DISTRIBUTION, DIVERSITY AND POPULATION STATUS OF HERPETOFAUNA IN LOWER TANA RIVER FORESTS, KENYA

Philothamnus punctatus, a harmless snake species found in Shakababo forest, lower Tana River, Kenya.

By

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A thesis submitted in partial fulfillment for the degree of Master of Science, University of Nairobi

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DECLARATION

This thesis is my original work and has not been presented for any other degree to the best of my knowledge.

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DEDICATION

This thesis is dedicated to my wife, Esther Mbithe and my children, Joy Mutheu, Emmanuel Muthama and Juliet Mbesa. You are the inspiration that drives me on.

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ACRONYNYMS AND ABBREVIATIONS

TARDA	Tana and Athi Rivers Development Authority
IUCN	International Union for Conservation of Nature
GAA	Global Amphibian Assessment
KWS	Kenya Wildlife Service
KFS	Kenya Forest Service
NMK	National Museums of Kenya
TRPNR	Tana River Primate National Reserve

ABSTRACT

A study of the herpetofauna of lower Tana River forests was conducted between September 2007 and May 2008, to determine the community structure and threats of the protected and unprotected forest patches, with a view to improving habitat conservation and management. Standardized methods (a time-limited search, traps with drift fences and night transects) as well as opportunistic visual encounter survey were used for herpetofauna survey. A questionnaire was also used to assess the cultural significance and threats to the herpetofauna. Species richness (S) and Shannon-Wiener's diversity index (H^I) were used for comparisons amongst forest fragments. One-way ANOVA test was used to test for differences in the mean values of habitat characteristics within sites, among forests and herpetofaunal species richness, abundance and diversity among the three forests. Two sample t-test was used for differences in the mean values of herpetofaunal species richness, abundance and diversity between the wet season and dry season. Regression analysis was used to assess relationship between habitat characteristics and herpetofaunal species richness, abundance and diversity. A total of 56 species were recorded of which 7 amphibian and 17 reptile species were recorded for the first time in this region. Habitat characteristics (leaf litter cover, percent canopy cover, soil pH, tree density, ambient temperature, percent vegetation cover) differed significantly ($p < 0.05$) within sites in the forests. However, the same habitat characteristics did not differ significantly ($p > 0.05$) across the forests. Herpetofaunal species abundance and diversity did not differ significantly ($p > 0.05$) between the dry and wet season.

Similarly, amphibian and lizard species abundance and diversity did not differ significantly ($p > 0.05$) across the forests, except for snakes ($p < 0.05$). There was no significant relationship between habitat characteristics and herpetofaunal species abundance and diversity ($p > 0.05$). The study confirmed that the lower Tana River forests surveyed supported a moderately rich herpetofauna which is characteristic of coastal forests. It also confirmed that the major threats to herpetofauna were forest destruction through burning and clearing for agriculture. It also detected seasonal variability in the abundance and diversity of herpetofauna in these forests. Species found within the forests were generally similar, reflecting similarity in forest habitat structure. Amphibian species abundance, richness and diversity were lower in disturbed than in protected forest fragments. This study provided crucial information in establishing the conservation status of herpetofauna of the lower Tana River forests. A study of the offtake of crocodiles and the cost-benefit analysis of their utilization by the local communities is recommended.

Key words: Species richness, abundance and diversity, herpetofauna and lower Tana River forests.

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Forests and wetlands have been identified as the most threatened habitats despite their importance for endemic or near endemic fauna and flora. In East Africa as a whole, only a relatively small portion of the total land area is covered with closed natural forest (Channing and Howell, 2006). The coastal forests of Tanzania and Kenya have been recognized as having strong affinities with those of the Eastern Arc Mountains, including high species diversity and endemism and their importance has been emphasized by their recognition as the Eastern Arc/Coastal Forest Global Biodiversity Hotspot (Channing and Howell, 2006).

The lower Tana River forest habitats are part of the Eastern Africa Coastal Forests (Myers, 2000). They are fragmented forests supporting a high and endemic biodiversity and are classified as key biodiversity areas within the East African Coastal region. The forests lie in a transition zone between the typical eastern and south-eastern fauna with close affinity to coastal biome species (Malonza *et. al.*, 2006).

Despite their biodiversity importance, like many other coastal forests in East Africa, the lower Tana River forests are threatened by the ever expanding human population which exerts threats, such as expanding agriculture, charcoal burning and fuel wood extraction, uncontrolled fires, unsustainable logging, human settlement, and destructive mining practices (Bennun and Njoroge, 1999).

Recently, a major rice irrigation scheme has been initiated in the Tana Delta by the Tana and Athi Rivers Development Authority (TARDA) and 4000 ha of the flood plain have been converted for rice production near Garsen (Robertson and Luke, 1993). Further, the government has approved clearing of 4000 ha of land for sugar cane farming.

It has been recognized that on a global basis, some amphibian populations are declining, and according to IUCN Global Amphibian Assessment (GAA), 32% of the worlds 5743 amphibian species are threatened with extinction (Channing and Howell, 2006; Stuart *et. al.*, 2004). Only a few populations of East African amphibians have been monitored and it is therefore difficult to say whether or not populations in the region are generally stable or declining (Channing and Howell, 2006).

Many of the amphibians and reptiles live in tiny habitats which are often forested, and with increase in human population, these forests are vulnerable for their rich resources (Spawls *et. al.,* 2002). In general, ecological and conservation aspects of Kenyan herpetofauna linked to conservation, are not yet worked out and especially historical aspects (Wasonga *et. al.*, 2006).

Despite the biodiversity conservation significance of the lower Tana River ecosystem, the herpetofauna of these forests remain poorly known, though, herpetological studies in the region, which were mainly limited to taxonomic descriptions, began in the British colonial era (Malonza *et. al.*, 2006).

The Tana River Delta, the flood plain just south of the Tana River Primate National Reserve (TRPNR) from Garsen, is the only section of the river basin that received some attention from early herpetological collectors (*e.g.* Loveridge, 1936a, b, 1957).

A recent brief expedition by Malonza *et. al*., (2006) provides an updated overview of the currently known herpetofauna species though focused mainly within the forests covered by the TRPNR. In general, the baseline information on the zoogeography and ecology of the local herpetofauna of the lower Tana River forests, especially those outside the TRPNR remains patchy and scanty.

In the current study, an ecological survey of the diversity, abundance and distribution of herpetofauna in relation to micro-habitat characteristics was conducted. This study goes a step further to assess the cultural significance, perception of herpetofauna and threats in the study area. Apart from the general herpetofauna survey in eight forest fragments, a comparison of herpetofaunal diversity and abundance in three selected forest fragments which constituted two protected and one unprotected forest fragments was done. A number of factors that were expected to have influence on diversity and abundance of the herpetofauna were also assessed. These included: Leaf litter cover, tree density, canopy cover, vegetation cover, soil moisture, temperature, soil pH, forest size and disturbance level.

1.2.0 Literature Review

1.2.1 Amphibians

Amphibians and reptiles are two distinct clades of vertebrates that arose within the Tetrapoda, a clade of bony fish appearing first in the Paleozoic Era. Tetrapods are the fish that took the first "step" from fin to limb – from water to land – and one of their earliest divergent groups became the amphibians. Amphibians have successfully exploited humid (and even arid) environments in most areas of the world while remaining closely tied to water or moist microhabitats for propagation. Most amphibians experience rapid desiccation in dry environments, but some species have evolved adaptations for existence in dry habitats (Zug *et. al.*, 2001).

Living amphibians consist of three clades: caecilians, salamanders, and frogs. Caecilians superficially resemble earthworms and are formally labeled with the node-based name Gymnophiona (naked snake) and the stem-based name Apoda (without foot). All the extant caecilians lack limbs, are strongly annulated, and have bullet-shaped heads and tails. This morphology reflects the burrowing lifestyle of these tropical amphibians. There are only 160 species, currently divided into six families. Most caecilians are fossorial, living in moist soils often adjacent to streams, lakes, and swamps; a few species are aquatic.

The salamanders, labeled with the node-based name Caudata (having tail) and the stem based name Urodela (tail visible), have cylindrical bodies, long tails, distinct heads and necks, and well developed limbs or even have lost the hind limbs.

Salamanders are represented by many ecological types, including totally aquatic taxa, barrowing and terrestrial species, and arboreal species that live in epiphytes in the forest canopy.

The frogs, given the node-based name Anura (without tail) and the stem-based name Salientia (jumping), are like other vertebrates in having robust, tailless bodies with continuous head and body and well developed limbs. Not all frogs jump or even hop; some taxa are totally aquatic and use synchronous hind limb kick for propulsion, whereas other species, including both terrestrial and arboreal forms, walk (Zug *et. al.,* 2001). Among amphibians, frogs are the most speciose and show the highest morphological, physiological, and ecological diversity and broadest geographic occurrence (Zug *et. al.,* 2001).

1.2.2 Reptiles

In the Carboniferous, another divergent group of tetrapods, the anthracosaurs, appeared; they evolved modifications for propagation on the land in the absence of water, and, perhaps coincidentally, developed an effective skin barrier to reduce rapid and excessive water loss. Today, this group is represented by the reptiles (including birds) and mammals. The living reptiles consist of three clades: turtles, archosaurs, and lepidosaurs. The turtles, called by the node-based name of Testudines (tortoises/turtles/terrapins), like frogs, cannot be mistaken for any other animal. The body is encased within upper and lower bony shells. In some species, the two portions of the shell can close, fitting tightly together and completely protecting the limbs and head (Zug *et. al.,* 2001).

Living archosaurs include the closely related crocodilians and birds. Although, the archosaur origin of birds has been long recognized, only recently have biologists insisted on classification accurately depicting evolutionary relationships, thereby promoting birds as "glorified" reptiles. The crocodilians, called by the node-based name Crocodylia (lizard), are armored by thick epidermal plates underlain dorsally by bone. The elongate head, body, and tail dwarf the short, strong limbs. Crocodilians are a small group of predaceous, semi-aquatic reptiles that swim with strong adulatory strokes of a powerful tail. The limbs also allow mobility on land, although terrestrial activities are usually limited to basking and nesting (Zug *et. al.*, 2001).

The lepidosaurs include the tuataras, snakes, and lizards. The two species of tuataras, referred to by the node-based name Sphenodontida (wedge tooth) and the stem-based name Rhynchocephalia (nose or snout head), are lizard-like but represent an early divergence within the lepidosaurian clade; today, they occur only on islets off the coast of New Zealand. The node-based name Squamata (scale) includes the lizards, snakes, and amphisbaenians. These groups are the most diverse and speciose of the living reptiles, occupying habitats ranging from tropical oceans to temperate mountain tops (Zug *et. al.*, 2001).

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1.2.3 The importance of herpetofauna in the ecosystem

Amphibians are an important but often overlooked component of most terrestrial and freshwater aquatic ecosystems. Adult frogs are important predators on invertebrates; they feed on insects, such as mosquitoes, as well as insects that could feed on crops (Channing and Howell, 2006). In addition, amphibians are also important food items for other animals, including other amphibians at all stages of their life cycles. Amphibians may also serve as sensitive biological indicators of environmental deterioration because their highly permeable skin rapidly absorbs toxic substances from air, water and soil (Pough *et. al*., 1998). Apart from their utilization for food and clothing items by man, reptiles consume insects and help to keep the rodent population under control. In turn, rodents are preyed upon by amphibians, birds, mammals and even their own kind; thus forming part of the complex web of life, the intricate food chain of which even man is ultimately an integral part (Patterson, 1987).

1.2.4 Human and natural impact on herpetofauna communities

Beginning in the 1980s, herpetologists began to note the disappearance of frogs from localities where they had been abundant only a few years earlier. In international meeting held in USA in 1989, numerous scientists presented overwhelming evidence showing that many populations and some species of amphibians worldwide had disappeared or were in sharp decline (Zug *et. al*., 2001). The greatest threat to amphibians and reptiles is the modification and destruction of their habitats (Patterson, 1987 and Pough *et. al*., 1998).

Many habitats are shrinking or disappearing at an accelerating pace due to pressures of human population growth and economic development (Pough *et. al*., 1998). Human activities have resulted in climatic effects, which range from global climatic changes to the local loss of a marsh in a patch of a forest which in return affects herpetofauna in all areas, especially in coastal and low-lying areas (Zug *et. al*., 2001). The direct effect of habitat loss on herpetofauna species or community is obvious: it disappears from that area and the consequences, reduced abundance and diversity, extend beyond the edges of the lost habitat (Gibbs, 1998).

Selective logging or total removal of all the trees and the associated destruction of the under-storey vegetation and broad disruption of the ground cover litter to expose the soil to direct sunlight. Thereafter, the soil attains significantly higher temperatures, experiences greater temperature fluctuations, and becomes drier; these microclimatic changes are lethal to amphibians (Zug *et. al*., 2001). In most cases, the species under cultivation are exotic, and generally speaking, both large-scale and small scale agricultural areas have been created at the expense of natural habitats more suited to herpetofauna (Bennun and Njoroge, 1995).

The construction of hydropower dams, hotels, lodges, roads, and mines may create conditions that are harmful to amphibians, many of which undergo seasonal movements to and from breeding sites, resulting in incomplete movement patterns, which are necessary for successful breeding and dispersal, when their route is blocked or altered (Channing and Howell, 2006).

Amphibians and reptiles are widely harvested, for consumption (food and traditional medicines), luxury trade (leathers and curios), and the pet trade (Zug *et. al.*, 2001). Unfortunately, harvesting of amphibians and reptiles for world's luxury food market and pet trade is generally done without regard to local population dynamics. This has often led to depletion of wild populations (Pough *et. al.*, 1998).

Environmental pollution (especially agricultural chemicals) is a possible cause for the decline of some amphibians (Pough *et. al.*, 1998). Some agrochemicals (e.g. polychlorinated biphenyls - PCBs) act as hormones that interfere with reproduction in amphibians by disrupting the normal development of their reproductive organs. If their use is not tightly controlled, their entrance into the natural ecosystem may have negative effects on amphibians, especially in the aquatic systems (Channing and Howell, 2006).

Natural disruptions such as floods, landslides, and fires occur regularly in all ecosystems and may foster regular occurrence of disturbances in high species - and community - diverse areas (Zug *et. al.*, 2001). Diseases are also a natural phenomenon and no plant or animal can be free from them. However, it becomes a concern to conservationists when it results in sudden die-offs of populations or when its frequency of occurrence increases (Crawshaw, 1997). The chytrid fungus has recently been identified a new threat to amphibians in Africa and it is believed to be also responsible for the demise of frog populations elsewhere in the world (Channing and Howell, 2006).

1.2.5 Problem statement and justification of the study

As recognized globally, some amphibian populations are in decline, and some species are threatened with extinction (Stuart *et. al.*, 2004). This phenomenon has prompted many studies that seek to assess amphibian diversity at the species level, and to track changes in the number of species over time (Sutherland, 2006). Only a few populations of East African amphibians have been monitored. It is therefore difficult to say whether or not populations in the region are generally stable or declining (Channing and Howell, 2006).

According to Spawls *et. al.*, (2002), many reptiles live in small habitats, especially fragmented forests. The lower Tana River forests are such fragmented habitats, supporting a high and endemic biodiversity. A great deal of attention should therefore be given to these forest fragments since they contain a tremendous diversity of herpetofauna. Some of the species in these forest habitats are probably rare and/or restricted to certain micro-habitats. Previous studies have provided valuable baseline information, but not a complete assessment of the herpetofauna.

In order to bridge these gaps in knowledge, the study of the herpetofaunal diversity, abundance, distribution and their micro-habitats is therefore critical for better understanding of the community structure and ecological process that affect them in the riverine forest habitats. This scientific information would be useful in the management of the lower Tana River forests and wetlands.

1.3.0 Objectives

1.3.1 Main objective

To determine the community structure and threats to herpetofauna of Lower Tana River basin with a view to improving their conservation and habitat management.

1.3.2 Specific objectives

i) To determine various habitat variables in the lower Tana River forest fragments.

ii) To determine the diversity, abundance and distribution of the herpetofauna in the lower Tana River forest fragments.

iii) To determine how herpetofauna changed with habitat variables.

iv) To determine the cultural significance and threats to the herpetofauna.

1.3.3 Research questions

- What habitat variables influence the community structure of herpetofauna in lower Tana River forest fragments?
- What herpetofaunal species are found there and in which habitats?
- Are there any differences in the community structure of herpetofauna between the protected and unprotected forest fragments?
- What are the cultural perceptions and threats of the local people towards herpetofauna?

1.3.4 General hypothesis

Two hypothesis were set for this study. Firstly, that there is likely to be significant difference in diversity and abundance of herpetofauna species in the protected and unprotected forest fragments. Secondly, that there is likely to be significant influence in diversity and abundance of herpetofauna species by habitat variables.

CHAPTER TWO

2.0 STUDY AREA

2.1 Location

The study area was in Tana River and Lamu districts of Coast Province. The Tana River forests are riparian forests along the meandering course of the lower Tana river, some 350 km east of Nairobi and 240 km north of Mombasa. These forests lie on both banks of the Tana river. There are seventy one distinct forest fragments, ranging in size from one to 1,100 ha and covering around 3,700 ha in total (Butynski and Mwangi, 1995). Sixteen of the seventy two patches covering 1,000 ha fall within the 17,000 ha TRPNR which extends for about 36 km along the river's present course. They are managed by the Kenya Wildlife Service. Fourteen forest parches are managed by the Tana Delta Irrigation Project and the Kenya Forest Service. The remainder are in Trust Land and are managed by the community and local authorities (Seal *et. al.*, 1991). These fragments are located between 01° 52' 04.7" S, 040° 08' 15.7" E and 02° 31' 30.2" S, 040° 31' 26.3" E (Fig. 2.1 a and 2.1 b).

Figure 2. 1 a: Map of lower Tana River Forests within TRPNR (Adopted from Bennun and Njoronge (1999). Inset is the map of Kenya showing the location of the study area

Legend:

1. Guru North
2. Guru South
3. Mchelelo West
4. Congolani
5. Hewani East

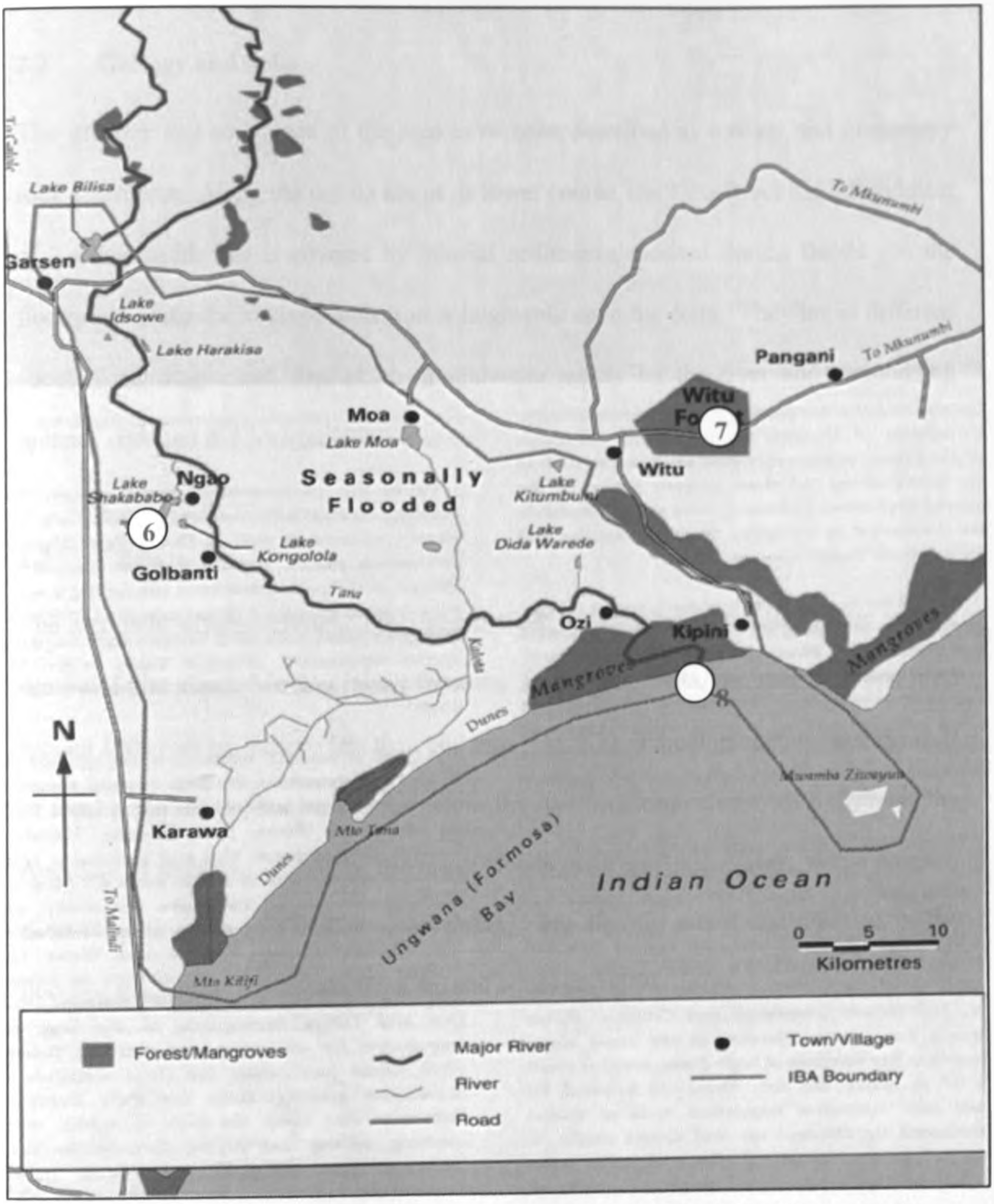

Figure 2.1 b: Map of lower Tana River forests outside TRPNR (Adopted from Bennum and Njoroge, 1999).

Legend:

6. Shakababo
7. Mambo Sasa
8. Kipini

2.2 Geology and Soils

The geology and soil types of the area have been described as tertiary and quaternary rock sediments. Along the last 65 km of its lower course, the Tana River has a floodplain of 1-6 km width that is covered by alluvial sediment deposited during floods. On the floodplain occur the lowland moist forest fragments up to the delta. They are of different successional stages and depend on groundwater supply by the river and surrounding uplands (Bennun & Njoroge, 1999).

2.3 Climate

The area falls within a climatic zone intermediate between humid coastal biome and the semi-arid hinterland. Moving inland from the Tana River Delta, the rainfall drops from around 1000 mm per year to less than 600 mm (Fig. 2.2). Flooding happens not as result of local precipitation, but because of rain in the river's catchments on Mt Kenya and the Aberdare Mountains. Normally, the major floods occur in April – May, with a smaller, short-rains flooding in October – November. The timing, extent and duration of the flooding vary from year to year (Bennun and Njoroge, 1999).

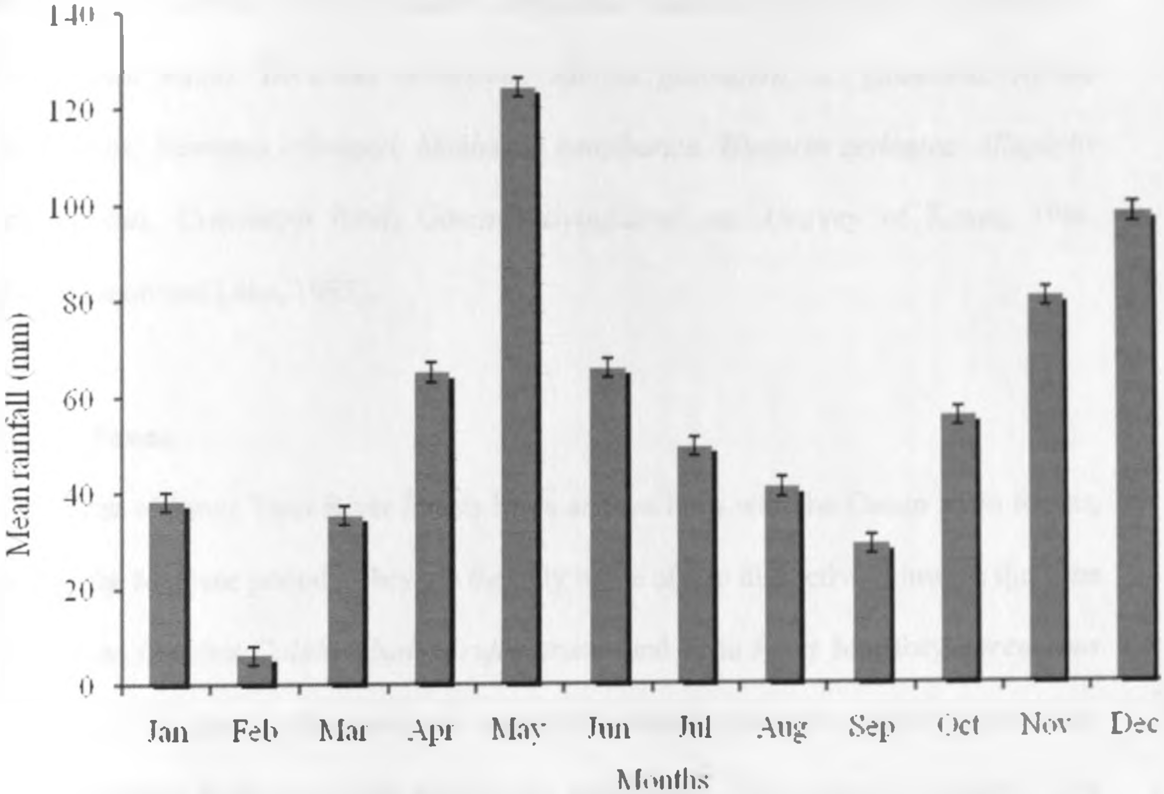

Figure 2.2: Mean rainfall trend at Garsen station, over a period of ten years, (1998-2007), source TARDA.

2.4 Flora

The area has heterogeneous vegetation with habitats ranging from open grassland, dry bush lands to deciduous woodland and lowland evergreen forests (Butsynki and Mwangi, 1995). Characteristic trees include: *Ficus natalensis, Ficus sycomorus, Phoenix reclinata, Acacia robusta, Populus ilicifolia, Blighia unijuguta, Sorindeia madagascariensis, Diospyros mespiliformis, Minusops obtusifolia, M. fruitcosa, Terminalia brevipes, Polysphaeria multiflora, Alangium salviifolium, Tamarindus indica, Saba comorensis, Spirostachys venenifera, Pavetta sphaerobotrys, Oncoba spinosa, Trema orientalis, Chytranthus obliquenervis, Cordia geotzei, Grewia densa, Harrisonia abysinica, Erythroxylum fischeri, Sterculia appendiculata, Rinorea elliptica,* *Hyphaene compressa, Thespesia danis, Antidesma venosum, Lecaniodiscus fraxinifolius, Pachystella msolo, Borossus aethiopum, Albizia gummifera, A. glaberima, Afzelia quanzensis, Newtonia erlongeri, Makhamia zanzibarica, Hunteria zeylanica, Allophylis alternifolius, Cynometra lukei, Garcinia livingstonei* etc. (Survey of Kenya, 1984, Robertonson and Luke, 1993).

2.5 Fauna

The fauna of lower Tana River forests bears ancient links with the Congo basin forests, during the Miocene period. They are the only home of two distinctive primates, the Tana River Red Colobus *Colobus badius rufomitratus* and Tana River Magabey *Cercocebus galeritus*. The highly threatened and restricted Hunters Antelope or Hirola *Damaliscus hunteri* occurs in the dry bush land in the floodplain. Two globally-threatened bird species (Malindi pipit – *Anthus melindae* and Basra reed warbler – *Acrocephalus griseldis*) occur in this ecosystem, along with at least two and possibly three of the species in the East Africa Coastal Forests Endemic Bird Area. The area hosts 19 of the 30 Kenyan species in the East African Coast Biome (Bennun and Njoroge, 1999). The rare species of herpetofauna include the, Tana Writhing Skink *Lygosoma tanae* Loveridge, 1935, the Mabuya–like Writhing Skink *Lygosoma mabuiiformis* (Loveridge, 1935), the mud-dwelling caecilian *Schistometopum gregorii* (Boulenger, 1894) and the endemic Tana river caecilian *Boulengerula denhardi* Nieden, 1912 (Malonza *et. al.*, 2006).

2.6 Human Activities and Land Use

There are different ethnic communities with varied lifestyles and levels of socio-economic development that inhabit the area. The Pokomo people are a sedentary river community whose livelihood depends on farming, bee-keeping and fishing. Luo and Luhya immigrants in the lower Tana River also practice active fishing, while Wardei and Orma peoples are mainly semi-nomadic pastoralists. The latter practice subsistence farming but mainly use the forests and wetlands as dry-season grazing areas (Bennun and Njoroge, 1999).

The main subsistence crops grown include *Oryza sativa*, *Pennisetum glaucum*, *Zea mays* and *Phaseolus vulgaris*, and fruit trees, such as *Carica papaya*, mango species of the genus *Mangifera* and banana species of the genus *Musa*. Both the farming activities and pastoral activities affect the stability of the ecosystem, where shifting cultivation, overgrazing and general land degradation threaten biodiversity conservation (Ochiago, 1991). Large-scale irrigation schemes and hydroelectric power dams upstream are believed to have caused negative impacts on the ecological characteristic of the lower Tana River basin (Butynski and Mwangi, 1995).

2.7 Forest Utilization

All raw materials (poles, palm branches, stems etc.) for construction are obtained from the forests, the major tree species being *Mkoma*, *Hyphaene compressa* and *Mukindu*, *Phoenix reclinata*. The forest resources provide materials for household items such as utensils and bedding.

Mkoma and *Mukindu* trees are tapped for their sap from which a local brew is fermented (Plate 2.1) as well as providing raw materials for mats, baskets and beds for the Pokomo community and to a much lesser extent the Wardei. Plant and plant parts, such as roots, leaves and bark are collected for medicinal purposes. The communities here collect wild fruits (*Ficus sycomorus, Rhus natalensis, Psidium quajava, Grewia villosa, Balanitis aegyptiaca, Adansonia digitata, Tamarindus indica* etc.) from the forest, especially during poor crop harvests, famine and times of emergencies. Wild animals in the forest are also hunted for meat. These forests are used for grazing by the Wardei and Orma communities (Bennun and Njoroge, 1999).

There is unsustainable utilization of forest resources in some forest fragments such as Shakababo. Local brew tapping from Mkoma trees in Shakababo forest is very rampant. The *Mkoma* trees are dominant species here though still vulnerable from the local brew tapping, which starts when the trees are immature. Trees in this forest are also being cut down for building materials (Plate 2.2).

Plate 2.1: *Mkoma* trees cut on top to tap local brew using bottles in Shakababo forest

Plate 2.2: Illegal logging in Shakababo forest outside TRNPR

2.8 Floods

These forests lie on the flood plain which is flooded seasonally. Normally, the major floods occur in April-May, with a smaller, short rains flooding in October-November. The timing, extent and duration of the flooding vary greatly from year to year (Bennun and Njoroge, 1999). There are also long-term flooding cycles associated with El nino phenomenon. The existence of cut off meanders and forest enclaves is closely linked to past flooding regimes and occurrence of shallow oxbow lakes (Bennun and Njoroge, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Selection of Study Sites

Eight forest fragments were selected for sampling. However, selection of the forest fragments was determined by accessibility, security and the community cooperation around the forest fragment. The criteria for selection was on the bases of conservation status. These forests were Guru North (Plate 3.1), Guru South, Mchelelo West (Plate 3.2), Congolani, Shakababo (Plate 3.3), Mambo Sasa (Plate 3.4) Hewani South (Plate 3.5) and Kipini. Three of these forests were sampled in detail for both herpetofauna and habitat characteristics: (a) Mchelelo West within the TRPNR, (b) Shakababo forest within the Community Trust Land, (c) Mambo Sasa (Witu) under Kenya Forest Service. Three field sessions were made from 3rd to 17th of September 2007, 24th February to 10th March 2008 and 2nd to 18th of May 2008. Sampling was done between 7.30 am to 11.00 am and 4.00 pm to 7.30 pm every sampling day. Several sampling methods such as time-limited searches, pitfall traps with drift fences, night transect sampling and opportunistic visual encounter surveys were employed. Congolani and Kipini forests were surveyed by the opportunistic visual encounter survey method. Wetlands that formed part of the forest ecosystems within the selected forests were identified and sampled.

Plate 3.1: Guru North forest (01° 51'13.2'' S, 040° 06'59.8'' E) **– dominated by acacia species**

Plate 3. 2: Mchelelo West forest (01° 52' 43.4" S, 040° 08' 0.97" E) **– sharp change from forest to dry bushland**

Plate 3.3: Shakababo forest (02° 24' 52.1" S, 040° 10' 43.6" E) **– dominated by palm trees**

Plate 3.4: Mambo Sasa forest (02° 22' 56.1" S, 040° 29' 13.4." E) – thick vegetation cover of mixed forest

Plate 3.5: Hewani South forest (02°13' 37.01" S, 040° 10' 38.6" E) – small forest patch with thick vegetation cover

3.2 Characteristics of Forest Fragments

The eight forest fragments studied were of different sizes, altitudes, levels of disturbance and protection status. Four of these forests protected under the TRPNR (Guru North, Guru South, Mchelelo West, Congolani), one protected under the Forest Department (Mambo Sasa), and three unprotected (Hewani South, Shakababo and Kipini). The forest's altitude varied between 13 and 46 m above sea level. Their approximate sizes also varied between 17 and 3937.6 ha, see table 3.1.

Table 3. 1: Characteristics of eight forest fragments studied in lower Tana River

Forest	Altitude (M)	Size (ha)	Latitude and Longitude	Protection status
Guru North	42	51	01° 51' 13.2" S 040° 06' 59.8" E	Protected
Guru South	46	46	01° 52 '04.7" S 040° 08'15.7." E	Protected
Mchelelo West	38	17	01° 52' 43.4" S 040° 08' 0.97" E	Protected
Congolani	43	50	01° 59' 38.3" S 040° 07' 0.7" E	Protected
Mambo Sasa	13	3937.6	02° 22' 56.1" S 040° 29' 13.4" E	Protected
Hewani South	25	17	02°13' 37.01" S 040° 10' 38.6" E	Unprotected
Shakababo	18	405	02° 24' 52.1" S 040° 10' 43.6" E	Unprotected
Kipini	19	1000	02° 31' 30.2" S 040° 31' 26.3" E	Unprotected

3.3.0 Herpetofauna Sampling Techniques

3.3.1 Time limited searches

Time-limited searches described by Karns (1986) and Heyer *et. al.*, (1994) were used. Three sample plots (sizes 25m x 25m) were established (by marking boundaries with flagging tape) in each selected forest fragment, starting from outside the forest, at the edge of the forest and inside the forest. A team of two persons working for 30 minutes per search in each plot (1 man-hour) made three visits to each site. Intensive search for amphibians and reptiles was done by visually examining trees, different type of ground cover, shrubs, leaf litter and turning over logs, digging for burrowing species and replacing them (Plates 3.6, 3.7, 3.8, 3.9 and 3.10).

Plate 3.6: Digging for burrowing species

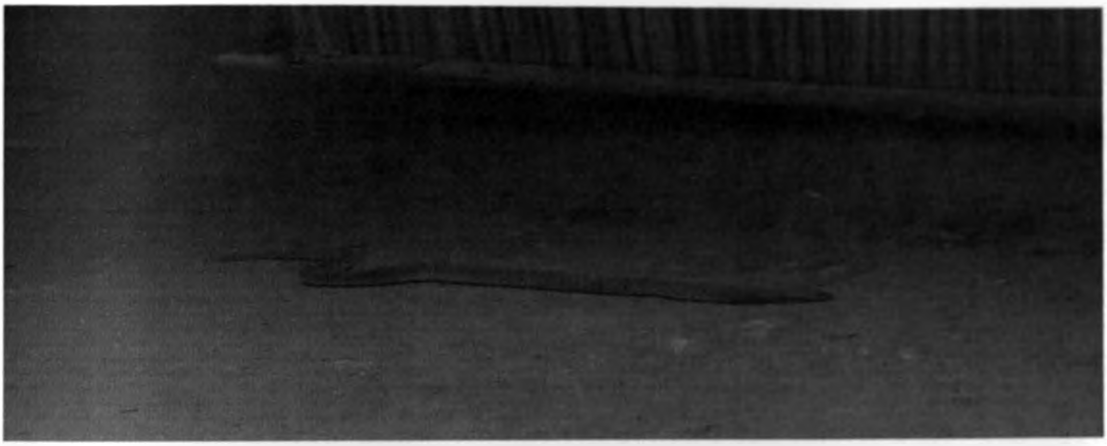

Plate 3.7: ***Causus resimus*** **recorded in Mchelelo West forest**

Plate 3.8: ***Chamaeleo roperi*** **recorded in Shakababo forest**

Plate 3.9: Searching for herpatofauna

Plate 3.10: ***Dasypeltis medici*** **found in between rooting log in Mchelelo West**

3.3.2 Night belt transect sampling

Standard size rectangular (200 x 100m) plots (Heyer *et. al.*, 1994) were systematically established in each study site. Starting from randomly selected points, walks were made recording all species found within a belt of 1m on either side of and above the transect line (Plate 3.12). A team of two persons working for two hours per search night (4 man-hours) made three visits to each site between 6.30 and 8.00 pm.

Plate 3.11: Sampling along the edge of an oxbow lake

3.3.3 Opportunistic visual encounter survey

This sampling method described by Karns (1986) and Heyer *et. al.*, (1994) was used to generate species lists and to determine relative abundance as well as habitat use. In this method sample habitats were selected and searched for two hours in three visits. No spatial boundaries were set other than staying within the study habitat.

3.3.4 Pit fall traps with drift fence

This trapping technique was employed as described by Karns (1986), Heyer *et. al.*, (1994) and Sutherland (1996). A 5 bucket array of X- shape trap was set within each plot. The traps consisted of 10 litre plastic buckets dug in flush with ground surface. Holes were punched at the bottom of the buckets to drain rain or flood water. A plastic drift fence 50cm in height and 5m from each bucket were erected, with approximately 10 cm of the plastic buried into the ground (Plate 3.12). One and half metre stakes were used to anchor the fence. The artificial barrier (drift fence) intercepted herpetofauna moving through the surface and directed them towards the traps along the barrier. Herpetofauna that fell in were trapped. Two arrays of traps were set up in each selected forest fragment during the dry and wet seasons for six days in each fragment and checked daily before 07.30 hours.

Plate 3.12: Pit fall traps (see arrows) with drift fence

3.3.5 Specimen collection, preservation and identification

Amphibians and reptiles were immobilized and collected using a variety of methods. For capturing amphibians, a scoop net as well as hand capturing were employed. Non-venomous snakes were caught using tongs (Gentle Giant Tong – pro line) and put into cotton cloth bags. Venomous snakes were observed. Specimens were killed using chloroform/chlorobutanol solution, and then fixed with 4% formalin. Specimens that identification could be determined in the field were released. Nevertheless some specimens were retained for identification in the laboratory by the use of taxonomic keys. Amphibian and reptile guides, such as; Branch, 1988; Channing and Howell, 2006; Spawls *et. al.,* 2002, were used. To confirm these identification, consultation with herpetologists and herpetological reference collection at the National Museums of Kenya were also done.

3.4.0 Habitat Sampling Techniques

Habitats were characterized using several variables that were recorded at three sample plots (sizes 25m x 25m) established in each selected forest fragment, starting from outside the forest, at the edge of the forest and 50 m from the edge of the forest.

3.4.1 Tree density

A Quadrat sampling sechnique was adopted to determine tree densities for the three forest fragments selected (Cox, 1990). Density refers to the number of individuals per unit area (Cox, 1990). One sample sub-plot (sizes 10 x 10m) was randomly established in each sample plot in the selected forest fragment. The numbers of individual trees were counted in each sub-plot. Trees with rooted bases lying more than halfway inside the boundary were counted as if they lay completely inside, and plants lying more than halfway outside were completely excluded.

3.4.2 Leaf litter cover

Leaf litter cover was sampled using a quadrant of 0.5m x 0.5m from five points (at the four corners and centre) within the three sample plots in each sampling site. Collected litter content was separated, dried and weighed using a digital scale - Precisa BJ 210C (Maximum weight of 210g and 0.01g accuracy) to estimate leaf litter cover.

3.4.3 Percent canopy cover

Canopy cover was estimated using a digital camera viewfinder (Plates 3.14). Estimations were made from the centre of the sample plots in each sampling site.

Plate 3.13: Percent canopy cover (95%) inside Mchelelo West forest

3.4.4 Percent vegetation cover

Estimates were made at the centre of each sample plot in each sampling site using a digital camera viewfinder. Plate 3.15 below shows percent vegetation cover estimates for Mambo Sasa forest fragment.

Plate 3.14: Percent vegetation cover (95%) inside Mambo Sasa forest

3.4.5 Soil moisture

An estimation of the soil moisture (up to 5cm deep) of the selected forest fragments was done during the dry and wet season. This estimation was given three categories; given 1 score if the soil substrate was dry, 2 scores if the soil substrate was moist and 3 scores if the soil substrate was wet.

3.4.6 Ambient temperature

Both soil and air temperatures were taken (at 10.00 am) using a thermometer, in the entire sample plots established both during the dry and wet season.

3.4.7 Soil pH

Nine soil samples were taken (at 5cm depth) from each sample plot in all the sampling sites to determine soil pH. Samples of the soil were crushed to break clumps, and closed in a jar filled with distilled water. After some vigorous shaking samples were left for 5 to 10 minutes to let all soluble substances to dissolve. Then pH of the solution above sediment was measured using a portable microcomputer pH meter (HI 9024).

3.4.8 Estimation of forest disturbance

Disturbance assessment in the forest fragments was given three categories: Low: Given 1 score if the disturbance variable was low; moderate: given 2 scores if the disturbance variable was moderate and high: given 3 scores if the disturbance variable was high. The following variables were measured to determine the level of disturbance.

The number of tree stumps and invasive species were counted in each of the three plots (25m x 25m) established for time limited searches. Their densities were calculated and given three categories: Given 1 score if the density was 0-1 tree stump/invasive species per 25 m^2: Given 2 scores if the density was 2-3 tree stump/invasive species per 25 m^2: Given 3 scores if the density was 4-5 tree stump/invasive species per 25 m^2.

The area disturbed by fire and agriculture activity (cleared for cultivation/cultivation) that occurred within the same plots (25m x 25m) were measured. They were given three categories: Given 1 score if 0-33% of plot was burned or cultivated: Given 2 scores if 33% - 66% of plot was burned or cultivated: Given 3 scores if 66% - 100% of plot was burned or cultivated. Livestock numbers grazing in the sampling area were also recorded and their densities calculated using the same plots (25m x 25m). Their densities were also given three categories: Given 1 score if the livestock density was 0-5 animals per 25 m^2: Given 2 scores if the livestock density was 6-10 animals per 25 m^2: Given 3 scores if the livestock density was 11-15 animals per 25 m^2.

3.5 Questionnaire Survey

Questionnaires were used to assess attitudes and perceptions of local communities in the study area (Appendix 8). People were interviewed at each of the three selected forest sites (Appendix 8).

3.6.0 Data Analysis

The herpetofauna and habitat characteristics data were entered into Excel spreadsheets and analysis done using SPSS (student version 12.0) software, STATISTICA (version 6.0), PAST (version 1.36) software and Microsoft Office Excel 2003.

3.6.1 Habitat characteristics

Habitat variables data was log-transformed and arcsine-transformed as appropriately to achieve normality before analysis. ANOVA (One way) was used to determine significant differences in the means of habitat characteristics within sites and among the forests.

3.6.2 Herpetofauna species richness, abundance and diversity

Herpetofauna abundance was expressed in terms of individuals observed and identified. Species richness and diversity indices were computed for amphibian and reptile species recorded in each of the three forests selected. Comparisons were illustrated by two ecological indices:

3.6.2.1 Species richness (S)

The simplest measure of species richness is the total number of species (S) present in a sample of individuals in an area. However, since sample size frequently varies, S can only be used as a crude measure of community species richness. The total numbers of species recorded were used as a measure of species richness.

3.6.2.2 Shannon-Wiener's diversity index (H^1)

This index is dependent upon species richness (number of species), and evenness (number of individuals in each species in the same sample). Shannon-Wiener's Index of diversity is sensitive to either rare or common species (Zar, 1996).

$$H' = -\Sigma\,(Pi)\,(\log Pi)$$

Where H' is the index of species diversity.

Pi is the proportion of the i^{th} species in the sample

Two sample t-test was used test for differences in the mean herpetofauna species richness, abundance and diversity between the dry and wet seasons, while one way ANOVA was used to test among three forests. Herpetofauna data were log-transformed to approximate normal distribution before analysis.

3.6.3 Relationship between herpetofauna and habitat characteristics

Regression ANOVA was used to assess the relationship between habitat variables, and herpetofauna species richness, abundance and diversity.

3.6.4 Cultural significance and threats to amphibians and reptiles

To test for statistical differences in the median responses of cultural significance and threats to herpetofauna Kruskal-Wallis test was used. Data were ranked before analysis.

CHAPTER FOUR

4.0 RESULTS

4.1.0 Detailed description of the forest fragments

Three forest fragments selected for the study of both herpetofauna and habitat characteristics (Mchelelo West, Shakababo and Mambo Sasa) had the following characteristics.

4.1.1 Size

The forest fragments studied varied in size from 17 to nearly 3937.6 ha (Appendix 1). However, there were open patch spaces with herbs, shrubs or secondary forest or cultivated. Tall trees were scattered in the unprotected forest fragments compared to the protected. The forest's sizes showed gradual reduction because of clearing for settlements and shifting agriculture.

4.1.2 Leaf litter cover

There was an increase in leaf litter content from outside to the inside of forests. However, Mchelelo West had the highest leaf litter cover followed by Mambo Sasa and Shakababo respectively (Appendix 1). There was significant difference in the mean leaf litter cover within sites in the forests (One way ANOVA: $F_{1, 2} = 266.75$, $p < 0.05$, table 4.1). These forest sites were subjected to different levels of disturbance that might have led to difference in loss of leaf litter cover. Disturbance decreased from outside to the inside of the forests.

Table 4. 1: One way ANOVA test of habitat variables within sites in the forests

Habitat characteristics	*F*-value	df	*P*-value
Leaf litter cover	266.75	2	0.000005
Percent canopy cover	9.705	2	0.0207
Soil pH	995.65	2	0.000001
Tree density	11.003	2	0.016
Temperature	1128.13	2	0.000001
Percent vegetation cover	169.15	2	0.000013

However, there was no significant difference in the mean leaf litter cover (One way ANOVA: $F_{2,6} = 0.018, p > 0.05$) among the forests (table 4.2).

Table 4. 2: One way ANOVA test of habitat variables among forests

Habitat characteristics	*F*-value	df	*P*-value
Litter cover cover	0.018	6	0.98
Percent canopy cover	0.699	6	0.53
Soil pH	1.341	6	0.33
Tree density	0.728	6	0.52
Temperature	0.871	6	0.45
Percent vegetation cover	1.500	6	0.52

4.1.3 Percent canopy cover

There was also an increase in canopy cover from outside to the inside of forests. Mchelelo West had the highest canopy cover followed by Mambo Sasa and Shakababo respectively (Appendix 1). There was significant difference in the mean percent canopy cover within sites in the forests (One way ANOVA: $F_{1,2} = 9.705$, $p < 0.05$, table 4.1). Protected forests had more closed canopies compared to the unprotected, which were open due to disturbance. However, there was no overall significant difference in the mean percent canopy cover (One way ANOVA: $F_{2,6} = 0.699$, $p > 0.05$) among the forests (table 4.2).

4.1.4 Soil moisture content

Soil moisture content increased from outside to the inside of forests. Mchelelo West had the highest soil moisture content followed by Mambo Sasa and Shakababo respcetively (Appendix 1). Shakababo had high loss of soil moisture content due to its openness.

4.1.5 Soil pH

There was an increase in soil acidity from outside to the inside in Shakababo and Mambo Sasa forests. Shakababo had the highest soil acidity followed by Mambo Sasa and then Mchelelo West respectively (Appendix 1). There was significant difference in the mean soil pH within sites in the forests (One way ANOVA: $F_{1,2} = 995.65$, $p < 0.05$, table 4.1) above. However, there was no significant difference in the mean soil pH (One way ANOVA: $F_{2,6} = 1.341$, $p > .05$, table 4.2) among the forests.

4.1.6 Tree density

Tree density increased from edge to the inside of the forests. Forests openness decreased from inside to edge. Mchelelo West had the highest tree density followed by Mambo Sasa and Shakababo among all sites (Appendix 1). There was significant difference in the mean tree density within sites in the forests (One way ANOVA: $F_{1,2} = 11.003$, $p < 0.05$, table 4.1). Tree density was highest in protected forests. There was no significant difference in the mean tree density (One way ANOVA: $F_{2,6} = 0.728$, $p > 0.05$, table 4.2) among the forests.

4.1.7 Temperature

Temperature assessed during both the dry and wet seasons decreased from outside to the inside of forests. However, Shakababo had the highest temperature followed by Mambo Sasa and then Mchelelo West respectively (Appendix 1). There was significant difference in the mean temperature within sites in the forests (One way ANOVA: $F_{1,2} = 1128.13$, $p < 0.05$, table 4.1). However, there was no significant difference in the mean temperature (One way ANOVA: $F_{2,6} = 0.871$, $p > 0.05$, table 4.2) among the forests.

4.1.8 Percent vegetation cover

Percent vegetation cover increased from outside to the inside of forests. Mambo Sasa had the highest vegetation cover followed by Mchelelo West and Shakababo respectively (Appendix 1). There was significant difference in the mean percent vegetation cover within sites in the forests (One way ANOVA: $F_{1,2} = 169.15$, $p < 0.05$, table 4.1). However, there was no significant difference in the mean percent vegetation cover (One way ANOVA: $F_{2,6} = 1.500$ $p > 0.05$, table 4.2) among the forests.

4.1.9 Forest disturbance

Disturbance decreased from the outside of the forest to the inside. Shakababo had a higher disturbance level as compared to Mchelelo West and Mambo Sasa (Appendix 1).

4.2.0 Herpetofaunal Community

A total of 2181 individuals of herpetofauna species were recorded in eight forest fragments in lower Tana River forests. The number of species, the number of individuals per species and individuals in all the forest fragments are shown in appendix 2. The herpetofauna comprised amphibians (19 species) and reptiles (37 species). The amphibians belonged to 5 families and 10 genera while the reptiles belonged to 12 families and 27 genera (table 4.3). The taxonomic profile of the herpetofauna is also provided. A single species was recorded in the Order Crocodylia and Cheloniae (Testudinata) with substantial number in the orders Anura and Squamata (Lacertilia and Serpentes) (table 4.3). Amphibians were most abundant in all forest fragments compared to reptiles, except in Guru South where lizards were the most abundant species. Snakes were the least abundant in all the forest fragments compared to amphibians and other reptiles. Amphibians accounted for 33.9% and lizards, snakes, tortoises and crocodiles accounted for 33.9%, 28.6%, 1.8% and 1.8% in all the forests respectively of herpetofauna sampled (table 4.3).

Table 4. 3: Taxonomic profile of herpetofauna species detected in the lower Tana River forests

Taxon rank	Family	Genera	Species	Species (%)
Order Anura	5	10	19	33.9
Order Testudinata	1	1	1	1.8
Order Squamata				
Sub-order Lacertilia	6	11	19	33.9
Sub-order Serpentes	4	14	16	28.6
Order Crocodylia	1	1	1	1.8
Total	17	37	56	100

4.2.1 Amphibian species abundance, richness and diversity

Comparison of amphibian species abundance during the wet and dry seasons showed that abundance was highest in wet season as compared to dry season in all forests (Appendix 2). There was no significant difference in the mean amphibian species abundance between the dry and wet season in Mchelelo West (Two sample t-test: $t = 0.52$, $p > 0.05$), Shakababo ($t = 0.329$, $p > 0.05$) and Mambo Sasa ($t = 0.604$, $p > 0.05$) table 4.4. Amphibians were most abundant in Mambo Sasa, and Mchelelo West compared to reptiles. Amphibians were also more abundant compared to reptiles in shakababo (Appendix 2).

Table 4. 4: T - test of amphibian species abundance and diversity between dry and wet seasons

Forest		n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	t - value	df	P - value
Mchelelo								
West	Abundance	8	11	22.62	18.54	0.520	17	0.609
	Species diversity	8	11	0.1599	0.082	1.265	17	0.222
Shakababo	Abundance	7	10	8.850	7.800	0.329	15	0.746
	Species diversity	7	10	0.101	0.088	0.4816	15	0.637
Mambo Sasa	Abundance	12	12	17.58	22.166	0.604	22	0.552
	Species diversity	12	12	0.074	0.075	0.097	22	0.923

There was no significant difference in the mean amphibian abundance (One - way ANOVA: $F_{2, 32} = 1.59, p > 0.05$) among the forests (table 4.5).

Table 4. 5: One way ANOVA test of herpetofaunal variation in abundance and diversity among forests

Herpetofauna		F - value	df	P - value
Amphibians	Abundance	1.590	32	0.219
	Species diversity	0.438	32	0.649
Lizards	Abundance	0.252	28	0.779
	Species diversity	1.676	28	0.205
Snakes	Abundance	13.54	13	0.0007
	Species diversity	112.3	13	0.00001

The number of amphibian species was higher during wet than the dry season in all the forests. However, the highest number of amphibian species was recorded in Mambo Sasa (S=475), followed by Mchelelo West (S=385), while Shakababo(S=140) had the least (Appendix 2).

Amphibian species diversity calculated using Shannon-Wiener Index (H') showed variation in both seasons. There was higher amphibian diversity in the wet than dry season in all forests (Appendix 2). However, there was no significant difference in the mean amphibian species diversity between the dry and wet season in Mchelelo West (Two sample t-test: $t = 1.265$, $p > 0.05$), Shakababo ($t = 0.4816$, $p > 0.05$) and Mambo Sasa ($t = 0.097$, $p > 0.05$) table 4.4.

Mambo Sasa had the highest amphibian diversity (H' = 0.92731) followed by Mchelelo west (H' = 0.86192) and then Shakababo (H' = 0.84361) respectively (Appendix 2). There was no significant difference in the mean amphibian species diversity (One way ANOVA: $F_{2, 32} = 0.438$, $p > 0.05$, table 4.5) among the forests.

4.2.2 Lizard species abundance, richness and diversity

Abundance of lizard species was higher during wet compared to the dry season in all the forests (Appendix 2). There was no significant difference in the mean lizard species abundance between the dry and wet season in Mchelelo West (Two sample t-test: $t = 0.315$, $p > 0.05$), Shakababo ($t = 0.825$, $p > 0.05$) and Mambo Sasa ($t = 0.709$, $p > 0.05$) table 4.6.

However, the highest abundance was recorded in Mchelelo West followed by Shakababo and Mambo Sasa respectively (Appendix 2). There was no significant difference in the mean lizard species abundance (One way ANOVA: $F_{2, 28}$ =0.252, $p > 0.05$, table 4.5) among the forests.

Table 4. 6: T - test of lizard species abundance and diversity between the dry and wet seasons

Forest		n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	t - value	df	P - value
Mchelelo								
West	Abundance	8	13	7.750	6.38	0.315	19	0.755
	Species diversity	8	13	0.069	0.071	0.0459	19	0.903
Shakababo	Abundance	5	10	3.000	8.600	0.825	13	0.424
	Species diversity	5	10	0.112	0.058	2.080	13	0.057
Mambo Sasa	Abundance	2	3	1.000	7.330	1.542	3	0.221
	Species diversity	2	3	0.151	0.112	0.709	3	0.529

There was also higher lizard species numbers during wet as compared to the dry season in all the forests (Appendix 2). The highest lizard species numbers were recorded in Mchelelo west (S=145). These were followed by Shakababo (S=101) and Mambo Sasa respectively (S= 24) (Appendix 2). Lizard species diversity was also higher in the wet season compared to the dry season in all the forests (Appendix 2). There were no significant difference in the mean lizard species diversity between the dry and wet season in Mchelelo West (Two sample t-test: $t = 0.0459$, $p > 0.05$), Shakababo ($t = 2.080$, $p > 0.05$) and Mambo Sasa ($t = 0.709$, $p > 0.05$) table 4.6.

The highest species diversity (H' = 0.82796) was recorded in Mchelelo west. This was followed by Shakababo (H' = 0.62478), while Mambo Sasa (H' = 0.48623) had the least (Appendix 2). There was no significant difference in the mean lizard species diversity (One way ANOVA: $F_{2,28}$ =1.676, $p > 0.05$, table 4.5) among the forests.

4.2.3 Snake species abundance, richness and diversity

Abundance of snakes was higher in the dry season compared to the wet season in Mchelelo west. There was no significant difference in the mean snake species abundance between the dry season and wet season in Mchelelo West (Two sample t-test: $t = 0.866$, $p > 0.05$), table 4.7. The highest abundance in the wet season was recorded in Shakababo. However, there were no snakes recorded in Shakababo during the dry season and Mambo Sasa in both seasons (Appendix 2). The highest snake abundance was recorded in Mchelelo West (Appendix.2). However, there was significant difference in the mean snake species abundance (One way ANOVA: $F_{2,13}$ = 13.54, $p > 0.05$, table 4.5) among the forests.

Table 4. 7: T - test of snake species abundance and diversity between the dry and wet seasons in Mchelelo West forest

Forest		n_1	n_2	$\bar{x}_1$	$\bar{x}_2$	t - value	df	P - value
Mchelelo								
West	Abundance	6	2	1.16	1.5	0.866	6	0.419
	Species diversity	6	2	0.126	0.138	0.878	6	0.416

The snake species numbers were higher in the dry as compared to wet season in Mchelelo West. Similarly, the highest snake species richness was recorded in Shakababo during the wet season (Appendix 2). The highest snake species numbers were recorded in Mchelelo West (S= 10) followed by Shakababo (S= 5) (Appendix 2).

Snake species diversity was higher in the dry season than wet season in Mchelelo West (Appendix 2). There was no significant difference in the mean snake species diversity between the dry and wet season in Mchelelo West (Two sample t-test: t = 0.878, $p > 0.05$), table 4.7. Mchelelo West had the highest snake species diversity (H' = 0.87958), followed by Shakababo (H' = 0.57355) (Appendix 2). However, there was no significant difference in the mean snake species diversity (One way ANOVA: $F_{2, 13} = 112.54$ $p > 0.05$, table 4.5) among the forests.

4.2.4 Comparison of herpetofauna

Comparing herpetofauna abundance, species richness and diversity in the three forests, the results showed that the highest abundance, species richness and diversity were recorded in Mchelelo West. Abundance was higher in Mambo Sasa than Shakababo, but it was lower in species richness and diversity (Fig. 4.1 and 4.2).

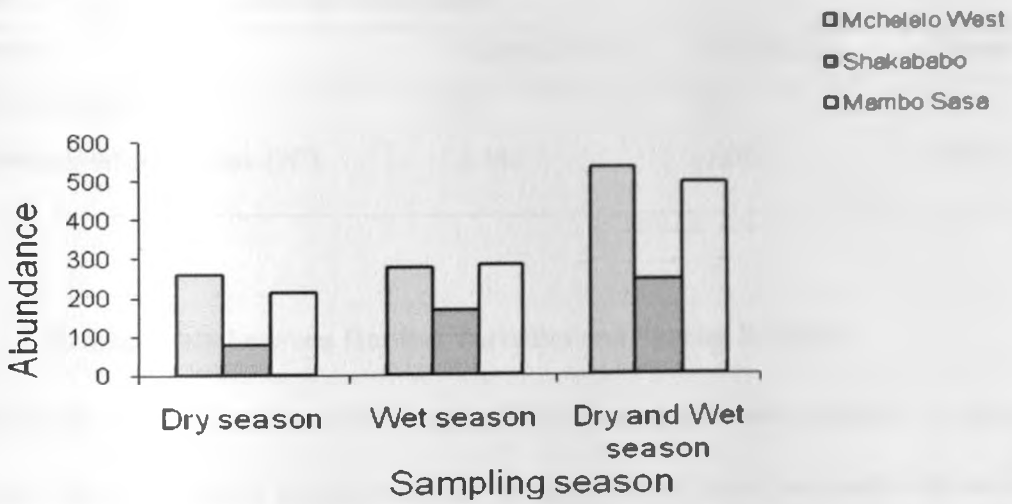

Figure 4. 1: Dry and wet season abundance

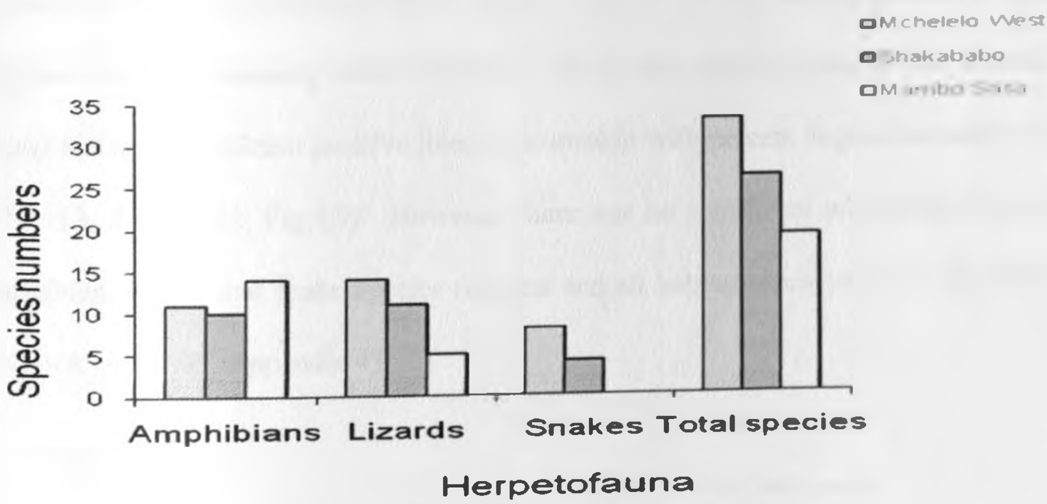

Figure 4. 2: Species richness

Similarly, herpetofauna species diversity in the three selected forest fragments showed that Mchelelo West was the most diverse forest (S=33, H'=1.143). This was followed by Shakababo (S=26, H'=1.081) and Mambo Sasa (S=19, H'=0.099) forests respectively (table 4.9).

Table 4. 8: Overall species richness and diversity

Forests	Mchelelo West	Shakababo	Mambo sasa
Species richness (S)	33	26	19
Shannon-Wiener index (H')	1.143	1.081	0.099

4.3 Relationship between Habitat Variables and Species Richness

Correlation between species richness and habitat characteristics was evaluated by plotting habitat variables against species numbers of amphibians, lizards and snakes separately. All the regression analysis showed weak relationships for habitat variables except lizard species richness (Regression ANOVA: $F_{1,2} = 5.8$, $R^2 = 0.853$) which showed a strong negative linear relationship with forest size. Amphibian species richness also showed a strong but non-significant positive linear relationship with percent vegetation cover ($F_{1,2} = 10.313$, $R^2 = 0.911$, Fig.4.3). However, there was no significant relationship between amphibian, lizard, and snake species richness and all habitat characteristics (Regression ANOVA: $p > 0.05$, Appendix 4).

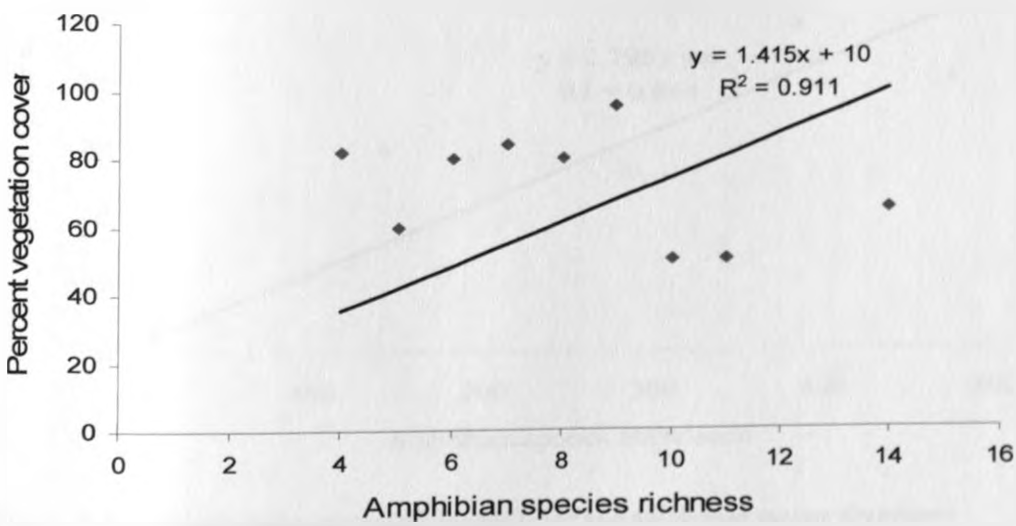

Figure 4. 3: Relationship between percent vegetation cover and amphibian species richness

4.4 Relationship between Habitat Variables and Species Abundance

The relationship between habitat variables and species abundance was evaluated by plotting habitat variables against individual numbers of amphibians, lizards and snakes. All the regression analysis showed weak relationships for habitat variables except for the lizard (Regression ANOVA: $F_{1,2} = 4.8$, $R^2 = 0.828$) and snake species abundance ($F_{1,2} = 9.01$, $R^2 = 0.90$) which showed a strong negative relationship with forest size.

Amphibian species abundance also demonstrated a strong positive linear relationship with percent canopy cover ($F_{1,2} = 5.411$, $R^2 = 0.844$, Fig. 4.4), negative for temperature ($F_{1,2} = 7.289$, $R^2 = 0.879$) and positive for percent vegetation cover ($F_{1,2} = 10.06$, $R^2 = 0.909$). However, there was no significant correlation between amphibian, lizard, and snake species abundance and habitat variables (Regression ANOVA: $p > 0.05$, Appendix 5).

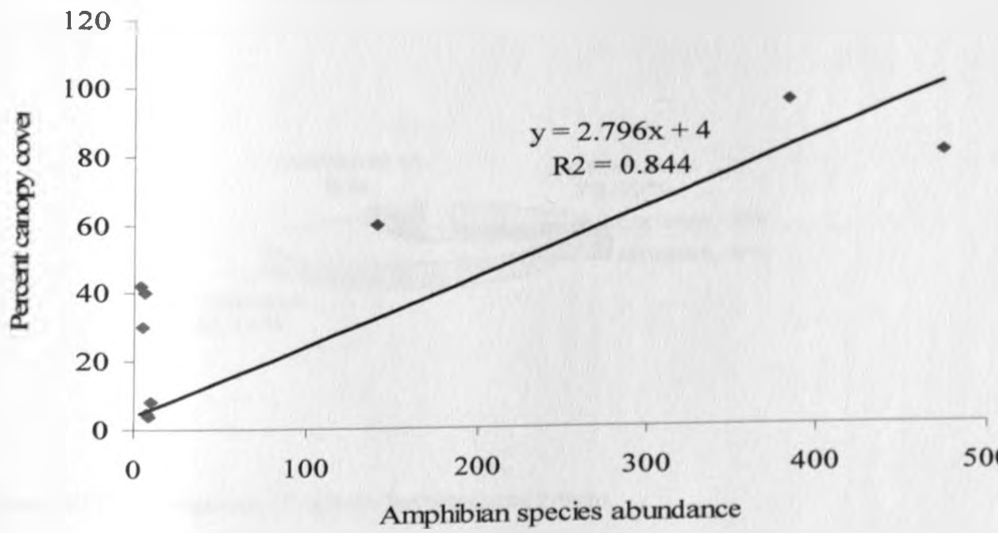

Figure 4. 4: Relationship between percent canopy cover and amphibian species abundance

4.5 Relationship between Habitat Variables and Species Diversity

Relationship between habitat variables and species diversity was also determined by plotting habitat variables against species diversity of amphibians, lizards and snakes. Regression analysis showed weak relationships for habitat variables except amphibian species diversity that exhibited a strong positive linear relationship with percent vegetation cover ($F_{1, 2} = 6.311$, $R^2 = 0.863$). There was no significant relationship between amphibian, lizard, and snake species diversity and habitat characteristics (Regression ANOVA: $p > 0.05$, Appendix 6).

4.6.0 Cultural Significance and Threats to Amphibians and Reptiles

4.6.1 Herpetofauna utilization

Majority of the respondents (67%) ranked crocodiles as their first important herpetofauna for utilization. Other herpetofauna utilized were amphibians (21%), lizards (3%), snakes (3%) and chameleons (6%) respectively (Fig. 4.5).

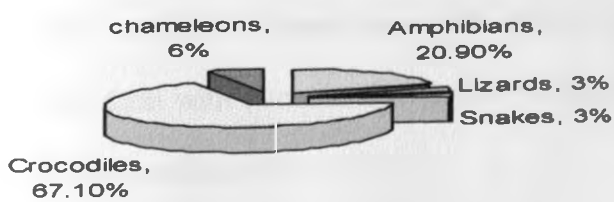

Figure 4. 5: Percentage use of various herpetofauna groups

Evaluation of the uses of various herpetofaunal species revealed that majority of the respondents (37.1%) ranked food as their first and preferred use for herpetofauna followed by trade (26%), cultural use (26%) and others (11%) (Fig. 4.6).

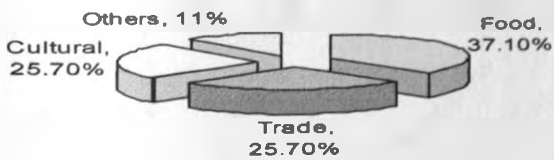

Figure 4. 6: Different uses of herpetofauna in lower Tana River forests

There was no significant difference in the responses of herpetofauna group utility for food, trade, culture and other purposes in the three forests (Kruskal-Wallis test: H = 3.54, $p > 0.05$, Appendix 7).

4.6.2 Herpetofauna habitats

The local community associated herpetofauna with various habitats. 38% of the respondents associated them with forests and 34% with wetlands while 28.5% believed that herpetofauna lived in bushlands (Fig. 4.7).

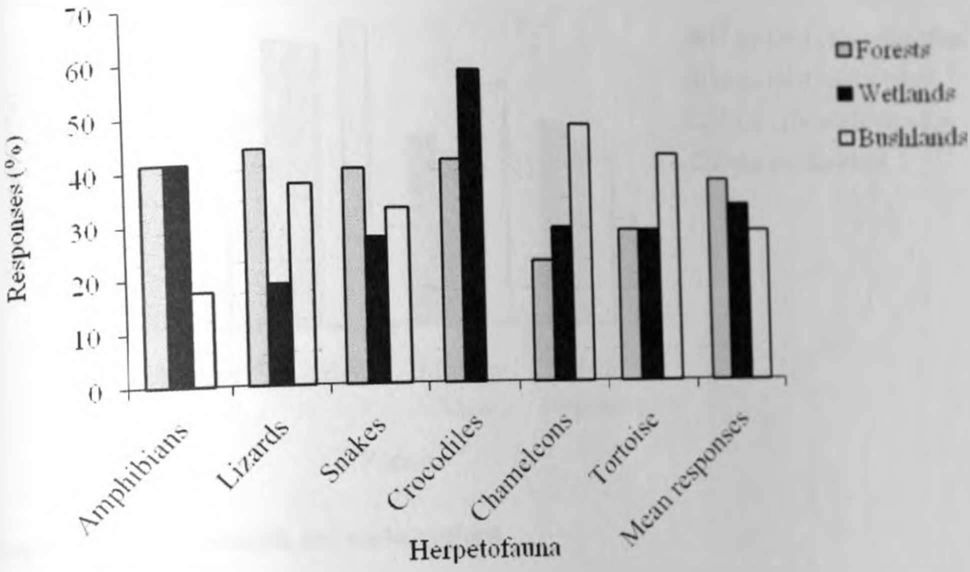

Figure 4. 7: Distribution of herpetofauna in various habitats

However, there was no significant association between the herpetofauna groups and the three habitats (Kruskal-Wallis test: $H = 1.003$ $p > 0.05$, Appendix 7).

4.6.3 Human-crocodile and snake conflicts

Analysis of the respondents showed that there were conflicts between the community and reptiles (especially snakes and crocodiles) in the study area. According to the respondents, conflicts were linked to attacks that lead to injury and death of people and livestock and this varied between forest fragments. Most non-fatal crocodile attacks (43%) were reported in Lake Shakababo area. Similarly, most non-fatal snake bites (42%) and deaths due to fatal bites by venomous snakes (45%) and non-fatal crocodile attacks (35%) were also reported from Shakababo area. Nevertheless, incidents of snake bites and crocodile attacks were reported in each forest (Fig. 4.8).

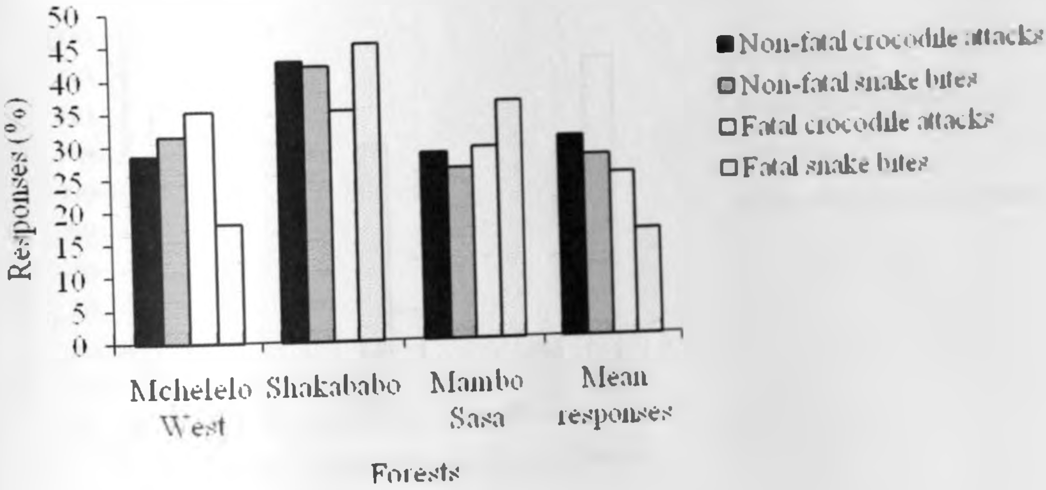

Figure 4. 8: Human-crocodile and snake conflicts

There was significant difference in the number of human-herpetofauna conflicts among forests (Kruskal-Wallis test: H = 7.423, $p < 0.05$, Appendix 7).

4.6.4 Perception of the community to the herpetofauna

To assess the perception of people to the herpetofauna, responses were categorized as; (a) enemy and dangerous (negative), (b) indifferent (neutral), and (c) friendly and harmless (positive). Most of the respondents (69%) had positive attitude towards amphibians. Chameleons were least appreciated with 71% of the respondents showing indifference or neutral perception. Snakes were negatively perceived by 83% of the respondents. While 93% of the local land owners were willing to tolerate amphibians, none were willing to share their land with snakes (Fig. 4.9).

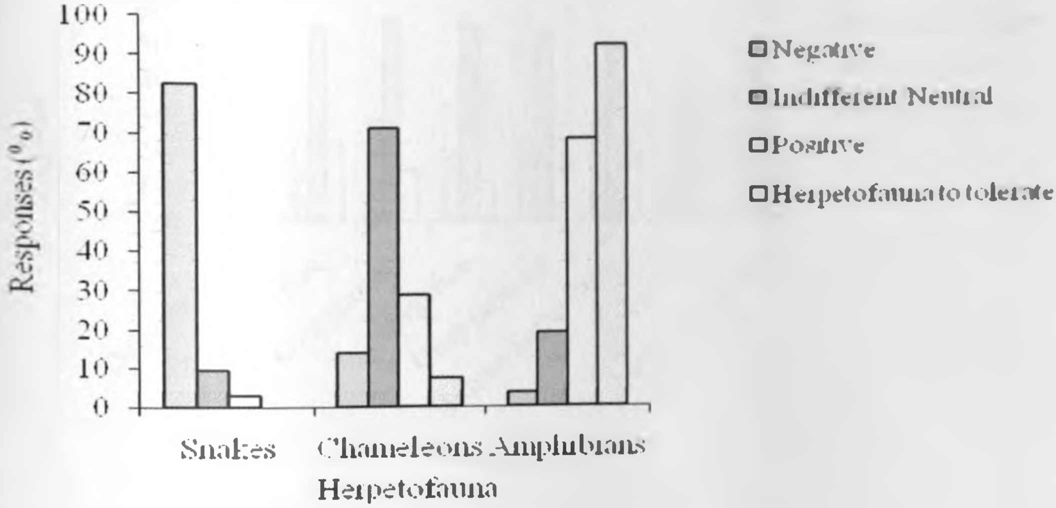

Figure 4. 9: Community perception of snakes, chameleons and amphibians

There was no significant difference in the median responses of community perception of snakes, chameleons, and amphibians (Kruskal-Wallis test: $H = 0.115$, $p > 0.05$, Appendix 7).

4.6.5 Threats to herpetofauna

Evaluation of the major disturbance activities threatening amphibians and reptiles indicated that 19%, 18% and 15% of the respondents ranked deforestation, human population pressure and crop farming respectively as the most threatening factors to herpetofauna habitats (Fig. 4.10). Fig. 4.10 also indicates that 51%, 26% and 23% of the respondents ranked Shakababo, Mchelelo West and Mambo Sasa respectively most threatened by disturbances that lead to herpetofauna habitat change.

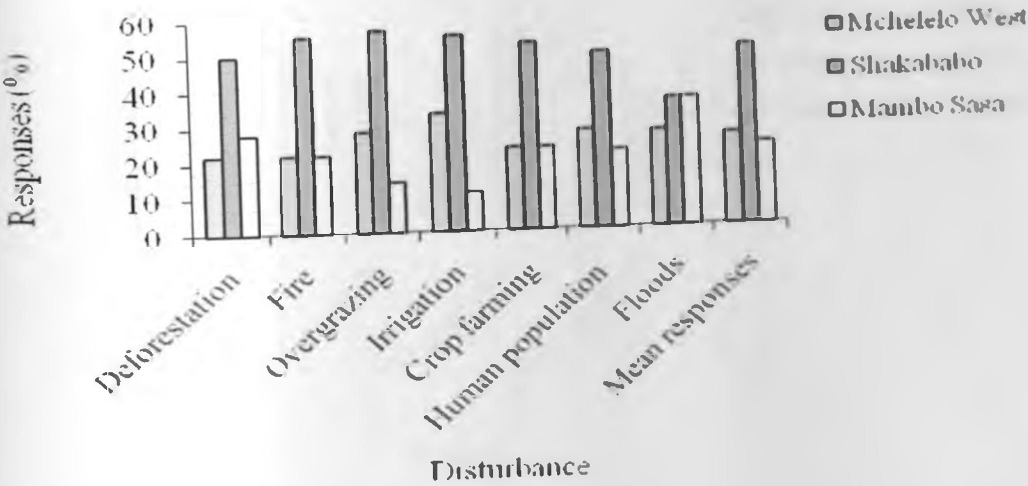

Figure 4. 10: Activities of habitat disturbances

There was significant difference in the median responses about high impact disturbances among the forests (Kruskal-Wallis test: H = 13.38, $p < 0.05$, Appendix 7).

4.6.6 Conservation and sustainable use of herpetofauna

Evaluation of traditional methods of conserving herpetofauna ranked important measures as: conserving forests (39%), wetlands (32%) and educating the community (30%) respectively. In Mambo Sasa and Mchelelo West, 47% and 44% respectively, preferred conserving wetlands and educating the community as the best strategies to conserve herpetofauna in the study area (Fig. 4.11).

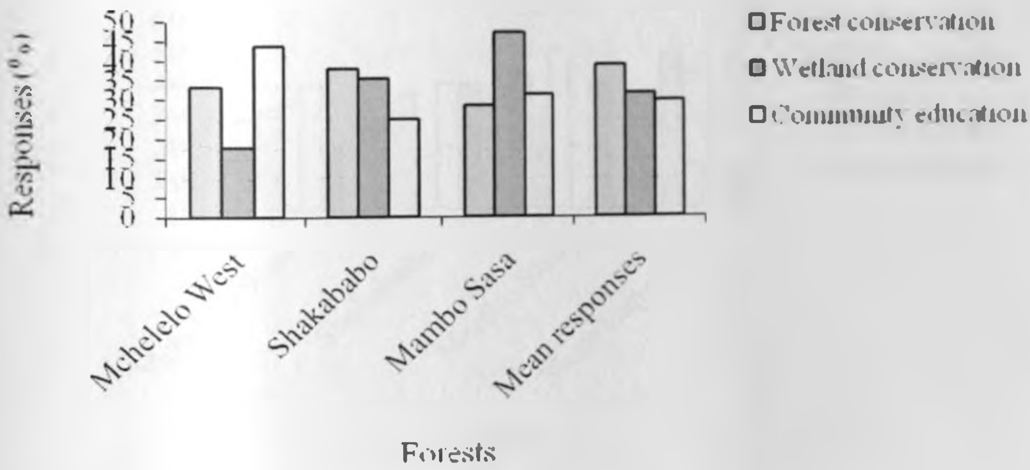

Figure 4. 11: Ranking of strategies to conserve herpetofauna

There was no significant difference in the responses of traditional strategies for conserving herpetofauna among the forests (Kruskal Wallis test: H = 0.089, $p > 0.05$, Appendix 7).

Analysis of the community responses showed that crocodile farming would be a principal activity by the community if given wildlife user rights by the government. The community preference for crocodiles was highest (49%) while chameleons (11%) and amphibians (11%) were less preferred (Fig. 4.12).

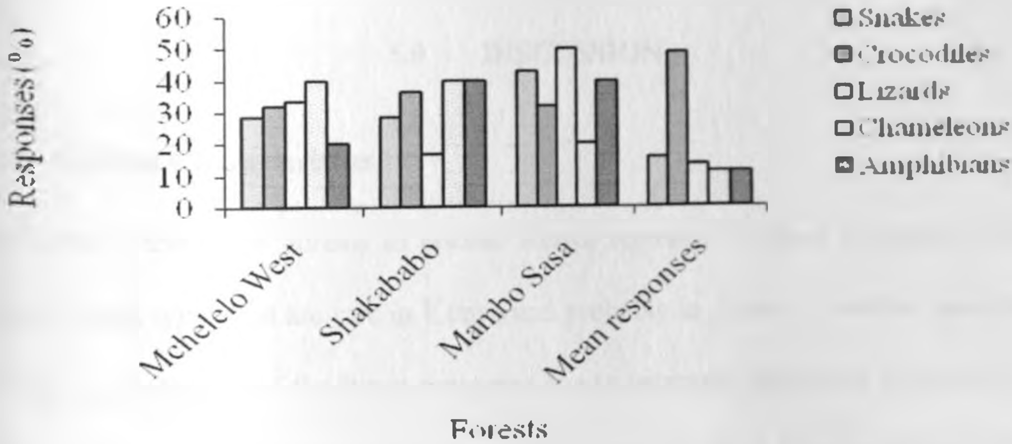

Figure 4. 12: Herpetofaunal group to target if the community is given wildlife use rights

There was no significant difference in the responses of ranking herpetofaunal group to be targeted by the community if given wildlife user rights (Kruskal-Wallis test: ($H = 2.015$, $p > 0.05$, Appendix 7).

CHAPTER FIVE

5.0 DISCUSSION

5.1.0 Habitat Characteristics

The Lower Tana River forests in coastal Kenya represent lowland evergreen riverine tropical forest types that are rare in Kenya and probably in Africa. Over the years, there has been a greater use of the forest resources due to increased population (Owino, *et. al.*, 2008). Habitat characteristics in the protected forests (Mchelelo West and Mambo Sasa) measured high values in leaf litter cover, percent canopy cover, soil moisture content, tree density, percent vegetation cover, and low values in disturbance level, temperatures and acidic soils. However, such habitat characteristics measured contrary in the unprotected forest patch (Shakababo) (Appendix 1). These forests also varied in sizes and altitude (table 3.1).

The results also show that all habitat characteristics measured differed significantly within the sites (table 4.1). All the forests were utilized differently for resources and these could have led to the significant differences in habitat characteristics within their sites. There emerged a common trend where leaf litter cover, percent canopy cover, soil moisture content, tree density and percent vegetation cover increased from outside to the inside of forest fragments. This could be probably because disturbance and openness of the forests increased from inside to the outside (Appendix 1). However, habitat characteristics did not differ significantly across the three forests (table 4.2). This could suggest that most forest patches had suitable habitats that ensured availability of food and protective cover for the herpetofauna species.

Given the current human population growth trends in the lower Tana River River area, the demand for forest products will increase tremendously in the future (Bennun and Njoroge, 1999). Measures of habitat characteristics also suggested that all forests were experiencing different levels of human disturbance, and indicated variability. The protected forests showed minimal disturbance. However, Shakababo, which was unprotected, had been disturbed for a long time through exploitation for its valuable tree species (Appendix 1).

5.1.1 Changes in herpetofauna community

The lower Tana River herpetofauna described here was collected between altitudes of 13 – 46 m above sea level. A total of 2181 individuals accounting for 56 species, comprising 19 amphibians (Anura), and 37 reptiles (19 lizards, 1 crocodile, 16 snakes, 1 tortoise) were recorded. However, seven expected amphibian species (*Arthroleptis stenodactylus, Phrynobatrachus natalensis, Mertensophryne micranotis, Hemisus marmoratus, Hyperolius tuberrilinguis, H. acuticeps* and *Leptopelis concolor*) and seventeen reptile species (*Lygosoma sundevalli, Lygodactylus keniensis, Hemidactylus ruspolii, Agama agama, Gerrhosaurus flavigularis, G. major, Hemidactylus barbouri, Aparallactus guentheri, Naja pallida, Dendroaspis polylepis, Hemirhagerrhis kelleri, Lamprophis fuliginosus, Lycophidion capensis, L. depressirostre, Dasypeltis medici, Letheobia unitaeniatus* and *Psammophis sudanensis*) were recorded for the first time in this region.

Twenty-six individuals of *Hyperolius argus* were recorded and some collected near water pools around Shakababo and Mambo Sasa forests during the wet season. This is the second record in the north coast after a single specimen was collected in Kipini in 2000 (Malonza *et. al.*, 2006) on the delta forest.

A number of amphibians and reptiles that may be present in the region were not detected during the current study. Caecilians could be found through active digging in suitable micro-habitats. Amphibians were more abundant than reptiles in all forest fragments sampled except Guru south which recorded lizards as the most abundant species. The most abundant amphibian species were *Ptychadena anchieta* and *Phrynobatrachus acridoides* while *Afrixalus fornasini, Leptopelis concolor* and *Hyperolius acuticeps* were infrequently encountered. This study yielded 56 herpetofaunal species. A comparison with the previous work by Malonza *et. al.*, (2006), yielded 48% more species, though their survey was restricted to the forests in the TRPNR. Chira (1993) also recorded 49 species in Arabuko-Sokoke and Gede coastal forests of Kenya. The high species richness and abundance suggest that these forests are stable habitats in terms of the diverse requirements of herpetofauna such as food, shelter and diversity of microhabitats.

Most amphibians depend on relatively moist conditions and need water in which to deposit eggs and for the successful development of larvae and in this case, majority of amphibians are seasonal breeders during the wet periods (Channing and Howell, 2006). This could probably explain the change in amphibian species abundance, richness and diversity over the sampling period, where it was higher during wet season than dry season (Appendix 2).

The highest amphibian species numbers, abundance and diversity were recorded in Mambo Sasa followed by Mchelelo West and Shakababo respectively (Appendix 2).

The edge of a forest patch provides a different environment from the forest interior, typically having greater light availability and higher temperatures (Turton and Freiburger, 1997). However, the altered microclimate of the edge has been found to be unsuitable for some species, while promoting an increased abundance of others (Turner, 1996). In this study most amphibians were found in moist microhabitats especially under rotting logs, leaf litter cover, thick green vegetation cover and wetlands. They were less common outside the forests where it was open with high temperatures and low soil moisture. This could be the reason why there was low amphibian abundance and diversity in Shakababo which was open with high temperatures and low soil moisture. Most of the lizards were recorded on the ground and on trees of the sandy forest edges. Others were found basking in sunny spots, on tree bark and rotting logs in the forests. Lizard species such as *Heliobolus spekii* were frequently encountered while others such as *Gerrhosaurus major*, *G. flavigularis* and *Hemidactylus barbouri* were infrequently encountered. The highest lizard species richness, abundance and diversity were also recorded during the wet season. Lizard species richness, abundance and diversity were highest in Mchelelo West followed by Shakababo and Mambo Sasa respectively (Appendix 2).

Reptiles are very secretive, they move away as humans approach and many live in places one would never think of looking (Spawls *et. al.*, 2002). In this study, snakes were the least abundant in comparison to all other herpetofauna in all forest fragments.

They were also found burrowing under or between spaces on the rotting logs which were moist with low temperatures. Others were found early in the morning basking on the sides and top of bushes. All snakes were infrequently encountered. The highest snake species richness, abundance and diversity were recorded in Mchelelo West followed by Shakababo. No snakes were recorded in Mambo Sasa (Appendix 2). It was difficult to locate reptiles in Mambo Sasa due the high vegetation cover, canopy cover and leaf litter cover but easy in Shakababo forest as it was open.

Generally, the loss and fragmentation of natural habitat rank among the most severe threats to biodiversity (Owino, *et. al*., 2008). For most organisms, such habitat changes represent significant threats to ecosystem sustainability, and have direct implication on the quality of habitats on which the organisms depends (Davis, 2004, Githiru and Lens, 2007). According to Wasonga (2003), human activities or natural influences have a profound influence on amphibian abundance and diversity. In this study, it was observed that Mchelelo West forest had the highest diversity possibly because it is the most protected forest (Mchelelo west forest is in the TRPNR under the Kenya Wildlife Service (KWS) and had suitable habitats. This forest patch had received minimal disturbance and in order to keep and preserve its diversity, it is necessary to improve its protection status.

The fragmentation of forest cover has profound ecological significance. Small populations in fragmented forests run much greater risks of reduced reproduction, genetic deterioration and extinction (Nason and Hamrick, 1997). Forest fragments are also vulnerable to fire, invasion by weedy species, and other process of habitat erosion (Malcolm and Ray, 2000).

The impact of fragmentation on any given species usually remains hard to assess because some species are edge specialists, or benefit from an increased diversity of habitats, whereas others may not even cross open ground or approach a forest edge (Newmark, 1991). The observed differing distribution with some species occurring in only some patches and not in others could also suggest the sensitivity of those herpetofauna species to such habitat changes.

The isolation of small forest fragments impact the survival of species and therefore depending on the position of the fragment within he landscape mosaic, there can be a reduction and/or prevention of immigration of fauna between patches, limiting colonization of species in other forest patches (Turner, 1996). Studies of tropical forests have shown that many forest species will not cross even relatively small deforested zones (Dale *et. al.*, 1994). However, the persistence of these species in isolated patches strongly depends upon the retention of enough suitable habitats to support the local population (Saunders *et. al.*, 1991). The lower Tana River fragmented forests are also isolated. It is therefore important that a large set of more or less interconnected fragments be maintained under protection.

5.1.2 Influence of Habitat Variables on Herpetofauna

Despite its small size Mchelelo West had the highest diversity and abundance of herpetofauna especially reptile species (lizard and snake species) when compared to the other forests. Mambo Sasa had higher amphibian diversity compared to Mchelelo West, but the difference was not significant.

Lizard and snake species numbers and abundance decreased with increase in forest size. However, Mambo Sasa, which was the biggest in size compared to the other forests, recorded low reptiles. No snakes were found in Mambo Sasa but this didn't necessarily mean they were missing. The habitat was suitable for snakes, though it was difficult to search due the thick vegetation cover. More survey work is needed for snakes in this forest. On the contrary, it was easy to search for reptiles in Shakababo, which had open vegetation cover due to its disturbance. Soil moisture content and temperature were not suitable for the amphibians in Shakababo except near Lake Shakababo which guaranteed availability of retreat sites in periods of moisture stress.

The effects of natural vegetation, especially forest replaced by agricultural crops (disturbances) on amphibian diversity are not yet clear, but available evidence suggests that responses of species to habitat disturbance is not uniform (Poynton, 1999). Both Mchelelo West and Mambo Sasa had characteristics of good habitats considering that they are protected and also judging from their high values of leaf litter content, canopy cover, vegetation cover, tree density and soil moisture content. These forests had high amphibian species richness, abundance and diversity. Wasonga (2003) observed that the least disturbed vegetation community recorded the highest amphibian species richness and diversity, which was also attributed to vegetation diversity as well as heterogeneity of microhabitats. Similarly in this study, amphibian species richness and abundance increased with increase in percent vegetation cover, percent canopy cover (Figs. 4.3, and 4.4) and decreased with increase in temperature and forest disturbance. Amphibian species diversity also increased with increase in percent vegetation cover.

5.1.3 Social-Economic Significance

In recent years a worldwide trade in herpetofauna has developed, and in East Africa thousands of some species have been shipped abroad (Channing and Howell, 2006). The Convention on the International Trade in Endangered Species of wild fauna and flora (CITES) controls the international trade in endangered species and establishes lists of species for which there is a need for monitoring and controlling trade (Channing and Howell, 2006). In this area of study, different herpetofauna groups are used differently by the local people. For instance crocodiles are used as food (meat), eggs sold to crocodile farms, their teeth (burned to ash) used to treat crocodile wounds, their penis used as love potions, bile used to treat AIDS related cancers.

Several authors have cited the utilization of amphibians and reptiles (Patterson, 1987, Pough *et. al.*, 1998, Zug *et. al.*, 2001 and Channing and Howell, 2006). Unfortunately, this utilization for world's luxury food market and pet trade are generally done without regard to local population dynamics leading to depletion of wild populations (Pough *et. al.*, 1998). In this area of study, the most preferred uses for herpetofauna are food, trade and cultural uses.

In some parts of East Africa, the larger species of frogs such as bull frogs (genus *Pyxicephalus*) are eaten (Channing and Howell, 2006). However, this area of study frogs are used as bait for fishing; their burned ash used to treat asthma and also used as indicators of rain. Chameleons burned ash and snake heads are culturally used in witchcraft. Snake ash is also used to make arrow head poison for hunting.

Crocodiles were considered as the most important herpetofauna as they could be farmed and used for food, tourism, trade for their products and used culturally. In this area of study, the utilization of these herpetofauna was not likely to have a serious effect on the species as whole, but could result in the depletion of local populations.

Conflicts between the community and reptiles (especially snakes and crocodiles) were recorded in the study areas and many of them were crocodile-human conflicts and snake-human conflicts. Human behaviour towards animals is influenced by cultural perceptions such that animals that are held in awe are protected and animals associated with evil are often killed (Pough *et. al.*, 1998). Perception responses given by the respondents in this study indicated negative, neutral and positive perception towards snakes, chameleons and amphibians respectively.

In some parts of the world frogs are revered because they are thought to posses supernatural powers. The alternating appearance and disappearance of populations of frogs and their seemingly magical metamorphosis have led to the worship of frogs as symbols of fertility, resurrection, and creation (Pough *et. al.*, 1998).
Similarly, in this area of study majority of the people would tolerate amphibians than chameleons and snakes. The dichotomy of perception is especially strong regarding snakes. They have been a source of fascination and fear for humans and this could be the reason why most people could not tolerate them.

5.1.4 Conservation

The continued forest loss and degradation in the lower Tana River of coastal Kenya represents a conservation challenge. Generally, the forest use within and outside the protected areas is thought to be unsustainable despite the protection status (Owino, *et. al.*, 2008). The forest patches are exploited by the local people mainly for fuel wood, timber, traditional medicines and local brews. Some of these trees targeted for exploitation are important in providing suitable microhabitats for herpetofauna. However, with the increase in human population within and around the protected areas, there is likelihood of unsustainable use.

This study provides essential information, which is needed for conservation actions using herpetofauna as key taxa in the lower Tana River forests. Shakababo and other forest fragments (which had high diversity) that are not protected should be conserved and their resources utilized sustainably. Whatever measures to be taken to conserve the forests, attention should be paid to the needs of the local people. They do not support the idea of protecting the forests for fear of being evicted and relocated to other areas. Therefore, conservationists and research institutions especially the KWS, KFS and non governmental institutions need to address this problem properly in order to win support from the local communities.

Several authors have cited various threats to amphibians and reptiles which result from pressures of human population growth and economic development (Patterson, 1987, Pough *et. al.*, 1998 and Zug *et. al.*, 2001).

Although the forest patches in the reserve are legally protected, they continue to experience human pressures like other patches located outside the reserve (Owino *et. al.*, 2008). The protection status of these forests needs to be improved. Major activities most threatening amphibians and reptiles were indicated as deforestation, human population pressure and crop farming respectively. The variation in the herpetofaunal diversity could have reflected varying levels of disturbance between the protected and unprotected forests. The most threatened habitat was Shakababo and it was the most disturbed forest among the three forest fragments studied.

The effect of fire is quite detrimental to the predominantly ground dwelling herpetofauna. It destroys leaf litter content, ground vegetation and canopy cover, interfering with the soil moisture balance in the ecosystem and eliminating arthropods, the major source of food to amphibians. This also affects the reptiles that feed on the amphibians. In the study area, fire is used to prepare land for cultivation. Large numbers of herbivores are associated with long-term wallowing which can damage resident tadpole communities. Animal wallows can also open up a forest and create wetlands in its midst where species of amphibians could breed. However, in the lower Tana River forests the situation is worsened during the dry season as large numbers of livestock congregate around the water areas. These forests are used by the pastoralists as refuges during the dry season.

The total removal of all the trees and the associated destruction of the under-storey vegetation and broad disruption of the litter ground cover expose the soil to direct sunlight resulting to microclimatic changes that are lethal to amphibians (Zug *et. al.*, 2001).

Crop farming is likely to involve total removal of vegetation cover and leaf litter depending on the initial method of land preparation. The species under cultivation are also exotic, and these agricultural areas have been created at the expense of natural habitats more suited to herpetofauna (Bennun and Njoroge, 1995). With the cultivation of rice and sugarcane in this area as proposed, agrochemicals will not be exempted from use. Some agrochemicals act as hormones that interfere with reproduction in amphibians by disrupting the normal development of their productive organs (Channing and Howell, 2006). Pough *et. al.*, (1998), has also indicated that agricultural chemicals are possible cause for the decline of some amphibians. Apart from the Pokomo community that farm along the river banks, the rice irrigation schemes and the proposed sugarcane project are also a threat to herpetofaunal habitats in this region. These could be some of the reasons to explain the low amphibian species abundance and diversity in unprotected forests.

According to Zug *et. al.*, (2001), natural disruptions such as floods, landslides, and fires occur regularly in all ecosystems and may foster regular occurrence of disturbances in high species - and community-diverse areas. The lower Tana River forests lie on a flood plain which has long-term flooding cycles associated with El niño phenomenon (Bennun and Njoroge, 1999). Though some reptiles are climbing species and others are known to "raft" on floating logs, vegetation mats etc. floods may be detrimental to the ground dwelling reptiles.

In considering various strategies to conserve herpetofauna, majority of the people preferred conserving forests and wetlands and educating the community respectively though most people in Mambo Sasa and Mchelelo West preferred conserving wetlands and educating the community. This local knowledge is important for conservation and involvement of communities in herpetofauna conservation in lower Tana River.

A spin-off from the depletion of wild crocodile population has been the appearance of crocodile "farms" (Patterson, 1987). As well as being tourist attractions, and thus playing an educational role in that visitors are shown the ecologically beneficial aspects of the crocodile, they create the job opportunities, and help to safeguard the wild populations (Patterson, 1987). Similarly, the lower Tana River communities would target crocodiles for conservation and sustainable use if given wildlife user rights by the government. They prefer them for their ability to be conserved and used sustainably. They can be farmed and used for food, tourism, trade for their products and cultural use.

5.2.0 Conclusion and Recommendations

5.2.1 Conclusions

This is the first study to provide herpetofauna species diversity and abundance data in the lower Tana River forests. From this study, it has been observed that:-

- The lower Tana River forest fragments studied contain high diversity of herpetofauna which vary from one forest fragment to another.
- All forests surveyed supported a moderately rich herpetofauna.
- Some habitat variables, of various magnitude may influence the diversity and abundance patterns of herpetofauna.

- Reptile species may vary depending on the openness of the forest.
- Conservation efforts in the lower Tana River forests must work within the culture of the region if they are to be successful. The culture of a community is likely to influence the attitude towards amphibians and reptiles that would have an impact in conserving them.

5.2.2 Recommendations

In order to improve on the conservation of the lower Tana River herpetofauna, the following considerations should be taken into account:-

5.2.3 Future research

This study has provided crucial information on our knowledge of the lower Tana River region herpetofauna. However, more thorough herpetological work is required especially the zoogeography, behaviour and habitat ecology of different species of herpetofauna in the various forests. There is also need for further quantitative studies of this kind in order to have comparisons for different ecological areas. This is also important in establishing the conservation status of herpetofauna in the coastal forests in general.

Compared with other vertebrate groups, East Africa amphibians and reptiles are rather poorly studied and insufficiently known. In order to provide conservations data for defining priorities for conservation it is necessary to obtain basic information on the diversity and community structure of the forest amphibians and reptiles.

A study of crocodile populations and the effects of hunting for meat and harvesting of eggs is very necessary in order to appropriately use existing national legislation.

5.2.4 Conservation action

Continued forest loss increases herpetofauna species extinction risks. In order to eliminate any possible over-exploitation, which is encouraged by economic problems for valuable tree species and domestic problems, conservationists need to come up with conservation actions.

- Since the herpetofauna community depends on the existence of these riverine forests which are faced with increasing human population pressure among others, management strategies may be difficult to work. Therefore management actions to be implemented should totally involve the local people to minimize their dependence on the forest resources. Problems resulting from human-herpetofauna conflicts should also be resolved through adequate medical services and awareness.

- The highest number of species, and the highest number of endemic species, occur in forests, those of the Eastern Arc and Coastal forests have been designated a among the world's top –ten biodiversity hotspots. And thus a major challenge for the future is to see that habitats which contain high amphibian biodiversity are included within the East African protected area network of national parks and other protected – area categories such as nature reserves.

- Keep herpetofauna in the public eye by using indigenous knowledge and names to help popularize herpetofauna and make them more familiar to the local communities in the lower Tana River region. Involve communities near forests fragments in conserving habitats for herpetofauna.

- Ensure that herpetofauna receive the necessary attention and consideration when planning and implementing development projects, especially those involving agriculture (rice and sugarcane projects) and initiate projects to monitor populations to detect short – and long – term changes in herpetofauna.

- A Study of the offtake of crocodiles and the cost-benefit analysis of any such utilization to the local communities in the area of study.

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APPENDICES

Appendix 1: Habitat characteristics in the three forests studied.

Habitat characteristics		Mchelelo west	Shakababo	Mambo Sasa
Forest size (ha)		17.00	407.00	3937.60
	Outside	62.04	360.57	142.46
Litter content	Edge	479.6	375.5	576.46
($g/0.25m^2$)	Inside	1521.00	541.29	790.14
Percent	Outside	5.00	4.00	8.00
canopy cover	Edge	42.00	30.00	40.00
	Inside	95.00	60.00	80.00
Soil moisture	Outside	2.50	1.50	1.50
content	Edge	3.00	1.50	2.00
	Inside	3.00	2.00	2.00
Soil pH	Outside	6.89	5.97	5.96
	Edge	7.66	5.89	6.16
	Inside	5.64	6.09	6.22
Tree density	Outside	4.00	2.00	4.00
($No./100m^2$)	Edge	25.00	4.00	8.00
	Inside	33.00	18.00	30.00
Temperature	Outside	27.80	31.6	27.65
(C^o)	Edge	24.65	26.45	25.50
	Inside	24.05	25.65	24.75
	Outside	50.00	50.00	65.00
Percent	Edge	82.00	60.00	80.00
vegetation cover	Inside	84.00	80.00	95.00
Forest	Outside	5.00	10.00	6.00
disturbance	Edge	3.00	5.00	2.00
	Inside	2.00	4.00	2.00

Appendix 2: Herpetofauna species abundance, richness and diversity in the three forests studied

		Forest	Dry	Wet	Total
Amphibians	Abundance	Mchelelo West	181	204	385
		Shakababo	62	78	140
		Mambo Sasa	211	264	475
	Species richness (S)	Mchelelo West	8	11	11
		Shakababo	7	10	10
		Mambo Sasa	12	12	14
	Species diversity (H')	Mchelelo West	0.78	0.89	0.86
		Shakababo	0.70	0.88	0.84
		Mambo Sasa	0.89	0.89	0.92
Lizards	Abundance	Mchelelo West	62	83	145
		Shakababo	15	86	101
		Mambo Sasa	2	22	24
	Species richness (S)	Mchelelo West	9	12	14
		Shakababo	5	11	11
		Mambo Sasa	2	3	5
	Species diversity (H')	Mchelelo West	0.59	0.92	0.83
		Shakababo	0.56	0.59	0.62
		Mambo Sasa	0.30	0.37	0.49
Snakes	Abundance	Mchelelo West	7	3	10
		Shakababo	0	5	5
		Mambo Sasa	0	0	0
	Species richness	Mchelelo West	6	2	8
		Shakababo	0	4	4
		Mambo Sasa	0	0	0
	Species diversity	Mchelelo West	0.76	0.28	0.88
		Shakababo	0	0.57	0.57
		Mambo Sasa	0	0	0

Appendix 3: The occurrence of herpetofauna species in different forests studied: (1) Guru North; (2) Guru South; (3) Mchelelo West (4) Congolani; (5) Hewani South; (6) Shakababo; (7) Mambo Sasa (8) Kipini.

Higher taxa	Family	Genera/Species	1	2	3	4	5	6	7	8
Class Amphibia Order Anura	Bufonidae									
		Amietophrynus maculatus	10	26	59	2	0	0	0	0
		A. steindachneri	0	5	18	0	8	23	14	0
		A. xeros	51	12	32	0	0	0	0	0
		A. gutturalis	0	0	3	0	0	10	5	0
		Mertensophryne micranotis	0	3	0	0	0	0	96	0
	Ptychadenidae	*Ptychadena schillukorum*	0	18	3	0	0	21	0	0
		P. anchietae	64	39	31	0	64	39	88	1
		P. mossambica	0	4	81	2	0	0	0	2
		P. macsareniensis	0	0	0	0	26	0	38	0
	Petropetidae	*Phrynobatrachus acridoides*	4	8	108	0	84	0	71	0
		P. natalensis	2	0	6	0	78	7	16	0
		Arthroleptis stenodactylus	0	7	0	0	4	4	91	0
		Hydrophylax galamensis	0	0	14	0	0	0	2	0
	Hemisotidae	*Hemisus marmoratus*	5	12	30	0	13	26	15	0
	Heperolidae	*Afrixalus fornasini*	0	0	0	0	0	0	6	0
		Hyperolius argus	0	0	0	0	0	6	20	0
		H. tuberilinguis	0	0	0	0	0	0	11	0
		H. acuticeps	0	0	0	0	0	3	0	0
		Leptopelis concolor	0	0	0	0	0	1	4	0
Class Reptilia Order Chelonidae	Testudinidae	*Kinixys belliana*	0	0	1	0	0	0	1	0
Order		*Heliobolus spekii*	26	70	66		6	47	11	

Lacertilia	Lacertidae					1				0
	Gekkonidae	*Latastia longicaudata*	2	21	17	0	0	3	0	0
		Lygodactylus picturatus	0	27	9	0	0	35	0	0
		L. keniensis	19	0	0	0	20	1	0	0
		Hemidactylus brooki	0	4	2	0	0	1	0	0
		H. platycephalus	8	5	0	0	4	1	1	0
		H. mabouia	0	6	15	0	9	3	0	0
		H. ruspolii	0	1	2	0	0	0	0	0
		H. barbouri	0	0	0	1	0	0	0	0
	Agamidae	*Agama agama*	0	0	3	0	3	0	0	0
	Scincidae	*Lygosoma sundevalli*	0	4	4	0	0	3	1	1
		Trychylepis varia	0	0	12	0	9	0	10	0
		T. maculilabris	5	4	10	0	0	3	0	0
		T. striata	3	5	3	0	1	0	0	0
	Varanidae	*Varanus niloticus*	1	5	0	0	3	0	0	0
		Gerrhosaurus major	0	0	2	0	0	0	0	0
		G. flavigularis	0	0	0	0	0	1	0	0
	Chamaeleonidae	*Chamaeleo roperi*	0	0	0	0	1	1	1	0
		Rieppeleon kerstenii	0	0	0	0	0	1	0	0
Order Serpentes	Atractaspididae	*Aparallactus quentheri*	0	0	1	0	0	0	0	0
	Colubridae	*Dendroaspis polylepis*	0	0	1	0	0	0	0	0
		Letheobia unitaeniatus	0	1	1	0	0	0	0	0
		Lycophidion capense	0	0	0	0	0	0	0	1
		L. depressirostre	0	1	0	0	0	0	0	0
		Philothamnus punctatus	0	0	0	0	1	1	0	0
		P. hoplogaster	2	0	0	0	0	0	0	0

		Lamphrophis fuliginosus	0	3	2	2	0	1	0	0
	Viperidae	*Causus resimus*	0	0	1	0	1	0	0	0
		Psammophis orientalis	0	0	1	0	0	1	0	0
		P. sudanensis	0	0	0	0	0	2	0	0
		Dasypeltis medici lamuensis	0	0	1	0	0	0	0	0
		Crotaphopelties hotamboeia	0	0	2	0	0	0	0	0
		Philothamnus spp.	0	0	0	0	1	0	0	0
		Hemirhagerrhis kelleri	1	0	0	0	0	0	0	0
	Elapidae	*Naja pallida*	0	1	0	0	0	0	0	0
Order Crocodylia	Crocodylidae	*Crocodylus niloticus*	0	36	13	0	0	0	0	0
Total individuals in all the sampled			2181							

Appendix 4: Regression ANOVA analysis between habitat characteristics and species richness

Habitat variables	Herpetofauna	*F*- value	R^2	df	*P*- value
Forest size (ha)	Amphibians	8.36	0.89	1	0.212
	Lizards	5.80	0.853	1	0.25
	Snakes	4.67	0.820	1	0.276
Litter content (g/0.25m^2)	Amphibians	0.0001	0.0001	1	0.999
	Lizards	0.403	0.29	1	0.639
	Snakes	0.888	0.47	1	0.518
Percent canopy cover	Amphibians	0.269	0.21	1	0.695
	Lizards	0.001	0.001	1	0.932
	Snakes	0.087	0.08	1	0.81
Soil pH	Amphibians	0.0.014	0.013	1	0.925
	Lizards	0.693	0.402	1	0.55
	Snakes	1.489	0.59	1	0.437
Tree density (No./100m^2)	Amphibians	0.046	0.045	1	0.865
	Lizards	0.144	0.126	1	0.765
	Snakes	0.382	0.27	1	0.647
Temperature (C^o)	Amphibians	0.429	0.30	1	0.631
	Lizards	0.001	0.001	1	0.997
	Snakes	0.035	0.034	1	0.882
Percent vegetation cover	Amphibians	10.313	0.911	1	0.192
	Lizards	0.683	0.40	1	0.564
	Snakes	0.299	0.23	1	0.681

Appendix 5: Regression ANOVA analysis between habitat characteristics and species abundance

Habitat variables	Herpetofauna	*F*- value	R^2	df	*P* – value
Forest size (ha)	Amphibians	0.69	0.41	1	0.55
	Lizards	4.80	0.82.8	1	0.272
	Snakes	9.008	0.90	1	0.205
Litter content (g/0.25m^2)	Amphibians	0.38	0.27	1	0.648
	Lizards	0.467	0.318	1	0.618
	Snakes	0.889	0.471	1	0.518
Percent canopy cover	Amphibians	5.411	0.844	1	0.258
	Lizards	0.017	0.017	1	0.916
	Snakes	0.087	0.081	1	0.817
Soil pH	Amphibians	0.203	0.161	1	0.730
	Lizards	0.794	0.443	1	0.536
	Snakes	1.489	0.598	1	0.437
Tree density (No./100m^2)	Amphibians	0.88	0.469	1	0.437
	Lizards	0.176	0.149	1	0.519
	Snakes	0.382	0.28	1	0.647
Temperature (C^o)	Amphibians	7.287	0.879	1	0.225
	Lizards	0.001	0.001	1	0.980
	Snakes	0.035	0.03	1	0.881
Percent vegetation cover	Amphibians	10.057	0.909	1	0.194
	Lizards	0.593	0.372	1	0.582
	Snakes	0.299	0.23	1	0.681

Appendix 6: Regression ANOVA analysis results between habitat characteristics and species diversity

Habitat variables	Herpetofauna	*F*-value	R^2	df	*P*- value
Forest size (ha)	Amphibians	0.757	0.44	1	0.537
	Lizards	2.75	0.73	1	0.345
	Snakes	0.124	0.528	1	0.481
Litter content (g/0.25m^2)	Amphibians	0.001	0.001	1	0.989
	Lizards	1.37	0.579	1	0.449
	Snakes	0.433	0.30	1	0.629
Percent canopy cover	Amphibians	0.228	0.185	1	0.71
	Lizards	0.175	0.149	1	0.747
	Snakes	0.013	0.012	1	0.927
Soil pH	Amphibians	0.023	0.023	1	0.902
	Lizards	2.35	0.70	1	0.382
	Snakes	0.74	0.42	1	0.547
Tree density (No./100m^2)	Amphibians	0.033	0.031	1	0.885
	Lizards	0.608	0.378	1	0.678
	Snakes	0.159	0.137	1	0.758
Temperature (C^o)	Amphibians	0.37	0.270	1	0.651
	Lizards	0.092	0.084	1	0.812
	Snakes	0.001	0.001	1	0.992
Percent vegetation cover	Amphibians	6.311	0.863	1	0.241
	Lizards	0.176	0.145	1	0.751
	Snakes	0.63	0.389	1	0.571

Appendix 7: Kruskal-Wallis test (H) of responses of cultural significance and threats to herpetofauna.

	H -value	df	p - value
Utilization and preference	3.541	3	0.315
Herpetofauna habitats	1.003	2	0.606
Human-herpetofauna conflicts	7.423	2	0.024
Perception of herpetofauna	0.115	2	0.944
Threats to herpetofauna	13.38	2	0.001
Conservation strategies	0.089	2	0.956
Herpetofauna targets	2.015	2	0.365

Appendix 8: Questionnaire

Cultural significance and threats to herpetofauna in lower Tana River forests.

Sheet number..

Date interview one...

Interviewer..

Introduction:

1. This study seeks to ask you question about the cultural significance and threats to herpetofauna.
2. There is no wrong or right answer and your response is confidential
3. Information sought is purely academic with no commercial value

Locality data

District....................Forest fragment ....Village...................................

GPS co-ordinates...

Interviewee

i. Name ....
ii. Date of birth/age...
iii. Sex...
iv. Marital status..
v. Level of education...
vi. Profession..
vii. Others (Specify)..

Herpetofaunal exploitation and uses

i. Which species do you use? Name them……………………...............................

ii. a) For what purpose (commercial, subsistence, recreational, cultural etc.

Others specify)…………………………………………………………………………..

b) Which methods and equipment or tools do you use to capture……………

iii. Are you aware of any other local uses of herpetofauna? Yes/No

If yes (specify)……………………………………………………………………

Use	Species	Remarks
Food		
Medicinal		
Traditional uses		
Others (specify)		

Herpetofaunal habitats

Where do you commonly find amphibians and reptiles?

a) Forests……………………………………………………………………………

b) Wetlands (including rivers, swamps, lakes etc.)…………………………………...

c) Bush lands……………………………..………………………………………

d) Others (specify)……………………………………………………………………

(In each case specify the species)

Herpetofauna interactions

Have you personally interacted with herpetofauna? Yes/No.

i) What type? ....

ii) When did you see it?' ....

iii) Season (dry or wet)? ....

iv) Age (Juvenile/adult)? ....

v) Time of the day ....

vi) Location ....

vii) Activity at that time (e.g. Feeding, basking) ....

How do you perceive herpetofaunas? especially;

- Snakes ....
- Chameleons ....
- Amphibians ....

Among the three which one would you tolerate? ....

What myths does your community have about:-

- Snakes ....
- Chameleons ....
- Amphibians ....

Human-herpetofauna conflicts

i) How many interactions are you aware of? ....

ii) Briefly describe the kinds of interactions of which you are aware of by observation

type ....

iii) Are interactions of which you are personally aware led to damage, personal injury, death caused by the herpetofauna. Yes/No

Which herpertofauna was involved?...

Where?...

How?...

When?..

What regarding the damages?..

iv) Are you aware of snake bites? Yes/No

If yes specify the snake involved..

v) How frequent are the snake bites?..

Threats

The interaction of which I am aware of led to mortality of amphibians or reptiles are:-

....

Among the following activities, which one do you think are most threatening to amphibians and reptiles? (Habitat change factors)

Deforestation..

Soil erosion...

Fire ....

Overgrazing...

Pollution – agriculture..

Over harvesting of products..

High livestock number..

Over extraction of water e.g. irrigation...

Reclamation of forest for agriculture...

Human population pressure...

Trade...

Others (specify).................................

Incase of farming, how do you prepare the field..

Are you aware that some herpetofaunas are threatened due to activities mentioned above?

Yes /No.

(If yes) which one?..

Are you aware of modifications that you think would make particular activities safer for the herpetofauna?...

Climatic changes

Are there floods Yes/No

If yes, how frequent? ....

Conservation and sustainable use

i. If you are given wildlife user rights by the government, which species will you target?..

ii. For what reason?...

Community around the sampling site

Name of the community...