anurans is strongly linked to the conditions where anurans live, for example anurans may

use different foraging behaviors in order to avoiding food competition (Vignoli *et al.,* 2009).

2.7 Techniques for Investigating the Diet of Anurans

Scientists use many techniques for investigating the diets of anurans. These various techniques involve direct observation of the food that is been eaten by anurans or their collected faeces but also through dissecting or flushing of their stomachs. The most common techniques used are dissection and stomach flushing. This is because direct observation and collected feaces observation are very difficult since there are low chances of spotting anurans in action of feeding and in observing collected faeces many prey items may be completely digested or unrecognisable (Hirschfield and Rodel, 2011). Many researchers recommend stomach flushing instead of stomach dissection which involves killing of specimens and agree that ultimately stomach dissection should not be used any more. The reason behind has been that there is no significant differences on compared data of stomach dissection and stomach flushing (Wu *et al.,* 2007).

However, most dietary studies continue to rely upon freshly killed specimens, most likely because stomach-flushing techniques proved rather inadequate and difficult to replicate. For example in the analysis of food composition of amphibians both techniques stomach flushing and dissection give similar qualitative prey composition when applied but, different quantitative. The quantitative difference is brought by the fact that stomach flushing might be less effective in terms of larger food items (Hirschfield and Rodel, 2011). Again, researchers cannot perform stomach flushing if selected species are too small and fragile (Macale *et al*., 2008), and when they want to obtain the entire digestive tract in order to include the intestine to avoid overestimating larger prey (Peltzer *et al*., 2000; López *et al*., 2007).

In order to be able to perform either stomach flushing or dissection anurans are captured by pitfall traps or with drift fences or by hand (Sousa and Avila, 2015). However, capturing anurans by hand or net and immediate processing of anurans by flushing of stomach contents or killing of anurans is a more suitable method than the use of pitfall traps and drift fences, the method facilitate stopping of the digestion of prey. Digestion of prey tends to cause underestimation of number and volume of prey. Thus, minimising the time between capture and processing is important as the number and volume of preys obtained are affected by the time taken between capture to processing (Covaciu-Marcov *et al.*, 2010).

2.8 Importance of Amphibians in the Ecosystem

Amphibians are often a diverse component of an ecosystem (Watling and Ngadino, 2007). Amphibians have an immense contribution to ecosystems as they play direct and indirect roles in provisioning, regulating, cultural, and supporting services (Hocking and Babbitt, 2014). Amphibians provide provisioning services by serving as a food source to human societies throughout the world (Parker, 2011). Examples of the famous species of amphibians used as food sources include variety of *Lithobates* species consumed by Chorti people of Hondurasa and the large frog *Leptodactylus fallax* known as the Mountain Chicken in the West Indies (Valencia-Aguilar *et al*., 2013).

Additional contribution to provisioning services of anurans is that they are used as specimen in medical research and provide potential for new Pharmaceuticals (Hocking and Babbitt, 2014). In medical research frogs from different families, usually *Xenopus laevis* were used in experiments of testing human pregnancy during the 20th century. Amphibians are also used in traditional medicines to treat a diversity of ailments, from warts to heart disease throughout the world (Jensen and Camp, 2003). Research show that there is a

possibility that the antimicrobial peptides secreted from frog skin could inhibit infection and transfer of (HIV) the human immune deficiency virus (Lorin *et al*., 2005).

Again, amphibians can contribute to regulating services through predation of invertebrates which transmit diseases and pests. The frog *Lysapsus limellus* is a good example of a predatory frog feeding on flies of the family Ephydridae, which transmit human diseases in the neotropics (Valencia-Aguilar *et al*., 2013). Another example is Cane Toads (*Rhinella marina*) which were used to combat the Cane Beetle (*Dermolepida albohirtum*) and to protect sugar cane crops in Australia (Turvey, 2013). Further, another way in which amphibians contribute to regulating services is by predation of arthropods example flies, butterflies, moths (mostly larvae), and beetles which are important pollinators for many plants including agricultural crops (Abrol, 2012).

Beyond regulating services amphibians also play important roles in the culture of human societies all the way through mythology, literature, and art (Hocking and Babbitt, 2014). For example, amphibians are usually used in literature, music, art, jewelry, and in decorations (Gibbons, 2003).

Lastly, supporting services where amphibians are likely to have the largest contribution to ecosystem services. Amphibians can affect both ecosystem functions and ecosystem structure. Mainly amphibians contribute to ecosystem supporting services through direct and indirect alteration of ecosystem functions (Hocking and Babbitt, 2014). For instance, Ranvestel *et al*. (2004) confirmed that tadpoles in tropical streams decreased algal abundance and biomass, altered algal community structure, and reduced sediment accumulation. Therefore, near to completely extirpation of tadpoles in tropical streams resulted to increased algal biomass and sedimentation of fine detritus in streams.

Additionally, Whiles *et al*. (2013) also reported on the effect of near to completely extirpation of tadpoles in the tropic streams whereby the whole stream respiration and nitrogen uptake rates was found to be reduced.

Furthermore, terrestrial and terrestrial-stage predatory amphibians may support ecosystem services through their role in regulating invertebrate populations (Hocking and Babbitt, 2014). At high densities terrestrial amphibians can reduce invertebrate abundances and plant herbivores (Beard *et al.,* 2003). In addition to amphibian roles in terrestrial ecosystem functions, amphibians are expected to affect various processes through predatory changes in the food web. For instance, many amphibians are primarily invertebrate predators feeding on invertebrates such as ants. Ants play important roles in ecosystem functions including nutrient cycling, plant protection, seed dispersal, and especially complex roles such as harvesting plants for farming fungi. Therefore, predation of amphibians on ants can cause changes in various ecosystems functions (Sanford *et al*., 2009).

Besides, anurans are highly efficient and crucial indicators of environmental health and contamination (Garg and Hippargi, 2007). The ability of anurans to be sensitive bio-indicator is brought by mainly three reasons: first, is their lifestyle which involves both aquatic and terrestrial life stages; second is because their ectothermic (MacCulloch, 2002), meanings that their metabolism and other life processes maintenance depend on environmental conditions; and lastly because of their moist semi-permeable skin, which plays role in chemical uptake. And this is why amphibians are used by biologists in arguing the actions that are crucial for biodiversity conservation (Ferenti *et al.,* 2010).

2.9 Threat to Amphibians

Global declines of amphibians refer to the phenomenon of the population declines and even extinctions of amphibian species around the world (Whittaker *et al.,* 2013). A report on assessments of the world's amphibians (Stuart *et al*., 2004) established that nearly a third of the known species of amphibians are globally threatened with extinction. In the last two decades there have been an alarming number of extinctions, nearly 168 species are believed to have gone extinct and at least forty three percent of amphibian populations are declining. Amphibian populations decline are more rapid than those described for birds, mammals, or reptiles, while evidence indicates that the number of extinct and threatened species will probably continue to rise (Stuart *et al*., 2004).

Furthermore, amphibian populations are more sensitive to environmental disturbances than other wildlife, for the reason that they possess several characteristics that make them more sensitive to environmental disturbances than other wildlife. For instance, amphibians' semi-permeable skin which is important for both gas exchange and osmoregulation, makes them especially sensitive to changes in hydric conditions as well as contaminants and some of the skin diseases (Rowe *et al.,* 2003). Additionally, amphibians face double threats because of their dependence on both aquatic and terrestrial habitats. Their life style makes them vulnerable to disturbances that affect the quality or availability of either habitat. The disturbances may disrupt amphibian life cycle and affect their populations (Dunson *et al*., 1992).

In Africa, Tanzania has more endemic species than any other country. Nevertheless, Tanzania is also one of the four countries in Africa which threatened amphibian species are concentrated, other are Madagascar, Cameroon, and South Africa. In many African

countries, the percentage of threatened species can be anticipated to rise as new species discoveries are made or important habitats are destroyed (Andreone *et al*., 2008).

There are two major categories of potential causes of amphibians' declines in the world: (1) general factors to the overall biodiversity crisis, including habitat destruction, alteration and fragmentation, introduced species, and overexploitation and (2) factors associated with amphibians' decline in relatively undisturbed habitats. The first category is well understood ecological phenomena, but the second includes less well understood agents that are having complex basic mechanisms, such as infectious diseases, climate change, increased UV–B radiation, chemical contaminants, and the causes of deformities (Whittaker *et al.*, 2013).

Further, habitat degradation and land conversion are known to be the main factors that cause the loss of amphibians. Most of amphibian species require undisturbed or relatively undisturbed habitat, even though some amphibians may not only persist but flourish in urbanised or agricultural areas. In temperate zones loss of wetlands is a major factor for amphibian loss, while in the tropics deforestation is the most serious threat. Habitat fragmentation which means the forest remnants persist but are separated by disturbed habitat is a serious problem for widespread species and in those that have natural metapopulation structures. For instance, documented evidence shows that the construction and use of roads have lead to increased harm to fauna habitat, fragmentation of the territory of fauna species, increased 'edge effect', restricted movements of individuals in the territory and growing genetic isolation of populations residing on each side of the road (Scoccianti, 2001).

In the same way, logging operations have caused important ecological changes, such as reducing vertical and horizontal structural complexity; increasing of the rate of soil erosion; altering the microclimate through a reduction of shadow on the land; increasing daily fluctuations of temperature; increasing evaporation rate; altering the rate of decomposition. All of these ecological changes affect the features of the environment and consequently modifies the features of the forest floor. These ecological changes affect negatively the communities and modifying their characteristics. A good example is in amphibian communities, where amphibians were reported to decrease feeding activities as a result of alteration of the microclimate towards drier conditions. The decrease of feeding activities is due to the tendency of amphibians spending most of time hiding under shelter to protect themselves from less favorable time of the year (Scoccianti, 2001). Waldick (1997) established that logging can have negative effects on distribution, richness and abundance of amphibians' species.

Again, habitat degradation such as pollution from agricultural herbicides, insecticides, and fertilisers impacts amphibians with aquatic life stages, (Hayes *et al*., 2010). These chemical pollutants at certain concentrations can actually kill larvae, but even in less dangerous concentrations they can affect behavior, reproduction, and life history, and can reduce the food supply of amphibian (Relyea and Diecks, 2008). Amphibians can be in contact with these substances both in terrestrial and aquatic environments. In wetlands, contamination can occur directly when flooded fields or the banks of water bodies inside or bordering farm areas are sprayed. Nevertheless, indirect contamination of water bodies occurs when chemical substances are washed away from sprayed areas and carried into neighboring water bodies (Scoccianti, 2001).

Beyond habitat degradation and land conversion infectious diseases have been presented to be the greatest threat to amphibian populations. Infectious diseases have been associated with collapsing amphibian populations almost everywhere that amphibians occur (Fisher *et al*., 2009). Most of the reported amphibian mass mortality events have been associated with the emerging fungal pathogen *Batrachochytrium dendrobatidis* causing infectious disease chytridiomycosis and viruses of the family Iridoviridae, but other agents such as bacteria, water molds, and trematode parasites have also been associated with mortality and population decline of amphibian. The infectious disease chytridiomycosis is reported to be the reason behind extinctions and declining of assemblages of amphibian worldwide (Hoffmann *et al*., 2010).

Again, the viruses of family Iridoviridae (ranaviruses) are linked with mass mortality in both frogs and salamanders. Yet again, amphibian declines are also contributed by pathogens including the bacteria *Aeromonas hydrophila* which is responsible for local extirpations of ranid frogs in California and Rhode Island, while pathogenic water molds (*Saprolegnia* species) have been found to be responsible for local extinctions in some North American frogs (Whittaker *et al.*, 2013).

In Africa, however, changes in amphibian assemblages were mainly due to habitat change. Until now only one amphibian species in the Afrotropics, namely the Kihansi Spray Toad *Nectophrynoides asperginis* is reported to decline probable to extinction because of the fungal disease chytridiomycosis (Krajick, 2006).

Another cause of amphibian population decline is the establishment and spread of exotic species. Exotic species can affect amphibians as competitors, predators, and as vectors for parasites and diseases. A good example of an exotic amphibian is the bullfrog (*Rana*

catesbeiana) of eastern North America which has been transported around the world by humans for food consumption. The bullfrogs became exotic simply because they usually escaped from commercial frog farms in particular South America, and established themselves in wild areas where native amphibian population had collapsed. Another invasive amphibian species is Xenopus laevis, the African clawed frog, which is now extensively established around the world. African clawed frog is prolific, highly invasive, and resistant to chytridiomycosis. The frog is responsible for the spread of both chytridiomycosis and rana viruses to native amphibians (Whittaker *et al.*, 2013). Additionally, exotic species such as introduced fish can increase water turbidity in shallow water bodies, which can result to decrease of amphibian productivity. Thus, for some species of amphibians, the introduction of fish can mean a clear decrease in the abundance and distribution of species (Knapp and Matthews, 2000).

Climate change is another factor affecting amphibian survival. Amphibians are more sensitive to climate change than other vertebrates (Pounds *et al*., 2006). Evidence shows that increased temperature variability from climate change may decrease frog immunity; making it easier for pathogens to cause death (Rohr and Raffel, 2010). Again another effect of climate change on amphibian population can result in shifting of amphibian distributions either latitudinal or altitudinal. In tropical regions, amphibians with narrow distribution are literally pushed off the mountain into extinction. This is because amphibians tend to move higher up the mountain to avoid warm or dry environments (Rovito *et al*., 2009).

Increase of UV–B is another factor that has been hypothesised to contribute to increased mortality rates in amphibians. Reported studies show that synergism between UV–B exposure and stress from the risk of predation on tadpole increases tadpole mortality.

Although, UV–B is not the major factor of amphibian declines (Blaustein *et al*., 2010), elements of climate change are known to make conditions more favorable for amphibian diseases and parasites. But the causal link between climate change and disease virulence is unclear and debated (Pounds *et al.*, 2006). On the other hand, another reason that contributes to amphibian population decline is overharvesting of wild species for the global pet trade and for human consumption (Gratwicke *et al*., 2010).

Finally, many of the factors causing amphibian population declining are by themselves pose severe threats to amphibian survival, but synergistic interactions between factors can magnify the negative effects on amphibians (Blaustein *et al*., 2010). For instance, the effects of infectious diseases may be greater in the presence of unusual weather conditions, elevated by UV–B, or chemical pollutants, which may compromise amphibian immune systems (Hayes *et al*., 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Study area

Kimboza Forest Reserve is located approximately 50 km south east of Morogoro district in Morogoro region, Tanzania (Bayliss, 1994). The forest lies between 06°59' - 7°02' S and 37°47'- 37° 49'E. It covers an area of about 385ha with a boundary length of 15.6 Km and was declared a forest reserve by the government of Tanzania in 1964 (Werema, 2016). Kimboza Forest Reserve is surrounded by four villages including Uponda to the West, Mwarazi to the East, Kibangile to the South, and Changa to the North (MNRT, 2004). This lowland forest is isolated and not connected to the higher elevation Uluguru Forest Nature Reserve (Werema, 2016). In the recent past there was once a continuum between Uluguru and Kimboza forest reserve, however currently the area is surrounded by fragmented forest blocks. As a result of this relationship, Kimboza Forest Reserve shares some of its species with the Uluguru forest nature reserve (Bayliss, 1994).

Kimboza Forest Reserve is a priority conservation area (IUCN category IV-habitat or species management area) as it is the home to many important endemic floras, and several fauna. Among fauna species found in this forest is the highly threatened species a blue dwarf gecko (*Lygodactylus williamsi*). Furthermore, human activities including rampant deforestation activities have intensified the threat to the existence of some of the once abundant and flourishing flora species, for example *Khaya anthotheca, Milicia excelsa, Pterocarpus angolensis* and *Cynometra uluguruensis* (Temu and Andrew, 2008).
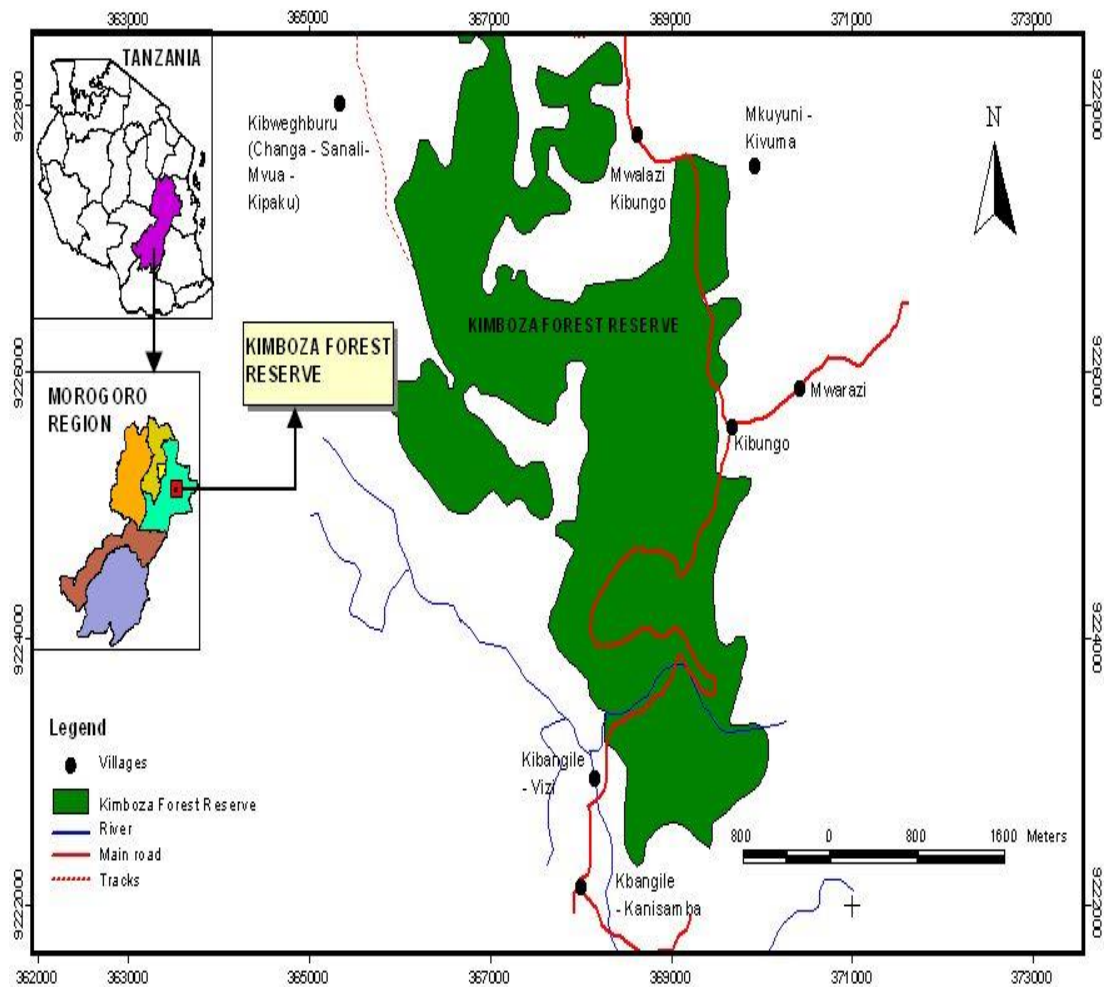
Figure 1: The map of Kimboza Forest Reserve showing the forest location in Tanzania and the surrounding villages.

Source: SUA GIS Centre (2016)

3.1.1.1 Climate

The climate of Kimboza Forest Reserve is influenced by tropical eastern African oceanic temperatures that are slightly modified by altitude lying with Morogoro regions, the area has bimodal rainfall pattern averaging 1600 mm per year. Most of the rains fall in during April and May. This period is accompanied by decrease in temperature leading to a relative cooler season between April and September. October and March is usually the dry season with little rain in which temperatures are relative higher therefore referred as hot season (Werema, 2015).

3.1.1.2 Vegetation

The vegetation of the forest is typically of lowland rain forest, which is classified as coastal or eastern arc transition forest (Rodgers *et al*., 1983). Kacholi (2013) reported that Kimboza Forest Reserve had 52 species of plants. Out of those species 13 are recorded as endemic plant species making it the richest lowland forest in East Africa. Examples of the endemic plants include *Baphia pauloi*, *Cynometra uluguruensis, Pavetta crebrifolia* var. *kimbozensis*, *Streptocarpus kimbozana*, and *Cololejeunea jonesii* (Rodgers *et al*., 1983).

In the forest canopy huge nest of epiphytes, such as *Platycerium elephantotis* and *Davallia chaerophylloides*, are common. Many smaller trees for instance *Cola stelenacantha, Cussonia zimmermannii*, *Dialium holtzii*, *Drypetes parviflora*, *Uvariodendron gorgonis* and *Zenkerella egregia* form the second or third storey of the forest. Moreover, close to the springs and streamlets *Pandanus englerii* forms large stands. The layer of herbs also occurs in the forest dominated by *Nephrolepis biserrata* and rare aroids occur such as *Amorphophallus stuhlmannii*, *Anchomanes difformis*, *Callopsis volkensii* and *Gonatopus boivinii*. On shady limestone or marble rocks *Zamioculcas zamiifolia* and the endemic *Impatienscin nabarin* occur. Lastly, along the road there is an invasive species known as *Cedrela* species and teak plantation forests are cultivated. The invasive species from the nearby plantations is now replacing the indigenous trees, and thus potential threat to biodiversity of the area (Rodgers *et al*., 1983).

3.1.1.3 Fauna

Studies which were done on Kimboza Forest Reserve (e.g. Bayliss, 1994; Doggart *et al.,* 2004) show that the forest has over 100 vertebrate species. This includes 82 birds, 6 amphibian species, 21 mammals and 20 reptiles species. Some of these vertebrate species are endemic or near endemic. The forest has one recognized endemic species known as the

blue dwarf gecko (*Lygodactylus williamsi*). This endemic lizard is found only on the *Pandanus* tree species in the forest. Further, the known near endemic species of Kimboza forest include two mammals (*Otolemur garnettii* and *Galagoides zanzibaricus*), two reptiles (*Agama montana* and *Rhampholedoi brevicaudatus*) and two amphibians (*Nectophrynoides tornieri* and *Leptopelis parkeri*) (Doggart *et al*., 2004; EAMCEF, 2008). However, the species list is incompletely described as many animals have been seen to enter and leave the forest on regular or seasonal patterns.

3.2 Methods

3.2.1 Sampling Designs

The forest was divided into two parts (upper and lower segment) separated from each other by a dirt road passing between the two parts. Then each part was stratified into four habitats: (i) a forest interior, (ii) areas were the forest border with farms, (iii) along forest and road border, and (iv) along Kimboza forest streams. One sampling station was purposively chosen and established in each selected study habitat making a total of eight sampling stations in both segments of the forest. One sampling station contained one transect of 300×4m. Within each transect, six rectangular plots of 50×4 m were established making a total of 48 plots in both segments of the forest for the entire study. Each sampling station was surveyed twice: in March (the period of the beginning of rainfall) and April (the period of heavy rainfall).

3.2.2 Data collection methods

3.2.2.1 Primary data

The data collection method used to study the distribution of amphibian (anuran) species followed the standard approaches proposed by Lips *et al.* (2001). In this case, visual encounter survey was used to study the distribution of amphibians as well as collection of

specimens for assessing food taken by the anurans. Further, data for feeding ecology assessment was obtained through analysis of gut contents of anurans in relation to the habitats to which they were collected (López *et al*., 2003).

In order to achieve the purposes of the specific objectives, data was collected through undertaking active searches in delineated habitats as stated above in section 3.2.1. First, two transects (one in upper and another in lower fragment of the forest) were placed as near as possible to Kimboza streams. This was done in order to encounter majority of amphibians which usually aggregate near water sources (Naniwadekar and Vasudevan, 2007). Second, two transects were placed in areas along forest and farms borders, one transect per each segment of the forest (upper and lower). Third, two transects were placed in areas along forest and road borders, again one transect per each segment of the forest. Transects in forest boundaries (areas along forest and farms borders and forest border with road) were placed between 0 m to 50 m from the forest boundary to the interior of the forest. The edge effect on amphibians is known to extend 100 m from the forest boundaries to the forest interiors (Maynard, 2016).

Lastly, Two transect were placed in forest interiors of the upper and lower segment, one transect per each part of the forest. Transects in forest interiors placed were between 100 m to 400m from the forest boundaries transects to the forest interior to avoid edge effect. Therefore, in each habitat searches for anurans in leaf litter, under logs, tree holes and stones were performed. Similarly, tree canopies and bushes near water sources were also searched for arboreal amphibians (Khatiwada, 2011). A total of eight 300×4m transects which each had six rectangular plots of 50×4 m were searched from 0600 to 1800 hours for diurnal anurans. The rectangular plots of 50×4 m were searched for anurans in 30 minutes by four persons.

3.2.2.2 Secondary data

In order to compliment collected primary data, more information to strengthen and solidify the gist of this study were obtained through reading literatures which included latest available ecological books on the Eastern Arc mountains, journals' papers, various consultancy reports, relevant unpublished materials, and previous researches. The full list is available in the reference section.

3.2.2.3 Species identification and voucher specimen preservation

Handing of live amphibians can result into several hazardous impacts. The impacts are either to the handler or the animal itself. For the handler, the main danger comes from toxic skin secretions produced by some amphibians. To amphibians, the main dangers of being handled are skin damage that could result in secondary skin infections, and bone and muscle injuries caused by struggling when being held. Tadpoles and larvae have thin delicate skin that is very easily damaged by the slightest handling. The skin of larvae lacks keratin and has fewer cell layers than adult amphibian skin. The fact that we know less of the ecology of these animals maximum care was taken during the handling processes.

To this case, every reasonable effort was made to avoid unnecessarily disturbing of these species or their habitat in which some are highly endemic and high in the IUCN red-list. All animals from their habitats were captured by gloved hands and representative voucher specimens preserved in 10% formalin. Others which were sighted but not captured, and were identified on spot to the species level using the keys and field guidebooks (Channing and Howell, 2006; Spawls *et al.*, 2006; Harper *et al.*, 2010).

All detailed information embedded and associated to their habitats such as altitude, vegetation type and cover, status of the microhabitat, and activity patterns of each sighted

or captured anurans were recorded. A 14.1 megapixel digital camera was used for photographing and documenting the forest vegetation, microhabitats and some of the activities of the species sighted and captured in the field. Further, all individuals that could not be identified were taken to Zoology and Wildlife Conservation laboratory at the University of Dar es Salaam for identification with assistance from herpetology expert (Dr. Ngalason) and the specimen were later deposited at the Sokoine University of Agriculture Zoology laboratory for preservation. Photographs of sighted individuals were also taken to the University of Dar es Salaam for identification by herpetology expert.

3.2.2.4 Data handling in the laboratory

Preserved specimens were taken to Sokoine University of Agriculture Zoology laboratory for further processing. In the laboratory the whole digestive tract of each specimen, starting from the esophageal area to the rectum was removed, sectioned and examined. Where, each section of the digestive tract was carefully cut open and stored food and fecal material were emptied into containers for a closer under dissecting microscopy. Items found in the digestive tract of each specimen were identified possibly down to the order level through the help of field guide books.

3.2.3 Data analysis

Various statistics were used in the analysis of data collected during this study. Secondary data collected from previous studies were used to confirm the distribution and feeding pattern of anurans in Kimboza Forest Reserve.

3.2.3.1 Distribution of anurans across different habitats within and along boundaries of Kimboza Forest Reserve

Data on presence and distribution of species was analysed using Cochran's Q test (Zar, 1996) SPSS version 20. Further, the comparison of anurans' distribution between the

upper and lower segment of the forest was analysed using McNemar Test SPSS version 20. The same test was used for analysis of the comparison of anurans' distribution between March and April.

3.2.3.2 Dietary composition of anuran species

The dietary composition was analysed using three parameters: The abundance of different food groups, the frequency of occurrence of different food groups and the rate of feeding activity.

i. The abundance of various food groups was estimated from the guts contents (percentage of the total number of individual prey/total number of all prey).

ii. The frequency of occurrence was determined by dividing the number of digestive guts that contained a particular prey by the total number of guts with prey. A food group was then classified as constant when registered in > 50% of the guts of a particular species, secondary when present in 25 - 50% of guts or accidental when observed in < 25% of the guts (Dajoz, 1983).

iii. The rate of feeding activity was estimated as the percentage of guts containing food with respect to the total number of guts examined (Sala and Ballesteros, 1997).

$$\text{Rate of feeding activity} = \frac{100n}{N}$$…………………………………………………...…………(1)

Where n is the number of guts with food, N is the total number of guts examined.

The comparison of abundance of food groups among anuran species was analysed using Kruskal-Wallis test SPSS version 20, while Mann-Whitney U test SPSS version 20, was used in analysis of the comparison of abundance of food groups consumed by anurans found in the upper segment and in the lower segment of the forest.

The same program of SPSS version 20 was used to perform statistical analysis for the frequency of occurrence of food groups whereby Kruskal-Wallis test was used to compare frequency of occurrence of food groups among anuran species but also between anurans found in the upper and lower fragment of the forest. The variation of the frequency of occurrence of food groups between March and April was also tested by Kruskal-Wallis test.

3.2.3.3 Dietary diversity of anuran species

The diet diversity was analysed in two parts: First, diet diversity per each species and second, diet diversity of anurans in each studied habitat. The diet diversity was estimated with Shannon–wiener diversity index (H) (Margurran, 1988).

$$H = -\sum \left[\frac{ni}{N}\right] \ln \left[\frac{ni}{N}\right] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\text{(2)}$$

Where n is the number of prey category i and N is the total number of prey.

Microsoft office excel 2007 was used to calculate the diet diversity of each anuran species and to calculate the diet diversity of each habitat. Besides, the program of SPSS version 20 was used to perform statistical analysis for dietary diversity whereby Kruskal-Wallis test was used to compare the dietary diversity of anurans in different habitats within and along forest boundaries. Mann-Whitney U test was used to compare the dietary diversity of anurans between the upper and the lower segment. Also the dietary diversity of anurans between March and April was compared using the Wilcoxon Signed Rank Test.

3.2.3.4 The influence of the habitat on the feeding preferences of anuran species

The degree of food preference was inferred using the index of Degree of Food Preference (DFP) developed by Braga (1999). Food groups were ranked by categories from 1 to 4, in the following way: the maximum value (4) was assigned when only one food group was found in a gut. When guts contained more than one group, the value "3" was given to the most abundant, while "2" was given to the second most common, and "1" was attributed to less abundant groups.

DFP was calculated as:

$$DFP = S\,(i)\,/N \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(3)$$

Where $S\,(i)$ is the sum of values given to a food group i in the guts, and N, the total number of guts of each species analysed. Food groups were then categorised as highly preferential ($3 < DFP < 4$), preferential ($2 < DFP < 3$), secondary ($1 < DFP < 2$) or occasional ($0 < DFP < 1$).

Kruskal-Wallis test and Mann-Whitney U test were used to compare the Degree of Food Preferences among anurans within the same habitat. Mann-Whitney U test was also used to compare the Degree of Food Preferences among anurans between the upper and the lower segment. Kruskal-Wallis test was also used in comparison of the Degree of Food Preferences among anurans between March and April. All the tests were in the SPSS version 20 program.

CHAPTER FOUR

4.0 RESULTS

4.1 The Distribution of Anurans in Different Habitats within and Along Boundaries of Kimboza Forest Reserve

Thirteen species of amphibian (Plate 1), which belong to 7 families of order anuran, were recorded in Kimboza Forest Reserve (Table 1).

Table 1: Anuran species of Kimboza Forest Reserve

Family	Species
Arthroleptidae	*Arthroleptis affinis*
	Arthroleptis xenodactyloides
	Leptopelis flavomaculatus
	Leptopelis uluguruensis
Bufonidae	*Nectophrynoides tornieri*
Hyperoliidae	*Afrixalus stuhlmanni*
	Afrixalus uluguruensis
	Hyperolius mitchelli
Phrynobatrachidae	*Phrynobatrachus acridoides*
	Phrynobatrachus natalensis
Pipidae	*Xenopus borealis*
Ptychadenidae	*Ptychadena anchietae*
Rhacophoridae	*Chiromantis xerampelina*

a) *Leptopelis flavomaculatus*

b) *Arthroleptis xenodactyloides*

c) *Xenopus borealis*

d) *Arthroleptis affinis*

e) *Ptychadena anchietae*

f) *Afrixalus stuhlmanni*

g) *Hyperolius mitchelli*

h) *Nectophrynoides tornieri*

Plate 1: Anuran species of Kimboza Forest Reserve

Continuation of Plate 1

i) *Phrynobatrachus natalensis*

j) *Chiromantis xerampelina*

k) *Afrixalus uluguruensis*

l) *Leptopelis uluguruensi*

m) *Phrynobatrachus acridoides*

Among all habitats in Kimboza Forest Reserve areas along Kimboza streams and areas where the forest border with farms in the upper segment of the forest had the highest number of occurrences of anurans. Each habitat had 70% of occurrences of anurans meaning each had 7 out of 10 species occurrences.

Table 2: The distribution of anuran species among different habitats of Kimboza Forest Reserve

Species name	HABITATS							% occurrence of species in different habitats
	UFI	UFF	UFS	UFR	LFI	LFF	LFRS	
Leptopelis uluguruensis	x			x				29
Leptopelis flavomaculatus	x	x	x	x		x		71
Arthroleptis xenodactyloides	x	x	x	x	x	x		86
Arthroleptis affinis	x		x			x		43
Nectophrynoides tornieri	x			x	x			43
Afrixalus stuhlmanni		x						14
Afrixalus uluguruensis		x	x					29
Hyperolius mitchelli							x	14
Phrynobatrachus acridoides			x					14
Phrynobatrachus natalensis		x				x		29
Xenopus borealis	x	x	x					43
Ptychadena anchietae			x					14
Chiromantis xerampelina		x			x			29
% occurrence of all species in each habitat	60	70	70	40	30	40	10	

UFI= interior of the forest in the upper segment, **UFF**= along the forest and farm border in the upper segment of the forest, **UFS**= along the Kimboza streams in the upper segment of the forest, **UFR**= along the forest and road border in the upper segment of the forest, **LFI** = interior of the forest in lower segment of the forest, **LFF** = along the forest and farm border in the lower segment of the forest, **LFRS** = along the forest border with road and along Kimboza stream in lower segment of the forest.

Following was forest interiors of the upper segment of the forest which had 6 out of 10 species occurrences (60%). However, areas along the forest and tarmac road border and along Kimboza streams of the lower segment of Kimboza forest had the lowest occurrence of anurans. Each had 10% occurrences of species meaning 1 out of 10 species occurrence (Table 2). The general trend throughout this study was that in the whole forest the variation of total number of occurrences of anurans in different habitats was not significant

(Cochran's Q test, Q=11; DF =6; P=0.096). Nonetheless, the variation of total number of occurrences of anurans between the upper and lower segment of the forest was significant (McNemar Test, P<0.05).

Arthroleptis xenodactyloides was the species with the highest occurrence (occurred in 6 out of 8 habitats) (Table 2). *A. xenodactyloides* occurred in all habitats except in the lower segment of the forest areas along Kimboza streams and where the forest border with the tarmac road. This was followed by *Leptopelis flavomaculatus* (5 out of 8 habitats) which occurred in all habitats with the exception of the forest interiors, the areas where forest border with the road and areas along Kimboza streams all in the lower segment of the forest (Table 2).

Ptychadena anchietae, Phrynobatrachus acridoides, Hyperolius mitchelli, Afrixalus stuhlmanni were among the species with the lowest occurrence, and this was because each one of them occurred only in one habitat (Table 2). There was no significant variation of the distribution of the species among habitats in the whole forest (Cochran's Q test, Q =19; DF =12; P = 0.089). Nevertheless, the variation of the distribution of the species between upper and lower segment was significant (McNemar Test, P<0.05).

Seven out eight habitats in Kimboza Forest Reserve had species occurrence in both March and April (Fig. 2). However, areas along the forest and road border in the lower segment of the forest had species occurrence in April only. Areas in the forest interior, along the forest and road border in the upper segment and interior of lower segment of the forest had more species occurrence in March (Fig. 2). Further, areas along Kimboza streams in the upper segment and along forest and farms border in the lower fragment of the forest had more species occurrence in April, while the area along forest and farms border in the

upper segment of the forest had equal number of occurrence of species in both months (Fig. 2).

There were no significant variation of the total number of occurrences of anurans in different habitats within the same month March (Cochran's Q test, Q=10; DF =6; P>0.05) and April (Cochran's Q test, Q=7; DF =6; P>0.05). Also, the variation of total number of occurrences of anurans in the forest between April and March (McNemar Test, P>0.05) was not significant.
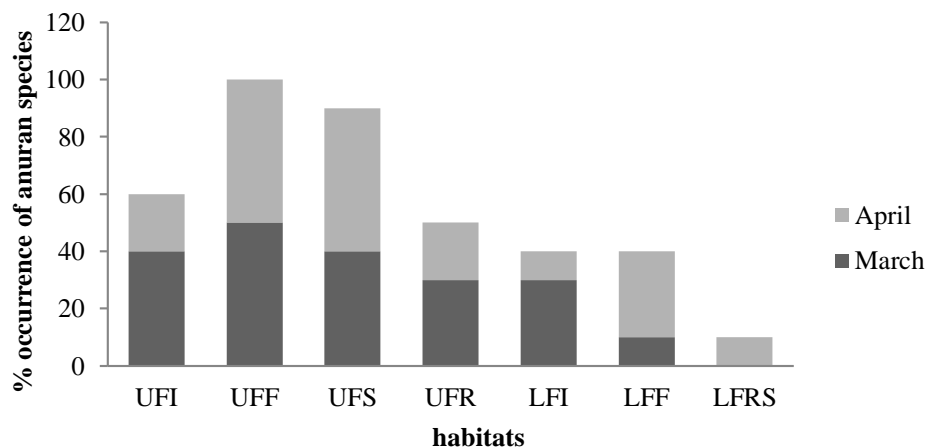
Figure 2: The total occurrences of anuran species in different habitats during March and April

The most frequently encountered species in March was *Leptopelis flavomaculatus*, while in April were *Arthroleptis xenodactyloides*, *Arthroleptis affinis* and *Xenopus borealis* (Fig. 3). Some of the species occurred only in one of the month. For instance, *Leptopelis uluguruensis* and *Nectophrynoides tornieri* were recorded in March only, whereas *Hyperolius mitchelli*, *Phrynobatrachus acridoides*, *Phrynobatrachus natalensis* and *Xenopus borealis* were recorded in April only (Fig. 3). In general, *Leptopelis*

flavomaculatus and *Arthroleptis xenodactyloides* were the most frequently encountered species in both months (Fig. 3).
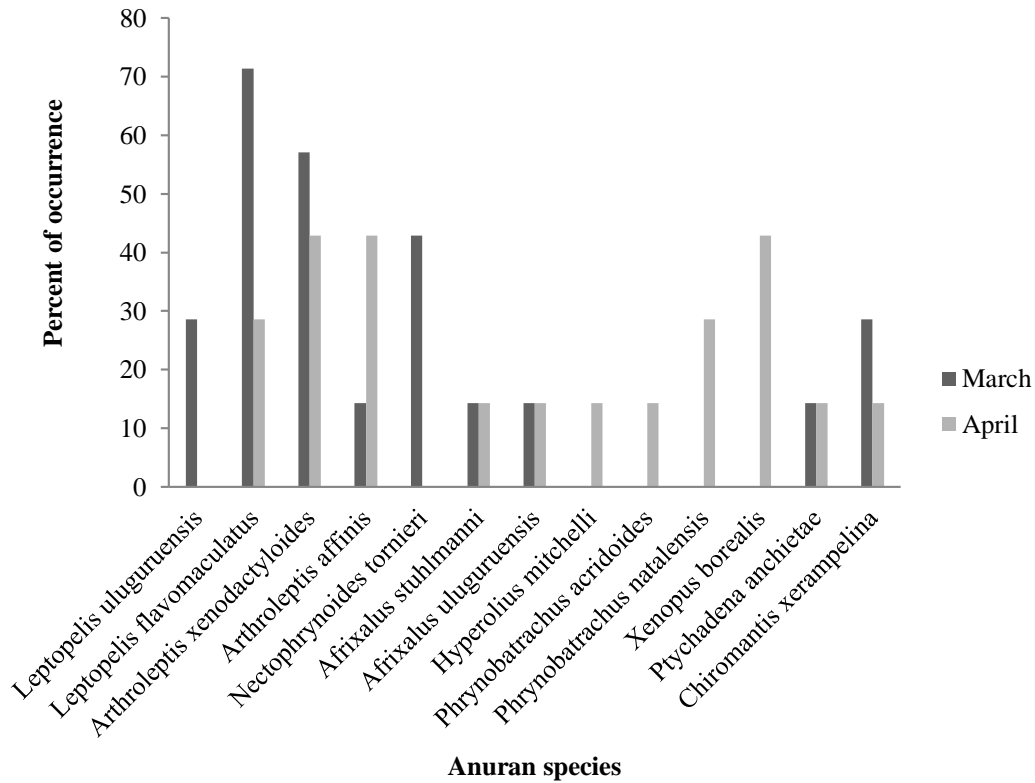
Figure 3: Occurrence of anuran species during March and April in Kimboza Forest Reserve

There was significant variation of the distribution of the species among habitats in the whole forest during March (Q =26; DF =12; P <0.05), but the variation was not significant during April (Q =11; DF =12; P>0.05). The variation of species distribution among habitats in the whole forest between March and April was not significant (McNemar Test, P>0.05). The variation of the distribution of the species between upper and lower segment was significant in both months March (McNemar Test, P<0.05) and April (McNemar Test, P<0.05).

4.2 Dietary Composition of Anuran Species in Kimboza Forest Reserve

4.2.1 The rate of feeding activities

A total of 93 adult anurans belonging to 12 anuran species were examined. Out of 93 adult anurans approximately 65% had full gut contents, while 35% guts were empty. *Arthroleptis xenodactyloides* contributed largely to the number of individuals with full gut contents (40% of all individuals with gut content), followed by *Leptopelis flavomaculatus* 18% of all individuals with full gut contents (Table 3). Further, *Afrixalus stuhlmanni* was the species that contributed largely to the number of empty guts *(*by 36% of all individuals with empty guts) (Table 3*)*. However, species like *Chiromantis xerampelina, Phrynobatrachus acridoides, Ptychadena anchietae, Xenopus borealis* and *Nectophrynoides tornieri* had no any individuals with empty gut, while *Afrixalus uluguruensis* no individuals had gut contents (Table 3).

Most of the species with empty guts were from the upper segment of the forest in the areas along the forest and farms border (contributed 76% of all individuals with empty guts) followed by the areas along forest and road border (contributed 12% of all individuals with empty guts). The areas along Kimboza streams in the upper segment of the forest had the least number of empty guts (1 individual: contributed 3% of all empty guts). In the lower segment of the forest both areas along the farm and forest border and in the interior of the forest had no individuals with empty guts (Table 4*)*.

Table 3: The rate of feeding activities of anuran species in Kimboza Forest Reserve

Species name	N	Individuals with gut contents (N)	Individuals with Guts content (%)	Individuals with empty guts(N)	Individuals with empty guts (%)
Arthroleptis affinis	4	3	5	1	3
Arthroleptis xenodactyloides	27	24	40	3	9
Leptopelis flavomaculatus	14	11	18	3	9
Leptopelis uluguruensis	3	2	3	1	3
Nectophrynoides tornieri	3	3	5	0	0
Afrixalus stuhlmanni	13	1	2	12	36
Afrixalus uluguruensis	6	0	0	6	18
Phrynobatrachus acridoides	2	2	3	0	0
Phrynobatrachus natalensis	12	5	8	7	21
Xenopus borealis	2	2	3	0	0
Ptychadena anchietae	3	3	5	0	0
Chiromantis xerampelina	4	4	7	0	0
Total number of individuals	**93**	**60**		**33**	
Percent of individuals		**65**		**35**	

Table 4: The rate of feeding activities of anuran species in different habitats in Kimboza Forest Reserve

Habitats	N	Individuals with gut contents (N)	Individuals with Guts content (%)	Individuals with empty guts (N)	Individuals with empty guts (%)
UFI	12	9	15	3	9
UFF	41	16	27	25	76
UFR	8	4	7	4	12
UFS	19	18	30	1	3
LFI	5	5	8	0	0
LFF	8	8	13	0	0
Total individuals (N)	**93**	**60**		**33**	

UFI= interior of the forest in the upper segment, **UFF**= along the forest and farm border in the upper segment of the forest, **UFS**=along the Kimboza streams in the upper segment of the forest, **UFR**=along the forest and road border in the upper segment of the forest, **LFI** = interior of the forest in lower segment of the forest, **LFF**= along the forest and farm border in the lower segment of the forest.

4.2.2 Abundance of the prey items eaten by anuran species in Kimboza Forest Reserve

About 462 prey items belonging to 10 categories of food groups were collected from digestive guts of 60 adult anurans. The categories of the food groups included Isoptera, Orthoptera, Coleoptera, Gastropoda, larvae, Hymenoptera, Araneae, Decapoda, Diptera and unidentified (Plate 2).

Plate 2: Food groups consumed by anurans in Kimboza Forest Reserve

The food groups in unidentified category consisted of fragments from invertebrate. The most abundant food group was Isoptera (53.25%) followed by Hymenoptera (37.88%), but Decapoda (0.22%) was the least abundant group with only one prey item (Table 5).

Table 5: Overall food groups eaten by anurans found in Kimboza Forest Reserve

Food group	N	A%
Isoptera	246	53.25
Orthoptera	8	1.73
Coleoptera	14	3.03
Gastropoda	6	1.08
larvae	5	1.08
Hymenoptera	175	37.88
Araneae	3	0.65
Decapoda	1	0.22
Diptera	2	0.43
unidentified	2	0.43
Total	**462**	

N=number of prey items A%=percentage abundance of prey items

Seventy nine percent of all prey items collected were from digestive guts of anurans found in the upper segment of the forest and 21% from anurans found in lower segment of the forest (Table 6). Anurans found in the upper segment of the forest had isopterans as the most abundant food group (62%) of all prey items found in the upper segment. Conversely, in the lower segment of the forest hymenopterans were the most abundant food group making (78%) of all prey items found in this part of the forest (Table 6). The variation of the percentages of prey items in upper and lower segment was significant (Mann Whitney U test, U=18, P<0.05).

Table 6: Overall food groups eaten by anurans found in upper and lower segments of

Kimboza Forest Reserve

Food groups	Abundance of prey			
	Upper segment		Lower segment	
	N	A%	N	A%
Orthoptera	7	1.92	1	1.03
Isoptera	227	62.19	19	19.59
Coleoptera	14	3.84	0	0
Gastropoda	6	1.64	0	0
Hymenoptera	99	27.12	76	78.35
Araneae	3	0.82	0	0
larvae	5	1.37	0	0
unidentified	1	0.27	1	1.03
Decapoda	1	0.27	0	0
Diptera	2	0.55	0	0
Total number of prey items	**365**		**97**	
% of prey items each segments	**79**		**21**	

Diet analysis involved only 10 out of 12 anurans species which were examined (Fig. 4). Anurans from two species *Afrixalus stuhlmanni* and *Afrixalus uluguruensis* were not included in the analysis since almost all of them had empty guts (Table 3). *Arthroleptis xenodactyloides* was the species with the highest number of food groups (5 out of 10) while *Leptopelis uluguruensi* had the least number of food groups (1 out of 10) (Fig. 4).

a) *Leptopelis flavomaculatus*

b) *Phrynobatrachus natalensis*

c) *Xenopus borealis*

d) *Chiromantis xerampelina*

e) *Leptopelis uluguruensis*

f) *Phrynobatrachus acridoides*

g) *Arthroleptis xenodactyloides*

h) *Arthroleptis affinis*

i) *Ptychadena anchietae*

j) *Nectophrynoides tornieri*
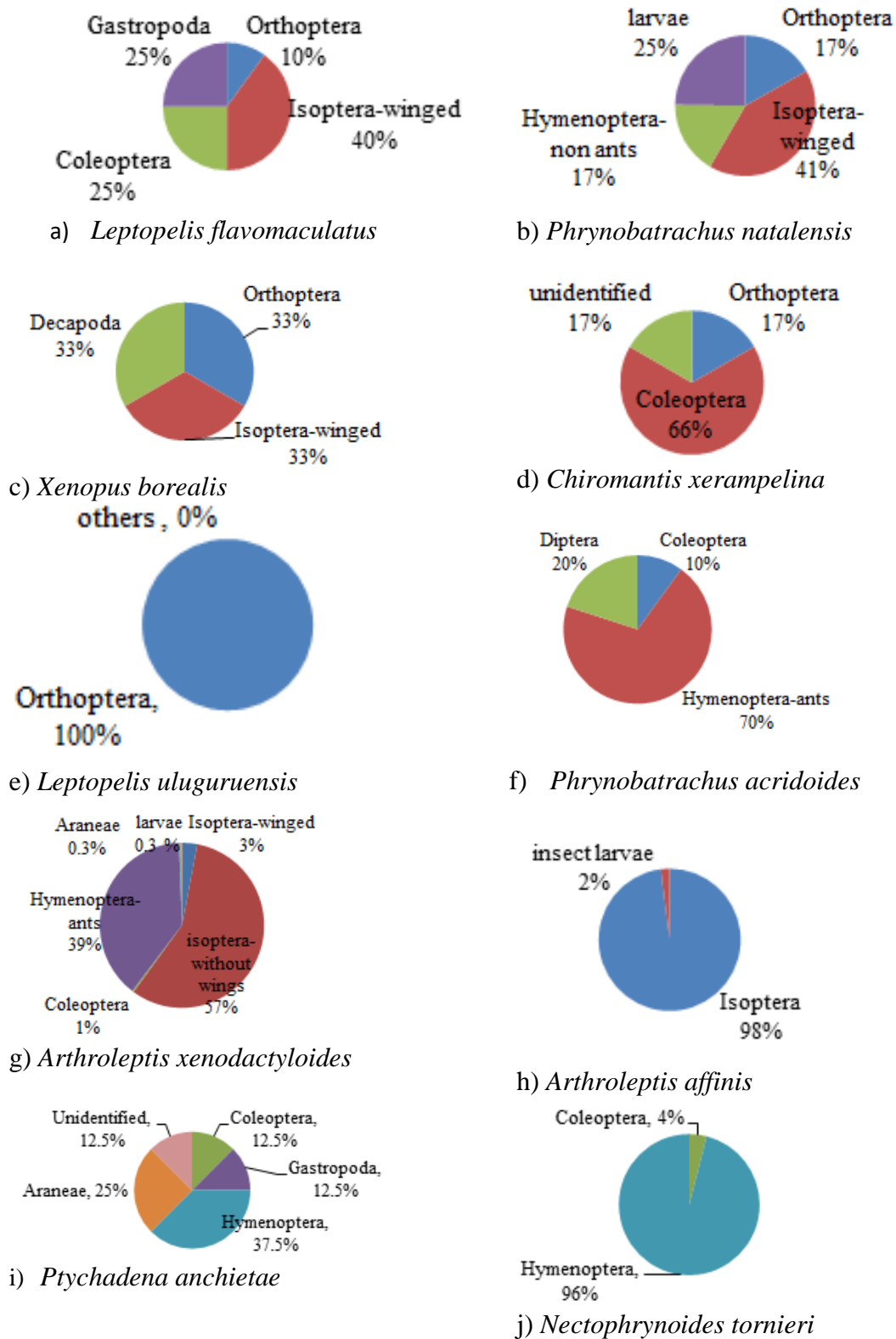
Figure 4: Food groups eaten by each anuran species of Kimboza Forest Reserve

The anuran species with highest number of prey items was *Arthroleptis xenodactyloides* (63% of all prey items) while *Leptopelis uluguruensi* (0.4% of all prey items) was the species with lowest number of prey items (Table 7). The variation of the percentages of prey items for each anuran species in different habitats was not significant (Kruskal-Wallis Test, H=7, P > 0.05).

Table 7: Number of prey items per each anuran species in Kimboza Forest Reserve

Species Name	Number of Prey Items	Percent of prey items
Leptopelis uluguruensis	2	0.4
Leptopelis flavomaculatus	20	4.3
Arthroptis xenodactyloides	293	63.4
Nectophrynoides tornieri	52	11.3
Arthroleptis affinis	56	12.1
Chiromantis xerampelina	6	1.3
Ptychadena anchietae	8	1.7
Xenopus borealis	3	0.6
Phrynobatrachus natalensis	12	2.6
Phrynobratrachus acridoides	10	2.2
Total number of prey items	**462**	

4.2.3 The frequency of occurrence of food groups eaten by anuran species in Kimboza Forest Reserve

The frequency of occurrence of different food groups varied among different anurans species. Generally, the variation of frequency of occurrence of food groups between anurans in lower and upper segment was significant (Kruskal-Wallis Test, H = 22.9, P < 0.05).

The most frequently occurring food groups were Coleoptera found in digestive guts of 6 out of 10 anurans species (Fig. 5). Coleopterans were a secondary food group in the digestive guts of *Leptopelis flavomaculatus* (27%), *Nectophrynoides tornieri* (33%), *Chiromantis xerampelina* (50%), *Ptychadena anchietae* (33%) and *Phrynobatrachus acridoides* (50%) but was accidental for *Arthroleptis xenodactyloides* (4%) (Appendix 1).
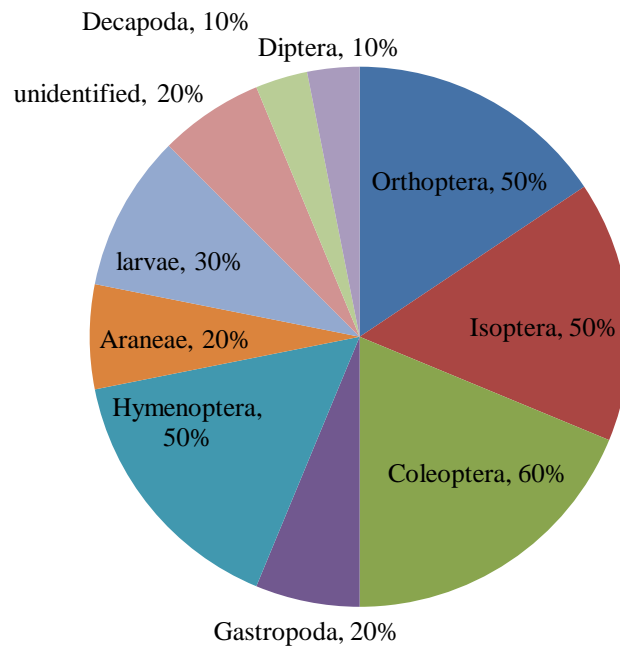
Figure 5: Overall Frequency of occurrence of food groups among different anuran species of Kimboza Forest Reserve

The second frequently occurring food groups were Orthoptera, Hymenoptera and Isoptera which were found in the digestive guts of 5 out of 10 anurans species (Fig. 5). Orthoptera was a constant food groups in *Leptopelis uluguruensis* (67%) and *secondary* food group in *Chiromantis xerampelina* (25%), *Xenopus borealis* (33%) and *Phrynobatrachus natalensis* (33%), however it was accidental in *Leptopelis flavomaculatus* (9%). Hymenoptera was a constant food group in *Phrynobatrachus acridoides* (100%) and *Nectophrynoides tornieri* (100%), but also as a secondary food in guts of *Arthroleptis xenodactyloides* (47%), *Ptychadena anchietae* (33%) and *Phrynobatrachus natalensis*

(33%). Further, Isoptera was a constant food group for *Arthroleptis xenodactyloides* (79%) and *Arthroleptis affinis* (100%), though a secondary food group in *Leptopelis flavomaculatus* (27%), *Xenopus borealis* (33%) and *Phrynobatrachus natalensis* (33%) (Appendix 1).

The least occurring food group was Decapoda and Diptera (Fig 5). Decapoda was a secondary food group in *Xenopus borealis* (33%), and Diptera a constant food group in *Phrynobatrachus acridoides* (100%) (Appendix 1). However, the variation of frequency of occurrence of food groups among anuran species was not significant (Kruskal-Wallis Test, $H = 5$, $P > 0.05$).

4.2.4 The frequency of occurrence of food groups eaten by anuran species in Kimboza Forest Reserve during March and April

The frequency of occurrence of food groups varied among different anurans species. During March most frequently occurring food group was Coleoptera found in guts of 5 out of 10 anurans species, though in April the most frequently occurring food group was Isoptera 5 out of 10 anuran species (Fig. 5). The variation of frequency of occurrence of food groups among anuran species between March and April was not significant (Kruskal-Wallis Test, $H = 4.5$, $P > 0.05$).
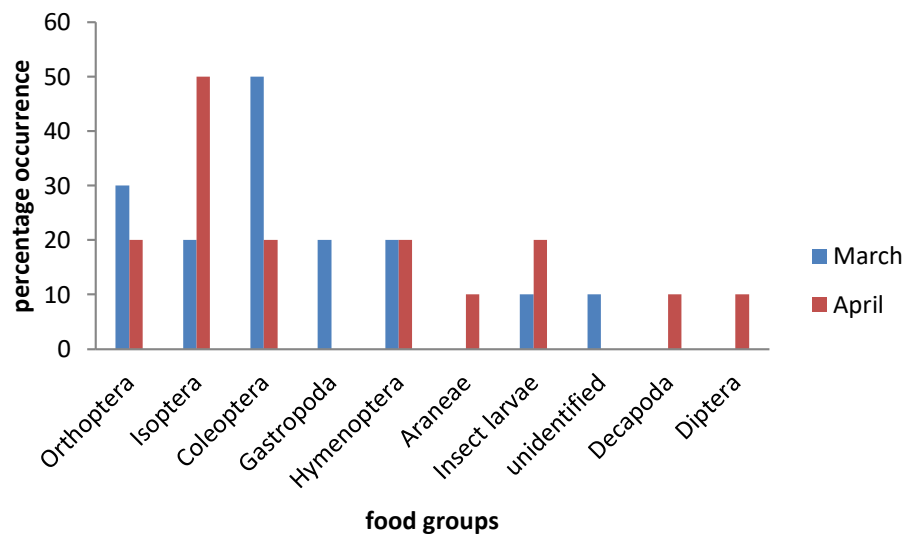
Figure 6: The frequency of occurrence of food groups eaten by anuran species in Kimboza Forest Reserve during March and April

4.3 Dietary Diversity of Anuran Species in Kimboza Forest Reserve

4.3.1 Diversity of prey items eaten by anurans in different habitats in Kimboza Forest Reserve

In Kimboza Forest Reserve the diversity of prey items eaten by anurans from areas along forest and tarmac road border (Shannon-Wiener Function, H = 1.395), was the highest diversity index among all habitats in the forest. The lowest prey diversity index (Shannon-Wiener Function, H = 0.7875) was from anurans in areas along forest and farms border (Table 8). However, the diversity of prey items eaten by anurans found in different habitats in the whole forest including areas where forest border with farms, along Kimboza streams, along forest and tarmac road border and in forest interiors had no significant difference (Kruskal-Wallis test, H = 6, P > 0.05).

Table 8: Shannon-Wiener Function, H of prey items eaten by anurans in different habitats of Kimboza Forest Reserve

Food groups	Diversity of prey items			
	FR	FI	FS	FF
Orthoptera	1	3	-	4
Isoptera	2	14	93	137
Coleoptera	5	3	2	4
Gastropoda	2	3	1	-
Hymenoptera	7	78	57	33
Araneae	-	-	3	-
larvae	-	1	1	3
unidentified	-	1	1	0
Decapoda	-	-	-	1
Diptera	-	-	2	-
Total number of prey items	**17**	**103**	**160**	**182**
Shannon-Wiener (H)	**1.395**	**0.8808**	**0.9623**	**0.7875**

FR = forest border road, FI = forest interiors, FS = along forest streams, FF = forest border farms

Further, the diversity of prey items eaten by anurans in Kimboza Forest Reserve varies significantly between the upper and lower segment of the forest (Mann Whitney U test, U = 22, P < 0.05). The highest diversity of prey items (Shannon-Wiener Function, H = 1.395) was recorded in area along forest and tarmac road border in the upper segment of the forest, while the lowest diversity of prey items was recorded in forest interiors of the lower segment of the forest (Shannon-Wiener Function, H = 0.4825) (Table 9).

Table 9: Shannon-Wiener Function, H of prey items eaten by anurans in different habitats of Kimboza Forest Reserve during March and April

Habitat	Diversity of prey items		
	Both rounds	March	April
Upper fragment	1.077	0.8755	1.345
Lower fragment	0.6048	0.4825	0.6365
Upper fragment and tarmac road border	1.395	1.119	0.673
Lower fragment and tarmac road border	-	-	-
Upper fragment interior	1.167	1.167	-
Lower fragment interior	0.4825	0.4825	-
Upper fragment along Kimboza streams	0.9623	0.7163	1.06
Lower fragment along Kimboza streams	-	-	-
Upper fragment and farms border	0.5536	0.2494	1.517
Lower fragment and farms border	0.6365	-	0.6365

Furthermore, the variation of diversity of prey items eaten by anurans in March and April was not statistical significant (Wilcoxon Signed Rank Test, Z = -0.42, P>0.05). Also, the overall diversity of prey items eaten in both months was not significant different to the diversity of prey items eaten in April (Wilcoxon Signed Rank Test Z, = -0.34, P>0.05). Though the overall diversity of prey items in both months were significant different to the diversity of prey items in March (Wilcoxon Signed Rank Test Z, = -2.20, P<0.05). The highest diversity of prey items was recorded in April (Shannon-Wiener Function, H= 1.517) and the lowest diversity (Shannon-Wiener Function, H= 0.2494) was in March (Table 9).

4.3.2 The diversity of prey items eaten by each anuran species

Among species *Ptychadena anchietae* had the highest diversity of prey items (Shannon-Wiener Function, H=1.4942), while *Leptopelis uluguruensis* (Shannon-Wiener Function, H = 0), had the lowest diversity of prey items (Table 10).

Table 10: Shannon-Wiener Function (H) of different anuran species in Kimboza Forest Reserve

	Number of prey items per anuran species									
Food groups	**L.u**	**L.f**	**A.x**	**N.t**	**A.a**	**C.x**	**P.a**	**X.b**	**P.n**	**P.ac**
Orthoptera	2	2	0	0	0	1	0	1	2	0
Isoptera	0	8	177	0	55	0	0	1	5	0
Coleoptera	0	5	1	2	0	4	1	0	0	1
Gastropoda	0	5	0	0	0	0	1	0	0	0
Hymenoptera	0	0	113	50	0	0	3	0	2	7
Araneae	0	0	1	0	0	0	2	0	0	0
larvae	0	0	1	0	1	0	0	0	3	0
Unidentified	0	0	0	0	0	1	1	0	0	0
Decapoda	0	0	0	0	0	0	0	1	0	0
Diptera	0	0	0	0	0	0	0	0	0	2
Total number of prey items	**2**	**20**	**293**	**52**	**56**	**6**	**8**	**3**	**12**	**10**
Shannon-Wiener (H)	**0**	**1.29**	**0.73**	**0.16**	**0.09**	**0.87**	**1.49**	**1.10**	**1.31**	**0.80**

L.u= *Leptopelis uluguruensis*, L.f = *Leptopelis flavomaculatus*, C.x = *Chiromantis xerampelina*, P.a = *Ptychadena anchietae*, A.x = *Arthroleptis xenodactyloides*, N.t = *Nectophrynoides tornieri*, A.a = *Arthroleptis affinis* X.b = *Xenopus borealis*, P.n = *Phrynobatrachus natalensis,* P.ac = *Phrynobatrachus acridoides*

4.4 Influence of Habitat on the Feeding Preferences of Anuran Species in Kimboza Forest Reserve

4.4.1 Degree of Food Preference by anurans in different habitats in Kimboza Forest Reserve

The Degree of Food Preference of anurans found in upper and lower segment forest varied significantly (Mann Whitney U test, U = 23, P < 0.05). For instance, majority of the food groups eaten by anurans found in the upper segment of the forest were considered secondary and occasional (Appendix 2). On the other hand, in the lower segment of forest most of the food groups were considered preferential (Appendix 3).

The upper segment had highly preferential as the highest level of DFP given to food groups eaten by anurans. The food group in highly preferential category was Hymenoptera. Hymenoptera was highly preferential for both *Nectophrynoides tornieri* (3.50) and *Phrynobatrachus acridoides* (3.00). Preferential food groups were Isoptera Orthoptera and Diptera. Occasional food groups were all food groups except Diptera, Gastropoda and Decapoda while secondary food groups were Isoptera, Orthoptera, Gastropoda, Decapoda, Coleoptera and Hymenoptera (Appendix 2). However, the variation of values of Degree of Food Preference (DFP) among anuran species found in the upper fragment of the forest was not significant (Kruskal-Wallis Test, H= 6.2, P > 0.05).

Food groups from anurans found in the lower segment of the forest had preferential as the highest level of DFP. Preferential food groups were Isoptera and Orthoptera. Isoptera and Orthoptera were preferential for *Arthroleptis xenodactyloides* (2.89) and *Chiromantis xerampelina* (2.00) respectively. Another level of DFP given to the food groups eaten by anurans in lower fragment was secondary. Hymenopterans in *Arthroleptis xenodactyloides*

(1.22) was secondary preferred (Appendix 3). The variation of the values of DFP among anuran species found in the lower fragment of forest was not significant (Kruskal-Wallis Test, H =16.5, P = 0.057).

Furthermore, anurans found in areas along Kimboza forest streams of upper and lower fragment of the forest had majority of their food groups in secondary and occasional categories. Highly preferential was the highest level of DFP given to food groups found in anurans of this part of the forest. The food groups in highly preferential category were Isoptera and Hymenoptera. Preferential food groups were Isoptera and Diptera (Appendix 4). However, the variation of DFP values of the food groups was not significant in this habitat (Kruskal-Wallis Test, H=1.2, P > 0.05).

Along forest and farms border most of the food groups were occasional. Highly preferential was the highest level of DFP given to food group found in anurans of this part of the forest. Coleoptera was the food group considered highly preferential. Isoptera and Decapoda were considered preferential, while Coleoptera, Hymenoptera, Isoptera, Orthoptera and larvae were occasional. Isoptera was also a secondary preferred food group (Appendix 5). The variation of DFP values of the food groups was not significant in this habitat (Kruskal-Wallis Test, H=1.5, P > 0.05).

Along forest and tarmac road border the highest level of DFP was preferential. The food group in preferential category was Orthoptera in *Leptopelis uluguruensis* (2.00). The Secondary preferred food groups were Coleoptera and Gastropoda while occasional food group was Isoptera (Appendix 6). The variation of DFP values of food groups eaten by anurans in this habitat was not significant (Mann Whitney U test, U = 42, P >0.05).

In the forest interior majority of the food groups were secondary, and the highest level of DFP was secondary. The secondary preferred food groups were Gastropoda, Coleoptera, Isoptera and larvae. Orthoptera and Isoptera were occasional food group in this part of the forest (Appendix 7). The variation of DFP values of food groups eaten by anurans in this habitat was not significant (Mann Whitney U test, U = 41, P >0.05).

Finally, majority of the variations of DFP values for each anuran species found among different habitats (areas were forest border with farms, along Kimboza streams, along forest and tarmac road border and in forest interiors) was not significant (Table 11). However, three species *Ptychadena anchietae* (Kruskal-Wallis Test, H=16.6, P<0.05), *Phrynobatrachus natalensis* (Kruskal-Wallis Test, H=12.96, P<0.05) and *Phrynobatrachus acridoides* (Kruskal-Wallis Test, H= 9.5 P<0.05), they had significant variation of their DFP values among different habitats.

Table 11: Independent Samples Kruskal Wallis Statistic Test Results on comparison of DFP values of each anuran species found among habitats

Species	P Value
Leptopelis flavomaculatus	0.115
Arthroleptis xenodactyloides	0.320
Ptychadena anchietae	0.001*
Phrynobatrachus natalensis	0.005*
Xenopus borealis	0.104
Chiromantis xerampelina	0.392
Arthroleptis affinis	0.104
Phrynobatrachus acridoides	0.024*
Leptopelis uluguruensis	0.392

Significance level = 0.05

4.4.2 Degree of food preference of anurans species in Kimboza Forest Reserve during March and April

During March in the upper segment of the forest majority of the food groups eaten by anurans were occasional. The highest level of DFP in this month was highly preferential. The food groups in highly preferential category were Coleoptera and Hymenoptera. Food groups Orthoptera and Isoptera were considered preferential while Gastropoda and Coleoptera were secondary food groups. In contrast in April the majority of food groups were secondary, and the highest level of DFP in this month was highly preferential. Diptera was considered highly preferential in *Phrynobatrachus acridoides* (3.00). All food groups were in secondary category except Gastropoda, Decapoda, larvae and Araneae. Occasional food groups included Orthoptera, Coleoptera, larvae, Isoptera and Hymenoptera (Appendix 8). However, the variation of DFP values of food groups was not significant between March and April (Kruskal-Wallis Test, H=5.6, P > 0.05).

On the other hand, in the lower segment of the forest during March only two species were found and the highest level of DFP in this month was highly preferential. The food group in highly preferential category was Hymenoptera in *Arthroleptis xenodactyloides* (3.00). Orthoptera was in preferential category, while Isoptera as a secondary food group. In April, the lower segment of the forest had highly preferential as the highest level of DFP. The food group in highly preferential category was Isoptera in *Arthroleptis xenodactyloides* (3.43). There were no food groups in secondary, though Hymenoptera was considered occasional food group (Appendix 9). The variation of DFP values of food groups was not significant between March and April (Kruskal-Wallis Test, H=16.5 P = 0.057).

CHAPTER FIVE

5.0 DISCUSSION

5.1 The Distribution of Anuran Species across Different Habitats within Kimboza Forest Reserve

Anurans' distribution across different habitats within the forest and along forest borders was significantly different. Most of anurans occurred in areas along Kimboza forest streams, along forest and farms border and in the interiors of the upper segment of the forest, while in the lower segment most of the species occurred in the interior areas of the forest and areas along forest and farm borders. Different factors contributed to high occurrence of anurans in these habitats. For instance, the highest occurrence of anuran species in areas along forest streams was attributed to the fact that areas with water sources have high structural heterogeneity which offers different microhabitats for various species to exploit, and thus led to high diversity of species in these areas (Narváez *et al*., 2014).

Further, the highest occurrences of anuran in areas along forest and farms border could be due to the presence of ponds in this habitat which were formed during the period of heavy rain and used by several species for breeding activities. In literature (da Silva and Rossa-Feres, 2011; da Silva *et al*., 2012) established that water bodies within agricultural landscape and along forest edge are important as high abundance of anurans use these areas for breeding activities. Again, higher occurrence of anuran species in forest interiors habitats than in forest and road border habitats could be a result of a tendency of forest anuran species to prefer forest interiors areas than the forest edges. Forest edges are known to have higher changes in moisture (e.g. humidity in important microhabitats), microhabitat availability, food availability and more risk of predation than forest interior

(McCracken and Forstner, 2014). As a result some of anurans which are sensitive to such changes tend to avoid forest edges and prefer more forest interiors (Maynard *et al.*, 2016).

Furthermore, higher number of occurrence of anurans was recorded in the upper segment than the lower segment of the forest. This could be attributed to deforestation and the associated disturbances. During the study there were several observations of illegal harvesting of timber in the forest. Similar findings by Kacholi (2013) also reported deforestation activities in Kimboza forest reserve. However, the encounter of these events was more in the lower segment than in the upper fragment. Changes caused by deforestation are known to threaten amphibian species (Stuart *et al.*, 2004; Cushman, 2006), and these changes are known to alter their distribution, habitat use and range (Duellman and Trueb, 1994). For instance, deforestation cause changes like increase in temperature and decrease in soil moisture in the forest. As a result anuran species with high rates of water loss by evaporation fail to survive in such areas and leading to mortality due to desiccation (Rothermel and Semlitsch, 2002). Therefore, it is reasonable to assume that the lower occurrence of anurans species in the lower segment than that of the upper segment of the forest could be due to changes caused by deforestations activities going on in the lower fragment.

Among the 13 anuran species found in Kimboza forest the most common species were *Arthroleptis xenodactyloides* and *Leptopelis flavomaculatus*. Anuran species *Arthroleptis xenodactyloides* were found in forest interior (on forest floor hiding in leaf litters), areas where forest border with the road (also in leaf litter), along forest and farms border areas (in grasses and on herbs) and along Kimboza forest streams (in grasses and dry leaves). Harper *et al.* (2010) reported that *Arthroleptis xenodactyloides* live and breed in leaf litter of the forest floor and can occur in various habitats including lowland and montane forests, swamps, woodland and wet grasslands. *Leptopelis flavomaculatus* was found on

low vegetation of different habitats within the forest but also on forest floor. In literature (Channing and Howell, 2006; Harper *et al*., 2010) reported that *Leptopelis flavomaculatus* is a forest frog primarily found in semi deciduous forest in coastal areas, but also occurs in lowland and montane forest.

Second in occurrence was anuran species *Nectophrynoides tornieri, Arthroleptis affinis* and *Xenopus borealis. Nectophrynoides tornieri* was found on low vegetation on the forest but also on forest floor in forest interiors and areas were forest border with road. Harper *et al.* (2010) reported that *Nectophrynoides tornieri* is usually found on low vegetation of Lowland and montane forest and on forest edges. Additionally, Channing and Howell (2006) reported on the same species and stated that the species is usually found in leaf litter, forest floor growth, soil cracks, and in rocks crevices but it can also be found on vegetation surface. *Arthroleptis affinis* was found on forest floor hiding in leaf litter of three habitats including forest interiors, along Kimboza forest streams and along forest and farms border areas. In literature (Channing and Howell, 2006; Harper *et al*., 2010) reported that *Arthroleptis affinis* was associated with leaf litter on forest floor and usually found in montane and sub montane forests as well as grasslands and a range of degraded habitat types. Further, *Xenopus borealis* was found in stagnant water bodies, along forest and farm border, in forest interior and along Kimboza forest stream. Tinsley *et al.* (1996) found that amphibians belonging to genus Xenopus have colonised a variety of habitats both natural and manmade and they are found in stagnant, slow or even fast moving water bodies.

Third in occurrence were *Chiromantis xerampelina, Phrynobatrachus natalensis, Afrixalus uluguruensis* and *Leptopelis uluguruensis,* each of them occurred only in two habitats. *Chiromantis xerampelina* was found in forest interiors and along forest and farms

borders, while *Leptopelis uluguruensis* occurred along forest and road borders areas and in forest interiors. Various studies (e.g. Channing and Howell, 2006; Harper *et al.,* 2010; IUCN, 2017) reported that *Chiromantis xerampelina* occupies a variety of habitats including forests, all types of savannah, humid wooded savannah, shrubland, pastureland and urban areas. In addition IUCN (2017) has drawn attention to the fact that *Chiromantis xerampelina* is found in disturbed forest this evidence seems to support the finding of this study as this species was found inside the lower segment of Kimboza forest which had several sign of disturbance includes burned areas and illegal harvesting of trees, but also on forest and farm borders which are also altered parts of the forest. *Leptopelis uluguruensis* was reported to occupy forests of Eastern Arc mountain of Tanzania but also found in disturbed habitat including banana patches near mature forest. While *Afrixalus uluguruensis* occurred in areas along Kimboza forest streams, along forest and farms borders, and *Phrynobatrachus natalensis* occurred only in areas along forest and farms borders. In literature Harper *et al*. (2010) reported that *Afrixalus uluguruensis* usually occur in intact moist lowland and montane forest Uluguru, and Udzungwa Mountains, but also it can occur in coastal areas of Tanzania though it is not yet confirmed. Thus, the occurrence of *Afrixalus uluguruensis* and *Leptopelis uluguruensis* in Kimboza forest reserve support the findings by (Bayliss, 1994) which found that Uluguru nature reserve share some of its species with Kimboza forest reserve. Furthermore*, Phrynobatrachus natalensis* was reported to usually occur on vegetation on the edges of water in forest, grassland, savanna and agricultural areas (Channing and Howell, 2006; Harper *et al.,* 2010).

Ptychadena anchietae, Phrynobatrachus acridoides, Hyperolius mitchelli and *Afrixalus stuhlmanni* were the species that were least observed since each of them species occurred only in one habitat type. All of them occurred in areas along Kimboza forest streams

except *Afrixalus stuhlmanni* which was found in ponds and dry areas along forest and farms borders. Reporting on one of the species *Ptychadena anchietae,* Harper *et al.* (2010) and Barnes (2016) found that this species is associated with open areas, woodland, grassland, suburban areas and forest, but also it is always found near water. Also *Hyperolius mitchelli* was found to be a species associated with water bodies in the forest (Channing and Howell, 2006). However, Harper *et al*. (2010) reported the species to be found in dry and moist forest, but also in degraded habitat including gardens and low-intensity agricultural land. *Phrynobatrachus acridoides* was also reported to be associated with water in various habitats including forest, grassland, shrubland and savannas (Harper *et al*., 2010). This species was found in these various habitats wherever there is water like near puddles, streams or flooded grassy areas. Lastly, *Afrixalus stuhlmanni* is reported to occupy coastal forests, grassland, and savanna in Coastal areas of Tanzania and inland to the Kilombero floodplain (Channing and Howell, 2006; Harper *et al.,* 2010). In general, the reason behind the sporadic occurance of these species was due to the fact that most of these species are associated with water and thus they could only be found in habitats within the forest that has water sources such as along Kimboza streams and in ponds along forest and farms borders.

5.2 Dietary Composition of Anuran Species of Kimboza Forest Reserve

5.2.1 The rate of feeding activities

The proportion of empty guts in a given sample of species could be a good estimator of energy balance. Individuals having empty guts are assumed to be in negative energy balance and dependent on reserve stores whereas individuals having food in their guts are assumed to be in positive energy balance because they are gaining energy. Therefore, in a given sample of species a low proportion of empty guts indicate a positive energy balance while a high proportion indicate a negative energy balance (Huey *et al*., 2001; Arrington *et*

al., 2002). In Kimboza Forest Reserve anurans with empty guts were approximately 35%, therefore the study data suggest that the forest had a positive energy balance which means it provided optimal feeding conditions for anurans survival.

Further, comparing the energy balance among different habitats within the forest, areas along forest and farms border (contributed 76% of all individuals with empty guts) seemed to be the areas with the least energy balance compared to all other habitats in the forest. The lower rate of feeding activity might be induced by the scarcity of available food but also might be because of the energetic constraints associated with the reproductive behaviour of anurans (Biavati *et al*., 2004). Kovács *et al*. (2007) found that during reproductive period (March-end of May) the number of empty stomachs was higher than the other seasons. Since the study was conducted during the same period then the high number of empty guts of anurans found in ponds along forest and farms border could be due to the reproductive period but also due to the scarcity of available food in this habitat. Another reason for empty guts of anurans studied here could be because of the time period anurans were captured. Sole and Rödder (2009) found that feeding activities of anurans usually start after 2 to 4h after night fall. Active search of anurans in this study was conducted between 0600 to 1800 h. On this basis this could be the reason for empty guts in studied specimen.

5.2.2 Abundance and frequency of occurrence of the prey items eaten by anuran species in Kimboza Forest Reserve

The diet of anurans of Kimboza forest reserve had high abundance of termites and ants, this may be attributed to the fact that the diet of these anurans may be to a certain degree reflecting the prey availability in Kimboza forest. For instance, the high abundance of ants in anuran diet could be reflecting the fact that Kimboza forest is a lowland forest (Rodgers

et al., 1983), and such forests have high abundance of ants (Lima *et al.*, 2010). Again, some species of anurans are known to consume large amount of termites if such insects are abundant in their habitats. For instance Biavati *et al.* (2004) found that anuran species *Ameerega flavopicta (*Dendrobatidae) consumed large amount of termites at a site of Cerrado vegetation in central Brazil, where such insect were abundant. Given the evidence it can be seen that the large consumption of isopterans (termites) and hymenopterans (ants) by anurans in Kimboza Forest Reserve was due to the high abundance of these insects in this study area. Wachlevski *et al.* (2008) concluded that anurans' diet to a certain degree may reflect the prey availability in the surrounding environment.

However, it is also possible that the greater representation of these food groups, termites and ants is due to their relative higher indigestibility compare to other prey items. As Measey *et al.* (2004) point out that there is a tendency of arthropods and other social insects to be overestimated in gut contents analysis due to their relatively indigestible chitinized exoskeleton. As a result, most of the times the soil-dwelling social insects (termites and ants) are ranked higher in frequency compared to the other gut contents excised. Meanwhile, Decapoda (Crustacean) aquatic prey was the least abundant food group. Decapoda was consumed by only one species (*Xenopus borealis)* which is an aquatic species. Most of the preys consumed by anurans in Kimboza Forest Reserve were Terrestrial. Terrestrial invertebrates are known to dominate the diet of most anurans, even in those species which are aquatic or semi aquatic (e.g. Hirai and Matsui, 2001, Sas *et al.*, 2009).

In contrast, the most frequently collected food group from the guts of anurans was Coleoptera 6 out of 10 anuran species (Fig. 6). Coleoptera was found to be the most frequently collected food group, even though it was not the most abundant food group.

The tendency of most of anurans to consume the less abundant food group is said to be a strategy to save energy, capturing a big prey being more advantageous, and then hunting a high number of small preys (Ferenti *et al*., 2010). Likewise Klaion *et al.* (2011) found that coleopterans are important prey for large leaf litter frogs, as they present large body sizes and mass, which provide an appropriate amount of food and energy. Further, the second frequently occurring food groups were Orthoptera, Hymenoptera and Isoptera. Plitsi *et al* (2016) reported that the food groups which are abundant in the diet of anurans are also the same food groups which are frequent in most cases. Therefore**,** Hymenoptera and Isoptera high frequency was the result of high abundance of these food groups in the study area. However, Orthoptera was among the less abundant food groups but was the second most frequent food groups. This could be due to the fact that anurans tend to prefer large body sized preys (e.g. Orthoptera) which offer appropriate amount of food and energy. As Klaion *et al*. (2011) further point out that Orthopterans are also important prey as Coleopterans which offer appropriate amount of food and energy for anurans.

A study by Cogălniceanu *et al*. (2000) found a relationship between abundance and frequency of occurrence of food groups in the diet of species. They reported that the consideration of both abundance and frequency for the same sample offers an informative estimate of the homogeneity of feeding. If the food groups which are more abundant are the same food groups which are more frequent then the given population exploits its habitat sources in an effective way. However, the vice versa would mean the population is not using the habitat sources in an effective way (Plitsi *et al*., 2016). On this basis, it is was evident that all of anurans species except one species *(Phrynobatrachus natalensis)* exploit their habitat sources in an effective way as the most abundant food groups for each anuran species were also the same food groups which are most frequent in their diet. *Phrynobatrachus natalensis* had Isoptera as the most abundant food group in it diet, but

insect larvae were the most frequent food groups (Appendix 1 and Table 9). The reason behind poor utilisation of habitat sources by *Phrynobatrachus natalensis* could be the nature of the habitat the species was found. *Phrynobatrachus natalensis* was found in ponds along forest and farm borders and these areas during the study were found to have negative energy balance (high number of empty stomachs of anuran species), which means they had scarcity of food. Therefore, the lack of efficiency in utilisation of sources by *Phrynobatrachus natalensis* could be due to lack of food in the habitat it occupied. (Plitsi *et al*., 2016) found that species in a habitat which has limited diversity of the invertebrate fauna tends to fail to utilise the resource of the habitat in an effective way.

Furthermore, anurans of Kimboza forest were found to consume 10 different food groups and all belonging to the invertebrate category. The work of Anderson *et al.* (1999) reveals that the diets of anurans consisted mainly of invertebrates. The diets of anuran species depend on several factors, but some of them are specialisation, foraging mode, diet plasticity, and changes in resource availability due to habitat alterations by humans (Lima *et al*., 2010). Reflecting these factors the diet composition of anurans in this study was for instance found to show that anurans used different foraging modes, sit- and -wait and active search. According to Toft (1981) there are two adaptive peaks of foraging strategies which are sit-and-wait, and active search. Species which use sit-and-wait foraging strategies consume a few large preys, mobile and solitary invertebrates as grasshoppers, snails, beetles, larvae, and spiders, while active search consume large amount of small preys which often live in aggregations such as ants and termites. Several species of Kimboza forest including *Leptopelis uluguruensis, Leptopelis flavomaculatus, Chiromantis xerampelina, Ptychadena anchietae, Xenopus borealis* and *Phrynobatrachus natalensis* used sit and wait as the only foraging strategy, as consumed large preys and avoided consumption of small preys like ants and termites (Fig. 4). The food groups

consumed by these species included Orthoptera (grasshoppers), Isoptera (harvester termites), Coleoptera (beetles), Gastropoda (snails and slugs), insect larvae, Hymenoptera (bees) Araneae (spiders) and Decapoda (crustaceans). The reason behind the use of sit and wait foraging strategy by these species could be due to the high abundance and diversity of preys in the habitats were they were found. As Narváez *et al.* (2014) point out that anurans feeding on areas with great availability of prey items are expected to exhibit a sit and wait foraging strategy. However, this was not the case for *Phrynobatrachus natalensis*, as the species was found only on areas along forest and farms which had low availability of food. *Phrynobatrachus natalensis*, foraging strategy was not due to high abundance but simply a strategy used by this species in order to consume the most available and easily captured preys in a habitat it was found. As Rödel (2000) point out that *Phrynobatrachus natalensis* is an opportunistic predator, which consumes the most accessible and easily captured preys.

Conversely, other anurans used intermediate forage strategies, alternating between sit and wait and active search. The tendency of alternating between sit-and-wait and active searching behaviors enable anurans to consume few large preys and a large amount of small preys (Ferenti *et al.*, 2010). For instance, leaf litter anurans *Arthroleptis xenodactyloides* and *Arthroleptis affinis* ate large amount of small preys such as ants and termites, but also eat few large preys like beetles, spiders and larvae (Fig. 4). Another species which used intermediate forage strategies was *Nectophrynoides tornieri* which ate large amount of small preys ants (Hymenoptera) and also ate few large prey Coleoptera (beetles) (Fig. 4). Again, *Phrynobatrachus acridoides* also used intermediate forage strategies where it consumed small preys including ants and flies (Diptera), but also large preys like beetles (Fig. 4). Research by Junca and Eterovick (2007) found that the foraging strategy of a species is not always rigidly fixed, which is consistent with the

findings of this study as the studied species alternates between sit-and-wait and active searching behaviors. The changes of foraging strategies which led to different diets of anuran species could be due to fluctuation of the availability of food in the habitat they occupied (Narváez *et al*., 2014; Sousa and Avila, 2015). Falico *et al*. (2012) established that generalist species have the ability to adjust diet to the more available resources so as to improve energy uptake and fitness. Anurans studied here have shown a tendency of diet plasticity as they were able to alternate their foraging strategies which led to adjustment of their diet to the more available resources to improve energy uptake and fitness. Thus, it could be concluded that *Phrynobatrachus acridoides, Nectophrynoides tornieri, Arthroleptis xenodactyloides* and *Arthroleptis affinis* are to a certain extent generalist predators.

5.3 Dietary Diversity of Anurans of Kimboza Forest Reserve

5.3.1 Diversity of prey items eaten by anurans in different habitats in Kimboza Forest Reserve

There were significant differences between the diet diversity of anurans from upper and lower segment of the forest. Anurans from the upper segment consumed more abundant and diverse food groups than the lower fragment of the forest. Bogdan *et al.* (2013) established that in order for a habitat to meet the trophic need of amphibians it must offer abundant and diversified food resources. The upper segment seemed to satisfy anurans' trophic needs as it offer abundant and diversified food groups different from the lower segment which its anurans consumed less abundant and less diversified food groups. The diet diversity depends on the quality of habitat inhabited by amphibians (Kovacs *et al.,* 2007). Therefore, the diet diversity data from this study suggest that the upper segment of Kimboza forest reserve is of higher quality compared to the lower segment.

Studies on Kimboza forest (Temu and Andrew, 2008; Kacholi, 2013) revealed the presence of illegal timber harvesting activities in the forest, which could be affecting its health. Harper *et al.* (2015) found that timber harvesting can cause dramatic changes in quality and extent of forest ecosystems. Consequently, the habitat quality affects the source of food for anurans (Daly *et al.*, 2008). Further, anurans are highly sensitive taxa and crucial indicators of environmental health and contamination (Fabricante and Nuñeza, 2012), and therefore the dietary diversity of anurans in the lower fragment could be reflecting the negative effects of deforestation activities currently going on in Kimboza forest which are more intense in the lower fragment of the forest as it was observed during the study.

Again, considering habitats within the forest and along forest edges, areas along forest and road borders had the highest diversity of prey items. Though, these areas were not considered of highest quality since anurans found within them consumed the lowest number of prey items among all habitats and for a habitat to be considered of high quality it should offer abundant and diversified food resources (Bogdan *et al.*, 2013). Areas along forest and farms and forest interiors had almost the same diet diversity index but areas in forest interiors were slightly above. Anurans from areas along forest and farms and forest interiors had the same number of food groups consumed 7 out of 10. However, forest interiors are of higher quality than areas along forest and farms border because the later had higher number of species which were collected and examined but still its diversity index was lower than the forest interior. Further, anurans from areas along Kimboza forest stream consumed 8 out of 10 food groups, and had both high diet diversity index and number of prey items. Anurans from this part of the forest consumed more diverse food groups than all other habitats except areas along forest and road borders but had more abundant food than all habitats except areas along forest and farms.

The habitat morphology is reflected by the food eaten by anurans (Narváez *et al.,* 2014). For instance, anurans feeding on the water source areas are expected to have greater availability of prey items than anurans in dry areas (Tews *et al.,* 2004). This is because areas with water sources tend to have higher structural heterogeneity compared with dry areas (Narváez *et al.,* 2014). These findings support the data on diet of anurans studied here, where anurans in areas along Kimboza forest stream had higher abundance and diversity of prey (Table 7). Therefore, these areas were considered to be of the highest quality than all other habitats within the forest followed by forest interiors and areas along forest and farms.

5.3.2 The diversity of prey items eaten by each anuran species

In general the diversity of the diet of anurans described here was low compared to other anurans studies (e.g. in Rödel, 2000; Bwong and Measey, 2010; Blackburn and Moreau, 2006; Channing and Howell, 2006; Konan *et al.,* 2016; Tohe *et al*., 2015; Enabulele and Aisien, 2012), as it was observed that most of anurans consumed less than 5 different food groups. The reason behind low prey electivity could be due to the period the study was conducted. The study started during the beginning of reproductive period early rain seasons (March) to the middle of reproductive period heavy rain season (April). Woodhead *et al.* (2007) found that the low number of elected food groups by a forest anuran species *Mantella aurantiaca* in Madagascar was due to the fact that the study was conducted during its reproductive period and thus this reflects the findings of this study.

Further, published data which describe the diet of the ten anurans species studied here are scarce. Similar observation by Hirschfield and Rödel (2011) also indicated that studies on African anurans are rare. Therefore, most of the literatures on the diet of anurans used here are at genus or family level. A number of studies (e.g. Rödel, 2000; Bwong and Measey,

2010; Enabulele and Aisien, 2012; Tohe *et al*., 2015; Konan *et al*., 2016) on the diet of anuran species belonging to genus *Ptychadena, Leptopelis, Phrynobatrachus* and *Xenopus* established that these anurans are opportunistic generalist predators which lack feeding preferences and have a wide diversity of food groups with no constant food in their diets. These results to some extent match with the findings on species like *Ptychadena anchietae, Phrynobatrachus natalensis, Leptopelis flavomaculatus* and *Xenopus borealis* which had a wide diversity of food more than other anuran species in the forest and no food group was constant.

On the other hand, some of the studied species (*Phrynobatrachus acridoides, Arthroleptis affinis, Nectophrynoides tornieri, Arthroleptis xenodactyloides* and *Leptopelis uluguruensis*) showed a certain degree of specialisation as the diet of these species were dominated by few food groups leading to a narrow diversity of food groups plus the presence of constant food (Appendix 1 and Table 9). *Phrynobatrachus acridoides, Arthroleptis affinis, Nectophrynoides tornieri,* and *Arthroleptis xenodactyloides* consumed large amount of small preys and few large preys. Toft (1980, 1981) found that leaf litter anurans have a diet continuum from species specialised in slow moving and hard-bodied arthropods (e.g. ants or termites) to generalists anuran species which prey on mostly soft-bodied and mobile arthropods (avoiding ants and termites). Since, *Phrynobatrachus acridoides, Arthroleptis affinis, Nectophrynoides tornieri and Arthroleptis xenodactyloides* consumed both large and small preys then these species are neither generalists nor specialist but intermediate species. The diet of intermediate species is known to be within the generalist-specialist continuum whereby species have highly varied diets, but with intense consumption of a few prey categories (Lima *et al.,* 2010). However, *Leptopelis uluguruensis* diet suggested that the species is a specialist as it consumed only one food group Orthoptera (grasshoppers). Caution should be taken here

on the interpretation since the study had only three individuals. Previous studies are in contrast with the study findings as species in genus *Leptopelis* are considered generalist.

The specialisation in diets of various anurans described here reflects to a certain degree, prey availability in the surrounding local environment (Wachlevski *et al*., 2008; Peltzer *et al*., 2010), since the absence of any prey type could encourage predators to specialise in other prey (Maneyro and da Rosa, 2004). Therefore, in absence of a valid prey availability test and due to the limited sample of anurans from each species it is reasonable to conclude that the diet of various anurans which showed some degree of specialisation in this study suggest high abundance attained by some particular prey types (e.g. Isoptera, and Hymenoptera) in each type of habitat found within Kimboza forest reserve. And that the possible preys for each species are diverse but specialisation might be present at local population level.

5.4 The Influence of Habitat on the Feeding Preferences of Anuran Species in Kimboza Forest Reserve

Majority of the food groups eaten by anurans in the upper segment of Kimboza forest reserve were considered secondary or occasional. However in the lower segment most of the food groups were considered preferential. This difference in degree of food preference between the upper and lower segment may be explained by the difference in the quality of each habitat in the forest. The quality of habitat is known to influence the feeding preferences in anurans (Ferenti *et al*., 2010). The upper segment offered more diverse of food groups than the lower segment, thus the upper segment was of higher quality than the lower segment. Bogdan *et al.* (2013) found that for a habitat to be considered of high quality should offer abundant and diversified food resources. As a result, anurans from upper fragment had a wide diversity of food groups to select and therefore anurans also

consumed a diverse of food groups without most of them having preferential or highly preferential food groups. Abundance and availability of prey is said to greatly influence what is ingested and may tend to conceal preferences (Piatti and Souza, 2011). Although the lack of trophic preference of anurans in this segment may also be due to the fact that most of these anurans are opportunistic predators.

On the other hand, anurans from lower segment had lower diversity meaning narrow range of selectivity forcing them to have a higher degree of food preference for the most abundant and available food groups. Maneyro and da Rosa (2004) also found that the absence of any type of prey could encourage predators to specialise in other prey. Further, anurans are known to change their diet preferences in response to the fluctuation of prey availability (Whitfield and Donnelly, 2006). Feeding of anurans is usually a result of adaptation to a present situation. Anurans do not use homogenous strategy all the times (Kovács *et al*., 2010). Therefore, the diet of anurans in the lower fragment reflects the prey availability in this part of the forest instead of a certain degree of specialisation. However, the comparison of the degree of food preference of anurans within different habitats (areas along Kimboza forest, in forest interiors, areas where forest border with farms and areas along forest and road border) showed no significant difference. The similarity of food preferences among species may be explained through the fact that these species use the same habitats in the forest area (Nuneza *et al.,* 2012), or it could be due to the opportunistic feeding behavior of the studied species (Lima *et al.*, 2010).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Kimboza forest reserve is a home for a diverse number of amphibians (anurans). Thirteen species of amphibian which belong to 7 families of order anuran were recorded in Kimboza forest reserve. Most these anuran species occurred in areas along Kimboza forest streams, along forest and farms border and the forest interiors. There were different reasons for high occurrences of species in each habitat. For instance, high occurrence of species in areas along Kimboza forest streams was due to the fact that these areas had the highest structural heterogeneity compare to all other which offered different microhabitats for various species to exploit and thus result to the highest diversity of species in this habitat. However, areas along forest and farm borders had low structural heterogeneity compare to others but still had the highest occurrence of species due to the presences of pools used by high number of anurans for reproductive activities. These pools were formed during a period of heavy rains. These findings are important as they reveal a need for more conservation effort in areas along Kimboza forest streams and areas along forest and farm borders.

Further, the whole forest in general was reported to offer optimal feeding conditions for anurans. However, anurans feeding in areas along forest and farms border had the lowest rate of feeding due to the reproductive period and the scarcity of available food in this habitat. Anurans consumed ten different food groups and the most abundant food groups were Isoptera (termites) and Hymenoptera (ants) .On the other hand, Coleoptera was the most frequent food group. The high frequency of Coleoptera in the diet of anurans was

due to a strategy used by anurans to save energy. The dietary diversity of each anuran species varied, whereby *Ptychadena anchietae* had the highest diet diversity and *Leptopelis uluguruensis* had the lowest. *Ptychadena anchietae, Phrynobatrachus natalensis, Leptopelis flavomaculatus* and *Xenopus borealis* had a wide diversity of food more than other anuran species with no constant, and were found to be opportunistic generalist predators lacking feeding preferences. In contrast, other species such as *Phrynobatrachus acridoides, Arthroleptis affinis, Nectophrynoides tornieri, Arthroleptis xenodactyloides* and *Leptopelis uluguruensis* were found to be intermediate. The diet specialisation of these species was found to be due to the availability of prey in the surrounding local environment. There was no significant difference of the feeding preferences of anurans within different habitats within the forest and along forest edges. The lack of difference was due to the fact that most of anurans species using the same habitats in the studied area but also it could also be due to opportunistic feeding behavior of the studied species. Major difference between the diet of anurans in the upper and lower segment of the forest was revealed on the findings from both distribution and the diet of anuran species of Kimboza forest reserve. The lower segment was affected by deforestation activities. Hence, the findings revealed a need for future studies focused on impact of deforestation activities on anurans distribution and diet. In general, this study is the first report on distribution and the feeding ecology of anurans in Kimboza forest reserve. The study provides preliminary estimation of the actual diet of these species and establishes a general distribution and feeding pattern for anurans in Kimboza forest reserve.

6.2 Recommendations

The following are recommendations for improvement of conservation of anurans in Kimboza forest reserve and advancement of the information on the distribution and the feeding ecology of anurans in this forest.

i.   First, future studies should focus on dry season and nocturnal species so as to come up with a complete understanding of the distribution and feeding ecology of anuran species of Kimboza forest reserve.

ii. Second, Areas along forest and farms borders have proven to be important breeding habitat for anurans during heavy rain seasons, therefore the forest management should consider conservations strategies for protecting these areas as it was also proven that these areas are currently not energetically balanced as some of the species were found to fail to utilize the habitat well.

iii. Third, a larger sample of each species found in Kimboza forest should be used to study the diet of anurans studied here so as to confirm the feeding pattern which was established.

iv. Finally, future studies should focus on the impact of deforestation activies on the distribution and diet of anuran species of Kimboza forest reserve, as the study findings revealed major difference between the disturbed and undisturbed segments of the forest.

REFERENCES

Abrol, D. P. (2012). *Pollination Biology: Biodiversity Conservation and Agricultural Production*. Springer, USA. 792pp.

Allmon, W. D. (1991). A plot study of forest floor litter frogs, Central Amazon, Brazil. *Journal of Tropical Ecology* 7: 503–522.

Amphibia web (2017). Species by numbers. [https://amphibiaweb.org/amphibian/speciesnums.html] site visited on 27/10/2017.

Anderson, A. M., Haukos, D. A. and Anderson, J. T. (1999). Diet composition of three anurans from the Playa Wetlands of Northwest Texas. *Copeia* 2: 515-520.

Andreone, F., Channing, A., Drewes, R., Gerlach, J., Glaw, F., Howell, K., Largen, M., Loader, S., Lötters, S., Minter, L., Raxworthy, C., Rödel, M. O., Schiøtz, A., Vallan, D. and Vences, M. (2008). Amphibians of the Afrotropical Region. In: *Threatened Amphibians of the World*. (Edited by Stuart, S.) Lynx Editions, Barcelona. pp. 53–58.

Arrington, D. A., Winemiller, K. O., Loftus, W. F. and Akin, S. (2002). How often do fishes "run on empty"? *Ecology* 83: 2145-2151.

Arroyo, S. B., Cardozo, V. H. and Pinilla, M. P. (2008). Diet, microhabitat and time of activity in a Pristimantis (Anura,Strabomantidae) assemblage. *Phyllomedusa* 7 (2): 109-119.

Barrat, C., Tonelli, E., Menegon, M., Doggart, N., Bowkett, A., Harris, E.W., Howell, K., Ngalason, W. and Loader, S. (2014). Fragmented habitats and species: The challenges of amphibian Conservation in Tanzania Today. *In: Frog log: Promoting Conservation, Research and Education for the World's Amphibians*. (Edited by Hansen, C.M. *et al*.)Global Wildlife ConservationAustin, USA. pp. 63-64.

Bayliss, J. (1994). Preliminary biological investigation into Kimboza Forest Reserve, Morogoro District, Morogoro region, Tanzania, Technical Report No 19. The Society for Environmental Exploration, London, UK and The University of Dar es salaam, Dar es salaam, Tanzania. 42pp.

Beard, K. H., Eschtruth, A. K., Vogt, A. K., Vogt, J. D. and Scatena, N. F. (2003). The effects of the frog *Eleutherodactylus coquion* invertebrates and ecosystem processes at two scales in the Luquillo Experimental Forest, Puerto Rico. *Journal of Tropical Ecology* 19: 607–617.

Beebee, T. J. C. (1996). *Ecology and Conservation of Amphibians*. Chapman and hall, London. 214pp.

Biavati, G. M., Wiederhecker, H. C. and Colli, G. R. (2004). Diet of *Epipedobates flavopictus* (Anura: Dendrobatidae) in a Neotropical savanna. *Journal of Herpetology* 38: 510-518.

Bickford, D., Howard, S. D., Daniel, J. J. N. and Sheridan, J. A. (2010). Impacts of climate change on the amphibians and reptiles of Southeast Asia. *Biodiversity and Conservation* 19: 1043–1062.

Blackburn, D. and Moreau, C. (2006). Ontogenetic diet change in the arthroleptid frog and *Schoutedenella xenodactlyloides. Journal of Herpetology* 40: 388-394.

Blaustein, A. R., Walls, S. C., Bancroft, B. A., Lawler, J. J., Searle, C. L. and Gervasi, S. S. (2010). Direct and indirect effects of climate change on amphibian populations. *Diversity* 2: 281–313.

Bogdan, H. V., Covaciu-Marcov, S. D., Cupsa, D., Cicort-Lucaciu, A. S. and Sas, I. (2012). Food composition of a *Pelophylax ridibundus* (Amphibia) population from a thermal habitat in Banat region (southwestern Romania). *Acta Zoologica Bulgarica* 64(3): 253-262.

Braga, F. M. S. (1999). O grau de preferênciaalimentar: métodoqualitativo e quantitativo para o estudo do conteúdoestomacal de peixes. *Acta Scientiarum, Maringá* 21:291- 295.

Bwong, B. A. and Measey, G. J. (2010). Diet composition of *Xenopus borealis* in Taita Hills: effects of habitat and predator size. *African Journal of Ecology* 48: 299– 303.

Carr, L. W. and Fahrig, L. (2001). Effect of road traffic on two amphibian species of differing vagility. *Conservation Biology* 15: 1071–1078.

Carss, N. D. (1995). Foraging behaviour and feeding ecology of the otter *Lutra lutra*: A selective review. *Italian Journal of Mammalogy* 7 (1-2): 179-194.

Channing, A. and Howell, K. (2006). *Amphibians of East Africa*. Cornell University Press, Ithica, New York. 418pp.

Clarke, G. P. and Dickinson, A. (1995). Status reports for 11 coastal forests in Coast Region, Tanzania. Frontier-Tanzania Technical Report 17.The Society for Environmental Exploitation, London, UK and the University of Dar-es-Salaam, Dar-es-Salaam, Tanzania. 113pp.

Cogălniceanu, D., Palmer, M. W. and Ciubuc, C. (2000). Feeding in Anuran communities on islands in the Danube floodplain. *Amphibia-Reptilia* 22: 1–19.

Collins, J. P. and Wilbur. M. H. (1979). Breeding habits and habitats of the amphibians of the E. S. George Reserve, Michigan, with notes on the distribution of fishes. *Occasional Papers of the Museum of Zoology, University of Michigan* 686: 1–34.

Connelly, S., Pringle, C. M., Whiles, M. R., Lips, K. R., Kilham, S. and Brenes, R. (2011). Do tadpoles affect leaf decomposition in neotropical streams? *Freshwater Biology* 56: 1863-1875.

Covaciu-Marcov, S. D., Cupsa, D., Ferenti, S., David, A. and Dimanceas, N. (2010).Human influence or natural differentiation in food composition of four Amphibian species from Histria Fortress, Romania. *Acta Zoologica Bulgarica* 62(3): 307-313.

Cushman, S. A. (2006). Effects of habitat loss and fragmentation on amphibians: a review and prospectus. *Biological Conservation* 128: 231-240.

da Silva, F. R. and Rossa-Feres, D. C. (2011). Influence of terrestrial habitat isolation on the diversity and temporal distribution of anurans in an agricultural landscape. *Journal Tropical Ecology* 27: 327-331.

da Silva, F. R., Candeira, C. P. and Rossa-Feres, D. C. (2012). Dependence of anuran diversity on environmental descriptors in farmland ponds. *Biodivers Conservation* 21: 1411-1424.

Dajoz, W. E. (1983). *Ecologia Geral*. São Paulo, Vozes. 474 pp.

Daly, J. W., Garraffo, H. M., Spande, T. F., Giddings, L. A., Saporito, R. A., Vieites, D. R. and Vences, M. (2008). Individual and geographic variation of skin alkaloids in three species of Madagascan poison frogs (Mantella). *Journal of Chemical Ecology* 34: 252–279.

Daly, J. W., Myers, C. W. and Whittaker, N. (1987). Further classification of skin alkaloids from neotropical poison frogs (Dendrobatidae), with a general survey of toxic/noxious substances in the Amphibia. *Toxicon* 25: 1023–1095.

Dodd, C. K. and Smith, L. L. (2003). Habitat destruction and alteration. In: *A summary of the effects of habitat destruction on amphibians: Amphibian conservation*. (Edited by Semlitsch, D.R.) Smithsonian Institution Press, Washington, D.C. pp. 94-112.

Doggart, N., Lovett, J., Mhoro, B., Kiure, J. and Burgess, N. (2004). Biodiversity surveys in the Forest Reserves of the Uluguru Mountains Part I: An overview of the biodiversity of the Uluguru Mountains. [http://www.easternarc.or.tz/groups/ webcontent/documents/pdf/Ulugurus%20draft%20Part%201%20v.5.pdf] site visited on 22/9/2016.

Duellman, W. E. and Trueb, L. (1994). *Biology of Amphibians*. McGrawHill, Baltimore. 670pp.

Duellman, W. E. and Trueb, L. (1986). *The Biology of Amphibians*. McGraw-Hill, New York. 670pp.

Duffy, J. E. (2002). Biodiversity and ecosystem function: the consumer connection.*Oikos* 99: 201–219.

Dunson, W. A., Wyman, R. L. and Corbett, E. S. (1992). A Symposium on Amphibian Declines and Habitat Acidification. *Journal of Herpetology* 26: 349-352.

Duré, M.I. and Kehr A.I. (2004).Influence of Microhabitat on the Trophic Ecology of Two Leptodactylids from Northeastern Argentina. *Herpetologica* 60: 295-303.

Eastern Arc Mountains Conservation Endowment Fund, (2008).Forest reserves, amphibians and birds of the eastern arc mountains. [http://www.easternarc. or.tz/groups/webcontent/documents/pdf/Species%20by%20Forest%20Reserves %20Report.pdf] site visited on 22/9/2016.

Enabulele, E. E. and Aisien, M. S. O. (2012). Diets of *Hemisus mamoratus* and *Leptopelis hyloides* (order anura) from monoculture plantations in southern Nigeria. *Zoologist* 10: 48-52.

Fabricante, K. M. B. and Nuñeza, O. M. (2012). Diet and endoparasites of *Rana grandocula* (Amphibia, *Ranidae*) and *Limnonectes magnus* (Amphibia, *Dicroglossidae*) in Mt. Sambilikan, Diwata Range, Agusan del Sur, Philippines. *International Journal of Bioflux Society* 4(3): 113-121.

Falico, D. A., López, J. A., Antoniazzi, C. E. and Beltzer, A. H. (2012). Variacióninter poblacionaly ontogenéticaen la dieta de la rana llorona *Physalaemus albonotatus* (Anura: Leiuperidae). *Revista Mexicana de Biodiversidad* 83: 1187–1193.

Ferenţi, S., Ghira, I., Mitrea, I., Hodişan, O. and Toader, S. (2010). Habitat induced differences in the feeding of *Bombina variegata* from Vodiţa Valley (Mehedinti County, Romania). *North–Western Journal of Zoology* 6(2): 245–254.

Fisher, M. C., Garner, T. W. J. and Walker, S. E. (2009). Global emergence of *Batrachochytrium dendrobatidis* and amphibian chytridiomycosis in space, time and host. *Annual Review of Microbiology* 63: 291–310.

Franca, L. F., Facure, K. G. and Giaretta, A. A. (2004). Trophic and spatial niches of two large-sized species of Leptodactylus (Anura) in southeast tern Brazil. *Studies on Noetropical Fauna and Environment* 39: 243-248.

Garg, A. D. and Hippargi, R.V. (2007). Significance of frogs and toads in environmental conservation. In: *Souvenir of National Seminar on Eco-Environmental Impact and Organism Response*. Department of Chemistry, Kamla Nehru Mahavidalaya, RTM Nagpur University, Nagpur (M.S.), India. pp. 80-85.

Gibbons, J. W. (2003). Societal values and attitudes: Their history and sociological influences on amphibian conservation problems. In: *Amphibian Conservation*. Semlitsch, R. D. (Ed.). Smithsonian Institute, Washington, D. C., USA. pp. 214–227.

Grant, T., Frost, D. R., Caldwell, J. P., Gagliardo, R., Haddad, C. F. B., Kok, P. J. R., Means, B. D. B., Noonan, P., Schargel, W. and Wheeler, W. C. (2006). Phylogenetic systematics of dartpoison frogs and their relatives (Anura: *Athesphatanura: Dendrobatidae*). *Bulletin of the American Museum of Natural History* 299: 1-262.

Gratwicke, B., Evans, M. J., Jenkins, P. T., Kusrini, M. D., Moore, R. D., Sevin, J. and Wildt, D. E. (2010). Is the international frog legs trade a potential vector for deadly amphibian pathogens. *Frontiers in Ecology and the Environment* 8 (8): 438-442.

Gray, M. J. and Smith, L. M. (2005). Influence of land use on post metamorphic body size of playa lake amphibians. *Journal of Wildlife Management* 69: 515–524.

Haddad, C. F. B. and Prado, C. P. A. (2005). Reproductive Modes in Frogs and Their Unexpected Diversity in the Atlantic Forest of Brazil. *Bio Science* 55: 207-217.

Harding, J. H. (1997). *Amphibians and Reptiles of the Great Lakes Region.* The University of Michigan Press, USA. 379pp.

Harper, E. B., Measey, G. J., Patrick, D. A., Menegon, M. and Vonesh, J. R. (2010). Field Guide to the Amphibians of Eastern Arc Mountains and Coastal Forest of Tanzania and Kenya. Camerapix Publishers International, Nairobi, Kenya. 320pp.

Harper, E. B., Patrick, D. A. and Gibbs, J. P. (2015). Impact of forestry practices at a landscape scale on the dynamics of amphibian populations. *Ecological Applications* 25: 2271–2284.

Hayes, T. B., Falso, P., Gallipeau, S. and Stice, M. (2010). The cause of global amphibian declines: a developmental endocrinologist's perspective. *Journal of Experimental Biology* 213: 921–933.

Hecnar, S. J. and M'closkey, R. T. (1996). Amphibian species richness and distribution in relation to pond water chemistry in south-western Ontario, Canada. *Freshwater Biology* 36: 7–15.

Hirai, T. and Matsui, M. (2000). Ant specialisation in diet of the narrowmouthed toad, *Microhylaornata*, from Amamioshima Island of the Ryukyu Archipelago. *Current Herpetology* 19: 27-34.

Hirschfeld, M. and Rödel, M. O. (2011). The diet of the African Tiger Frog, *Hoplobatrachus occipitalis*, in northern Benin. *Salamandra* 47(3): 125-132.

Hocking, D. J. and Babbitt, K. J. (2014). Amphibian contributions to ecosystem services. *Herpetological Conservation and Biology* 9(1): 1−17.

Hoffmann, M., Taylor, C., Angulo, A., Böhm, M., Brooks, T. M., Butchart, S. H. M., Carpenter, K. E., Chanson, J., Collen, B. and Cox, N. A. (2010). The impact of conservation on the status of the world's vertebrates. *Science* 330: 1503–1509.

Huey, R. B., Pianka, E. R. and Vitt, L. J. (2001). How often do lizards "run on empty"? *Ecology* 82: 1-7.

IUCN Red List of Threatened Species (2017). *Chiromantis xerampelina* [http://www.iucnredlist.org/details/58801/0] site visited on 9/9/2017.

Jensen, J. B. and Camp, D. C. (2003). Human exploitation of amphibians: direct and indirect impacts. In: *Amphibian Conservation*. (Edited by Semlitsch, R.D.) Smithsonian Institution, USA. pp.199– 213.

Jordan, D. J., Rombough, C. H., Pearl, C.A. and McCreary, B. (2004).Cannibalism and predation by western toad (*Bufobore asboreas*) larvae in Oregon, USA. *Western North American Naturalist* 64(3): 403–405.

Juncá, F. A. and Eterovick, P. C. (2007). Feeding ecology of two sympatric species of Aromobatidae, *Allobates marchesianus* and *Anomaloglossus stepheni,* in Central Amazon. *Journal Herpetology* 41(2): 301-308.

Kacholi, D. S. (2013). Floristic Composition, Diversity and Structure of the Kimboza Forest in Morogoro Region, Tanzania. *Journal of Education, Humanities and Sciences* 2(2): 84–95.

Kamura, C. M., Morini, M., Figueiredo, C. J., Bueno, O. C. and Campos-Farinha, A. (2007). Ant communities (Hymenoptera: Formicidae) in an urban ecosystem near the Atlantic Rainforest. *Brazilian Journal of Biology* 67: 635-641.

Kenett, R. and Tory, O. (1996). Diet of Two Freshwater Turtles, *Chelodina rugosa* and *Elseza dentate* (*Testudines:Chelide*) from the Wet / Dry Tropics of Northern Australia. *Copeia* 2: 409-419.

Khatiwada, J. R. (2011). Amphibian species richness and composition along an elevational gradient in chitwan, Nepal. Dissertation for Award of MSc degree at Norwegian University of Life Sciences, Norway. pp. 14-44.

Klaion, T., Almeida, G. M., Tavares, L. E. R., Rocha, C. F. D. and Van sluys, M. (2011). Diet and nematode infection in *Proceratoprhys boiei* (Anura: Cycloramphidae) from two Atlantic rainforest remnants in Southeastern Brazil. *Anais da Academia Brasileira de Ciências* 83: 1303-1312.

Knapp, R. A. and Matthews, K. R. (2000). Non-native fish introductions and the decline of the mountain yellow-legged frog from within protected areas. *Conservation Biology* 14: 428-438.

Konan, J. C. B. Y. N., Kouamé, N. G., Kouamé, A. M., Gourène, A. B. A. and Rödel, M. O. (2016). Feeding Habits of Two Sympatric Rocket Frogs (Genus Ptychadena) in a Forest Remnant of Southern-Central Ivory Coast, West Africa. *Entomology, Ornithology and Herpetology* 5(2): 176.

Kovacs, E. H., Sas, I., Covaciu-Marcov, S. D., Hartel, T., Cupsa, D. and Groza, M. (2007). Seasonal variation in the diet of a population of *Hyla arborea* from Romania. *Amphibia- Reptilia* 28: 485-491.

Kovacs, I., Covaciu-Marcov, S. D., Doble, C., BlagaLungulescu, R. M. and Toth, G. (2010). The comparative analysis of the feeding of Bombina variegate populations from the Almas-Agrij Depression, Salaj County, Romania. *South-western Journal of Horticulture, Biology and Environment* 1 (2): 89-120.

Krajick, K. (2006). The lost world of the Kihansi toad. *Science* 311: 1230-1232.

Lima, A. P. and Magnusson W. E. (1998). Partitioning seasonal timeinteractions among size, foraging activity and diet in leaf litter frogs.*Oecologia* 116: 259-266.

Lima, J. E. P., Rödder, D. and Solé, M. (2010). Diet of two sympatric *Phyllomedusa* (Anura: Hylidae) species from a cacao plantation in southern Bahia, Brazil. *North-western Jcounal of Zoology* 6: 13-24.

Lima, J. E. P., Rödder, D. and Solé, M. (2010). Diet of two sympatric Phyllomedusa (Anura: Hylidae) species from a cacao plantation in southern Bahia, Brazil. *North-Western Journal of Zoology* 6: 13-24.

Lima, J. E. P., Rödder, D. and Solé, M. (2010). Diet of two sympatric Phyllomedusa (Anura: Hylidae) species from a cacao plantation in southern Bahia, Brazil. *North –Western Journal Zoology* 6: 13-24.

Lips, K. R., Diffendorfer, J., Mendelson, J. and Sears, M. (2008).Riding the wave: reconciling the roles of disease and climate change in amphibian declines. *Public Library of Science* (*PLOS Biology*) 6: 441–454.

Lips, K.R., Reaser, J.K., Young, B.E. and Ibanez, R. (2001).Amphibian monitoring in Latin America: A protocol manual. *Herpetological Circulars* 30:1-116.

López, J. A., Ghirardi, R., Scarabotti, P. A. and Medrano, M. C. (2007). Feeding ecology of *Elachistocleis bicolorin* a riparian locality of the middle Paraná River. *Herpetological Journal* 17: 48-53.

López, J. A., Perltzer, M. P. and Lajmanovich, R. C. (2005). Dieta y solapamiento del subnicho trófico de nueve especies de leptodactílidos en el Parque General San Martín (Argentina). *Revista Espanola de Herpetologia* 19: 19-31.

López, J. A., Perltzer, P. M. and Lajmanovich, R. C. (2003). *Physalaemus riograndensis* (NCN) Diet. *Herpetological Review* 34: 360- 360.

Lorin, C., Saidi, H., Belaid, A., Zairi, A., Baleux, F., Hocini, H., Bèlec, L., Hani, K. and Tangy, F. (2005). The antimicrobial peptide dermaseptin S4 inhibits HIV-1 infectivity in vitro. *Virology* 334: 264–275.

Macale, D., Vignoli, L. and Giuseppe, M. C. (2008). Food selection strategy during the reproductive period in three syntopic hylid species from a subtropical wetland of northeast Argentina. *Herpetological Journal* 18: 49–58.

Maneyro, R. and da Rosa, I. (2004). Temporal and spatial changes in the diet of *Hyla pulchella* (Anura, *Hylidae*) in southern Uruguay. *Phyllomedusa* 3: 101-113.

Martin, T. E. (1998). Are microhabitat preferences of coexisting species under selection and adaptive? *Ecology* 79 (2): 656-670.

Maynard, R. J., Aall, N. C., Saenz, D., Hamilton, P. S. and Kwiatkowski, M. A. (2016). Road-edge Effects on Herpetofauna in a Lowland Amazonian Rainforest. *Tropical Conservation Science* 9(1): 264-290.

McCracken, S. F. and Forstner, M. R. (2014). Oil road effects on the anuran community of a high canopy tank bromeliad (*Aechmea zebrina*) in the upper Amazon basin, Ecuador. *Public Library of Science* 9(1): 85-470.

Measey, G. J., Gower, D. J., Oomen, O. V. and Wilkinson. M. (2004). A subterranean generalist predator: Diet of the soil-dwelling caecilian *Gegeneophis ramaswamii* (Amphibia: *Gymnophiona; Caeciliidae*) in Southern India. C. R. *Biologies* 327: 65-76.

Méndez-Narváez, J., Ospina-Sarria, J. J. and Bolívar, W. (2014). Diet and trophic ecology of *Leptodactylus fragilis* (Leptodactylidae) and *Dendropsophus columbianus* (Anura: Hylidae) in a disturbed area in southwestern Colombia. *Herpetology Notes* 7: 299 – 305.

Menin, M., Rossa-Feres, D. C., Giaretta, A. A. (2005). Resource use and coexistence of two syntopic hylid frogs (Anura, Hylidae). *Revista Brasileira de Zoologia* 22: 61-72.

Meyers, J. J., James, C. O, Monroy, A. J. and Nishikawa, C. K. (2004). Mechanism of tongue protraction in microhylid frogs. *Journal of Experimental Biology* 207: 21-31.

Milligan, H., Deinet, S., McRae, L. and Freeman, R. (2014). *Protecting Species: Status and Trends of the Earth's Protected Areas.* Preliminary Report. Zoological Society of London, UK. 23pp.

Mohneke, M. and Rödel, M. O. (2009). Declining amphibian populations and possible ecological consequences-a review. *Salamandra* 45: 201–210.

Narváez, J. M., Sarria, O. J. J. and Bolívar, G. W. (2014). Diet and trophic ecology of *Leptodactylus fragilis* (Leptodactylidae) and *Dendropsophus columbianus* (Anura: *Hylidae*) in a disturbed area in southwestern Colombia. *Herpetology Notes* 7: 299-305.

Nuñeza, O. M., Fabricante, K. M. B., Alicante, A. A., Sucaldito, M. P., Ponce, A. G. (2012). The herpetofauna of Mounts Sambilikan, Ararat and Berseba of the Diwata Range, Agusan del Sur, Philippines. *Asia Life Sciences* 21(1): 203-216.

Parker, P. M. (2011). The world market for frogs' legs: a 2011 global trade perspective. Icon Group International, USA.14pp.

Peltzer, P. M., Attademo, A. M., Lajmanovich, R. C., Junges, C. M., Beltzer, A. H. and Sanchez, L. C. (2010). Trophic dynamics of three sympatric anuran species in a soybean agroecosystem from Santa Fe Province, Argentina. *Herpetological Journal* 20: 261–269.

Peltzer, P. M., Lajmanovich, R. C. and Cacivio, P. M. (2000). Diet of *Phyllomedusa hypochondrialis azurea* Cope, 1862 (Anura: Hylidae) in temporary ponds of Chaco, Argentina. *Bulletin de la Société Herpétologique de France* 93:5–11.

Piatti, L. and Souza, F. L. (2011). Diet and resource partitioning among anurans in irrigated rice fields in Pantanal, Brazil. *Brazilian Journal of Biology* 71(3): 653-661.

Plitsi, P., Koumaki, M., Bei, V., Pafilis, P. and Polymeni, R. M. (2016). Feeding ecology of the Balkan Water frog (Pelophylaxkurtmuelleri) in Greece with emphasis on habitat effect.*North-Western Journal of Zoology* (online first): art.e161502.

Pough, F. H., Andrews, R. M., Cadle, J. E., Crump, M. L., Savitzky, A. H. and Wells, K. D. (2004). *Herpetology*.Prentice Hall, USA. 577pp.

Pounds, J. A., Bustamante, M. R., Coloma, L. A., Consuegra, J. A., Fogden, M. P. L., Foster, P. N., La Marca, E., Master, K. L., Viteri, A., Puschendorf, R., Ron, S. R., Azofeifa, G. A., Still, C. J. and Young, B. E. (2006). Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature* 439: 161-167.

Pradhan, S., Mishra, D. J. and Sahu, K. R. (2014). Seasonal variation and abundance of herpetofauna in the Gandhamardan hills range, Western Orissa, India. *International Journal of Research in Zoology* 4(2): 51-54.

Price, S. J., Marks, D. R., Howe, R. W., Hanowski, J., and Niemi, G. J. (2005). The importance of spatial scale for conservation and assessment of anuran populations in coastal wetlands of the western Great Lakes. *Landscape Ecology* 20: 441–454.

Quiroga, M. F., Bonansea, M. I. and Vaira, M. (2011). Population diet variation and individual specialisation in the poison toad, *Melanophryniscus rubriventris* (Vellard, 1947). *Amphibia-Reptilia* 32(2): 261-265.

Ranvestel, A. W., Lips, K. L., Pringle, C. M., Whiles, M. R. and Bixby, R. J. (2004). Neotropical tadpoles influence stream benthos: evidence for the ecological consequences of decline in amphibian populations. *Freshwater Biology* 49: 274–285.

Reh, W. and Seitz, A. (1990). The influence of land use on the genetic structure of populations of the common frog *Rana temporaria. Biological Conservation* 54: 239–249.

Relyea, R. A. and Diecks, N. (2008). An unforeseen chain of events: Lethal effects of pesticides on frogs at sub lethal concentrations. *Ecological Applications* 18: 1728–1742.

Rödel, M. O. (2000). *Amphibians of the West African Savanna.* Edition Chimaira, Frankfurt, Germany. 332pp.

Rodgers, W. A., Hall, J. B., Mwasumbi, L. B., Griffiths, C. J. and Vollesen, K. (1983). The Conservation Values and Status of Kimboza Forest Reserve, Tanzania. University of Dar-es-Salaam, Tanzania. 86 pp.

Rohr, J. R. and Raffel, T. R. (2010). Linking global climate and temperature variability to widespread amphibian declines putatively caused by disease. In: *Proceedings of the National Academy of Sciences* USA. pp. 8269–8274.

Rothermel, B. B. and Semlitsch, R. D. (2002). An experimental investigation of landscape resistance of forest versus old field habitats to emigrating juvenile amphibians. *Conservation Biology* 16: 1324-1332.

Rovito, S. M., Olea, G., Vásquez-Almazán, R. C., T. J. Papenfuss, J. T. and Wake, B. D. (2009). Dramatic declines in neotropical salamander populations are an important part of the global amphibian crisis. *Proceedings of the National Academy of Sciences* 106: 3231–3236.

Rowe, C. L., Hopkins, W. A. and Bridges, C. (2003). Physiological ecology of amphibians in relation to susceptibility to natural and anthropogenic factors. In: *Amphibian Decline: An Integrated Analysis of Multiple Stressor Effects*. (Edited by Linder G. Society of Environmental Toxicology and Chemistry Press, Pensacola. pp. 9-58.

Sanford, M. P., Manley, P. N. and Murphy, D. D. (2009). Effects of urban development on ant communities: implications for ecosystem services and management. *Conservation Biology* 23: 131–141.

Santos, E. M., Almeida, A. V. and Vasconcelos, S. D. (2004). Feeding habits of six anuran (Amphibia: Anura) species in a rainforest fragment in Northeastern Brazil. *Iheringia, Série Zoologica* 94(4): 433-438.

Saporito, R. A., Donnelly, M. A., Norton, R. A., Garraffo, H. M., Spande, T. F. and Daly, J. W. (2007). Oribatid mites as a major dietary source for alkaloids in poison frogs. *Proceedings of the National Academy of Sciences of the USA* 104: 8885–8890.

Sas, I., Covaciu-Marcov, S. D., Strugariu, A., David, A. and Ilea, C. (2009). Food habit of *Rana* (*Pelophylax*) kl. *esculenta* females in a new recorded E-system population from a forested habitat in North-Western Romania. *Turkish Journal of Zoology* 33: 1-5.

Savage, J. M. (2002). *The amphibians and reptiles of Costa Rica: a herpetofauna between two continents, between two seas*. The University of Chicago Press, Chicago. 954pp.

Scoccianti, C. (2004). Amphibians: threats and conservation. *Italian Journal of Zoology* 71: 9-15.

Semlitsch, R. D. (2000). Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* 64: 615–631.

Siqueira, C. C., Sluys, M. V., Ariani, C. V. and Rocha, C. F. D. (2006). Feeding ecology of *Thoropamiliaris* (Anura, Cycloramphidae) in four areas of Atlantic rain forest, southeastern Brazil. *Journal of Herpetology* 40: 520-525.

Skelly, D. K., Werner, E. E. and Cortwright, A. S. (1999). Long-term distributional dynamics of a Michigan amphibian assemblage. *Ecology* 80: 2326–2337.

Solé, M. and Rödder, D. (2009). Dietary assessments in adult amphibians. In: *Amphibian ecology and conservation. A handbook of techniques.* (Edited by Dodd, K.) Oxford Universtiy Press, Oxford. pp.105-184.

Solé, M., Ketterl, J., Di-Bernardo, M. and Kwet, A. (2002). Ants and termites are the diet of the microhylid frog *Elachistocle isovalis* (Schneider, 1799) at an araucaria forest in Rio Grande do Sul, Brazil. *Herpetological Bulletin* 79: 14-17.

Sousa, G. J. G. and Avila, R. W. (2015). Body size, reproduction and feeding ecology of *Pleurodema diplolister* (Amphibia: Anura: Leiuperidae) from Caatinga, Pernambuco state, Northeastern Brazil. *Acta Herpetologica* 10(2): 129-134.

Spawls, S., Howell, K. M. and Drewes, R. C. (2006). *Pocket Guide to the Reptiles and Amphibians of East Africa.* A and C Black Publishers Ltd., London. 240pp.

Stebbins, R. C. and Cohen N. W. (1997). *A Natural History of Amphibians*. Princeton University Press, New Jersey. 336pp.

Stuart, S. N., Chanson, S. J., Cox, A. N., Young, E. B., Rodrigues, L. S. A., Fischman, L. D. and Waller, W. R. (2004). Status and trends of amphibiasn declines and extinctions worldwide. *Science* 306: 1783–1786.

SUA GIS Centre (2016). Map of Tanzania showing location of Kimboza Forest Reserve and adjacent villages surrounding the forest.

Temu, R. P. C. and Andrew, S. M. (2008). Endemism of Plants in the Uluguru Mountains, Morogoro, Tanzania. *Journal of Forest Ecology and Management* 255(7): 2858-2869.

Tews, J., Brose, U., Grimm, V., Tielborger, K., Wichmann, M. C., Schwager, M., Jeltsch, F. (2004). Animal species diversity driven by habitat heterogeneity, diversity: The importance of keystone structures. *Journal of Biogeography* 31: 79-92.

Tinsley, R. C., Loumont, C. and Kobel, H. R. (1996). Geographical distribution and ecology. In: *The Biology of Xenopus* (Edited by Tinsley, R. C. and Kobel, H. R.) Oxford University Press, Oxford. 462pp.

Toft, C. A. (1980). Feeding ecology of thirteen syntopic species of anurans in a seasonal tropical environment. *Oecologia* 45: 131-141.

Toft, C. A. (1981). Feeding ecology of Panamanian litter anurans: patterns in diet and foraging mode. *Journal of Herpetology* 15: 139-144.

Tohé, B., Kouamé, N. G., Assemian, N. E. and Gourène, G. (2015). The puddle frog *Phrynobatrachus latifrons* AHL 1924 diet in the fish farm of the banco national park (Ivory Coast).*Asian Journal of Biological and Medical Sciences* 1(2):14-22.

Turvey, N. (2013). *Cane Toads: A Tale of Sugar, Politics and Flawed Science*. Sydney University Press, Sydney, Australia. 247pp.

Valencia, A., Cortes, A. M. and Ruiz, C. A. (2013). Ecosystem services provided by amphibians and reptiles in Neotropical ecosystems. *International Journal of Biodiversity Science, Ecosystem Services and Management* 9 (3): 2-16.

Vignoli, L., Luiselli, L. and Bologna, M. A. (2009). Dietary patterns and overlap in an amphibian assemblage at a pond in Mediterranean central Italy. *Vie Milieu - Life and Environment* 59 (1): 47-57.

Wachlevski, M., De Souza, P. H. C., Kopp, K. and Eterovick, P. C. (2008). Microhabitat use and feeding habits of *Crossodactylus bokermanni* Caramaschi and Sazima, 1985 (Anura: *Hylodidae*) at a site in south-eastern Brazil. *Journal of Natural History* 42: 1421-1434.

Waldick, R. (1997). The impact of forestry practices upon amphibian populations in eastern North American. In: *Amphibians in Decline: Canadian Studies of a Global Problem*. (Edited by Green, D. M.) Society for the Study of Amphibians and Reptiles, St. Louis, Missouri, USA. pp. 191–205.

Watling, J. I. and Ngadino, L. F. (2007). A preliminary survey of amphibians and reptiles on the Nassau and Lely plateaus Eastern Suriname. In: *RAP Bulletin of Biological Assessment: A RapidBiological Assessment of the Lely and Nassau Plateaus, Suriname (with additional information on the Brownsberg Plateau)*. (Edited by Alonso, L.E. and Mol, J.H.) Conservation International, Arlington. pp.119-125.

Wells, K. D. (2007). *The Ecology and Behaviour of Amphibians*. The University of Chicago Press, Chicago. 1400pp.

Werema, C. (2016). Seasonal variation in under storey bird species diversity and abundance in the Uluguru Nature Reserve, Tanzania. *African Journal of Ecology* 54: 299–307.

Werema, C. (2015). Seasonal elevational movements of the Little Greenbul *Andropadus virens* in the Uluguru Mountains, Tanzania. *African Journal of Ecology* 53: 253–256.

Whiles, M. R., Lips, K. R., Pringle, C. M., Kilham, S. S., Bixby, R. J., Brenes, R., Connelly, S., Colon-Gaud, J. C., Hunte-Brown, M., Huryn, A. D., Montgomery, C. and Peterson, S.(2006).The effects of amphibian population declines on the structure and function of Neotropical stream ecosystems. *Frontiers in Ecology and the Environment* 4: 27–34.

Whiles, M. R., Hall, O. R., Dodds, K. W., Verburg, P., Huryn, D. A., Pringle, M. C., Lips, R. K., Kilham, S. S., Gaud, C. J. and Rugenski, A. T. (2013). Disease driven amphibian declines alter ecosystem processes in a tropical stream. *Ecosystems* 16: 146–157.

Whitfield, S. M. and Donnelly, M. A. (2006). Ontogenetic and seasonal variation in the diets of a Costa Rican leaf-litter herpetofauna. *Journal of Tropical Ecology* 22: 409–417.

Whittaker, K., Koo, M. S., Wake, D. B., and Vredenburg, V. T. (2013). Global Declines of Amphibians. In: *Encyclopedia of Biodiversity second edition*. (Edited by Levin S.A.) Academic Press,Waltham, M.A. pp. 691-699.

Williams, Y. M., Williams, S. E., Alford, R. A., Waycott, M. and Johnson, C. N. (2006). Niche breadth and geographical range: ecological compensation for geographical rarity in rainforest frogs. *Biology Letters* 2: 532–535.

Woodhead, C., Vences, M., Vieites, D. R., Gamboni, I. F., Brian, L. and Griffiths, R. A. (2007). Specialist or generalist? Feeding ecology of the Malagasy poison frog Mantella aurantiaca. *Herpetological Journal* 17 (4): 225-236.

Wu, Z. J., Li, M. Y. and Wang, P. Y. (2007). A comparison of stomach flush and stomach dissection in diet analysis of four frog species. *Acta Zoologica Sinica* 53: 364–372.

Zar, J. H. (1996). *Biostatistics Analysis.* (3rd Ed.), Prentice-Hall Inc., New Jersey. 662pp.

Zug, G. R., Vitt, L. J. and Caldwell, J. P. (Eds) (2001). *Herpetology: An Introductory Biology of Amphibians and Reptiles*. Academic Press, USA. 630pp.

APPENDINCES

Appendix 1: Frequency of occurrence of food groups per anuran species in Kimboza Forest Reserve

	Frequency of occurrence of food groups Anuran Species									
Food groups	**L.u**	**L.f**	**A.x**	**N.t**	**A.a**	**C.x**	**P.a**	**X.b**	**P.n**	**P.ac**
Orthoptera	66.67^C	9.09^a	-	-	-	25^S	-	33.33^S	33.33^S	-
Isoptera	-	27.27S	79.17^C	-	100^C	-	-	33.33^S	33.33^S	-
Coleoptera	-	27.27^S	4.17^a	33.33^S	-	50^S	33.33^S	-	-	50^S
Gastropoda	-	36.36^S	-	-	-	-	33.33^S	-	-	-
Hymenoptera	-	-	47.37^S	100^C	-	-	33.33^S	-	33.33^S	100^C
Araneae	-	-	4.17^a	-	-	-	33.33^S	-	-	-
larvae	-	-	4.17^a	-	33.33^s	-	-	-	50^S	-
unidentified	-	-	-	-	-	25^S	33.33^S	-	-	-
Decapoda	-	-	-	-	-	-	-	33.33^S	-	-
Diptera	-	-	-	-	-	-	-	-	-	100^C

C =constant, S = secondary, a = accidental

L.u = *Leptopelis uluguruensis,* L.f = Leptopelis *flavomaculatus,* C.x= *Chiromantis xerampelina,*
P.a = *Ptychadena anchietae,* A.x = *Arthroleptis xenodactyloides,* N.t = *Nectophrynoides tornieri,*
A.a = *Arthroleptis affinis*, X.b= *Xenopus borealis,* P.n= *Phrynobatrachus natalensis,*
P.ac = *Phrynobatrachus acridoides*

Appendix 2: Degree of Food Preference of food groups eaten by anurans in the upper segment of Kimboza Forest Reserve

Anuran species	Degree of Food Preference									
	L.u	L.f	A.x	N.t	A.a	C.x	P.a	X.b	P.n	P.ac
Food groups										
Orthoptera	2.67^P	0.07^O	-	-	-	-	-	1.33^S	0.36^O	-
Isoptera	-	0.79^O	2.39^P	-	2.75^P	-	-	1.33^S	0.09^O	-
Coleoptera	-	0.71^O	0.05^O	1.5^S	-	4^H	1.33^S	-	-	0.5^O
Gastropoda	-	1^S	-	-	-	-	1.33^S	-	-	-
Hymenoptera	-	-	0.67^O	3.5^H	-	-	1^S	-	0.55^O	3^H
Araneae	-	-	0.05^O		-	-	0.67^O	-	-	-
Insect larvae	-	-	0.05^O		0.5^O	-		-	0.82^O	-
Unidentified	-	-	-	-	-	-	0.33^O	-	-	-
Decapoda	-	-	-	-	-	-		1.33^S	-	-
Diptera	-	-	-	-	-	-		-	-	2^P

L.u = *Leptopelis uluguruensis*, L.f = *Leptopelis flavomaculatus*, C.x= *Chiromantis xerampelina*, P.a = *Ptychadena anchietae*, A.x = *Arthroleptis xenodactyloides,* N.t = Nectophrynoides *tornieri*, A.a= *Arthroleptis affinis*, X.b= *Xenopus borealis*, P.n= *Phrynobatrachus natalensis,* P.ac=*Phrynobatrachus acridoides*

H=highly preferential P=preferential S=secondary O= occasional

Appendix 3: Degree of Food Preference of food groups eaten by anurans in the lower segment of Kimboza Forest Reserve

Anuran Species	Degree of Food Preference									
	L.u	L.f	A.x	N.t	A.a	C.x	P.a	X.b	P.n	P.ac
Food groups										
Orthoptera	-	-	-	-	-	2.00^P	-	-	-	-
Isoptera	-	-	2.89^P	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-
Gastropoda	-	-	-	-	-	-	-	-	-	-
Hymenoptera	-	-	1.22^S	-	-	-	-	-	-	-
Araneae	-	-	-	-	-	-	-	-	-	-
Insect larvae	-	-	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	-	2.00^P	-	-	-	-
Decapoda	-	-	-	-	-	-	-	-	-	-
Diptera	-	-	-	-	-	-	-	-	-	-

L.u= *Leptopelis uluguruensis,* L.f = *Leptopelis flavomaculatus,* C.x= *Chiromantis xerampelina,* P.a = *Ptychadena anchietae,* A.x = *Arthroleptis xenodactyloides,* N.t =*Nectophrynoides tornieri,* A.a= *Arthroleptis affinis*, X.b= *Xenopus borealis,* P.n= *Phrynobatrachus natalensis,* P.ac= *Phrynobatrachus acridoides*

H=highly preferential P=preferential S=secondary O= occasional

Appendix 4: Degree of Food Preference of food groups eaten by anurans along forest streams in Kimboza Forest Reserve

Anuran species	Degree of Food Preference			
	A.x	P.a	A.a	P.ac
Food group				
Orthoptera	-	-	-	-
Isoptera	2.9^P	-	3.5^H	-
Coleoptera	-	1.33^S	-	0.5^O
Gastropoda	-	1.33^S	-	-
Hymenoptera	0.9^O	1^S	-	3^H
Araneae	0.9^O	0.67^O	-	-
Insect larvae	-	-	1^S	-
Unidentified	-	0.33^O	-	-
Decapoda	-	-	-	-
Diptera	-	-	-	2^P

A.x=*Arthroleptis xenodactyloides,* A.a=*Arthroleptis affinis,* P.a=*Ptychadena anchietae,* P.ac=*Phrynobatrachus acridoides*

H = Highly preferential, P=Preferential, S=Secondary, O= Occasional

Appendix 5: Degree of Food Preference of food groups eaten by anurans along forest and farms border in Kimboza Forest Reserve

Anuran species	Degree of food preference (DFP)				
	L.f	A.x	X.b	C.x	P.n
Food groups					
Orthoptera	-	-	-	-	0.36^O
Isoptera	1^S	2.67^P	2^P	-	0.09^O
Coleoptera	-	0.33^O	-	4^H	-
Gastropoda	-	0	-	-	-
Hymenoptera	-	0.67^O	-	-	0.55^O
Araneae	-	-	-	-	-
Insect larvae	-	-	-	-	0.82^O
Unidentified	-	-	-	-	-
Decapoda	-	-	2^P	-	-
Diptera	-	-	-	-	-

L.f=*Leptopelis flavomaculatus,* A.x=*Arthroleptis xenodactyloides,* X.b=*Xenopus borealis*, C.x=*Chiromantis xerampelina,* P.n=*Phrynobatrachus natalensis*

H = Highly preferential, P=Preferential, S=Secondary, O= Occasional

Appendix 6: Degree of Food Preference of food groups eaten by anurans along forest and tarmac road border in Kimboza Forest Reserve

	Anuran species	
Food groups	L.f	L.u
Orthoptera	-	2^P
Isoptera	0.67^O	-
Coleoptera	1^S	-
Gastropoda	1.33^S	-
Hymenoptera	-	-
Araneae	-	-
Insect larvae	-	-
Unidentified	-	-
Decapoda	-	-
Diptera	-	-

L.f= *Leptopelis flavomaculatus,* L.u= *Leptopelis uluguruensis*

H = Highly preferential, P=Preferential, S=Secondary, O= Occasional

Appendix 7: Degree of Food Preference of food groups eaten by anurans in interiors of Kimboza Forest Reserve

	Anuran species	
Food groups	L.f	A.x
Orthoptera	0.14^O	-
Isoptera	0.57^O	1.5^S
Coleoptera	1.14^S	-
Gastropoda	1.57^S	-
Hymenoptera	-	-
Araneae	-	-
Insect larvae	-	1^S
Unidentified	-	-
Decapoda	-	-
Diptera	-	-

L.f=*Leptopelis flavomaculatus,* A.x=*Arthroleptis xenodactyloides*

H = Highly preferential, P=Preferential, S=Secondary, O= Occasional

Appendix 8: Degree of Food Preference of anurans species in the upper segment of Kimboza Forest Reserve during March and April

Anuran species	L.u		L.f		A.x		A.a		N.t		C.x		P.a		X.b		P.n		P.ac	
Food groups	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Orthoptera	2.67		0.09	-	-	-	-	-	-	-	-	-	-	-	1	-		0.36	-	-
Isoptera	-		0.73	0.67	2.9	1.5		2.33		-				-	1	-		0.09	-	-
Coleoptera	-		0.73	1	0.1	-		-	1	-	4		2	-	-	-		-	-	0.5
Gastropoda	-		1.36	-			-		-	-	-		2	-	-	-		-	-	-
Hymenoptera	-		-	-	0.06	1.1		-	3.5	-	-		-	-	-	-		0.55	-	1
Araneae	-		-	-	-	0.1		-	-	-	-		-	-	-	-		-	-	-
Insect larvae	-		-	-	0.1	-		0.66	-	-	-		-	-	-	-		0.82	-	-
unidentified	-		-	-	-	-		-	-	-	-		-	-	-	-		-	-	-
Decapoda	-		-	-	-	-		-	-	-	-		-	-	-	1		-	-	-
Diptera	-		-	-	-	-		-	-	-	-		-	-	-	-		-	-	3

R1=March, R2 =April

L.u = *Leptopelis uluguruensis,* L.f = *Leptopelis flavomaculatus,* C.x= *Chiromantis xerampelina,* P.a = *Ptychadena anchietae,*

A.x = *Arthroleptis xenodactyloides,* N.t = *Nectophrynoides tornieri,* A.a= *Arthroleptis affinis,* X.b = *Xenopus borealis,*

P.n = *Phrynobatrachus natalensis,* P.ac = *Phrynobatrachus acridoides*

Appendix 9:   Degree of Food Preference of anurans species in the lower segment of Kimboza Forest Reserve during March and April

Anuran species	L.u		L.f		A.x		A.a		N.t		C.x		P.a		X.b		P.n		P.ac	
Food groups	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Orthoptera	-	-	-	-	-	-	-	-	-	-	2^P	-	-	-	-	-	-	-	-	-
Isoptera	-	-	-	-	1^S	3.43^H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hymenoptera	-	-	-	-	3^H	0.57^O	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Araneae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Insect larvae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
unidentified	-	-	-	-	-	-	-	-	-	-	2^P	-	-	-	-	-	-	-	-	-
Decapoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

R1=March, R2 =April, H= Highly preferential, P = Preferential, S = Secondary, O = Occasional

L.u = *Leptopelis uluguruensis, L.f* = Leptopelis *flavomaculatus,* C.x=   *Chiromantis xerampelina,* P.a =   *Ptychadena anchietae*

A.x = *Arthroleptis xenodactyloides,* N.t = Nectophrynoides *tornieri,* A.a= *Arthroleptis affinis*, X.b =   *Xenopus borealis,*

P.n = *Phrynobatrachus natalensis,* P.ac = *Phrynobatrachus acridoides*