AN ASSESSMENT OF DIVERSITY, ABUNDANCE AND DISTRIBUTION OF HERPETOFAUNA IN THE SERENGETI NATIONAL PARK, TANZANIA

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ABSTRACT

An assessment of diversity, abundance and distribution of herpetofauna in grassland, kopjes, woodland, riverine forest and wetlands habitats of Serengeti National Park (SENAPA), Tanzania was conducted between December 2012 and March 2013. Drift fence with pitfall, wire mesh funnel traps, active search and visual encounter survey, road survey and purposive point count methods were used to obtain data for this study. Besides, focus group discussion and literature review were used to supplement the data collected in the field through the aforementioned methods. A total of 36 amphibian and 48 reptilian species were recorded to exist in SENAPA. Six amphibian species; namely *Chiromantis xerampelina*, *Hemisus guineensis*, *Mentensophryne* sp, *Tomopterna cryptotis*, *Tomopterna turbeculosa* and *Phrynobatrachus scheffleri* are reported for the first time for a handy checklist of herpetofauna in SENAPA. The most abundant amphibian species was *Ptychadena mossambica* while *Agama mwanzae* was the most dominant reptile species. The distribution of both amphibians and reptiles varied significantly among habitats. *Bufo gutturalis*, *Ptychadena anchietae* (amphibians) and *Varanus niloticus* (reptiles) were widely spread in all habitats. Species richness also varied among habitats. The highest species richness of amphibia was recorded in the grassland and riverine forests with thirteen and eight species respectively. The highest species richness of reptiles was recorded in woodland and kopjes with 26 and 21 species respectively. Species diversity of amphibians among habitats was highest in riverine forest (H' 1.63) and grassland (H' 1.45). Species diversity of reptilians among habitats was highest in woodland (H' 2.79) and grassland (H' 2.1). The lowest species diversity of amphibians was recorded in kopjes (H' 0.99) while that of reptiles was recorded in wetland (H' 0.69). The study recommends further herpotofauna survey for a complete description of the species within the expansive SENAPA.

DECLARATION

I, IZUMBE MGANA MSINDAI, 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.

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The above declaration is confirmed

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i. My lovely wife, Florentina Kideka for her patience and taking care of the family when I was away conducting this study;

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LIST OF ABBREVIATIONS

CITES	Converssion on International Trade of Endangered Species
GMP	General Management Plan
IUCN	International Union for Conservation of Nature
MMNP	Mahale Mountain National Park
MMNR	Masai Mara National Reserve
SENAPA	Serengeti National Park
SUA	Sokoine University of Agriculture
TANAPA	Tanzania National Park
TCM	Tanzania Coastal Management
UNESCO	United Nations Educational, Scientific and Cultural Organisation
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Serengeti National Park (SENAPA) is the oldest and the second largest park in Tanzania measuring 14 763km^2. It is also a world heritage site and a biosphere reserve (Sinclair, 1995; Roodt, 2005; SENAPA-GMP, 2006; UNESCO, 2010; Philipo, 2011). It forms the heart of the Serengeti-Mara ecosystem, with a unique combination of diverse habitats, which enables it to support a variety of animal groups such as herbivores, carnivores, birds and invertebrates (Sinclair, 1995; SENAPA-GMP, 2006).

Besides, SENAPA is known to host the largest single herds of terrestrial mammal migration in the world (Sinclair, 1995), which was proclaimed in 2007 as the seventh natural travel wonder of the world (Philipo, 2011). The park also supports the highest numbers of large predators in the world (Sinclair, 1995; SENAPA-GMP, 2006).

SENAPA is divided into five main habitats; namely, riverine forests, swamps, kopjes, grasslands and woodlands. These diverse habitats support approximately 70 species of large mammals and 517 species of avifauna (Sinclair, 1995). Among the large mammals, wildebeest, gazelles, zebras and buffaloes are common in the park. The grassland habitat, which is found in the southern side of the park, is the most preferred habitat for the migratory ungulates, for calving and feeding during wet season (Hopcraft, 2010).

1.2 Problem Statement and Justification of the study

SENAPA is one of the most studied savannah ecosystems over the past 50 years, with research dated back from 1957 when the first scientific study of the ecosystem on monitoring large mammals was done by Bernhard and Michael Grzimek (Grzimek and

Grzimek, 1960; Sinclair and Norton-Griffith, 1979). There are over 1500 publications exploring the ecology of Serengeti and biology of different animals (Hopcraft, 2010) with more emphasis on the mammalian and avian fauna (Drewes, 1997).

Although SENAPA is well known in terms of its conservation status and scientific researches, studies related to the diversity, abundance and distribution of herpetofauna have received little attention, and there is no handy checklist of species for the animal groups. There have been a few herpetological studies in SENAPA. Two of such studies focused on vocalisation of amphibians (Elzen and Kreulen, 1979), distribution and monitoring baseline of Serengeti amphibians (Channing *et al*., 2004). Four other researches focused on single species such as the ecology of leopard tortoise (*Geochelone pardalis*) and hingedback tortoise (*Kinixys belliana*) (Betram, 1979a, b); the biology of the leopard tortoise (*Geochelone pardalis*) (Kabigumila, 2001) and the general description of new tree frog species *Hyperolius orkarkarri* (Anura: Hyperoliidae) (Drewes, 1997).

The herpetofauna, being the most diverse in terms of habitat preference and speciation, could play a greater role as indicators of both habitat quality and perturbation (Heyer *et al*., 1994; IUCN, 2009; Relox *et al*., 2010). Apart from being food for predators, they are also important consumers of most insects and small mammals to large mammals such as wildebeest and zebras. Because of their food and cover requirements, they are likely to be adversely affected by habitat requirements.

A sustainable ecosystem management requires regular inventory and monitoring. With better understanding of their diversity, abundance and distribution, it may be possible to draw sound conservation strategies and conclusions about ecosystem disturbance as a whole based on herpetofauna community.

The present study therefore aimed at assessing the diversity, distribution and abundance of herpetofauna in SENAPA, so as to bridge the knowledge gap on the wild animals of the park.

1.3 Objectives of the Study

1.3.1 General objective

The main objective of this study was to assess the diversity, abundance and distribution of herpetofauna in SENAPA.

1.3.2 Specific objectives

The specific objectives of the study were to:

i. determine the species of amphibians found in SENAPA,
ii. determine the species of reptiles found in SENAPA,
iii. assess the abundance and distribution of the amphibian species in different habitats in SENAPA,
iv. assess the abundance and distribution of the reptilian species in different habitats in SENAPA, and
v. prepare a checklist of the herpetofauna of SENAPA.

1.3.3 Research questions

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

i. Which species of amphibia are found in SENAPA?
ii. Which species of reptilia are found in SENAPA?
iii. How are these amphibian species distributed in SENAPA?
iv. How are these reptilian species distributed in SENAPA?
v. How abundant are these species on various habitats of SENAPA?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Herpetofauna

Herpetofauna is a collective term referring to amphibians and reptiles of a particular region, habitat or geological period (Harding, 1997). Besides sharing a common characteristic of being ectothermic, amphibians and reptiles have been grouped in the same scientific discipline based on a more product of tradition than biology (Harding, 1997). Amphibians and reptiles, both being cold blooded vertebrate animals, have been traditionally studied together due to the fact that the differences between the two groups were not recognised as being important enough to justify their placement in separate categories (Goin and Goin, 1971).

2.1.1 Amphibians

Amphibians are small quadrupedal vertebrates having two occipital condyles on the skull and they possess smooth, moist skins without scales (Goin and Goin, 1971; Duellman and Treub, 1986): these include Anurans, Caudata and Gymnophiona. In addition, amphibians are believed to be the first vertebrates to move from water to the land and later giving rise to all other terrestrial vertebrates such as reptiles, birds and mammals (Going and Goin, 1971). Amphibians are also believed to be the descendants of early fish (crossopterygian) (Harding, 1997). They are also believed to be the prominent element of the fauna during Mississippian, about 350 mya (Goin and Goin, 1971), but today they are more than 5400 living species (Channing and Howell, 2006; Hickman *et al.*, 2007) and more species are expected (Duellman, 1993; Glaw and Köhler, 1998).

All members of the amphibians, as said earlier, are cold blooded and their body temperature can be regulated by the ectothermal (external) environment. Activity patterns of amphibians are regulated and affected by seasons and climatic conditions (Duellman and Treub, 1986; Heyer *et al*., 1994; Howell, 2004). To illustrate, Duellman and Treub (1986) reported that rainfall is the main factor initiating breeding activity in amphibians. Furthermore, most members are more active during wet periods and also become more active during warm season than cold periods (Heyer *et al*., 1994; Howell, 2004). Amphibians are also known to hibernate and aestivate (Hill, 2005; Halliday, 2006). Ngalason (2007) observed that movements of *Probreviceps uluguruensis* (Anura: Microhylidae) increased shortly after rain periods and also the calls of the male increased during the rainy season. For example, movements of *Probreviceps uluguruensis* was not observed during coldest hours and the male vocalisation became reduced and were only heard when the temperature reached between 7 and 17^{o}C (Ngalason, 2007).

2.1.2 Reptiles

Reptiles are ectothermic, air-breathing vertebrates with a dry and scaly skin on their body, a common characteristic differentiating them from amphibians. Reptiles have been classified into four groups based on the patterns of opening in the skull roof behind the orbits, and these include anapsid, eurapsid, synapsid and diapsid. All living reptiles are diapsid except turtles and tortoises (Lucas, 1996; Harding, 1997). The living members of the reptiles include Rhynchocephalia, Testudines, Squamata and Crocodylia. Reptiles are believed to arise from the early amphibians during the Carboniferous period (Branch, 1988; 1998). Reptiles were also the dominant vertebrates of the earth during the Mesozoic era (Smith, 1969; Goin and Goin, 1971; Harding, 1997). Moreover, reptiles are believed to give rise to birds and mammals that have internal temperature control (Goin and Goin, 1971). Although reptiles are still numerous than amphibians, they have lost the dominance they held during the Mesozoic Era (Goin and Goin, 1971; Harding, 1997).

Furthermore, reptiles were more diverse in body size and form in the past and included dinosaurs (Alexander and Marais, 2010). Other group of extinct reptiles includes pelycosaurs, ichthyosaurs, plesiosaurs and pterosaurs (Paton, 1974; Brower, 1980; Motani *et al*., 199; Naish and Martill, 2003; Andreassen, 2004; Fische *et al*., 2013). Dinosaurs were classified as reptiles based on the fact that they laid amniotic egg and their skeleton showed extensive modification for terrestrial locomotion which is the basic characteristic of most reptiles (Lucas, 1996).

According to Lucas (1996), dinosaurs were diapsids since they had two temporal fenestrate on each side of the skull. Dinosaurus arose during the late Triassic (230 Ma) from thecodont precusors, the oldest dinosaurs were geographically restricted to South Pangaea. The group of dinosaurs achieved a nearly global distribution by the latest Triassic (Langer *et al*., 2010) and the distribution was attributed to equable climatic condition (Rees *et al*., 2004). Apart from their global distribution, dinosaurs became extinct at the end of the Mesozoic Era (65 Ma) though the reason for their extinction remains controversial (Sheehan *et al*., 1991). However, two hypotheses have been associated with the extinction of dinosaurs. One is that the population of dinosaurs dwindled gradually at the end of Cretaceous possibly as a result of climatic changes. The second hypothesis is that, earth ecosystem was significantly and globally disrupted by asteroid impact which produced sudden environmental changes that caused abrupt extinction of dinosaurs (Sheehan *et al*., 1991; Weishampel *et al*., 2004).

2.2 Diversity, Distribution and Abundance of Herpetofauna

2.2.1 Diversity, distribution and abundance of amphibians

The Anura are the most known amphibians (Howell, 2004; Hickman *et al*., 2007). Others are Gymnophiona (legless forms) and Caudata. Ecologically, amphibians are found in areas with fresh water and are intolerant of sea water (Goin and Goin, 1971) though some can survive in harsh arid conditions (Channing and Howell, 2006). They are also believed to be the only vertebrates that have not colonised the marine environment due to intolerance of salt water (Snell *et al*., 1999; Collins, 1981; Capula, 1989 cited by Rabou *et al*., 2007). There are also terrestrial amphibians, which remain dependent on moist environment for protection against desiccation (Hickman *et al*., 2007).

Additionally, amphibians are among the most diverse vertebrates, and their diversity is highest in the tropics (Hickman *et al*., 2007). Globally, Brazil has the most described species of amphibians where about 798 species of amphibians are found (IUCN, 2012). Howell, (2004); Channing and Howell, (2006) reported that there are over 200 species of amphibians in East Africa, out of which 10 species of Gymnophiona (Caecilians/apodans) are found in the forests of Kenya and Tanzania. So far, studies have proved the occurrence of caecilians in Kenya and Tanzania, with no species that have been collected in Uganda (Vonesh, 1998; Howell, 2004). However, according to IUCN (2012) there are 178 species of amphibians in Tanzania, and most of them are found in the Eastern Arc Mountains. Tanzania is among the 20 countries with the highest species diversity of amphibians in the world (Stuart *et al*., 2008). Out of the 178 species, 78 species are endemic while 50 species are threatened (IUCN, 2012).

2.2.2 Diversity, distribution and abundance of reptiles

Reptiles are among the most successful vertebrates in terms of diversity, distribution and abundance as they occupy and live in a great variety of aquatic and terrestrial habitats (Hickman *et al.,* 2007; McDiarmid *et al*., 2012). Reptiles can be found below the soil level as well as on tree canopies, and their habitats range from fossorial to arboreal (Howell, 2004). Some species of reptiles have adopted to live in very harsh climates such as desert and arid areas. The occurrence of these species in the dry climate is attributed to their thickened skin.

Besides, reptiles are widely distributed in the world; they inhabit every continent with the exception of Antarctica (BBC, 2012). However lizard-like tuataras are the only species confined to a few islands on the north coast of New Zealand (Branch, 1988; Hickman *et al.,* 2007).

Overall, the world contains nearly 8 000 living species of reptiles (Murton, 2008; Alexander and Marais, 2010), that are grouped in 900 genera and in 48 families (Branch, 1988; Branch, 1998). The order Squamata (lizards, snakes and worm lizard/amphisbaenians) forms 95% of all the living reptiles (Hickman *et al.*, 2007) of which turtles, crocodiles and tuataras represent only 4.1% (Uetz, 2000). Among the three groups (lizards, snakes and worm lizard/amphisbaenians), lizards are the most diversified and successful group as they are well adapted for walking, running, climbing swimming and burrowing (Hickman *et al.,* 2007).

In Sub-Saharan Africa, reptilian species are approximated to be 26 chelonians (excluding sea turtles), 680 lizards, 66 amphisbaenians, 466 snakes and three species of crocodiles (Howell, 2004). Alexander and Marais (2010) reported that 517 species of reptiles are found in Southern Africa. Similarly, Branch (2005) showed that over 420 species have been recorded from East Africa alone.

2.3 Habitat Preference, Threats and Importance of Herpetofauna

2.3.1 Habitat preference

Herpetofauna habitat preference and suitability depends on combination factors including seasonal temperatures, precipitation, soils and contour of the area. Globally, relatively few amphibians and reptiles are true forest animals (Harding, 1997). Most species occupy ecotone (edge habitats) between dense woodlands and open grasslands, and others live in wetlands or open habitats (Harding, 1997). Channing and Howell (2006) reported that most East African amphibians and reptiles are Afro-tropical species associated with savannah and woodland, and good examples are the mole snake (*Pseudaspis cana*) and leopard tortoise (*Geochelone pardalis*). Although closed natural forest cover a very small land area of East Africa forest, amphibian and reptilian forest inhabitants are also found in the region. These include the spiny reef frog (*Afrixalus osorioi*), reed frog (*Hyperolius castaneus*), rhinoceros viper (*Bitis nasicornis*) and forest hinge tortoise (*Kinixys erosa*) (Spawls *et al*., 2004; Channing and Howell, 2006).

Amphibian and reptilian species have also shown specific micro habitat requirements. For instance, terrapins, crocodile, snakes and most amphibians are associated with wetlands habitats whereas some live specifically on rock outcrops/kopjes (Drewes, 1997; Howell, 2004; Branch, 2005). Activity pattern and movements of most reptiles are influenced by specific habitat requirements and food (Branch, 2005; Alexander and Marais, 2010). For instance, specialist species such as spotted rock snakes (*Lamprophis guttatus*) (Squamata: Colubridae) and flat lizards (*Platysaurus* spp) (Squamata: Cordylidae) have very small ranges within which they inhabit specific places (found in exfoliating rock outcrops) (Branch, 2005; Alexander and Marais, 2010) and no flat lizard has ever been found away from a rock face (Spawls *et al*., 2004). Snakes have a wide range over large areas and occur in different habitats searching for specific prey (Branch, 2005).

Herpetofauna habitat preference in Madagascar shows that 42 species of amphibians and reptiles (60%) are found exclusively in forest habitats. While nine species of reptiles (12.9%) were reported to occur only in open areas, and 18 species (25.7%) were found in both open and forest habitats (Rakotondravony and Goodman, 2011). Only a single species, *Oplurus quadrimaculatus* (Squamata: Opluridae) is confined to rock outcrops (kopjes) (Rakotondravony and Goodman, 2011).

2.3.2 Threats to herpetofauna

Amphibians and reptiles play a vital role in an ecosystem though they are among the most overlooked and threatened fauna in many parts of Africa (Howell, 2004). Based on the human population growth and habitat loss, amphibians and reptiles have been seriously threatened. Amphibians are thought to have a higher number of globally threatened species than any other group of organisms except flowering plants (Zippel, 2010). IUCN (2004) reported that about 1856 (32%) described species of amphibians around the wolrd are threatened with extinction. This number is higher than 12% of birds and 23% of mammals that are threatened with extinction (*Ibid*).

Equally important, amphibians and reptiles threats to extinction are associated with environmental disturbances such as habitat destruction and degradation and development projects (Hero and Kriger, 2008). The Food and Agriculture Organization (FAO, 2010) estimates that between 2000-2010, 13 million hectares of the worlds tropical forest, a vast repository of amphibians diversity, were destroyed each year. Commercial agriculture is seen as one of the principal agent of habitat loss through deforestation and forest degradation in a number of countries in the world (Adu *et al*., 2012; Goll *et al*., 2014). Behnin (2006) reported that agriculture account for about 90 percent for all deforestation in tropics. However agriculture and infrastructure development can not be halted as are taken as the first crucial step toward economic development and the reduction of poverty and food insecurity (Alexandratos, 1999). Globally habitat degradation is directly linked with the remove of amphibians and reptilians breeding, feeding and alters assemblage habitats and hence reduces species diversity on the landscape (Corn and Bury, 1989; Hazell *et al*., 2003). For example in Australia, the decline of 18 of the 40 threatened species of amphibia is associated with habitat modification which is the primary cause in the population decline of the lowland frogs (Herro and Marrison, 2004). In Tanzania, IUCN (2009) related the extinction of the Kihansi spray toad *Nectophrynoides asperginis* (Anura: Bufonidae) in the wild to the hydro-power construction associated with rapid power demand, which altered the natural habitat by 90%. Furthermore Hinde *et al*. (2001) reported that establishment of teak plantation affected species richness, diversity, abundance and dispersion of some amphibian species in Kilombero valley. Hinde *et al*. (2001) recorded higher richness and diversity of amphibian species in miombo woodland than in fragmented teak plantation. On the same way, Gardner *et al*. (2007) recorded more species in intact woodland in Katavi than cultivated areas. However, forest fragmentation is also likely to favour some species that prefer edge at the expense of species favouring forest. For instance Patrick *et al*. (2011) recorded more individuals of *Chamaeleo dilepis* (Squamata: Chamaeleonidae) at the forest edge and no individual was recorded in the forest interior. Again, *Rhampholean temporalis* (Squamata: Chamaeleonidae) known to be forest dwellers were only recorded in the forest interior and not at the edge of East Usambara Mountain Forest in Tanzania.

Habitat degradation through tourism and tourist infrastructure is another type of economic development associated with threats to reptiles populations. Muir (2005) reported that availability of suitable nesting sites of marine turtles in Tanzania is decreasing as a result of coastal development at key nesting sites, particularly on small offshore island. For example, Tanzania Coastal Management (TCM, 2003) narrated that in Zanzibar tourism and hotel development has destructed many traditional turtles nesting grounds and there has been a marked decline in turtles nesting in areas of Kiwengwa beach Unguja.

Pollution is the second most significant threats to herpetofauna. Pollution affects about 29% of threatened amphibian species (Stuart *et al*., 2008). Environmental pollution can affect directly the diversity, abundance and distribution of herpetofauna through death of an individual exposed to higher level of pollution or indirectly by impairing reproductive biology of herpetofauna. For example Guillette *et al.* (1995) reported that sex reversal and abnormal gonads have been found in turtles exposed to Polychorinated biphenyls (PCBs). Furthermore Hopkins *et al*. (1999) narrated that water snake (*Nerodia fasciata*) with high accumulation of metal contaminants exhibit elevated metabolic rates, which may result in less energy being devoted to reproduction, growth and storage.

Other threats of amphibians and reptiles include anthropogenic activities, pet and live-animal trade, introduced species, increasing ultraviolet-B radiation, climate change and disease (Vonesh, 1998; Hinde *et al*., 2001; Howell, 2004; Channing and Howell, 2006; Blaustein *et al*., 2010; Jackson and Blackburn, 2010; Relox *et al*., 2010). For example in Northern Greece it is estimated that 50% of mortality of tortoise is attributed by anthropogenic activities (Hailey, 2000). Hailey (2000) noted that the majority of tortoise are killed by fire in coastal (< 5%), grassland (about 50%) and intermediate level in dry heath habitats of Greece. Although some species of reptiles are capable of surviving fires, depending on the structure of the habitat, the season and time of the day, fire intensity and duration still causes major threats to most herpetofauna (Popgeorgiev and Kornilev, 2009).

Disease is another threat implicated in decline and extinctions of amphibians and reptile species in various landscapes, although it appears relatively less significant threat when compared to habitat loss and degradation (Stuart *et al*., 2008). Recent studies have shown that fungal, bacterial and viral disease affect amphibians and reptiles through out the world (Weldon *et al*., 2004; Skerrat *et al*., 2007; Blaustein *et al*., 2012). Infectious diseases are increasing at an unprecedented rate and are intimately associated with the dynamics of biodiversity (Blaustein *et al*., 2012). Furthemore infectious disease may cause population declines and species extinctions and alter the structure and function of ecological communities in various habitats (Blaustein *et al*., 2012). For example chytridiomycosis disease caused by the chytrid fungus (*Batrachochytrium dendrobatidis*) is seen as the primary cause to population decline of multiple species of amphibians (Skerrat *et al*., 2007; Hero and Kriger, 2008). Australia has the highest threatened species affected by disease (36%), followed by Neotropical with 28% and the Neartic with 18%. Furthermore chytriomycosis is seen as the likely cause of many of the amphibian population decline that has occurred in Australia (Berger *et al*., 1998). Chytriomycosis is thought to be originated from South Africa and spread to other regions of the world through commercial trade (Weldon *et al*., 2004). Apart from South Africa, chytrid infections have also been reported in Eastern Democratic of Congo, West Africa and East Africa (Weldon *et al*., 2004; Greenbaum *et al*., 2008). The chytriomycosis has been associated with frog die off and mortality in most habitats of Africa though decline in frog populations are poorly documented (Weldon *et al*., 2004; Channing *et al*., 2006).

Climate change is another threat to the diversity, abundance, distribution and survival of herpetofauna in various habitats. To demonstrate this, Blaustein *et al.* (2010) reported that climate change may have both direct and indirect effects on the amphibians and reptiles at the individual, population and community level. Change in climate may affect survival, growth, reproduction and dispersal capabilities of herpetofauna. Climate change can also alter their habitats (vegetation, soil and hydrology). Moreover, climate change can influence food availability and overall predator-prey relationship and competitive interaction which affect the community structure (Blaustein *et al*., 2010). Another good example is the extinction of the golden toad (*Bufo periglenes*) in Costa Rica which was linked to unusual weather condition (Pounds and Crump, 1994).

Pet trade and over-harvesting are also factors threaten herpetofauna diversity, abundance and distribution. These factors are likely to cause mass extinction of species if are not well monitored and controlled. Amphibians and reptiles are harvested for food, medicine, for cultural, scientific and for leisure activites. Pet trade is legally permited and is regulated by Conversional on Internation Trade of Endangered Species (CITES) responsible for setting hunting/harvest quotas each year. Inadequate knowledge of species identification can cause harvesting of untargeted species in expense of the other as most species of chamelions and amphibians look alike/similar (URT, 2005). Harvesting of amphibians and reptiles species for exotic pet trade can affect breeding biology and fitness of species, if small males become breeders. For example in Tanzania Patrick *et al*. (2011) found a strong female sex-bias in adults, and the adult female of *Trioceros deremensis* (the most valued species for exotic trade) were larger than female contrary to literature which documents males as the larger sex (Spawls *et al*., 2006). If remain uncontrolled pet trade can lead to overharvesting of hepertofauna species beyond sustainable levels. According to Bridges *et al.* (2001) United States imported 56 676 reptiles from Tanzania in the year 1998 and majority were lizards (45 828). Harvesting quota of reptiles species for pet trade in Tanzania for the year 2014 is 38 040 individuals (CITES, 2014). Sea turtles are the most threatened species exploited for meat and illegal pet trade in Tanzania. Muir (2005) reported that turtle hunters are waiting turtles to emerge to nest along the beaches and 49% of nest recorded along the beach were poached by fisherman.

Community perception ranks amongst the main threats to herpetofauna population in many parts of the world, particulary Africa. Amphibians and reptiles are among the least appreciated vertebrates and are victims of many negative values and wrong ideas (Ceriaco *et al*., 2012). Some reptiles species (most being snakes) are hunted and killed due to conflicting relations with people (Alves *et al*., 2012). For example, in Portugal Ceriaco *et al*. (2012) found that despite its ecological importance and role in preventing mosquito plagues, the gecko is seen as a poisonous and evil animal and is therefore persecuted.

Positive attitude of communities play a major role in conservation of herpetofauna. For example, in Tanzania Kabigumila (1998) reported that the Ikoma tribe esteems leopard tortoise (*Geochelone pardalis babcocki*) as a totem animal and communities have shown strong willingness to conserve tortoise in their area. Else where in Africa the same finding was reported in Botswana by Setlalekgomo and Setlalekgomo (2013). When compared to other causes of threats habitat destruction and associated degradation and fragmentation ranks number one threats to the population, diversity and abundance of herpetofauna through out the world. Furthermore unsustainable harvesting for food, medicine and the pet trade are additional major threats to herpetofauna populations.

2.3.3 The importance of herpetofauna in the ecosystem

Amphibians and reptiles are important components of ecosystems and they form an important chain in ecosystem food web. Apart from being food to predators (birds and small mammals), amphibians and reptiles are also predators feeding on invertebrates and mammals which are pests and vectors of humans (Channing and Howell, 2006). Large predators like crocodiles (*Crocodylus niloticus*) feed on a wide variety of mammalian species and on the other hand tortoises (*Geochelone pardalis*) are important herbivores (*Ibid*). Additionaly larvae of amphibians are primary consumers of plant matter, such as algae and detritus (Stuarts *et al*., 2008). Thus, declining in abundance of amphibians and reptile is likely to affect the integrity of the ecosystem by affecting the population of specialised predators (Zippel, 2010).

Amphibians and reptiles are also known as important bioindicators of ecosystem integrity because of their sensitivity to environmental perturbations (Ferguson and Pilgrim, 2009). A concrete example is that, amphibians possess thin moist skin which makes them susceptible to pesticides poisoning which is likely to affect their populations. With this regard, most amphibians are very sensitive even to a low concentration of pesticides. Hayes *et al.* (2010) reported that a very low concentration of Atrazine regarded safe in drinking water can chemically sterilise male amphibians and even turn them to females. For instance, ten percent of genetic male African clawed frog *Xenopus laevis* exposed to Atrazine developed into functional females that copulated with unexposed males and produced viable eggs (Hayes *et al*., 2010). Changing in amphibia population either attributed by pesticides, habitat degradation or any other factor is linked to the ecosystem degradation likely associated with reduction in ecosystem services and direct health risks (Ferguson and Pilgrim, 2009).

The ecological role of fossorial amphibians and reptiles is overlooked, but studies (e.g. Channing and Howell, 2006; Ferguson and Pilgrim, 2009) highlight that fossorial species are important in aerating the soil and nutrients cycling in the system.

Amphibians and reptiles form and important part of the rural economy (Kabigumila, 1998), not only as a source of food, medicine and raw material but also in terms of ecological equilibrium (Ceriaco *et al*., 2012). For instance Ceriaco *et al.* (2012) reported that Gecko provides greater ecological importance and role in preventing mosquito plagues. Nearly 200 species of world's amphibians are used as food (Stuart *et al*., 2008). In Nigeria, Oduntan *et al.* (2012) pointed out that meat of Edible bull frog (*Rana esculenta*) is very nutritious in terms of strong bones and teeth development as it provides more than four times of calcium available in bush meat.

In Tanzania, Kabigumila (1998) reported that traditionally some species of reptiles (Leopard tortoise) are seen as totem animals and their scutes are used for treating various ailments such as muscular pains, boils, snake bites, fever and for witchcraft. Furthermore Setlalekgomo and Setlalekgomo (2013) reported that in Botswana a woman who happens to come across leopard tortoise (*Geochelone pardalis babcocki*) often in a day is likely to be pregnant. Amphibians are also being acknowledged as an important potential source of chemical substances for use in modern medicine and globally about 73 amphibian species are considered to have some kind of medicinal values (Stuart *et al*., 2008).

Amphibians and reptiles contribute to the growth of coutry economy through international pet trade. According to CITES (2014) Tanzania is exporting about 42 species of reptiles to the international market for pet trade. Crocodiles, lizards and snakes are source of skin which is also traded on international market for the leather industry (Mittermeier *et al*., 1992). Additionally amphibians and reptiles contribute to the country economy through tourism attractions and various kinds of products are sold as tourist curios (Mittermeier *et al*., 1992).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Study area

The study was conducted in grassland, woodland, kopjes, riverine forest and wetlands habitats of western and southern SENAPA, which is located in northern Tanzania (Fig.1). An area of 2,286 km^2 of the current southern and eastern SENAPA was declared as a Game Reserve in 1929. Then in 1951 the area currently composed Serengeti and Ngorongoro Conservation Area was declared as National Park, followed by 1959 inclusion of an area between Banagi River and the Kenya border. At the same time (1959) Ngorongoro Conservation Area was excised from Serengeti National Park. In 1965 the Lamai wedge between the Mara River and Kenya border was added to the park (Sinclair, 1995).

SENAPA is located between Latitude: 2° 19' 60 S and Longitude: 34° 49' 60 E. The elevation of SENAPA ranges from 1162 m on the shores of Lake Victoria to 1860 m in the northeast. It is the second largest park among the 16 currently established National Parks in Tanzania with an area of 14 763 km^2. It is part of the largest Serengeti ecosystem which covers an area of about 35 000 km^2. The park is the heart of Serengeti ecosystem (Fig. 2) surrounded by Ngorongoro Conservation Area on the southeast, Maswa and Kijereshi Game Reserves on the southwest, Ikorongo-Grumeti Game Reserve on the west, Loliondo Game Controlled Area on northeast and Maasai Mara National Reserve (Kenya).

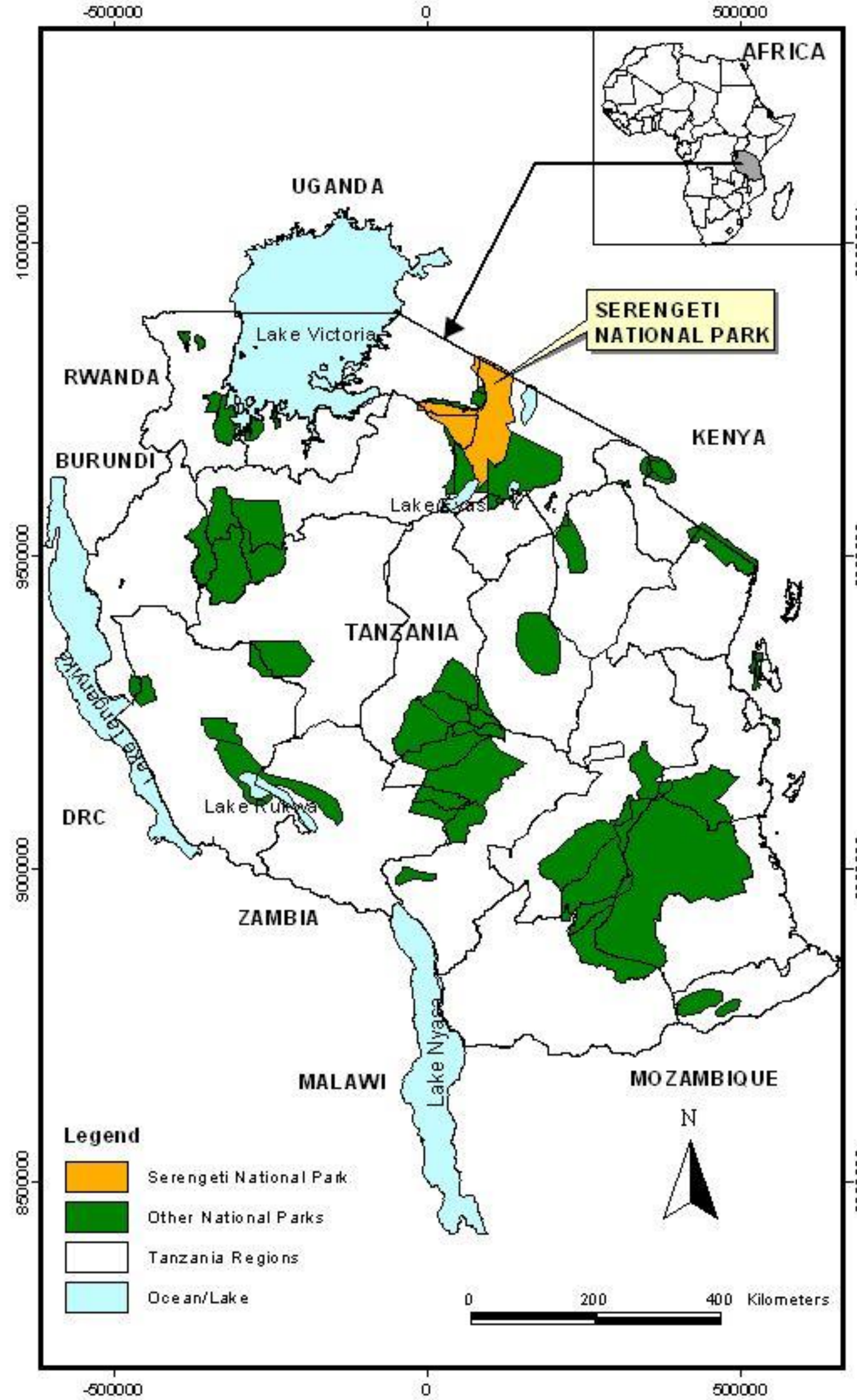

Figure 1: Map of Tanzania showing location of Serengeti National Park

Source: SUA GIS Centre (2014)

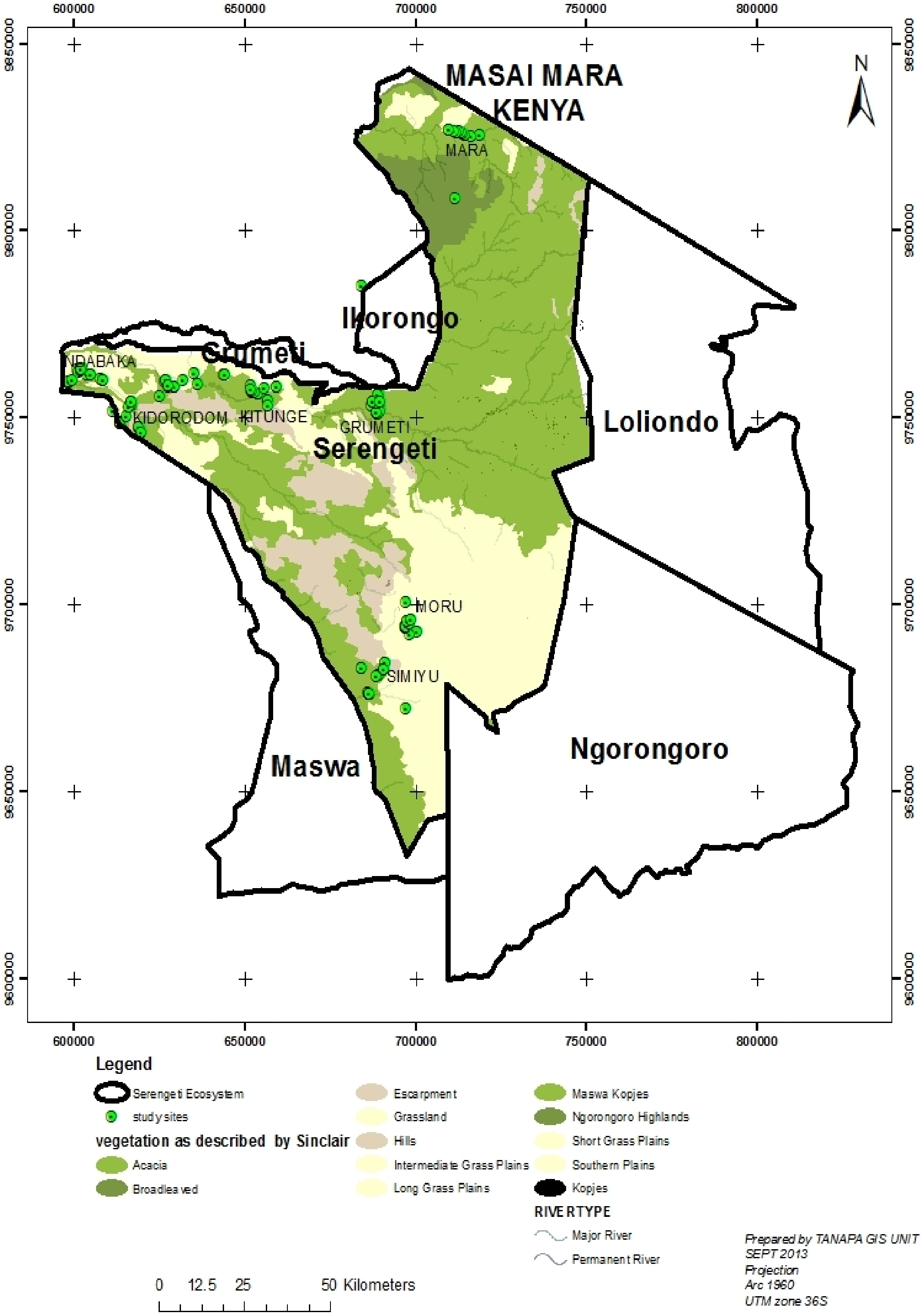

Figure 2: Map of Serengeti National Park and adjacent protected areas

Source: TANAPA GIS UNIT (2013)

3.1.1.1 Climate

SENAPA is a semiarid area with bimodal rainfall seasons. The long rains occur from February to mid May and the short rains from November to December (Fig. 3). The temperature is relatively uniform with the maximum temperature of 28^{o}C and minimum temperature of 20.8^{o}C during the dry season between June and October (Norton-Griffiths *et al*., 1975; Roodt, 2005; UNESCO, 2010). There is a strong gradient in mean annual rainfall from northwest woodland (1000 mm), central woodland and western corridor (800 mm) to southeast grassland (500 mm) Norton- Griffiths *et al*., 1975) (Fig. 4).

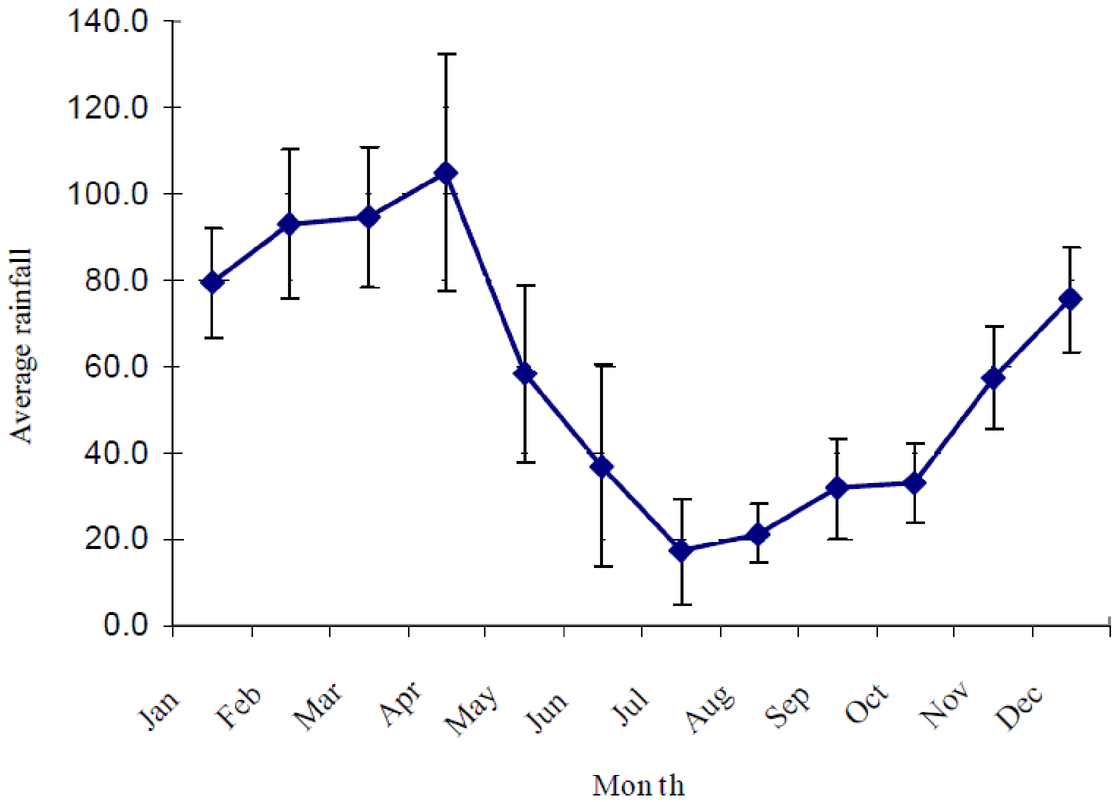

Figure 3: The average annual rainfall (mm) from 1984 to 1997 for Serengeti National Park, Tanzania

Source: Hopcraft (2002)

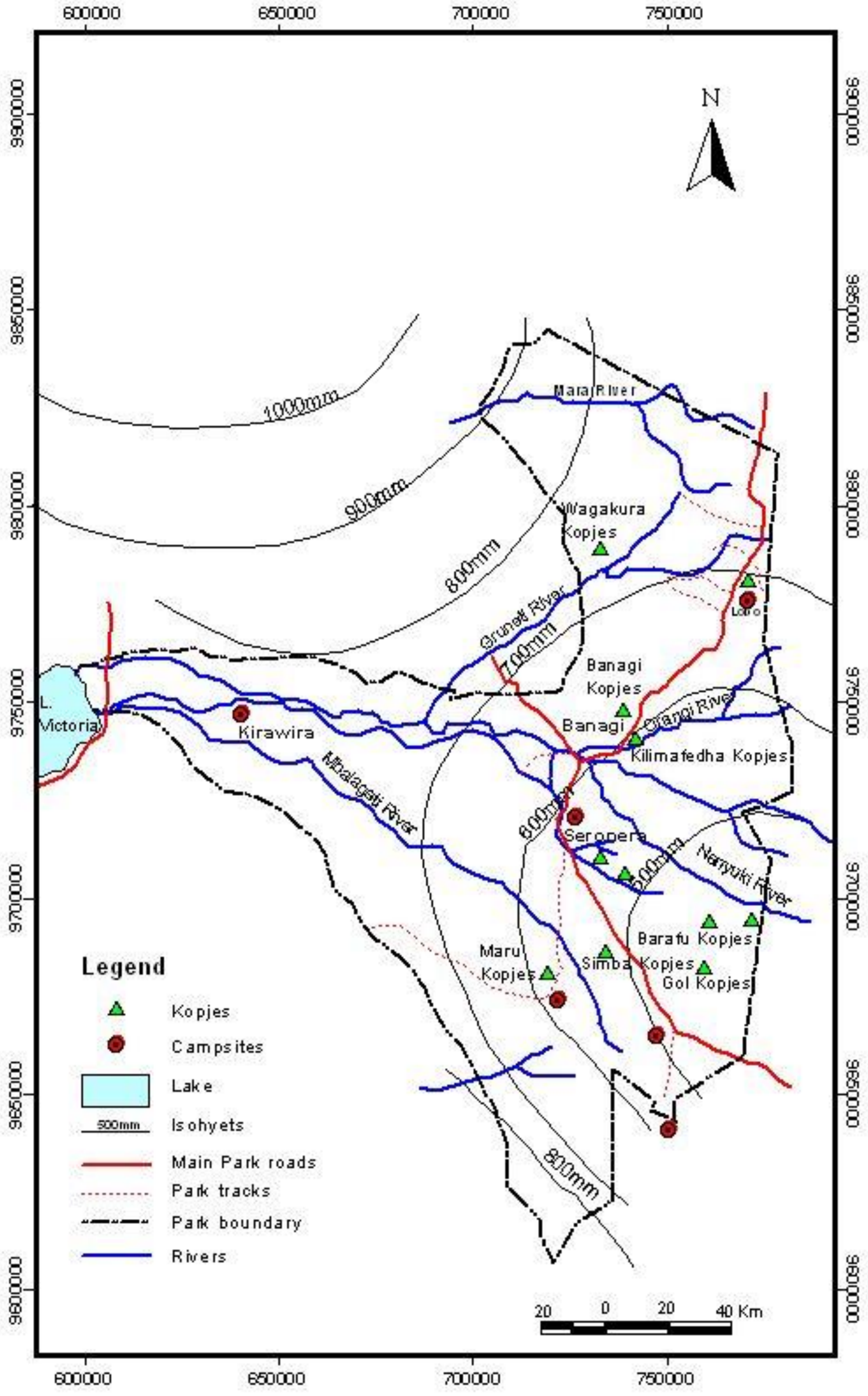

Figure 4: Map of Serengeti National Park showing rainfall patterns
Source: TANAPA GIS UNIT (2013).

3.1.1.2 Soil

The soils of SENAPA are divided into five groups and vary widely from southeast (shallow and alkaline) to northwest (deeper and less alkaline) (Roodt, 2005). First, the black cotton soil with poor drainage is found in west and south-west of Seronera (Fig. 4). Second, the alluvial soil consisting of a mixture of sand and clay is found along the rivers. Third, the sandy soil with large particles allowing good drainage is found in the northwestern side of the park. Then, the calcareous volcanic soil which is shallow, very alkaline and fertile and covered by a shallow layer of volcanic dust is found in the south-eastern part where grassland dominate. The soils in the south-eastern part are of volcanic origin (Anderson and Talbot, 1965).

3.1.1.3 Vegetation

The vegetation of SENAPA is determined by soil and rainfall patterns (Norton-Griffiths *et al*., 1975). They include riverine forest, woodland, kopjes vegetation, grasslands and wetland/swamp vegetation. The riverine forests cover most parts of rivers and are dominated by *Ficus* spp, *Grewia* spp, *Acacia brevispica*, *Cordia ovalis*, *Tamarindus indica*, *Olea europaea* subsp. *africana*, *Ziziphus pubescens*, *Turraea robusta*, *Teclea trichocarpa* and *Strychnos henningsii* (Roodt, 2005). The woodlands start at the boundary running south and east of seronera (central region) and are dominated by species of *Acacia* and *Commiphora* species in all areas except south and west of Kogatende (north west of SENAPA), where *Terminalia-Combretum* woodland takes over (Sinclair, 1995). Conversely, the grasslands extend from southeast on the plains and parts of the north and west of the park. *Themeda triandra* dominates the long grasslands, *Andropogon greenwayii* dominates the intermediate grasslands and short grasslands are dominated by *Michrochloa kunthii*, *Digitaria macroblephora*, *Dactyloctenium* spp and *Sporobolus consimilis*. Grasslands on southeast are on alkaline, volcanic derived soil and those in the west of SENAPA are of alluvial and of lacustrine origin. Notwithstanding, the vegetation on kopjes varies widely and differs from the surrounding vegetation. The most common species of the kopjes are *Euphorbia candelabrum*, *Cissus quadrangularis*, *Cordia ovalis* and *Ficus thornningii* (Roodts, 2005).

3.1.1.4 Fauna

SENAPA supports 28 species of ungulates, 13 species of large carnivores and about 517 species of birds (Sinclair, 1995). Wildebeests (*Connochaetes taurinus* are the most dominant herbivores forming the largest herds of migrating ungulates (Sinclair, 1979a). The wildebeests (*Connochaetes taurinus*) form a bulk of migration, being the most numerous large mammal performing characteristic seasonal movements, from the short-grass plains (calving ground) in the wet season to the western corridor in the early dry season, and, finally, to the north for the late dry season (Sinclair, 1979b). The zebras (*Equus burchelli*) form the second largest group of migratory animals and they follow the same route as the wildebeests. The Thomson’s gazelles (*Gazella thomsonii*) form much shorter migratory route than the wildebeests and zebras. In addition, Thomson’s gazelle (*Gazella thomsonii*) are the first migratory animals to arrive on grassland plains and the last to leave as they feed on short grasses, herbs and forbs (Roodts, 2005).

Other species, such as elands (*Taurotragus oryx*), Grant’s gazelles (*Gazella grantii*) and African buffaloes (*Syncerus caffer*) are more sedentary, but most of them show some local movements among habitats with change of seasons (Sinclair, 1979b; Roodt, 2005). The park ultimately supports one of the highest concentrations of predators in the world. The dominant predators are spotted hyenas (*Crocuta crocuta*) and lions (*Panthera leo*) (Sinclair, 1995). SENAPA is also known to support the highest number of ostrich (*Struthio camelus*) population in Tanzania and Africa (SENAPA-GMP, 2006).

SENAPA is known to host 27 species of amphibians (Channing *et al*., 2004). Incomplete collection of about 80 species of grasshoppers and over 1000 species of dung beetles have been collected on southern part of SENAPA (Sinclair, 1995). The park is also known to support a number of reptiles though their species diversity is unknown as the taxon is not well studied (Ibid).

3.2 Methods

3.2.1 Sampling design

The park was stratified into five habitats: riverine forests, wetlands/swamps, kopjes, grasslands and woodlands. Ten sampling stations (two stations for each habitat) were purposively choosen and established in five selected study habitats for data collection.

3.2.2 Data collection methods

The data collection methods used to survey the diversity, abundance and distribution of amphibians and reptiles in SENAPA followed the standard methods proposed by Branch (1988); Heyer *et al*. (1994) and Howell (2004). The methods included traps (drift fence with pitfall and wire mesh traps), active search and visual survey, road survey and purposive point count. Data collected from focus group discussion and literature review were also used to supplement data collected from the field to prepare a checklist of amphibians and reptiles of SENAPA.

3.2.2.1 Traps

(a) Drift fence and pitfall trap transect line

Drift fence and pitfall trap transect line (Fig. 5) consisting 20 litres bucket (adopted from Howell, 2004) were used to collect amphibian and reptilian species. The drift fence consisted of plastic sheeting, 60 cm in height and 55 m in length. This was constructed to intercept and redirect amphibians and reptiles moving on the ground into pitfall traps. Each transect line contained eleven buckets sunk into the ground with the rim level with the ground at 5 m interval along the drift fence. Four transect lines with drift and pitfall traps were constructed in ten data collection stations (two stations in each habitat). The distance between transect line was determined by suitability of the area to amphibians and reptiles, and in most cases it ranged from 50 m to 100 m. The drift fence and pitfall traps were checked twice a day early in the morning and late evening before sunset on daily basis for seven days. A total of sampling efforts of 308 trap nights per site were realized making sampling efforts of 3080 trap-nights across all sites during the study.

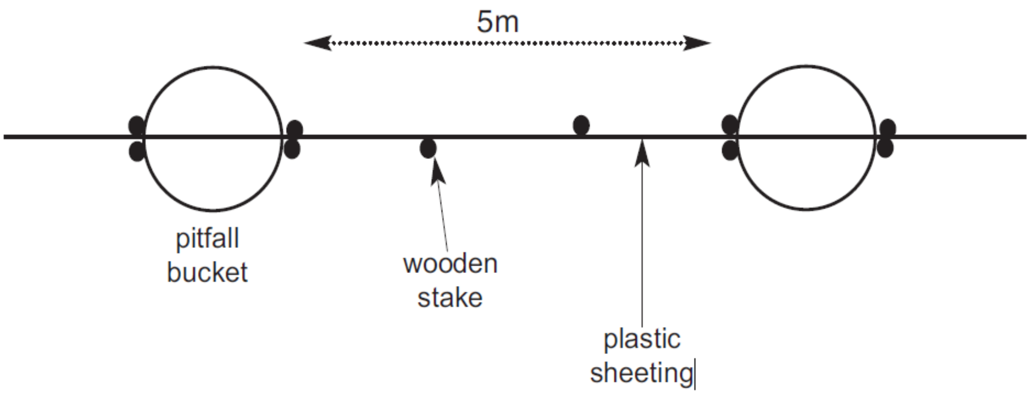

Figure 5: Sketch of Drift fence and pitfall trap layout
Source: Howell (2004)

(b) Wire mesh funnel trap

Wire mesh funnel traps (Plate 1) (Howell, 2004) were used to trap snakes. These traps were made locally by snares (20 cm in height, 43 cm in length) with funnel-shaped entrances at both ends to allow easy entry, but to make escape difficult (Howell, 2004). In addition, the traps were baited with live rodents and chicken eggs. A total of five wire mesh traps were randomly placed in five sites (i.e. one site from each stratum/habitat) for five days. Trap efforts were 25 trap nights per site and 125 trap nights across all sites during the study. The traps were checked twice a day, early in the morning and late evening before sunset on daily basis.

Plate 1: Wire mesh funnel trap

3.2.2.2 Active searching and visual encounter survey (ASVES)

Active search was undertaken randomly in sites away from the transect lines and it involved turning over logs, leaf litter, tree holes, rocks, and other potential hideout searching for amphibians and reptiles. Active search and visual survey was undertaken day and night. Night search was specifically adapted to spot nocturnal reptiles such as chameleons and snakes which are motionless at night and look pale in dark vegetation (Spawls *et al*., 2004). Each site was searched once for 30 minutes by a team of six people.

3.2.2.3 Road survey

Road surveys were conducted day and night to collect data of live or dead amphibians and reptiles on roads. Fourteen roads were surveyed and these include Nyasirori-Dara, Belabela-Kirawira, Kitunge–Kirawira B, Kirawira B-Grumeti, Handajega-Mbalageti, Kirawira-Ndabaka, Kirawira-Serena, Ikoma-Hembe, Seronera-Fort Ikoma, Moru-Simiyu, Moru-Sopa, Simiyu-Kusini Camp, Tabora B-Makutano and Kogatende –Machochwe. In this surveys a total of about 376 km were covered for 25 sampling days.

3.2.2.4 Point sampling

Point sampling was conducted along the Mara and Grumeti rivers to locate and count reptiles which are water dependant. The point sampling at Mara River started at the junction of Bologonja and Mara rivers and ended at Kogatende Bridge on Mara River. For Grumeti River sampling point started at Dara Bridge and extended up to Kirawira Ranger's Post. In fact, point count concentrated in areas with crocodile pools and basking grounds. All points were randomly selected along the river banks. The method was adopted as crocodiles concentrate in favourable habitats where resources are abundant (Combrink, 2004). To avoid biasness and double counting only crocodiles basking along the river banks were sighted and counted whereas trails and nests were avoided. At each point observers spent 30 minutes with the aid of binoculars.

3.2.2.5 Species identification and voucher specimen preservation

Captured amphibians were placed in individual plastic bags with water for moisture while captured reptiles were handled using a grabbing sticks and placed in individual cotton bags until the end of search time. Some sighted and caught individuals were identified to the species level, and this was done using the keys and field guidebooks (Branch, 1998, 2005; Marais, 2004; Spawls *et al*., 2004, 2006; Channing and Howell, 2006; Frost *et al*., 2008; Alexander and Marais, 2010; Harper *et al*., 2010). After taking records, caught individuals were released 50 m away from the capture area to avoid recapture. Nonetheless, individuals that could not be identified at the data collection sites were collected as voucher specimen and preserved in 10% formalin. In addition, voucher specimens were taken to Zoology and Wildlife Conservation laboratory at the University of Dar es Salaam for identification and later the voucher specimen were deposited at the Sokoine University of Agriculture Zoology laboratory for preservation.

A 10 megapixel digital camera was used for photographing and documenting habitat, micro habitats, traps and some of the species sighted and captured in the field. Photographs of sighted individuals were also taken to the University of Dar es Salaam for identification and later were deposited at the Sokoine University of Agriculture as reference material.

3.2.2.6 Focus group discussion

A focus group discussion was held with SENAPA staff including the Park Ecologist, Protection Warden, Zonal Wardens and Head of ranger post so as to get a list of names and conservation status of amphibians and reptiles which were not encountered during the data collection.

3.2.2.7 Secondary data

Primary publications (Betram, 1979a, b; Elzen and Kreulen, 1979; Drewes, 1997; Kabigumila, 2001; Channing *et al*., 2004) were reviewed for obtaining names and conservation status of the existing species of amphibians and reptiles of SENAPA which were not encountered during this study. For that matter, names of amphibians and reptiles obtained through literature review and focus group discussion were combined with the list of species observed in the field to prepare a checklist of SENAPA herpetofauna.

3.2.3 Data Analysis

Primary data collected from the field through traps (drift fence with pitfall and wire mesh), active search, road surveys and point counts were used for statistical analysis (diversity, abundance and distribution) of herpetofauna of SENAPA. Secondary data collected from previous studies, and data recorded from focus group discussion were used to prepare a checklist of SENAPA herpetofauna.

3.2.3.1 Species diversity

i. Shannon – Wiener Index of Diversity, (H′) was used to calculate diversity of species in various habitats

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

Where H' is the index of species diversity, s is number of amphibia or reptile, *pi* is the proportion of the total sample belonging to the **i-th** species and **ln** natural logarithm. Species richness was summed as the total number of species encountered.

ii. Simpson index was calculated to determine the dominance of species

$$C = \sum_i Pi^2$$

Then, the diversity and richness calculations were performed using Program diversity version 2.6.5.1506 (PISCES Conservation Ltd).

3.2.3.2 Abundance of species

A relative abundance of amphibian and reptilian species in various habitats was calculated as the ratio of the number of species found in each habitat and the total number of species recorded in all study habitats.

A relative abundance of amphibian and reptilian between species was calculated as the ratio number of each species and the total number of all species recorded.

3.2.3.3 Distribution of species

The distribution of species recorded as presence or absence of species in a particular habitat was analysed using Cochran's Q test (Zar, 1996) SPSS version 12.

The statistical analysis was performed using InStat 3 (Graph Pad Software, Inc., San Diego, CA, USA) and SPSS version 12. Besides, Kruskal-Wallis was used to compare the amphibians and reptiles diversity indices and relative abundance variations among the habitats. Here two-tailed probability results <0.05 was used to test the statistical significance (Zar, 1999).

CHAPTER FOUR

4.0 RESULTS

4.1 Herpetofauna Species Richness and Diversity

4.1.1 Amphibians

Thirty six species of amphibians (Appendix 1), from 12 families and 17 genera were recorded in SENAPA from previous and current study (Table 1). The most diverse families of amphibians were Hyperoliidae and Ptychadenidae, both families with 6 species. Six species of Hyperoliidae were recorded from 3 genera while 6 species of Ptychadenidae were reported from one genus (Table 1).

Table 1: Families, genera and number of species of Amphibians in SENAPA

Family	Genera	Number of species
Bufonidae	*Bufo*	2
	Mertensophryne	1
	Schismaderma	1
Hemisotidae	*Hemisus*	2
Hyperoliidae	*Afrixalus*	1
	Hyperolius	4
	Kassina	1
Arthroleptidae	*Leptopelis*	1
Microhylidae	*Phrynomantis*	1
Pipidae	*Xenopus*	3
Ranidae	*Amnirana*	1
Dicroglossidae	*Hoplobatrachus*	1
Phrynobatrachidae	*Phrynobatrachus*	5
Ptychadenidae	*Ptychadena*	6
Pyxicephalidae	*Tomopterna*	3
	Cacosternum	1
Rhacophoridae	*Chiromantis*	2
Total species		**36**

From the current study, 19 species in 11 genera distributed in 9 families were recorded in SENAPA (Table 2). The highest species richness was recorded in grassland (n = 13) whereas kopjes (n = 4) had the lowest species richness (Table 3). Again, the seventeen species recorded in previous studies were not encountered during this study. However, the study recorded other six amphibian species that were not encountered in SENAPA in the previous studies. The new recorded species are *Hemisus guineensis* (Anura: Hemisotidae), *Mentensophryne* sp (Anura: Bufonidae), *Tomopterna cryptotis* (Anura: Pyxicephalidae), *Tomopterna turbeculosa* (Anura: Pyxicephalidae), *Phrynobantrachus scheffleri* (Anura: Phrynobatrachidae) and *Chiromantis xerampelina* (Anura: Rhacophoridae).

Table 2: Families and genera of observed amphibians in SENAPA

		Number of species in habitats				
Families	Genera	GLSD	KPSE	RRFT	WOLD	WTLD
Bufonidae	*Bufo*	1	1	1	1	1
	Mertensophryne	1	0	0	0	0
Hemisotidae	*Hemisus*	2	0	2	2	2
Hyperoliidae	*Kassina*	1	0	0	0	0
	Hyperolius	1	1	0	0	0
Pipidae	*Xenopus*	1	0	0	0	0
Ptychadenidae	*Ptychadena*	5	1	2	2	4
Phrynobatrachidae	*Phrynobatrachus*	0	0	2	0	0
Dicroglossidae	*Hoplobatrachus*	0	0	1	0	0
Pyxicephalidae	*Tomopterna*	0	1	0	1	0
Rhacophoridae	*Chiromantis*	1	0	0	1	0

Note: GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland and WTLD Wetland

Amphibian species diversity differed among habitats. The highest species diversity of amphibians was recorded in the riverine forests (H' = 1.63), followed by grasslands (H' = 1.45) and the lowest in kopjes (H' = 0.99) (Table 3). All in all, no significant variation of species diversity of amphibians was detected among habitats (Kruskal-Wallis test, H = 4.43; DF = 4; P > 0.05).

Table 3: Diversity index of Amphibians in SENAPA

	Habitats				
	GLSD	KPES	RRFT	WOLD	WTLD
Species richness	13	4	8	7	7
Evenness	0.49	0.34	0.55	0.47	0.45
Shannon-Weiner diversity (H')	1.45	0.99	1.63	1.37	1.33
Simpson diversity (D)	2.79	2.33	4.08	3.19	2.94

Note: GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland and WTLD = Wetland

4.1.2 Reptiles

Forty eight species of reptiles (Appendix 2), from 16 families and 38 genera were recorded from SENAPA (Table 4).

Table 4: Families, genera and number of species of Reptiles in SENAPA

Family	Genera	Number of species
Agamidae	*Acanthocercus*	1
	Agama	1
Atractaspididae	*Atractaspis*	1
Chamaeleonidae	*Chamaeleo*	1
Colubridae	*Boiga*	1
	Crotaphopeltis	1
	Dispholidus	1
	Hemirhagerrhis	1
	Lamprophis	1
	Lycophidion	1
	Meizodon	1
	Philothamnus	1
	Psammophis	1
	Psammophyal	1
	Telescopus	1
Crocodylidae	*Crocodylus*	1
Elapidae	*Dendroaspis*	1
	Elapsoidea	1
	Naja	1
Gekkonidae	*Hemidactylus*	2
	Lygodactylus	2
Gerrhosauridae	*Gerrhosaurus*	1
Lacertidae	*Adolfus*	1
	Heliobolus	1
	Pedioplanis	2
Pelomedusidae	*Pelomedusa*	1
Pythonidae	*Python*	1
Scincidae	*Lygosoma*	2
	Mabuya	5
	Nucras	1
	Panaspis	1
Testudinidae	*Geochelone*	1
	Kinixys	1
	Malacochersus	1
Typhlopidae	*Typhlops*	2
	Rhinotyphlops	1
Viperidae	*Bitis*	1
	Caucus	1
Varanidae	*Varanus*	1
Total species		**48**

The most diverse family of reptiles was Colubridae with 11 species distributed in 10 genera. From the current study, 43 species of reptiles in 34 genera distributed in 15 families were recorded in SENAPA (Table 5).

Table 5: Families and genera of observed Reptiles species in SENAPA

Families	Genera	GLSD	KPSE	RRFT	WOLD	WTLD
		Number of species in habitats				
Agamidae	*Agama*	0	1	0	0	0
	Acanthocercus	0	0	0	1	0
Atractaspididae	*Atractaspis*	0	1	0	0	0
Chamaeleonidae	*Chamaeleo*	1	0	0	1	0
Colubridae	*Hemirhagerrhis*	0	0	0	1	0
	Philothamnus	0	2	0	2	0
	Dispholidus	0	0	0	1	1
	Lamprophis	0	0	1	1	0
	Lycophidion	0	0	0	1	0
	Psammophis	0	0	0	1	1
	Boiga	0	0	0	1	0
	Meizodon	1	0	0	0	0
	Telescopus	0	1	0	0	0
	Crotaphopeltis	1	0	0	1	0
Elapidae	*Dendroaspis*	0	0	0	1	0
	Naja	0	1	0	0	1
	Elapsoidea	1	0	0	0	0
Viperidae	*Bitis*	1	1	0	0	0
	Causus	1	0	0	1	0
Crocodylidae	*Crocodylus*	0	0	0	0	1
Gekkonidae	*Lygodactylus*	0	0	1	2	0
	Hemidactylus	0	1	0	1	0
Gerrhosauridae	*Gerrhosaurus*	1	0	0	1	0
Lacertidae	*Nucras*	1	1	1	1	0
	Adolfus	0	0	1	0	0
	Heliobolus	1	0	0	0	0
Scincidae	*Mabuya*	3	4	1	2	1
	Lygosoma	1	2	0	1	0
	Panaspis	0	1	0	1	0
Pelomedusidae	*Pelomedusa*	1	1	0	1	1
Testudinidae	*Geochelone*	1	1	0	1	1
Typhlopidae	*Typhlops*	1	1	0	0	2
	Rhinotyphlops	0	1	0	1	0
Varanidae	*Varanus*	1	1	1	1	1

Note: GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland and WTLD = Wetland

The highest species richness in reptiles was recorded in woodland (n = 27) and kopjes (n = 21). However, the riverine forest was found with the lowest reptile species richness (n = 6) (Table 6). The woodlands of SENAPA has the highest species diversity of reptiles (H' = 2.79) followed by grasslands (H' = 2.1). The lowest diversity was recorded in wetlands (H' = 0.69) (Table 6). There was a significant difference in species diversity of reptiles among the habitats (Kruskal-Wallis test, H = 25.688; DF = 4; $P < 0.05$). However, Dunn’s multiple comparison test revealed that there were no significant difference amongst habitats (P > 0.05); i.e the difference was only evident in Riverine Forest vs. Woodland (P < 0.05) and Woodland vs. Wetland (P < 0.05) (Appendix 3).

Table 6: Diversity index of Reptiles in SENAPA

	Habitats				
	GLSD	KPES	RRFT	WOLD	WTLD
Species richness	17	21	6	27	10
Evenness	0.56	0.29	0.39	0.74	0.18
Shannon-Weiner diversity (H')	2.1	1.08	1.49	2.79	0.69
Simpson diversity (D)	5.86	1.68	4.55	13.45	1.39

Note: GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland and WTLD = Wetland

4.2 Relative Abundance of Herpetofauna in SENAPA

4.2.1 Amphibians

A total of 952 amphibian individuals (Appendix 4), were recorded during the study. The abundance differed among species and habitats. To illustrate this, *Ptychadena mossambica* (45.48%) were the most abundant species, followed by *Hemisus marmoratus* (18.16%) and *Ptychadena mascareniensis* (11.64%) (Table 7).

Table 7: Relative abundance of selected Amphibian species in SENAPA

		Habitats					
Families and species	N	GLSD	KPES	RRFT	WOLD	WTLD	Total %
Bufonidae							
Mertensophryne sp	1	0.1	-	-	-	-	0.1
Hemisotidae							
Hemisus marmoratus	173	6.72	-	2.73	2.31	6.4	18.16
Hyperoliidae							
Hyperolius ferniquei	1	0.1	-	-	-	-	0.1
Hyperolius goetzei	1	-	0.1	-	-	-	0.1
Pipidae							
Xenopus muelleri	1	0.1	-	-	-	-	0.1
Ptychadenidae							
Ptychadena mossambica	433	41.28	-	0	-	4.2	45.48
Ptychadena mascareniensis	111	11.02	-	0.1	-	0.52	11.64
Dicroglossidae							
Hoplobatrachus occipitalis	1	-	-	0.1	-	-	0.1
Rhacophoridae							
Chiromantis petersi	1	0.1	-	-	-	-	0.1

Note: N = Number of individuals, GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland, WTLD = Wetland and - = Absence/not recorded

Nonetheless, six species, *Hyperolius ferniquei*, *Hyperolius goetzei*, *Xenopus muelleri*, *Mertensophryne* sp, *Hoplobatrachus occipitalis* and *Chiromantis petersi* were the least abundant species (0.1%) (Table 7). The highest abundance of amphibians species among habitats were recorded in grassland (73.26%), followed by wetlands (13.22%) and the lowest abundant species of amphibians were recorded in kopjes (1.45%) (Fig. 6). However, the variation of relative abundance among species and habitats was not statistically different (Kruskal-Wallis, H = 4.086; DF = 4; P > 0.05).

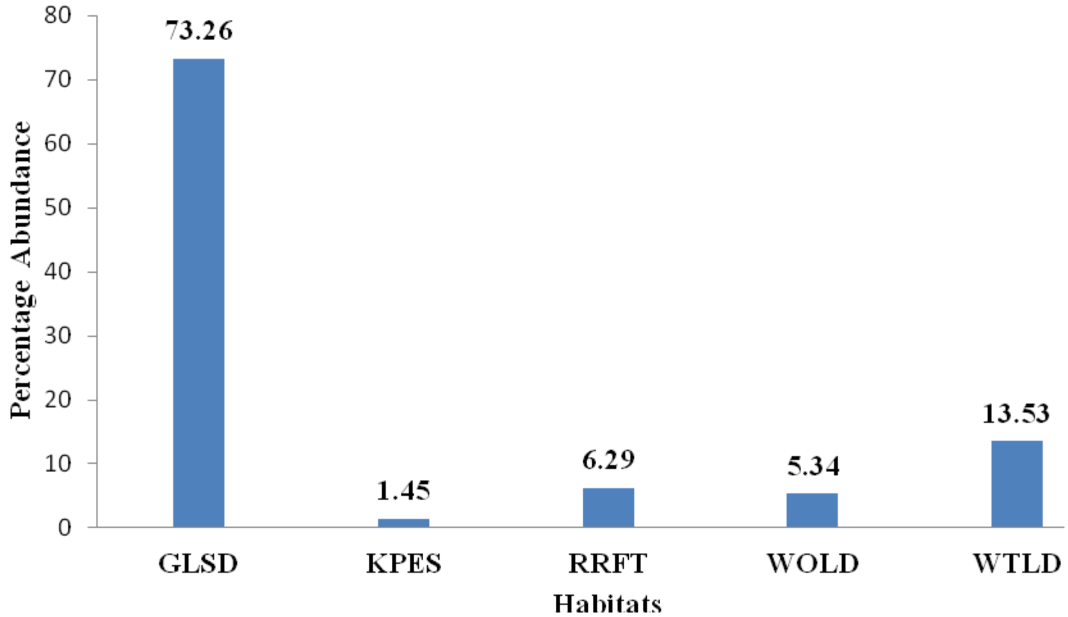

Figure 6: Relative abundance of Amphibian species by Habitats in SENAPA

4.2.2 Reptiles

A total of 603 individuals of reptiles (Appendix 5), were recorded during the study. Just as it was for the amphibians, the abundance differed among species and habitats (Table 8). For example, *Agama mwanzae* (30.18%) and *Crocodylus niloticus* (23.88%) were the most abundant species (Table 8). However, eleven species, *Adolfus jacksoni*, *Atractaspis bibronii*, *Elapsoidea loveridgei*, *Hemidactylus squamulatus*, *Heliobolus spekii*, *Lycophidion depressirostre*, *Lygodactylus gutturalis*, *Mabuya maculilabris*, *Teloscopus* *semiannulatus*, *Boiga pulverulenta* and *Hemirrhagerrhis nototaenia* were the least abundant species (0.16%) recorded (Table 8).

Table 8: Relative abundance of selected Reptiles species in SENAPA

		Habitats					
Families and species	N	GLSD	KPES	RRFT	WOLD	WTLD	Total %
Agamidae							
Agama mwanzae	182	-	30.18	-	-	-	30.18
Atractaspididae							
Atractaspis bibronii	1	-	0.16	-	-	-	0.16
Colubridae							
Boiga pulverulenta	1	-	-	-	0.16	-	0.16
Lycophidion depressirostre	1	-	-	-	0.16	-	0.16
Telescopic semiannulatus	1	-	0.16	-	-	-	0.16
Hemirhagerrhis nototaenia	1	-	-	-	0.16	-	0.16
Crocodylidae							
Crocodylus niloticus	144	-	-	-	-	23.88	23.88
Gekkonidae							
Hemidactylus squamulatus	1	-	0.16	-	-	-	0.16
Lygodactylus gutturalis	1	-	-	-	0.16	-	0.16
Scincidae							
Mabuya maculilabris	1	0.16	-	-	-	-	0.16
Elapidae							
Elapsoidea loveridgei	1	0.16		-	-	-	0.16
Lacertidae							
Adolfus jacksoni	1	-	-	0.16	-	-	0.16
Heliobolus spekii	1	0.16	-	-	-	-	0.16

Note: N = Number of individuals, GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland, WTLD = Wetland and - = Absence/not recorded

The highest relative abundance of reptiles species among habitats were recorded in kopjes (38.88%), followed by wetlands (28.33%) and the lowest abundant reptiles species were recorded in the riverine forest (2.3%) (Fig. 7). Not withstanding, the variation of relative abundance among species and habitats was not statistically different (Kruskal-Wallis, $H = 1.3$; $DF = 4$; $P > 0.05$).

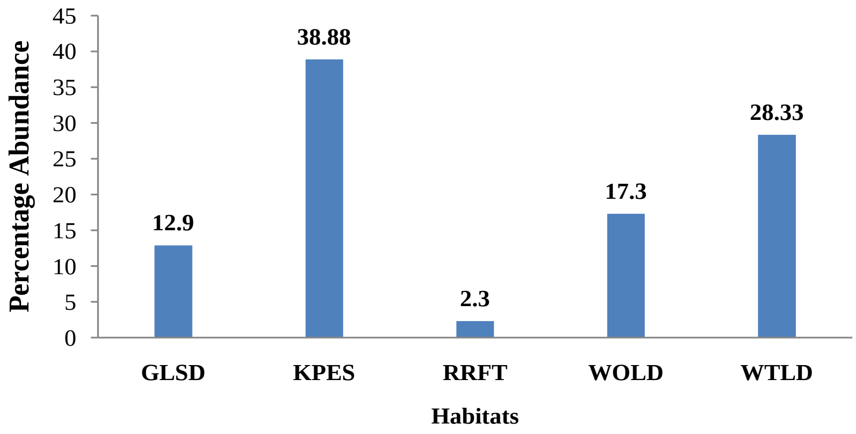

Figure 7: Relative abundance of Reptiles species by Habitats in SENAPA

4.3 Distribution of the Herpetofauna of SENAPA among Habitats

4.3.1 Amphibians

The distribution of amphibian species in SENAPA varies significantly among habitats ($Q = 12.91$; $DF = 4$; $P < 0.05$). For example, *Bufo gutturalis* and *Ptychadena anchietae* in the families Bufonidae and Ptychadenidae were widely distributed in all habitats. *Kassina senegalensis, Hyperolius goetzei, Hyperolius ferniquei, Xenopus muelleri, Ptychadena* sp, *Mertensophryne* sp, *Phrynobatrachus scheffleri, Chiromantis xerampelina, Chiromantis petersi, Hoplobatrachus occipitalis, Tomopterna turbeculosa* and *Tomopterna cryptotis* were the least widespread species in SENAPA confined to grassland, kopjes, riverine forest, and woodland (Table 9). Most species were recorded in grasslands (13 species; accounting for 68.42%), while the kopjes had the lowest species with only 4 species representing 21.05% of the species recorded (Appendix 6).

Table 9: Amphibia of SENAPA among Habitats

Family	Genera	Species
Amphibia of the Grassland		
Bufonidae	*Bufo*	*Bufo gutturalis*
	Mertensophryne	*Mertensophryne* sp
Hemisotidae	*Hemisus*	*Hemisus guineensis*
	Hemisus	*Hemisus marmoratus*
Hyperoliidae	*Kassina*	*Kassina senegalensis*
	Hyperolius	*Hyperolius ferniquei*
Pipidae	*Xenopus*	*Xenopus muelleri*
Ptychadenidae	*Ptychadena*	*Ptychadena anchietae*
	Ptychadena	*Ptychadena mossambica*
	Ptychadena	*Ptychadena mascareniensis*
	Ptychadena	*Ptychadena* sp
Phrynobatrachidae	*Phrynobatrachus*	*Phrynobatrachus scheffleri*
Rhacopholiridae	*Chiromantis*	*Chiromantis petersi*
Amphibia found in the Kopjes		
Bufonidae	*Bufo*	*Bufo gutturalis*
Hyperoliidae	*Hyperolius*	*Hyperolius goetzei*
Ptychadenidae	*Ptychadena*	*Ptychadena anchietae*
Pyxicephalidae	*Tomopterna*	*Tomopterna tuberculosa*
Amphibia found in the Woodland		
Bufonidae	*Bufo*	*Bufo gutturalis*
Hemisotidae	*Hemisus*	*Hemisus guineensis*
	Hemisus	*Hemisus marmoratus*
Ptychadenidae	*Ptychadena*	*Ptychadena anchietae*
Pyxicephalidae	*Tomopterna*	*Tomopterna cryptotis*
Rhacopholiridae	*Chiromantis*	*Chiromantis xerampelina*
Amphibia found in the Wetland		
Bufonidae	*Bufo*	*Bufo gutturalis*
Hemisotidae	*Hemisus*	*Hemisus guineensis*
	Hemisus	*Hemisus marmoratus*
Ptychadenidae	*Ptychadena*	*Ptychadena anchietae*
	Ptychadena	*Ptychadena mossambica*
	Ptychadena	*Ptychadena mascareniensis*
Phrynobatrachidae	*Phrynobatrachus*	*Phrynobatrachus natalensis*
Amphibia found in the Riverine Forest		
Bufonidae	*Bufo*	*Bufo gutturalis*
Hemisotidae	*Hemisus*	*Hemisus guineensis*
	Hemisus	*Hemisus marmoratus*
Ptychadenidae	*Ptychadena*	*Ptychadena anchietae*
	Ptychadena	*Ptychadena mascareniensis*
Phrynobatrachidae	*Phrynobatrachus*	*Phrynobatrachus natalensis*
	Phrynobatrachus	*Phrynobatrachus scheffleri*
Dicroglossidae	*Hoplobatrachus*	*Hoplobatrachus occipitalis*

4.3.2 Reptiles

The distribution of reptilian species varied significantly among habitats (Q = 20.39; DF = 4; P < 0.05). The only most widely distributed reptile species among habitats was *Valanus niloticus* species encountered in all habitats. On the contrary, *Agama mwanzae, Atractaspis bibronii, Boiga pulverulenta, Telescopus semionnulatus, Elapsoidea loverdgei, Hemidactylus squamalatus, Hemirhagerrhis nototaenia, Adolfus jacksoni, Mabuya maculilabris, Heliobolus spekii, Crocodylus niloticus, Hemidactylus mabouia, Typhlops* sp, *Lygodactylus capensis, Lygodactylus gutturalis, Lygosoma afrum, Lycophidion depressirostre, Dendroaspis polylepis, Meizodon semiornatus* and *Acanthocercus atricollis* were the least widespread species in SENAPA confined to kopjes, woodland, grassland, riverine forest and wetland (Table 10 and 11). Most species were recorded in woodlands (27 species; accounting for 61.36%), while the riverine forest had the lowest species with only 6 species representing 13.63% of the species recorded (Appendix 7).

Table 10: Reptiles of SENAPA found in Woodland, Riverine Forest and Wetland Habitats

Family	Genera	Species
Reptiles found in the Woodland		
Agamidae	*Acanthocercus*	*Acanthocercus attricollis*
Viperidae	*Causus*	*Causus resimus*
Chamaeleonidae	*Chamaeleo*	*Chamaeleo dilepis*
Colubridae	*Philothamnus*	*Philothamnus battersbyi*
	Philothamnus	*Philothamnus semivariegatus*
	Boiga	*Boiga pulverulenta*
	Dispholidus	*Dispholidus typus*
	Crotaphopeltis	*Crotaphopeltis hotamboeia*
	Hemirhagerrhis	*Hemirhagerrhis nototaenia*
	Psammophis	*Psammophis sundanensis*
	Lamprophis	*Lamprophis fuliginosus*
	Lycophidion	*Lycophidion depressirostre*
Elapidae	*Dendroaspis*	*Dendroaspis polylepis*
Gekkonidae	*Lygodactylus*	*Lygodactylus capensis*
	Lygodactylus	*Lygodactylus gutturalis*
	Hemidactylus	*Hemidactylus mabouia*
Gerrhosauridae	*Gerrhosaurus*	*Gerrhosaurus flavigularis*
Lacertidae	*Nucras*	*Nucras boulengeri*
Scincidae	*Lygosoma*	*Lygosoma sundevalli*
	Mabuya	*Mabuya brevicollis*
	Mabuya	*Maculilabris*
	Mabuya	*Mabuya striata*
	Panaspis	*Panaspis wahlbergii*
Pelomedusidae	*Pelomedusa*	*Pelomedusa subrufa*
Testudinidae	*Geochelone*	*Geochelone pardalis*
Typhlopidae	*Rhinotyphlops*	*Rhinotyphlops mucroso*
Varanidae	*Varanus*	*Varanus niloticus*
Reptiles found in the Riverine Forest		
Colubridae	*Lamprophis*	*Lamprophis fuliginosus*
Gekkonidae	*Lygodactylus*	*Lygodactylus capensis*
Lacertidae	*Nucras*	*Nucras boulengeri*
	Adolfus	*Adolfus jacksoni*
Scincidae	*Mabuya*	*Mabuya varia*
Varanidae	*Varanus*	*Varanus niloticus*
Reptiles found in the Wetland		
Colubridae	*Crotaphopeltis*	*Crotaphopeltis hotamboeia*
	Psammophis	*Psammophis sundanensis*
Elapidae	*Naja*	*Naja nigrocollis*
Scincidae	*Mabuya*	*Mabuya megalura*
Pelomedusidae	*Pelomedusa*	*Pelomedusa subrufa*
Testudinidae	*Geochelone*	*Geochelone pardalis*
Typhlopidae	*Typhlops*	*Typhlops lineolatus*
	Typhlops	*Typhlops* sp

Table 11: Reptiles of SENAPA found in Kopjes and Grassland Habitats

Family	Genera	Species
Reptiles found in the Kopjes		
Agamidae	*Agama*	*Agama mwanzae*
Atractaspididae	*Atractaspis*	*Atractaspis bibronii*
Viperidae	*Bitis*	*Bitis arientas*
Colubridae	*Philothamnus*	*Philothamnus battersbyi*
	Philothamnus	*Philothamnus semivariegatus*
	Telescopus	*Telescopus semiannulatus*
Elapidae	*Naja*	*Naja nigrocollis*
Gekkonidae	*Hemidactylus*	*Hemidactylus squamulatus*
Lacertidae	*Nucras*	*Nucras boulengeri*
Scincidae	*Mabuya*	*Mabuya varia*
	Mabuya	*Mabuya striata*
	Lygosoma	*Lygosoma sundevalli*
	Mabuya	*Mabuya megalura*
	Mabuya	*Mabuya maculilabris*
	Panaspis	*Panaspis wahlbergii*
	Lygosoma	*Lygosoma afrum*
Pelomedusidae	*Pelomedusa*	*Pelomedusa subrufa*
Testudinidae	*Geochelone*	*Geochelone pardalis*
Typhlopidae	*Typhlops*	*Typhlops lineolatus*
	Rhinotyphlops	*Rhinotyphlops mucroso*
Reptiles found in the Grassland		
Viperidae	*Bitis*	*Bitis arientas*
	Causus	*Causus resimus*
Chamaeleonidae	*Chamaeleo*	*Chamaeleo dilepis*
Colubridae	*Crotaphopeltis*	*Crotaphopeltis hotamboeia*
	Meizodon	*Meizodon semiornatus*
Elapidae	*Elapsoidea*	*Elapsoidea loveridgei*
Gerrhosauridae	*Gerrhosaurus*	*Gerrhosaurus flavigularis*
Lacertidae	*Nucras*	*Nucras boulengeri*
	Heliobolus	*Heliobolus spekii*
Scincidae	*Mabuya*	*Mabuya striata*
	Mabuya	*Mabuya megalura*
	Mabuya	*Mabuya maculilabris*
	Lygosoma	*Lygosoma sundevalli*
Pelomedusidae	*Pelomedusa*	*Pelomedusa subrufa*
Testudinidae	*Geochelone*	*Geochelone pardalis*
Typhlopidae	*Typhlops*	*Typhlops* sp
Varanidae	*Varanus*	*Varanus niloticus*

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Herpetofauna Species Richness and Diversity

Tanzania is a mega herpetofauna country with diverse habitats including montane rain forest, afro-alpine moorland, riparian forest, grasslands, woodland and semi-arid wooded savannah. About 178 species of amphibians (IUCN, 2012) and over 275 reptile species (Razzetti and Msuya, 2002) have been recorded in the country, and of these 78 amphibians are endemic while 50 species are threatened with extinction (IUCN, 2012). Channing *et al*. (2004) reported the existence of 27 species of amphibians in SENAPA. However, the current study recorded 36 species of amphibians and 48 species of reptiles living in different habitats of the park. Comparison of previous and current study of reptiles in SENAPA is constrained by the paucity of data. Systematic studies of reptiles in SENAPA have been far fewer (Sinclair, 1995).

5.1.1 Amphibians

The species richness and diversity of amphibians differed among habitats. Grasslands supported higher amphibian species richness, probably due to the presence of different micro habitats such as pools, ponds, swamps, pans, tall and short grasses, herbs and open ground, which support different species ecological requirements e.g. breeding sites. All these micro habitats favoured the occurrence of most amphibians (e.g. *Hemisus guineensis* and *Kassina senegalensis*). Seasonality also attributed to high species richness of amphibians in the grassland habitats. To illustrate this, Channing and Howell, 2006; and Spawls *et al*., 2006 argued that the breeding season of these species is during short rains in shallow temporariry ponds. Biologically, most amphibians breed during early rains. The fact that this study was undertaken during early rainy season highlights that amphibians were all over due to the presence of ponds (breeding sites) and abundant food as the main reasons of encountering their higher species richness in the grassland habitats. A study by Brotherton *et al.* (2004) found that most amphibians migrate from wetland habitat to bogs, open ponds, road sides, grassland and woodland for breeding, foraging and hibernation. Also, many studies (Msuya *et al*., 2004; Spawls *et al*., 2006; Rödel *et al*., 2009; IUCN SSC Amphibian Specialist Group, 2013) have reported that most recorded amphibians (e.g. *Bufo gutturalis, Hemisus marmoratus, H. guineensis, Ptychadena* sp and *Phrynobatrachus* sp) are widely distributed and found in savannah, grassland and woodlands habitats.

The low species richness and diversity of amphibians in kopjes was attributed probably by lack of suitable microhabitats (e.g. ponds) as kopjes are made of rock outcrops. Though kopjes are known to support unique fauna (Sinclair and Arcese, 1995), it is obvious that these fauna are not water dependant. For example Drewes (1997) recorded one species of tree frog (*Hyperolius orkarkarri*) that was exposed in full sunlight. Elsewhere in Africa, other species of tree frog such as *Hyperolius horstocki* of South Africa are known to rest in exposed position in sunlight (Wager, 1965 as cited by Drewes, 1997). Due to its uniqueness and rich vegetation composition (Anderson and Talbot, 1965) probably the kopjes support more tree frogs (e.g *Hyperolius* sp and *Leptopelis* sp).

However, many species were not encountered in the kopjes for this study despite the active searching efforts made. The absence of water ponds in kopjes likely affected food availability, feeding and breeding sites and hence low species richness and diversity of most water dependant amphibians such as *Xenopus* sp. Other researchers have also reported low species richness of amphibians in rock outcrops/kopjes. For example, Rakotondravony and Goodman (2011) recorded only four species of amphibians across five rock areas in Madagascar. Likewise, Karunarathna *et al*. (2008) reported only two amphibian species in rock outcrops, being lowest species richness of amphibians compared to other habitats in the Nilgala Forest Area and its vicinity, Monaragala District in Sri Lanka. Karunarathna *et al*. (2006) also pointed out that rock outcrops/kopjes are xeric due to direct sun exposure and are not suitable habitats for amphibians.

The seventeen amphibian species known to exist in SENAPA (Channing *et. al.,* 2004; Elzen and Kreulen, 1979) were not encountered during this study. However, this study recorded six new unreported amphibians for SENAPA (Plate 2). Discovering new unreported amphibian species and failure to encounter the 17 species reported in previous studies was probably attributed to different sampling techniques, area covered, elusive and cryptic behaviour of amphibians. For instance, Channing *et al*. (2004) employed sampling of tadpoles and advertisement calls as a sampling technique to establish baseline information on amphibians of Serengeti and the study was extended beyond park boundaries. Drewes (1997) encountered *Hyperolius orkarkarri* which has specific habitat requirement (rock dweller) and cryptic appearance that make detection difficult. Specific ecological habitat requirement and cryptic appearance probably are the reasons which made detection of this species difficult though Gong rock kopjes were also surveyed during this study.

a) *Hemisus guineensis*

b) *Mentensophryne* sp

c) *Tomopterna cryptotis*

d) *Tomopterna turbeculosa*

e) *Phrynobantrachus scheffleri*

f) *Chiromantis xerampelina*

Plate 2: New records of Amphibians to SENAPA

The six recorded species are not new species to science but rather new records to SENAPA. The six new amphibian species to the park were captured in drift fence with pitfall traps (four species) and active search sampling technique (two species). This justifies the need of using combined methods to establish species richness, diversity and abundance of amphibians in an area. Pitfall and drift fence traps and active search methods were not used by Channing *et al*. (2004), and Elzen and Kreulen (1979) during their study; probably that is why they could not find some species with cryptic behaviour. These species include *H. guineensis* and *Tomopterna* species which are fossorial and remain hidden for most time of the year (Spawls *et al*., 2006; Le Roux, 2010). What is important again is that, the newly recorded species showed different habitat preference as they were found in grassland, riverine forest and woodland habitats.

Although the grassland habitat had higher species richness (13 species) it had low value of diversity than riverine forest. This was mostly influenced by the higher number of *Ptychadena mossambica* which accounted for 45.48% of all individuals recorded. On the contrary, the riverine forest had the highest amphibian species diversity than other habitats presumably due to its difference in microclimate and microhabitats provided by different life forms of vegetation (herbaceous and woody). The riverine forest met ecological life requirements of most amphibians as these areas had moister environment most of the time, even if there was no rain, compared to other habitats (personal observation). Menegon *et al*. (2008) also found higher species in forest than any other habitat in Nguru Mountain. The literature reveals that amphibian species *B. gutturalis*, *H. guineensis*, *H. marmoratus*, *Ptychadena anchietae* and *Ptychadena masacariensis* prefer open woodland, grassland and savannah habitats and they can occur in very dry conditions (Channing and Howell, 2006; Spawls *et al*., 2006). These species admittedly occupied riverine forest during drier period to avoid desiccation. Then, the occurrence of

Phrynobatrachus scheffleri (Plate 2) and *Hoplobatrachus occipitalis* in the riverine forest is due to the preference of moist habitats (Spawls *et al*., 2006; Harper *et al*., 2010).

5.1.2 Reptiles

Woodland had both higher reptile species richness and diversity than other habitats. The presence of micro habitats such as foliage, tree trunks and branches, stones, open ground, termite mounds and tree crevices probably are the factors which favoured both high species richness and diversity of reptiles in the woodland habitat. This conforms to the study by Janzen (1979) who reported that macrotermes and odontotermes mounds provide dens for reptiles. In addition, the presence of large mammals in woodland is another factor which probably contributed to high species richness in woodlands. This is in line with Janzen (1979) who reported that carrions stored under water by hyenas provide food for Helmeted Terrapin (*Pelomedusa subrufa*) and skull leftovers provide hiding places for lizards and snakes.

Species specific life forms also contributed to high species richness. Species of reptiles observed in the woodland were adapted to different life forms. Some species were seen living in terrestrial habitats (e.g. *Geochelone pardalis* and *Causus resimus*), arboreal habitats (e.g. *Philothamnus battersbyi* and *Dispholidus typus*), fossorial habitats (e.g. *Attractaspis bibronii*) and some species were noted to be generalist (e.g. *Mabuya striata* and *Dendroaspis polylepis*). The family Colubridae has most species recorded in woodland and this probably was attributed to species adaptation to different life forms (e.g. terrestrial, arboreal and semi arboreal) and the dominance of the family to the member of living reptiles. According to Uetz (2000), 25% of reptiles belong to the family Colubridae snakes, and this might be the reason of encountering more snakes in SENAPA. During the study 19 snake species were recorded, which is higher species diversity than what Bateman *et al*. (2009) recorded along the middle Rio Grande Riparian Forest in Mexico.

Kopjes also had higher species richness of reptiles and this was attributed by its heterogeneity in micro habitats, shelter, abundance and a variety of preys. According to Sinclair (1975), kopjes have higher abundance of grasshoppers, other invertebrates and small mammals which are the main food for most reptile species (Plate 3). For instance, Timbuka and Kabigumila (2006) recorded 18 species of small mammals in kopjes. Most reptiles are carnivores, so the presence or absence of grasshoppers, invertebrates and small mammals can affect species richness, diversity, abundance and distribution of reptiles. Infrequent fire in kopjes is another factor which probably attributed higher diversity of reptile species. This is supported by SENAPA-GMP (2006) that kopjes are fire resistant and fire poses low threats to the biodiversity in kopjes habitats.

Plate 3: *Agama mwanzae* feeding on grasshopper

This study found that the riverine forest had the lowest species richness of reptiles, while wetlands had the lowest species diversity. The mostly encountered species in the wetlands was the crocodile (*Crocodylus niloticus*). The low species richness and diversity of these areas is probably attributed to the frequent overflow of Grumeti River (Plate 4) and Kitunge Wetland which affect micro climate, roosting and feeding grounds for most reptiles species in the area. The effect of flooding on species richness and diversity of herpetofauna was also noted in Kitobo Forest of Kenya by Malonza *et al*. (2011). The absence of open ground in the riverine forest may also have affected the low abundance of reptiles due to lack of basking sites. Malonza *et al*. (2011) found high species richness of reptiles in the forest edge than in the forest due to the presence of basking sites for reptiles. However, Laurencio and Malone (2009) argued that the diversity of reptiles among sites can be influenced by factors like changes in climate, vegetation, temporal and seasonal bias of data collection.

Plate 4: Overflow of the Grumeti River

Season bias may be true because during this study some species of reptiles known to exist in SENAPA such as Bell's hinged tortoise (*Kinixys belliana*) were not encountered. In addition, failure to encounter this tortoise (*Kinixys belliana*) may have been attributed by its small home range and its cryptic behaviour. Likewise, Bertram (1979a) found that *Kinixys belliana* has a specified smallest home range of 1.86 hectares, spending 84% of time within an area of 0.24 hectares.

Compared to other areas in Tanzania such as Arusha National Park, Udzungwa Scarp Forest Reserve and Nguru mountains, SENAPA is among the richest area in terms of species composition of amphibians and reptiles. To illustrate this argument, Razzeti and Msuya (2002) recorded 10 species of amphibians and 24 species of reptiles in Arusha National Park. On their side, Menegon and Salvidio (2005) recorded 33 species of amphibians and 36 species of reptiles in Udzungwa Scarp Forest Reserve.

Moreover, Menegon *et al*. (2008) recorded 41 species of amphibians and 51 reptile species in Nguru Mountains. Elsewhere in Africa, a similar trend of species richness has also been reported. A good example is the 15 species of amphibians and 34 species of reptiles which were recorded by Durkin *et al*. (2011) in forest fragments between the Montagne d'Ambre National Park and Ankara Special Reserve, Northern Madagascar. All these areas are known in terms of their high biodiversity and endemic species in ecosystem. Again, 94% of these species are endemic to the area, supporting the argument by IUCN (2013) that Madagascar is a country with higher species of endemism compared to other areas in Africa.

5.2 Abundance of Herpetofauna species in SENAPA

5.2.1 Amphibians

Ptychadena mossambica was the most abundant amphibian species recorded and most individuals were encountered in grasslands. Its dominance is probably attributed to its preferred habitats, breeding biology (explosive breeders) and its tolerance to harsh conditions. According to Channing and Howell (2006), *P. mossambica* lives in dry savannah, bush land and grassland areas, but it can occupy moist humid savannah and tropical forest. The breeding biology of *P. mossambica* also favoured its abundance in SENAPA. *P. mossambica* is regarded as abundant species with large breeding assemblage and it breeds in temporary and semi-permanent water, pans, dams and inundated grassland. The eggs of *P. mossambica* develop very quickly and it is estimated that a single female can lay up to 315 eggs (IUCN, 2013).

Other abundant amphibian species included *Ptychadena mascareniensis* (Plate 5) and *Hemisus marmoratus*, which are known to be generalist feeders, abundant, wide spread, and adaptable species and can tolerate a broad range of habitats. According to Channing and Howell (2006), *P. mascareniensis* is found along streams and in temporary and permanent water. It can also tolerate habitats (agricultural area or rice fields) exposed to severe pressure from human disturbance (IUCN, 2013). *P. mascareniensis* is also a generalist species that feeds on beetles, grasshoppers, ants and other invertebrates (Fatroandrianjafinonjasololiaovazo *et al*., 2011). All these preys might have accounted for the abundance of *P. mascareniensis* in SENAPA. The abundance of *H. marmoratus* was presumably attributed to their fossorial habit which enables it to escape predators and avoid feeding competition. *H. marmoratus* are thought to forage underground and they feed mainly on termites (Harper *et al*., 2010). Enabulele and Aisien (2012) indicated that members of the order Isoptera and Hymenoptera are the most preferred preys for *H.*

marmoratus. Breeding biology and parental care at young stage are also likely to favour the abundance of *H. marmoratus*. A female lays 150 – 200 eggs in an underground chamber, and protects the eggs against predators until they hatch (Harper *et al*., 2010; Le Roux, 2010).

Plate 5: *Ptychadena mascareniensis*

Six other species of amphibians were the least abundant in SENAPA. These are *Hyperolius ferniquei*, *Hyperolius goetzei*, *Xenopus muelleri*, *Mertensophryne* sp, *Hoplobatrachus occipitalis* and *Chiromantis petersi.* However, the literature reveals that *H. ferniquei*, *H. goetzei* and *X. muelleri* species are abundant and widely distributed (IUCN, 2013). Probably these species were less encountered due to their specific ecological habitat requirement, cryptic habit and reduced activity pattern. For example, *X. muelleri* (Plate 6) spends most of its time in water and is adapted to aquatic life (Channing and Howell, 2006; Spawls *et al*., 2006). *H. occipitalis* is reported to be decreasing in population (Rödel *et al*., 2004) and its population status in SENAPA is unknown.

Plate 6: ***Xenopus muelleri***

The highest abundance of amphibian species in grassland habitats were probably attributed by the time of the study (during the rainy season), which favour the distribution of resources (food and breeding pools), moist and humid environment for most amphibian species. In addition, most species recorded in grassland showed preference of grassland areas and other species were noted to be typical grassland inhabitants e.g. *H. guineensis* (Channing and Howell, 2006).

5.2.2 Reptiles

The data show that *Agama mwanzae* and *Crocodylus niloticus* were the most abundant reptile species confined to kopjes and riverine habitats. *A. mwanzae* is an endemic species to East Africa, and its dominance may be explained by diurnal activity patterns and social habits. *A. mwanzae* live in structured colonies of 20 or more individuals on rocks, cliffs and hills, or on small patches of rock sheet with fissures to hide (Spawls *et al*., 2004; Spawls *et al*., 2006).

This lizard was also observed in association with other lizards such as *Mabuya varia* and *Mabuya striata*. Living in social groups provides benefits to *A. mwanzae* such as thermoregulation at night and decreased predation risk (Menegon and Spawls, 2010). Furthermore, Razzetti and Msuya (2002) argued that *A. mwanzae* is regarded as the most adaptable, tolerant and common in human modified habitats such as bridges and buildings. This factor probably accounts for its abundance in other areas without rock outcrops. On its part, *Crocodylus niloticus* (Plate 7) abundance might be related to abundant food (zebras and wildebeest) and reduced human disturbance in the park. Furthermore viable population of *C. niloticus* are known to exist in most protected areas (Branch, 2005). Moreover, eleven species were the least abundant species of reptiles encountered in SENAPA. These were *Adolfus jacksoni*, *Atractaspis bibronii*, *Elapsoidea loveridgei*, *Hemidactylus squamulatus*, *Heliobolus spekii*, *Lycophidion depressirostre*, *Lygodactylus gutturalis*, *Mabuya maculilabris*, *Telescopus semiannulatus*, *Boiga pulverulenta* and *Hemirrhagerrhis nototaenia*. Msuya (2003) reported that reptile abundance and activity pattern increases during early rains as they respond to the abundance of their food.

Plate 7: *Crocodylus niloticus*

This justifies that the season when this study was conducted (i.e. during the rainy season) may not be the factor that affected the abundance of the aforementioned species. It is therefore likely that cryptic, nocturnal and fossorial behaviours are the factors that affected the poor encounter of these species. Good examples are the *Atractaspis bibronii* (Plate 8) and *Elapsoidea loveridgei* which are fossorial and nocturnal species feeding on other burrowing reptiles, frogs and rodents. This life style reduces activity patterns of these species as most of their requirements are obtained underground; thus making their detection difficult. *A. bibronii* and *E. loveridgei* are known to emerge and move on the surface looking for preys and mates following the onset of rains (Spawls *et al*., 2004; Spawls *et al*., 2006).

Plate 8: *Atractaspis bibronii,* a fossorial and nocturnal snake

5.3 Distribution of Herpetofauna of SENAPA

5.3.1 Amphibians

Most of amphibian species were not widely distributed; with the exception of a few species that had individuals' representatives in all habitats. *Bufo gutturallis*, *Ptychadena anchietae*, *Hemisus marmoratus* and *Hemisus guineensis* are amphibian species that showed wide distribution in the study habitats. Though *Ptychadena mossambica* was noted to be most abundant amphibian species it was not widely distributed among habitats. Instead, it was only found and recorded in two habitats (grassland and wetland) and this is possibly due to its preference in open savannah than other habitats (Channing and Howell, 2006).

The widespread of *B. gutturallis* (Plate 9), *P. anchietae* (Plate 10), *H. marmoratus* and *H. guineensis* (Plate 11) probably was attributed to the presence of their suitable habitat and breeding ponds and pools. The literature (Harper *et al*., 2010; Channing and Howell, 2006 and Spawls *et al*., 2006) reported on these species in savannah, grassland and open woodland. As for *B. gutturalis,* it tolerates disturbance and feeds on a variety of invertebrates and small sized amphibians (Harper *et al*., 2010). The occurrence of *H. marmoratus* and *H. guineensis* in woodland, grassland, riverine forest and wetland justifies that these species coexist and occupy various habitats (Plate 11). *H. marmoratus* and *H. guineensis* were only found in western side of the park and not on the same habitat in the southern part of the park. Probably their distributions are influenced by the rainfall pattern which is higher on the west (800 mm) and lower in the southern zone (500 mm) (Norton-Griffiths *et al*., 1975). Channing *et al*. (2006) recorded occurrences of *H. marmoratus* in central woodland of SENAPA, the area that have relatively the same mean annual rainfall with the western side.

Other researchers recorded only *H. marmoratus* and showed that the species is widely spread and occurs in different habitats (Gardener *et al*., 2007: Razzetti and Msuya, 2002). Moreover Gardner *et al*. (2007) recorded *H. marmoratus* in riverine, woodland, mbuga and cultivated soil habitats whereas Razzetti and Msuya (2002) recorded it in grassland, wooded areas and reported swamps, ponds and blackish water lakes as the preferred habitats. In contrast, this study recorded *H. marmoratus* and *H. guineensis* coexisting in most of the habitats though *H. marmoratus* were more abundant than *H. guineensis*. The finding of this study concurs with Spawls *et al*. (2006), who reported that *H. marmoratus* and *H. guineensis* can occur together in some habitats. Le Roux (2010) also recorded both *H. marmoratus* and *H. guineensis* in Okavango Delta.

Plate 9: ***Buffo gutturalis***

Plate 10: ***Ptychadena anchietae* and eggs on the right hand side**

Plate 11: **Co-occurrence of *Hemisus marmoratus* and *Hemisus guineensis***

Twelve species were least distributed amphibians in SENAPA. These are *Chiromantis xerampelina*, *Chiromantis petersi*, *Phrynobatrachus scheffleri*, *Tomopterna tuberculosa*, *Tomopterna cryptotis*, *Hoplobatrachus occipitalis*, *Xenopus muelleri*, *Ptychadena* sp, *Kassina senegalensis*, *Mertensophryne* sp, *Hyperolius goetzei* and *Hyperolius ferniquei.* Though the 12 amphibian species were not recorded in all study habitats, they have a wide range of distribution. The literature (e.g. Harper *et al*., 2010 and Spawls *et al*., 2006) indicates that most of the species recorded in this study ranged from woodland to savannah. For instance, Razzetti and Msuya (2002) found *K. senegalensis* in forest and grassland while *P. mascareniensis* was recorded in grassland, woodland and forest. Nevertheless, in this study *K. senegalensis* (Plate 12) was recorded only in grassland while *P. mascariniensis* was not recorded in woodland habitat. Fewer occurrences of these species in other habitats were probably attributed to their elusive, cryptic behaviour and fluctuation of weather condition which affect activity patterns of amphibia. *C. xerampelina* for example was observed twice in different locations occupying micro habitats (sign post and tree trunk) for more than two days without moving to another area. Again, *C. xerampelina* has been reported to be explosive breeder and only depends on water for breeding purpose (Le Roux, 2010). The species is also arboreal and spends most of the time in shelter in trees (*Ibid*.). Due to the elusive behaviour some species were not found as it was not easy to spot all of them.

Furthermore, the occurrence of *Mertensophryne* sp in grasslands as a new record for SENAPA indicates that members of the genus have a wider geographical range than what was reported earlier. Other researchers have reported *Mertensophryne micranotis* as endemic species to Eastern African Lowland Forest and Transitional Lowland-Afromontane Forest of Coastal Region (Spawls *et al*., 2006; Poynton, 1991). Menegon, (2006) as cited by Mahale Mountain National Park (MMNP), (undated) reported the occurrence of *Mertensophryne taitanus* in MMNP, and this justifies that the genus has a wider geographical range. However, *Mertensophryne* sp was not found in other habitats of SENAPA probably because their preferred microhabitat was not adequately investigated.

Plate 12: *Kassina senegalensis*

5.3.2 Reptiles

Reptile distributions indicate that *Varanus niloticus* was the most widely distributed species with occurrence in all habitats. Notwithstanding, *Geochelone pardalis*, *Pelomedusa subrufa*, *Nucras boulengeri* and *Lygosoma sundevalli* were also widely distributed among habitats with occurrence in four habitats out of five. *Agama mwanzae*, *Acanthocercus atricollis*, *Atractaspis bibronii*, *Boiga pulverulenta*, *Meizodon semiornatus*, *Teloscopus semionnulatus*, *Dendroaspis polylepis*, *Elapsoidea loverdgei*, *Hemidactylus squamulatus*, *Hemidactylus mabouia*, *Lygodactylus capensis*, *Lygodactylus gutturalis*, *Lygodactylus afrum*, *Hemirrhagerrhis notaenia*, *Adolfus jacksoni* and *Typhlops punctatus* were the least widespread species. Specific habitat and food requirements may have affected the distribution of these species. Branch (2005) reported that reptiles have only limited mobility and most of them have specific habitat requirements. One example of this is *A. mwanzae* (rock dweller) which was recorded only in areas where there are rock outcrops or kopjes since it utilises rock fissures as a nesting site. Spawls *et al.* (2006) noted that *A. mwanzae* lays eggs in rock fissures or holes. The same fissures are used as retreating ground to escape predators (personal observation). Branch (2005) argued that *A. mwanzae* also shares fissures with other lizards e.g. *Mabuya striata*. It was further observed in this study that *A. mwanzae* utilises rock outcrops as basking and hunting ground, prey are easily spotted from rocks (Plate 13). Another example is *A. atricollis* (arboreal) which was recorded only in woodland or areas with scattered trees.

Plate 13: A colony of *Agama mwanzae* on the kopjes

The distribution of *Causus resimus* (Plate 14) and *Crotaphopeltis hotamboeia* seems to be influenced by food availability. These species were captured mostly in pond areas, and they were seen twice feeding on frogs. Micro habitats and food availability support higher species and distribution of reptiles in SENAPA. Reptile species recorded showed differences in food preference. For example Tiger snake (*T. semiannulatus*) was observed feeding on swallow whereas Battersby's Green Snake (*Philothamnus battersbyi*) was seen hunting and feeding on Blue-headed Tree Agama (*A. atricollis*). However, *T. semiannulatus* and *P. battersbyi* were only recorded in woodlands as their prey species (swallow and *A. attricollis*) are confined to this habitat and they can be easily hunted.

The occurrence of *A. jacksoni* in the riverine forest is an indication that the species is likely in existence in SENAPA for some years and probably it reached in the area from Maasai Mara National Reserve (MMNR) Kenya where it is known to occur (Spawls *et al*., 2004). Of course, SENAPA and MMNR together form the famous Serengeti-Mara ecosystem and they share common topographical characteristics, so it is not surprising for *A. jacksoni* to occur in SENAPA. This species was recorded in the western side of the park, and probably it is widespread in the northern area of the park which borders MMNR. The northern SENAPA was not surveyed, and this is presumably the reason for failure to record the occurrence of *A. jacksoni* in other habitats. In other areas of Tanzania *A. jacksoni* (Plate 15) has been reported to occur in north-east Bukoba District and north on Kilimanjaro and Meru Mountains (Spawls *et al*., 2004).

Plate 14: *Causus resimus* feeding on *Hemisus marmoratus*

The wide distribution of *Varanus niloticus* was probably attributed to its adaptation to different life forms and feeding habits. Spawls *et al*. (2004) reported that *V. niloticus* is active in both water and ground. The species also utilises different micro habitats (trees, logs and termite mounds) searching for food and suitable basking grounds (Plate 16). The presence of a variety of food also favours the distribution of *V. niloticus*. The species feeds on frogs, fish, lizards, birds, crocodiles and eggs (Spawls *et al*., 2004) that are widely distributed in SENAPA.

Plate 15: *Adolfus jacksoni*

Plate 16: ***Varanus niloticus*** **resting on the kopjes**

The diversity, distribution and abundance of amphibians and reptiles are also likely to be affected by the high abundance of migratory ungulates (wildebeest and zebras). In the grasslands a number of amphibians of different species were found dead as they were trampled by wildebeests and zebras (personal observation). It was also observed in this study that *Ptychadena* sp was hunting flies in a difficult environment following the reduction of cover by trampling effect of migratory ungulates. This is in line with Janzen's observation (1979) that the presence of migratory animals in the Serengeti plains affects the abundance and distribution of reptiles through enhancing competition for food and reduction of herbaceous cover through direct trampling.

5.4 Threats to Herpetofauna of SENAPA

Though conservation, photographic tourism and research are the only human activities permitted in SENAPA (URT, 2002), fire and infrastructure development were identified as potential threats to herpetofauna during this study. Fire and infrastructure development are likely to have an adverse impact on herpetofauna species diversity abundance and distribution. Tourism business in SENAPA is on increase and this goes hand in hand with increasing infrastructure development (SENAPA-GMP, 2006). The improper placement of infrastructure is likely to fragment habitats of amphibians and reptiles hence contributing to less dispersion, abundance and diversity through increased road kills. For example, in this study *Pelomedusa subrufa* (Plate 17), *Chamaeleo dilepis* and *Lamprophis fuliginosus* are reptile species found knocked over by vehicles in various roads while migrating to different habitats. Though amphibians were not recorded knocked by vehicles, they are also victims of traffic kills. To supplement this, Cicort-Lucaciu (2012) recorded 64 individuals and five species of amphibians being killed by vehicles in Carei Plains Natural Protected Area, Romania.

Furthermore, the use of fire as a management tool is also likely to cause a severe impact on the diversity, abundance and distribution of herpetofauna through the removal of microhabitats e.g. rotten logs. This study observed that *Dispholidus typus* (Plate 18) abandoned its favourite habitat because of the fire lightened during early burning.

Plate 17: ***Pelomedusa subrufa*** **knocked over by a vehicle**

Plate 18: ***Dispholidus typus*** **abandoning its favourite habitat**

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

SENAPA has a diverse number of herpetofauna. Thirty six species of amphibians have been reported to exist in SENAPA. In addition, six amphibian species; namely *Hemisus guineensis*, *Mertensophryne* sp, *Tomopterna cryptotis, Tomopterna tuberculosa*, *Phrynobatrachus scheffleri* and *Chiromantis xerampelina* have been found to exisit in the area. As such these species are going to be reported to SENAPA for the first time to add to the checklist of the available amphibian species in the area. The amphibian species diversity was higher in riverine while species richness was higher in grassland. Again, the grassland ranked the highest in abundance of amphibian species and kopjes ranked the lowest. Unlike other habitats, kopjes had both lowest species diversity and richness for amphibian species. Additionally, Hyperoliidae and Ptychadenidae was noted to be the most diverse and dominant families in SENAPA. The abundance of amphibians differed among species and habitats. *Ptychadena mossambica* was the most abundant species.

Forty eight species of reptiles are reported to exist in SENAPA. The woodland showed higher species richness and diversity of reptiles. However, the lowest species richness of reptiles was recorded in the riverine forest while wetland had lower species diversity. Colubridae with 11 species distributed in 10 genera was the most diverse reptile family. The abundance of reptiles differed among species and habitats. *Agama mwanzae* was the most abundant species in kopjes habitats. Kopjes ranked the highest in the abundance of reptile species whereas the riverine forest ranked the lowest.

The six amphibian species reported for the first time to SENAPA indicates that the inventory of herpetofauna in SENAPA is incomplete. More species of herpetofauna are expected as the study was undertaken during early rainy season when resources (e.g. food) were widely distributed. However, the species diversity, abundance and distribution are a temporal and spatial phenomenon.

The diverse species richness of herpetofauna in SENAPA is attributed to habitat heterogeneity which allows species to occupy different habitat type to meet basic species ecological needs e.g. breeding ponds. Differences in species richness, diversity, abundance and distribution among habitats are mainly influenced by different species requirements such as change in climatic condition, life forms, feeding habits, food availability and presence of microhabitats in SENAPA.

Although no human activity (e.g. agriculture, settlement or livestock keeping) is allowed in SENAPA, the use of fire as a management tool and increase in construction for photographic tourism facilities are factors likely to cause an adverse impact upon the diversity, abundance and distribution of herpetofauna species.

This study has come up with findings that are in line with other previous studies done by other researchers. Good examples are the Menegon and Salvido (2005); Menegon *et al*. (2008) and Durkin *et al*. (2011).

Conclusively, the study serves as a baseline data for similar future studies in and outside Serengeti and Tanzania at large, notably on the distribution, abundance and diversity of herpetofauna.

6.2 Recommendations

i. The following are recommendations for enrichment of the checklist and information of the herpetofauna of Serengeti National Park.

ii. First, future studies should focus on early, long rains and dry season to come up with a complete species diversity, abundance and distribution of herpetofauna found in SENAPA.

iii. Second, the different species of amphibians and reptiles have shown different habitat requirements. Grasslands, kopjes, woodlands, wetlands and riverine forests habitats of SENAPA have to be conserved equally as each habitat supports unique species which are not found in other habitats.

iv. Further, the park management should undertake an environmental impact assessment to determine the impact of infrastructure and tourism facilities development on the diversity, abundance and distribution of herpetofauna before the commencement of the projects and suggest appropriate measures to reduce the impact.

v. Finally, the park management should take into consideration the impacts of the prescribed fire to herpetofauna before starting burning every year.

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APPENDICES

Appendix 1: A Checklist of Amphibians of Serengeti National Park

Scientific Name	Common name	Order	Family
*Afrixalus quadrivittatus***	Four-Lined Spiny Reed Frog**	Anura	Hyperoliidae
*Amnirana galamensis***	Galam White-Lipped Frog**	Anura	Ranidae
Bufo gutturalis	Guttural Toad	Anura	Bufonidae
*Bufo taitanus***	Taita Toad**	Anura	Bufonidae
Cacosternum sp**	Plimton's Dainty Frog**	Anura	Pyxicephalidae
Chiromantis petersi	Peter's Foam-Nesting Frog**	Anura	Rhacophoridae
*Chiromantis xerampelina**	Southern Foam-Nest Frog	Anura	Rhacophoridae
*Hemisus guineensis**	Guinea Snout-Burrower	Anura	Hemisotidae
Hemisus marmoratus	Marbled Snout-Burrower	Anura	Hemisotidae
Hoplobatrachus occipitalis	Eastern Groove-crowned Bullfrog	Anura	Dicroglossidae
*Hyperolius acuticeps***	Sharp-Nosed Reed Frog**	Anura	Hyperoliidae
Hyperolius ferniquei	Reed Frog	Anura	Hyperoliidae
Hyperolius goetzei	Reed Frog	Anura	Hyperoliidae
*Hyperolius orkarkarri***	Maasai Reed Frog	Anura	Hyperoliidae
Kassina senegalensis	Senegal Kassina	Anura	Hyperoliidae
*Leptopelis bocagii***	Bocage's Tree Frog**	Anura	Arthroleptidae
Mertensophryne sp*	Woodland Toad	Anura	Bufonidae
*Phrynobatrachus bullans***	Bubbling Puddle Frog**	Anura	Phrynobatrachidae
*Phrynobatrachus mababiensis***	Mababe Puddle Frog**	Anura	Phrynobatrachidae
*Phrynobatrachus natalensis***	Natal Puddle Frog**	Anura	Phrynobatrachidae
*Phrynobatrachus scheffleri**	Scheffler's Puddle Frog	Anura	Phrynobatrachidae
*Phrynomantis bifasciatus***	Banded Rubber Frog**	Anura	Microhylidae
Ptychadena anchietae	Anchieta's Ridged Frog	Anura	Ptychadenidae
*Ptychadena chrysogaster***	Golden-throated Rocket Frog	Anura	Ptychadenidae
Ptychadena mascareniensis	Mascarine Rocket Frog	Anura	Ptychadenidae
Ptychadena mossambica	Mozambique Ridged Frog**	Anura	Ptychadenidae
*Ptychadena oxyrhynchus***	Sharp-nosed Rocket Frog	Anura	Ptychadenidae
*Ptychadena schillukorum***	Schilluk Ridged Frog**	Anura	Ptychadenidae
*Ptychadena stenocephala***	Narrow-headed Ridged Frog**	Anura	Ptychadenidae
*Schismaderma carens***	Red Toad**	Anura	Bufonidae
*Tomopterna cryptotis**	Cryptic Sand Frog	Anura	Pyxicephalidae
*Tomopterna luganga***	Red Sand Frog**	Anura	Pyxicephalidae
*Tomopterna tuberculosa**	Rough Sand Frog	Anura	Pyxicephalidae
*Xenopus victorianus***	Lake Victoria Clawed Frog**	Anura	Pipidae
*Xenopus borealis***	Northern Clawed Frog**	Anura	Pipidae
Xenopus muelleri	Müller's Clawed Frog	Anura	Pipidae

* New records to SENAPA

** Recorded from publications but not encountered during the data collection

Appendix 2: A Checklist of the Reptiles of Serengeti National Park

Scientific Name	Common Name	Order	Family
Acanthocercus atricollis	Blue-headed Tree Agama	Squamata	Agamidae
Adolfus jacksoni	Jackson's Forest Lizard	Squamata	Lacertidae
Agama mwanzae	Mwanza Flat-headed Agama	Squamata	Agamidae
Atractaspis bibronii	Bibron's Burrowing Asp	Squamata	Atractaspididae
Bitis arientas	Puff Adder	Squamata	Viperidae
Boiga pulverulenta	Powdered Tree Snake	Squamata	Colubridae
Causus resimus	Velvety-green Night Adder	Squamata	Viperidae
Chamaeleo dilepis	Flap -necked Chameleon	Squamata	Chamaeleonidae
Crocodylus niloticus	Nile crocodile	Crocodylia	Crocodylidae
Crotaphopeltis hotamboeia	White-lipped Snake	Squamata	Colubridae
Dendroaspis polylepis	Black Mamba	Squamata	Elapidae
Dispholidus typus	Boomslang	Squamata	Colubridae
Elapsoidea loveridgei	East African Garter Snake	Squamata	Elapidae
Geochelone pardalis	Leopard Tortoise	Testudines	Testudinidae
Gerrhosaurus flavigularis	Yellow-throated Plated Lizard	Squamata	Gerrhosauridae
Heliobolus spekii	Speke's Sand Lizard	Squamata	Lacertidae
Hemidactylus mabouia	Tropical House Gecko	Squamata	Gekkonidae
Hemidactylus squamulatus	Nyika Gecko	Squamata	Gekkonidae
Hemirhagerrhis nototaenia	Bark Snake	Squamata	Colubridae
*Kinixys belliana***	Bell's Hinged Tortoise**	Testudines	Testudinidae
Lamprophis fuliginosus	Brown House Snake	Squamata	Colubridae
Lycophidion depressirostre	Flat-Snouted Wolf Snake	Squamata	Colubridae
Lygodactylus capensis	Cape Dwarf Gecko	Squamata	Gekkonidae
Lygodactylus gutturalis	Forest Dwarf Gecko	Squamata	Gekkonidae
Lygosoma afrum	Peter's Writhing Skink	Squamata	Scincidae
Lygosoma sundevalli	Sundevall's Writhing Skink	Squamata	Scincidae
Mabuya brevicollis	Short-Necked Skink	Squamata	Scincidae
Mabuya maculilabris	Speckle-lipped Skink	Squamata	Scincidae
Mabuya megalura	Long-tailed Skink	Squamata	Scincidae
Mabuya striata	Striped Skink	Squamata	Scincidae
Mabuya varia	Variable Skink	Squamata	Scincidae
*Malacochersus tornieri****	Pancake Tortoise***	Testudines	Testudinidae
Meizodon semiornatus	Semi-ornate Snake	Squamata	Colubridae
Naja nigrocollis	Black-necked Spitting Cobra	Squamata	Elapidae
Nucras boulengeri	Boulenger's Scrub Lizard	Squamata	Scincidae
Panaspis wahlbergii	Wahlberg's Snake-Eyed Skink	Squamata	Scincidae
*Pedioplanis burchelli****	Burchell's Sand Lizard***	Squamata	Lacertidae
*Pedioplanis inornata****	Plain Sand Lizard***	Squamata	Lacertidae
Pelomedusa subrufa	Helmeted Terrapin	Testudines	Pelomedusidae
Philothamnus battersbyi	Battersby's Green Snake	Squamata	Olubridae
Psammophis sundanensis	Northern Stripe-Bellied Sand Snake	Squamata	Colubridae
Psammophyal multisquamis	Kenyan Striped Skaapsteker	Squamata	Colubridae
*Python sebae****	Central African Rock Python***	Squamata	Pythonidae
Rhinotyphlops mucroso	Zambezi Blind Snake	Squamata	Typhlopidae
Telescopus semiannulatus	Tiger Snake	Squamata	Colubridae
Typhlops lineolatus	Lioneolate Blind Snake	Squamata	Typhlopidae
Typhlops punctatus	Spotted Blind Snake	Squamata	Typhlopidae
Varanus niloticus	Nile Monitor	Squamata	Varanidae

** Recorded from publications but not encountered during the data collection
***Reported by SENAPA staff during the focus group discussion

Appendix 3: Dunn's Multiple Comparison Statistical Test Results

Comparison of diversity indices of Reptiles species between Habitats	
Habitats	P Value
GLSD vs. KPES	ns P > 0.05
GLSD vs. RRFT	ns P > 0.05
GLSD vs. WOLD	ns P > 0.05
KPES vs. RRFT	ns P > 0.05
KPES vs. WOLD	ns P > 0.05
KPES vs. WTLD	ns P > 0.05
RRFT vs. WOLD	**P < 0.001
RRFT vs. WTLD	ns P > 0.05
WOLD vs. WTLD	**P < 0.001

GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland and WTLD = Wetland

Appendix 4: Relative Abundance of observed Amphibians species of SENAPA

		Habitats					
Families and species	N	GLSD	KPES	RRFT	WOLD	WTLD	Total %
Bufonidae							
Bufo gutturalis	59	0.94	0.94	1.05	2.2	1.05	6.18
Mertensophryne sp	1	0.1	-	-	-	-	0.1
Hemisotidae							
Hemisus guineensis	14	0.73	-	0.21	0.31	0.21	1.46
Hemisus marmoratus	173	6.72	-	2.73	2.31	6.4	18.16
Hyperoliidae							
Kassina senegalensis	15	1.57	-	-	-	-	1.57
Hyperolius ferniquei	1	0.1	-	-	-	-	0.1
Hyperolius goetzei	1	-	0.1	-	-	-	0.1
Pipidae							
Xenopus muelleri	1	0.1	-	-	-	-	0.1
Ptychadenidae							
Ptychadena anchietae	48	3.15	0.31	0.84	0.31	0.42	5.03
Ptychadena natalensis	71	6.61	-	0.42	-	0.42	7.45
Ptychadena mossambica	433	41.28	-	0	-	4.2	45.48
Ptychadena mascareniensis	111	11.02	-	0.1	-	0.52	11.64
Ptychadena sp	8	0.84	0	0	0	0	0.84
Ptychadeniade							
Phrynobatrachus scheffleri	8	-	-	0.84	-	-	0.84
Pyxicephalidae							
Tomopterna cryptotis	2	-	-	-	0.21	-	0.21
Tomopterna tuberculosa	2	0	0.1	0	0	0.1	0.2
Dicroglossidae							
Hoplobatrachus occipitalis	1	-	-	0.1	-	-	0.1
Rhacophoridae							
Chiromantis petersi	1	0.1	-	-	-	-	0.1
Chiromantis xerampelina	2	-	-	-	-	0.21	0.21
Number of individuals	952	-	-	-	-	-	-
Abundance %	-	73.26	1.45	6.29	5.34	13.53	99.87

N = Number of individuals, GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland, WTLD = Wetland and - = Absence/not recorded

Appendix 5: Relative Abundance of observed Reptile species of SENAPA

		Habitats					
Families and species	N	GLSD	KPES	RRFT	WOLD	WTLD	Total %
Agamidae							
Acanthocercus attricollis	9	-	-	-	1.49	-	1.49
Agama mwanzae	182	-	30.18	-	-	-	30.18
Atractaspididae							
Atractaspis bibronii	1	-	0.16	-	-	-	0.16
Chamaeleonidae							
Chamaeleo dilepis	4	0.16	-	-	0.49	-	0.65
Colubridae							
Boiga pulverulenta	1	-	-	-	0.16	-	0.16
Dispholidus typus	3	-	-	-	0.49	-	0.49
Crotaphopeltis hotamboeia	7	0.83	-	-	0.16	0.16	1.15
Lamprophis fuliginosus	7	-	-	0.83	0.33	-	1.16
Lycophidion depressirostre	1	-	-	-	0.16	-	0.16
Meizodon semiornatus	10	1.66	-	-	-	-	1.66
Philothamnus battersbyi	4	-	0.16	-	0.49	-	0.65
Philothamnus semivariegatus	2	-	0.16	-	0.16	-	0.32
Psammophis sundanensis	2	-	-	-	0.16	0.16	0.32
Telescopic semiannulatus	1	-	0.16	-	-	-	0.16
Hemirhagerrhis nototaenia	1	-	-	-	0.16	-	0.16
Crocodylidae							
Crocodylus niloticus	144	-	-	-	-	23.88	23.88
Gekkonidae							
Hemidactylus mabouia	3	-	-	-	0.49	-	0.49
Hemidactylus squamulatus	1	-	0.16	-	-	-	0.16
Lygodactylus capensis	15	-	-	0.83	1.66	-	2.49
Lygodactylus gutturalis	1	-	-	-	0.16	-	0.16
Gerrhosauridae							
Gerrhosaurus flavigularis	2	0.16	-	-	0.16	-	0.32
Scincidae							
Lygosoma afrum	2	-	0.33	-	-	-	0.33
Lygosoma sundevalli	26	0.16	1.49	-	2.49	0.16	4.3
M. brevicollis	2	-	0.16	-	0.16	-	0.32
Mabuya maculilabris	1	0.16	-	-	-	-	0.16
Mabuya megalura	4	0.33	0.33	-	-	-	0.66
Mabuya striata	33	3.65	0.83	-	0.99	-	5.47
Mabuya varia	20	-	3.15	0.16	-	-	3.31
Panaspis wahlbergii	2	-	0.16	-	0.16	-	0.32

Appendix 5 continued

		Habitats					
Families and species	N	GLSD	KPES	RRFT	WOLD	WTLD	Total %
Elapidae							
Dendroaspis polylepis	2	-	-	-	0.33	-	0.33
Naja nigricollis	3	-	0.16	-	-	0.33	0.49
Elapsoidea loveridgei	1	0.16		-	-	-	0.16
Pelomedusidae							
Pelomedusa subrufa	20	0.66	0.16	-	1.66	0.83	3.31
Testudinidae							
Geochelone pardalis	39	3.32	0.16	-	2.65	0.33	6.46
Typhlopidae							
Typhlops lineolatus	2	-	0.16	-	-	0.16	0.32
Rhinotyphlops mucroso	2	-	0.16	-	0.16	-	0.32
Typhlops sp	2	0.16	-	-	-	0.16	0.32
Lacertidae							
Adolfus jacksoni	1	-	-	0.16	-	-	0.16
Heliobolus spekii	1	0.16	-	-	-	-	0.16
Nucras boulengeri	7	0.16	0.16	0.16	0.66	-	1.14
Varanidae							
Varanus niloticus	26	0.49	0.33	0.16	1.16	2.16	4.3
Viperidae							
Bitis arientas	3	0.33	0.16	-	-	-	0.49
Causus resimus	3	0.33	-	-	0.16	-	0.49
Number of individuals	603	-	-	-	-	-	-
Abundance %	-	12.9	38.88	2.3	17.3	28.33	99.69

N = Number of individuals, GLSD = Grassland, KPES = Kopjes, RRFT = Riverine Forest, WOLD = Woodland, WTLD = Wetland and - = Absence/not recorded

Appendix 6: Distribution of Amphibian species of SENAPA by Habitats

Families and Species	Habitats GLSD	WOLD	RRFT	KPES	WTLD	% Occurrence
Bufonidae						
Bufo gutturalis	+	+	+	+	+	100
Mertensophryne sp	+	-	-	-	-	20
Hemisotidae						
Hemisus guineensis	+	+	+	-	+	80
Hemisus marmoratus	+	+	+	-	+	80
Hyperoliidae						
Kassina senegalensis	+	-	-	-	-	20
Hyperolius goetzei	-	-	-	+	-	20
Hyperolius ferniquei	+	-	-	-	-	20
Pipidae						
Xenopus muelleri	+	-	-	-	-	20
Ptychadenidae						
Ptychadena anchietae	+	+	+	+	+	100
Ptychadena mossambica	+	-	-	-	+	40
Ptychadena mascareniensis	+	-	+	-	+	60
Ptychadena sp	+	-	-	-	-	20
Phrynobatrachidae						
Phrynobatrachus natalensis	+	-	+	-	+	60
Phrynobatrachus scheffleri	-	-	+	-	-	20
Dicroglossidae						
Hoplobatrachus occipitalis	-	-	+	-	-	20
Pyxicephalidae						
Tomopterna cryptotis	-	+	-	-	-	20
Tomopterna tuberculosa	-	-	-	+	-	20
Rhacophoridae						
Chiromantis xerampelina	-	+	-	-	-	20
Chiromantis petersi	+	-	-	-	-	20
Number of species	13	6	8	4	7	-
Species Percentage	68.42	31.57	42.11	21.05	36.84	-

GLSD = Grassland, WOLD = Woodland, RRFT =Riverine Forest, KPES = Kopjes, WTLD = Wetland and - = Absence

Appendix 7: Distribution of Reptile species of SENAPA by Habitats

Families and Species	Habitats GLSD	WOLD	RRFT	KPES	WTLD	% Occurrence
Agamidae						
Agama mwanzae	-	-	-	+	-	20
Acanthocercus atricollis	-	+	-	-	-	20
Atractaspididae						
Atractaspis bibronii	-	-	-	+	-	20
Viperidae						
Bitis arientas	+	-	-	+	-	40
Causus resimus	+	+	-	-	-	40
Chamaeleonidae						
Chamaeleo dilepis	+	+	-	-	-	40
Colubridae						
Philothamnus semivariegatus	-	+	-	+	-	40
Philothamnus battersbyi	-	+	-	+	-	40
Boiga pulverulenta	-	+	-	-	-	20
Dispholidus typus	-	+	-	-	+	40
Crotaphopeltis hotamboeia	+	+	-	-	-	40
Meizodon semiornatus	+	-	-	-	-	20
Telescopus semiannulatus	-	-	-	+	-	20
Lamprophis fuliginosus	-	+	+	-	-	40
Lycophidion depressirostre	-	+	-	-	-	20
Hemirhagerrhis nototaenia	-	+	-	-	-	20
Psammophis sundanensis	-	+	-	-	+	40
Elapidae						
Naja nigrocollis	-	-	-	+	+	40
Dendroaspis polylepis	-	+	-	-	-	20
Elapsoidea loveridgei	+	-	-	-	-	20
Gekkonidae						
Lygodactylus capensis	-	+	+	-	-	40
Lygodactylus gutturalis	-	+	-	-	-	20
Hemidactylus squamulatus	-	-	-	+	-	20
Hemidactylus mabouia	-	+	-	-	-	20
Gerrhosauridae						
Gerrhosaurus flavigularis	+	+	-	-	-	40
Lacertidae						
Nucras boulengeri	+	+	+	+	-	80
Heliobolus spekii	+	-	-	-	-	20
Adlfus jacksoni	-	-	+	-	-	20
Scincidae						
Mabuya varia	-	-	+	+	-	20
Mabuya striata	+	+	-	+	-	60

Appendix 7 continued

Families and Species	Habitats					
	GLSD	WOLD	RRFT	KPES	WTLD	% Occurrence
Pelomedusidae						
Pelomedusa subrufa	+	+	-	+	+	80
Testudinidae						
Geochelone pardalis	+	+	-	+	+	80
Typhlopidae						
Typhlops lineolatus	-	-	-	+	+	40
Typhlops sp	+	-	-	-	+	20
Rhinotyphlops mucroso	-	+	-	+	-	40
Varanidae						
Varanus niloticus	+	+	+	+	+	100
Crocodylus niloticus	-	-	-	-	+	20
Number of Species	17	27	6	21	10	-
Species Percentage	38.63	61.36	13.63	47.72	22.72	-

GLSD = Grassland, WOLD = Woodland, RRFT = Riverine Forest, KPES = Kopjes, WTLD = Wetland and - = Absence