Ecology and population status of the Serval

Leptailurus serval (SCHREBER, 1776) in Zambia

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Table of Content

page

Abstract

Ecology and population status of the Serval *Leptailurus serval* (SCHREBER, 1776) in Zambia

By

Christine Thiel

(February 2011)

Academic dissertation for the Degree of Doctor of Science (Dr. rer. Nat.) in Zoology at Rheinischen Friedrich-Wilhelms-Universität, Bonn.

Little is known about the Serval's ecology, its needs and population status. This thesis is providing a new and detailed groundwork on this elusive felid species. The study was conducted between 2006 and 2008 in Zambia, with the focus area being Luambe National Park (LNP) in the Luangwa Valley.

Using transect line walking, signs of Serval presence (faeces, spoor and sightings) were recorded. Analyses of these records revealed new information on the diet, habitat preferences, the distribution within LNP, and parasite composition in faecal samples. The most studied fact on Servals found in literature is their diet, through scats analyses, observations and stomach analyses. Faeces analyses of this thesis supported the previous studies' findings that the *Leptailurus serval* is a rodent hunter. But besides that, they also prey extensively on birds, on reptiles, and on arthropods. A diet breadth of 0.5 also indicates a more opportunistic lifestyle. People associate Servals with grasslands and wetlands, but this study proved the Servals to use also thickets and riverine woodland. This felid needs water resources nearby and a certain degree of cover, whether it is grass or thickets/bushes. Closed forests with little ground cover are less preferred or even avoided habitats. parasites of Servals were never analysed up to now. This analysis revealed *Rhipicephalus sanguineus* and *Haemaphysalis leachi*, both so-called 'Dog Ticks', to be the most common tick of *Leptailurus serval*.

Additionally, camera traps were set up to calculate the minimum population size of *Leptailurus serval* in LNP. In an area of 134 km² composed of 30% potentially preferred habitat, this study found a density of 9.9 Servals per 100 km^2. This study has been the first density estimation proved by the capture-recapture method with the usage of camera traps.

Zambia-wide collections of scat samples, observations and spoors completed the data to produce an overview of Zambian Serval populations. Zambian-wide distribution proclaimed by ANSELL (1978) was reviewed and most of the areas were confirmed. Distribution patterns of the different pelage morphs of Servals occurring in Zambia, following ANSELL (1978), were reviewed. His statement on the south-eastern boundary of the distribution of a small spotted morph could neither be proven nor rejected.

Also the first African-wide species distribution model for the Serval was created with the software MAXENT. The MAXENT model revealed good results and showed possible distribution areas mostly south of the Sahara, with hotspots in the highlands of Ethiopia, in Kenya, Tanzania, Uganda, Rwanda, the eastern highlands of Zimbabwe, and at the South African coast line. On the basis of the newly gained knowledge on preferred and less preferred habitats the output map was overlaid and modified with land cover data, eco-region maps, areas of wilderness and areas of critical or endangered conservation status. If all these factors are taken into consideration, the potential Serval distribution area decreases, especially the areas of high probability are endangered and unsuitably influenced to provide good and stable Serval habitats.

Keywords: Felidae, Serval, *Leptailurus serval*, diet, habitat, minimum population size, SDM model, ticks, Zambia, Africa

Zusammenfassung

Ökologie und Populationsstatus des Servals *Leptailurus serval* (SCHREBER, 1776) in Sambia.

Vorgelegt von

Christine Thiel

(Februar 2011)

Dissertation zur Erlangung des Doktorgrades (Dr. rer. nat.) in Zoologie
an der Mathematisch-Naturwissenschaftlichen Fakultät der
Rheinischen Friedrich-Wilhelms-Universität Bonn.

Bis jetzt ist über den Serval, seine Ökologie, seine Ansprüche und seinen Populationsstatus, wenig bekannt. Diese Arbeit bietet ein neues und detailliertes Basiswissen für diese heimliche Katzenart. In den Jahren 2006 bis 2008 bildete zusätzlich zu ausgewählten Orten in ganz Sambia der im Luangwa Tal gelegene Luambe National Park (LNP) das vorrangige Untersuchungsgebiet.

Mit Hilfe von Transektläufen wurden Anzeichen der Anwesenheit von Servalen (Kotproben, Spuren und Sichtungen) aufgenommen. Analysen dieser Aufnahmen lieferten neue Informationen über das Nahrungsspektrum, die Habitatpräferenzen, die Verbreitung innerhalb des LNP und über die im Kot vorhandenen Parasitenarten. Die häufigsten Angaben in der Literatur über die Ökologie des Servals beziehen sich auf sein Beutespektrum, untersucht anhand von Kotanalysen, Beobachtungen oder Untersuchungen des Mageninhalts. Kotanalysen der vorliegenden Arbeit bestätigten die Aussage der vorangegangenen Studien, dass der Serval ein Nager-Jäger ist. Allerdings ernährt er sich ebenfalls in großen Mengen von Vögeln, Reptilien und Arthropoden. Ein mittlerer Wert der errechneten Breite des Nahrungsspektrums von 0,5 deutet ebenfalls eine eher opportunistische Art der Nahrungswahl an. Des Weiteren wird der Serval im Allgemeinen mit Grasland und Feuchtgebieten assoziiert, aber diese Studie belegt ebenfalls die Nutzung von uferbegleitender Vegetation und Dickichten. Diese Katze ist auf nah gelegene Wasservorkommen und auf einen gewissen Grad an Deckung, egal welcher Form, ob Gras, Dickicht oder Büschen, angewiesen. Habitate geschlossener Wälder mit wenig Bodendeckung werden weniger bevorzugt oder gar gemieden. Die Parasiten der Servale wurden bisher noch nicht genauer untersucht. Diese Studie stellte eine Zeckenbelastung fest, die vor allem durch die zwei Hundezeckenarten *Rhipicephalus sanguineus* und *Haemaphysalis leachi* gebildet wird.

Zusätzlich zu den vorangegangenen Analysen wurden Kamerafallen zur Bestimmung der minimalen Populationsgröße von *Leptailurus serval* im LNP aufgestellt. In einem Untersuchungsgebiet von 134 km² mit einer über 30%igen Abdeckung an bevorzugtem Habitat konnte eine Dichte von 9,9 Servalen pro 100 km² bestimmt werden. Diese Arbeit bietet die erste Dichtebestimmung über die Fang- und Wiederfang-Methode mit Hilfe von Kamerafallen.

Sambia weite Sammlungen von Kotproben, Sichtungen und Spuraufnahmen haben zur Vervollständigung des Bildes zur Ökologie und des Status der sambischen Servalpopulationen beigetragen. Die Sambia weite Verbreitung nach ANSELL (1978) wurde überprüft und die meisten Gebiete bestätigt. Die von ANSELL (1978) beschriebenen verschiedenen Fellmuster und ihr Vorkommen in Sambia wurden ebenfalls untersucht. Seine Aussage, dass innerhalb von Sambia die süd-östliche Verbreitungsgrenze der einen Fellform liegt, konnte hier weder bestätigt noch widerlegt werden.

Ebenfalls zum ersten Mal wurde ein Art-Verbreitungs-Model für den Serval für ganz Afrika mit der Software MAXENT erstellt. Das MAXENT Model erbrachte gute Ergebnisse und zeigte mögliche Verbreitungsgebiete vor allem südlich der Sahara, mit Bereichen der höchsten Wahrscheinlichkeit in den Höhenlagen in Äthiopien, in Kenia, Tansania, Uganda, Ruanda, in den östlichen Gebirgen Simbabwes und entlang der Küstenlinie Südafrikas. Auf der Grundlage der bekannten Habitatpräferenzen wurde dieses Model mit Karten zur Landnutzung, zu den Öko-Regionen, Schutzgebieten und stark bedrohten Bereichen überlagert. Diese Betrachtung aller Umstände beeinflusste die potentiellen Verbreitungsgebiete des Servals in großem Maße, insbesondere die Gebiete mit hoher Wahrscheinlichkeit geeigneter Lebensräume wurden stark reduziert und negativ beeinflusst, so dass eine stabile und nachhaltige Population an diesen Orten vielleicht nicht mehr möglich ist.

Schlagwörter: Felidae, Serval, Leptailurus serval, Nahrungsanalysen, Habitatsanalysen, minimale Populationsgröße, MAXENT Modell, Zecken, Sambia, Afrika

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Zambia turned out to be my big adventure. Its bad infrastructure and its leisureliness could drive a European mad. But it is everything what you expect if you think of Africa. Its diversity in fauna and flora amazed me and instantly it infected me with the "African Fever". This beautiful and wild country holds 11 million friendly, broadminded, helpful and generous people. To some of them I would like to express my gratitude: Roland Norton (who saw us waiting for one day until the cleaning personnel came and who then took us under his wings and helped us tremendously), Bob Chiwala & Julie Vlhakis (who surrounded our little tent at Eureka Farm with another 10 tents and since then were great friends and a huge help in all situations in life), Thomas – the genie (who always fixed my car with a smile), ZAWA (Zambia Wildlife Authority) and its staff members, e.g. the Director General, the Director of Research Victor Siamudaala and his whole department (Griffin, Priscilla, his secretary), the ZAWA Mfuwe Headquarters (James Milanzi) and the staff, the staff of the School of

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The creation and execution of my PhD project followed the typical scientific process and taught me the pros and cons of being a scientist. First I was faced with the question what I want my thesis to be about. This was easy: Cats of the Luambe National Park (LNP) in Zambia! My next decision about which species it should be, was made very quickly as well: Servals – in my eyes the forgotten felid species. Not only most non-scientists but also biologists did not know my target species, which encouraged me to find out more about this elegant hunter. The following step was to design a study plan and its targets, involving an extensive review of published literature. This literature study made it clear: there are many possible paths to take as not much is known about this elusive cat. Consequently, I wanted this study to aim to be a new foundation of Serval knowledge, which has to answer fundamental ecological questions as well as current conservation issues. Therefore, the study area was enlarged from the borders of Luambe National Park to the ones of Zambia. During these study years, the longer I studied Servals the more obvious it became to me, why only a few researchers worked with them before. These cats are very secretive, they do not behave like other cats do and they do not follow any rules scientists wish for. At the same time, the more I found out the more questions were raised. Hence, the objectives and methods had to evolve and needed adjustments every consecutive year. But in the end, after uncounted hours of frustration and the same amount of hours of joy and amazement, I managed to explore some new and exciting parts of the Serval's ecology and its population status. I hope, this study will lead to a new awareness of *Leptailurus serval* and it will encourage researchers to study and protect this incredible felid.

List of Tables

List of Figures

The Story of the Serval and how it got its spots
(A Tswana Story)

Long, long ago Tortoise was slowly crawling home when he met Serval on his path.
"Hello old friend," said Serval heartily. "Have you found much to eat today?" "No," replied Tortoise sadly. "Hardly anything at all."

Serval began to dance up and down and chortle with laughter. He had a mischievous idea. "Follow me, poor old Tortoise. And when you get to my home, I will have supper ready for you."
Tortoise gratefully accepted as Serval turned around and gaily bounced along the track that led to his home. Tortoise followed as fast as he could. But he was very slow, especially when he went uphill. Though he was tired, the thought of a lovely meal kept him going, so on he plodded.

When Tortoise eventually reached the patch of scrub Serval called home, Serval laughed to himself. As soon as he caught sight of Tortoise, he teased him. "Goodness me, what a long time that took!"
"I'm sorry," apologized Tortoise as he regained his breath, "but surely you have had enough time to get the meal ready, so do not grumble."

"Oh, yes indeed!" replied Serval. "There is your meal," he chortled, pointing up to the branches overhanging his home. Poor Tortoise could only look wistfully at the distant meal, well out of reach.

Serval was very pleased with his prank and ran off laughing. All Tortoise could do was slowly crawl off to his home hoping that tomorrow would bring a decent meal. He also began to plot his revenge.

Several weeks later, Tortoise sent Serval an invitation to eat with him. Serval was surprised; but knowing Tortoise to be a good-natured fellow, he thought to himself, "Oh well, Tortoise must have seen the joke and bears me no malice. I'll go along and see what I can get out of him.

As it was dry season, Tortoise had burned a patch of grassland near his home by the river. Serval had to cross this large patch of land to get to the savory smell waiting from Tortoise's home.

"Ah, my friend Serval," said Tortoise. "Look at the state of you! You are covered with black spots and your paws are filthy. Run back to the river and clean yourself up and then you can come and have supper. You really do have poor manners!"
Serval scampered off to the river to wash, as he was keen to taste the supper that so good. On his return, he had to cross the burned ground again. He arrived just as dirty as before.
"That will never do! Off to the river with you and get properly cleaned up!" shouted Tortoise, with his mouth full of food.

Serval went back to the river time and time again, but try as he might, he was always dirty on his return. And each time Serval returned, Tortoise refused to serve him. Serval could see that the delicious food was disappearing fast.

As Tortoise gulped down the last morsel of food, Serval realized that he had been tricked. With a cry of embarrassment, he hurried across the burned ground for the last time and ran all the way home.
"That will teach you a lesson, my friend," said Tortoise, laughing the last laugh. Full and content, Tortoise withdrew into his shell for a good night's sleep.

To this day, Serval is still covered in black spots from the soot of the burned vlei.

When Lion Could Fly and other tales from Africa. Told by Nick Greaves, illustrated by Rod Clement. Struik Publisher, South Africa. 2000

**What sort of philosophers are we,
who know absolutely nothing of the origin and destiny of cats?**
- Henry David Thoreau

1. Introduction

1.1. Carnivore and Serval conservation

Modern technologies have improved and facilitated studies in ecology and behaviour; analyses of living wild animals can be performed in an easier and more detailed way than several years ago. Molecular methods have been developed, allowing non-invasive study of wildlife populations via hair samples (FORAN et al. 1997) or scat collection (PIGGOTT AND TAYLOR 2003, BHAGAVATULA 2006, NAPOLITANO et al. 2008, MIOTTO et al. 2007A) for many applications including species presence/absence surveys, population size estimations, assessments of genetic structure, and prey use analyses (AVISE 1996). Also methods such as camera trapping, abundance estimation via transect counts or habitat modelling have evolved tremendously (CLARK et al. 1993, NIELSEN & WOOLF 2002, BUCKLAND et al. 2004, LARUE 2007, Rowcliffe & Carbone 2008).

The effects of habitat loss, fragmentation, and degradation on carnivore populations and their prey species are still only partially known (CREEL 2001). Many species of wild felids are becoming endangered due to habitat disturbance (NOWELL & JACKSON 1996) through human activity, including e.g. burning firewood, agricultural land use, trophy hunting and subsistent hunting. These effects need to be analyzed and the impacts on wild cats determined. Understanding the needs and threats of these species is the most important step towards their protection.

The Serval *Leptailurus serval* (SCHREBER, 1777) is known as a cat of the Sub-Saharan region, inhabiting a variety of habitats besides the rainforest areas. Formerly the Serval was known to exist in northern Africa as well where it became nearly extinct; these populations are likely to have been isolated from sub-Saharan populations for at least 6.000 -7.000 years (GOUTTENOIRE 1954, LAMBERT 1966, SWIFT 1975, SMITHERS 1983, DE SMET 1989). But as recent research shows, e.g. in the Ferlo North Faunal Reserve, Senegal, and in Free State, central South Africa (CLÉMENT 2007, HERRMANN et al. 2008), the Serval can be found again in places where it was believed to be extinct. This is positive for the conservation of this species, but at the same time, it reminds us that there are still many unsolved questions about this species.

Although the IUCN Wild Cats Status Survey and Conservation Plan (NOWELL & JACKSON 1996) has identified no specific research priority to investigate the distribution and ecology of *Leptailurus serval,* I believe that it is necessary to examine the ecology and the population status of this cat, as there is no information about these aspects, except the Ngorogoro Crater, Tanzania (GEERTSEMA 1981 & 1985) and on South African farmland (BOWLAND 1990). Despite the fact that this species seems to be widely spread throughout sub-Saharan Africa no studies have been carried out to determine the Servals' habitat needs or to identify possible threats. Hence, it is difficult to reliably assess its role as one of the important predators of the savannah regions or its conservation status and vulnerability.

The species can be described as an umbrella species for savannah biotopes, especially for the most endangered humid savannahs. Increased interest in and popularity of such carnivores could also help to protect these biotopes. As GEERTSEMA (1985) and BOWLAND (1990) mentioned, the key to Serval conservation is wetland habitat conservation. By calculating the minimum population size for Luambe National Park (LNP) this study can help dimensioning the area necessary to maintain a stable and viable Serval population. LNP is well known for its high abundance of Servals. Determining the minimum population size in this area can also help to more accurately modulate an estimated minimum population size of Servals living in Zambia.

1.2. Project Background and motivation

The newly established (2006) Serval Monitoring Project is currently the only existing *in situ* Serval project**.** Little has been achieved since the last field studies on Servals by A. GEERTSEMA (1985) in Tanzania and J. BOWLAND (1990) in South Africa. Servals are common wild felids of the savannah, but due to their cryptic nature it is extremely difficult to monitor their populations.

When I had the chance to choose my own project and study animal in the LNP in Zambia, I took the opportunity to examine the Serval, *Leptailurus serval*. I had been fascinated by cats, having worked on them previously and wanted to look into one of the least known cats. Information about these animals is scarce or incomplete, and often hasn't been peer reviewed (SUNQUIST & SUNQUIST 2002). I was also keen for the challenge to work in a country with habitats and cultures very new to me, whilst studying such an elusive species.

This study relies on data collected in LNP (300 km^2), which is situated in the centre of the Luangwa Valley, the southern extension of the East African Rift Valley. Here, tourism and research had very little impact until 2004, while poaching was consistently high. With the potential of LNP to function as a stepping stone between the two large National Parks in the southern and northern end of Luangwa valley, it is imperative that studies on fauna and flora, and their conservation status, are carried out in the area to prepare and implement further management plans. Additionally eight other study sites could also be examined and later compared to the finding in LNP.

1.3. Objectives

All data were collected in the years 2006 (June-October), 2007 (June-October) and 2008 (June-October), with a total 15 months of field work. Methods were chosen to provide results to the following objectives:

1. Determination of the prey spectrum.
   - ⇒ Are there any prey preferences – is the Serval a generalist or an opportunist?
   - ⇒ Do Servals feed on the same prey in different regions of Zambia?
2. Identification of habitat preferences of *Leptailurus serval*.
   - ⇒ Are there annual changes in habitat preferences?
   - ⇒ Are there dietary changes between different populations within Zambia?
3. Identification of parasite species within Serval faeces.
   - ⇒ Are these parasites the ones using Servals as hosts?
   - ⇒ Do these parasite species change at different locations within Zambia?
   - ⇒ Is there a correlation in LNP between tick composition and precipitation?
4. Identification of Serval distribution within Luambe National Park.
5. Determination of the minimum population size of the Serval *Leptailurus serval* in LNP.
6. Confirmation of the Serval distribution map in Zambia as shown by ANSELL (1978).
7. Modelling of a distribution map for *Leptailurus serval* built on presence data in combination with climate variables with the Program MAXENT.

To provide data for most of these questions the method of transect line walking was chosen. During the transect walks faeces, spoors and sightings were recorded. These signs of Serval presence were used for dietary analyses, parasite composition determination, habitat preference analyses, and distribution pattern identification of Servals within LNP. In addition, randomly found signs of Serval presence completed this data.

Camera traps and olfactory baiting stations were set up in LNP in the first two seasons (2006 & 2007) to prove Serval presence, too. After the first two study years the distribution pattern of *Leptailurus serval* within LNP was identified, so that a camera trap grid was set up in 2008 specifically to calculate the minimum population size of the local Serval population in the demonstrated area of presence.

Prey spectrum determination was done by an extensive scat analyses while a collection of the small mammal diversity in LNP illustrated the prey preferences of the local Serval population in LNP.

Furthermore, signs of Serval presence were searched for Zambia-wide to compare prey spectrum and parasite composition between nine study areas in order to make an overall statement on Zambian Servals. In addition, this presence data was reconciled with the only existing distribution map of Zambia (ANSELL 1978). Moreover, sightings and pictures of Zambian Servals were included into a newly created map of pelage morphs within Zambia, postulated by ANSELL (1978). Presence records, completed with presence data from international databases and published literature, were used to calculate an Africa-wide distribution model for this felid with MAXENT.

1.4. *Leptailurus serval* (SCHREBER, 1777)

Until now, little has been known about Serval ecology. There has not been a single ecological study about this cryptic wild cat recently, the last large studies being by GEERTSEMA (1985) in Tanzania and BOWLAND (1990) in South Africa.

Figure 1.1: Serval Leptailurus serval (SCHREBER, 1777).

The name 'Serval' is believed to be derived from the Portuguese language. Not knowing what they had seen, early explorers named the newly discovered animal in the eighteenth century "lobo-cerval", meaning lynx (ROSEVEAR 1974, SUNQUIST & SUNQUIST 2002). The book CONCISE OXFORD DICTIONARY OF WORD ORIGINS (1986) states that the word 'Serval' means 'lynx' or 'bush cat'.

The Serval is an elegant and fast hunter of the African Savannah. The first impression on observing this cat is one of extremes - a long neck, very long legs and the slim face is dominated by very large oval-shaped ears (Fig. 1.1). The legs of a Serval are the longest legs of any cat in comparison with the rest of the body and the hind legs being longer than the front ones. Body size and the short tail length are similar to the lynx. Fur patterns resemble the cheetah. The coat is yellowish-buff to reddish-yellow, with black markings consisting either of large spots that merge into stripes on the neck and back, or of numerous small spots (Fig. 1.1). The underside is whitish-yellow, and unmarked.

Due to its tall legs, the high position of the head enables the Serval to hunt small mammals in high grass. The big ears help to locate prey. The Serval is believed to be specialist hunter for rodents, but also feeds on reptiles, birds or amphibians. Like a Fox, the Serval hunts with a very high leap onto the prey. With the sharp, hook-like claws, Servals can also reach into small holes to catch their prey.

Servals are usually crepuscular and nocturnal, but will hunt in the day during the wet season or if feeding a litter (VAN AARDE & SKINNER1986). During the heat of the day they often rest in abandoned burrows, in high thick grass or under a shady bush. SMITHERS (1971) points out the preferences of Servals for damp, wet habitats.

In emergencies they climb trees, but normally move on the ground. They are believed to be solitary cats. Social interactions between the sexes are limited to short periods when they travel and rest together. As the female comes into heat, these periods become more frequent and prolonged.

After a 65-75 days gestation, one to four kittens are born in an old burrow, rock crevice or under a thicket (ESTES 1999). Their eyes open in 9 to 12 days, and they take their first solid food at three weeks. Females take care of the litters on their own. At around 18 months, the young are chased out of the mother's home range and forced to disperse. Longevity in the wild has not been reported but is expected to be around 12 years. Servals have lived to over 23 years of age in captivity (GÜRTLER 2006).

The Serval is widely distributed over Africa south of the Sahara (Fig. 1.4), but is mostly dependent on water accessibility and cover (ESTES 1999).

There have been long debates about the systematics of the felids. Different methods have been used to classify the cat family, using morphological (POCOCK 1917, HEMMER 1978, GROVES 1982, HAST 1989, MATTERN & MCLENNAN 2000), behavioural (LEYHAUSEN 1979), and genetic features. Researchers have used vocalizations (PETERS & HAST 1994, PETERS & TONKIN-LEYHAUSEN 1999, PETERS et al. 2009), shapes of the pupils (NEFF 1982, NOWAK 1991), hybridization records, karyotype (WURSTER-HILL & CENTERWALL 1982, KRATOCHVÍL 1982, MATTERN & MCLENNAN 2000) and more recently DNA analyses (SALLES 1992, JOHNSON & O'BRIEN 1997, PECON-SLATTERY & O'BRIEN 1998, BININDA-EMONDS et al. 1999, MATTERN & MCLENNAN 2000, O'BRIEN et al. 2008). Lately the cat family has been divided into 37 species; however numbers vary between 36 and 39 species, depending on the author.

The genus *Leptailurus* was not always accepted as a separate genus. The Serval was first named by SCHREBER (1776) by monotype as *Felis serval.* This name was valid until the 90's of the 20th century, but is still used today by laymen. SEVERTZOV (1858) first brought up the genus *Leptailurus*. SEVERTZOV (1858), GROVES (1982), and MCKENNA & BELL (1997) considered *Leptailurus* as a subgenus of *Felis*. Another unsolved problem was to agree on the taxonomic relationship of *Leptailurus* to other cat groups. POCOCK (1917) positioned it with *Leopardus*; whereas WEIGEL (1961), HEMMER (1978), and BININDA-EMONDS et al. (1999) placed it with *Felis*, *Lynx*, and *Caracal*. SALLES (1992) grouped it with the Leopard Cat (*Prionailurus bengalensis*), and JOHNSON & O'BRIEN (1997) as well as MATTERN & MCLENNAN (2000) with *Caracal* and *Profelis*. The taxonomy by WOZENCRAFT (1993) supports the existence of eight different cat lineages (Fig. 1.2). This taxonomy is accepted by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the World Conservation Monitoring Centre (WMCC) and the Wild Cats Status and

Conservation Plan (SUNQUIST & SUNQUIST 2002). In these eight lineages the Serval is not united with a lineage but stands by itself. In 2006 researchers from the Laboratory of Genomic Diversity at the National Cancer Institute in Maryland did a whole raft of genetic analyses using X chromosomes, Y chromosomes, Autosomes and Mitochondrial DNA from all living cat species (JOHNSON et al. 2006). These led to a recently published phylogenetic tree (Fig. 1.3, O'BRIEN 2008), where the Serval is now within the Caracal lineage of Africa.

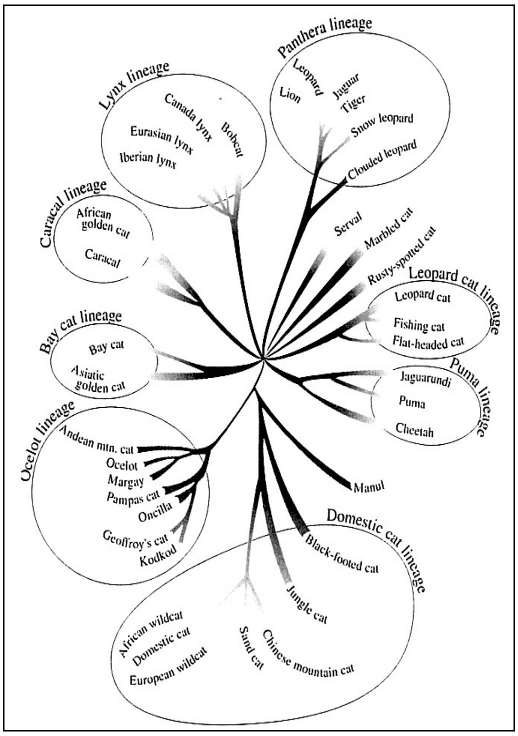


Figure 1.2: Molecular phylogeny of Felidae after WOZENCRAFT 1993; after Sunquist & Sunquist 2002.

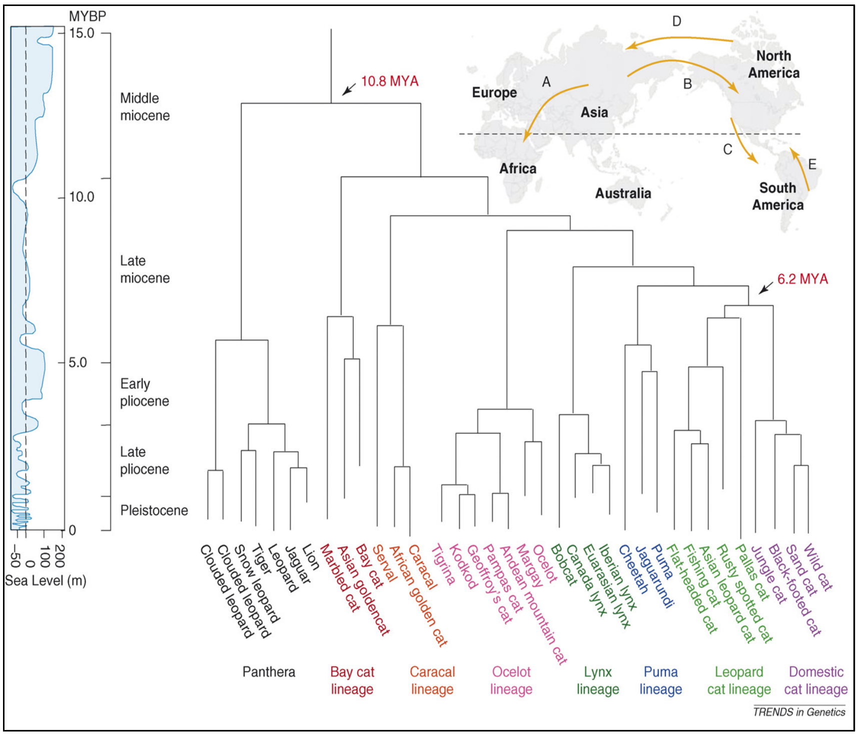


Figure 1.3: Molecular phylogeny of Felidae (O'BRIEN *ET AL*. 2008).

Another unanswered question is how many subspecies of *Leptailurus serval* exist. There are two different types of pelage pattern with the Serval; the big spotted form, as described above, and the small spotted form which looks freckled and shows nearly no stripes (Fig. 1.1). These two marking types originally led to a classification done by POCOCK (1907) into two separate species, with the large spotted cats called Serval, and the speckled variety called Servaline (*Felis brachyuran* WAGNER, 1841). Only in 1917 POCOCK revised his own statement of the year 1907 and re-classified the Servaline as a subspecies of the nominate race of the Serval (POCOCK 1917). It has since been found that the small spotted subspecies occurs in dense vegetation and secondary forests, while the big spotted Serval inhabits grasslands, bush and open savannahs. 17 morphologically different subspecies are listed by ALLEN (1939), 14 subspecies of the big spotted morph and 3 of the small spotted one. SMITHERS (1978) examined specimens from one locality in southern Africa and differentiated six subspecies within this sub-region alone. WILSON & REEDER (2005) state that there are 18 subspecies. The whole published literature contains numbers between 24 and 6 subspecies, often without any citation which makes their validity doubtful. No genetic analysis on this subject exists so far.

1.5. Study area

Previously known as Northern Rhodesia, Zambia was founded in 1924, and gained independence in 1964. With its size of 752,614 km^2, the country lies in the central southern part of Africa, surrounded by Zimbabwe, Botswana, Namibia, Angola, Democratic Republic of Congo, Tanzania, Malawi and Mozambique. Zambia is classified as a tropical country, but as it has an average altitude of 1300 m above sea level the climate is more moderate. Roughly speaking, Zambia is a relatively high situated flat country with a large valley system in the eastern part. This valley system is formed by the Zambezi and Luangwa rivers. The only true mountainous region is in the north-east of Zambia is the Nyika Plateau at 2164 m above sea level (KUEPPERS & KUEPPERS 2001). Another physiogeographical feature is the variety of basins, formed by aeolian soil accumulations, e.g. the Busanga-Kafue and Bangweulu basin at the north-central boundary to the Democratic Republic of the Congo (KUEPPERS & KUEPPERS 2001).

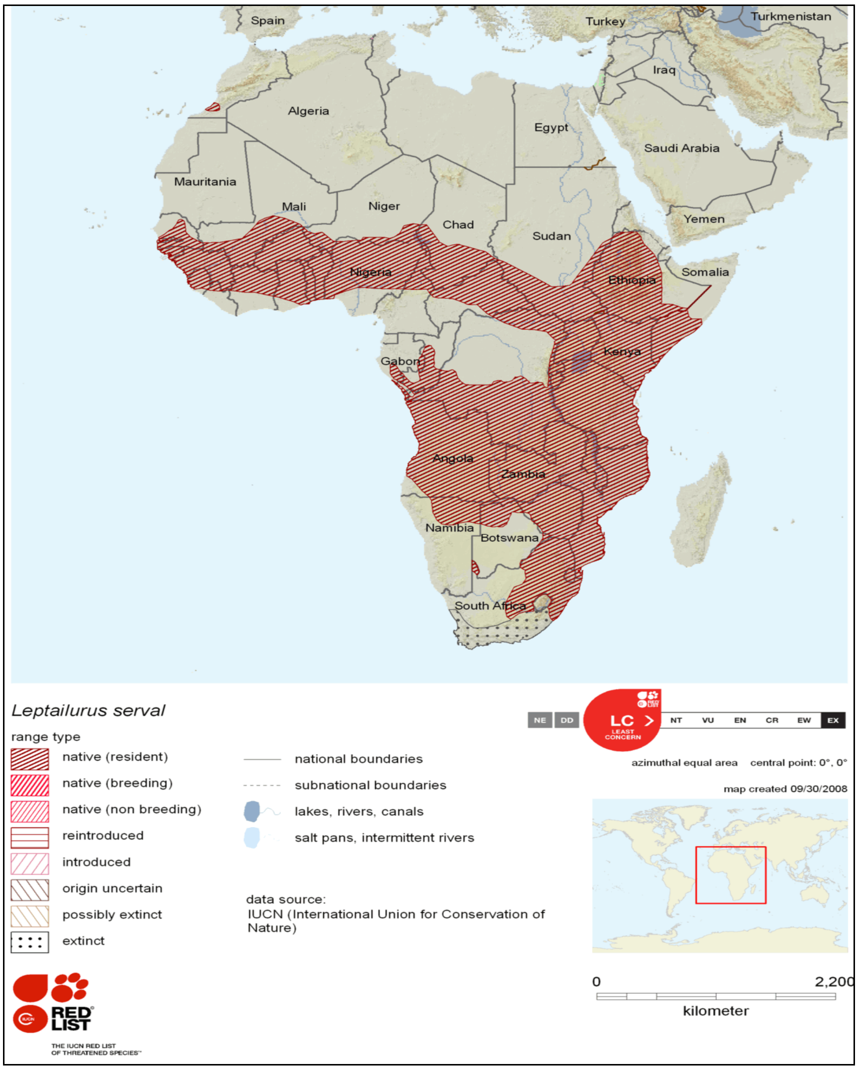


Figure 1.4: Serval distribution map after IUCN.
(Source: http://www.iucnredlist.org/apps/redlist/details/11638/0; 12.2010)

Zambia has a democratic form of government and elections are held regularly every five years, the last in 2006, followed by an irregular election in 2008 due to the death of acting president Levy Mwanwasa. At independence in the year 1964 the population was 3.2 million, and this has since tripled. Zambia is one of the most urbanized countries in Sub-Saharan Africa with about 35% of its population living in urban areas. The official language is English and despite some 72 language groups in Zambia, the incidence of ethnic conflict is low. Although it is surrounded by a number of countries that have undergone very turbulent times in the past four decades, Zambia has been one of the most stable countries in southern Africa. The majority of Zambians depend on agriculture-related activities for livelihood, with 67% of the labour force employed in agriculture (UNITED NATIONS DEVELOPMENT PROGRAMME: GLOBAL ENVIRONMENT FACILITY 2007). The importance of this sector to Zambian people is also illustrated in the 75% of Zambia's 600.000 farms being 'small scale' (less than 9 hectares) (REPUBLIC OF ZAMBIA 2000). The Zambia Poverty Reduction Strategy Paper (PRSP) in 2002 defines tourism development as the second most important sector for economic growth and poverty reduction after agriculture (ZAMBIA POVERTY REDUCTION STRATEGY PAPER 2002).

Zambia lies at the heart of the Miombo Eco-region, listed as a WWF Global 200 Eco-region because of its high species richness (OLSON et al. 2001). It is also referred to as the Zambezian Regional Centre of Endemism (WHITE 1998), an area of some 3,770 million km^2, covering parts of 11 countries and extending from the Katanga Province (DRC) to the Vaal River in South Africa. The Miombo Eco-region supports important populations of fauna, particularly large mammals, and flora.

Zambia's National Protected Areas System is considerably larger than the global mean. The most important areas in Zambia are the 19 National Parks (NP) and 35 Game Management Areas (GMAs) – together they cover over 30% of the territory of Zambia (Fig. 1.5). Conventional tourism, based on game-viewing, is the main economic use permitted within a NP. A full 85% of the GMAs were intentionally created as buffer areas to NPs. In total, these areas cover over 22% of the total country. The rationale is that NPs should protect nucleus breeding populations of wildlife; spillover populations may then be utilized in GMAs, for the benefit of the local communities living in these zones. Trophy hunting is an important economic activity in GMAs that have viable wildlife populations.

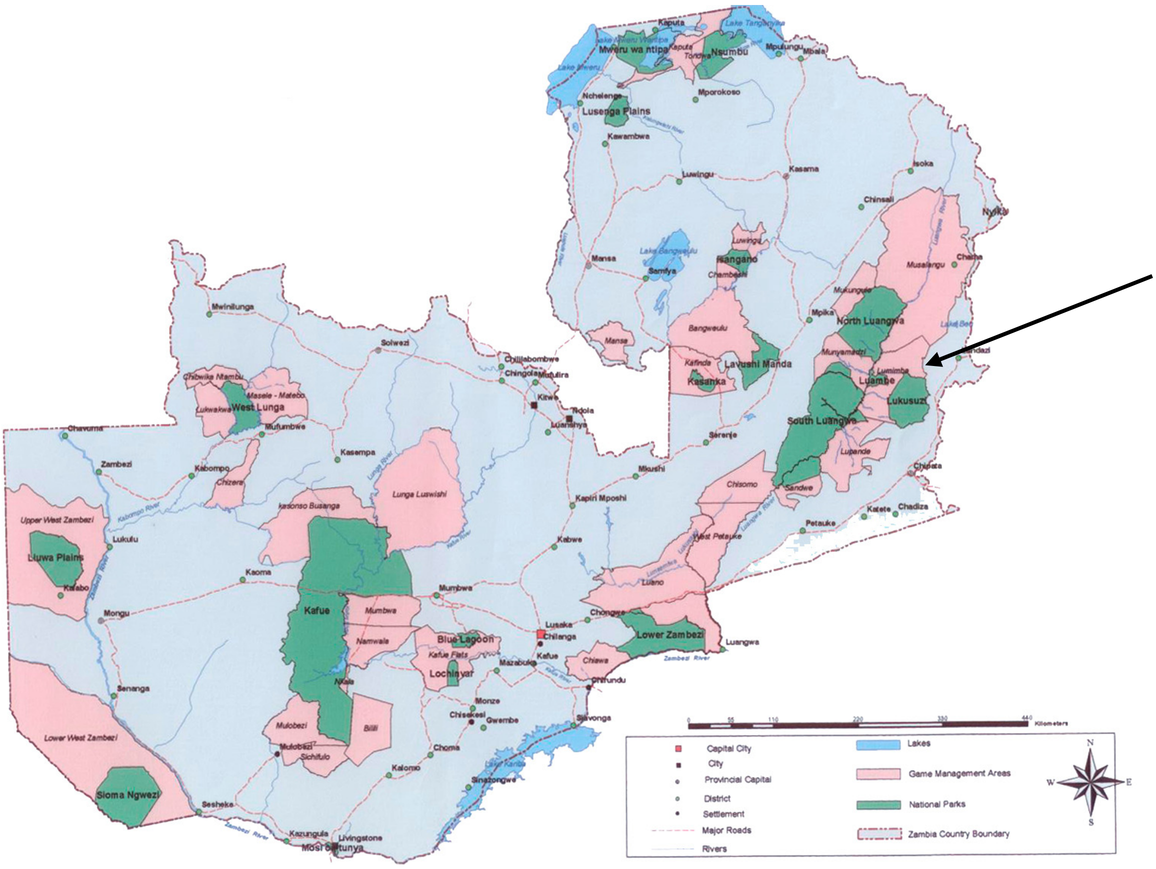


Figure 1.5: National Parks and Game management Areas in Zambia
(source: ZAWA-Zambia Wildlife Authority). Luambe National Park is marked with an arrow.

The main study area, Luambe National Park (LNP), is situated in the Luangwa valley in the eastern part of Zambia (Fig. 1.5). LNP is located on the Luangwa River, which forms a large valley, 800 km in length, from the Mafingi Hills to the confluence with the Zambezi River at the border with Mozambique (ASTLE 1999). The largest width is approximately 100 km. The Luangwa Valley forms an extension of the Great Rift Valley, which runs along a fault line from the Dead Sea in Israel down through eastern Africa (Fig. 1.6). The valley floor is mostly open, with the western side of the valley the escarpment rising abruptly into the Muchinga Mountains, whilst the eastern side of the escarpment rises more gradually. The Luangwa Valley is part of the Zambezian Regional Centre of Endemism (WHITE 1983) and provides habitat to populations of some globally threatened species including Black Rhinoceros (*Diceros bicornis*), African Painted Dogs (*Lycaon pictus*), African Elephant (*Loxodonta africana*), Cookson's Wildebeest (*Connochaetes taurinus cooksoni*) and Thornicroft Giraffe (*Giraffa camelopardalis thornicrofti*). The latter two are also endemic subspecies in the Luangwa Valley (WILSON & REEDER 2005).

The dominant vegetation type in the valley is the Mopane Forest, which is a mixed forest dominated by *Colophospermum mopane.* Other tree species like the Baobab (*Andansonia digitata)*, Acacia (*Acacia* spp.), African Star Chestnut (*Sterculia africana*), Teak (*Tectona* spp.) and Woolly Caper-bush (*Capparis tomentosa*) also occur here. Ecosystems such as *Combretum-Terminalia* woodland, savannah, humid savannah and riverine forests are also present. Environmental conditions are typical for a tropical country. In the rainy season (October-April) precipitation rises up to 900 mm in the north of the valley. The river floods and as it recedes; lagoons remain beside the main channel. The river does not dry out completely at LNP but by the end of the dry season flows are reduced to a minimum. Temperatures are about 10 °C in July and 45 °C in November (KUEPPERS & KUEPPERS 2001). Figure 1.7 shows the mean monthly rainfall, daylight and temperature recorded at the meteorological station at Mfuwe airport, which lies in the southern part of the valley, for the year 2007.

The LNP lies at around 550 m above sea level encompassing approximately 350 km^2 (JACHMANN 2000). LNP is situated between two other large National Parks close by, the South and North Luangwa National Park, and the Luangwa River forms its western border (Fig. 1.5). Luambe National Park has existed since the 1970`s. In 2002 the Zambian Ministry of Tourism, Environment and Natural Resources rated the status of Luambe National Park as "declining" (REPUBLIC OF ZAMBIA 2002). In 2004 a German NGO "Luangwa Wilderness" signed a Memorandum of Understanding with ZAWA (Zambia Wildlife Authority) to co-manage this National Park. Rangers have been hired and poaching has been reduced. Scientific research on flora and fauna only started in 2005. Despite these facts much more need to be done and to learn about this area and its wildlife and vegetation. In 2009 Neil Anderson submitted the first detailed vegetation map for Luambe National Park (ANDERSON 2009).

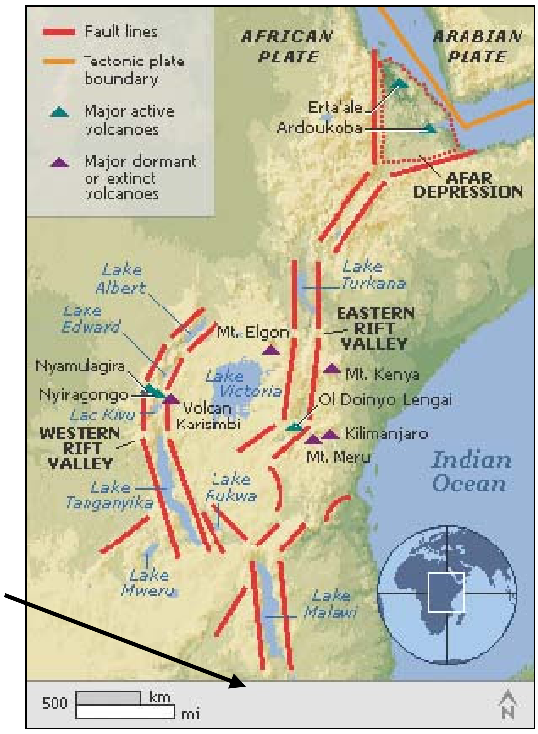


Figure 1.6: East African Rift Valley and its south-western end, the Luangwa Valley.
(source: http://orgone-ite.org/images/080601GreatRiftValley.jpg; 12.2010)

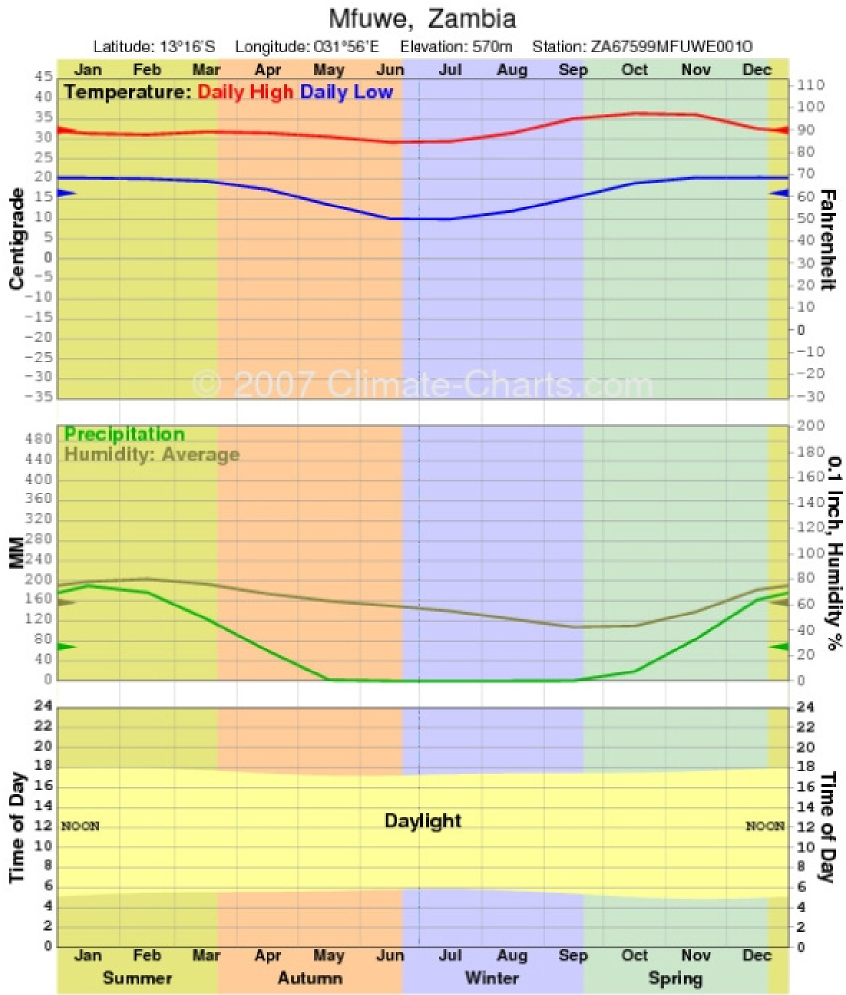


Figure 1.7: Mean monthly rainfall, daylight and temperature recorded at the meteorological station at Mfuwe airport for the year 2007.
(source: http://www.climat-charts.com/Locations/z/ZA67599MFUWE0010.php; 14.01.2009)

Figure 1.8: Luangwa River at the western border of Luambe National Park.

Besides Luambe National Park, other study sites were visited and examined for Serval occurrence using sightings and other direct observations such as spoor and droppings. The eight different study areas are distributed throughout Zambia (see Fig. 1.9): Kafue National Park, Kasanka National Park, Kahl Amazi Farm, Kushiya Farm, Lilayi Lodge, Lower Zambezi National Park, North Luangwa National Park, and South Luangwa National Park.

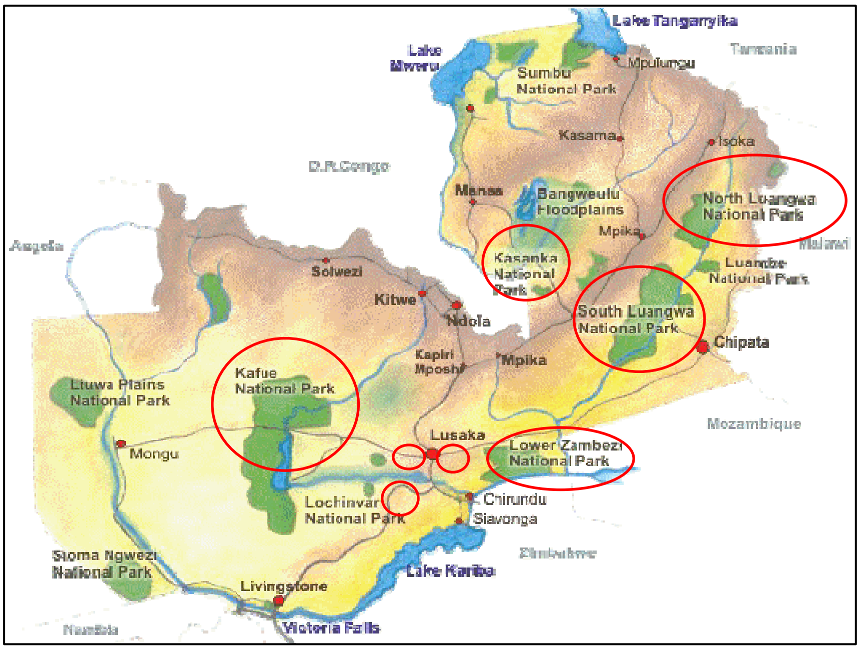


Figure 1.9: Zambia and the eight study sites outside LNP in 2008.

The Kafue National Park (Fig. 1.10) is one of the world's largest National Parks at 22.400 km^2. Many water courses run through it: Lufupa, Lunga and Kafue River with the Itzehi-tezhi dam. The Kafue NP is well known as Africa's region of the richest antelope diversity. Its characteristic landscapes are the Lufupa-Forest, the large open pastures and in the south bushland and a Kalahari like area.

The Kasanka National Park (Fig. 1.11) with its 450 km² is one of the smallest National Parks in Zambia. It is run by the Kasanka Trust LTD., a private organization. It contains swamp areas and is close to the world famous Bangweulu Swamps. It is known for its rare birds and antelopes, like Sitatunga, Black Lechwe and Puku.

Figure 1.10: Floodplain habitat in Kafue National Park.

Figure 1.11: Termitaria islands in swampy areas of Kasanka National Park.

The Khal Amazi Farm (Fig. 1.12) is situated west of Lusaka, about 10km off the city borders. It comprises of 2500 ha and is divided into a commercial part and a wild game area. There is a dam in the centre of the farm as well as a large power line running through. The wild game area supports 250 cattle, but otherwise there is low human disturbance, apart from the private dirt roads leading through. The vegetation is dominated by Mopane forest and grassland. The area is surrounded by farmland for maize and livestock.

Kushiya Farm (Fig. 1.13) is situated near Mazabuka, approximately 500 km southwest of Lusaka. This area has high levels of agricultural activity, both arable (sugar cane and maize cultivation) and pastoral. The Kushiya Farm has 3000 ha where half of this area is for commercial use with crop growing (using crop rotation methods) and livestock farming and the other half is used as commercial game farm for hunting. The fields are mostly bare soil or grassland with bordering trees. The wild game area comprises bushy grassland with forest sections on rocky ground, sometimes big boulders are visible.

Lilay Lodge is a tourist venue east of Lusaka, approximately 20 km out of the city borders. The area is 600 ha large and contains a lodge area for around 20 guests. The rest of the property is used for game drives, hiking and riding trails. There are two small ponds as well as two artificial troughs for the game. The vegetation is mostly grassland with bushes and trees. The area is surrounded by farmland for maize and livestock.

Figure 1.12: Power line and Giraffes at Khal Amazi Farm, outside Lusaka.

The Lower Zambezi National Park (Fig. 1.14) lies on the Zimbabwean border, at the Chongwe and Zambezi rivers. It is Zambia's youngest National Park and its size is 4000 km^2. The park slopes from the Zambezi Escarpment down to the river, across two main woodland savannah eco-regions, distinguished by the dominant trees, Miombo (*Brachystegia* spp.) and Mopane (*Colophospermum mopane*). At the river's edge floodplain habitat is found.

South Luangwa National Park borders Luambe National Park to the north. The National Park is 9050 km^2 and probably the most visited park in Zambia. It runs along the Muchinga Escarpment and is dominated by Miombo Forest and open grassland, as well as floodplain habitat along the Luangwa River. It is run by a private organization, the South Luangwa Conservation Society, in cooperation with the government (ZAWA).

The North Luangwa National Park is situated close to the northern border of Luambe National Park. The Frankfurter Zoologische Gesellschaft (Frankfurt Zoological Society) is running a Black Rhino Project there and supports the governmental management of the Park. The park is 4,636 km^2 in size, and is also enclosed by the Muchinga Escarpment. Main vegetation types are Miombo and Mopane Forest, as well as floodplain habitat along the Luangwa River, some open grassland and *Acacia* forest.

Figure 1.13: Area around Kushiya Farm, outside Mazabuka.

Figure 1.14: Riverine vegetation in Lower Zambezi National Park.

Figure 1.15: Riverbed in South Luangwa National Park.

Figure 1.16: View from the lower part of Muchinga Escarpment onto North Luangwa National Park.

2. Diet

This chapter is describing the Serval's diet in Zambia with the focus on Luambe National Park. Therefore the prey spectrum will be identified. There are answers to questions as:

1. Are there annual changes in food composition in Luambe National Park?,
2. Is there a change in the prey spectrum depending on areas within Zambian biotopes?,
3. Is the Serval an opportunist or a specialist in its food choice?

2.1. Introduction

The majority of available information about the Serval's diet is based on anecdotal accounts or incidental observations (FITZSIMMONS 1919, PIENAAR 1969, DORST & DANDELOT 1972, KINGDON 1977, ROWE-ROWE 1978). However, some studies have described the Serval's diet from direct observations, stomach contents analyses and scat analyses (SMITHERS 1978, SMITHERS & WILSON 1979, GEERTSEMA 1985, BOWLAND 1990). Through scat analyses BOWLAND (1990) found that in Natal 75% of the Serval's diet is made up of rodents and shrews, with birds constituting 19%, reptiles 4% and insects 3%. GEERTSEMA (1985) determined that Servals in the Ngorogoro Crater have an average daily intake of 12 rodents, 0.9 snakes and 0.2 birds, with an average consistency of 43% small mammals, 33% amphibians, 9% birds, 6% reptiles and 9% insects/arthropods in their diet. Annually the individuals studied fed on 4000 rodents, 260 snakes, 130 birds and an unknown, but large quantity of insects (GEERTSEMA 1985, ANONYMOUS 1995). In ZIMBABWE, SMITHERS (1978) and SMITHERS & WILSON (1979) examined 65 stomach contents and found 71% mammal, 13% bird, 8% reptile, 6% insect and 2% amphibian remains. In Zimbabwe and South Africa Vlei Rats (*Otomys angoniensis* & *O. irroratus*) are the chief prey species of Servals (SMITHERS 1978, BOWLAND & PERRIN 1993), which indicates their affinity for vlei areas, aquatic grasslands and savannah (DE GRAAFF 1981). Duiker (*Sylvicapra grimmia*) and Oribi (*Ourebia ourebi*) have been listed as prey species by DORST & DANDELOT (1970). However, SMITHERS (1978) suggested that the Serval is incapable of tackling such large prey items. Servals are also known as notorious poultry raiders; these incidences were observed mostly in South Africa, Tanzania and Zimbabwe. Since 1990, no further studies on the Servals' diet have been conducted, and information for Zambia is actually completely absent.

Servals are predominantly nocturnal, but also active in the early mornings and late afternoons (VAN AARDE & SKINNER 1986, SKINNER & SMITHERS 1990). Hunting activity occurs at diurnal or/and nocturnal times depending on the area (ROWE-ROWE 1978, VAN AARDE &

SKINNER 1986). GEERTSEMA (1985) stated that activity pattern depend on disturbance by humans, habitat and terrain conditions, prey availability and habit. The Serval's suite of morphological refinements, unique among cats, makes this elegant felid a rodent specialist. The elongated legs raise the Serval above tall grasses and with its long flexible spine, allows it to accomplish four-metre-long jumps. As the Serval's hunting behaviour rarely includes long chases (GEERTSEMA 1976, KINGDON 1977) or arboreal tactics (GEERTSEMA 1976, PINAAR et al. 1980), the Serval has little need for any speed or balance compensation and so its tail is relatively short. Hunting involves sound, more than vision (HUNTER 2000). The prey is often killed on impact by pouncing (ROSEVEAR 1974, SMITHERS 1978, STOTT 1980, GEERTSEMA 1985). If the first leap misses, the Serval will follow through with its attack with a series of rapid pounces in pursuit of the fleeing target. The claws are shaped to dig out prey and investigate holes, e.g. while hunting for Mole Rats of the genus *Trachyoryctes* and *Cryptomys* (VERHEYEN 1951, RAHM & CHRISTIAENSEN 1963). Birds and insects can also be caught in the air by jumping and clapping the front paws together (ROSEVEAR 1974, KINGDON 1977, SMITHERS 1978, LEYHAUSEN 1979). Servals are capable of hunting in wet areas with up to 30 cm of water (SMITHERS 1978, GEERTSEMA 1985). Scavenging appears to be very rare, as GEERTSEMA (1985) recorded this in only 0.2% of her observations.

GEERTSEMA (1985) noted that hunting success of Serval is very high compared to other felids. In Ngorogoro Crater, a Serval caught its prey in 48.1% of attempts in the day and this increased to 52.3% at night. A female Serval which had to feed its young had a hunting success rate of 62% (GEERTSEMA 1985). When taking only rodents into account hunting success is 81% (GEERTSEMA 1985). STOTT (1980) reports on Servals in Ethiopia and Kenya deliberately waiting for the spotlights of the cars to aid their hunt next to the road; this seemed to increase their hunting success and they didn't show any signs of alarm at human presence. In contrast Servals in Kenya ran away from cars during the late afternoon although they were regularly exposed to car traffic. The Serval is a solitary cat, although there have been observations of associative hunting (RAHM & CHRISTIAENSEN 1963, KINGDON 1977, SMITHERS 1978, STOTT 1980). However, KINGDON (1977) observed that wild cats sometimes hunt in pairs or family groups 3-30 m apart at the same spot which can be misinterpreted as group hunting.

Detailed dietary information is often obtained by sorting the contents of faeces to identify the origin of bones and other hard tissue that survive digestion (SHAW 2006). Servals don't cover their faeces (SMITHERS 1978, SKINNER & SMITHERS 1990, WALKER 1996) and do not deposit them at the same locations (GEERTSEMA 1985, WALKER 1996). They deposit their faeces mainly on roads and tracks (Fig. 2.1) placed in the grass, on sand, and sometimes on other carnivores' droppings (GEERTSEMA 1985, SKINNER & SMITHERS 1990, SKINNER & CHIMIMBA 2005, own observation). The faeces are sausage shaped and fairly long (Fig. 2.2), in relation to the animal's size, and are about 2 cm in diameter (SMITHERS 1978, WALKER 1996). GEERTSEMA (1985) observed that the faeces of a Serval varies in colour from dark brown to pale grey with sometimes visible particles (bones, teeth, jaws) on the outside. The droppings are held together by hair and feather materials.

Figure 2.1: Serval scat on a trail.

Figure 2.2: Typical shape and size of Serval faeces.

Attempting to quantify and identify the relative abundance and thus the importance of different food types using scat analysis does present some problems:

1. Varying digestibility of different prey types causes the proportions of the remnants in the scats to differ from the actual intake proportion (PUTMAN 1984).
2. The remains of certain types of prey are not easy to quantify (PUTMAN 1984).
3. Different passage rates of prey species and parts may lead to overestimation of consumed prey, especially if sequentially passed scats are collected (FLOYD et al. 1978, HISCOCKS & BOWLAND 1989, BOWLAND & BOWLAND 1991, BAKER et al. 1993).
4. Large prey may leave less evidence, as it is only partially eaten and has less indigestible parts compared to body size than small prey (BOWLAND & BOWLAND 1991).

Passage rates were tested in Servals by BOWLAND (1990) and BOWLAND & BOWLAND (1991) with captive individuals, living indoors. They were fed *Rattus rattus* and *Mastomys natalensis*. The majority of bones and hair passed through with the first and second scat although one prey's hair could be represented in up to seven scats with an average of 4.2 days passage period. BOWLAND (1990) tried to determine a correction factor for the calibration between digested biomass and undigested mass of the remains as well as the percent age detectability of various prey types to gain the exact numbers of consumed prey. The detectability trials showed a high degree of individual variation making any calculation of a correction factor impossible; the same was the case with the biomass correction factor. As the Servals' diet is relatively uniform, BOWLAND (1990) decided not to apply a correction factor. Relative contributions to the diet made by each prey category can be expressed in terms of prey occurrence or transformed to represent proportional contribution to biomass ingested. This approach has been used in numerous felid studies including those of Ocelot (*Leopardus pardalis*) (EMMONS1988), Jaguar (*Panthera onca*) (RABINOWITZ & NOTTINGHAM, 1986), Leopard (*Panthera pardus*) (HENSCHEL 2002, STOMMEL 2009) and African Golden Cat (*Profelis aurata*) (HART et al. 1996).

Under my supervision a Diploma Thesis was conducted with this PhD by Margit SCHMITT (SCHMITT 2009). Margit SCHMITT found the feeding ecology of the Servals of Luambe National Park in Zambia to be similar to the results of studies conducted in South Africa, Tanzania and Zimbabwe by BOWLAND (1990), GEERTSEMA (1985) and SMITHERS (1978), which define the Serval as a rodent specialist. The raw data of Schmitt's study is used within this thesis.

2.2. Methods

2.2.1. Determination of prey components in the Serval diet

Serval scats were opportunistically collected, whenever and wherever they were encountered, rather than by systematic survey. During this study scats were located either on small roads, paths, sometimes singly on prominent positions on tree roots, termite hills (Fig. 2.3) or grass lumps. No evidence was found of latrine sites but sometimes Serval scats were found placed on top of other carnivore scats, e. g. in Civet (*Civettictis civetta*) latrines or Genet (*Genetta genetta*) faecal sites (Fig. 2.4). Each scat was labelled according to collection date, location (using a handheld GPS, Garmin eTrex legend) and relative age of the scat.

Figure 2.3: Serval scat on top of a termite hill in Kasanka NP.

Figure 2.4: Serval scat together deposited with other carnivore species scat in Kafue NP.

Scat samples were air-dried, then put into plastic bags filled with silica gel to keep them dry before transporting to Germany. If samples were fresh (up to 2 weeks old, depending on their condition) a piece was separated for later DNA analyses.

Faeces were identified by associated tracks, their characteristic morph, length and diameter; shape was the main indicator. Misclassification of scats from similar species like African Wildcat (*Felis silvestris lybica*), Caracal (*Caracal caracal*), Civet (*Civettictis civeta*), Genet (*Genetta genetta*), Leopard (*Panthera pardus*) or the Side-striped Jackal (*Can*is *adustus*) were minimized on site by experienced collectors and later through guard hair analyses. Unidentifiable samples were discarded; such as samples bigger then 2.4 cm in diameter (as they could also be of Leopard origin) and samples smaller then 1.7 cm (possibly African Wildcat scat).

In the laboratory scats were photographed and diameters were measured at the thickest part of each scat sample, this was followed by softening in 70% ethanol. After 2-4 days in ethanol the faeces were softly crushed, washed and their different components were sorted and classified (Fig. 2.5). Teeth, jaws, bone fragments, feathers, vegetation and other identifiable remains were separated from the rest of the scat, which mostly consisted of hair. All longer hair, which presumably did not belong to the prey species, was sorted and collected separately.

Figure 2.5: Sorted components of faecal samples and their storage.

Teeth and jaws, as well as other pieces of bone, were used to identify mammal species, bones, beaks and feathers were used for birds, scales for reptiles and some chitin pieces for insects. Remains were determined using reference material of the Zoological Research Museum Alexander Koenig (ZFMK), which has a large collection of all of these taxonomic groups as well as highly trained staff. Additionally reference material of small mammals had been collected in the years 2006 and 2008 during the study period within the study area (SCHMITT 2009). Parasites and vegetation were treated separately. If components were still dirty after the washing procedure they were cleaned in an ultra-sonic bath. After this, all parts were air-dried (vegetation, feathers, skeletal remains, prey hair) or stored in 99% ethanol (parasites, scales, carnivore hair, unidentified parts).

Vegetation was noted and categorized in ‘grasses’ and ‘other vegetation’ and unidentified parts were recorded. Prey hair was stored in plastic bags only to be examined if skeletal remains would not lead to a conclusion about their origin.

Parasites were stored to be determined with the help of PROF. EBERHARD SCHEIN from the Institute of Parasitological and Tropical Veterinary Medicine of the Free University Berlin (see Chapter 3).

Scales of reptiles were compared with ZFMK collection material and identified with the help of PROF. DR. WOLFGANG BÖHME.

Birds of the ZFMK collection were used as reference material to identify the remains of recovered feathers, beaks and claws with DR. RENATE VAN DEN ELZEN's supervision.

Mammal bones were divided into teeth/jaws and bones. The bones were separated again into small bones from small rodents and large bones from unknown origin.

The teeth and jaws were mounted onto Plasticine© (Fig. 2.6) and identified with a dissecting microscope. Reference material from the ZFMK and from the supervised study of SCHMITT (2009) was used to identify the samples at family, genus or species level, supported by DR. RAINER HUTTERER. The numbers of one type of tooth (specified upper/lower jaw, right/left side) indicated the amount of consumed individuals.

Figure 2.6: Teeth of rodents ready to identify.
(Picture by Margit Schmitt)

2.2.2. Guard hair analysis

Due to grooming behaviour Servals swallow their own hair (BOWLAND 1990) and this hair can therefore be extracted from the remains of the consumed prey. Once isolated from the faeces, guard hair analysis represents a useful way of identifying the species that deposited the faecal samples. The hair of mammals is divided into 5 groups, but for analyses of cuticular and medulla the guard hair is the most accurate type in distinguishing at species level (MATHIAK 1938, MAYER 1952, DAY 1966). The cuticular is the outer layer of the hair and the medulla is the core (which is highly pigmented). Both are unique for each species (BRUNNER & COMAN 1974) in the relation to each other (Fig. 2.7) as well as in shape (Fig. 2.8).

Macroscopic analyses are possible as the hair does not loose its characteristics even over extended periods of time (OLI 1993). Single hairs were also studied with bare eyes or with a magnifying glass (10x). Contour, length, width, colour and pattern were the recorded criteria. There is only one description of serval hair, done by SMITHERS (1989): "The hair of the guard coat on the upper parts is soft and while shorter on the head about 10 mm is fairly even in length over the remainder of the body at about 30 mm. The individual hairs of the guard coat conform to the colour of the area in which they are situated either being black on the black markings or lighter on the background colour these latter with lighter tips. The underfur is dense, wavy and shorter than the hairs of the guard coat and tends to have a tinge of grey at the base. Interspersed through the coat are numerous tactile hairs up to about 60 mm in length with pale bases and broad black tips. The hair of the guard coat on the tail is slightly longer than that on the upper parts at 30-35 mm and is even in length throughout." Following KEOGH (1985) findings that storing and preserving of hair in a museum does not harm its structure, a reference collection of different carnivore species was created with hair samples from skins from the ZFMK and from skins of wild carnivores shot by professional hunters around Luambe National Park. Hair was taken from different parts of the body. To reduce damage of the hair only the hands were used to pull them out of the skin.

Before examination of the medulla the hair samples were cleaned with ethanol and dried. Up to five single guard hair were fixated with Euperal© and a cover glass, and the slides left to dry for several days. The medulla patterns were compared to the reference collection of several carnivores (Fig. 2.6). The samples were photographed with a camera (Olympus DP 50) on a microscope (Olympus BX51TRF) at 600x enhancement.

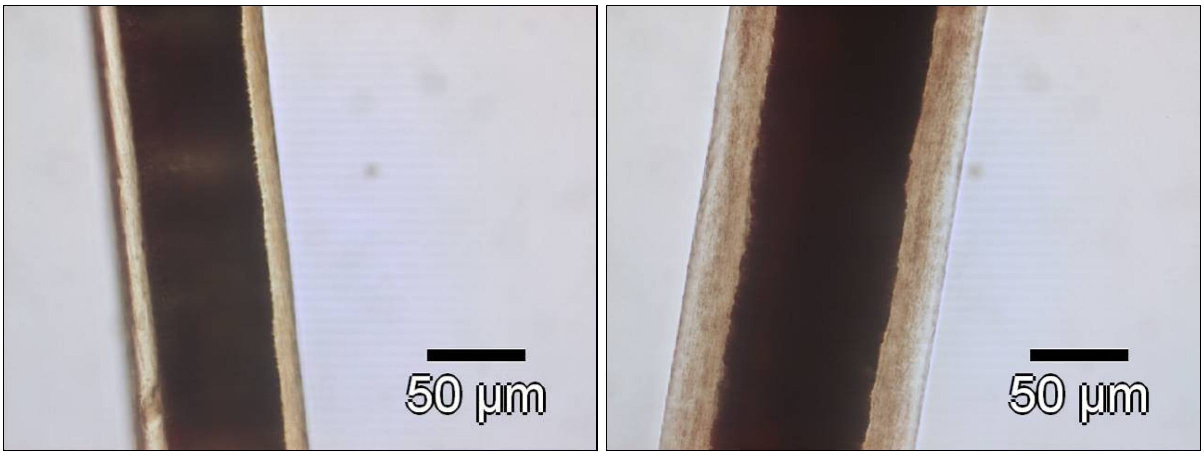


Figure 2.7: Medulla of guard hair (left: Serval; right: Banded Mongoose (*Mungos mungo*)).

For the cuticular analysis, the hair samples were cleaned with Ethanol, dried and most of the proximal hair was held on a 0.75 mm x 1 cm x 2 cm celluloid plate and brushed over with a small brush soaked with acetone (after WACHTER et al. 2004). The hair thereby sinks into the celluloid plate. After 3 to 5 seconds hair was removed and left the characteristic contours of the cuticular as a negative imprint (Fig. 2.9) on the celluloid plate. The cuticular patterns were viewed in the impression of the hair surfaces and compared to the same reference collection of several carnivores. The samples were photographed with a camera (Olympus DP 50) on a microscope (Olympus BX51TRF) at 600x enhancement (Fig. 2.8).

For all the faecal samples of the right shape and size as mentioned in 2.2.1 the origins of extracted hair were determined using three possible identification methods: a) cuticular patterns, b) medulla patterns and c) macroscopic structure. HARRISON (2002) studied the reliability of these three methods to distinguish between felid and non-felid hair. He stated that one criterion alone is not secure enough for identification but all variables need to be considered. Hence, samples are marked as ‘positive’ if at least two of the three mentioned categories pointed to the Serval as origin. Other samples showing clear indications for other species as origin, the samples were discarded as ‘negative’. Other samples with no conclusive proof to any origin were classified as ‘unclassified’, containing two subclasses: 1. ‘without guard hair’, where determination was not possible due to missing guard hair; and 2. ‘unidentified’ where no conclusive hair structures could be found or only one out of these three categories pointed to the Serval.

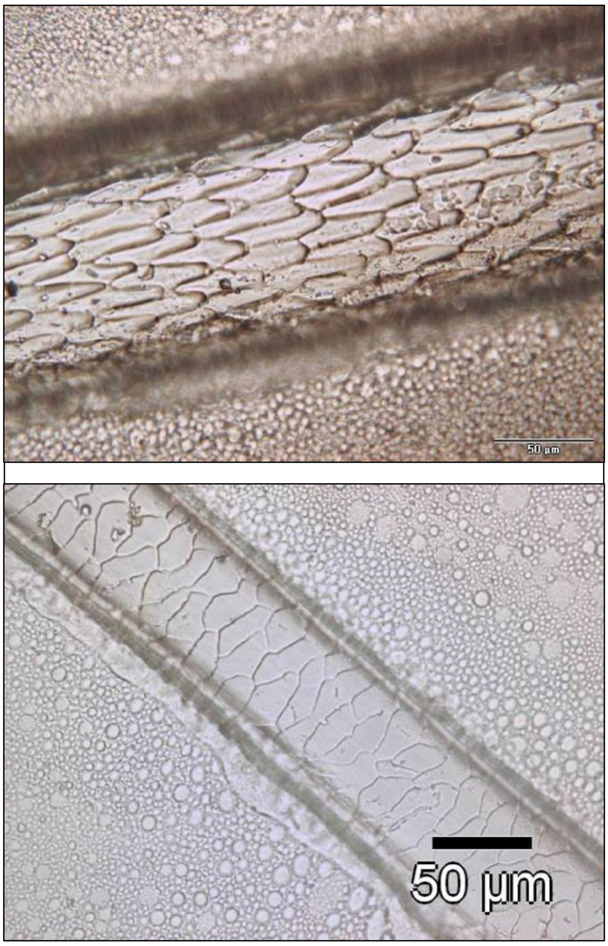


Figure 2.8: Cuticular imprint of hair samples on celluloid plate (top: Side-striped jackal, down: Serval).

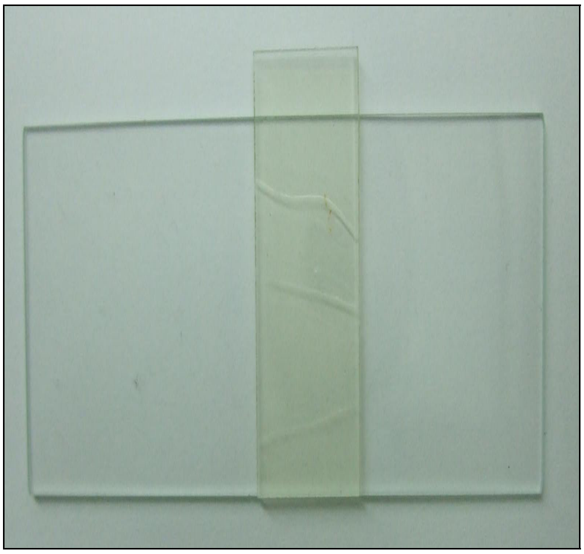


Figure 2.9: Celluloid plate with imprints (Picture by Margit Schmitt)

2.2.3. Data analyses

Dietary composition was expressed as ‘frequency of occurrence’ (FO) - the percentage of scats in which a particular item was found, and as ‘percentage occurrence’ (PO) - the number of times a prey item was found, expressed as a percentage of all items recorded (LOCKIE 1959).

The term ‘prey item’ here refers to the classification of prey to the lowest taxonomic resolution possible. This was taken to species level whenever feasible; however, in some cases prey could be determined to the level of family or order only.

An estimate of the minimum number of consumed prey items was given by counting claws, tooth types, and beaks or other skeletal remains in each faecal sample. This number was used to provide the percentage occurrence in the diet of the Serval. Due to different sizes and digestibility of the diverse prey items, percentage occurrence could only be determined within each group itself, not for the whole diet. The numbers of insects and reptiles is certainly underestimated in this study due to the small remains of insects and due to the fact that an accurate estimate of the number of reptiles only identified by scales was impossible. But with the group 'reptile' it is safe to give a minimum estimation of one animal per finding. Hence percentage occurrence could be applied for the taxonomic groups 'reptiles', 'birds' and 'small mammals'.

The percentage occurrence of within groups was also calculated separately to identify the importance of the single prey item within this group. Calculations were made of the biomasses of the different prey items, and how they relate to each other, to verify the results of the method of percentage occurrence, but only on the groups 'birds' and 'small mammals'. This allowed an estimate of the total biomass ingested by these animals (Total biomass = average prey body mass x number of individuals in the faecal samples) (WANG 2002, ABREU et al. 2008).

For the data on the Servals' diet in Luambe National Park the diet breadth was calculated. After PHILLIPS et al. (2007) the importance of a particular prey category is determined by calculating the 'relative frequency of occurrence' (number of times each prey item occurs/ total number of occurrences of all prey items * 100), which is the same as the 'percentage occurrence' (PO) after LOCKIE (1959). This 'relative frequency of occurrence' is also used to determine the diet breadth (REYNOLDS & AEBISCHER 1991, PHILLIPS et al. 2007) using the standardized Levins index (COLWELL & FUTUYMA 1971) given below:

$$B = \left(\sum_{i=1}^{n} pi^2 \right)^{-1},$$

where n is the number of prey categories and p is the proportion of records in each prey category (i). The standardized form of the formula is:

$$B_{standard} = (B-1) / (B_{max}-1),$$

where B is the Levins index of niche breadth and B_{max} is the total number of prey categories. $B_{standard}$ values can range between 0 (minimum diet breadth) and 1 (maximum diet breadth). Diet breadth was assessed using the major prey categories 'mammals', 'birds' and 'reptiles' (PHILLIPS et al. 2007).

All statistical tests were calculated with SPSS 13 and R 2.11. Graphs were produced with Microsoft© Office Excel 2003 and SPSS© 13.

2.2.4. Prey availability

The relative abundance of small mammal species in Luambe National Park was evaluated within each study area via a grid-based live-trapping study. Small mammals were captured at ground level using three different types of Sherman live traps (H.B. Sherman Traps, Florida; Fig. 2.44). Altogether 126 traps were available (82 size A, 30 size B, 14 size C) which were split into two groups each with 63 traps. With these traps two locations could be set at the same time. Trap lines are the most commonly used method for studies on presence/absence of species (GURNEL & FLOWERDEW 2006). Two trap lines were set at riverbeds or waterholes (one line at each side), three trap lines were used in all other areas and different trap types were equally arranged by setting traps 10m apart. Hence trap lines covered an area of 3000 m^2 or 4000 m^2 respectively. Altogether 16 trapping areas were identified and studied (Fig. 2.45). For habitat descriptions for each area see Table 2.17. The trapping period started in June 2008 and lasted until end of August 2008. Trapping areas were determined in the first two study years. An area to be identified as trapping area needed to meet at least one of the following criteria: Serval scat found; Serval sighting took place; Serval spoor was found, close to water (Fig. 2.46). Some areas without any of these criteria were also chosen as control sites. Each trap line area was checked at dawn. Each evening traps were set with bait of popcorn, peanuts and roasted oats, ground and mixed with water just before applying to intensify the odour.

Captured animals were identified to species level at the ZFMK in Germany. In the field standard morphological measurements were taken as well as identification pictures and body weights to the nearest gram. Samples of up to 10 individuals per species found were collected and kept for the collection of the ZFMK; preserved whole in alcohol or skinned to keep only the skeleton. Sampling effort (number of traps x number of inspections) and trap nights (number of traps x number of nights trap were set) were the same in this study. As this study only aimed to ascertain the presence or absence of a species, the operation for a minimum of three consecutive nights of trapping (GURNEL & FLOWERDEW 2006) was not necessary. Each area was used for five consecutive nights, which led to 315 trap nights per area and altogether 5040 traps nights in LNP in the year 2008. After cleaning and repairing the traps, the set of traps for the next two new trapping areas was set for the following trapping period.

These trapping studies were combined with a review of the relevant literature to identify those small mammal species potentially present within each of the eight different study areas in Zambia.

Only lists of small mammals were compiled for each site, as these have been shown to be the main prey source of Servals. Lists could be obtained through literature review of the last 50 years. This study did not attempt to assess the relative abundance of bird, reptile nor arthropod species within the study areas.

2.2.5. Activity patterns of Servals in Luambe National Park

Through observations in the field the activity patterns of the Servals in Luambe National Park were determined. This was conducted by driving and walking in the study area searching for the Servals. As soon as a Serval was spotted the search was stopped, the Serval was observed and an observation sheet was filled out (see Appendix (Chapter 2)). The Date, the time, duration, the area and its GPS coordinates, the habitat type, the individual observation name, moon phase, wind strength, cloud cover, the sex, the age, proximity to water, the activity state and the behaviour was noted.

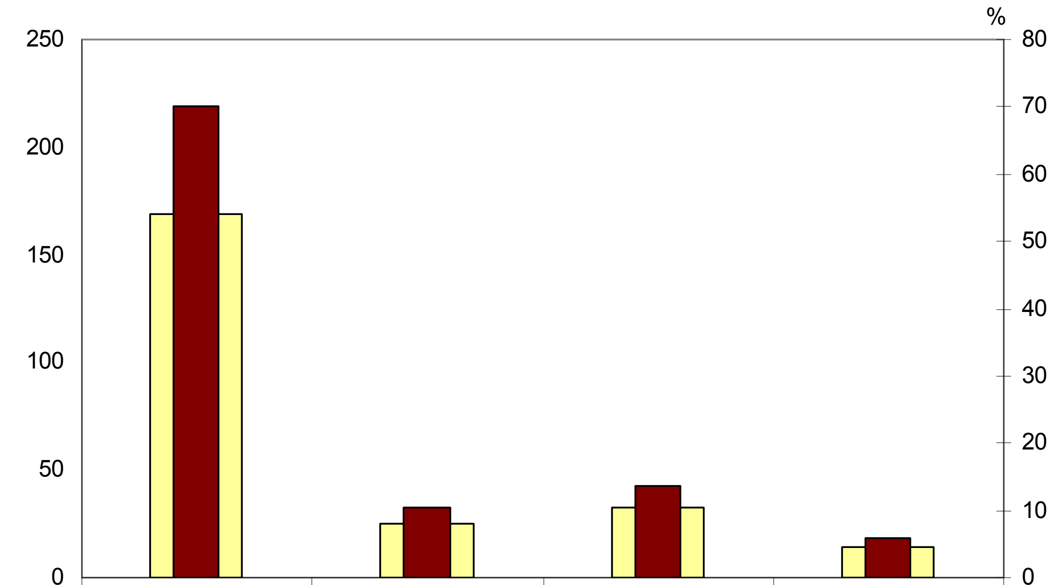
2.3. Results

2.3.1. Diet in Luambe National Park

2.3.1.1. Prey spectrum in Luambe National Park

The samples of LNP were washed and analyzed by Margit Schmitt (SCHMITT 2009) for her Diploma Thesis. The raw data were used in this PhD but results were calculated again with regards to questions specified by the hypotheses mentioned in Chapter 1.

It was possible to locate 241 faecal samples for prey spectrum analyses. Through guard hair analyses 169 (70.12%) samples were determined as Serval scat, 47 (19.5%) samples remained as unclassified and 25 (10.37%) were discarded as 'negative', non Serval scat (see Fig. 2.10). The class 'unclassified' contains the two subclasses 'without guard hair', where determination was not possible due to missing guard hair (5.81%) and 'unidentified' where no conclusive hair structures could be found (13.69%). The mean diameter of all positive determined samples was 21.72 mm, and of all unclassified samples 20.92 mm.



	Positive	Negative	Unidentified	without guard hair
Amount	169	25	33	14
Percentage	70,12	10,37	13,69	5,81

Figure 2.10: Identification of origin of faeces collected in LNP (N = 241).

For data analyses, unclassified samples were treated like positive samples, as shape and size of the scats were identified as Serval scat in the field before collection. Figure 2.9 also shows the results divided into the two groups to determine significant differences between these groups.

Following the cumulative curve of number of prey items determined against number of analyzed scats for all three study years (see Fig. 2.11) 118 faecal samples are necessary to identify principal prey remains, and only after 177 scat samples the asymptote is fully reached.

Subdivided into the three different years, 13 samples in the year 2006, 59 samples in the year 2007, and 98 samples in the year 2008 were positively identified as Serval scat. There were eight unclassified samples collected in 2006, nine in 2007 and 29 in 2008. Altogether 21 scats samples were used for the analyses in the year 2006, while in the following years 2007 and 2008 the number of analysed samples went up to 68 and 127 respectively. When looking at the cumulative curve of the number of prey types identified against number of analyzed scats, separated by year, it is obvious that only in 2008 enough faecal samples were collected to give an adequate representation of the Serval's annual prey spectrum in LNP. An asymptote occurs at scat 88 (Fig. 2.12).

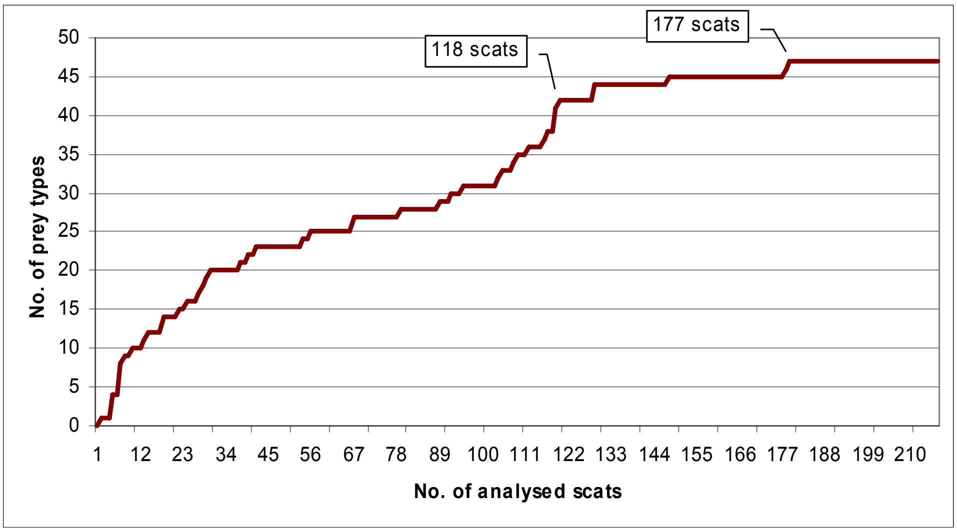


Figure 2.11: Cumulative curve of number of prey items identified against number of analyzed scats for all study years.

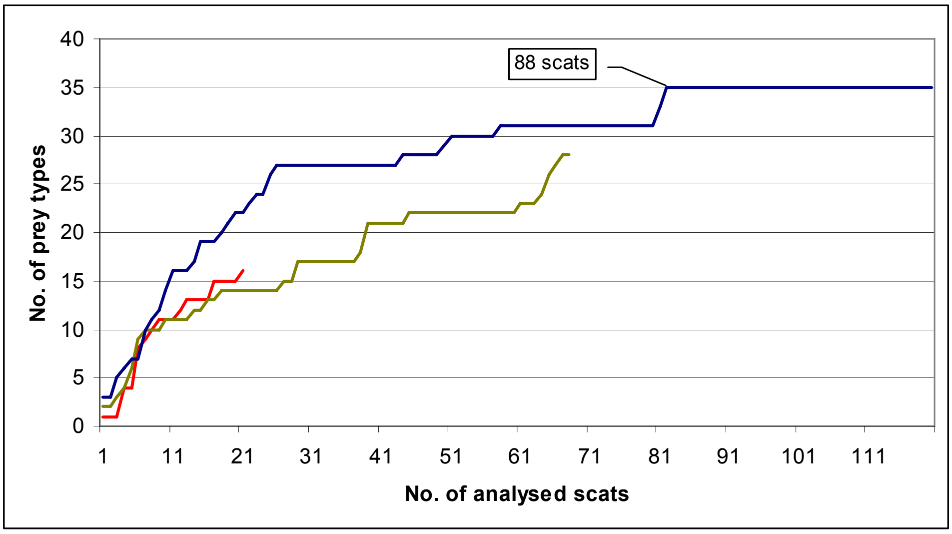


Figure 2.12: Cumulative curve of number of prey items identified against number of analyzed scats in the years 2006, 2007 and 2008.

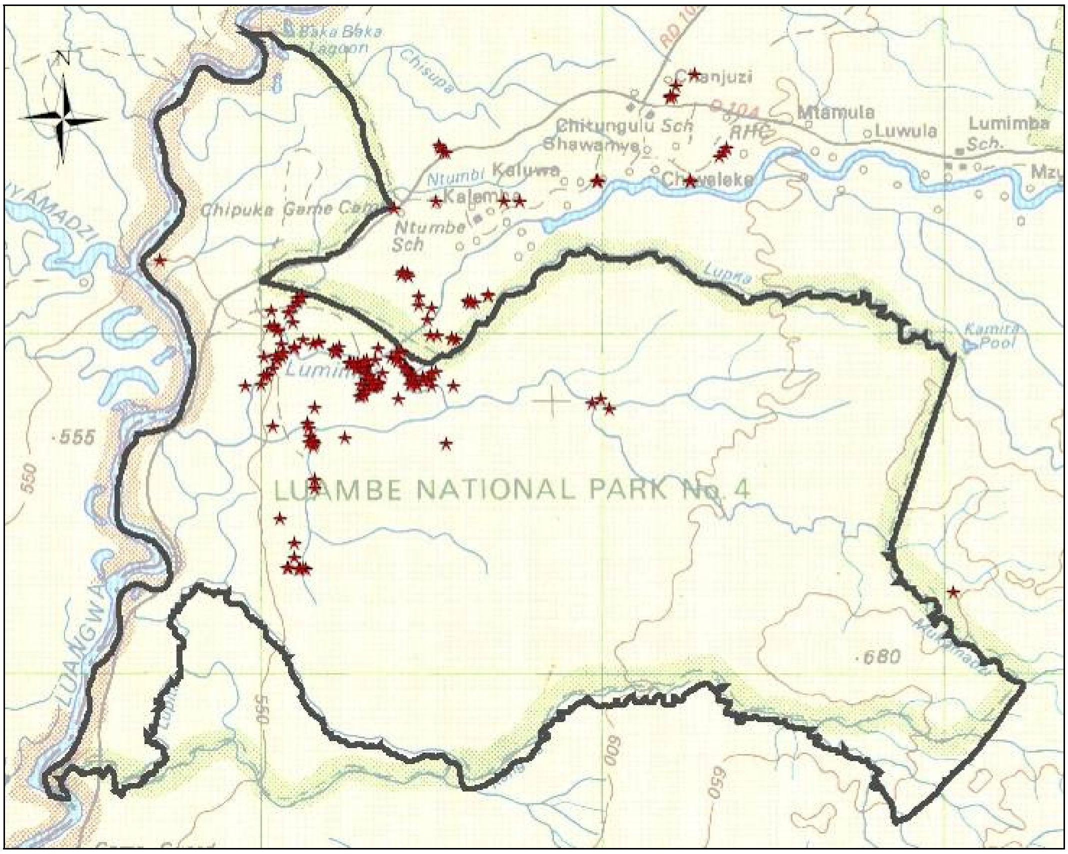


Figure 2.13: LNP (black line = border) with locations of all analyzed droppings (red stars).

After removing the negative samples, 216 faecal samples could be used to identify the Servals' diet in Luambe National Park and surrounding areas (Fig. 2.13). Servals were mainly feeding on small mammal prey (Fig. 2.14). The frequency of occurrence of small mammals was 88.89% as evidence of teeth and 84.26% in the form of hair. Birds were found in 25% of all scat samples, reptiles in 14.81% and arthropods in 21.30%. Figure 2.15 shows these results separated into positive and unclassified samples. There is no significant difference (Mann-Whitney-U-Test; $p = 0.462$) in the frequency of occurrence between these two groups.

Parasites, like ticks and tapeworms, were found in around 85% of all samples; results of the analyses will be discussed in Chapter 3. Grass could be found in almost all scat samples (89.81%). Other vegetation (like seeds, bark or leaves) was discarded as only small amounts occurred and further identification was difficult. Hair and bones of small mammals were found in almost all samples. Bones could represent skeletal remains of birds, small mammals and reptiles, but were not divided any further into the taxonomic groups. Teeth of small mammals were only found in 88.89% and thus in higher frequency than hair of these prey items (84.26%).

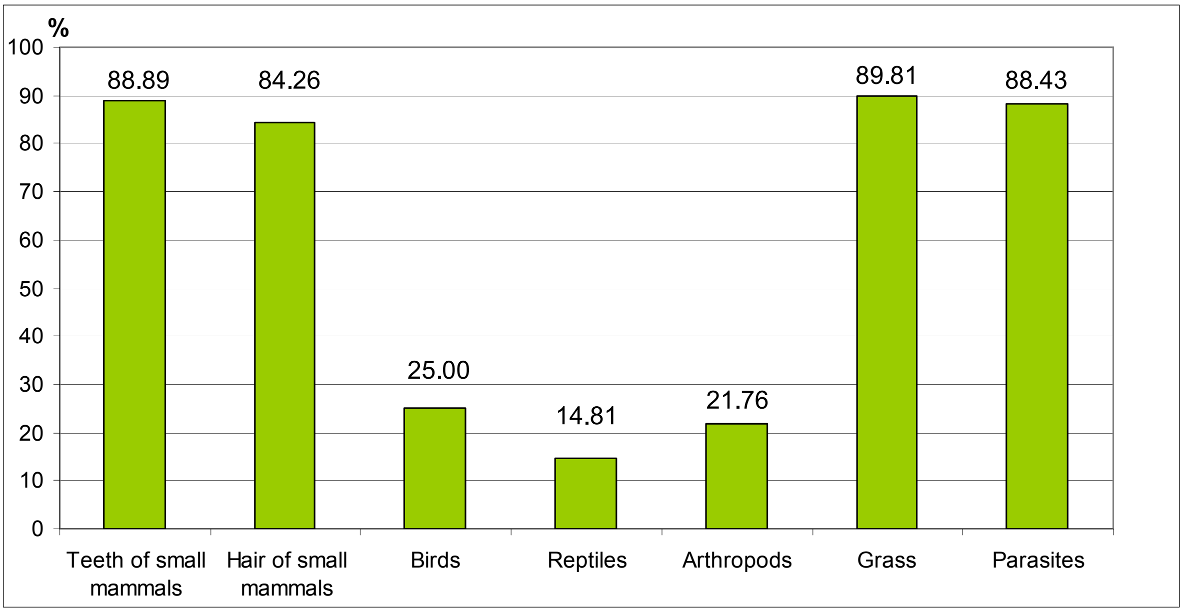
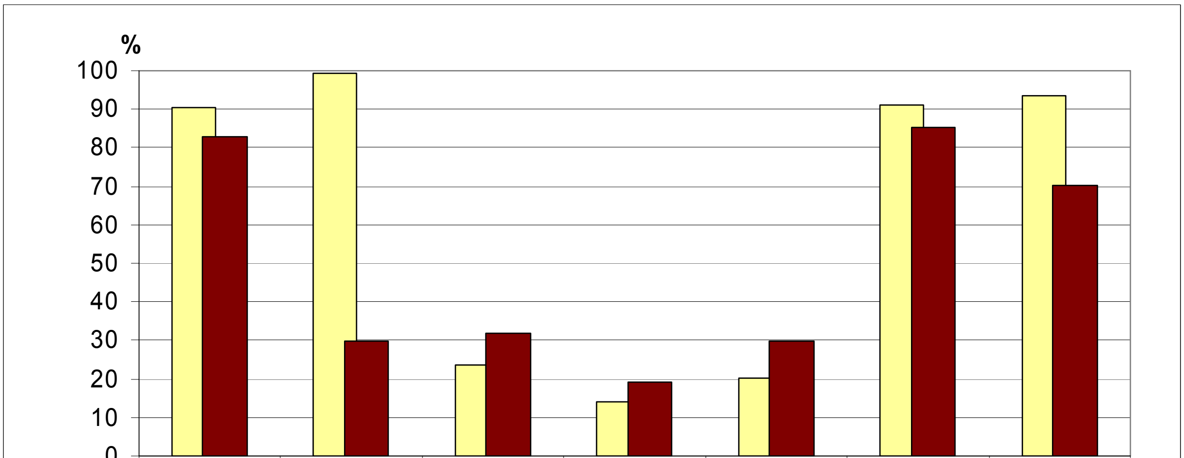


Figure 2.14: Frequency of occurrence of digested items in Serval scats in LNP.



	Teeth of small mammals	Hair of small mammals	Birds	Reptiles	Arthropods	Grass	Parasites
Positive	90.53	99.41	23.67	14.20	20.12	91.12	93.49
Unclassified	82.98	29.79	31.91	19.15	29.79	85.11	70.21

Figure 2.15: Frequency of occurrence of digested items in Serval scats in LNP, divided into positive identified and unclassified scat samples.

There was large insect diversity noted in the scats, see Table 2.1, in addition, one Chelicerata of the order Scorpiones was found. Altogether 47 scats contained insect remains. Within the group of insects the Formicidae (the Ants) were consumed most often, followed by the Coleoptera (with Carabidae beetles as their main representatives). When frequency of occurrence was calculated for the whole 216 sample within LNP, the Formicidae were represented in 12.50% and Coleoptera in nearly a tenth of all samples. Some residues could not be determined to species level, but most could be categorized within an order; 21.28% however, were undefined insect remains.

Reptile remains were found in 32 scat samples. Reptiles were specified down to suborder and where possible to family level (Tab. 2.2). The most frequent suborder found within the

32 samples is the suborder Serpentes, followed by Skinks, Gekkos, Lizards and Agamas, but altogether the frequency of occurrence within all 216 samples ranged only between 6% and 0.5% for each reptile group (Tab 2.2).

Table 2.1: Insect taxa frequency of occurrences in Serval scats in LNP.

Order	Family	No. of faeces with prey items	FO within the group	FO for all LNP samples
UNDEFINED	**spp.**	**10**	**21.28**	**4.63**
Orthoptera	**spp.**	**5**	**10.64**	**2.31**
Vespoidea	**Formicidae**	**27**	**57.45**	**12.50**
Coleoptera	**spp.**	**21**	**44.68**	**9.72**
Coleoptera	spp.	7	16.28	3.24
Coleoptera	Scarabeidae	6	13.95	2.78
Coleoptera	Carabidae	7	16.28	3.24
Coleoptera	Silphidae	1	2.33	0.46

Table 2.2: Reptile taxa frequency of occurrences and percentage occurrence found in Serval scats in LNP.

Sub-Order	Family	No. of faeces with prey items	FO within the group	FO for all LNP samples	No. of items	PO [%]
Serpentes	spp.	13	40.63	6.02	13	40.625
Autarchoglossa	Scincidae	10	31.25	4.63	10	31.25
Scleroglossa	Gekkonidae	4	12.50	1.85	4	12.5
Iguania	Agamidae	1	3.13	0.46	1	3.125
Autarchoglossa	Lacertidae	4	12.50	1.85	4	12.5

Small mammal remains were found in 189 scat samples and all were determined as members of the order of Rodentia and Soricomorpha. Identification down to the genus and species level was possible, 19 different taxa (4 genera and 15 species) were recorded (Tab. 2.3), two species of the Soricomorpha order and 17 rodent taxa. Broken elements of teeth or single incisivi could not be recognized and were stated as 'Unidentified". Examining the frequency of occurrence values within the group 'small mammals', as well as for all collected faecal samples in LNP, it is obvious that *Mastomys natalensis* and *Pelomys fallax* are the most frequent species, followed by *Gerbilliscus leucogaster* and *Uranomys ruddi* (see Fig 2.16).

Within the group 'small mammals' the percentage occurrence was calculated and also with this index it was clear that *Mastomys natalensis* (53.4%) and *Pelomys fallax* (19.69%) were again the most consumed prey items (see Fig. 2.17), although *Mastomys natalensis* nearly triples the value of *Pelomys fallax*. A different picture evolves if the percentages of the consumed biomass are determined (Fig. 2.18). Still *Mastomys natalensis* is the main biomass consumed (44.16%) but *Pelomys fallax*'s importance (36.63%) is similar. The rest of the graph 'percentage of consumed biomass' shows similar results to the percentage occurrence values within the small mammals, with *Gerbilliscus leucogaster* as the only other species with more than 5%, while all the other 16 species have a minor percentage value. Mean body mass values of the undefined samples of small mammals were calculated as the mean value of all other species.

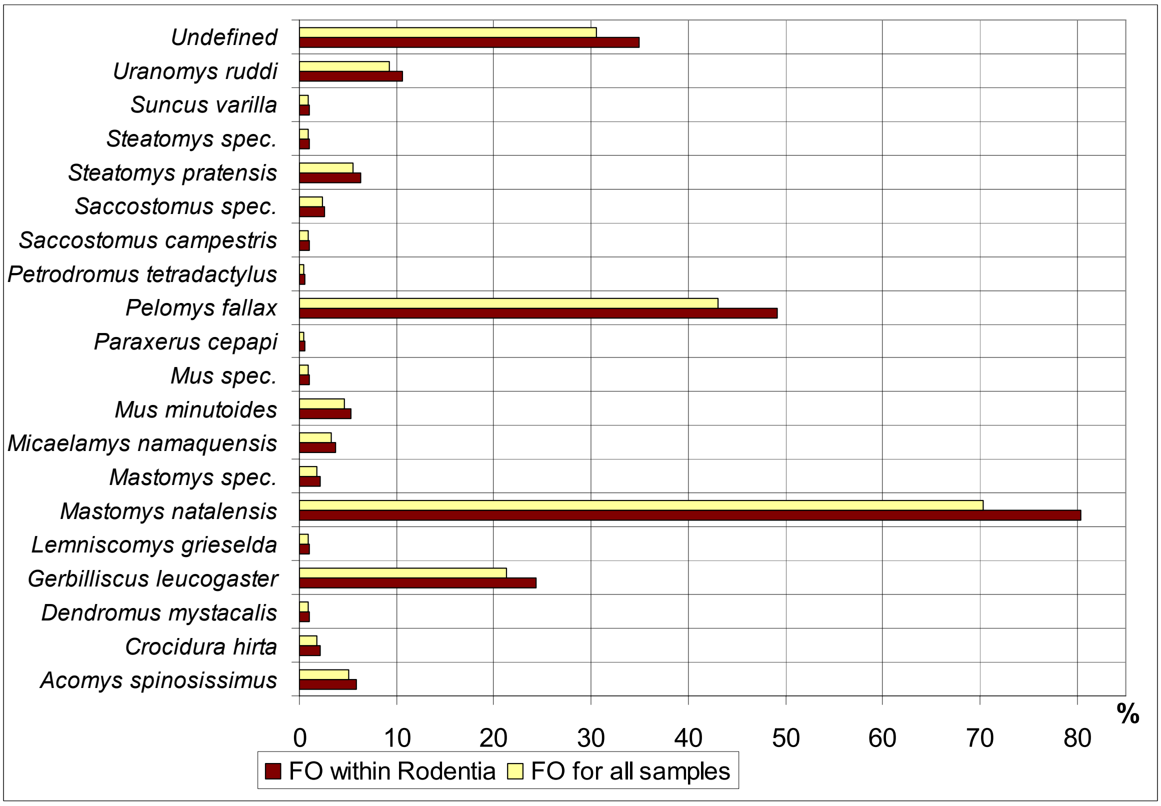


Figure 2.16: Frequency of occurrence of small mammals in Serval scats in LNP.

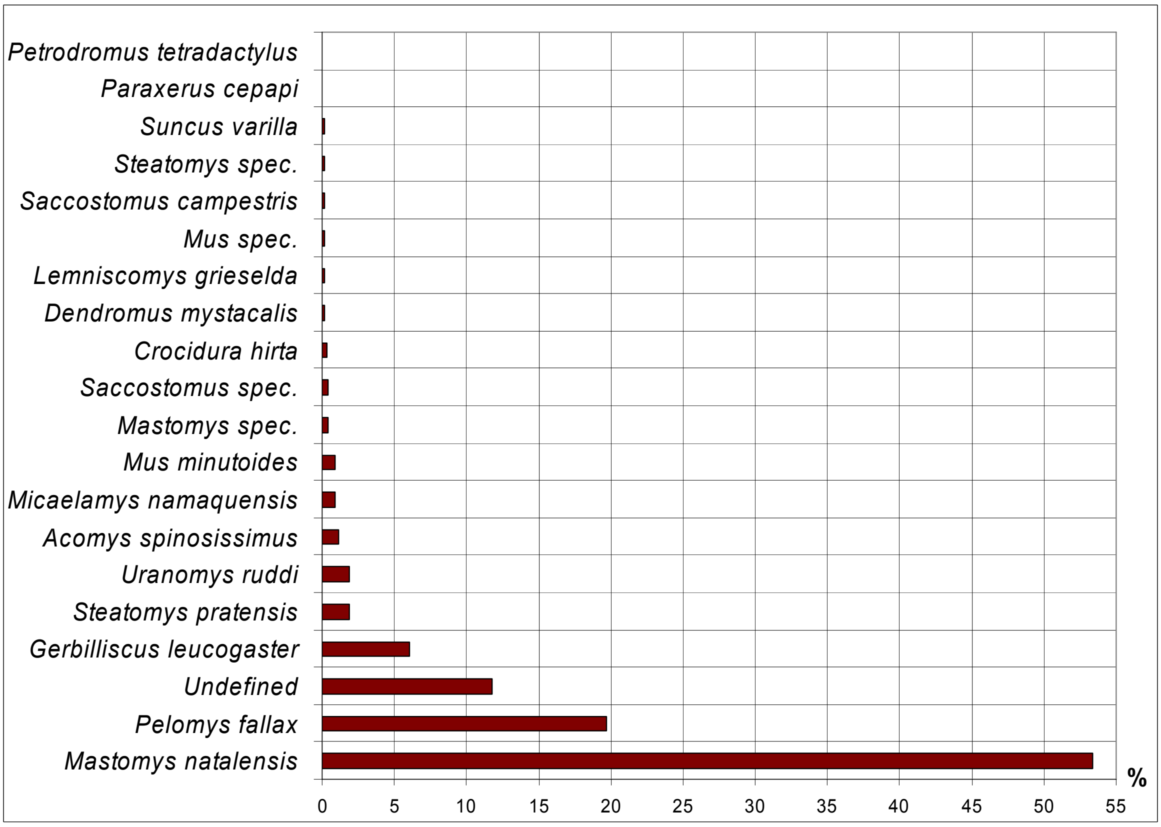


Figure 2.17: Percentage occurrence of small mammals in Serval scats.

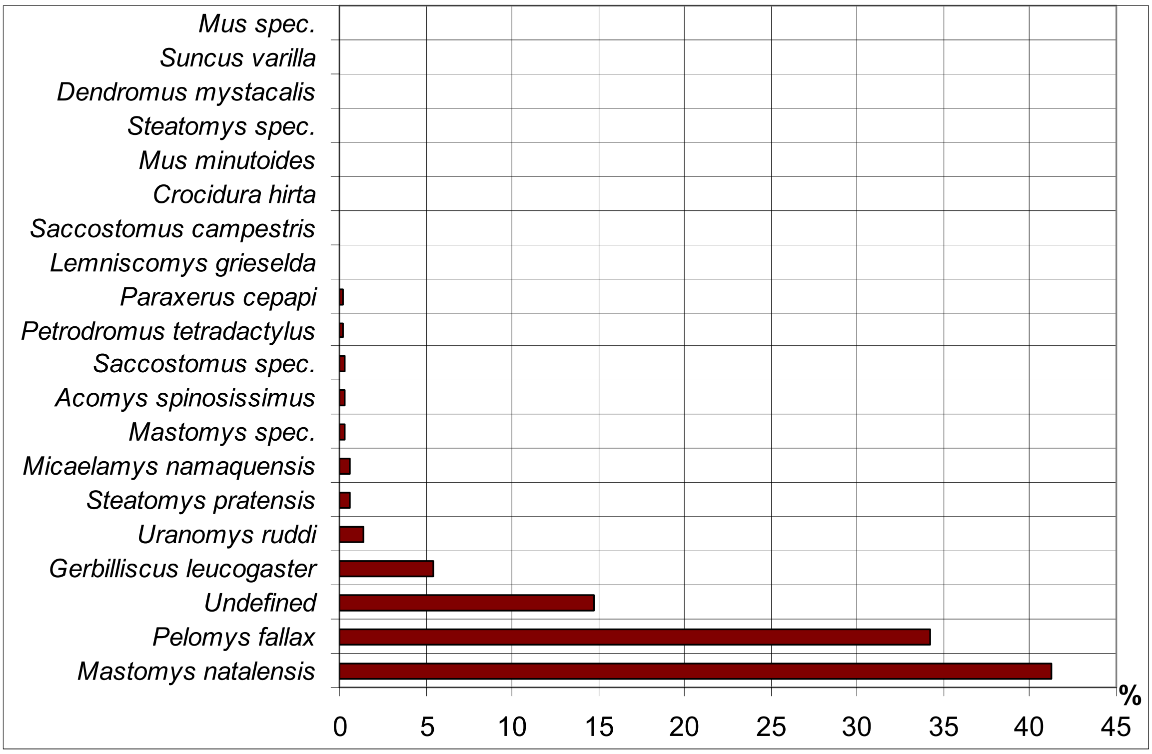


Figure 2.18: Percentage of consumed biomass of small mammals in Serval scats.

The following Figure, after BOWLAND 1990 (Fig. 2.19), shows the relative importance of the various small mammal taxa. Isolines connect points of equal importance. There you can also clearly see that *Mastomys natalensis* and *Pelomys fallax* as well as *Gerbilliscus leucogaster* are the major prey species. All the other prey items play a minor role, and at fairly equal rates, with only *Uranomys ruddi* indicated as a more important prey item.

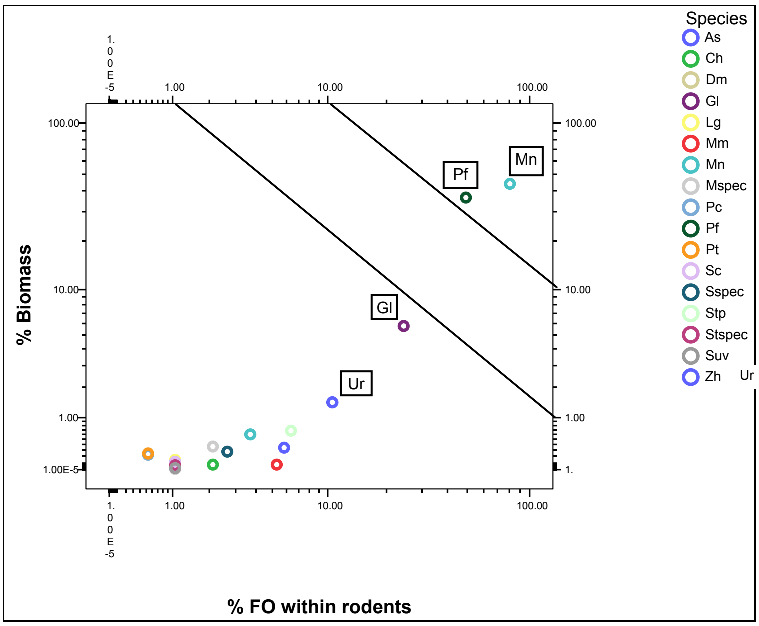


Figure 2.19: Relative importance of small mammal taxa in the Servals' diet in LNP.
As = *Acomys spinosissimus*; Ch = *Crocidura hirta*; Dm = *Dendromus mystacalis*; Gl = *Gerbilliscus leucogaster*; Lg = *Lemniscomys griselda*; Mn = *Mastomys natalensis*; Mspec = *Mastomys spp.*; Mn = *Micaelamys namaquensis*; Mm = *Mus minutoides*; Mspec = *Mus* spp.; Pc = *Paraxerus cepapi*; Pf = *Pelomys fallax*; Pt = *Petrodromus tetradactylus*; Sc = *Saccostomus campestris*; Sspec = *Saccostomus* spp.; Stp = *Steatomys pratensis*; Stspec= *Steatomys* spp.; Suv = *Suncus varilla*; Ur = *Uranomys ruddi*.

Table 2.3: Small Mammal analyses for Serval scats within LNP.

Species	No. of faeces	No. of consumed items	Mean No. of consumed prey in one scat	PO [%]	FO [%] within the group	FO [%] of LNP samples	Mean biomass [g] (Stuart & Stuart 2007)	Total biomass [g]	% of biomass
Acomys spinosissimus	11	13	1.18	1.13	5.82	5.09	22.00	286.00	0.34
Crocidura hirta	4	4	1.00	0.35	2.12	1.85	15.00	60.00	0.07
Dendromus mystacalis	2	2	1.00	0.17	1.06	0.93	8.00	16.00	0.02
Gerbilliscus leucogaster	46	69	1.50	6.01	24.34	21.30	70.00	4830.00	5.77
Lemniscomys griselda	2	2	1.00	0.17	1.06	0.93	60.00	120.00	0.14
Mastomys natalensis	152	613	4.03	53.40	80.42	70.37	60.00	36780.00	43.94
Mastomys spp.	4	5	1.25	0.44	2.12	1.85	60.00	300.00	0.36
Micaelamys namaquensis	7	10	1.43	0.87	3.70	3.24	50.00	500.00	0.60
Mus minutoides	10	10	1.00	0.87	5.29	4.63	6.00	60.00	0.07
Mus spp.	2	2	1.00	0.17	1.06	0.93	6.00	12.00	0.01
Paraxerus cepapi	1	1	1.00	0.09	0.53	0.46	180.00	180.00	0.22
Pelomys fallax	93	226	2.43	19.69	49.21	43.06	135.00	30510.00	36.45
Petrodromus tetradactylus	1	1	1.00	0.09	0.53	0.46	205.00	205.00	0.24
Saccostomus campestris	2	2	1.00	0.17	1.06	0.93	45.00	90.00	0.11
Saccostomus spp.	5	5	1.00	0.44	2.65	2.31	45.00	225.00	0.27
Steatomys pratensis	12	22	1.83	1.92	6.35	5.56	26.00	572.00	0.68
Steatomys spp.	2	2	1.00	0.17	1.06	0.93	26.00	52.00	0.06
Suncus varilla	2	2	1.00	0.17	1.06	0.93	6.50	13.00	0.02
Undefined	66	135	2.05	11.76	34.92	30.56	56.87	7677.24	9.17
Uranomys ruddi	20	22	1.10	1.92	10.58	9.26	41.00	902.00	1.08
Total	**444**	**1148**						**83290.76**	

There is a highly significant correlation between the frequency of occurrence and the percentage of consumed biomass (Spearman's rho test correlation factor = 0.794; $p < 0.001$) (see Fig. 2.20).

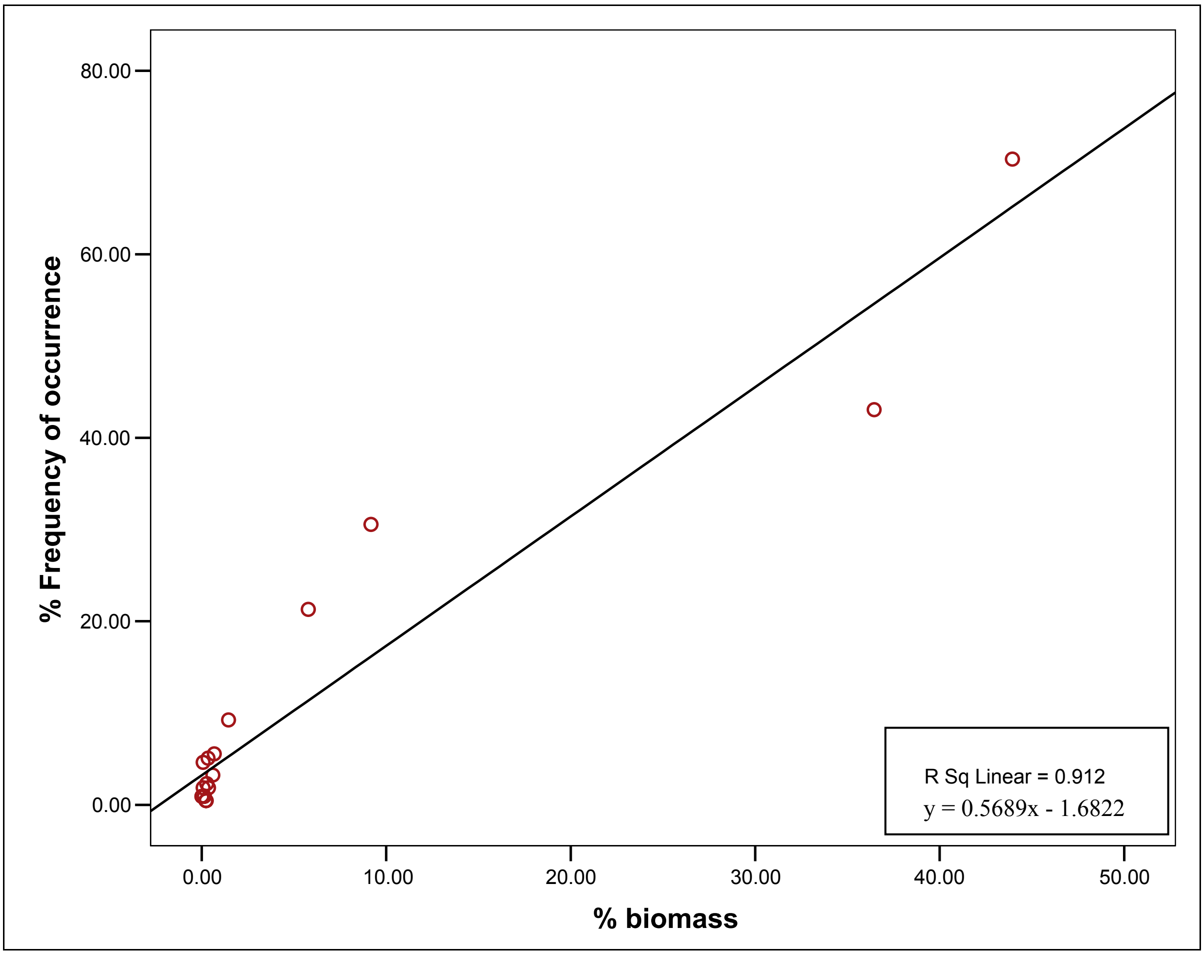


Figure 2.20: Scatter Graph for correlation between frequency of occurrence of small mammal species and percentage of consumed biomass.

If Servals feed more on high biomass prey (like *Petrodromus tetradactylus* with a mean body mass of 205g), a significant correlation is expected between the mean number of consumed individuals of one species and the species' body mass, which is not the case in this study (Spearman's rho test correlation factor = 0.382, $p = 0.096$) (Fig. 2.21). Correlation between total number of consumed items and species' body mass also shows no significance and only a low correlation value (Spearman's rho test correlation factor = 0.104, $p = 0.662$) (Fig. 2.22). Both linear fit lines only indicate a small tendency for heavier prey to be consumed more often (Fig. 2.21 & 2.22). If used a quadratic fit line the maximum can be found at approximately 110 g, with a mean of two consumed individuals of small mammals.

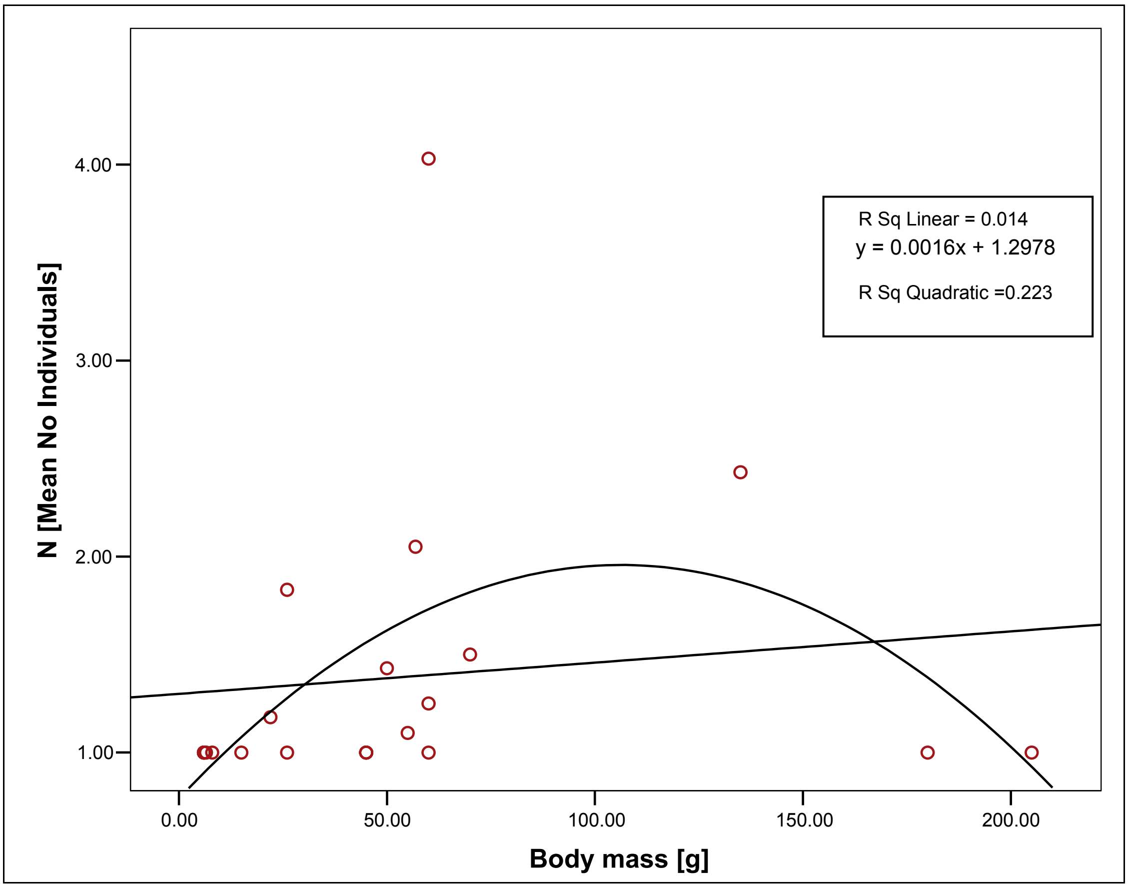


Figure 2.21: Scatter Graph showing the correlation between mean number of consumed individual small mammal species and their body mass.

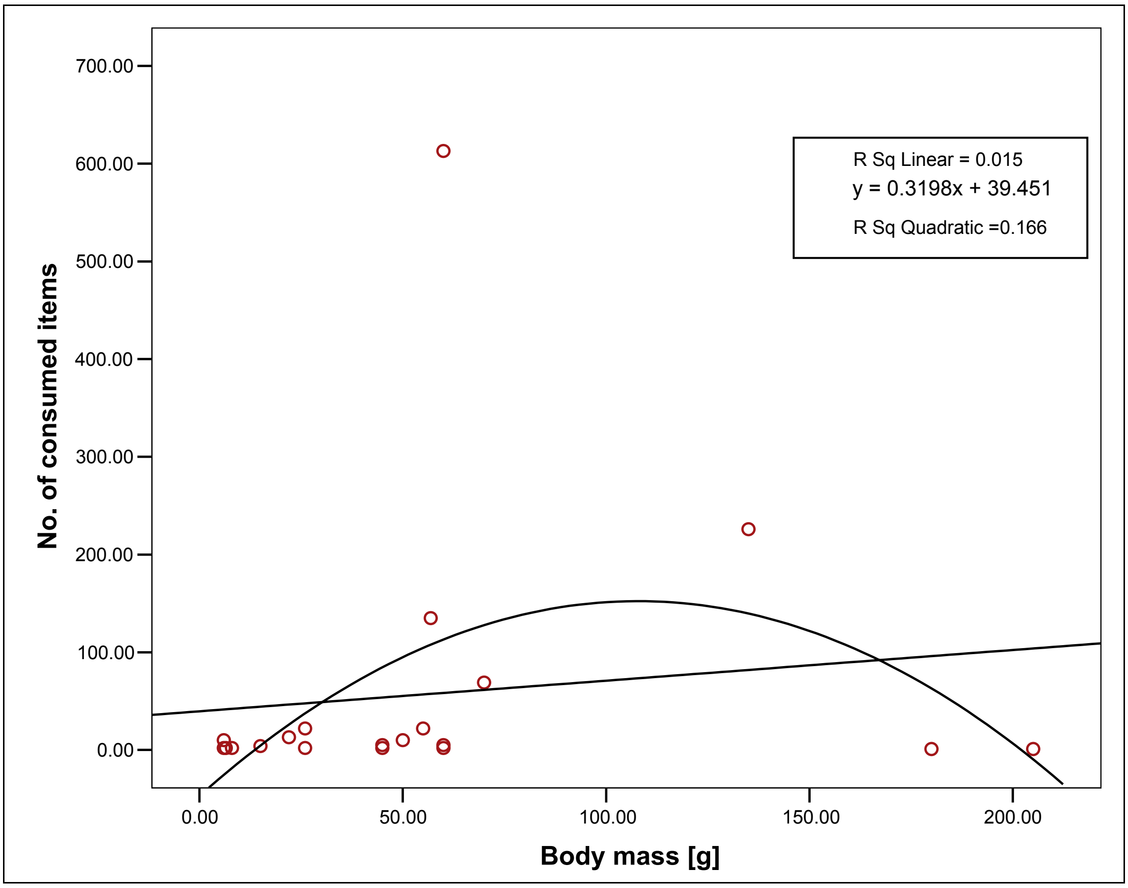


Figure 2.22: Scatter Graph showing the correlation between number of consumed individual small mammal species and their body mass.

Bird remains were found in 62 scat samples. Identification down to species level was partially possible, six different species, seven genera and 12 (sub-) families were recorded (Tab. 2.4). Broken sections of bones and partial feathers could not be recognized and were classified as 'Undefined'.

When examining frequency of occurrence values for within the 'birds' group and within all collected faecal samples in LNP, it is obvious that the most frequent (sub-) family is the Ploceinae, followed by Centropodidae and Numididae (see Tab. 2.4). The other (sub-) families' frequency of occurrence values are all below 10%, some even below 3%.

Within the group 'birds', the percentage occurrence was calculated and is shown in Figure 2.23; it is clear that again the Ploceinae show the highest percentage, followed by the Centropodidae and then Numididae. All other (sub-) families have a percentage occurrence of less than 5%. The difference in ranks is even higher in calculation of percentage occurrence than in the frequency of occurrence. The Ploceinae group is the only group which shows an even higher value in the percentage occurrence than frequency of occurrence.

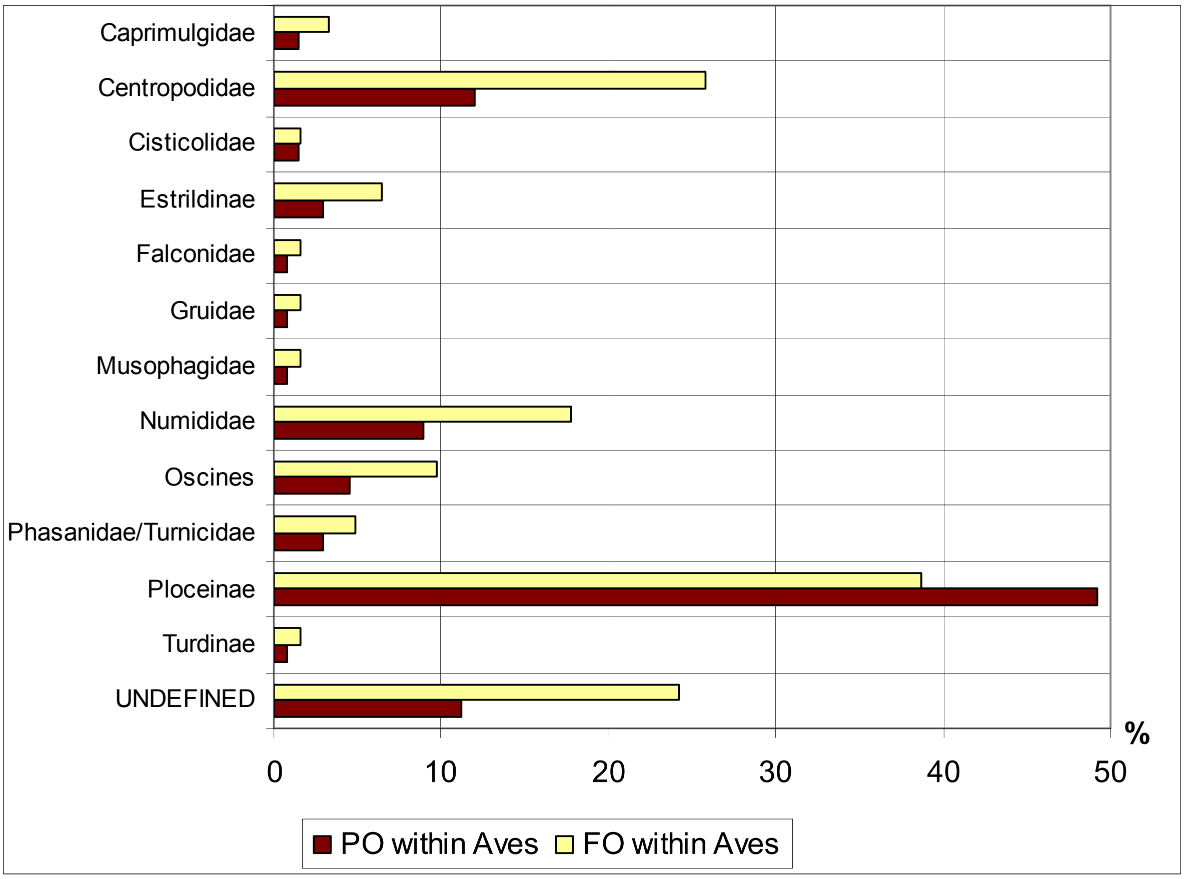


Figure 2.23: Percentage occurrence (PO) and frequency of occurrence (FO) of bird species in Serval scats with bird remains in LNP (N=62).

Table 2.4: Bird analyses for Serval scats within LNP. Scats with bird remains N=62, faecal samples LNP total N=216.

Species	No. of faeces with prey item	No. of items	Mean No. of items in one scat	PO [%]	FO [%] within the group	FO [%] of LNP samples	Mean biomass [g] (Dunning 1993)	Total biomass [g]	% of biomass
Caprimulgidae	**2**	**2**	**1.00**	**1.49**	**3.23**	**0.93**			
Caprimulgus spp.	2	2	1.00	1.49	3.23	0.93	53.79	107.58	0.35
Centropodidae	**16**	**16**	**1.00**	**11.94**	**25.81**	**7.41**			
Centropus grillii	2	2	1.00	1.49	3.23	0.93	125.50	251.00	0.82
Centropus spp.	14	14	1.00	10.45	22.58	6.48	205.92	2882.88	9.41
Cisticolidae	**1**	**2**	**2.00**	**1.49**	**1.61**	**0.46**			
Apalis spp.	1	2	2.00	1.49	1.61	0.46	7.90	15.80	0.05
Estrildinae	**4**	**4**	**1.00**	**2.99**	**6.45**	**1.85**			
Estrilda spp.	2	2	1.00	1.49	3.23	0.93	8.58	17.16	0.06
Estrilda astrild	2	2	1.00	1.49	3.23	0.93	9.05	18.10	0.06
Gruidae	**1**	**1**	**1.00**	**0.75**	**1.61**	**0.46**			
Balearica regulorum	1	1	1.00	0.75	1.61	0.46	3600.00	3600.00	11.75
Falconidae	**1**	**1**	**1.00**	**0.75**	**1.61**	**0.46**	190.83	190.83	0.62
Musophagidae	**1**	**1**	**1.00**	**0.75**	**1.61**	**0.46**			
Corythaixoides concolor	1	1	1.00	0.75	1.61	0.46	267.63	267.63	0.87
Numididae	**11**	**12**	**1.09**	**8.96**	**17.74**	**5.09**			
Numida meleagris	11	12	1.09	8.96	17.74	5.09	1299.00	15588.00	50.87
Oscines (small)	**6**	**6**	**1.00**	**4.48**	**9.68**	**2.78**	25.00	150.00	0.49
Phasanidae/ Turnicidae	**3**	**4**	**1.33**	**2.99**	**4.84**	**1.39**			
Coturnix/Turnix	3	4	1.33	2.99	4.84	1.39	60.56	242.22	0.79
Ploceinae	**24**	**66**	**2.75**	**49.25**	**38.71**	**11.11**			
Ploceinae spp.	3	3	1.00	2.24	4.84	1.39	28.40	85.20	0.28
Quelea quelea	21	63	3.00	47.01	33.87	9.72	18.90	1190.70	3.89
Turdinae	**1**	**1**	**1.00**	**0.75**	**1.61**	**0.46**			
Turdus spp.	1	1	1.00	0.75	1.61	0.46	65.94	65.94	0.22
UNDEFINED	**15**	**15**	**1.00**	**11.19**	**24.19**	**6.94**	397.80	5967.00	19.47
Total	**62**	**134**						**30640**	

Percentages of the consumed biomass were determined (see Fig. 2.24), and the body mass of the genera and species compared; the family was only included if there was no specific representative of this family determined. Mean body mass of the 'UNDEFINED' group was calculated using the mean of all other taxa. The highest biomass consumed was made up of *Numida meleagris* (50.87%). With far lower values this is followed by *Balearica regulorum* (11.75%) and *Centropus* spp. (9.41%). The Ploceinae have only one representative with a higher value, *Quelea quelea* with 3.89%. All other species/genera/ families show values less than 1%. This indicates a tendency to consume larger bird prey, like *Numida meleagris* with a mean body mass of 1299 g.

The correlation between the frequency of occurrence and the percentage of consumed biomass for birds is not significant (Spearman's rho test correlation factor = 0.462, p = 0.071) (see Fig. 2.25); but it does indicate a tendency for Servals to hunt larger prey in preference to small.

However, the correlation between mean number of consumed individuals of one species and the species' body mass (Fig. 2.26) is negative and not significant (Spearman's rho test correlation factor = -0.263, p = 0.326). The correlation between the total number of consumed items and the species' body mass also shows no significance and a negative correlation (Spearman's rho test correlation factor = -0.083, p = 0.761) (Fig. 2.27). Both linear reference lines indicate a slight tendency for heavier prey to be consumed in smaller amounts than small prey like *Quelea quelea* with a mean body mass of 18.90g (Fig.2.26 & 2.27). The quadratice fit line shows that Servals feed more on small bird (less than 100 g) and on big birds (more than 300 g) and seem to prefer less the medium sized birds.

Figure 2.28 shows the relative importance of different bird taxa in Serval diet after BOWLAND (1990). Isolines connect points of equal importance. There are many bird taxa with lower rank in the Servals' diet. There is no obvious preferred bird prey species, as in small mammals. Four taxa do stand out however; *Numida meleagris* at the highest importance, followed by *Centropus* spp., *Quelea quelea* and then *Balearica regulorum* and Oscines. The group of undefined bird taxa is placed in a high rank as their frequency of occurrence within the 'birds' is 25%.

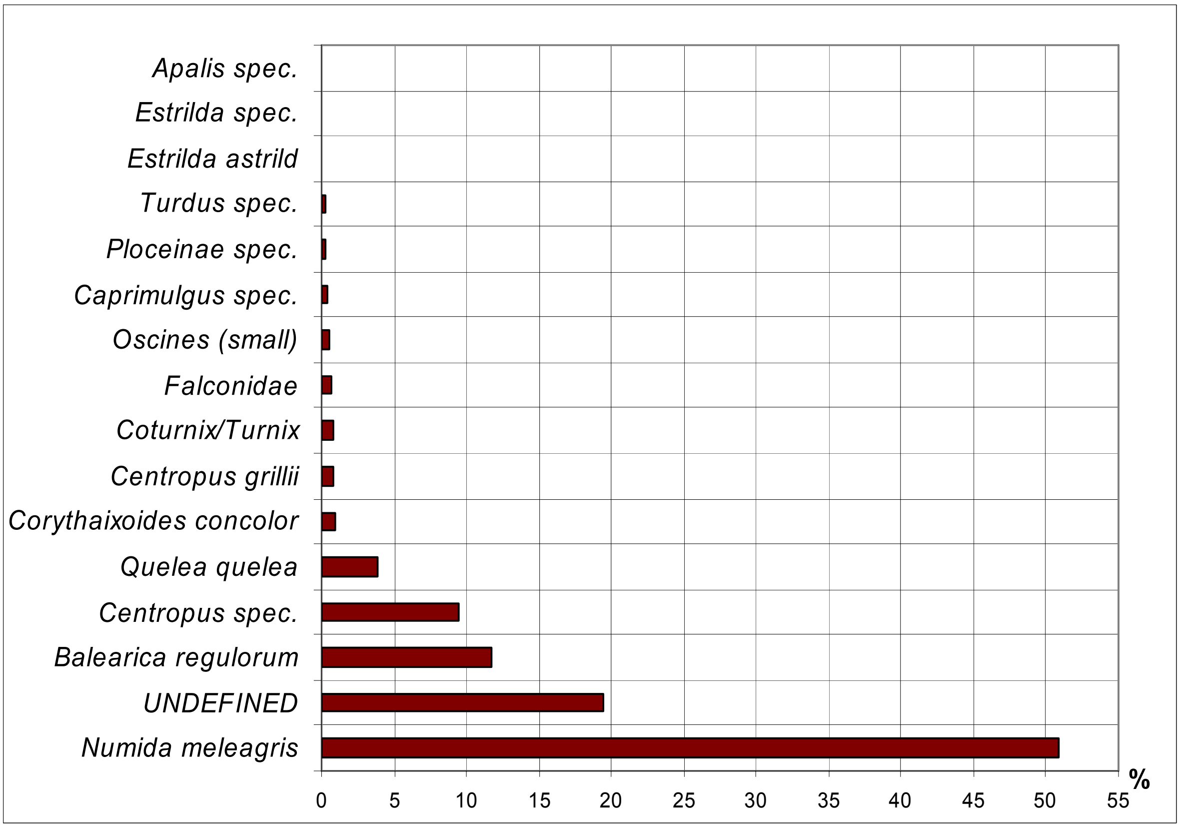


Figure 2.24: Percentage of consumed biomass of bird species in Serval scats within the class Aves.

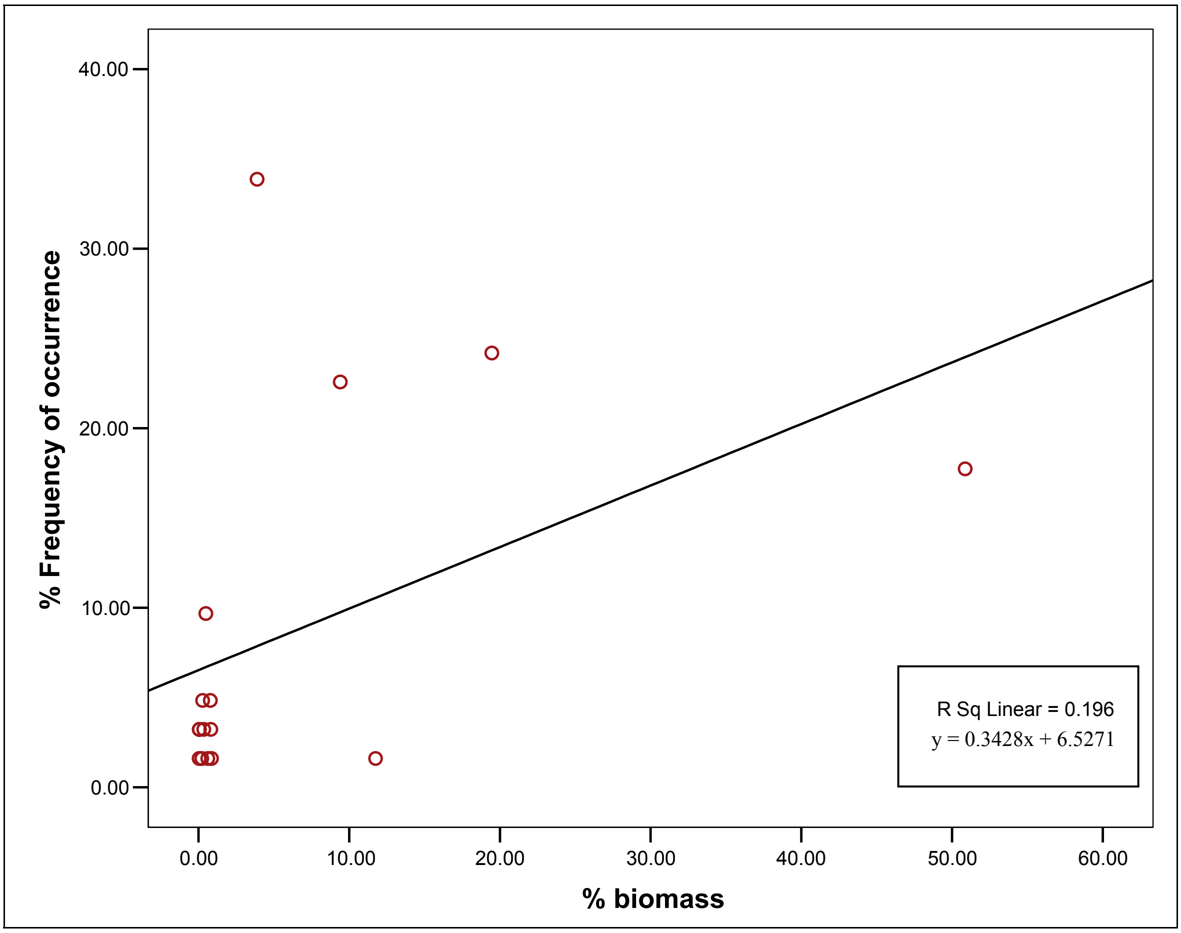


Figure 2.25: Scatter Graph for correlation between frequency of occurrence of bird taxa and their percentage of consumed biomass.

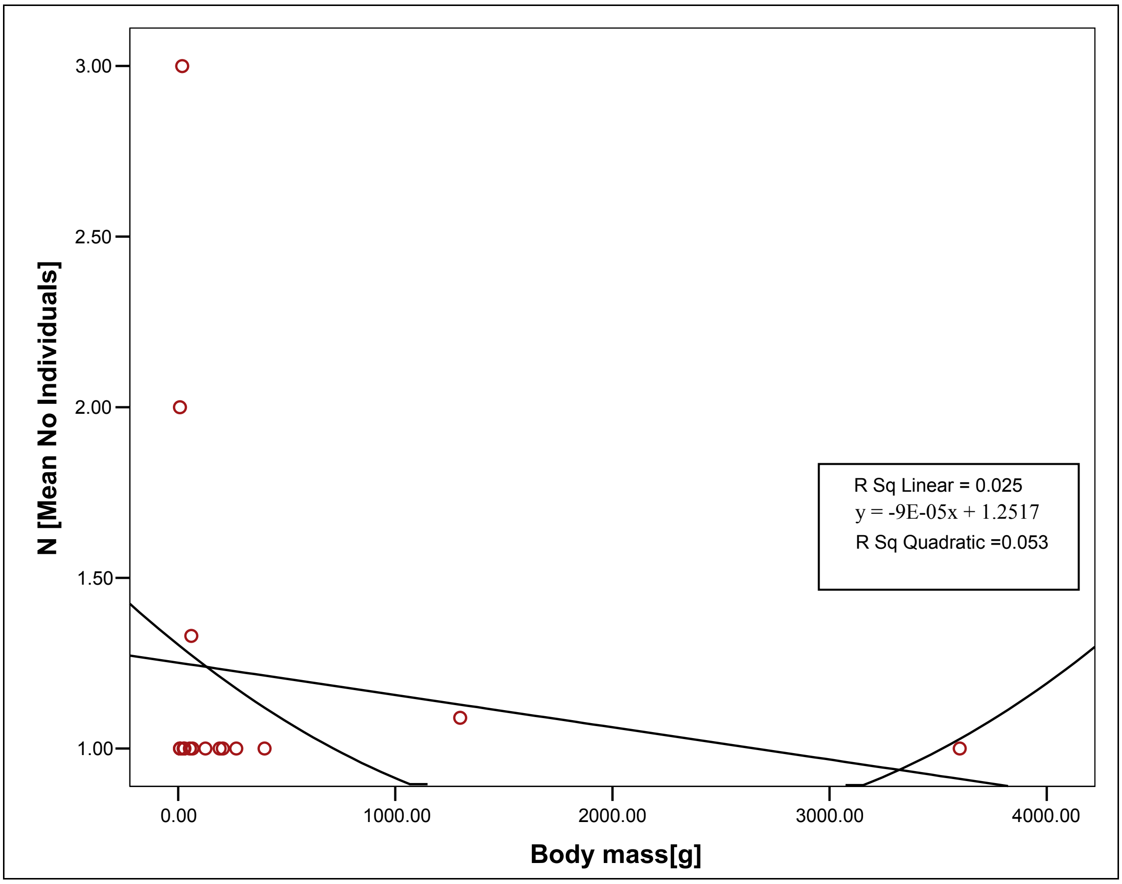


Figure 2.26: Scatter Graph for correlation between mean number of consumed individual bird taxa and their body mass.

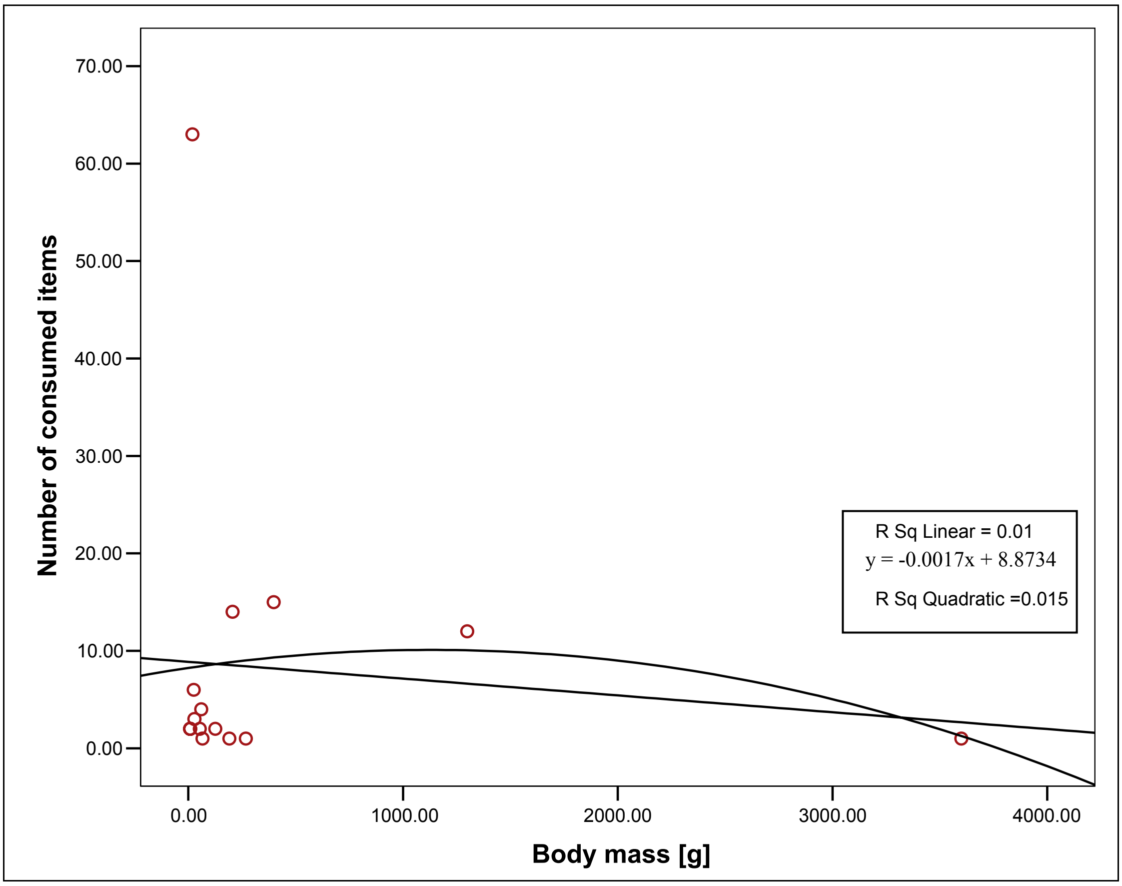


Figure 2.27: Scatter Graph for correlation between number of consumed individual bird taxa and their body mass.

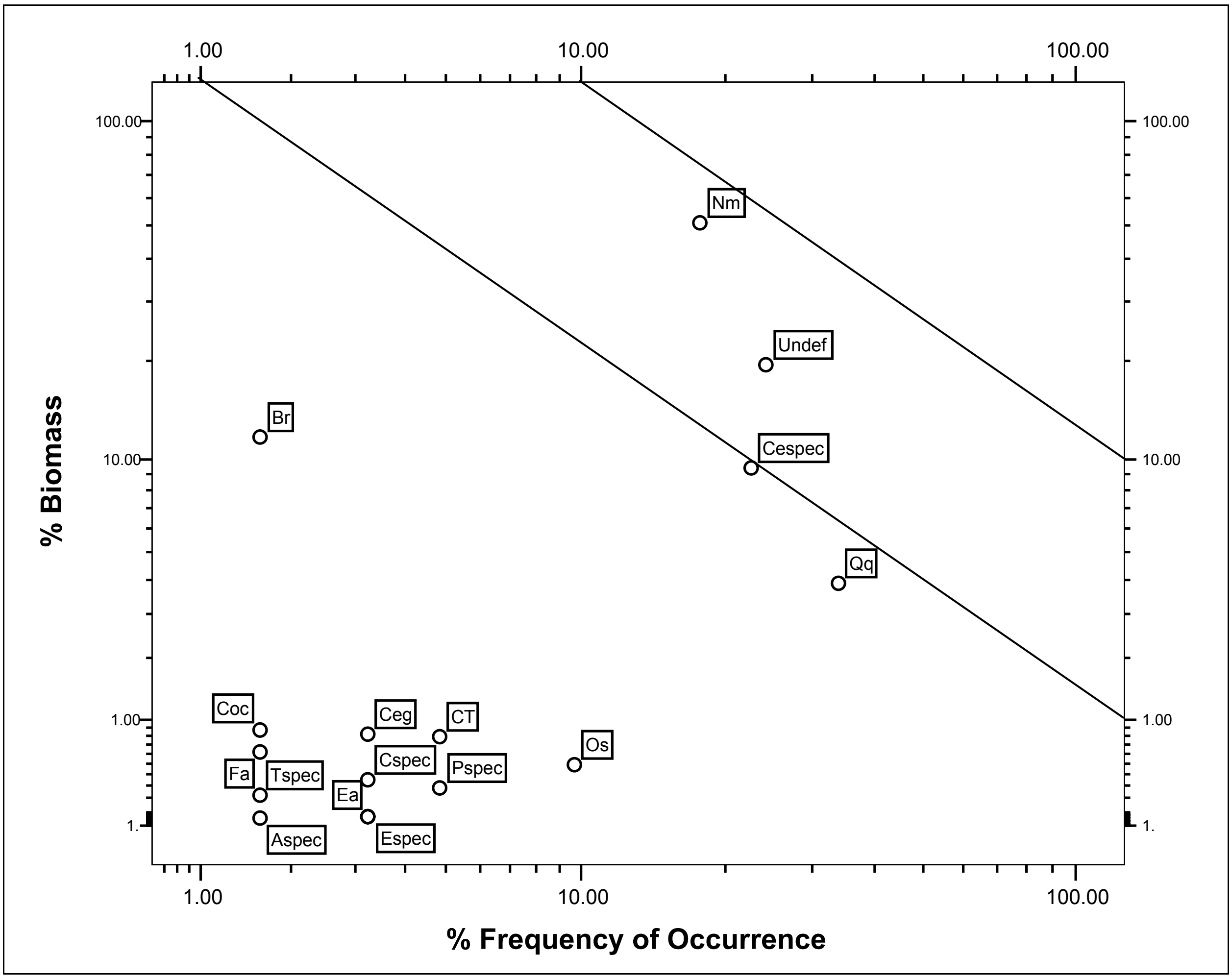


Figure 2.28: Relative importance of bird species in the Servals' diet in LNP.
Aspec = *Apalis spp.*; Br = *Balearica regulorum*; Cspec.= *Caprimulgus spp*; Ceg = *Centropus grillii*; Cespec.= *Centropus spp*; Coc = *Corythaixoides concolor*; CT = *Coturnix/Turnix*; Espec= *Estrilda spp.*; Ea = *Estrilda astrild*; Fa = Falconidae; Nm = *Numida meleagris*; Os = Oscines (small); Pspec = Ploceinae spp.; Qq = *Quelea quelea*; Tspec = *Turdus spp.*; Undef. = UNDEFINED

Regarding the amount of biomass consumed again small mammals constitute the major part (73.2%; 83698.2 g), while birds show a value of 26.8% (30640.04 g). These data are regardless of the biomasses of consumed reptile and arthropod biomasses as there was no quantification of these groups possible. The mean weight of mammalian prey was 72.9 g. while mean weight of consumed birds was 228.7 g.

The following 48 (sub-)orders, families, genera and species could be identified in the Serval scats in Luambe National Park (Tab. 2.5):

Table 2.5: All prey taxa found in faecal samples LNP total N=216.

(Sub-) Order	**Family**	**Genus**	**Species**	**Common name**
Vespoidea	Formicidae	spp.	spp.	Ants
Orthoptera	spp.	spp.	spp.	Grasshoppers
Coleoptera	spp.	spp.	spp.	Beetle
Coleoptera	Scarabeidae	spp.	spp.	Scarab Beetles
Coleoptera	Carabidae	spp.	spp.	Ground Beetles
Coleoptera	Silphidae	spp.	spp.	Carrion Beetles
Scorpiones	spp.	spp.	spp.	Scorpions
Serpentes	spp.	spp.	spp.	Snakes
Autarchoglossa	Scincidae	spp.	spp.	Skinks
Autarchoglossa	Scincidae	*Trachylepis*	spp.	Striped Skink
Autarchoglossa	Lacertidae	spp.	spp.	Wall Lizards
Scleroglossa	Gekkonidae	spp.	spp.	Geckos
Iguania	Agamidae	spp.	spp.	Agamas
Rodentia	Cricetidae	*Gerbilliscus*	*leucogaster*	Bushveld Gerbil
Rodentia	Cricetidae	*Saccostomus*	*campestris*	Pouched Mouse
Rodentia	Cricetidae	*Saccostomus*	spp.	Pouched Mice
Rodentia	Cricetidae	*Steatomys*	*pratensis*	Fat Mouse
Rodentia	Cricetidae	*Steatomys*	spp.	Fat Mice
Rodentia	Muridae	*Acomys*	*spinosissimus*	Southern African Spiny Mouse
Rodentia	Muridae	*Dendromus*	*mystacalis*	Chestnut African Climbing Mouse
Rodentia	Muridae	*Lemniscomys*	*griselda*	Griselda's Striped Grass Mouse
Rodentia	Muridae	*Mastomys*	*natalensis*	Natal Multimammate Mouse
Rodentia	Muridae	*Mastomys*	spp.	Multimammate Mouse
Rodentia	Muridae	*Micaelamys*	*namaquensis*	Namaqua Rock Rat
Rodentia	Muridae	*Mus*	*minutoides*	African Pygmy Mouse
Rodentia	Muridae	*Mus*	spp.	Old World Mice
Rodentia	Muridae	*Pelomys*	*fallax*	Creek Groove-toothed Swamp Rat
Rodentia	Muridae	*Petrodromus*	*tetradactylus*	Four-toed Elephant Shrew
Rodentia	Muridae	*Uranomys*	*ruddi*	Rudd's Bristle-furred Rat
Rodentia	Sciuridae	*Paraxerus*	*cepapi*	Smith's Bush Squirrel
Soricomorpha	Soricidae	*Crocidura*	*hirta*	Lesser Red Musk Shrew
Soricomorpha	Soricidae	*Suncus*	*varilla*	Lesser Dwarf Shrew
Caprimulgi	Caprimulgidae	*Caprimulgus*	spp.	Nightjars
Cuculiformes	Centropodidae	*Centropus*	*grillii*	Black Coucal
Cuculiformes	Centropodidae	*Centropus*	spp.	Coucals
Falconides	Falconidae	spp.	spp.	Falcons
Galliformes	Numididae	*Numida*	*meleagris*	Helmeted Guineafowl
Galliformes/ Turniciformes	Phasanidae/ Turnicidae	*Coturnix/ Turnix*	spp.	Quails/ Buttonquails
Gruiformes	Gruidae	*Balearica*	*regulorum*	Crowned Crane
Musophagiformes	Musophagidae	*Corythaixoides*	*concolor*	Grey Lourie
Passeri	Cisticolidae	*Apalis*	spp.	Apalis
Passeri	Estrildinae	*Estrilda*	spp.	Waxbills
Passeri	Estrildinae	*Estrilda*	*astrild*	Common Waxbill
Passeri	Oscines	spp.	spp.	Songbirds
Passeri	Ploceinae	*Ploceinae*	spp.	Weavers
Passeri	Ploceinae	*Quelea*	*quelea*	Redbilled Quelea
Passeri	Turdinae	*Turdus*	spp.	Thrushes

Comparing the results of the frequency of occurrence of all samples (positive and unclassified), separated into those for which sections were used for DNA analyses (n=136) and the intact samples (n=80), shows no significant difference (Mann-Whitney-U Test; p = 0.527) in the frequency of occurrence between groups of prey types (Fig. 2.29).

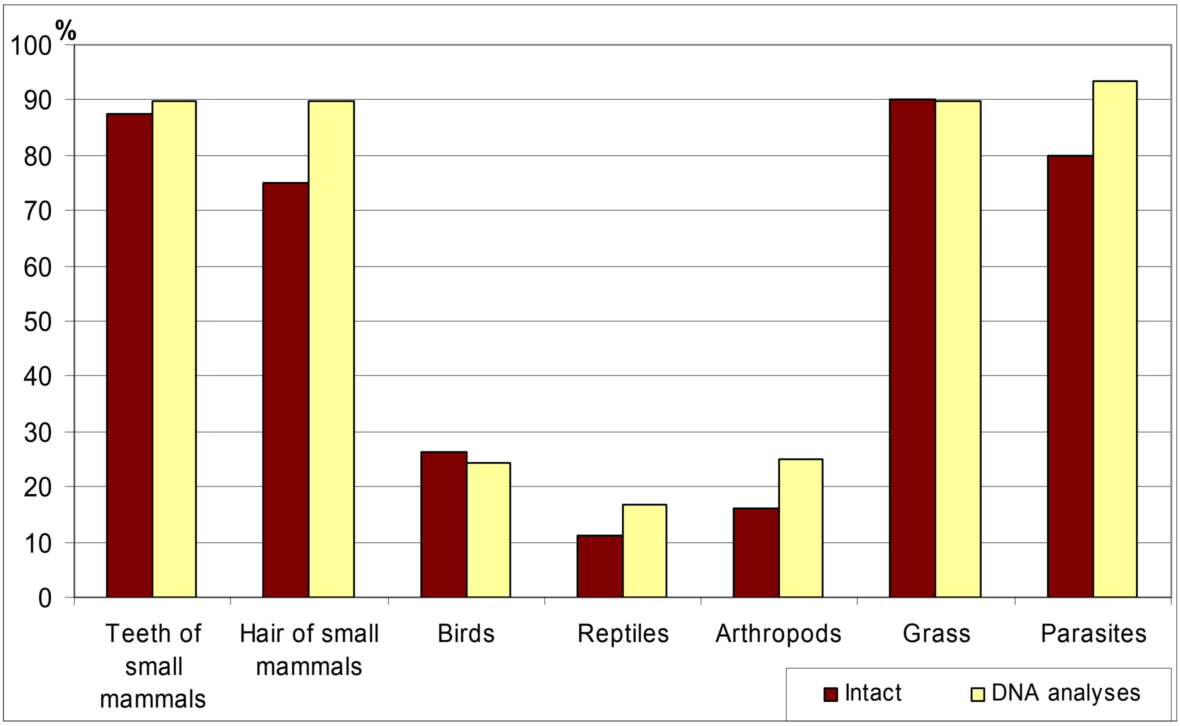


Figure 2.29: Frequency of occurrence of digested items in Serval scats in LNP, divided into intact scat samples and samples with a piece removed for DNA analyses.

For calculation of the diet breadth, three categories and their 'relative frequency of occurrence' were determined: Mammals, Birds and Reptiles. The proportion of each prey category is shown in Table 2.6. Mammals have the highest proportion, followed by the Birds and then Reptiles. Following the standardized formula the diet breadth of the Servals' diet in LNP is $B_{Standard} = 0.4993568$. This is exactly a medium diet breadth, which leads to the conclusion that the Serval is no specialist but also not an opportunist in its most distinctive form.

Table 2.7 shows the different relative frequency of occurrence for each prey item. Here it is obvious that *Mastomys natalensis* plays a key role in the Servals' diet in LNP showing a value of nearly 50%, which means that every second prey item is a Multimammate Mouse. *Pelomys fallax* (17.24%), *Gerbilliscus leucogaster* (5.26%) and *Quelea quelea* (4.81%) also have higher values, which mark them as an important prey species. All other prey items stay below 2% relative frequency of occurrence.

Table 2.6: Relative frequency of occurrence for all three prey categories.

Category	No. of prey items	Relative frequency of occurrence
Mammals	1148	87.57
Birds	131	9.99
Reptiles	32	2.44

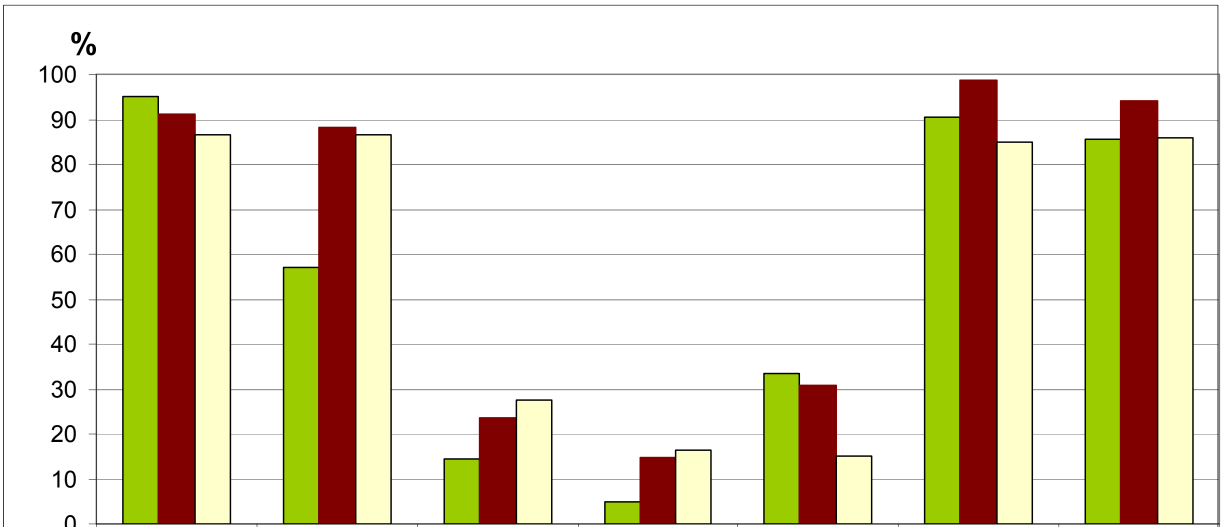
Table 2.7: Relative frequency of occurrence for all three prey items.

Category	Taxa	No. of prey items	relative frequency of occurrence
Mammals	*Acomys spinosissimus*	13	0.99
Mammals	*Crocidura hirta*	4	0.31
Mammals	*Dendromus mystacalis*	2	0.15
Mammals	*Gerbilliscus leucogaster*	69	5.26
Mammals	*Lemniscomys griselda*	2	0.15
Mammals	*Mastomys natalensis*	613	46.76
Mammals	*Mastomys* spp.	5	0.38
Mammals	*Micaelamys namaquensis*	10	0.76
Mammals	*Mus minutoides*	10	0.76
Mammals	*Mus* spp.	2	0.15
Mammals	*Paraxerus cepapi*	1	0.08
Mammals	*Pelomys fallax*	226	17.24
Mammals	*Petrodromus tetradactylus*	1	0.08
Mammals	*Saccostomus campestris*	2	0.15
Mammals	*Saccostomus* spp.	5	0.38
Mammals	*Steatomys pratensis*	22	1.68
Mammals	*Steatomys* spp.	2	0.15
Mammals	*Suncus varilla*	2	0.15
Mammals	*Uranomys ruddi*	22	1.68
Mammals	Undefined (small mammal)	135	10.30
Reptiles	Serpentes	13	0.99
Reptiles	Scincidae	10	0.76
Reptiles	Gekkonidae	4	0.31
Reptiles	Agamidae	1	0.08
Reptiles	Lacertidae	4	0.31
Birds	*Caprimulgus* spp.	2	0.15
Birds	*Centropus grillii*	2	0.15
Birds	*Centropus* spp.	14	1.07
Birds	*Apalis* spp.	2	0.15
Birds	*Estrilda* spp.	2	0.15
Birds	*Estrilda astrild*	2	0.15
Birds	*Balearica regulorum*	1	0.08
Birds	Falconidae	1	0.08
Birds	*Corythaixoides concolor*	1	0.08
Birds	*Numida meleagris*	12	0.92
Birds	Oscines (small)	6	0.46
Birds	*Coturnix/Turnix*	4	0.31
Birds	Ploceinae spp.	3	0.23
Birds	*Quelea quelea*	63	4.81
Birds	*Turdus* spp.	1	0.08
Birds	Undefined (Bird)	15	1.14

2.3.1.2. Annual changes in diet

Although enough samples were only collected in the year 2008 to describe the full spectrum of consumed prey (see Fig. 2.30), the annual differences in the Serval's diet in LNP are outlined using all collected data.

The composition of the Servals' diet did not vary significantly across the three years of sampling (ANOVA, $F_{2,20}$ = 0.088; p= 0.916). Small mammals are the main prey in all three years (91.01 ± 1.71%), followed by arthropods (26.39 ± 5.56%), birds (21.79 ± 8.14%) and reptiles (12.00 ± 5.17%). In the year 2006 there was only half the numbers of bird prey items compared to 2007 and 2008; also reptiles were found a third as often as in the following two years only.



	Teeth of small mammals	Hair of small mammals	Birds	Reptiles	Arthropods	Grass	Parasites
2006	95,24	57,14	14,29	4,76	33,33	90,48	85,71
2007	91,18	88,24	23,53	14,71	30,88	98,53	94,12
2008	86,61	86,61	27,56	16,54	14,96	85,04	85,83

Figure 2.30: Frequency of occurrence of digested items in Serval scats in LNP, for the years 2006 (N=21), 2007 (N=68) and 2008 (N=127).

Comparing the diversity of the Servals' main prey, small mammals, between the three years, it is obvious that in 2008 a higher species diversity was found then, than in the two years before (Fig 2.31). 14 species out of a total of 15 species (2006-2008) were identified in 2008; 9 out of 15 in 2007 and 7 out of 15 in 2006. Nevertheless *Mastomys* spp. (dominantly *Mastomys natalensis*) always represented the main prey, with a frequency of occurrence around 72%. This species is followed by *Pelomys fallax* (mean FO of 55%) and *Gerbilliscus leucogaster* (mean FO of 20%). Only in 2006 Servals apparently hunted *Pelomys fallax* individuals more often than *Mastomys* spp.. The other species seem to play a minor role in the Serval's diet in all three years, *Mus* spp. was consumed four times more often in 2006 than in the following years, and *Acomys spinosissimus* was consumed three times more often in 2007 than in the other study years.

Percentage occurrence between the three years shows similar results (see Fig. 2.32). *Mastomys* spp. and *Pelomys fallax* were the chief prey, followed by *Gerbilliscus leucogaster*. The other species play an even more minor role in the Serval's diet if percentage occurrence is used instead of frequency of occurrence; their values remain under 4%.

There is neither a significant difference in small mammal composition between the years concerning frequency of occurrence (Kruskal-Wallis-Test $x^2 = 2.748$, df = 2, p = 0.253), nor in the percentage occurrence values (Kruskal-Wallis-Test $x^2 = 3.016$, df = 2, p = 0.221).

The diversity of birds within the Servals' diet in LNP changed between these years with the number of scat samples collected in these years (Fig. 2.33). In 2006 only four scat samples showed remains of bird prey and there were only three different species found. In 2007 there were 19 faecal samples analysed with remains of three different species, four genera and one order of birds. During 2008 there were 39 scats found which included bird remains of four species, six genera and one order (see Table 2.9). Each year there are taxa which reappear in the scat samples of the Servals of LNP, but there are also new and single occurrences in the diversity of prey items; as in 2006 the occurrence of *Corythaixoides concolor* within the Musophagidae or 2007 *Apalis* spp. within the Cisticolidae (see Fig. 2.34). In all three years, representatives of the sub-family Ploceinae are the most commonly consumed birds, with a mean frequency of occurrence of 38.65% and a standard deviation of 9.78%. The second most important prey species within the birds are the Centropodidae with a value of 25.65% and a standard deviation of 0.58%. The Numididae also play an important role, although their presence was not recorded in the year 2006 (mean FO = 13% with a standard deviation of 9.3%). Regarding the percentage occurrences of the bird taxa in all three years, it is obvious that again only the Ploceinae (mean PO = 58.42% ± 16.92%), Centropodidae (mean PO = 10.23% ± 4.24%) and Numididae (mean PO = 6.78% ± 5.16%) have a major influence on these numbers, as all the other bird taxa show mean PO values of below 4% (see Fig. 3.34).

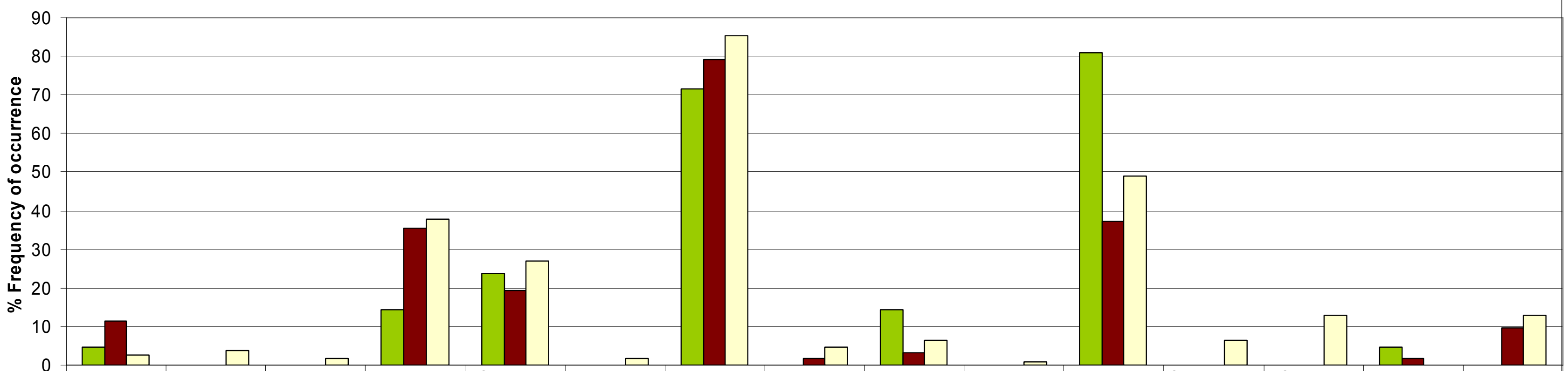
There is also neither a significant difference in bird composition between the years concerning frequency of occurrence (Kruskal-Wallis-Test $x^2 = 2.974$, df = 2, p = 0.226), nor in the percentage occurrence values (Kruskal-Wallis-Test $x^2 = 3.132$, df = 2, p = 0.209).

Table 2.8: Small mammal analyses for Serval scats within LNP divided into the years 2006, 2007 and 2008. Scats with small mammal remains 2006 N=21, 2007 N=62, 2008 N=108; faecal samples LNP total 2006 N=21, 2007 N=68, 2008 N=127.

Species 2006	No. of faeces with item	No. of consumed items	Mean No. of items in one scat	PO [%]	FO [%] within the group	FO [%] of all LNP samples	Mean biomass [g] (Stuart & Stuart 2007)	Total biomass [g]	% of biomass
Acomys spinosissimus	1	1	1.00	4.76	4.76	0.75	22.00	22.00	0.18
Crocidura hirta	0	0	0.00	0.00	0.00	0.00	15.00	0.00	0.00
Dendromus mystacalis	0	0	0.00	0.00	0.00	0.00	8.00	0.00	0.00
Undefined	3	11	3.67	14.29	14.29	8.21	52.75	580.25	4.72
Gerbilliscus leucogaster	5	8	1.60	23.81	23.81	5.97	70.00	560.00	4.56
Lemniscomys griselda	0	0	0.00	0.00	0.00	0.00	60.00	0.00	0.00
Mastomys spp.	15	50	3.33	71.43	71.43	37.31	60.00	3000.00	24.42
Micaelamys namaquensis	0	0	0.00	0.00	0.00	0.00	50.00	0.00	0.00
Mus spp.	3	3	1.00	14.29	14.29	2.24	6.00	18.00	0.15
Paraxerus cepapi	0	0	0.00	0.00	0.00	0.00	180.00	0.00	0.00
Pelomys fallax	17	60	3.53	80.95	80.95	44.78	135.00	8100.00	65.92
Saccostomus spp.	0	0	0.00	0.00	0.00	0.00	45.00	0.00	0.00
Steatomys spp.	0	0	0.00	0.00	0.00	0.00	26.00	000	0.00
Suncus varilla	1	1	1.00	4.76	4.76	0.75	6.50	6.50	0.05
Uranomys ruddi	0	0	0.00	0.00	0.00	0.00	55.00	0.00	0.00
Total	**21**	**134**						**12286.75**	

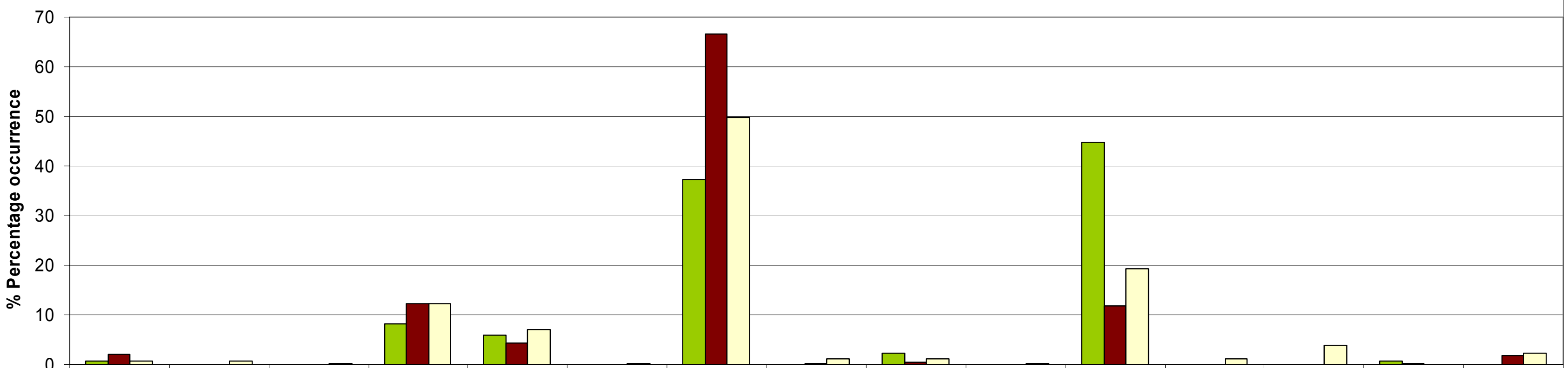
Species 2007	No. of faeces with item	No. of consumed items	Mean No. of items in one scat	PO [%]	FO [%] within the group	FO [%] of all NP samples	Mean biomass [g] (Stuart & Stuart 2007)	Total biomass [g]	% of biomass
Acomys spinosissimus	7	8	1.14	11.29	10.29	2.12	22.00	176.00	0.69
Crocidura hirta	0	0	0.00	0.00	0.00	0.00	15.00	0.00	0.00
Dendromus mystacalis	0	0	0.00	0.00	0.00	0.00	8.00	0.00	0.00
Undefined	22	46	2.09	35.48	32.35	12.17	52.75	2426.50	9.56
Gerbilliscus leucogaster	12	16	1.33	19.35	17.65	4.23	70.00	1120.00	4.41
Lemniscomys griselda	0	0	0.00	0.00	0.00	0.00	60.00	0.00	0.00
Mastomys spp.	49	252	5.14	79.03	72.06	66.67	60.00	15120.00	59.60
Micaelamys namaquensis	1	1	1.00	1.61	1.47	0.26	50.00	50.00	0.20
Mus spp.	2	2	1.00	3.23	2.94	0.53	6.00	12.00	0.05
Paraxerus cepapi	0	0	0.00	0.00	0.00	0.00	180.00	0.00	0.00
Pelomys fallax	23	45	1.96	37.10	33.82	11.90	135.00	6075.00	23.94
Saccostomus spp.	0	0	0.00	0.00	0.00	0.00	45.00	0.00	0.00
Steatomys spp.	0	0	0.00	0.00	0.00	0.00	26.00	0.00	0.00
Suncus varilla	1	1	1.00	1.61	1.47	0.26	6.50	6.50	0.03
Uranomys ruddi	6	7	1.17	9.68	8.82	1.85	55.00	385.00	1.52
Total	**62**	**378**						**25371.00**	

Species 2008	No. of faeces with item	No. of consumed items	Mean No. of items in one scat	PO [%]	FO [%] within the group	FO [%] of all LNP samples	Mean biomass [g] (Stuart & Stuart 2007)	Total biomass [g]	% of biomass
Acomys spinosissimus	3	4	1.33	2.78	2.36	0.63	22.00	88.00	0.19
Crocidura hirta	4	4	1.00	3.70	3.15	0.63	15.00	60.00	0.13
Dendromus mystacalis	2	2	1.00	1.85	1.57	0.32	8.00	16.00	0.04
Undefined	41	78	1.90	37.96	32.28	12.32	52.75	4114.50	9.09
Gerbilliscus leucogaster	29	45	1.55	26.85	22.83	7.11	70.00	3150.00	6.96
Lemniscomys griselda	2	2	1.00	1.85	1.57	0.32	60.00	120.00	0.27
Mastomys spp.	92	315	3.42	85.19	72.44	49.76	60.00	18900.00	41.76
Micaelamys namaquensis	5	7	1.40	4.63	3.94	1.11	50.00	350.00	0.77
Mus spp.	7	7	1.00	6.48	5.51	1.11	6.00	42.00	0.09
Paraxerus cepapi	1	1	1.00	0.93	0.79	0.16	180.00	180.00	0.40
Pelomys fallax	53	122	2.30	49.07	41.73	19.27	135.00	16470.00	36.39
Saccostomus spp.	7	7	1.00	6.48	5.51	1.11	45.00	315.00	0.70
Steatomys spp.	14	24	1.71	12.96	11.02	3.79	26.00	624.00	1.38
Suncus varilla	0	0	0.00	0.00	0.00	0.00	6.50	0.00	0.00
Uranomys ruddi	14	15	1.07	12.96	11.02	2.37	55.00	825.00	1.82
Total	**108**	**633**						**45254.50**	



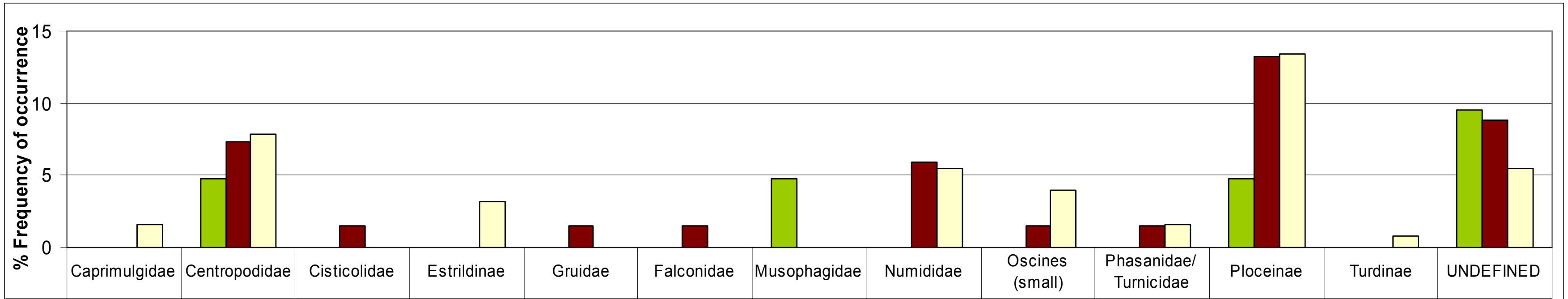
	Acomys spinosissimus	Crocidura hirta	Dendromus mystacalis	Undefined	Gerbilliscus leucogaster	Lemniscomys grieselda	Mastomys spec.	Micaelamys namaquensis	Mus spec.	Paraxerus cepapi	Pelomys fallax	Sacoostomus spec.	Steatomys spec.	Suncus varilla	Zelotomys hildegardeae
2006	4.76	0.00	0.00	14.29	23.81	0.00	71.43	0.00	14.29	0.00	80.95	0.00	0.00	4.76	0.00
2007	11.29	0.00	0.00	35.48	19.35	0.00	79.03	1.61	3.23	0.00	37.10	0.00	0.00	1.61	9.68
2008	2.78	3.70	1.85	37.96	26.85	1.85	85.19	4.63	6.48	0.93	49.07	6.48	12.96	0.00	12.96

Figure 2.31: Frequency of occurrence of small mammal species in Serval scats in all LNP for the years 2006(N=21), 2007 (N=68) and 2008 (N=127).



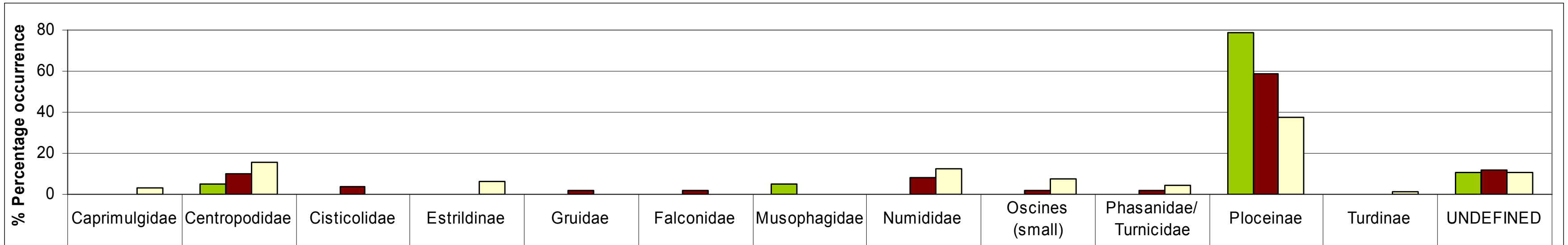
	Acomys spinosissimus	Crocidura hirta	Dendromus mystacalis	Undefined	Gerbilliscus leucogaster	Lemniscomys grieselda	Mastomys spec.	Micaelamys namaquensis	Mus spec.	Paraxerus cepapi	Pelomys fallax	Sacoostomus spec.	Steatomys spec.	Suncus varilla	Zelotomys hildegardeae
2006	0.75	0.00	0.00	8.21	5.97	0.00	37.31	0.00	2.24	0.00	44.78	0.00	0.00	0.75	0.00
2007	2.12	0.00	0.00	12.17	4.23	0.00	66.67	0.26	0.53	0.00	11.90	0.00	0.00	0.26	1.85
2008	0.63	0.63	0.32	12.32	7.11	0.32	49.76	1.11	1.11	0.16	19.27	1.11	3.79	0.00	2.37

Figure 2.32: Percentage occurrence of prey in Serval scats in LNP for the years 2006(N=21), 2007 (N=62) and 2008 (N=108).



	Caprimulgidae	Centropodidae	Cisticolidae	Estrildinae	Gruidae	Falconidae	Musophagidae	Numididae	Oscines (small)	Phasanidae/ Turnicidae	Ploceinae	Turdinae	UNDEFINED
2006	0.00	4.76	0.00	0.00	0.00	0.00	4.76	0.00	0.00	0.00	4.76	0.00	9.52
2007	0.00	7.35	1.47	0.00	1.47	1.47	0.00	5.88	1.47	1.47	13.24	0.00	8.82
2008	1.57	7.87	0.00	3.15	0.00	0.00	0.00	5.51	3.94	1.57	13.39	0.79	5.51

Figure 2.33: Frequency of occurrence of bird taxa in Serval scats in all LNP for the years 2006(N=21), 2007 (N=68) and 2008 (N=127).



	Caprimulgidae	Centropodidae	Cisticolidae	Estrildinae	Gruidae	Falconidae	Musophagidae	Numididae	Oscines (small)	Phasanidae/ Turnicidae	Ploceinae	Turdinae	UNDEFINED
2006	0.00	5.26	0.00	0.00	0.00	0.00	5.26	0.00	0.00	0.00	78.95	0.00	10.53
2007	0.00	9.80	3.92	0.00	1.96	1.96	0.00	7.84	1.96	1.96	58.82	0.00	11.76
2008	3.13	15.63	0.00	6.25	0.00	0.00	0.00	12.50	7.81	4.69	37.50	1.56	10.94

Figure 2.34: Percentage occurrence of bird prey in Serval scats in LNP divided for the years 2006(N=4), 2007 (N=19) and 2008 (N=39).

Table 2.9: Birds analyses for Serval scats within LNP divided into the years 2006, 2007 and 2008. Scats with bird remains 2006 N=4, 2007 N=19, 2008 N=39; faecal samples LNP total 2006 N=21, 2007 N=68, 2008=127.

Species 2006	**No. of faeces with item**	**No. of consumed items**	**Mean No. of items in one scat**	**PO [%]**	**FO [%] within the group**	**FO [%] of LNP samples**	**Mean biomass [g]** (Dunning 1993)	**Total biomass [g]**	**% of biomass**
Centropodidae	**1**	**1**	**1.00**	**5.26**	**25.00**	**4.76**			
Centropus grillii	1	1	1.00	5.26	25.00	4.76	125.50	125.50	13.19
Musophagidae	**1**	**1**	**1.00**	**5.26**	**25.00**	**4.76**			
Corythaixoides concolor	1	1	1.00	5.26	25.00	4.76	267.63	267.63	28.13
Ploceinae	**1**	**15**	**15.00**	**78.95**	**25.00**	**4.76**			
Quelea quelea	1	15	15.00	78.95	25.00	4.76	18.90	283.50	29.80
UNDEFINED	**2**	**2**	**1.00**	**10.53**	**50.00**	**9.52**	137.34	274.69	28.87
Total	**4**	**19**						**951.32**	

Species 2007	**No. Of faeces with item**	**No. Of consumed items**	**Mean No. of items in one scat**	**PO [%]**	**FO [%] within the group**	**FO [%] of LNP samples**	**Mean biomass [g]** (Dunning 1993)	**Total biomass [g]**	**% of biomass**
Centropodidae	**5**	**5**	**1**	**9.80**	**26.32**	**7.35**			
Centropus spp.	5	5	1	9.80	26.32	7.35	205.92	1029.60	7.18
Cisticolidae	**1**	**2**	**2**	**3.92**	**5.26**	**1.47**			
Apalis spp.	1	2	2	3.92	5.26	1.47	7.90	15.80	0.11
Gruidae	**1**	**1**	**1**	**1.96**	**5.26**	**1.47**			
Balearica regulorum	1	1	1	1.96	5.26	1.47	3600.00	3600.00	25.09
Falconidae	**1**	**1**	**1**	**1.96**	**5.26**	**1.47**	190.83	190.83	1.33
Numididae	**4**	**4**	**1**	**7.84**	**21.05**	**5.88**			
Numida meleagris	4	4	1	7.84	21.05	5.88	1299.00	5196.00	36.21
Oscines (small)	**1**	**1**	**1**	**1.96**	**5.26**	**1.47**	25.00	25.00	0.17
Phasanidae	**1**	**1**	**1**	**1.96**	**5.26**	**1.47**			
Coturnix spp.	1	1	1	1.96	5.26	1.47	78.38	78.38	0.55
Ploceinae	**9**	**30**	**3.33**	**58.82**	**47.37**	**13.24**			
Ploceinae spp.	1	1	1	1.96	5.26	1.47	28.40	28.40	0.20
Quelea quelea	8	29	3.63	56.86	42.11	11.76	18.90	548.10	3.82
UNDEFINED	**6**	**6**	**1**	**11.76**	**31.58**	**8.82**	606.04	3636.22	25.34
Total	**19**	**51**						**14348.33**	

Species 2008	No. Of faeces with item	No. Of consumed items	Mean No. of items in one scat	PO [%]	FO [%] within the group	FO [%] of LNP samples	Mean biomass [g] (Dunning 1993)	Total biomass [g]	% of biomass
Caprimulgidae	**2**	**2**	**1.00**	**3.13**	**5.13**	**1.57**			
Caprimulgus spp.	2	2	1.00	3.13	5.13	1.57	53.79	107.58	0.67
Centropodidae	**10**	**10**	**1.00**	**15.63**	**25.64**	**7.87**			
Centropus grillii	1	1	1.00	1.56	2.56	0.79	125.50	125.50	0.78
Centropus spp.	9	9	1.00	14.06	23.08	7.09	205.92	1853.28	11.48
Estrildinae	**4**	**4**	**1.00**	**6.25**	**10.26**	**3.15**			
Estrilda spp.	2	2	1.00	3.13	5.13	1.57	8.58	17.16	0.11
Estrilda astrild	2	2	1.00	3.13	5.13	1.57	9.05	18.10	0.11
Numididae	**7**	**8**	**1.14**	**12.50**	**17.95**	**5.51**			
Numida meleagris	7	8	1.14	12.50	17.95	5.51	1299.00	10392.00	64.37
Oscines (small)	**5**	**5**	**1.00**	**7.81**	**12.82**	**3.94**	25.00	125.00	0.77
Phasanidae/Turnicidae	**2**	**3**	**1.50**	**4.69**	**5.13**	**1.57**			
Coturnix/Turnix	2	3	1.50	4.69	5.13	1.57	60.56	181.67	1.13
Ploceinae	**17**	**24**	**1.41**	**37.50**	**43.59**	**13.39**			
Ploceinae spp.	2	2	1.00	3.13	5.13	1.57	28.40	56.80	0.35
Quelea quelea	15	22	1.47	34.38	38.46	11.81	18.90	415.80	2.58
Turdinae	**1**	**1**	**1.00**	**1.56**	**2.56**	**0.79**			
Turdus spp.	1	1	1.00	1.56	2.56	0.79	65.94	65.94	0.41
UNDEFINED	**7**	**7**	**1.00**	**10.94**	**17.95**	**5.51**	397.80	2784.60	17.25
Total	**39**	**64**						**16143.42**	

A plausible comparison of the composition of reptile (Fig 2.36) and insect (Fig. 2.35) taxa between the three years is difficult due to minimal numbers of samples in some years. However, in Figure 2.38 a high level of ant consumption in 2007 is notable, as well as large amounts of Scincidae preyed on in 2007. The 100% bar in 2006 is as a result of only one scat sample being found to contain reptile remains.

There is also no significant difference in arthropod and reptile composition between the years concerning frequency of occurrence (Kruskal-Wallis-Test x^2 = 3.1, df = 2, p = 0.212, respectively x^2 = 2.373, df = 2, p = 0.305).

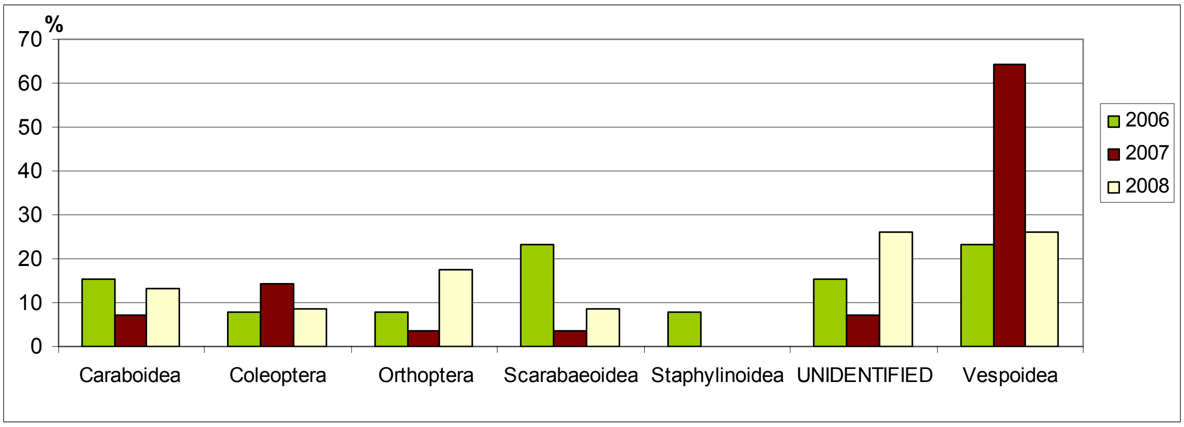


Figure 2.35: Frequency of occurrence of insect taxa in Serval scats containing insect remains in LNP for the years 2006 (N=13), 2007 (N=28) and 2008 (N=23).

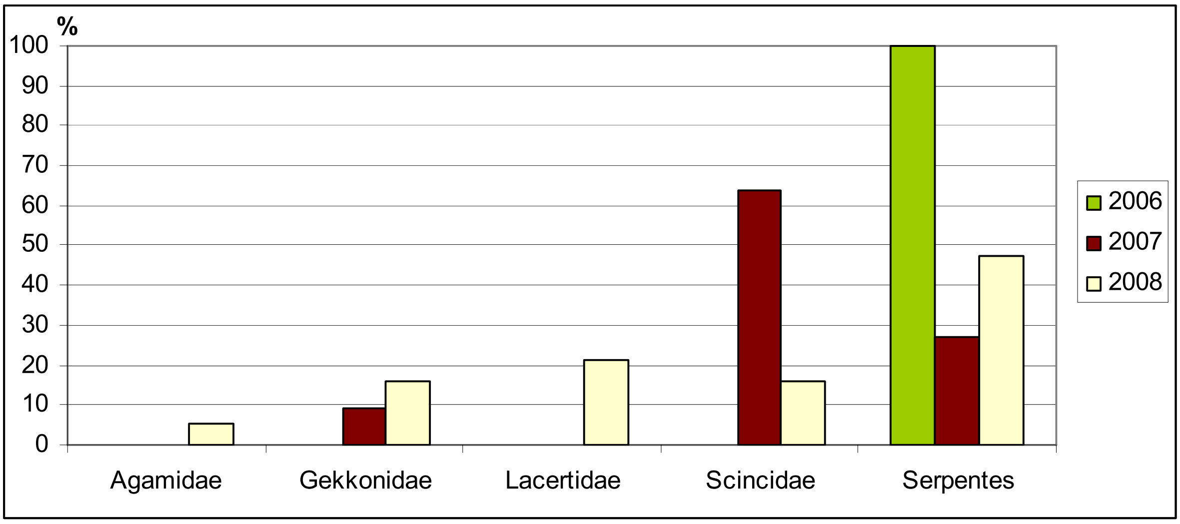
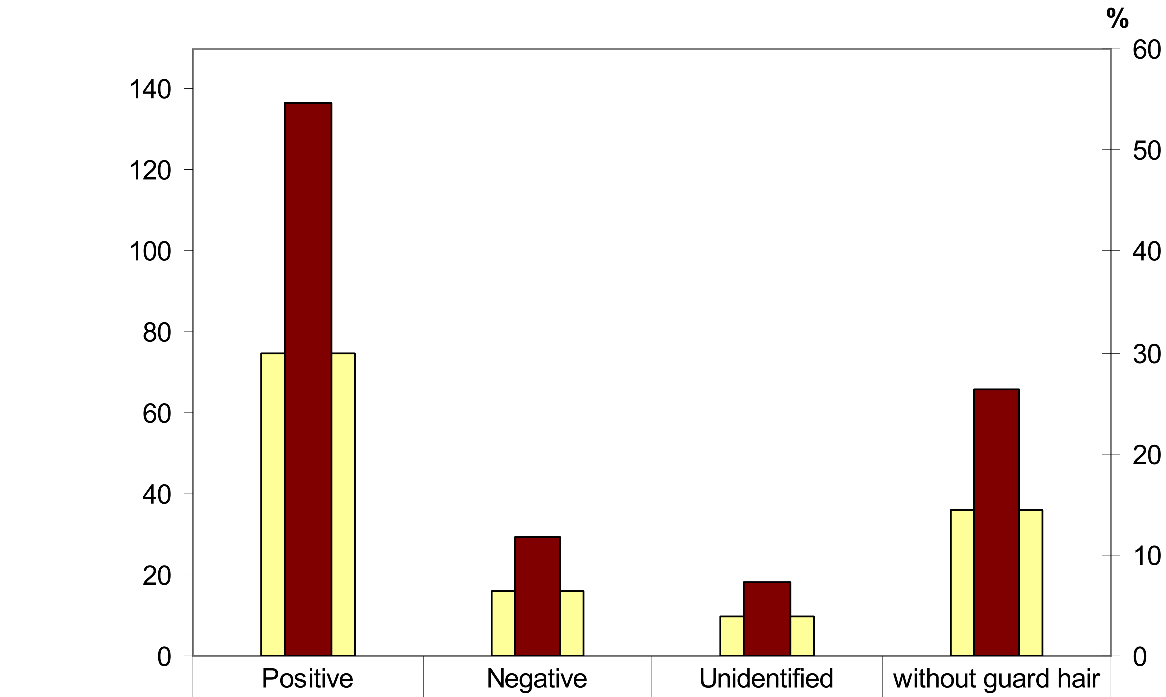


Figure 2.36: Frequency of occurrence of reptile groups in Serval scats containing reptile remains in LNP for the years 2006 (N=1), 2007 (N=11) and 2008 (N=19).

2.3.2. Diet in different locations in Zambia

The scat samples were collected in the year 2008 in eight different locations in Zambia besides LNP (see map 1.9 in Chapter 1). In this year it was possible to locate 137 faecal samples for prey spectrum analyses. Through guard hair analyses 75 samples were identified as Serval scat, 46 samples remained as unclassified and 16 were discarded as 'negative', not Serval scat (see Fig. 3.39). The mean diameter of all positive determined samples was 19.94 mm and of all unclassified samples it was 18.91 mm.

For data analyses unclassified samples were treated as positive samples, as the shape and size of the scats were identified as Serval scat in the field before collection. The data was also divided into the two groups to determine for significant differences between these groups (Fig. 2.37).



	Positive	Negative	Unidentified	without guard hair
Amount	75	16	10	36
Percentage	54,74	11,68	7,30	26,28

Figure 2.37: Determination of origin of faeces collected in Zambia.

Divided into the eight locations the following 121 scat samples were analyzed for their prey item composition:

Table 2.10: Total numbers of analysed scats in eight different locations in Zambia.

Location	N samples
Kafue National Park	17
Kasanka National Park	20
Kahl Amazi Farm	1
Kushiya Farm	32
Lilayi Lodge	8
Lower Zambezi National Park	22
North Luangwa National Park	4
South Luangwa National Park	17

Following the cumulative curve of number of prey types determined against number of analysed scats for all study areas with a sample number >15 (see Fig. 2.38) it was not possible to get enough samples in any region to reach the asymptote. However, after 15 samples the data does nearly approach an asymptote. Therefore Lilayi Lodge and Kahl Amazi Farm are from now on counted as one region 'Lusaka Area' and North Luangwa and South Luangwa are combined to the region 'Luangwa Valley'. Hence, the Serval's diet is analysed at six study sites.

By examining all 121 scat samples collected in different parts of Zambia it was possible to identify the Servals' diet within Zambia. Servals were mainly feeding on small mammal prey in most parts of Zambia (Fig. 2.39). Evidence of the consumption of small mammals was found in over 71% of all sampled scats. Bird remains were found in 54.55%, reptiles in 17.36% and arthropods in 31.40% of scats. Grass was found in nearly 85% of all samples, other vegetation (like seeds, bark or leaves) was discarded as only small amounts were found and these could not be determined accurately. In one sample there was evidence of amphibian prey. Parasites like ticks and tapeworms could be found as well; results of the analyses on parasites will be discussed in Chapter 4. Figure 2.40 shows the results separated into positive and unclassified samples. There is no significant difference ($t = 0.963$; $p = 0.350$) between the frequency of occurrence values for these groups.

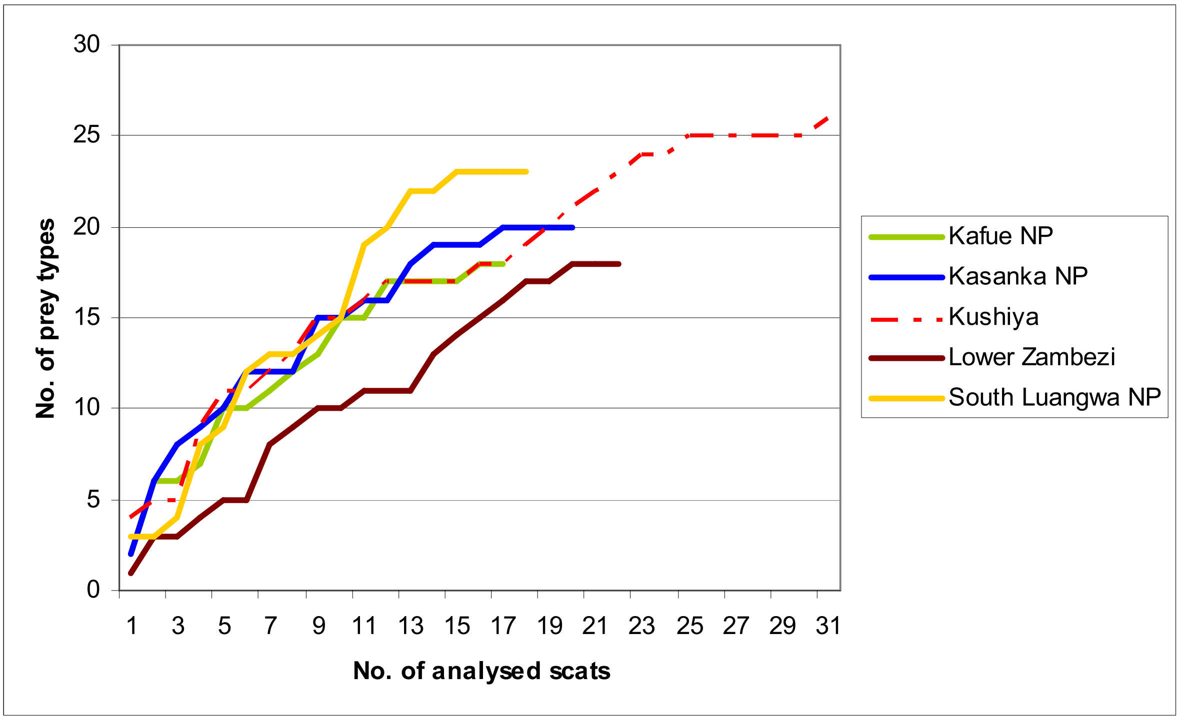


Figure 2.38: Cumulative curve of number of prey types identified against number of analyzed scats for the different study sites with sample size >15.

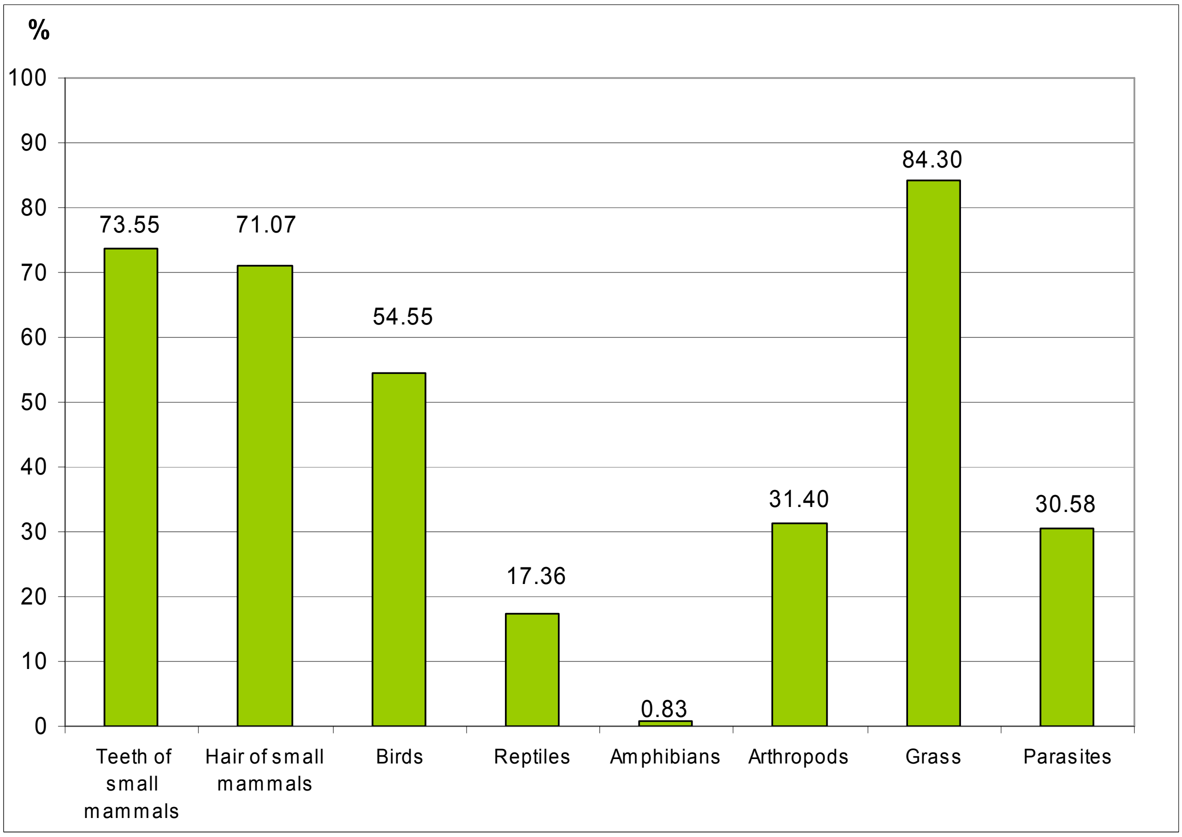


Figure 2.39: Frequency of occurrence of prey in Serval scats in the six study areas.

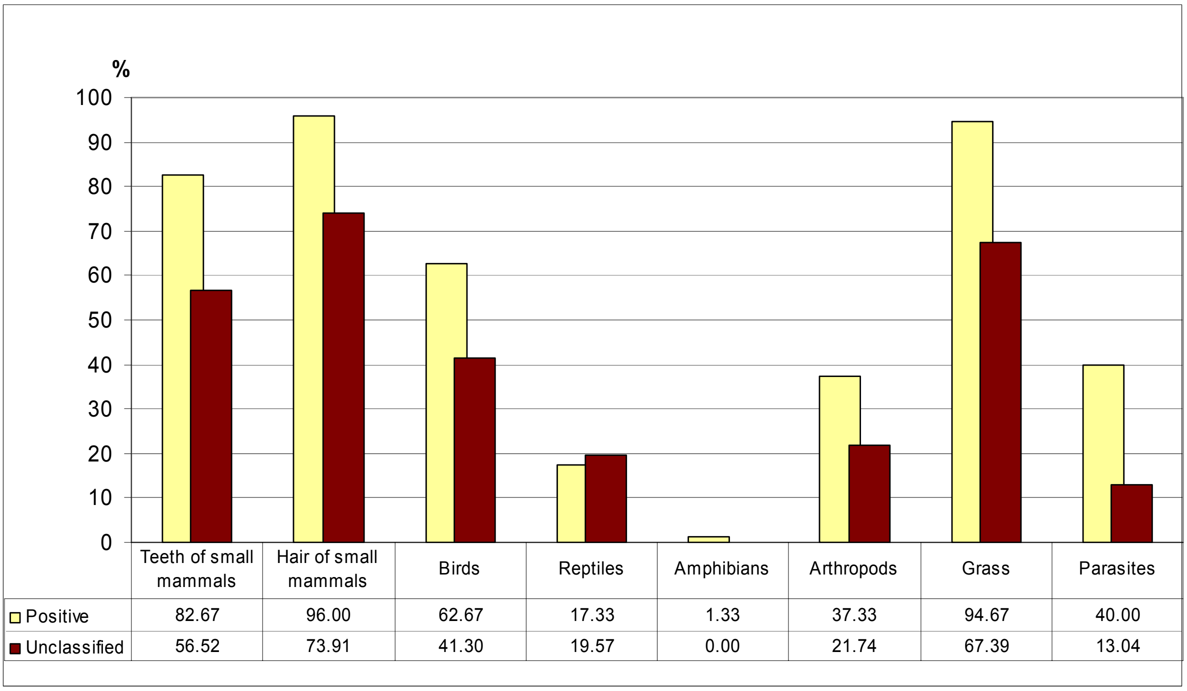


Figure 2.40: Frequency of occurrence of prey in Serval scats in the six study areas, separated into positive identified and unclassified scat samples.

Altogether the following 57 species, genuses, families and orders could be identified in the Serval scats in all six study sites:

Table 2.11: All prey types found in Serval scat samples in six different locations in Zambia.

(Sub-) Order	Family	Genus	Species	Common name
Coleoptera	spp.	spp.	spp.	Beetle
Coleoptera	Carabidae	spp.	spp.	Ground Beetles
Coleoptera	Scarabeidae	spp.	spp.	Scarab Beetles
Coleoptera	Chrysomelidae	spp.	spp.	Leaf Beetles
Coleoptera	Tenebrionidae	spp.	spp.	Darkling Beetles
Decapoda	spp.	spp.	spp.	Decapod
Isoptera	spp.	spp.	spp.	Termites
Orthoptera	spp.	spp.	spp.	Grasshoppers
Scorpiones	spp.	spp.	spp.	Scorpions
Vespoidea	Formicidae	spp.	spp.	Ants
Serpentes	spp.	spp.	spp.	Snakes
Scleroglossa	Gekkonidae	spp.	spp.	Gekkos
Eusuchia	Crocodylidae	spp.	spp.	Crocodiles
Iguania	Agamidae	spp.	spp.	Agamas
Autarchoglossa	Lacertidae	spp.	spp.	Wall Lizards
Autarchoglossa	Scincidae	spp.	spp.	Skinks
Anura	Microhylidae	spp.	spp.	Microhylid Frogs
Soricomorpha	Soricidae	*Crocidura*	spp.	Musk Shrews
Soricomorpha	Soricidae	*Crocidura*	*cf. nanilla*	Tiny white-toothed shrew
Soricomorpha	Soricidae	*Crocidura*	*hirta*	Lesser Red Musk Shrew
Macroscelidea	Macroscelididae	*Elephantulus*	spp.	Elephant Shrews
Macroscelidea	Macroscelididae	*Petrodromus*	*tetradactylus*	Four-toed Elephant Shrew
Rodentia	Muridae	*Cricetomys*	spp.	Giant Pouched Rats
Rodentia	Bathyergidae	*Fukomys*	spp.	Mole Rats
Rodentia	Cricetidae	*Gerbilliscus*	*leucogaster*	Bushveld Gerbil

(Sub-) Order	Family	Genus	Species	Common name
Rodentia	Sciuridae	*Heliosciurus*	*gambianus*	Gambian Sun Squirrel
Rodentia	Muridae	*Lemniscomys*	spp.	Striped Grass Mice
Rodentia	Muridae	*Mastomys*	*natalensis*	Natal Multimammate Mouse
Rodentia	Muridae	*Mastomys*	spp.	Multimammate Mouse
Rodentia	Muridae	*Micaelamys*	spp.	Rock Rats
Rodentia	Muridae	*Mus*	*minutoides*	African Pygmy Mouse
Rodentia	Muridae	*Mus*	spp.	Old World Mice
Rodentia	Muridae	*Pelomys*	*fallax*	Creek Groove-toothed Swamp Rat
Rodentia	Cricetidae	*Saccostomus*	spp.	Pouched Mice
Rodentia	Cricetidae	*Steatomys*	*pratensis*	Fat Mouse
Apodiformes	Apodidae	*Apus*	spp.	Swifts
Caprimulgi	Caprimulgidae	*Caprimulgus*	spp.	Nightjars
Coraciiformes	spp.	spp.	spp.	Rollerlike Birds
Cuculiformes	Centropodidae	*Centropus*	*superciliosus*	Whitebrowed Coucal
Cuculiformes	Centropodidae	*Centropus*	spp.	Coucals
Cuculiformes	Centropodidae	*Centropus*	*cupreicaudus*	Coppery tailed Coucal
Falconides	Falconidae	spp.	spp.	Falcons
Galliformes	Numididae	*Numida*	*meleagris*	Helmeted Guineafowl
Galliformes	spp.	spp.	spp.	Game birds
Galliformes	Phasianidae	*Francolinus*	spp.	Francolins
Galliformes/ Turniciformes	Phasanidae/ Turnicidae	*Coturnix/ Turnix*	spp.	Quails/ Buttonquails
Muscicapoidea	Sturnidae	*Lamprotornis*	spp.	Starlings
Passeri	Ploceinae	*Ploceinae*	spp.	Weavers
Passeri	Ploceinae	*Quelea*	*quelea*	Redbilled Quelea
Passeri	Oscines	spp.	spp.	Songbirds
Passeri	Cisticolidae	*Apalis*	spp.	Apalis
Passeri	Fringillidae	*Serinus*	*flaviventris*	Yellow Canary
Passeri	Cisticolidae	*Prinia*	*subflava*	Tawny flanked Prinia
Passeri	Viduidae	*Vidua*	spp.	Widowfinches
Passeri	Estrildinae	*Ortygospiza*	*atricollis*	Quail Finch
Strigi	Tytonidae	*Tyto*	spp.	Owls
Strigi	Tytonidae	*Tyto*	*alba*	Barn Owl

Figure 2.41 shows the different frequency of occurrence values of all digested items found in Serval scat divided into the six study sites. It is obvious that the values are diverging between locations; small mammals are not always the major digested item. But there is no significant difference in FO values between the six study areas (ANOVA, $F_{5,37} = 0.79$, $p = 0.564$).

The following tables show the species' lists divided into mammals, birds, reptiles and arthropods occurring in the different areas (Tab. 2.13 – 2.16). At the same time the frequency of occurrence of these species at the specific study area is shown, as well as the percentage occurrence values with the group 'small mammals' and 'birds'.

In **Kafue NP** in ten scat samples (58.8%), eight different species of small mammals were found, two *Crocidura* species compared to six rodent species. Out of all faecal samples, there were four (23.5%) which included bird remains covering three different bird taxa; two species of the sub-family Ploceinae and one member of the Galliformes. Within the group of arthropods insects and also a scorpion were found (see Table 2.14). As the only location showing evidence of amphibian prey items, in Kafue NP one frog of the family Microhylidae was identified (by the small size of the spine bone).

In 18 scat samples (90%) thirteen species of small mammals were found in **Kasanka NP**; two *Crocidura* species and eleven rodent species. In five faecal samples (25%) which contained bird remains, there were six taxa of birds.

Examining all 32 scat samples of **Kushiya** farmland it shows that the Servals on this farm fed slightly less often on small mammals compared to the other locations and a higher proportion of their diet is made up of birds. At Kushiya Farm seven different species of small mammals were found in 23 faeces samples (71.9%), including one Musk Shrew species and six rodent species. Eighteen faecal samples (56.3%) were found to contain bird remnants of nine different taxa. Within the group of arthropods, insects and a scorpion were found (see Tab. 2.14). Several members of the reptiles could be identified, including the remnants of a Crocodile of young age (Tab. 2.13).

In **Lower Zambezi** 19 faecal samples (86.4%) showed seven species of small mammals, two Crocidura species and five rodent species (see Tab. 2.13). In sixteen scats (72.8%), bird remains of ten different taxa were found (see Tab. 2.16).

In **North and South Luangwa NP** there were more bird than small mammal remains found (Fig. 2.41). There was also a high level of reptile (33%) and arthropod (38%) remnants. In the two National Parks of Luangwa Valley, seven small mammal species could be determined in six scat samples, while 76.2% of scat samples contained bird remains. Eight different bird taxa could be determined. Within the group of arthropods a variety of insects were found, as well as one Decapod (see Tab. 2.14).

The nine analysed samples of **Lusaka Area** show that Servals there also hunt more birds than small mammals (Fig. 2.41). In Lusaka Area seven out of nine faecal samples contained five different rodent species (Tab. 2.15). 77.78% of all Lusaka Area faecal samples contained bird bones or feathers of seven different taxa.

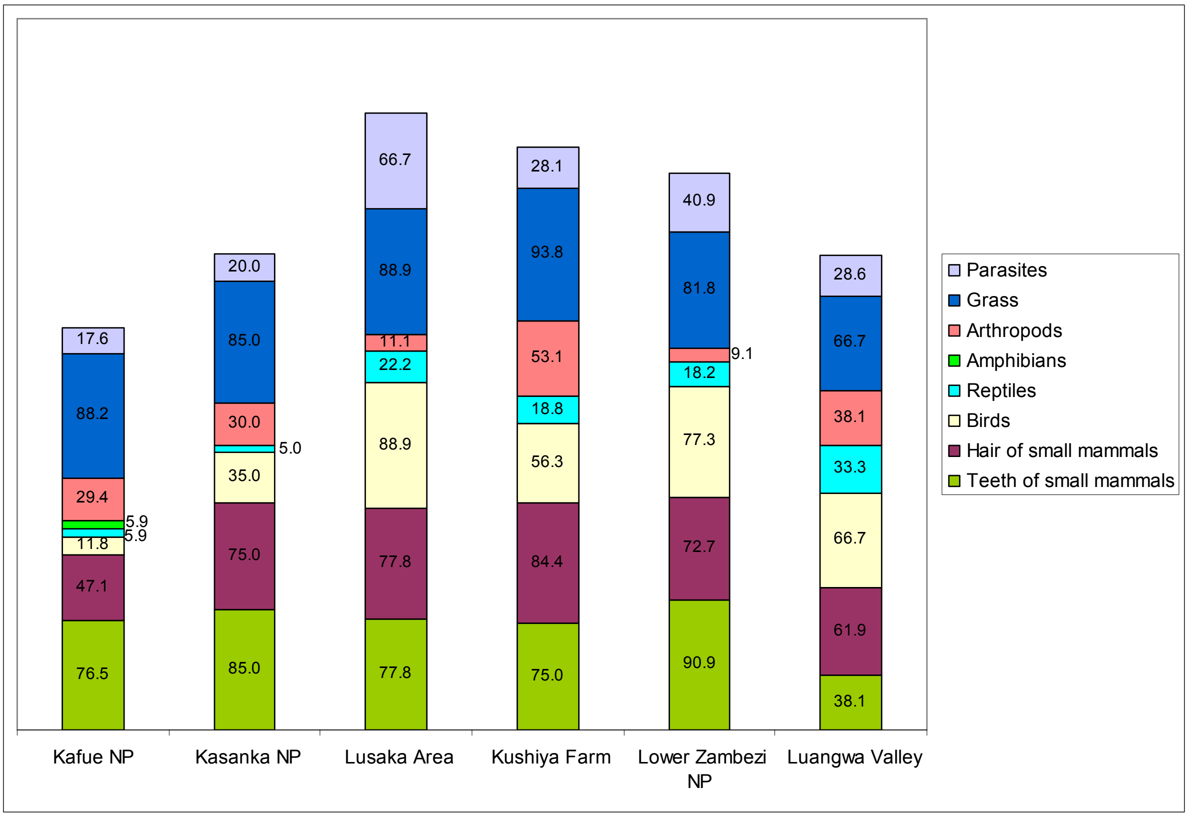


Figure 2.41: Relative frequency of occurrence of digested items in Serval scats, separated into the six study areas in comparison to each other.

Contrary to the results in Luambe NP small mammals do not clearly constitute the major part of the amount of biomass consumed in all different Zambian study sites (median 48.83%, mean 51.04% ± 28.70845). Consumed birds make also a median value of 51.17%; (mean 48.94% ± 28.70845) of the total consumed biomass. Of a total sum of 49641.5 g of consumed biomass of birds and small mammals in all locations the birds constitute 26985.01 g. These data are regardless of the biomasses of consumed reptile and arthropod biomasses as there was no quantification of these groups possible. Mean biomass of consumed birds is 296.6 g, while mammalian prey showed a mean biomass value of 69.1 g. Table 2.12 shows the differences in consumed biomasses of the small mammal and the bird groups between all study sites and the mean weight of the specific prey category. Concerning FO and PO the prey category of small mammals seems to be favoured (Fig. 2.43) but values of consumed biomasses show a more differentiated picture as the values of the small mammal group varies between 14% and 90% (Tab. 2.12). Mean values also vary a lot in both groups. Usually mean weight of consumed birds is higher than the one of mammalian prey but in Kasanka National Park.

Table 2.12: Percentages of biomasses of the small mammal and bird prey group of the total consumed biomasses.

	Kafue NP	Kasanka NP	Kushiya Farm	Lower Zambezi NP	Luangwa Valley	Lusaka Area
Small mammals [%]	76.98	89.89	27.76	47.70	13.83	49.96
Birds [%]	23.02	10.11	72.24	52.30	86.17	50.04
Mean weight of mammalian prey [g]	56.79	259.95	41.40	83.78	62.06	50.06
Mean weight of consumed birds [g]	220.73	131.59	482.38	240.85	134.39	417.56

Table 2.13: Reptile species occurring at the six different study sites in Zambia.

Sub-Order	Family	FO [%] of all samples	Location
Autarchoglossa	Scincidae	6.25	Kushiya Farm
		11.11	Lusaka Area
		23.81	Luangwa Valley
Eusuchia	Crocodylidae	3.13	Kushiya Farm
Iguania	Agamidae	11.11	Lusaka Area
Scleroglossa	Gekkonidae	9.38	Kushiya Farm
		9.09	Lower Zambezi NP
Serpentes	spp.	6.25	Kushiya Farm
		22.22	Lusaka Area
		5.88	Kafue NP
		19.05	Luangwa Valley
		9.09	Lower Zambezi NP
		10.00	Kasanka NP

Table 2.14: Arthropod species occurring at the six different study sites in Zambia.

Order	Family	FO [%]	Location
Caraboidea	Carabidae	5.00	Kasanka NP
		5.88	Kafue NP
		3.13	Kushiya Farm
		4.76	Luangwa Valley
Chrysomeloidea	Chrysomelidae	5.88	Kafue NP
Coleoptera	spp.	14.29	Luangwa Valley
Scarabaeoidea	Scarabeidae	4.76	Luangwa Valley
Decapoda	spp.	4.76	Luangwa Valley
Isoptera	spp.	4.76	Luangwa Valley
Orthoptera	spp.	5.00	Kasanka NP
		17.65	Kafue NP
		21.88	Kushiya Farm
		9.52	Luangwa Valley
Scarabaeoidea	Scarabeidae	12.50	Kushiya Farm
		11.76	Kafue NP
		5.00	Kasanka NP
		19.05	Luangwa Valley
Scorpiones	spp.	5.88	Kafue NP
		3.13	Kushiya Farm
Tenebrionoidea	Tenebrionidae	3.13	Kushiya Farm
Vespoidea	Formicidae	15.00	Kasanka NP
		11.76	Kafue NP
		12.50	Kushiya Farm
		4.55	Lower Zambezi NP
		9.52	Luangwa Valley

Table 2.15: Small mammal species occurring at the six different study sites in Zambia.

Species	PO [%]	FO [%] of all samples	Mean biomass [g] (Stuart & Stuart 2007)	% of biomass	Location
Cricetomys spp.	8.33	10.00	2000	64.11	Kasanka NP
Crocidura *cf. nanilla*	5.13	5.88	2.5	0.23	Kafue NP
	2.78	5.00		0.03	Kasanka NP
	0.97	3.13		0.06	Kushiya Farm
	6.25	4.76		0.19	Luangwa Valley
Crocidura hirta	2.56	5.88	60	2.71	Kafue NP
	1.41	4.55		1.69	Lower Zambezi NP
Crocidura spp.	26.76	22.73	16.8	8.98	Lower Zambezi NP
	5.56	5.00	16.8	0.36	Kasanka NP
Elephantulus spp.	2.78	5.00	144	1.54	Kasanka NP
Fukomys *(Cryptomys)*	2.78	5.00	125	1.34	Kasanka NP
Gerbilliscus *leucogaster*	23.08	41.18	70	28.44	Kafue NP
	16.67	20.00		4.49	Kasanka NP
	0.97	3.13		1.64	Kushiya Farm
	1.41	4.55		1.97	Lower Zambezi NP
	18.75	14.29		15.67	Luangwa Valley
	6.45	22.22		1.50	Lusaka Area
Heliosciurus *gambianus*	1.41	4.55	295	8.30	Lower Zambezi NP
Lemniscomys spp.	2.78	5.00	60	0.64	Kasanka NP
Mastomys *natalensis*	17.95	29.41	60	18.96	Kafue NP
	2.78	10.00		0.64	Kasanka NP
	11.65	18.75		16.88	Kushiya Farm
	57.75	72.73		69.22	Lower Zambezi NP
	12.50	9.52		8.95	Luangwa Valley
	61.29	66.67		12.18	Lusaka Area
Mastomys spp.	2.78	5.00	60	0.64	Kasanka NP
Micaelamys *namaquensis*	6.25	4.76	50	3.73	Luangwa Valley
Mus *minutoides*	7.69	17.65	6	0.81	Kafue NP
	2.91	9.38		0.42	Kushiya Farm
	2.82	9.09		0.34	Lower Zambezi NP
Mus spp.	2.78	5.00	6	0.06	Kasanka NP
Pelomys *fallax*	12.82	23.53	135	30.47	Kafue NP
	30.56	45.00		15.87	Kasanka NP
	10.68	21.88		34.82	Kushiya Farm
	31.25	19.05		50.35	Luangwa Valley
	9.68	22.22		4.33	Lusaka Area
Petrodromus *tetradactylus*	6.25	4.76	205	15.29	Luangwa Valley
Saccostomus spp.	5.56	5.00	45	0.96	Kasanka NP
	0.97	3.13		1.06	Kushiya Farm
	5.63	18.18		5.06	Lower Zambezi NP
	9.68	11.11		1.44	Lusaka Area
	12.82	23.53		10.16	Kafue NP
Steatomys *pratensis*	17.95	17.65	26	8.22	Kafue NP
	2.78	5.00		0.28	Kasanka NP
	71.84	65.63		45.12	Kushiya Farm
	18.75	9.52		5.82	Luangwa Valley
	12.90	33.33		1.11	Lusaka Area

Table 2.16: Bird species occurring at the six different study sites in Zambia.

Species	PO [%]	FO [%] of all samples	Mean biomass [g] (Dunning 1993)	% of biomass	Location
Apodidae	**12.50**	**5.00**			Kasanka NP
Apus spp.	12.50	5.00	35.98	3.42	Kasanka NP
Caprimulgidae	**5.00**	**4.76**			Luangwa Valley
Caprimulgus spp.	5.00	4.76	53.79	0.64	Luangwa Valley
Centropodidae	**25.00**	**10.00**			Kasanka NP
	4.35	**3.13**			Kushiya Farm
	12.50	**4.76**			Lusaka Area
	30.00	**28.57**			Luangwa Valley
Centropus cupreicaudus	4.35	3.13	285.50	2.57	Kushiya Farm
	12.50	4.76		14.82	Lusaka Area
	5.00	4.76		3.42	Luangwa Valley
Centropus spp.	12.50	5.00	205.92	19.56	Kasanka NP
	25.00	23.81		12.33	Luangwa Valley
Centropus superciliosus	12.50	5.00	152.00	14.44	Kasanka NP
Cisticolidae	**10.00**	**9.52**			Luangwa Valley
Apalis spp.	5.00	4.76	7.90	0.09	Luangwa Valley
Prinia subflava	5.00	4.76	8.99	0.11	Luangwa Valley
Coraciiformes	**3.45**	**4.55**	72.00	1.85	Lower Zambezi NP
Estrildinae	**25.00**	**9.52**			Lusaka Area
Estrilda astrild	12.50	4.76	9.05	0.47	Lusaka Area
Ortygospiza atricollis	12.50	4.76	11.00	0.57	Lusaka Area
Falconidae	**3.45**	**4.55**	190.83	4.90	Lower Zambezi NP
Fringillidae	**4.35**	**3.13**			Kushiya Farm
Serinus flaviventris	4.35	3.13	16.98	0.15	Kushiya Farm
Galliformes	**33.33**	**5.88**	614.90	92.86	Kafue NP
	12.50	**5.00**		58.41	Kasanka NP
	4.35	**3.13**		5.54	Kushiya Farm
	3.45	**4.55**		15.78	Lower Zambezi NP
Numididae	**21.74**	**12.50**			Kushiya Farm
	12.50	**4.76**			Lusaka Area
	3.45	**4.55**			Lower Zambezi NP
	20.00	**19.05**			Luangwa Valley
Numida meleagris	21.74	12.50	1299.00	58.54	Kushiya Farm
	12.50	4.76		67.42	Lusaka Area
	3.45	4.55		33.33	Lower Zambezi NP
	20.00	19.05		62.22	Luangwa Valley
Oscines (small)	**12.50**	**5.00**	25.00	2.37	Kasanka NP
	4.35	**3.13**		0.23	Kushiya Farm
	12.50	**4.76**		1.30	Lusaka Area
	6.90	9.09		1.28	Lower Zambezi NP
Phasanidae/Turnicidae	**4.35**	**3.13**			Kushiya Farm
	3.45	**4.55**			Lower Zambezi NP
	5.00	**4.76**			Luangwa Valley
	4.35	**3.13**			Kushiya Farm
	10.00	**9.52**			Luangwa Valley
Coturnix/Turnix	4.35	3.13	60.56	0.55	Kushiya Farm
	10.00	9.52		1.45	Luangwa Valley
Francolinus spp.	4.35	3.13	458.35	4.13	Kushiya Farm
	3.45	4.55		11.76	Lower Zambezi NP
	5.00	4.76		5.49	Luangwa Valley
Ploceinae	**66.67**	**11.76**			Kafue NP
	12.50	**5.00**			Kasanka NP
	4.35	**3.13**			Kushiya Farm
	25.00	**9.52**			Lusaka Area
	51.72	**31.82**			Lower Zambezi NP
Ploceinae spp.	33.33	5.88	28.40	4.29	Kafue NP
	12.50	4.76		1.47	Lusaka Area
Ploceus spp.	12.50	4.76	27.99	1.45	Lusaka Area

Species	PO [%]	FO [%] of all samples	Mean biomass [g] (Dunning 1993)	% of biomass	Location
Quelea quelea	33.33	5.88	18.90	2.85	Kafue NP
	12.50	5.00		1.80	Kasanka NP
	4.35	3.13		0.17	Kushiya Farm
	51.72	31.82		7.27	Lower Zambezi NP
Sturnidae	**3.45**	**4.55**			Lower Zambezi NP
Lamprotornis spp.	3.45	4.55	95.03	2.44	Lower Zambezi NP
Tytonidae	**6.90**	**9.09**			Lower Zambezi NP
Tyto alba	3.45	4.55	447.00	11.47	Lower Zambezi NP
Tyto spp.	3.45	4.55	386.67	9.92	Lower Zambezi NP
Viduidae	**4.35**	**3.13**			Kushiya Farm
Vidua spp.	4.35	3.13	14.98	0.14	Kushiya Farm

2.3.3. Prey availability

This chapter only deals with small mammal prey, not with birds, reptiles and arthropods, as these analyses could not be done to a full extent due to missing data and time limits.

2.3.3.1. Prey availability in Luambe National Park

Nine different small mammal species were trapped in traps shown in Fig. 2.42: one squirrel, two Scorimorpha species and six rodent species at 16 trapping areas (Tab. 2.17). Not all species were caught in each trapping area, but *Mastomys natalensis* could be found in 14 traps out of 16 trapping areas, while for example *Acomys spinosissimus* could only be trapped in one of these areas. The amount of trapped animals varied between one to 25 individuals (Fig. 2.43).

Notably *Crocidura nanilla*, which was caught in the traps but not found in the Serval faecal samples, has not been previously recorded for the Luangwa valley (ANSELL 1978).

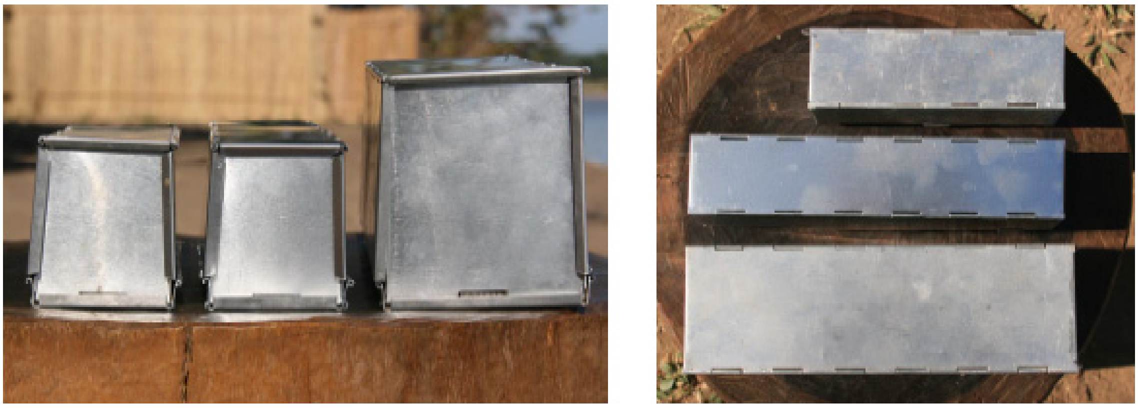


Figure 2.42: Sherman Traps.
Left: size A (5x16x6cm); Middle: size B (5x23x6cm); Right: size C (7.5x23x8.5cm). (Picture by Margit Schmitt)

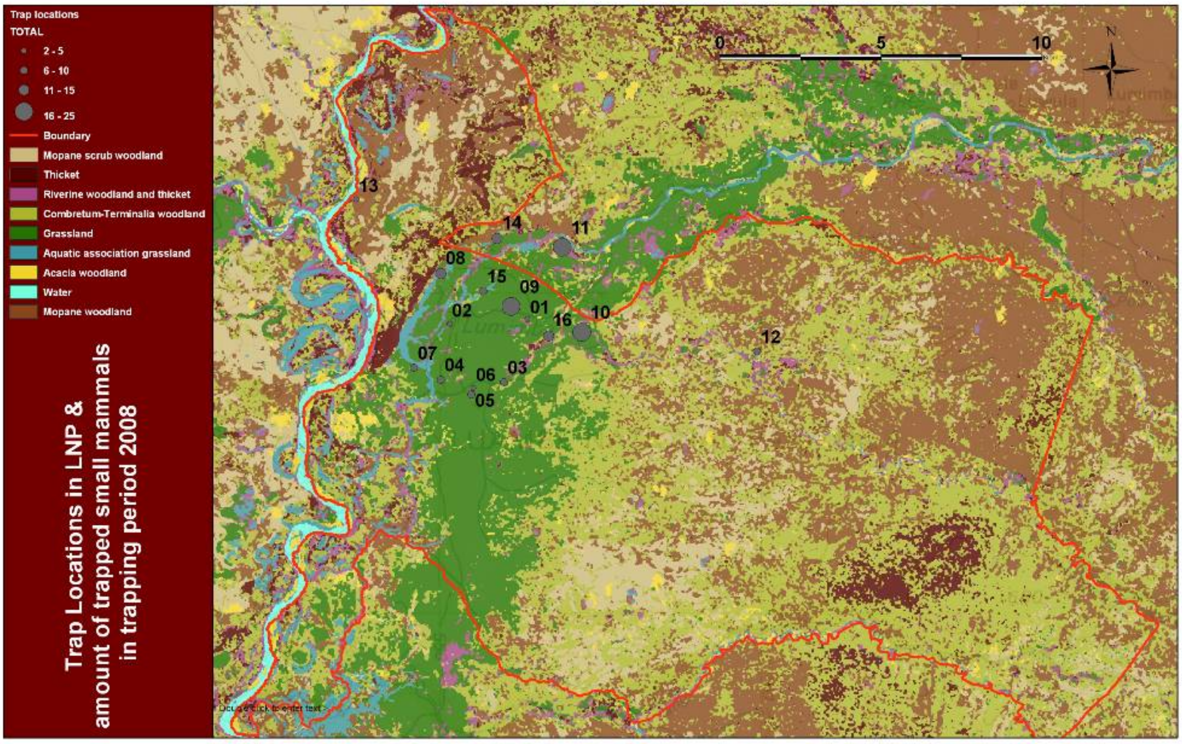


Figure 2.43: Trap locations in LNP. Size of point indicates the amount of small mammals trapped at each trapping location (vegetation categories after ANDERSON 2009).

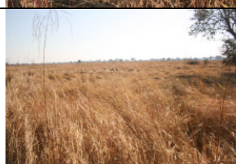
Table 2.17: a) Species of small mammals trapped at the different trapping areas in 2008 (X = trapped, 0 = not trapped) and b)Trapping areas in LNP and their habitat description.
(Pictures by Margit Schmitt.)

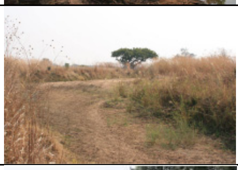
a)

Area	*As*	*Ch*	*Cn*	*Gl*	*Mn*	*Mna*	*Mn*	*Pc*	*Ur*
01	0	0	0	0	X	0	X	0	X
02	0	X	0	X	X	0	0	0	0
03	0	X	0	X	X	0	0	0	0
04	0	X	X	0	0	0	0	0	X
05	0	X	X	0	X	0	0	0	0
06	0	X	0	0	X	0	0	0	0
07	0	X	X	0	X	0	0	0	0
08	0	0	X	0	X	0	0	0	0
09	0	0	0	0	X	0	0	0	0
10	0	0	0	X	X	0	X	0	0
11	0	0	0	X	X	0	0	0	0
12	X	0	0	X	X	X	0	X	0
13	0	0	0	0	0	0	0	X	0
14	0	0	0	0	X	0	0	0	0
15	0	0	0	0	X	0	0	0	0
16	0	0	0	0	X	0	0	0	0

As = *Acomys spinosissimus*; Ch = *Crocidura hirta*; Cn = *Crocidura* cf. *nanilla*; Gl = *Gerbilliscus leucogaster*; Mn = *Mastomys natalensis*; Mna = *Micaelamys namaquensis*; Mm = *Mus minutoides*; Pc = *Paraxerus cepapi*; Ur = *Uranomys ruddi*.

b)

Area	Habitat description	Reason for choosing this area	
01	open grassland, surrounded by Elephant Grass; soft soil	Serval scats & sightings, many active small mammal holes	
02	riverbed, partly dry; riverine vegetation, open grassland & bushes	close to water, Serval scats	
03	reed and Elephant Grass; sandy soil	Serval scats & sightings, many active small mammal holes	
04	dry open grassland, dry hard soil	cross check	
05	dry open grassland with Elephant Grass	Serval scats & sightings	
06	dry open bushy grassland	Serval scats & sightings	

Area	Habitat description	Reason for choosing this area	
07	dry hard soil; sparse vegetation like herbs and some trees	cross check	
08	dry open grassland with trees and bushes	Serval scats & sightings	
09	open grassland, surrounded by Elephant Grass; soft soil; after bush fires	Serval scats & sightings	
10	Open grassland, with partly green gras and partly sandy soil	Serval scats & sightings	
11	reeds; soft sandy soil; riverbed close	Serval scats	
12	Mopane Forest, partly grass vegetation; very dry and hard soil	Serval scats	
13	Riverine Forest close to Luangwa River (still flowing); hard soil	cross check	
14	riverbed, partly dry; riverine vegetation; one side with grassland the other side with riverine forest vegetation	Serval sightings	
15	riverbed, partly dry; open grassland with Elephant Grass; hard soil	Serval scats & sightings	
16	open grassland after bush fires; green fresh grass; soil semi-dry	Serval scats	

2.3.3.2. Prey availability in Zambia

Throughout Zambia there are several prey types available for the Serval. Here only the small mammal species, which are occurring at the different study sites, are listed.

In 2003 a team of 'Greenforce Zambia' listed the animals of **Kafue National Park**. In Table 2.18, all possible prey items within the small mammals of Kafue National Park are given.

Also in **Kasanka National Park** a list of small mammals already exists (Tab. 2.19). This information was produced by the Kasanka Trust and its employees.

At **Kushiya Farm** or in the surrounding area, a small mammal survey has not been completed. As this area is a semi-agricultural country, there could be many Muridae species. Following the distribution maps of ANSELL (1978) there are 18 small mammals occurring (Tab. 2.20).

In the **Lower Zambezi National Park** there is no small mammal list available. But ANSELL (1978) stated that 10 species occur there and in 1998 COTTERILL did a survey in the Zambezi wetlands of Zimbabwe and additionally trapped another six species (Tab. 2.21).

Table 2.18: List of the 22 small mammals of Kafue National Park **(Source: Greenforce Zambia).**

Scientific name	Common name
Acomys spinosissimus	Spiny Mouse
Aethomys chrysophilus	Red Veld Rat
Micaelamys namaquensis	Namaqua Rock Mouse
Arvicanthis niloticus	Unstriped Grass Rat
Crocidura fuscomurina	Tiny Musk Shrew
Crocidura hirta	Lesser Red Musk Shrew
Cryptomys hottentotus	Common Molerat
Dendromus melanotis	Grey Climbing Mouse
Graphiurus murinus microtis	Woodland Dormouse
Lemniscomys (rosalia) griselda	Striped Mouse
Mastomys natalensis	Natal Multimammate Mouse
Mus indutus	Desert Pygmy Mouse
Mus minutoides	Pygmy Mouse
Paraxerus cepapi	Smith's Bush Squirrel
Pelomys fallax	Creek Groove-toothed Swamp Rat
Petrodromus tetradactylus	Four-toed Elephant Shrew
Saccostomus campestris	Pouched Mouse
Steatomys pratensis	Fat Mouse
Suncus lixus	Greater Dwarf Shrew
Suncus varilla	Lesser Dwarf Shrew
Gerbilliscus leucogaster	Bushveld Gerbil
Gerbilliscus valida	Tatera Gerbil

Table 2.19: List of the 23 small mammals of Kasanka National Park **(Source: Kasanka Trust).**

Scientific name	Common name
Acomys spinosissimus	Spiny Mouse
Aethomys spp.	Veld Rat
Arvicanthis niloticus	Unstriped Grass Rat
Crocidura gracilipes	Peter's Musk Shrew
Crocidura hirta	Lesser Red Musk Shrew
Cryptomys spp.	Molerat
Grammomys dolichurus	Woodland Mouse
Lepus saxatilis	Scrub Hare
Mastomys natalensis	Natal Multimammate Mouse
Mastomys denniae	Multimammate Mouse
Mus minutoides	Pygmy Mouse
Mus triton	Grey-bellied Pygmy Mouse
Dasymys incomptus	Water Rat
Rattus rattus	House Rat
Otomys angoniensis	Angoni Vlei Rat
Pelomys fallax	Creek Groove-toothed Swamp Rat
Petrodromus tetradactylus	Four-toed Elephant Shrew
Petrodromus brachyrynchus	Short-snouted Elephant Shrew
Steatomys pratensis	Fat Mouse
Cricetomys gambianus	Giant Rat
Heliosciurus gambianus	Gambian Sunsquirrel
Gerbilliscus spp.	Gerbil
Thryonomys swinderianus	Greater Cane Rat

Table 2.20: List of the 17small mammals of Kushiya Farm and surrounding area (Source: ANSELL 1978).

Scientific name	Common name
Acomys spinosissimus	Spiny Mouse
Aethomys chrysophilus	Red Veld Rat
Arvicanthis niloticus	Unstriped Grass Rat
Crocidura spp.	Musk Shrew
Cricetomys gambianus	Giant Rat
Cryptomys hottentotus	Common Molerat
Dendromus mystacalis	Chestnut Climbing Mouse
Gerbilliscus leucogaster	Bushveld Gerbil
Lemniscomys griselda	Griselda's Striped Grass Mouse
Mastomys natalensis	Natal Multimammate Mouse
Mus minutoides	Pygmy Mouse
Pelomys fallax	Creek Groove-toothed Swamp Rat
Saccostomus campestris	South African Pouched Mouse
Steatomys pratensis	Fat Mouse
Thallomys paedulcus	Acacia Rat
Thryonomys swinderianus	Greater Cane Rat
Rattus rattus	House Rat

Around **Lusaka** ANSELL's (1978) distribution maps of small mammals are again the only source of information on small mammals for the area. The following 10 species of small mammals are described for the Lusaka Area in Table 2.22.

For the **Luangwa Valley** the occurrence of the small mammals should be similar to that in Luambe National Park (Tab. 2.3).

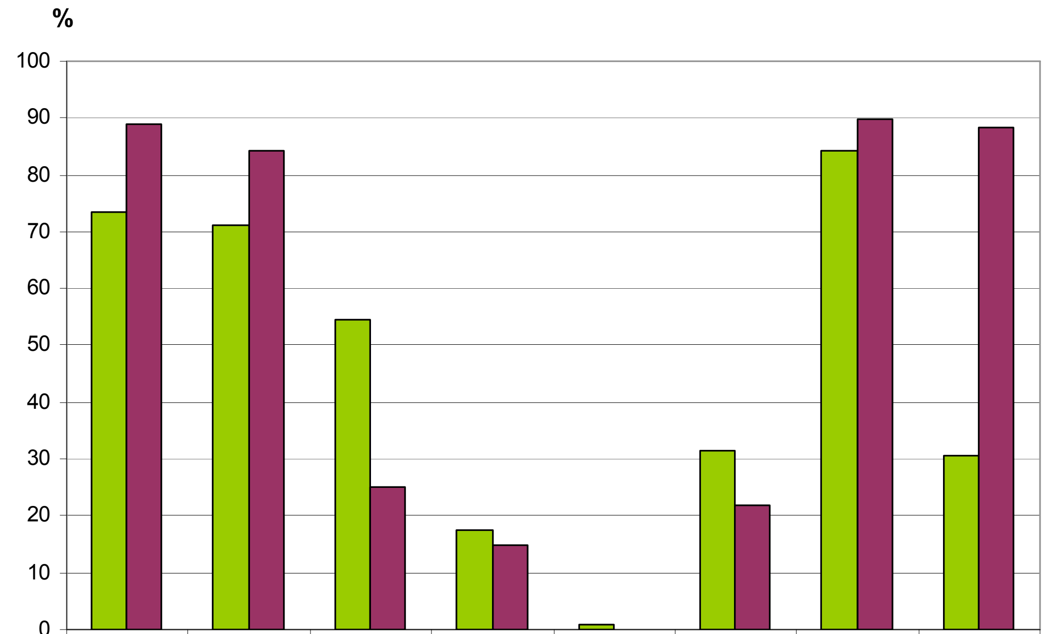
Table 2.21: List of the 16 small mammals of Lower Zambezi National Park. (Source: ANSELL 1978, COTTERILL 1998)

Scientific name	**Common name**
Aethomys chrysophilus	Red Veld Rat
Cryptomys damarensis	Damara Molerat
Cryptomys darling	Mashona Molerat
Dasymys incomtus	African Marsh Rat
Gerbilliscus leucogaster	Bushveld Gerbil
Graphiurus spp.	Dormouse
Lemniscomys griselda	Griselda's Striped Grass Mouse
Mastomys natalensis	Natal Multimammate Mouse
Mus minutoides	Pygmy Mouse
Paraxerus palliatus	Red Bush Squirrel
Pelomys fallax	Creek Groove-toothed Swamp Rat
Rattus rattus	House Rat
Petrodomus tetradactylus	Four-toed Elephant Shrew
Saccostomus campestris	South African Pouched Mouse
Thallomys paedulcus	Acacia Rat

Table 2.22: List of the 10 small mammals of Lusaka Area (Source: ANSELL 1978).

Scientific name	**Common name**
Acomys spinosissimus	Southern African Spiny Mouse
Aethomys kaiseri	Kaiser's Rock Rat
Aethomys chrysophilus	Red Veld Rat
Gerbilliscus leucogaster	Bushveld Gerbil
Graphiurus murinus	Woodland dormouse
Mastomys natalensis	Natal Multimammate Mouse
Lemniscomys griselda	Griselda's Striped Grass Mouse
Pelomys fallax	Creek Groove-toothed Swamp Rat
Rattus rattus	House Rat
Saccostomus campestris	Pouched Mouse

Compared with the extensive study in LNP, this faecal sample collection can give us only an idea of the Servals' diet in Zambia. There is no difference in the frequencies of occurrence of the different digested items found in Serval scats in LNP compared to the other areas within Zambia. There is no significant difference in the two data sets (t=0.353, df=14, p=0.73), as well as in the values of all prey items (Teeth of small mammals, Birds, Reptiles, Arthropods, and Amphibians) between the two study areas (t=-0.119, df= 10,p =0.907). The largest difference between results from LNP and the other eight locations, is the frequency of occurrence of 54.6% for the group 'birds', compared to an FO of 25% in LNP (Fig. 2.44). Within the reptiles, the Serpentes and Scincidae groups are the main prey, followed by the Gekkonidae, as found in LNP. Only the Serpentes and the Scincidae occur in all eight different locations, and Gekkonidae, Agamidae and Crocodylidae were consumed only at same locations. The same was the case with the birds; the Ploceinae and the Numidae are the main bird prey, with an occurrence in seven out of eight locations followed by the Centropodidae in five out of eight locations. In all eight locations, ground dweller birds, such as *Francolinus* spp., *Numida meleagris*, Galliformes spp., *Coturnix* spp. or *Turnix* spp. have the highest value of frequency of occurrence. Within the group of small mammals, there were remnants of *Mastomys natalensis* and *Gerbilliscus leucogaster* found in all eight locations. In seven out of eight areas *Pelomys fallax* was consumed by Servals, as well as various *Crocidura* spp.. Therefore it appears that Servals do not reject shrews as part of their diet in general (giving a mean FO = 15% and a PO = 10% out of all small mammals). Compared to LNP, the mean values of consumed Scorimorpha are 4 times and 10 times (PO) higher.



	Teeth of small mammals	Hair of small mammals	Birds	Reptiles	Amphibians	Arthropods	Grass	Parasites
Zambia wide	73.55	71.07	54.55	17.36	0.83	31.40	84.30	30.58
Luambe NP	88.89	84.26	25.00	14.81		21.76	89.81	88.43

Figure 2.44: Comparison of digested item frequency of occurrence between Luambe NP and the eight additional study areas in Zambia.

2.3.4. Activity patterns of Servals in Luambe National Park

In Luambe National Park Servals could be observed for an extended periods of time, allowing to study their activity patterns (Fig. 2.45). Observation success was 68 observation of different length (only seconds up to two hours) within 1200 hours of search time, which is a success rate of 1.47% (one sighting every 17.5 hours). In Figure 2.45 the time of sunrise and sunset is marked with yellow boxes. Within the months of the study times of sunrise and sunset changed with the seasons. The Serval's behaviour follows a crepuscular/nocturnal pattern. They are especially active during the first hours after sunset up to midnight. After midnight there is reduced activity up to the early mornings (before 10 o'clock). Between 10:00 and 18:00 no Serval was found to be active. Observations are biased towards active animals, as resting Servals lie down in high grass, in burrows or other hidden places, which reduces the chances to spot them. Figure 2.48 shows the number of observed animals with the number of active Servals. In only one out of 68 observations, an inactive/resting Serval was spotted. The Servals in other parts of Zambia seemed to be equally active during the night and around dusk and dawn (own observations).

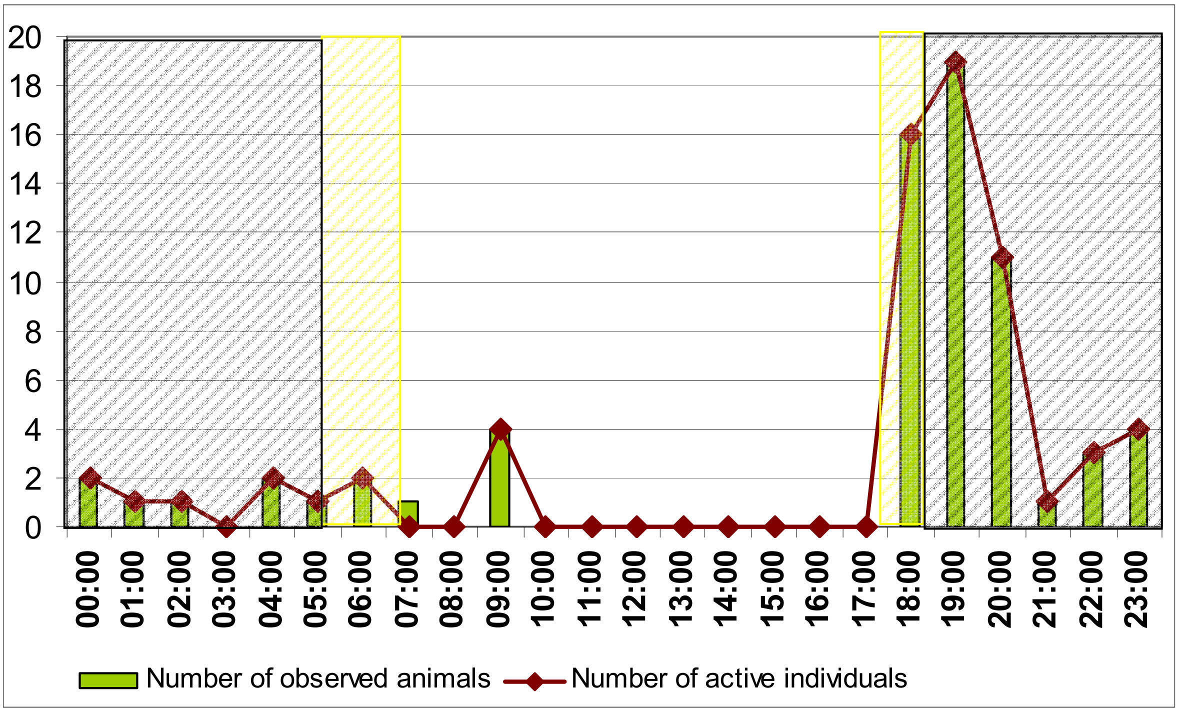


Figure 2.45: Activity pattern of the Servals in Luambe National Park.
(Black markings = night; yellow markings = dusk/dawn)

2.4. Discussion

The study of faeces of terrestrial mammals helps to obtain biological and ecological data such as the species presence, diet, behaviour, territory, parasitic fauna, and home-range use, which can be applied to conservation projects (CHAME 2003). As a non-invasive method, it provides researchers with useful details, especially if they track one of the threatened, rare, evasive or nocturnal animals. Tracking reveals information about the studied animals without any influence by the observer (WEMMER et al. 1996). Tracking is probably the oldest scientific method to gain information on presence or absence of certain species (LIEBENBERG 1990).

Although it requires observers who are well trained, its low cost and accessible technology make tracking a feasible choice for field studies (DAVISON et al. 2002, CHAME 2003). Faeces are the most evident and easily recognizable sign (LIEBENBERG 2000). Faeces are used as strategic sensorial marks by all Carnivora species except Hyaenidae (GORMAN & TROWBRIDGE 1989, ESTES 1999).They are used as territorial marks when deposited in small volumes in prominent places, such as trail junctions, rocks, trunks, or termite nests.

DAVISON et al. (2002) proved in their study that even well trained observers fail to distinguish scats of sympatric living carnivores, leading to the conclusion that a multi-evidence approach is needed when monitoring elusive animals, involving DNA methods, cast hair identification, camera traps and questionnaires. For this study guard hair analyses, camera traps and questionnaires of local scouts were used to confirm the presence of Servals and helped to give additional evidence for the origins of the faecal samples.

Hair analysis has been proved to be a useful tool to identify faecal samples, in addition to morphometric data and DNA analyses (SAUNDERS 1963, MIOTTO et al. 2007b, GRAEFF et al. 2008). This is because hair keeps its structure (DAY 1966; BRUNNER & COMAN 1974) despite the digesting acid (unlike feathers or bones), which is the prerequisite for successful determination of species (BRUNNER & COMAN 1974). But this method depends on the examiner’s talent and training. It also requires guard hairs that are well formed and complete, for a successful application (GRAEFF 2008). In addition, there are two types of guard hairs, the primary and secondary hairs (TEERINK 1991). The latter type displays a somewhat homogeneous hair cuticle pattern throughout the hair shaft in all mammalian groups (MEYER, SCHNAPPER & HÜLMANN 2002). When used to make a distinction between the Felidae and other carnivore families these are useful (HARRISON 2002). The medulla is similar among all felid species (QUADROS 2002) and so it is difficult to determine the cat species by only medulla pattern. For this reason large (>2.4 cm in diameter) and small (<1.7 cm in diameter) faecal samples were sorted out right away. Based on faeces size there is no other species to be confused with the Serval scats, except the caracal in some places like Kafue National Park, Kasanka National Park and North Luangwa National Park. As this species is even rarer than the Serval this bias should be minimal. Altogether, the method of guard hair analyses proofed to be an adequate and reliable tool for identification of Serval faeces.

BOWLAND (1990) found that after the 50th scat sample no new prey species could be determined in the faeces samples, hence she determined her 90 samples to be an adequate representation of serval diet on farmland. TRITES & JOY (2005) stated that 59 samples are needed to identify principle prey remains, even 94 samples when comparing over time or between areas. In this study only after 88 analysed scat samples no new prey species were found, if the samples were collected within a single year. When samples of all three years were pooled together, the sample size to find the principle prey remains nearly doubled (174 samples). BOWLAND (1990) did not identify insects and reptiles down to species level so that her calculation of a minimum samples size may have been biased by inaccurate identification of all remains. This thesis has sample sizes that are large enough to adequately represent the Servals' diet in LNP. Sampling sizes from other areas are too small and thus do not reflect the whole spectrum of prey diversity, but give an idea of the Servals' diet in a variety of areas in Zambia.

Numerous studies do not use a correction factor for prey less than 2 kg as they argue that the small prey is digested with the first, and larger with the second scat, so overestimation is not likely (ACKERMAN et al. 1984, KARANTH & SUNQUIST 1995, HART et al. 1996, HENSCHEL 2002, STOMMEL 2009). BOWLAND & PERRIN (1993) think that Serval scat is suitable for an examination of frequency of occurrence and percentage occurrence without bias from different prey types and their digestibility as they mainly prey on small vertebrates. The percentage ingested is an indication of the importance of a prey type (BOWLAND & PERRIN 1993). Digestibility of prey is however, influenced by the physiological state of the predator (BOWLAND 1990). BOWLAND (1990) stated that a correction factor is not necessary if the majority of prey falls in one order. This is the case with the Serval, having a FO value of 88% to 98% of its diet made up of small mammals (mostly rodents).

In this study the remains of teeth and jaws of small mammals were used as the real number for the frequency of occurrence and percentage occurrence for this prey type. BOWLAND & BOWLAND (1991) found that teeth passed through the Servals' digestion tract within one scat, while hairs of one prey individual only passed within the next 7 scats (with an average of 4.2 days). Hence, if counting faecal samples with only small mammal hair in it, there is a high possibility of overestimation. GEERTSEMA (1985) based her small mammal identification on teeth and jaws. Therefore, if the frequency of occurrence of small mammals is corrected to faecal samples with teeth only, the percentage drops from 98.2% to 94.64%. BOWLAND

(1990) des not make a distinction between small mammal evidence as 'hair' or 'teeth', so it is possible that the frequency of occurrence for her data would be different when only tooth remains are used as conclusive evidence of consumed small mammals. SMITHERS (1978) examined stomach contents and found that rodents were cut up into five or six pieces by the teeth of the Servals, so that identification was fairly easy and the frequency of occurrence of 95 % may not be biased. But BOWLAND & BOWLAND (1991) also stated that recovery of teeth consumed was low (x = 23.7%, SD = 19.2), meaning that the already high frequency of occurrence of 88.89% of small mammals within the Servals' diet in LNP might be an underestimation, as it was based on tooth identification. If faecal samples with hairs and/or teeth are combined, a value of 97.22% as frequency of occurrence is obtained. This value is closer to the results of SMITHERS (1978), GEERTSEMA (1985) and BOWLAND (1990).

Unclassified samples were often not considered in other studies (GEERTSEMA 1985, BOWLAND 1990) but in this study they were treated as positive samples. There was no significant difference in the results between these two groups, so this method was applicable to this study. The faecal samples of the group classified as 'unclassified' showed more remains of birds, arthropods and reptiles (Fig. 2.15), and in contrast they contained fewer hair of small mammals. Hair gives the faeces their compactness, hence, the unclassified scats are less compact and fall apart easily, and so it is difficult to find any guard hair of the Serval or any predator to identify the origin of these samples. Unclassified samples were often older scat samples which were lying unprotected from weather and sun. REYNOLDS & AEBISCHER (1991) did not find any effect of weathering on scat composition, so these older unclassified samples are still valid to be used as additional samples.

2.4.1. The Servals' diet

Frequency of occurrence provides an indication of how common an item is in the diet, but percentage occurrence also takes into account the presence of multiple prey items in individual scats.

DIJK et al. (2007) stated that percentage occurrence is the most appropriate method for wolverine diet studies, due to the extreme variation in prey items. They also stated that frequency of occurrence should still be included in the studies for comparability to other studies. The FO also gave a very good estimation of the actual diet provided in their trials (DIJK et al. 2007). ACKERMAN et al. (1984) also considered percentage occurrence to provide a better indication of the relative frequency with which each item is consumed, however, this method can over-represent minor items and under-represent major ones (LOCKIE 1959, WISE et al. 1981, CORBETT 1989, MEDINA 1997). Both indices were therefore used to describe dietary composition in order to minimize misinterpretation, and to make these results comparable with other descriptions of carnivore diet (REYNOLDS & AEBISCHER 1991). For the group ‘birds’ and ‘small mammals’ the estimated biomass consumed was added to include another index for that main prey group. Care must be taken when comparing results of values of frequency of occurrence and percentage occurrence. Some authors interpret their meanings differently and use the phrases interchangeable. Also some studies calculate the percentage occurrence for all prey items, but only count the minimum numbers of prey of the large prey items. Therefore, the percentage occurrence becomes biased and should only be used within the groups where the minimum number can be determined accurately. Figure 2.46 shows all available data for frequency of occurrence of Servals’ prey categories. It reveals that Servals feed mainly on mammals. The results in Chapter 2.3 indicate that this category of ‘mammals’ is represented by small mammals below 2 kg. The frequency of occurrence values vary between 88.9% in Zambia and 98.2% in Tanzania. Birds are consumed with a frequency of occurrence between 17% in Zimbabwe and 25% in Zambia. Especially snakes (also poisonous ones) seem to be one of the main reptilian prey items (GEERTSEMA 1985, SMITHERS 1989, and http://carnivoraforum.com/index.cgi?board=feline &action=print&thread=3271; 12. 2010). Reptiles and arthropods are consumed nearly equally often, depending on the area. The reptile consumption varies between 4.4% in South Africa and 14.8% in Zambia, while the arthropod consumption varies between 3.3% in South Africa and 21.8% in Zambia.

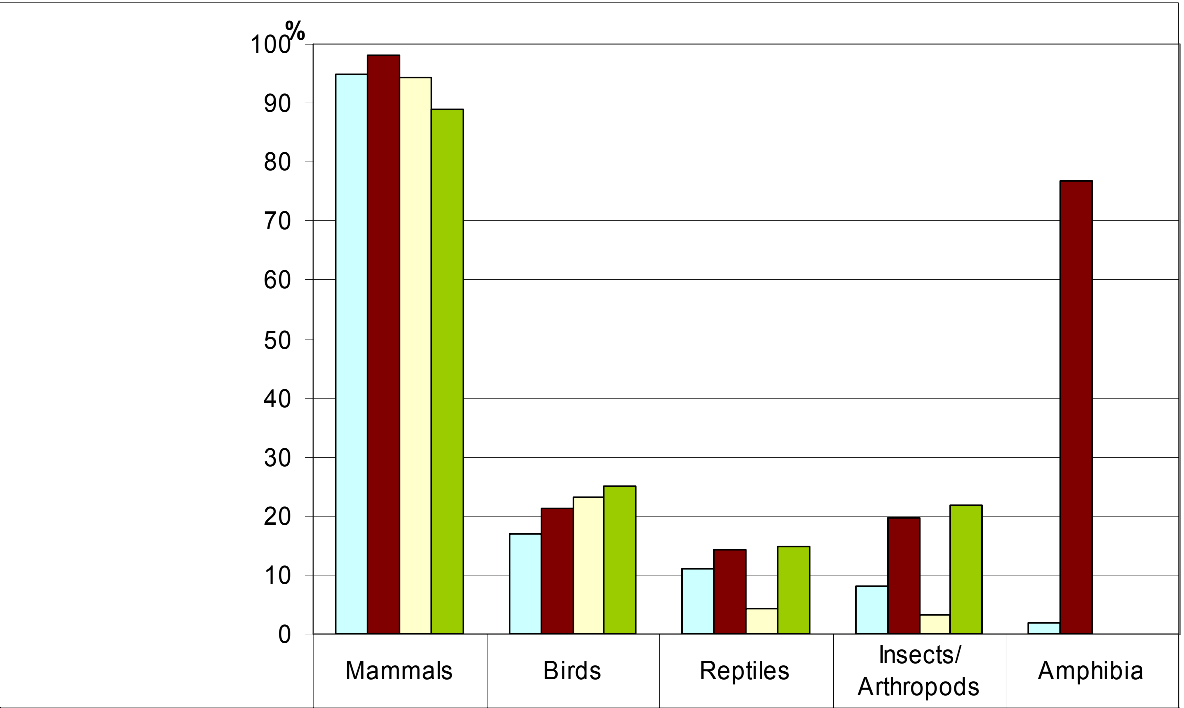
Only in the study of GEERTSEMA (1985) amphibians have an equally important dietary role as small mammals. This is explained mainly by the swampy habitat in which her study took place. GEERTSEMA (1976 & 1985) and SMITHERS (1978) note the Serval’s ability to stand in water of 30 cm depth and to hunt there for several hours. If present, frogs can be caught in relatively large numbers with minimum effort. In Zambia, I could not obtain enough samples during the rainy season to prove the presence of frogs in the Serval’s diet in Luambe National Park. There is one sample with evidence of amphibian prey in Kafue National Park, where water was still plentiful and several lagoons were still filled with water.

To be able to compare data from previous studies on Serval diet, these data were recalculated and combined with data from this study. Results are given in Figure 2.47. Servals feed mainly on mammals (as shown with the high percentage in Figure 2.46), but other prey items are also clearly important. In the Ngorogoro Crater (GEERTSEMA 1985) amphibians are one of the main prey items due to the previously discussed habitat of the Crater. SMITHERS (1978) and BOWLAND (1990) found a low percentage of birds and reptiles and more than 70% consist of small mammals. This can be explained by the fact that both studies were conducted on semi-agricultural land in South Africa and Zimbabwe, which biased the studies towards the Muridae, which are highly abundant in these habitats. In this study 41% of all prey items consist of animals other than small mammals. The present study was based in a National Park, which is a more "natural" habitat for the Serval. Here the Servals have a higher diversity of prey choice.

The Servals in Zambia also feed in large amounts on arthropods/insects (FO=21.8%, and 31.4% respectively) (Fig. 2.46 & 2.39). This prey does not appear to contribute much to the biomass intake, but definitely plays a role in the Servals' diet. Some arthropods might have got stuck in fresh Serval faeces and died there before collection, however, records such as the high amount of ants found in some samples cannot be explained by this, as most of the ants were found within the faeces and the majority were in pieces which can lead to the conclusion that they must have past through the digestive tract. Another explanation could be that Servals fed on carcasses which had the ants already on them. But Servals are not known to be scavengers, as this study and other studies do not have any indication on that. Also GEERTSEMA (1985) states that even after 1300 hours of observation time "it occurs rarely and mostly due to accidental if not exceptional circumstance" (two times for only some scraps and little bites of the entrails), so that this explanation also does not fully explain the high amount of ants found in Serval scats. The high percentage of Orthoptera and Coleoptera within the arthropods could be due to the larger size of these taxa and most remains came from individuals at least 5 cm in size. Jumping and flying insects could be important targets for playing behaviour and then be consumed (LEYHAUSEN 1979).

Grass was found in the faecal samples in all areas in Zambia. In LNP 90% of the faecal samples contained grass. In the other eight areas, the frequency of occurrence of grass was between 88% and 66%, with a mean of 83%. Other cats also feed on grass (LEYHAUSEN 1979). In the SMITHERS (1978) study, 11% of the scat samples consisted of grass, GEERTSEMA (1985) found a larger value of 55% and in BOWLAND's (1990) study nearly all samples showed evidence of grass remains. Grass does not have any food value but it is a mechanical aid for the digestive system (SMITHERS 1978, GEERTSEMA 1985)

In Table 2.23 all published prey taxa of Servals are listed. Some prey taxa seem to be common in the Servals' diet; some seem to be correlated to the location and habitat. New prey types were found in this study not recorded previously as part of the Serval's diet (Table 2.23).



	Mammals	Birds	Reptiles	Insects/ Arthropods	Amphibia
Smithers 1978 (N=65)	95	17	11	8	2
Geertsema 1985 (N=56)	98.2	21.4	14.3	19.6	76.8
Bowland 1990 (N=90)	94.4	23.3	4.4	3.3	0
Thiel (N=216)	88.89	25	14.81	21.76	0

Figure 2.46: Comparison of frequency of occurrence values of the main prey categories between studies on Serval diet.

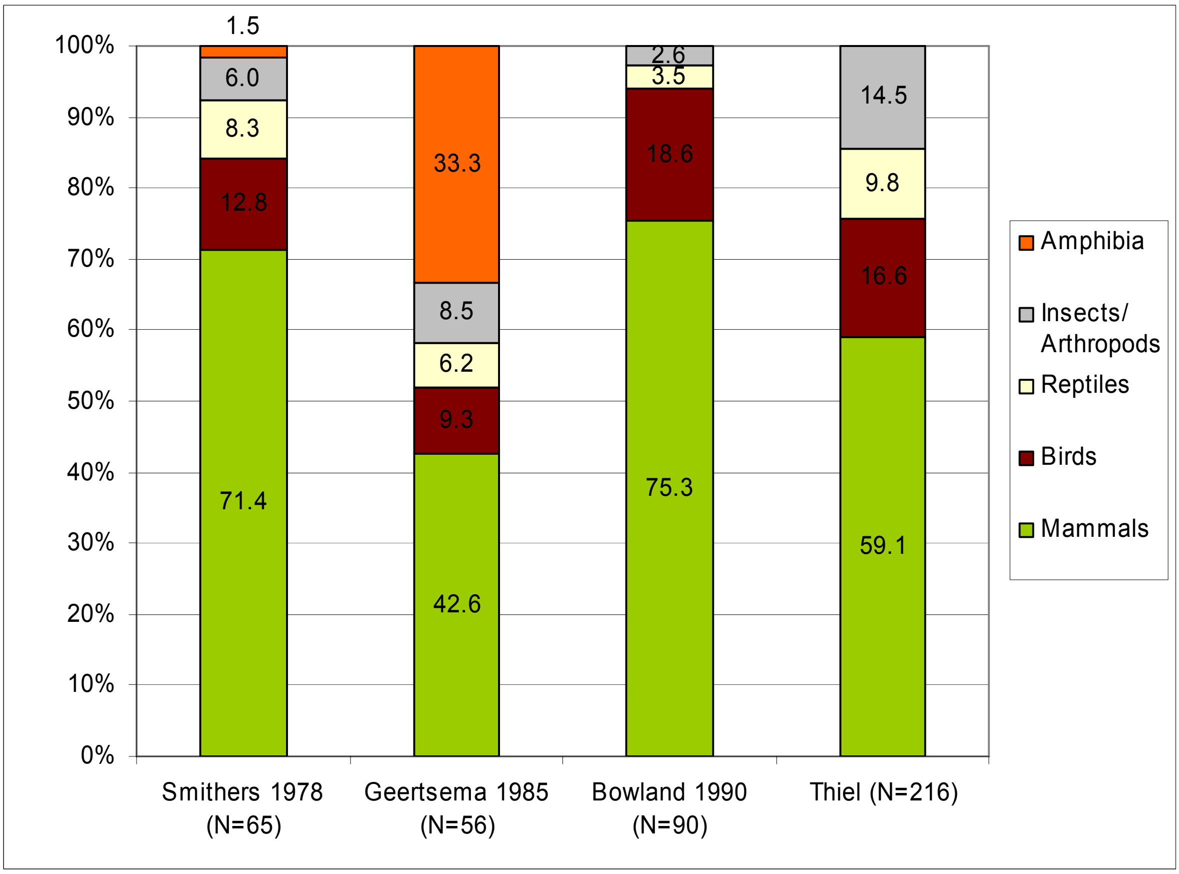


Figure 2.47: Comparison of prey item composition between studies on Serval diet.

Table 2.23: List of prey types and comparison of their occurrences found in serval scat, stomach contents or due to direct observations (red colour = new proof of prey type).

Type of prey Scientific name	Common name	**Authors,** who mentioned the type of prey	**Smithers 1978 (N=65)**	**Geertsema 1985 (N=56)**		**Bowland 1990 (N=90)**		**This study (different N)**	
			FO	**FO**	**PO**	**FO**	**PO**	**FO**	**PO**
Mammals									
Acomys spinosissimus	Southern African Spiny Mouse	This study						5.09	1.13
Aepycerus melampus	Impala	Pienaar 1969							
Aethomys chrysophilus	Red Rock Rat	Smithers 1978	3						
Amblysomus hottentotus	Hottentot Golden Mole	Bowland 1990				4.4	0.9		
Arvicanthis niloticus	Nile Grass Rat	York 1973. Geertsema 1985			10.80				
Arvicanthis spp.	Kusu Rats/ Grass Rats	Kingdon 1977. Stott 1980							
Cephalophus spp.	Duiker	Pienaar 1969							
Cricetomys spp.	Giant Pouched Rats	York 1973. Rosevear 1974. This study						10.00	8.33
Crocidura allex	East African Highland Shrew	York 1973							
Crocidura cf nanilla	Tiny white-toothed shrew	This study						5.00	3.00
Crocidura flavenscens	Greater Red Musk Shrew	York 1973							
Crocidura hirta	Lesser Red Musk Shrew	Smithers & Wilson 1979. This study						1.85	0.35
Crocidura spp.	Musk shrews	Smithers 1978. Geertsema 1985. This study	5		5.60			13.8	15.3
Cryptomys hottentotus	African Mole Rat	Bowland 1990				10	2.1		
Fukomys (Cryptomys) spp.	Mole Rats	Kingdon 1977. York 1973. This study						5	2.78
Dasymys incomptus	African Marsh Rat	Smithers 1978. Bowland 1990	2			10	2.3		
Dendrohyrax arboreus	Southern Tree Hyrax	Fitzsimons 1919							
Dendromus melanotis	Gray Climbing Mouse	Bowland 1990				3.3	0.7		
Dendromus mystacalis	Chestnut African Climbing Mouse	Smithers 1978. This study	3					0.93	0.17
Elephantulus spp.	Elephant Shrew	This study						5.00	2.78
Gazella thomsonii	Thomson Gazelle	York 1973							
Gerbilliscus (Tatera) brantsii	Highveld Gerbil	Bowland 1990				2.2	0.5		
Gerbilliscus (Tatera) leucogaster	Bushveld Gerbil	Smithers 1978. Smithers & Wilson 1979. This study	3					21.30	6.01

Grammomys (Tamnomys) dolichurus	Woodland mouse/ Woodland thicket rat	Hoffmann 1987							
Heliosciurus gambianus	Gambian Sun Squirrel	This study						4.55	1.41
Lemniscomys griselda	Griselda's Striped Grass Mouse	This study						0.93	0.17
Lemniscomys spp.	Striped Grass Mice	Watson 1950. This study							
Lepus capensis	Cape Hare	York 1973. Rosevear 1974							
Lepus saxatilis	Scrub Hare	Smithers 1978	3						
Mastomys (Praomys) natalensis	Natal Multimammate Mouse	York 1973. Smithers 1978. Geertsema 1985. Bowland 1990. This study	48		6.10	13.3	4.6	70.37	53.40
Mastomys spp.	Multimammate Mouse	This study						1.85	0.44
Micaelamys namaquensis	Namaqua Rock Rat	This study						3.24	0.87
Mus minutoides	African Pygmy Mouse	York 1973. Smithers 1978. Geertsema 1985. Bowland 1990. This study	3		18.50	5.6	1.4	4.63	0.87
Mus spp.	Old World Mice	Smithers 1971. This study						0.93	0.17
Myosorex varius	Forest Shrew	Bowland 1990				41.1	12.6		
Oreotragus oreotragus	Klipspringer	Smithers & Wilson 1979							
Otomys angoniensis	Angoni Vlei Rat	York 1983. Smithers 1978. Geertsema 1985	48		42.60				
Otomys irroratus	Southern African Vlei Rat	Rowe-Rowe 1978. Bowland 1990				94.4	35.6		
Ourebia ourebi	Oribi	Verheyen 1951							
Paraxerus cepapi	Smith's Bush Squirrel	This study						0.46	0.09
Pedetes capensis	South African Spring Hare	York 1973							
Pelomys fallax	Creek Groove-toothed Swamp Rat	Smithers 1978. Geertsema 1985. This study	3		7.20			43.06	19.69
Petrodromus tetradactylus	Four-toed Elephant Shrew	This study						0.46	0.09
Raphicerus campestris	Steenbok	Pienaar 1969							
Rattus rattus	House Rat	Smithers 1978	5						
Rhabdomys pumilio	Four-striped Grass Mouse	Smithers 1978. Geertsema 1985. Bowland 1990	2		5.10	75.6	30.7		
Saccostomus campestris	Pouched Mouse	Smithers 1978. This study	5					0.93	0.17
Saccostomus spp.	Pouched Mice	This study						2.31	0.44
Soricidae spp.	Shrews	Smithers & Wilson 1979							

Steatomys pratensis	Fat Mouse	Smithers 1971. This study						5.56	1.92
Steatomys spp.	Fat Mice	This study						0.93	0.17
Suncus varilla	Lesser Dwarf Shrew	This study						0.93	0.17
Tachyoryctes splendens	East African Mole Rat	York 1973. Geertsema 1985			0.10				
Thryonomys spp.	Cane Rats	Rahm & Christiaensen 1969. Rosevaer 1974. Kingdon 1977							
Thryonomys swinderianus	Greater Cane Rat	Smithers 1978	2						
Uranomys ruddi	Rudd's Bristle-furred Rat	This study						9.26	1.92
Xerus erythropus	Striped Ground Squirrel	Kingdon 1977							
Xerus inauris	Cape Ground Squirrel	York 1973							
Birds									
Alaudidae/Motacillidae (Alandidae/Montacillidae)	Larks/ Pipits	York 1973. Bowland 1990				3.33			
Anas spp.	Teal	York 1973. Geertsema 1985		1.79					
Anthus spp.	Pipits	York 1973							
Apalis spp.	Apalis	This study						0.46	1.49
Apus spp.	Swifts	This study						5.00	12.50
Balearica regulorum	Crowned Crane	This study						0.46	0.75
Caprimulgus spp.	Nightjars	This study						0.93	1.49
Centropus cupreicaudus	Coppery tailed Coucal	This study						4.76	5.00
Centropus grillii	Black Coucal	This study						0.93	1.49
Centropus spp.	Coucals	This study						6.48	10.45
Centropus superciliosus	Whitebrowed Coucal	This study						5.00	12.50
Cisticola spp.	Cisticolas	Bowland 1990				2.22			
Coraciiformes	Rollerlike Birds	This study					.	4.55	3.45
Corythaixoides concolor	Grey Lourie	This study						0.46	0.75
Coturnix delegorguei	Harlequin Quail	York 1973. Geertsema 1985		1.79					
Coturnix spp.	Quails	Kingdon 1977. This study						1.39	2.99
Estrilda astrild	Common Waxbill	Bowland 1990. This study				1.11		0.93	1.49
Estrilda spp.	Waxbills	Smithers & Wilson 1979. This study						0.93	1.49
Euplectes spp.	Bishops & Widowbirds	Smithers 1983. Bowland 1990				1.11			
Eupodotis melanogaster	Korhaans	York 1973							
Falconidae spp.	Falcons	This study						0.46	0.75

Francolinus (Pternistes) spp.	Francolins	Kingdon 1977. York 1973. Thiel						4.00	4.00
Galliformes	Game birds	Rowe-Rowe 1978. Rahm & Christiaensen 1963. This study						5.00	4.00
Gallus gallus	Domestic Chicken	Rahm & Christiaensen 1963. Smithers 1971 & 1979. Rosevear 1974. Fitzsimons 1919							
Lamprotornis spp.	Starlings	This study						4.55	3.45
Numida meleagris	Helmeted Guineafowl	This study						5.09	8.96
Numididae spp.	Guineafowls	Kingdon 1977							
Ortygospiza atricollis	Quail Finch	This study						4.76	12.50
Ortygospiza spp.	Quailfinches	Bowland 1990				1.11			
Oscines spp.	Songbirds	This study						2.78	4.48
Otididae spp.	Bustards/Korhaans	Verheyen 1951							
Phoenicopterus minor	Lesser Flamingo	York 1973. Geertsema 1985		1.79					
Ploceidae	Weavers	Smithers 1978. This study	6.50					11.11	49.25
Prinia subflava	Tawnyflanked Prinia	This study						4.76	5.00
Quelea quelea	*Red-billed Quelea*	Smithers 1978. Bowland 1990; This study	1.54	1.79				9.72	47.01
Sarothrura spp.	Flufftails	Bowland 1990				6.67			
Serinus flaviventris	Yellow Canary	This study						3.13	4.35
Turdus spp.	Thrushes	This study						0.46	0.75
Turnix spp.	Buttonquails	This study						1.39	2.99
Tyto alba	Barn Owl	This study						4.55	3.45
Tyto spec	Owls	This study						4.55	3.45
Vidua spp.	Widowfinches	This study						3.13	4.35
Reptiles									
Agamidae	Agamas	York 1973. Geertsema 1976. This study						0.46	3.12
Chameleo dilepis	Flap-necked chameleon	Smithers 1978	1.5						
Crocodylidae	Crocodile	This study						3.13	12.5
Crotaphopeltis hotamboeia	Herald Snake	Smithers 1978	1.5						
Gekkonidae	Gekkos	This study						1.85	12.5
Gerrhosaurus flavigularis	Yellow-throated Plated Lizard	Smithers 1983							
Ichnotropis spp.	Rough-scaled Lizards	This study						0.93	6.35

Lacertidae	Wall Lizards	This study						1.85	12.5
Naja haje	Egyptian Cobra	Smithers 1978	1.5						
Naja mozambiqua	Mozambique Spitting Cobra	Smithers & Wilson 1979							
Riopa opisthorhodum (sundevallii)	Fire Skink	Smithers 1983							
Scincidae	Skinks	This study						4.63	31.25
Serpentes	Snakes	Geertsema 1985. This study						6.02	40.63
Trachylepis spp.	Striped Skink	This study						4.76	11.1
Trachylepis (Mabuya) striata	African Striped Skink	Smithers 1978	1.5						
Amphibians & Fishes									
Anura	Frogs	Geertsema 1985		76.8					
Microhylidae	Microhylid Frogs	This study						5.88	
Pyxicephalus adspersus	African Bullfrog	Smithers 1983							
Pisces		Smithers 1971							
Arthropods									
Arachnidae	Spiders	Smithers 1971							
Carabidae	Ground Beetles	This study						3.24	
Chrysomelidae	Leaf Beetles	This study						5.88	
Coleoptera	Beetles	Pienaar 1969. Smithers 1971. Geertsema 1985. This study						3.24	
Formicidae	Ants	This study						12.50	
Isoptera	Termites	Kingdon 1977. This study						4.76	
Orthoptera	Grasshoppers	York 1973. Kingdon 1977. Smithers & Wilson 1979. Geertsema 1985. Bowland 1990. This study						2.31	
Scarabeidae	Scarab Beetles	This study						2.78	
Silphidae	Carrion Beetles	This study						0.46	
Solifugae	Solifuges	Smithers 1971							
Tenebrionidae	Darkling Beetles	This study						3.13	
Decapoda	Decapod	This study						4.76	
Scorpiones	Scorpions	This study						0.46	

2.4.1.1. Diet in Luambe National Park

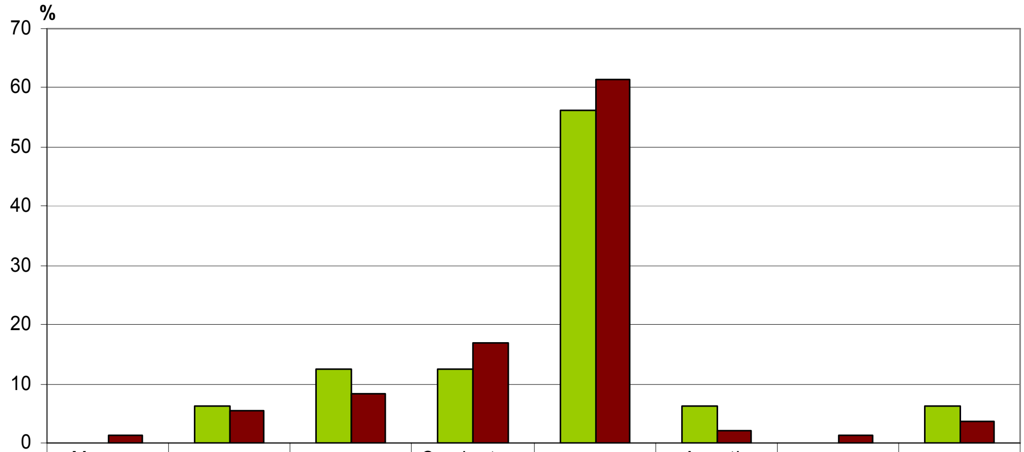
As described by other authors (GEERTSEMA 1985, SKINNER & SMITHERS 1990, SKINNER & CHIMIMBA 2005) also this study found nearly a third of all scat (32.3%) on roads or game paths. Often, several scats of different ages were found lying in one row along the road or path. This could be an indication of using faeces to mark territories. It is possible that roads function as territorial boundaries and therefore may be marked more often than other places. In addition, it might be easier to spot faces on roads and paths than in more vegetated areas, so that there is a possible observer error for the other scat deposition places. As BULINSKI & MCARTHUR (2000) point out, the probability of overlooking a scat is positively related to vegetation height while it is negatively related to vegetation cover. More detailed home range analysis in future is needed to confirm these hypotheses.

The mean diameter of the scats in LNP is larger than that of faecal samples in other areas of Zambia. This could be explained by Servals feeding more on small mammals here than in the other Zambian areas (FO of 88.9% compared to 73.5% respectively). From personal observations, the presence of more hair of small mammals results in a more compact scat, held together by the hairs. Bird feathers and reptile skin appear to loosen the scat so it falls apart more easily and its shape is not as defined as when more mammal hairs are present. Measurements of compact scats are more precise and the shape is not altered by time and transport methods. Zambia-wide, Serval scats contained small mammal hair in 71% of scats and in LNP in 84%.

Reptiles were consumed in LNP with a frequency of occurrence of 14.8%, with Serpentes being the most frequent group, followed by the Scincidae. Gekkonidae and Lacertidae were less frequently and only one Agama was found. Snakes are killed by repeated slap-type strokes by the front paw (GEERTSEMA 1985, citing EWER 1973). Looking at the activity pattern of these main reptilian prey species, the Scincidae, Lacertidae and Serpentes are more diurnal than the Gekkonidae. This does not fit in with the activity patterns of the Servals in LNP. The only time there is an overlap of activity period is the time around dusk. During this time snakes are especially active in search of a sleeping place for the night. In the morning hours, when the sun has not risen high yet and temperatures are low, reptiles tend to be slower than during the day. That may be a good time for Servals to prey on them.

The most important bird species for Servals in LNP are *Numida meleagris*, *Centropus* spp. and *Quelea quelea*. Like in the reptile species, most of the birds the Servals of LNP are feeding on are diurnal (Table 2.26), but most of them are associated with grassland, vlei or water associated vegetation, which is also the preferred habitat for the Servals (SMITHERS 1978, GEERTSEMA 1985, own observation). Some of these taxa also rest in tall grass during the night, like the Coucals *Centropus* spp. or the weavers. These birds occur more often in the Servals' diet, with both a high frequency of occurrence and with a high percentage occurrence. The high percentage occurrence in comparison to the frequency occurrence of the *Quelea quelea* and the negative correlation between the mean number of consumed items and the biomass (Fig. 2.26) indicate that Servals tend to prey on flocking species. The Servals of LNP seem to consume higher amounts of small birds, like the Oscines and Estrildinae, than on bigger birds, but *Numida meleagris* is a larger species frequently preyed on. *Numida meleagris* is diurnal and roosts high up in trees at night. The best time to hunt these animals would be at dawn and dusk, on their way from and to the trees. Behaviour of Servals hunting Galliformes seems to be different from hunting behaviour on other birds, as the prey is bigger and ground dwelling. As BOWLAND (1990) stated "Flufftails are ground dwellers and easy to catch and nocturnal"; therefore they are easy prey for the Serval and the Galliformes in LNP make an easy catch for Servals, too. Although *Coturnix spp.* is mostly active at twilight and at night, which fits the Servals' activity patterns, there is only little evidence of *Coturnix spp.* in the faecal samples. Strictly nocturnal birds, like the Nightjars, have also not been found in high percentages in the Servals' diet. The reason for this may be the Servals' dependence on its sense of hearing when hunting; Nightjars often sit stock-still at night without moving. During the day the Serval is able to complement its sense of hearing with its excellent vision.

Presence/absence estimations of small mammals were undertaken to identify the Servals' possible prey spectrum and to compare it to their actual one. In Figure 2.48 the scat finding and trap locations within the main habitat types of LNP (after ANDERSON 2009) are compared. The majority of all faecal samples were found in Grassland, followed by Combretum Terminalia Woodland and Riverine Woodland and so trapping areas were chosen in these three categories. Of the nine trapped species of small mammals, eight were confirmed as being part of the Servals' prey spectrum in LNP (Table 2.24). One species could not be confirmed and in addition 7 more species and 3 unknown species out of the same genera (Table 2.24) were identified as part of the prey spectrum. This shows that the trapping method used (trap types and locations) was not completely successful in finding all small mammal species in the Servals' prey spectrum, only capturing about 50% of it. This bias was also found in other studies, as in BRUNNER et al. (1975). Therefore, it is very important to have sufficient faecal samples to identify the Servals' diet and to compare with trapping studies and with literature.



	Mopane Scrub Woodland	Thicket	Riverine Woodland	Combretum Terminalia Woodland	Grassland	Aquatic Associated Grassland	Acacia Woodland	Mopane Woodland
Trap location	0	6.25	12.5	12.5	56.25	6.25	0	6.25
Scat location	1.18	5.51	8.27	16.93	61.42	1.97	1.18	3.54

Figure 2.48: Trap locations and scat locations within the eight main habitat types

Table 2.24: Prey spectrum of the small mammals in the Servals' diet (green = trapped but not found in faecal samples; red = not trapped but found in faecal samples; black = trapped and found in faecal samples)

Species	Species	Species
Acomys spinosissimus	*Micaelamys namaquensis*	*Saccostomus* spp.
Crocidura hirta	*Mus minutoides*	*Steatomys pratensis*
Crocidura cf. nanilla	*Mus* spp.	*Steatomys* spp.
Dendromus mystacalis	*Paraxerus cepapi*	*Suncus varilla*
Gerbilliscus leucogaster	*Pelomys fallax*	*Uranomys ruddi*
Lemniscomys griselda	*Petrodromus tetradactylus*	
Mastomys natalensis	*Saccostomus campestris*	

In LNP the Servals feed mainly on *Mastomys natalensis* and *Pelomys fallax*, followed by *Gerbilliscus leucogaster* and *Uranomys ruddi* (see Fig. 2.16). While in *Mastomys natalensis* the percentage occurrence values are nearly three times as large than those of *Pelomys fallax, Mastomys natalensis'* and *Pelomys fallax*'s consumed biomass are nearly similar in levels (43.94% and 36.45%). In LNP the total consumed biomass found in Serval scats constituted mostly of small mammal prey (73.2%), where mean weight was 72.9 g, which is similar to the weight of *Mastomys natalensis* (60g).

Why is the Serval feeding mostly on these species? BOWLAND (1990), GEERTSEMA (1985) and SMITHERS (1978) state, that *Otomys*, in their study, is the main prey, because it is slow and easy to catch therefore it needs minimal effort to obtain high energy food. *Otomys* is restricted to wetter areas (vlei, wet grassland, reed beds), in what is described as part of Serval habitat (SMITHERS 1978). However, there is no *Otomys* in LNP. A very similar species to *Otomys* is *Pelomys fallax*, which is only present in the northern part of the southern African region. As these species have similar ecological, physiological and behavioural features, they are good to use to compare between studies. In this study, the importance of a crepuscular/nocturnal, grassland/vlei depending rodent species with a weight of over 100 g could be confirmed (FO (*Otomys*, SMITHERS (1978)) = 48%, FO (*Pelomys*) = 43%).

Mastomys natalensis however, is the small mammal species most frequently consumed by Servals in LNP. This species is one of the most widely distributed and common Muridae (SMITHERS & TELLO 1976) and its activity pattern is mainly nocturnal, with peaks after sunset and just before sunrise. These two features of the species suit the Servals in LNP.

Micaelamys and *Mus* are also common, nocturnal inhabitants of the area, but are not fed on often *Mus* may not be consumed often by the Servals of LNP due to its small size (6 g only). Reasons for the lower consumption levels of *Micaelamys* could be due to its taste or ability to defend itself or its territory. The other species, like *Saccostomus* or *Steatomys* are medium-sized rodents (20-45 g), nocturnal and mostly abundant in sandy habitats. The sandy habitat may make hunting more difficult for the Serval. Further study is needed on these hypotheses.

Lemniscomys griselda and *Paraxerus cepapi* are the only diurnal small mammals found in the scats samples in LNP, but their frequency of occurrence was less than 1%, so it might have been more a catch by chance rather than a targeted hunt for it.

Surprisingly the Servals' diet in LNP gave evidence of Soricomorpha (*Crocidura* (FO = 3%) and *Suncus* (FO = 1%)). These species have nauseous glands which should prevent them from being consumed, as shown in cafeteria tests with predators (EWER 1973). GEERTSEMA (1985) and SMITHERS (1978) also found *Crocidura* spp. remains in Serval scats and stomach contents (FO ~5%). Although BOWLAND (1990) recorded *Crocidura* to be present in the study area, she did not find any *Crocidura* remains in Serval scats, but *Myosorex* was present, which she states is less distasteful than *Crocidura*. *Suncus* species have never been recorded in Serval scats prior to this study.

Table 2.23 indicates that the Servals of LNP would feed on the most commonly trapped animals (*Mastomys natalensis* and *Gerbilliscus leucogaster*), but with the other species, there is no obvious pattern to show a link between consumption and trapping rate. *Pelomys fallax* is the exception here; while Servals in LNP feed on it on a regular basis, it has not been caught during the trapping period, which could be explained by several factors, such as trap-shyness, inappropriate traps or baits, inedibility to Servals, or difficulties in catching. To give a closer insight into the correlations of FO, respectively PO of the small mammals and the percentages of trapped individuals of the species during trapping occasions a bootstrap analysis (1000 random values of the sample values and 1000 repetitions) for each small mammal species' FO respectively PO value vs. the trapping value was calculated (Fig. 2.49). The error bars are the 95% confidence intervals. If the red bar of the trapping success lies outside these error bars there is a clear difference between these values, maybe even a significant difference. It is important to mention that the trapping success not only correlates with the density of a certain species, but is influenced by many unswayable facts. For example, species with a bigger home range are more likely to be caught in several traps, and the rough living ones/the rarer ones might not have the chance to be caught in a trap as traps could already be occupied by the more common/gregarious species, behavioural aspects differ with each species, and the type of traps and baits can always influence trapping success. Hence, the results of this analysis need to be taken with caution. Figure 2.49 shows *Steatomys pratensis*, *Pelomys fallax*, *Mastomys natalensis* and the two *Crocidura* species having a big deviation from their FO/PO values and the trapping success for this species. The two *Crocidura* species were caught significantly more often than they were consumed. As mentioned above that could be the case because Soricomorpha have nauseous glands. *Pelomys fallax* was not caught at all, which explains the significance. As mentioned above, the fact that some species were not trapped at all could be due to behavioural patterns of the specific species or due to inappropriate traps/baits. *Paraxerus cepapi* also shows a significant difference, but as numbers in all three categories are very low this difference is more due to the low numbers. *Mastomys natalensis* was trapped a lot more than individuals of other species and hence the trapping rate was significantly different to the FO/PO values. *Mastomys natalensis* is the most wide spread, very adaptable rodent in southern Africa; it is known to be gregarious (COETZEE 1975) and can live in big colonies. That could explain the high trapping success on this species. All the other species do not show a significant difference between trapping success and the FO respectively their PO. Especially the values of PO are often closer related to the trapping success than the FO values. The reason for this is, because the Serval seems to feed opportunistically, it preys on whatever species there is; and if this species occurs in high numbers at one spot, the Serval also feeds in higher amounts of this prey. This fact could also explain why only *Mastomys natalensis* shows a big difference between the PO and FO values. Servals, if they find *M. natalensis*, they catch as many as they can feed on. That is why *M. natalensis* shows so much higher percentages in the number of individuals fed on compared to the number of scat that species was found. On the other hand, there are species occurring more often in the faeces, but in smaller numbers (1-2 individuals), e.g. *Uranomys ruddi*, *Steatomys pratensis*, *Mus minutoides*, *Gerbilliscus leucogaster*, *Crocidura hirta*, and *Acomys spinosissimus*. This might have different reasons. Species like *Crocidura hirta* or *Mus minutoides* might cost to much effort to catch compared to the intake effect; Servals might catch them by chance, if the opportunity arises, but these species are very small and, in case of *Crocidura*, they also might not taste so good, and therefore Servals might not go for another individual if they would need to raise a lot of energy for it. The other four species mentioned life rough or as pairs, so that this could be the reason why the Servals feed on them only in small amounts.

The most frequently trapped species are also the most frequently consumed species (Tab. 2.25) leading to the conclusion that the Serval is a generalist in its feeding behaviour concerning small mammals. The Servals of LNP do not feed more often on larger prey, which also supports this conclusion. As GEERTSEMA (1985) previously stated “Although he seems to be a ‚rodent specialist’ the Serval can probably survive also on others small prey, like frogs.”, the Serval seems to be an opportunist, not specializing in particular prey species. This is also supported by the analyses of the diet breadth, which shows a medium diet breadth for the Servals of LNP.

Table 2.25: Total numbers of trapped small mammal species and their occurrence in the Servals’ diet.

Species	Total N of trapped individuals	% of trapped animals	FO (within the group)	PO
Acomys spinosissimus	1.00	0.61	5.82	1.13
Crocidura hirta	11.00	6.75	2.12	0.35
Crocidura nanilla	9.00	5.52	0.00	0
Dendromus mystacalis	0.00	0.00	1.06	0.17
Gerbilliscus leucogaster	17.00	10.43	24.34	6.01
Lemniscomys griselda	0.00	0.00	1.06	0.17
Mastomys natalensis	116.00	71.17	80.42	53.4
Mastomys spp.	0.00	0.00	2.12	0.44
Micaelamys namaquensis	2.00	1.23	3.70	0.87
Mus minutoides	2.00	1.23	5.29	0.87
Mus spp.	0.00	0.00	1.06	0.17
Paraxerus cepapi	3.00	1.84	0.53	0.09
Pelomys fallax	0.00	0.00	49.21	19.69
Petrodromus tetradactylus	0.00	0.00	0.53	0.09
Saccostomus campestris	0.00	0.00	1.06	0.17
Saccostomus spp.	0.00	0.00	2.65	0.44
Steatomys pratensis	0.00	0.00	6.35	1.92
Steatomys spp.	0.00	0.00	1.06	0.17
Suncus varilla	0.00	0.00	1.06	0.17
Uranomys ruddi	2.00	1.23	10.58	1.92

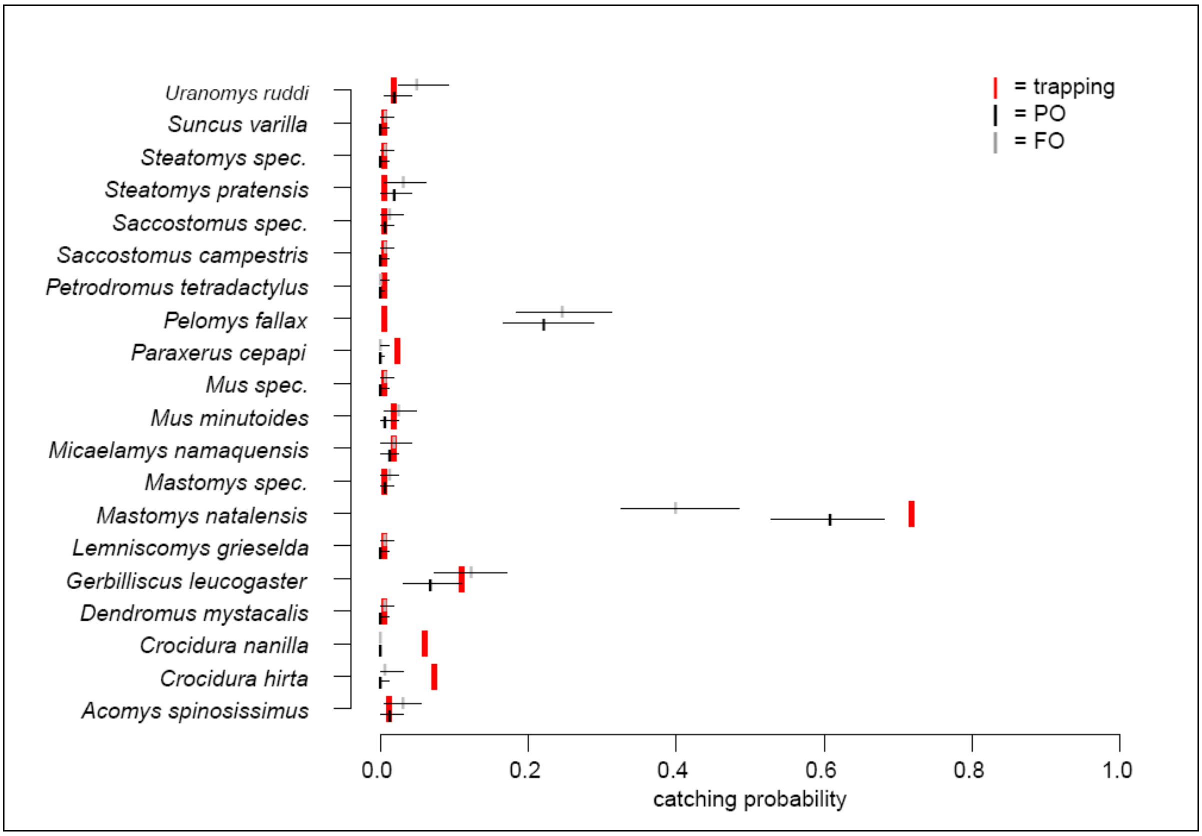


Figure 2.49: Bootstrap plot comparing FO, PO and trapping success of each small mammal species in LNP.

There is little difference in the results from the different years of scat collection. *Mastomys natalensis* and *Pelomys fallax* are the most frequently consumed species, followed by *Gerbilliscus leucogaster* and *Uranomys ruddi,* with *Pelomys fallax* and *Mastomys natalensis* being of high importance. The Serval is a 'rodent-specialist', but feeds on a variety of small animals of similar.

In the year 2006 the frequency of occurrence of birds was much reduced (15% instead of 25%) and this is also the case with reptiles (5% instead of 15%). This could be a bias resulting from the small number of samples (N=21) for this year. But this year also ornithologists perceived the rarity of the Numididae (VAN DEN ELZEN, personal communication) in LNP which could explain the absence of these birds in Serval scats in 2006 although they play a bigger role in the Servals' diet in the following two years. In the year 2006, there were more consumed *Mus spp.* and *Pelomys fallax*, while in 2007 both species were less than half as frequent as in the year before (Fig. 2.31). These two species are more confined to wet habitats, like flood plains (SHEPPE & OSBORNE 1971), so that the low occurrence cannot be explained by the better rainy season of 2006/2007 (1000 mm instead of around 700 mm). With the bird species there is no such pattern.

2.4.1.2. Diet in Zambia

All over Zambia the Servals' diet is based on small mammal prey, with birds, reptiles and arthropods being of less importance to different extents.

The main prey items are primarily nocturnal (like *Mastomys, Gerbilliscus*; see Tab. 2.26) which supports the results of the activity patterns and the preferred prey items of Servals in LNP. As described in 2.4.3.1 other mammals with diurnal activity patterns are more likely to be preyed upon during the hours of dusk and dawn.

Although some of the locations are represented only by a few scat samples (Table 2.10), a comparison between them is discussed here as well.

The dietary composition of Zambia-wide locations rely more on birds of big biomasses like *Numida meleagris* and other Galliformes than in Luambe National Park, where small mammals make up over 70% of the total consumed biomass compared to 51.02%.

But looking at the individual values of all study areas it is obvious that Luambe NP is just one example of different possibilities of dietary composition like the other locations are; the percentage values vary a lot between locations (SD of ± 28.70845) with LNP being within the scope of these. If LNP is included with the other locations the median values change slightly from 48.83% respectively 51.17% to 49.96% respectively 50.04%, and also the mean values do not change significantly (T-Test for mammalian biomass consumed: $t = 0.203$, $p = 0.843$; T-Test for consumed bird biomasses: $t = 0.203$, $p = 0.843$) (see Appendix for data table). Generally, small mammals and birds seem to contribute equally to the total biomass a Serval in Zambia consumes, but with high variations depending on the area. The reason for this variation needs a closer examination. But this equally distribution of consumed biomass does not mean that the Servals in Zambia feed on small mammals as often as they feed on birds. The mean weight of mammalian prey lies between 40 and 80 g, while consumed birds are in average between 130 and 240 g, depending on the area. Hence, Servals need to prey three times as often on small mammals as on birds to reach the same amount of biomass. Only in Kasanka National Park small mammals consumed by Servals show a high mean weight of 260 g. This rise in weight can be explained by the presence of *Cricetomys* spp. in this Serval population's diet. These Pouched Rats have a weight of 6000g in average. At Kushiya farm and in Luangwa Valley consumed birds have a mean weight of more then 400 g, which is more than double the weight of other locations. This can be explained by the high consumption of *Numida meleagris*, which led to a reversed biomass distribution between mammalian biomass and biomass of consumed birds with the birds making up the major part of consumed biomass at these two locations.

In **Kafue NP** there were eight different species of small mammals occurring, which formed the main prey type (FO = 75%). Three species, *M. natalensis, G. leucogaster and P. fallax*, were found to make up the majority of the small mammal diet, followed by *Saccostomus* spp.. Birds and reptiles only accounted for 18% of the diet, and one amphibian prey was found (not found in scats in other areas). This composition of prey items can be explained through the habitat in Kafue NP. Many water courses traverse through the area and there are floodplains where the faecal samples were found. Therefore, the Servals would easily have access to frogs, as well as to the sandy soil loving *Saccostomus spp.*, while reptiles and birds would prefer the surrounding grassland.

Although Kafue NP is part of the distribution range of *Arvicanthis* (ANSELL 1978, GREENFORCE REPORT 2003) and GEERTSEMA (1985) recorded a high occurrence of *Arvicanthis* in the Servals' diet in Tanzania, there is no evidence of this species in the scat samples found here in this study. In Tanzania the Serval is mainly crepuscular, but can also be diurnal at times. *Arvicanthis* is diurnal and therefore provides an additional prey item to *Otomys*. The Servals in Kafue NP are not diurnal but appear to be more nocturnal/crepuscular, like many other observations indicate (FITZSIMMONS 1919, RAHM & CHRISTIAENSEN 1963, SMITHERS 1971, ROSEVAER 1974), which reduces the chances of *Arvicanthis* to be preyed on by the Zambian Servals.

The Servals of **Kasanka NP** prey on a higher variety of small mammals; there were 13 different species found in the scat samples. Apart from the high amount small mammals, they also hunt frequently on birds (FO = 35%), with high diversity of smaller birds (e.g. *Apus*, *Quelea* and Oscines) and *Centropus* species. Reptiles have a minor role in their diet. This could be due to the fact that Kasanka NP is cooler than the other locations. Kasanka NP contains swampy habitat which results in the mornings and nights being cold and moist. There has not been any study on reptilian population estimation undertaken, but it is possible that there is less reptilian diversity in Kasanka NP.

On **Kushiya Farm**, seven small mammal species were found in the faecal samples, with *Steatomys pratensis, Pelomys fallax* and *Mastomys natalensis* as main prey. *Steatomys* prefers sandy soil and open habitat, hence it easily adjusts to agricultural land use, despite overgrazing (MONADJEM 1999), which may be one reason for its high occurrence. The Serval as an opportunist takes what it can get, so the diet will be biased towards more common species. Kushiya Farm is also within the distribution range of *Arvicanthis* (ANSELL 1978), but as in the Kafue NP, there is no evidence of consumption of this species here in this study. This reiterates the more nocturnal behaviour of Zambian Servals compared to Tanzanian ones. At Kushiya Farm there is a large dam, where the Servals may like to hunt. This could explain the occurrence of a Crocodile in the diet of the Kushiya Farm Servals. The scale size of that Crocodile skin pointed to a young individual, maybe a newly born or a foetus still inside the egg. This study provides the first evidence of crocodile predation by Servals. Other reptiles occurred in high diversity and with relatively high occurrence (FO = 19%). The high diversity of reptiles can be explained through the diversity of habitats, as game farm, cattle farm and agricultural land make up the area. Birds in the Serval diet show similar results; there is a very high occurrence in the scat samples (FO = 56%) and a very high diversity of both small and big birds of nine taxa and some additional unknown taxa.

Birds in **Lower Zambezi NP** are nearly as important a prey category as the small mammals (77% compared to 90%). There are seven species of both small mammals and bird species found in scat samples. The soils in Lower Zambezi NP seem very hard and dry (personal observations). It may be that this reduces the occurrence of small mammals such as burrowing mice. In Lower Zambezi NP, the Servals also feed on reptiles in a higher percentage of 19%. It seems that the Servals need this additional food resource in this area more than at the other locations.

Samples from the **Luangwa Valley Area**, North and South Luangwa NP, were collected and these results are very different to those of LNP, which lies in the middle between these NPs. The results show a high frequency of occurrence of birds (FO = 77%), reptiles (FO = 33%) and arthropods (FO = 38%), but very few small mammals (FO = 38%). This area shows the highest variety of arthropods of all eight locations. Bird diversity is also high, but reptiles only have two representatives, in the Serpentes and Scincidae. There are still seven species of small mammals found, with *Pelomys fallax* being the main prey, followed by *Gerbilliscus leucogaster* and *Steatomys pratensis.* Surprisingly *Mastomys natalensis* plays only a minor role in the Serval diet here. These results are difficult to explain. From personal observations the environment of North Luangwa NP was very dry resulting in hard and dry soil, however, 17 out of the 21 samples of Luangwa Valley area were collected in South Luangwa NP which has a very similar habitat, soil and climate to LNP. To explain the large difference of prey spectrum of Servals within the whole of the Luangwa valley more faecal samples are need to complete an accurate comparison study.

In **Lusaka Area**, the Servals feed mostly on birds (FO = 88%), and on small mammals (FO = 78%) and then reptiles (FO = 22%). This is the only location where birds are the main prey category. There is lower diversity in arthropods and in the reptiles. This may be due to the close proximity to the capital city of Lusaka where human impacts may have reduced the diversity and abundance of these species. There is no inventory list of species around Lusaka as yet, so this cannot be confirmed. Within the bird group the small birds, like the Estrildinae or Ploceinae, are the most frequently consumed taxa, while the larger ones such as *Numida meleagris* and *Centropus* spp. have a frequency of occurrence about 30%

combined. It may be that bigger birds do not settle often around the capital Lusaka due to human influence, like poaching/hunting and disturbance. There are only five species of small mammals, with *Mastomys natalensis* being the main prey item, followed by *Steatomys pratensis* and *Pelomys fallax*. The high occurrence of *S. pratensis* may be for the same reason as that given for Kushiya Farm. Around Lusaka there is a lot of agricultural land which is preferred by this species. Lusaka also lies within the distribution range of *Arvicanthis* (ANSELL 1978), but also here there is no evidence of consumption of this species here. This again indicates more nocturnal behaviour in Zambian Servals. This is especially the case around a city like Lusaka as animals like the shy Serval are expected to be more nocturnal, even if they would naturally be more crepuscular or diurnal in the wilderness areas. GEERTSEMA (1985) noted that the Serval can be nocturnal in Tanzania, depending on the impact of human activities.

Table 2.26: All species occurring in all collected Serval scats with their activity patterns and preferred habitat. N = Nocturnal, D = Diurnal, C = Crepuscular

Taxa	Species	Common name	N	D	C	Habitat
Apalis	spp.	Apalis		X		thickets, woodland
Apus	spp.	Swifts		X		forages over open ground
Balearica	*regulorum*	Crowned Crane		X		water associated land
Caprimulgus	spp.	Nightjars	X		X	woodland, savannah
Centropus	spp.	Coucals		X		water associated land
Centropus	*cupreicaudus*	Coppery tailed Coucal		X		water associated land
Centropus	*grillii*	Black Coucal		X		water associated land
Centropus	*superciliosus*	Whitebrowed Coucal		X		water associated land
Coraciiformes	spp.	Rollerlike Birds		X		every
Corythaixoides	*concolor*	Grey Lourie		X		savannah, bushveld
Coturnix/Turnix	spp.	Quails/ Buttonquails		X		grassland, vlei
Estrilda	spp.	Waxbills		X		water associated land
Estrilda	*astrild*	Common Waxbill		X		water associated land
Falconidae	spp.	Falcons		X		every
Francolinus	spp.	Francolins		X		grassland, vlei, open woodland
Galliformes	spp.	Game birds		X		grassland, vlei, open woodland
Lamprotornis	spp.	Starlings		X		dry savannah, woodland
Numida	*meleagris*	Helmeted Guineafowl		X		grassland, vlei
Ortygospiza	*atricollis*	Quail Finch		X		grassland, vlei
Oscines	spp.	Songbirds		X		every
Ploceinae	spp.	Weavers		X		savannah, woodland
Prinia	*subflava*	Tawnyflanked Prinia		X		riverine weed and bushes
Quelea	*quelea*	Redbilled Quelea		X		savannah
Serinus	*flaviventris*	Yellow Canary		X		every
Turdus	spp.	Thrushes		X		woodland, savannah
Tyto	spp.	Owls	X			open
Tyto	*alba*	Barn Owl	X			open
Vidua	spp.	Widowfinches		X		savannah, woodland
Acomys	*spinosissimus*	Southern African Spiny Mouse	X		X	rocky or sandy riverbed
Crocidura	spp.	Musk Shrews	X	X	X	every
Cricetomys	spp.	Giant Pouched Rats	X			every
Crocidura	*cf. nanilla*	Tiny white-toothed shrew	X	X	X	grassland, vlei

Taxa	Species	Common name	N	D	C	Habitat
Crocidura	*hirta*	Lesser Red Musk Shrew	X	X	X	wetlands, dense vegetation
Dendromus	*mystacalis*	Chestnut African Climbing Mouse	X			trees and bushes
Elephantulus	spp.	Elephant Shrews			X	bushy, scrubby
Fukomys (Cryptomys)	spp.	Mole Rats	X			open woodland
Gerbilliscus	*leucogaster*	Bushveld Gerbil	X			sandy, bushy grassland
Heliosciurus	*gambianus*	Gambian Sun Squirrel		X		woodland, grassland
Lemniscomys	*griselda*	Griselda's Striped Grass Mouse		X		grassland
Lemniscomys	spp.	Striped Grass Mice		X		grassland
Mastomys	*natalensis*	Natal Multimammate Mouse	X			every
Mastomys	spp.	Multimammate Mouse	X			every
Micaelamys	*namaquensis*	Namaqua Rock Rat	X			rocky or sandy
Micaelamys	spp.	Rock Rats	X			rocky or sandy
Mus	spp.	Old World Mice	X			grassland
Mus	*minutoides*	African Pygmy Mouse	X			grassland
Paraxerus	*cepapi*	Smith's Bush Squirrel		X	X	woodland
Pelomys	*fallax*	Creek Groove-toothed Swamp Rat	X		X	vleis, water associated land
Petrodromus	*tetradactylus*	Four-toed Elephant Shrew			X	woodland
Saccostomus	*campestris*	Pouched Mouse	X			sandy
Saccostomus	spp.	Pouched Mice	X			sandy
Steatomys	spp.	Fat Mice	X			sandy
Steatomys	*pratensis*	Fat Mouse	X			sandy
Suncus	*varilla*	Lesser Dwarf Shrew	X	X	X	termite hills
Uranomys	*ruddi*	White-bellied Brush-furred Rat	X			grassland

2.5. Summary Chapter 2

The Servals' diet is mainly described as 'rodent specialist', but only three studies (in South Africa, Tanzania, and Zimbabwe) focused on that topic. In this study faecal samples from Servals in Zambia were collected. Luambe National Park was the main focus area for this study, while eight other locations throughout Zambia were sampled as well. Scat samples were dried, transported and analysed at the ZFMK. Before processing, the collected samples were checked for their origin. Measurements, shape of the faeces, patterns of the guard hair found in the scat samples, and the macroscopic analyses of these hairs were all criteria to identify the predator which produced these samples.

In Luambe National Park, 216 scats were used for further analyses and 121 samples were taken from the other eight locations. The prey spectrum was determined by sorting through the samples, after washing, followed by determination of the remains, like bones, feathers, teeth, skins and chitin remnants. Small mammal fur was sorted, along with grass and other vegetation. Four categories were used to separate prey items into larger groups: small mammals, birds, reptiles and arthropods.

The minimum sample size for accurate estimations of diet composition was reached in Luambe National Park, but not at the other eight locations. Dietary composition was expressed as 'frequency of occurrence' (FO) - the percentage of scats in which a particular item was found, and as 'percentage occurrence' (PO) - the number of times a prey item was found, expressed as a percentage of all items recorded and additional information was provided by calculating biomass consumed using the prey categories 'small mammals' and 'birds'. Regarding the FO in Luambe National Park, the Servals' diet includes 89% small mammals (mostly rodents), 25% birds, 15% reptiles and 22% arthropods. Arthropods were represented by Formicidae, Coleoptera and Orthoptera. Serpentes and Scincidae represented three quarters of all found reptilian remains. Within the bird diversity of Luambe National Park the Ploceinae, Centropodidae and the Numididae formed the main prey. *Mastomys natalensis, Pelomys fallax* and *Gerbilliscus leucogaster* were the most frequently consumed small mammal species. Soricomorpha (*Crocidura* and *Suncus*) also formed part of the Servals' diet. Detailed analyses within the prey categories as well as comparison between the years were done. There was no significant change in diet composition between years. Altogether 48 (sub-) orders, families, genera and species could be identified in the Serval scats in Luambe National Park.

On average, in the other eight locations, Servals preyed on small mammals (FO = 74%), birds (FO = 55%), arthropods (FO = 31%), reptiles (FO = 18%) and also once on amphibians (FO = 0.83%). These results were separated by location and there was a clear difference in the diet composition dependant on the area. Servals are specializing on small mammals throughout Zambia, but also feed on other prey to different amounts which are affected by factors linked to the areas studied.

Prey availability (using the small mammals group) was checked using live trapping surveys in Luambe National Park and through collating existing species lists. Activity patterns of Servals in Luambe National Park were analysed and the findings compared with the determined prey spectrum. Servals in Zambia feed mainly on small mammals weighing in average ~70 g and up to 1.5 kg, which mostly are nocturnal and have a preference for grassland, vlei or habitats associated with water. *Mastomys natalensis* was the most preferred prey in most areas, while the frequency of occurrence of the other small mammals showed high variation between study areas. Birds and reptiles are the second most important food resources, followed by arthropods. Birds mostly caught are in average ~250 g in weight, in form of smaller birds (up to 200g) or larger Galliformes (ground dwellers up to 4kg).

Analyses of the Servals' diet breadth in Luambe National Park showed a medium diet breadth ($B_{standard}$ = 0.5), consequently Servals are neither specialized feeder nor clearly opportunistic predators. Hence Servals of Luambe National Park are rodent hunters with a highly variable spectrum of other prey items, which is also applicable to the findings in the eight other study areas throughout Zambia.

3. Parasites

Chapter three is dealing with the biodiversity of ectoparasites found in Serval scats throughout Zambia. The focus is set on tick composition. It also determines if tick composition in Luambe National Park is correlated with rainfall or rather underlies annual or monthly fluctuations.

3.1. Introduction

Literature review only showed one note on the Servals' ectoparasites diversity (HOFFMANN 1987). HOFFMAN (1987) found a dead Serval road kill near Empamgeni in KwaZulu-Natal Province, South Africa and examined it for ectoparasites. Besides one species of flees, he also found ticks of the species *Haemaphysalis spinulosa*, which belongs to the *Haemaphysalis leachi* group. Other cats' ectoparasites have been studied in more detail (WEHINGER et al. 1995, ROBBINS et al. 1997, GRASSMAN et al. 2004, LABRUNA et al. 2005, DURDEN et al. 2006, FIORELLO 2006, MILLAN et al. 2007). There are only a few publications on African cats' ectoparasites, in contrast to studies on the diseases which are transferred by these parasites (HORAK 1998, ZIEGER et al. 1998, FYUMAGWA et al. 2007, FYUMAGWA et al. 2008). FYUMAGWA et al. (2008) found *Rhipicephalus sanguineus* on lions of the Ngorogoro Crater, Tanzania, while KOK & PETNEY (1993) found *Haemaphysalis* spp. on Caracal in South Africa. MBAYA et al. (2008) found *Rhipicephalus sanguineus* to be the most common ectoparasites encountered in the captive held carnivores (Lion, Cheetah, Hyaena, Golden Jackal) in north-eastern Nigeria. In Zambia ticks on a game ranch were investigated (ZIEGER et al. 1998a &1998b) and the diversity of ticks was studied, as well as the infestation of wild birds and some mammals (Rodentia, Lagomorpha, Ungulata).

3.2. Methods

Ticks found in faecal samples collected in the years 2006 to 2008 were kept in 70% Ethanol and were stored until identification. Nematodes and mites were also stored in 70% Ethanol but were not identified to a finer level. Mites and Nematodes were too difficult to distinguish from each other; there is only a hand full of specialists world-wide. Mites could not be counted individually as ticks, due to their very small size and this would introduce errors from the beginning. Flees could not be found in faecal samples.

The ticks of one scat sample were placed in a Petri dish and counted and identified with a dissecting microscope. Ticks were determined using WALKER et al. (2003) and with the help of Prof. Eberhard Schein from the Institute of Parasitological and Tropical Veterinary Medicine of the Freie Universität Berlin. Immature ticks (nymphs) were identified as well as fed individuals, although fed specimens were not in as good condition as unfed ones.

All statistical tests were done with SPSS© 13. Correlations of tick abundance and diversity with climate data was done, as ticks often rely on a humid climate and are depended mainly on rainfall, as well as on temperature and humidity (MOORING et al. 1994, Brewer et al. 2003, MOHAMMED & HASSAN 2007). Only rainfall data was used to correlate with tick abundance, as no monthly values humidity and temperature were recorded for this region during the study period. Rainfall data was provided by ZAWA (Zambia Wildlife Authority) South Luangwa NP Headquarters.

Graphs were produced with Microsoft© Office Excel 2003, SPSS© 13 and XLSTAT© 2011.1.03.

3.3. Results

3.3.1. Parasites of all Zambia-wide samples

There were 223 faecal samples (66%) from all over Zambia containing a parasite sample. The frequency of occurrence (FO) of all types of parasites found is shown in Figure 3.1. Four families (Ixodidae) and five species of ticks were found in addition to a variety of Nematoda and Mites. The most common parasite (with FO = 78%) was *Rhipicephalus sanguineus*, the 'Brown Dog Tick'. Mites were found in more than 60% of all samples, as was *Haemaphysalis leachi*, the 'Yellow Dog Tick'. Other tick species could only be found with a frequency of less than 4% each. Nematoda occurred in nearly a fifth of all samples.

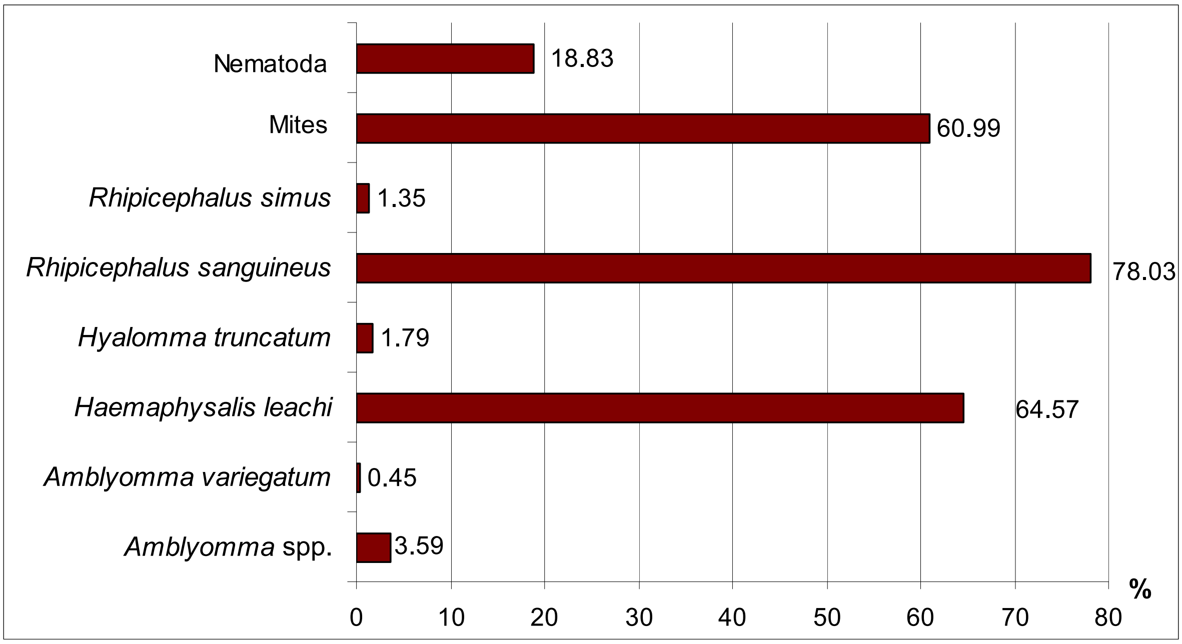


Figure 3.1: Frequency of occurrence of parasites in all Zambian faecal samples (N=223).
(All species names are tick species.)

Looking at the frequency of occurrence within the group of ticks *Rhipicephalus sanguineus* occurred in 83.65% and *Haemaphysalis leachi* in 69.23% of all samples (N = 208). By determining the percentage occurrence (PO) within the group of ticks, *Rhipicephalus sanguineus* was found to be the most common tick. Its percentage occurrence was 64.75% compared to 34.66% for *Haemaphysalis leachi*, which makes a difference of 30% between these two species. When looking at the frequency of occurrence there was only a difference of 15% (Tab. 3.1).

The sex ratios of all tick species found showed a relatively even split between males and females, while nymphs were found only rarely (see Tab. 3.2). Fed ticks were found only in 2.22% of the samples; only 8.7% of these were males, the rest were females. Mean numbers of ticks found in single faecal sample is shown in Table 3.3. On average a range between as many as 8.4 *Rhipicephalus sanguineus* ticks and 0.005 *Amblyomma variegatum* ticks were found in one scat sample.

Table 3.1: Frequency of occurrence of ticks in all Zambian faecal samples with ticks (N=208) and their percentage occurrence.

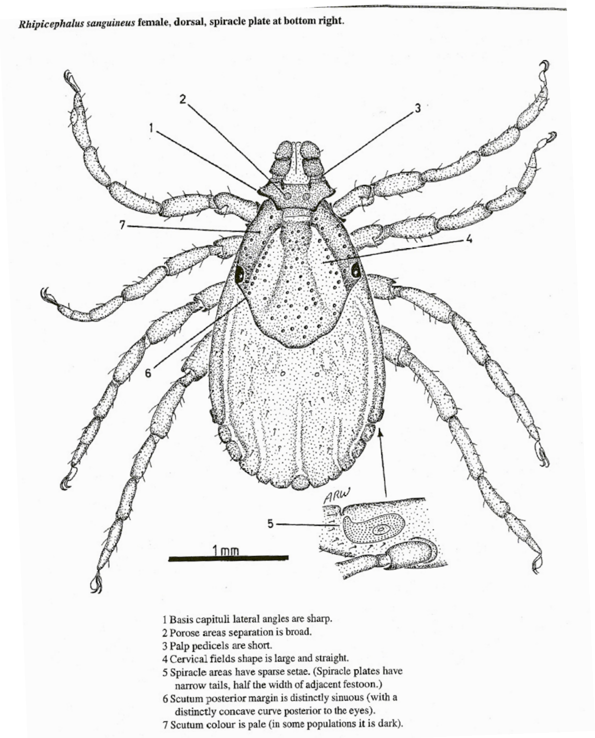
Species	**FO of all tick samples (N=208)**	**Percentage occurrence**
Amblyomma spp.	3.85	0.30
Amblyomma variegatum	0.48	0.04
Haemaphysalis leachi	69.23	34.66
Hyalomma truncatum	1.92	0.15
Rhipicephalus sanguineus	83.65	64.75
Rhipicephalus simus	1.44	0.11

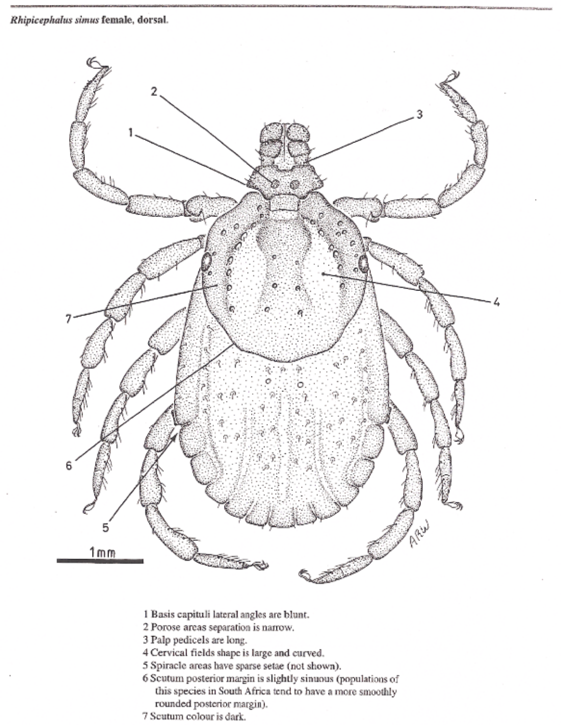
Table 3.2: Sex ratio of all ticks found Zambia-wide in all faecal samples with ticks (N=208).

Species	**% male ticks**	**% female ticks**	**% nymphs**	**% fed ticks**	**Total**
Amblyomma spp.			100.00		**8**
Amblyomma variegatum	100.00				**1**
Haemaphysalis leachi	46.06	48.19	1.60	4.16	**938**
Hyalomma truncatum	25.00	75.00			**4**
Rhipicephalus sanguineus	46.00	52.51	0.29	1.20	**1752**
Rhipicephalus simus	33.33	66.67			**3**
Average	**45.86**	**50.89**	**1.03**	**2.22**	

Table 3.3: Mean numbers of found ticks per each faecal sample containing ticks (N=208).

Species	**Mean No. of male ticks**	**Mean No. of female ticks**	**Mean No. of nymphs**	**Mean No. of fed ticks**	**Total**
Amblyomma spp.			0.038		**0.038**
Amblyomma variegatum	0.005				**0.005**
Haemaphysalis leachi	2.077	2.173	0.072	0.188	**4.510**
Hyalomma truncatum	0.005	0.014			**0.019**
Rhipicephalus sanguineus	3.875	4.423	0.024	0.101	**8.423**
Rhipicephalus simus	0.005	0.010			**0.014**





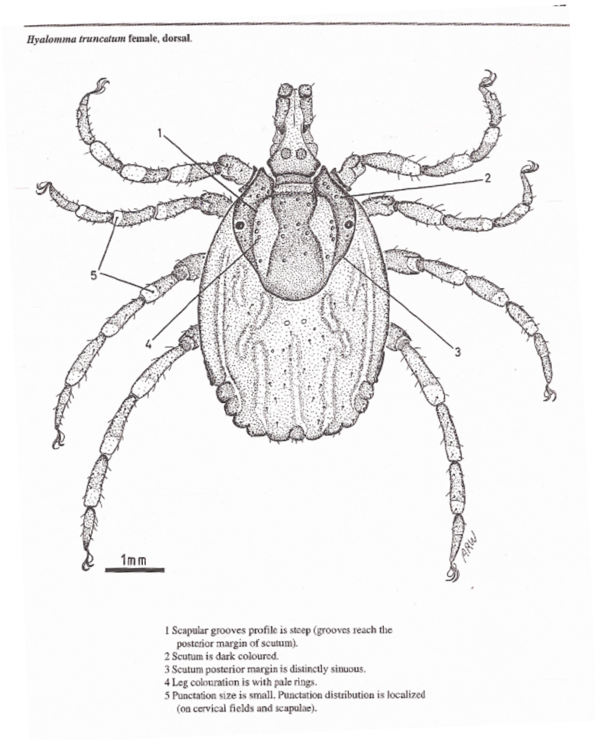


Figure 3.2-3.5: Photo & drawing of *Rhipicephalus sanguineus*, and drawing of *Rhipicephalus simus* and *Hyalomma truncatum*.
Source: WALKER et al. (2003) & Prof. E. Schein (Photo).

3.3.2. Parasites in LNP

There were 183 faecal samples (84.7%) found within LNP containing parasites. In all sample 2578 ticks were found. The mean values are calculated as the mean of all three years 2006-2008. Standard deviation is calculated using a multiplier of 1.

The mean frequency of occurrence (FO) of all types of parasites found is shown in Figure 3.6. Besides Nematoda and Mites there were four families (Ixodidae) and four different species of ticks identified. The most common parasite (72.78%) is *Rhipicephalus sanguineus*, the ‘Brown Dog Tick’. *Haemaphysalis leachi*, the ‘Yellow Dog Tick’ was found (70.15%) as being the second common, whilst mites were found as the third most common ectoparasites. Nematoda occur in nearly one fifth of all samples, while tick species only could be found with a frequency of less than 6% each, *Amblyomma* spp. having the highest percentage of 5.36% with a SD of 3.62% (for all numbers see Tab. 3.1 in Appendix 3). The Kruskal-Wallis-Test also supports that the distribution of the five different tick species is not random, but that some species occur more often than others (mean tick numbers of all species in all three years) (χ^2 = 11.566, df = 4, p = 0.021).

Rhipicephalus sanguineus occurs in 77.83% (FO within the ‘tick’ group) of scats and *Haemaphysalis leachi* in 75.23% (N = 174). When percentage occurrence (PO) within the group of ticks is calculated, *Rhipicephalus sanguineus* is not the most common tick, but *Haemaphysalis leachi*; their percentage occurrences are 48.12% and 51.06% respectively (all numbers see Tab. 3.2 Appendix 3). Hence *Rhipicephalus sanguineus* is found in more scat samples but in a lesser amount than *Haemaphysalis leachi.* Other tick species show percentage occurrence values below 1%. Figure 3.7 shows the mean frequency of occurrence and mean percentage occurrence of all tick species in the years 2006-2008.

Comparing the mean sex ratios of all tick species found in LNP in the years 2006-2008, there is obviously a relatively even split between males and females, slightly in favour of female ticks (see Tab. 3.4). Nymphs were found rarely, while fed ticks were found in 2.68% of the samples. Only 9.5% were fed males, the rest were fed females. These results are very similar to those found Zambia-wide. Mean numbers of ticks found in a single faecal sample is shown in Table 3.5, where, on average, 9.6 *Rhipicephalus sanguineus* ticks and 0.006 *Rhipicephalus simus* ticks were found in one scat sample.

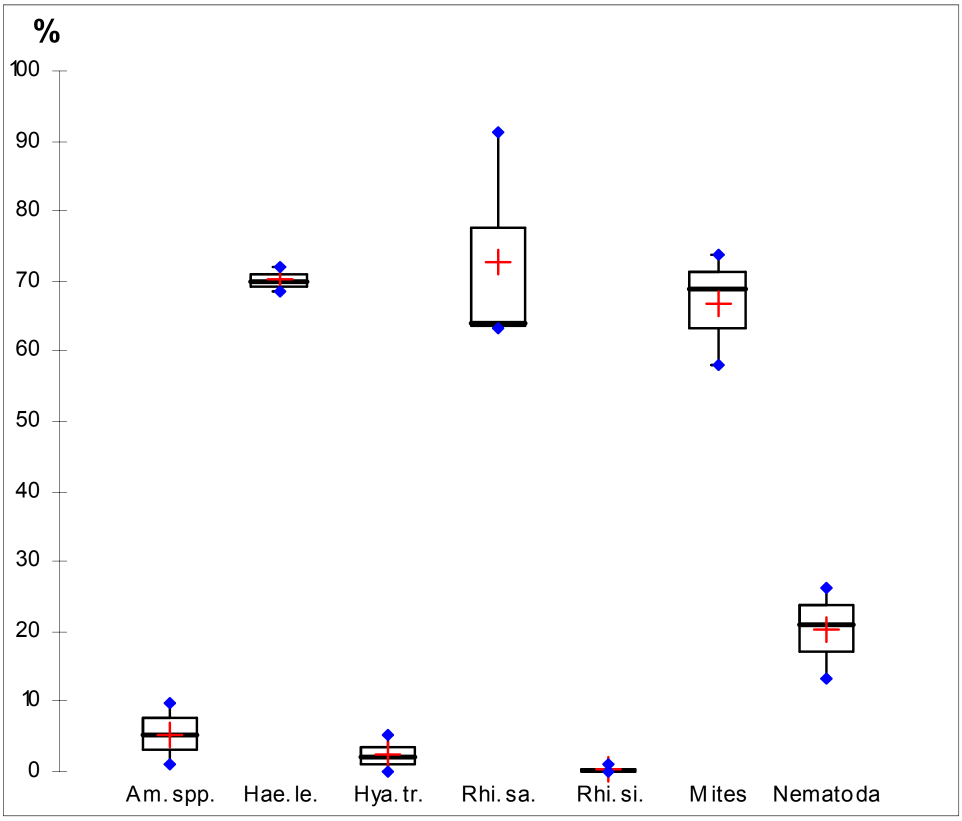


Figure 3.6: Box plot of frequency of occurrence of parasites in all Luambe NP faecal samples in the years 2006-2008 (N=183).
Am.spp.= *Amblyomma* spp.; Hae.le.= *Haemaphysalis leachi*; Hy.tr.= *Hyalomma truncatum*; Rhi.sa.= *Rhipicephalus sanguineus*; Rhi.si.= *Rhipicephalus simus*.

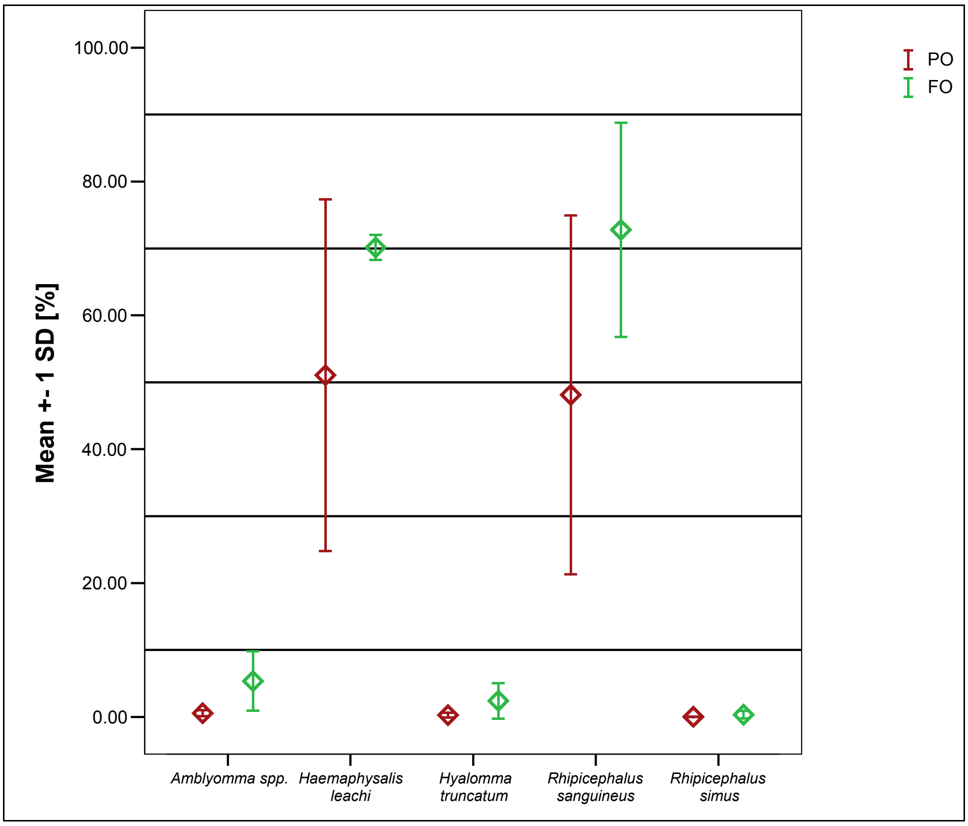


Figure 3.7: Mean frequency of occurrence (FO) and percentage occurrence (PO) of tick species within all tick samples in the years 2006-2008 and the standard deviation.

Table 3.4: Mean sex ratio of all ticks found in LNP in all faecal samples with ticks in the years 2006-2008 (N=174).

Species	% male ticks	%female ticks	% nymphs	% fed ticks	Total
Amblyomma spp.	0.00	0.00	100.00	0.00	**8**
Haemaphysalis leachi	46.41	48.86	0.93	3.79	**897**
Hyalomma truncatum	25.00	75.00	0.00	0.00	**3**
Rhipicephalus sanguineus	42.88	54.70	0.07	2.35	**1669**
Rhipicephalus simus	0.00	100.00	0.00	0.00	**1**
Average	**45.27**	**51.09**	**0.97**	**2.68**	

Table 3.5: Mean numbers of ticks found in LNP in a single faecal sample containing ticks in the years 2006-2008 (N=174).

Species	Mean No. of male ticks	Mean No. of female ticks	Mean No. of nymphs	Mean No. of fed ticks	Total mean
Amblyomma spp.			0.046		**0.046**
Haemaphysalis leachi	2.397	2.489	0.063	0.207	**5.155**
Hyalomma truncatum	0.006	0.011			**0.017**
Rhipicephalus sanguineus	4.454	5.006	0.017	0.115	**9.592**
Rhipicephalus simus		0.006			**0.006**

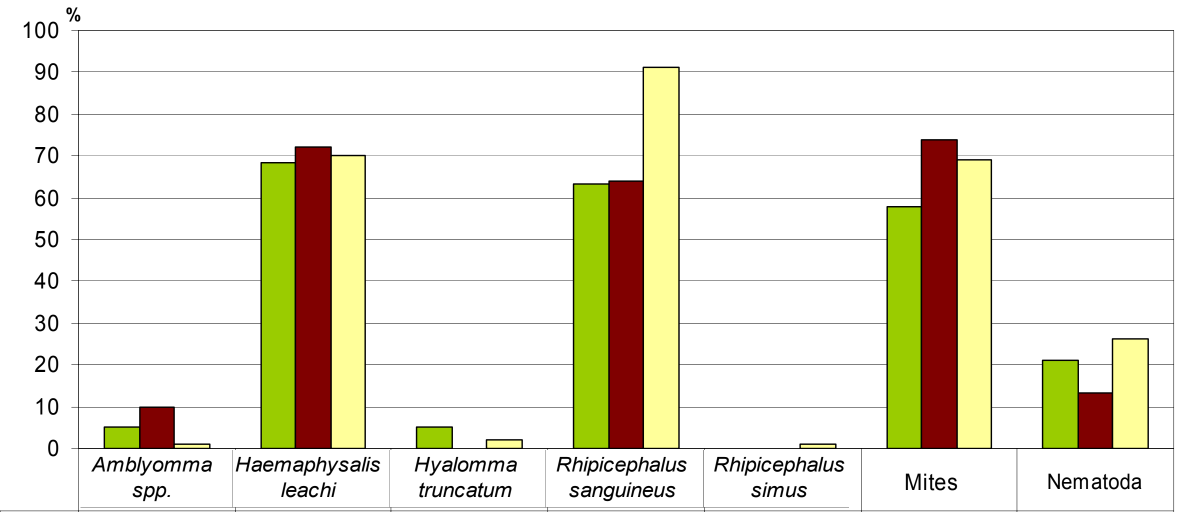
3.3.2.1. Annual change of parasite composition

Taking a closer look at annual changes in parasite compositions of the LNP scat samples, it becomes clear that there is no significant variation between the years (ANOVA, $F_{2,14}$= 0.21, p = 0.980). In all years *Rhipicephalus sanguineus* and *Haemaphysalis leachi* are the most frequently found tick species (Fig. 3.8). They have similar values, although in 2008 *Rhipicephalus sanguineus* was found in 91% of all samples containing ectoparasites, which is the maximum value found. The numbers of rarer species vary the most between the years. *Hyalomma truncatum* was not found in 2007, while *Rhipicephalus simus* was only found in 2008. The frequency of occurrence of mites and nematodes varies within the three years as well (Fig. 3.8). Mites were found in more than 50% of all samples every year and Nematodes were found in more than 10% each year. In the year 2007, there were more Mites than in the others, and in the same year the lowest number of Nematodes occurs.

Table 3.6 shows the frequency of occurrence and percentage occurrence values of all tick species, within all samples containing ticks. In 2006 and 2007, *Haemaphysalis leachi* is the most frequently found tick as well as the tick species with the highest percentage occurrence value; percentage occurrence is double that of *Rhipicephalus sanguineus.* The other species found had percentage occurrences of less than 1%, which means there were not many individuals per samples found. In 2008 there is a change in the tick composition; *Rhipicephalus sanguineus* was the most frequently occurring tick species with 96%, while *Haemaphysalis leachi* is only second with 73%. Within the percentage occurrence it is even clearer that *Rhipicephalus sanguineus* is the most common tick making up nearly 80% of individuals found in the scat samples in 2008. Statistically there is neither a significant difference in tick composition (FO) between the years (Kruskal-Wallis-Test, χ^2 = 0.142, df = 2, p = 0.932), nor in the PO of the ticks (Kruskal-Wallis-Test, χ^2 = 0.081, df = 2, p = 0.96). Table 3.7 shows the average numbers of *Rhipicephalus sanguineus* individuals found per scat sample each year; in 2008 the value is 14.27 individuals per scat, which is 7 times, and 3.5 times, higher than in the years before. *Haemaphysalis leachi* does not vary much in its average numbers of individuals each year with SD of ± 2.03, in comparison with the SD of ± 6.35 of *Rhipicephalus sanguineus* (Fig. 3.9). The other three tick species always showed an average number of less then one per faeces. In the year 2008 the average number of tick individuals per faecal sample is much higher than in the two previous years (Tab. 3.7), but statistically there is no significant difference in the total average tick numbers found in scats (ANOVA, $F_{2,14}$ = 0.256, p = 0.778). Looking at the sex ratio of all found tick individuals there is a relatively even split between males and females, with a slightly higher percentage of female ticks in all three years (see Tab. 3.3 in Appendix 3). *Amblyomma* spp. could only be found in its nymph state and in all three years in low numbers (1-6 individuals).

Figure 3.10 shows the correlation between the frequency of occurrence of ticks, from all three study years, and the total rainfall data of the wet season before faecal sample collection. The wet season of 2006 started in October 2005 lasting until April 2006, followed by the first faeces collection period, carried out from July until September 2006. In the wet season of 2007, there was higher rainfall than in the 2006 wet season, the frequency of occurrence of ticks decreased in 2007. In the wet season of 2008 the amount of rainfall was similar of that of 2007, and the frequency of occurrence of ticks increased, even higher than in 2006. There is no significant correlation between frequency of occurrence of ticks and total rainfall (Pearson correlation factor = -0.229, p_2 = 0.853).

A higher amount of rainfall results in fewer *Haemaphysalis leachi* individuals (small PO) in the scat samples, while the frequency of occurrence stays the same despite higher rainfall (Fig. 3.11). *Rhipicephalus sanguineus* (Fig. 3.12) seems to show the opposite; the wetter it gets and stays the more individuals are found in the faecal samples (high PO) and the frequency of occurrence also increases. Statistically there is neither a significant correlation between annual rainfall and the frequency of occurrence of *Haemaphysalis leachi* (Pearson correlation factor = -0.742, p_2 = 0.468), nor with its percentage occurrence (Pearson correlation factor = -0.393, p_2 = 0.743). The same for counts for the correlation between the occurrence of *Rhipicephalus sanguineus* and the annual amount of rain (Pearson correlation factor (FO) = -0.475, p_2 = 0.685, Pearson correlation factor (PO) = -0.399, p_2 = 0.739).



	Amblyomma spp.	*Haemaphysalis leachi*	*Hyalomma truncatum*	*Rhipicephalus sanguineus*	*Rhipicephalus simus*	Mites	Nematoda
2006	5.26	68.42	5.26	63.16	0.00	57.89	21.05
2007	9.84	72.13	0.00	63.93	0.00	73.77	13.11
2008	0.97	69.90	1.94	91.26	0.97	68.93	26.21

Figure 3.8: Frequency of occurrence of ectoparasites in scat samples in the years 2006 (N=19), 2007 (N=61) and 2008 (N=103).

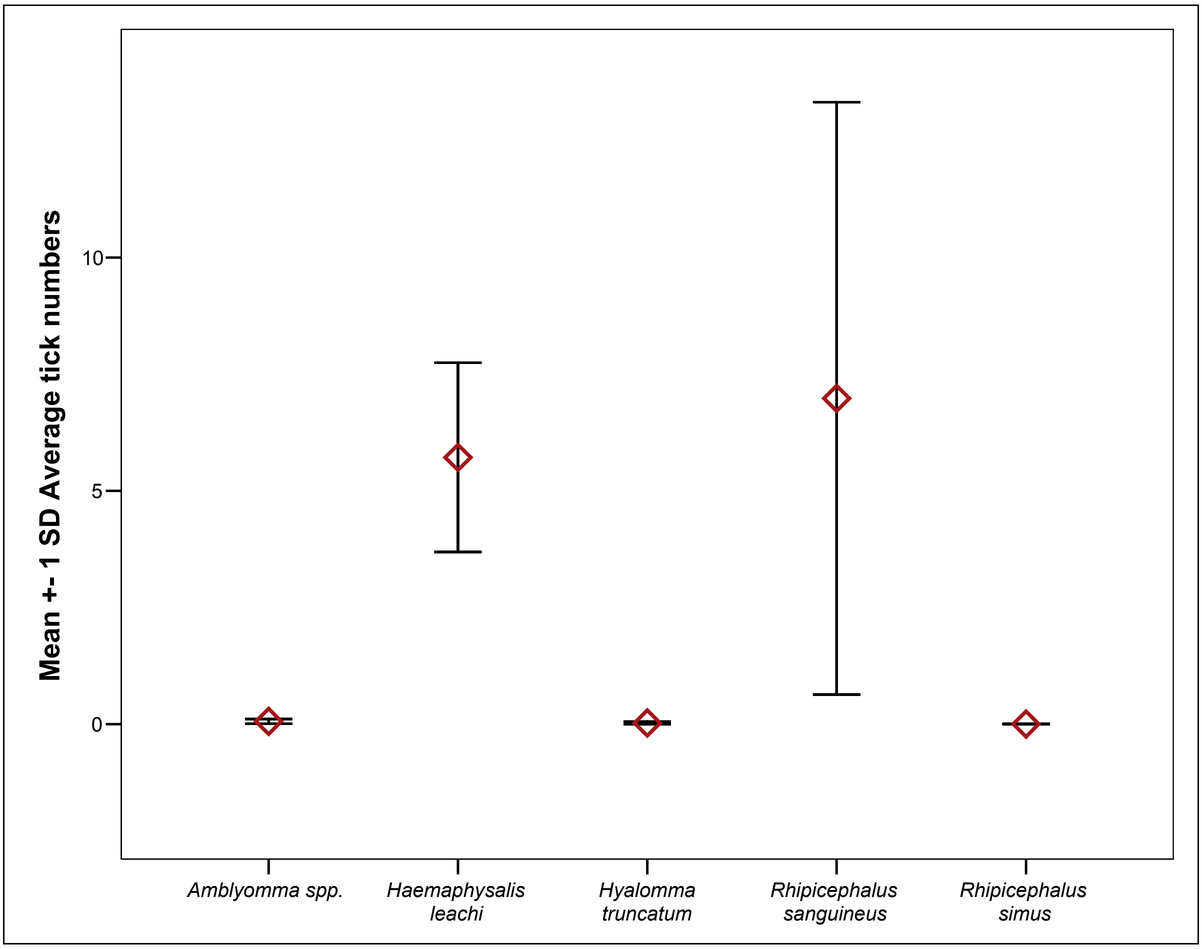


Figure 3.9: Average numbers of ticks and their SD in the years 2006, 2007 and 2008.

Table 3.6: Frequency of occurrence and percentage occurrence of ticks within the group 'ticks' in the years 2006 (N=18), 2007 (N=55) and 2008 (N=98).

Species	**FO of samples with ticks 2006 (N= 18)**	**PO (2006)**	**FO of samples with ticks 2007 (N= 55)**	**PO (2007)**	**FO of samples with ticks 2008 (N= 98)**	**PO (2008)**
Amblyomma spp.	5.56	0.67	10.91	0.91	1.02	0.06
Haemaphysalis leachi	72.22	67.33	80.00	65.10	73.47	20.75
Hyalomma truncatum	5.56	0.67			2.04	0.11
Rhipicephalus sanguineus	66.67	31.33	70.91	33.99	95.92	79.03
Rhipicephalus simus					1.02	0.06

Table 3.7: Numbers of ticks found in LNP (2006, 2007 & 2008) and the average numbers of ticks in a single faecal sample containing ticks.

Species 2006	**No. of male ticks**	**No. of female ticks**	**No. of nymphs**	**No. of fed ticks**	**Total**	**Average**
Amblyomma spp.			1		**1**	0.06
Haemaphysalis leachi	47	51	0	3	**101**	5.61
Hyalomma truncatum		1			**1**	0.06
Rhipicephalus sanguineus	17	28	0	2	**47**	2.61
Total	**64**	**80**	**1**	**5**	**150**	**8.33**
Species 2007	**No. of male ticks**	**No. of female ticks**	**No. of nymphs**	**No. of fed ticks**	**Total**	**Average**
Amblyomma spp.			6		**6**	0.11
Haemaphysalis leachi	206	203	5	15	**429**	7.80
Rhipicephalus sanguineus	102	118	0	4	**224**	4.07
Total	**308**	**321**	**11**	**19**	**659**	**11.98**
Species 2008	**No. of male ticks**	**No. of female ticks**	**No. of nymphs**	**No. of fed ticks**	**Total**	**Average**
Amblyomma spp.			1		**1**	0.01
Haemaphysalis leachi	164	179	6	18	**367**	3.74
Hyalomma truncatum	1	1			**2**	0.02
Rhipicephalus sanguineus	656	725	3	14	**1398**	14.27
Rhipicephalus simus		1			**1**	0.01
Total	**821**	**906**	**10**	**32**	**1769**	**18.05**

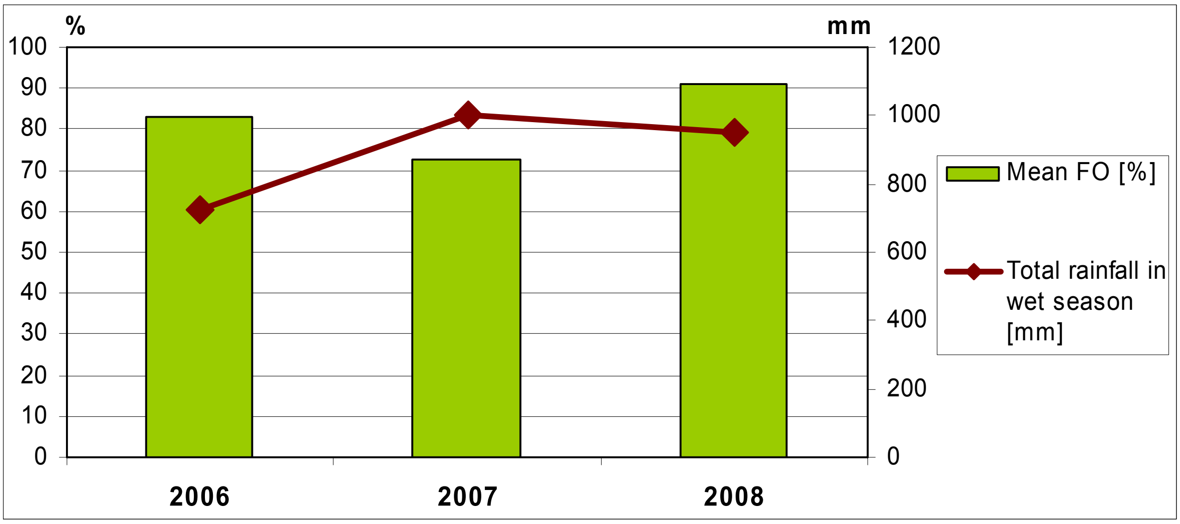


Figure 3.10: Frequency of occurrence of ticks in the years 2006 (N=19), 2007 (N=61) and 2008 (N=103) correlated with total rainfall data.

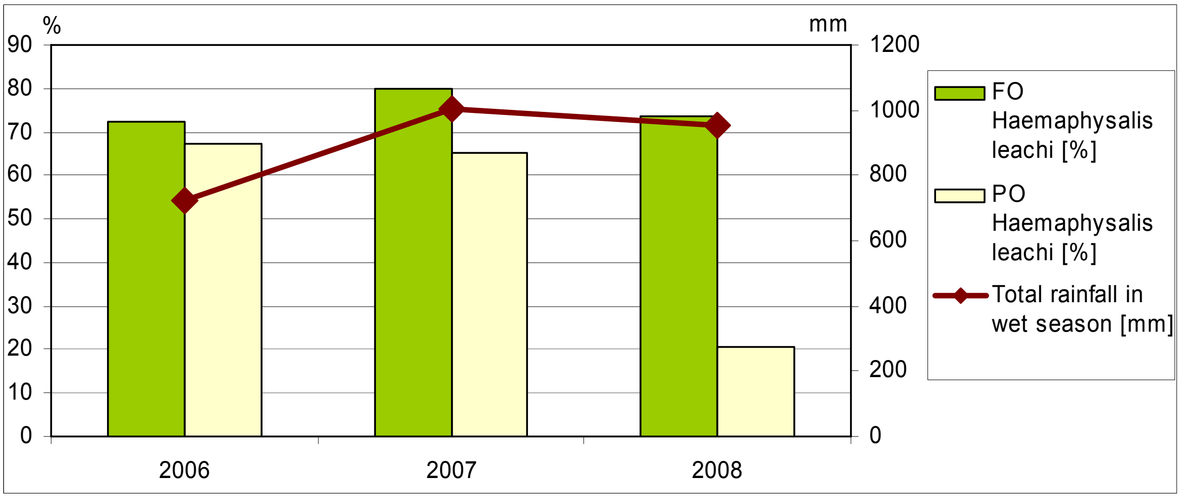


Figure 3.11: Frequency of occurrence and percentage occurrence of *Haemaphysalis leachi* in the years 2006, 2007 and 2008 correlated with total rainfall data.

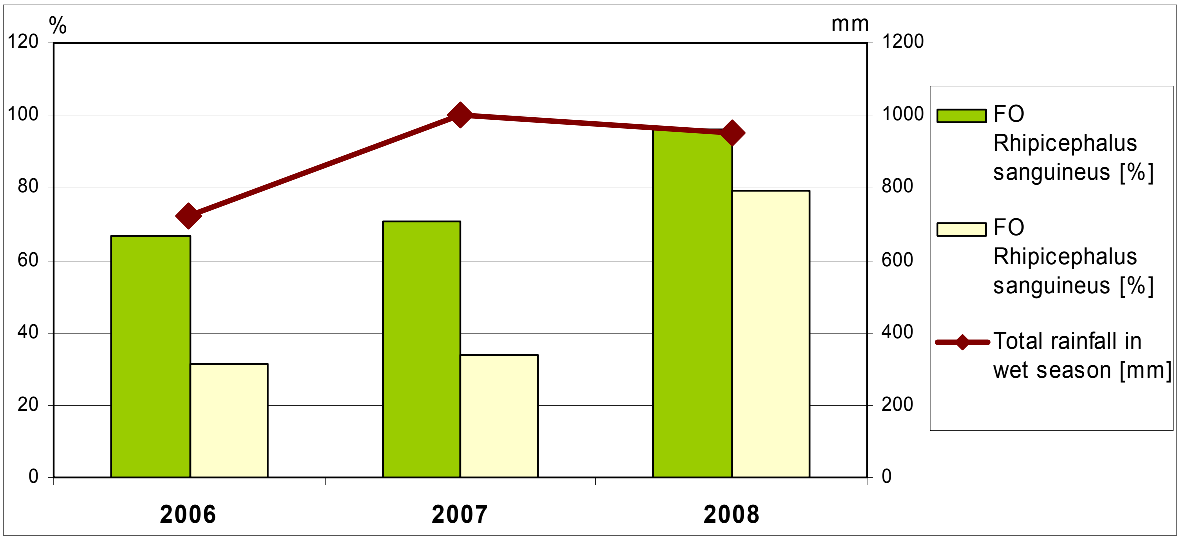


Figure 3.12: Frequency of occurrence and percentage occurrence of *Rhipicephalus sanguineus* in the years 2006, 2007 and 2008 correlated with total rainfall data.

3.3.2.2. Monthly change of parasite composition

Analyses of monthly changes in tick composition revealed that adult *Rhipicephalus sanguineus* are more frequent in FO and PO in the beginning of the dry season, while with *Haemaphysalis leachi* the percentage occurrence rises towards the end of dry season (Fig. 3.13 -3.18). *Haemaphysalis leachi* is weakly negative correlated with the monthly rain amount (Pearson correlation factor = -0.289, p_2 = 0.338), which supports the statement that this species seems to occur more often at the end of dry season when it was drier. In contrast *Rhipicephalus sanguineus* is weakly positive correlated with the monthly rainfall data (Pearson correlation factor = -0.300, p_2 = 0.319), which could explain the higher occurrences just after the rainy season. Figures 3.13 to 3.15 show the frequency of occurrence of all different types of ectoparasites. In the mites and the Nematoda there is no obvious pattern between months; this is also the case with *Hyalomma truncatum. Amblyomma* spp. seems to occur only later in the year. The percentage occurrence of the tick species within all months of this study is shown in Figures 3.16 to 3.18.

There is no significant correlation between monthly rainfall and frequency of occurrence of *Rhipicephalus sanguineus* (Fig. 3.19; Spearman's rho correlation factor = 0.067, p_2 = 0.844), *Haemaphysalis leachi* (Fig. 3.20; Spearman's rho correlation factor = 0.095, p_2 = 0.758) and ticks in general (Fig. 3.21; Spearman's rho correlation factor = 0.068, p_2 = 0.825). There is no significant correlation between PO of *Rhipicephalus sanguineus* or *Haemaphysalis leachi* and monthly rainfall (Spearman's rho correlation factor = 0.067, p_2 = 0.844 respectively Spearman's rho correlation factor = 0.095, p_2 = 0.758).

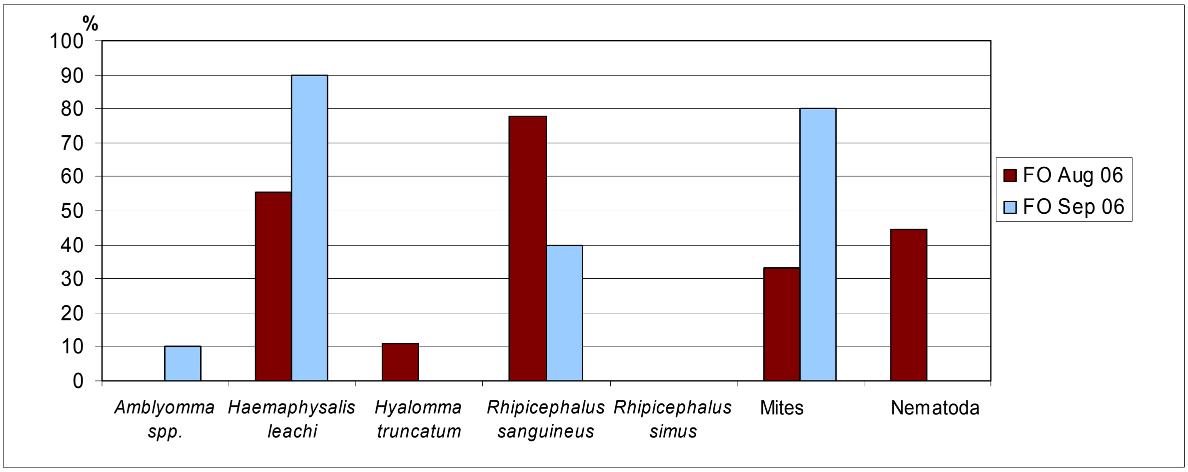


Figure 3.13: Frequency of occurrence of ectoparasites in August and September 2006.

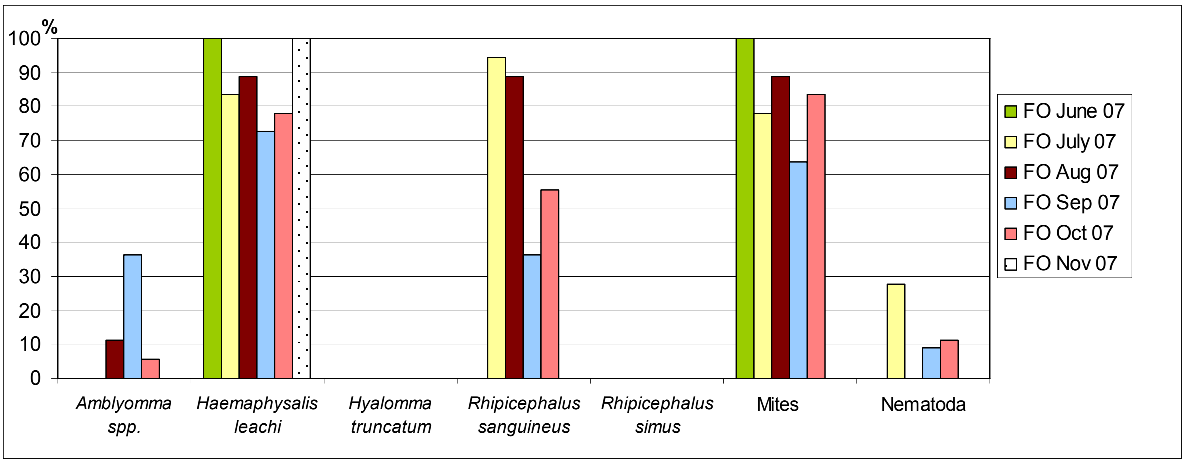


Figure 3.14: Frequency of occurrence of ectoparasites in June to November 2007.

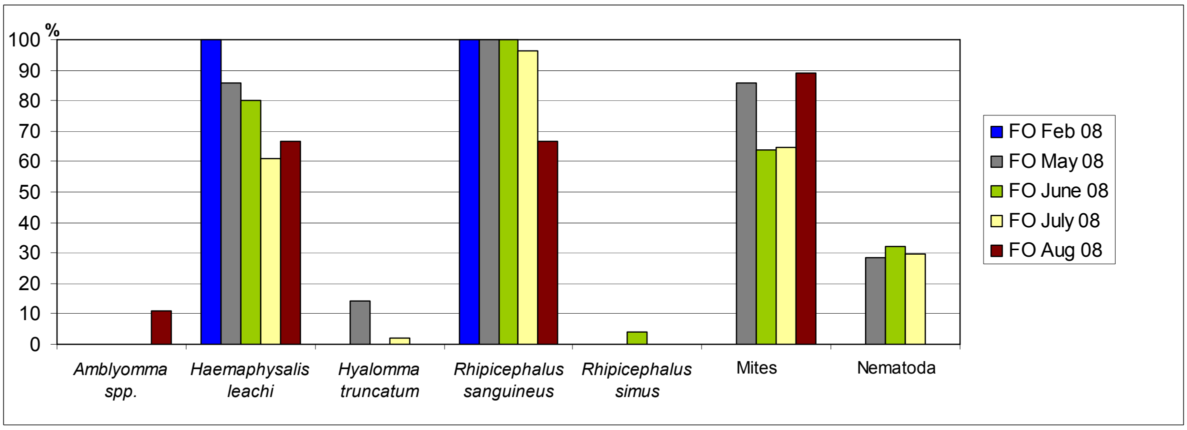


Figure 3.15: Frequency of occurrence of ectoparasites in February to August 2008

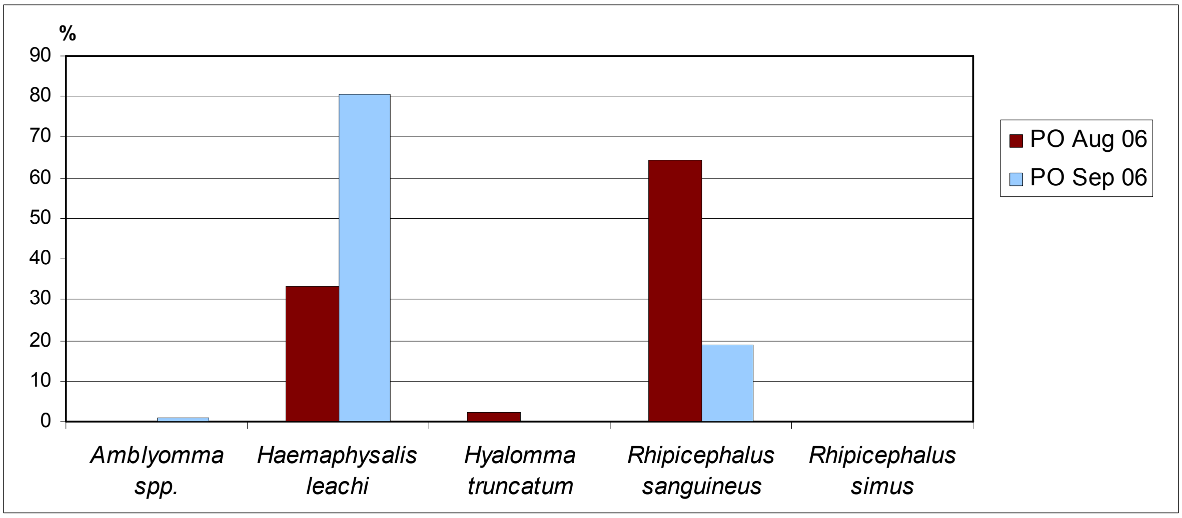


Figure 3.16: Percentage occurrence of tick species in August and September 2006.

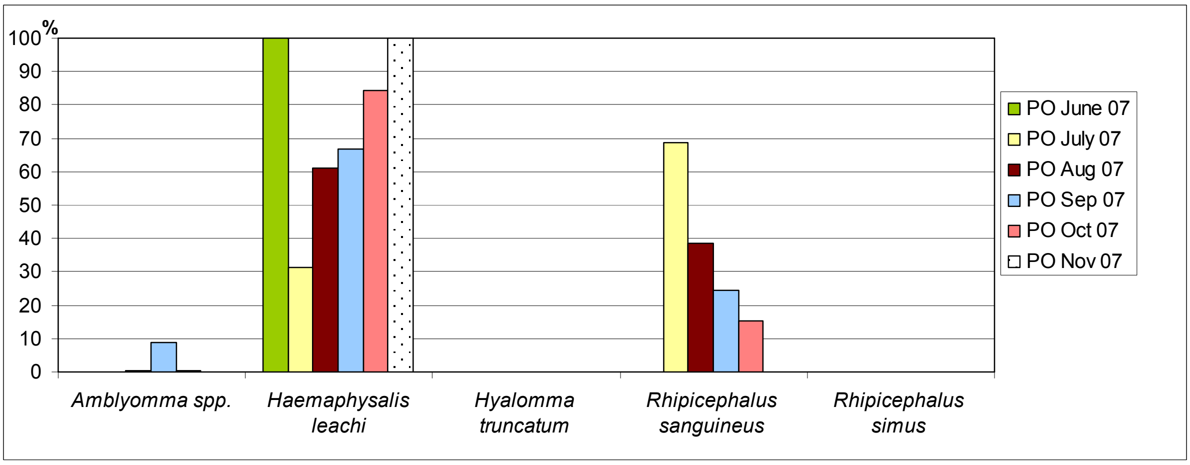


Figure 3.17: Percentage occurrence of tick species in June to November 2007.

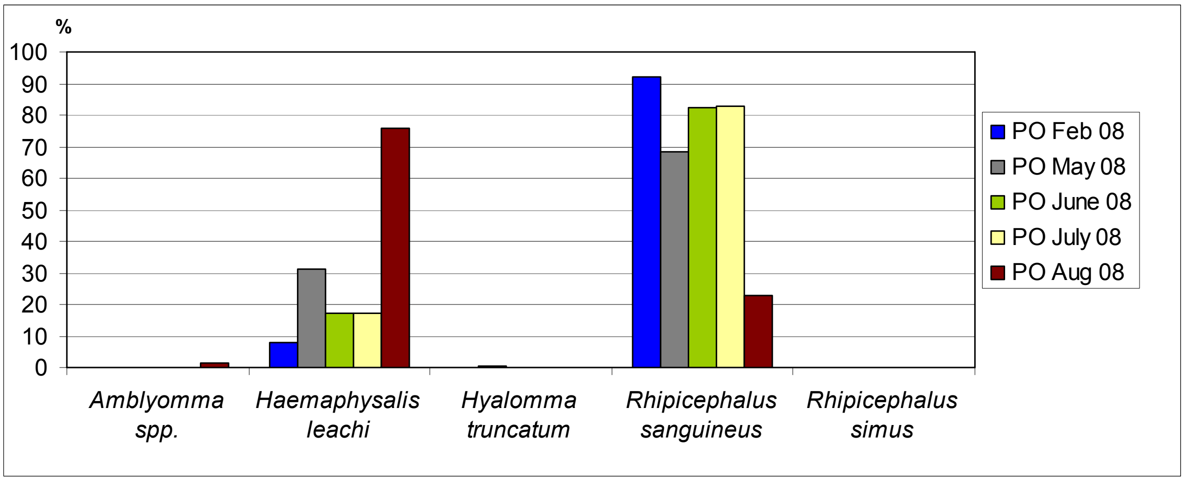


Figure 3.18: Percentage occurrence of tick species in February to August 2008.

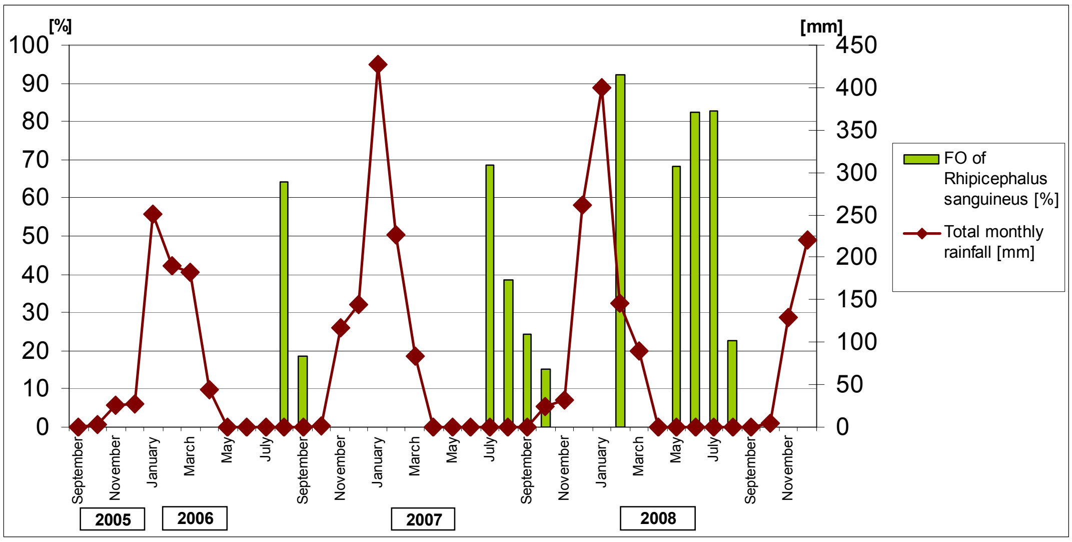


Figure 3.19: Monthly frequency of occurrence of *Rhipicephalus sanguineus* correlated with the monthly rainfall.

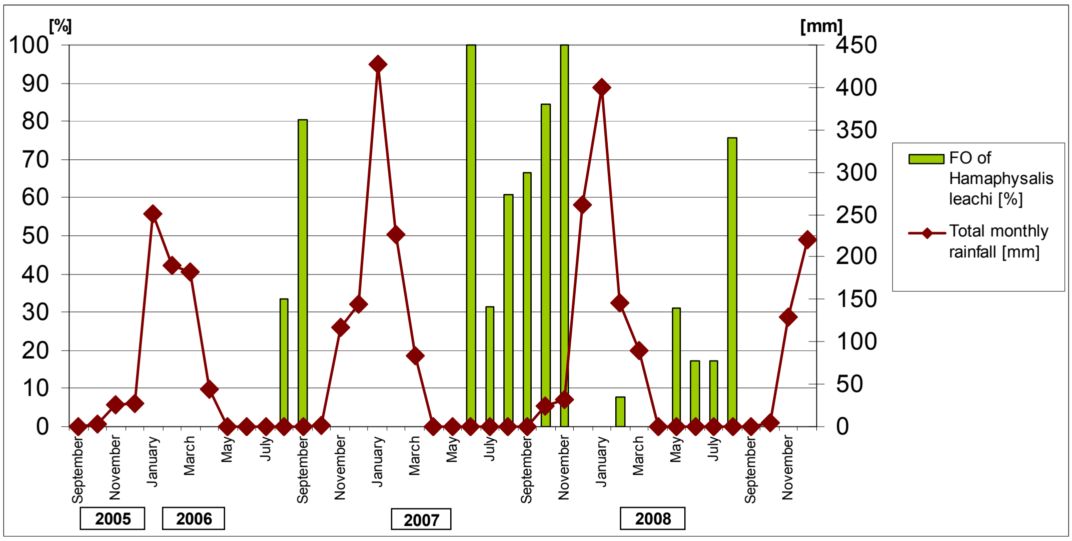


Figure 3.20: Monthly frequency of occurrence of *Haemaphysalis leachi* correlated with the monthly rainfall.

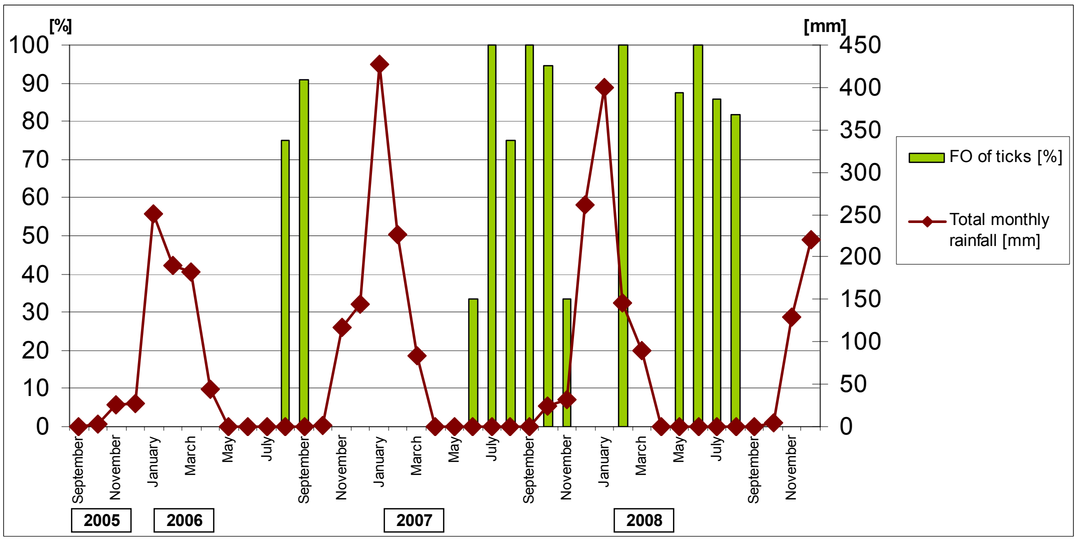


Figure 3.21: Monthly frequency of occurrence of tick species correlated with the monthly rainfall.

3.4. Discussion

Ticks are vectors of diseases and a burden to their hosts. It was surprising how many ticks were found in the faecal samples of the Servals in LNP in contrast to the study of KOK & PETNEY (1993), where they examined a total of 1.640 stomach contents from 56 South African species of small and medium sized mammals for ticks. There, only six ticks were found in three specimens of the Caracal (*Caracal caracal*), including the genus *Haemaphysalis.* They conclude that predation on ticks by small and medium sized mammals is uncommon in South Africa. Whether the Servals in Zambia prey on ticks actively or swallow them while grooming is not yet clear, but this study showed that high amounts of ticks are consumed by Zambian Servals.

In total, four genera and five species were identified with a total frequency of occurrence of 66% in Zambia-wide samples. Zambia-wide and LNP-wide results are similar, due to the fact that 82.06% of all Zambia-wide samples were collected in LNP. That is the reason accurate analyses on annual and monthly parasite composition were only possible with LNP samples. Although the total frequency of occurrence was 66% there was a big difference in the values for the various locations throughout Zambia. Most areas had a value lower than 30% (Kafue NP, Kasanka NP, Luangwa Valley, and Kushiya Farm), LNP showed evidence of ectoparasites in nearly 90% of all faecal samples. The samples from the Lower Zambezi NP had an ectoparasites frequency of occurrence of 41%, a little higher than the value for other areas in Zambia. Only the Lusaka area showed a higher percentage than Luangwa valley (67%), but the analyses of this area is based on only nine scat samples, which is not enough to show an accurate picture. The LNP shows high numbers of ectoparasites, which could be related to the human influence there due to small size of the National Park. The people living around LNP keep a lot of dogs, which are the main host of the Dog Ticks *R. sanguineus* and *H. leachi*. The locals also take their dogs into the LNP to help hunting, which additionally may support tick spreading onto wild animals. Servals also hunt on poultry in the villages, which may get them infested easier than staying in LNP. Other larger wilderness areas, like Kafue NP and Lower Zambezi NP, show lower infesting numbers (18%, respectively 41%). The other possible explanation is that the values are biased towards the number of collected scats. As shown in Chapter 2, only numbers above 88 scat samples could describe the prey spectrum accurately; the ectoparasites composition may also only be fully documented after a similar number of samples.

Zambia-wide, mites were found in 61%, while nematodes could only be found in 19% of the scats. In LNP, the frequency of occurrence of mites was 67% and that of nematodes was 20%. Nematodes may only be found in small pieces after they have been digested and therefore are difficult to identify. Mites are clearly underestimated in this study as they might also have been washed away while rinsing the faecal samples.

Ticks were found, identified and counted mostly in their adult stage. That could be due to the fact that the mature ticks have a harder ectodermis, which protects them from being digested. This may also be because immature ticks prefer to have smaller mammals as hosts, like rodents (Prof. SCHEIN, personal communication). FYUMAGWA et al. (2007) stated that in the Ngorogoro Crater in Tanzania most adult ticks were present in the wet season between March and June and most immature ticks were present during the peak dry season in September and October. Adult *Hyalomma* spp. are more common in the wet months, as well are *Rhipicephalus* spp., while adult *Haemaphysalis leachi* are found throughout the whole year (WALKER et al. 2003),

In all faecal samples found at the different locations in Zambia, *Rhipicephalus sanguineus* and *Haemaphysalis leachi* are the most frequently occurring tick species. The same picture emerges in LNP. All tick species occurred in nearly equal sex ratios. The mean number of ticks occurring in one scat sample in all Zambian locations was 13.01 individuals, where *Rhipicephalus sanguineus* occurs with 8.4 individuals and *Haemaphysalis leachi* with 4.5 individuals. In LNP the mean number of ticks was slightly higher, with 14.7 individuals per scat, 9.6 on average were found of *Rhipicephalus sanguineus* individuals and 5.2 of *Haemaphysalis leachi* individuals. ZIEGER et al. (1998b) identified a mean burden of one to 17608 ticks per animal, where birds and rodents showed the lowest mean number of ticks in contrast to the ungulates (which carried some thousands, e.g. an impala with 25735 ticks of all stages). These high numbers were counted on a game ranch, but are comparable to the heavy burden of animals living in wildlife areas in South Africa (HORAK et al. 1992, ZIEGER et al. 1998b).

Adult *Amblyomma* and *Hyalomma* species usually seek for hosts from the ground, and ticks of both genera are apparently more active at night (FYUMAGWA et al. 2007, WALKER et al. 2003), whereas COLBO & MACLEOD (1976) stated that certain birds are important hosts for these genera. Both these genera were not common in the Servals in LNP despite Servals here being mostly nocturnal animals (see Chapter 2) and their height is not far from the ground, and they feed on birds on a quite high amount (~25%) as well. *Amblyomma variegatum* is most widely distributed tick on livestock in Africa (HOOGSTRAAL 1956), but in Luangwa valley no livestock farming is possible due to the sleeping sickness carried by the Tsetse Fly. ZIEGER et al. (1998b) identifies the hosts of *A. variegatum* as some birds, but no rodents. Through birds the Serval preys on, the ticks could be ingested, without the Serval being the host of this species. This could explain the low numbers of this tick species. *Hyalomma truncatum* is common in drier areas (HOOGSTRAAL 1956). Following WALKER et al.

(2003) adult *H. truncatum* prefer large ungulates as hosts, but the immature stages feed on rodents, especially gerbils. In this study immature ticks could be found only on rare occasions, so that there is no comparison possible.

Adult *Rhipicephalus simus* feed on large carnivores, the immature on rodents (COLBO 1973, MACLEOD 1977, WALKER et al. 2003). Although it is most common in savannah climates, it prefers moderate to high rainfall (WALKER et al. 2003), which the eastern parts of Zambia do not have, but at locations such as Lower Zambezi NP, Kasanka NP, Lusaka Area and Kushiya Farm, the preferred climate occurs. It is also mentioned that this tick never occurs in high numbers (WALKER et al. 2003), which could explain the fact that this tick was found only once in 2008.

Rhipicephalus sanguineus is the most wide-spread tick throughout the tropics and sub-tropics (WALKER et al. 2003). Adult and immature stages nowadays are specialized to feed on dogs; possibly originally feeding on the smaller carnivores these also fit the needs of this tick. But this genus is not found on birds or reptiles (HOOGSTRAAL 1956). The fact that *Rhipicephalus* species are very difficult to tell apart (HOOGSTRAAL 1956) could have biased the result on this genus. The data of the study of ZIEGER et al. (1998a) shows *Rhipicephalus appendiculatus* comprising 90% of all collected ticks, which could be explained by high cattle farming shifting the tick composition (MACLEOD 1970) and *R. sanguineus* is more specialized on carnivore hosts. Therefore, in this study there cannot be a misidentification of *R. appendiculatus* as *R. sanguineus,* due to the obvious appendix (“tail”) of *R. appendiculatus*.

Haemaphysalis leachi is a ubiquitous species in tropical and southern Africa (HOOGSTRAAL 1956) and like *Rhipicephalus sanguineus* prefers dogs, but also is found on larger cats and other carnivores, like jackal and civet (HOOGSTRAAL 1956, COLBO 1973, MACLEOD 1977, WALKER et al. 2003). In contrast to *R. sanguineus* the immature ticks can feed on the same hosts as the adult ones (WALKER et al. 2003), which is supported by this data as *H. leachi* nymphs could be found nearly five times as often as the nymphs of *Rhipicephalus sanguineus*. This tick prefers the warm and humid conditions (WALKER et al. 2003).

The analyses of annual and monthly changes revealed that, in all three years and each month *Haemaphysalis leachi* and *Rhipicephalus sanguineus* are the most frequently occurring tick species, with the other species playing a minor role. The only big difference within the years occurred in 2008 when *Rhipicephalus sanguineus* had double the percentage occurrence value of *Haemaphysalis leachi* and also showed higher values in frequency of occurrence; the percentage occurrence increased to 80%. This situation cannot be explained by the data or observations in this study, but a possible explanation is that

Rhipicephalus sanguineus benefited from the last good rainfalls in the years before (Fig. 3.10) as the wetter it gets and stays the more often and the more individuals are found. This also fits the description given by WALKER et al. (2003) that *Rhipicephalus sanguineus* prefers the moister habitats than the desert areas. Why *Haemaphysalis leachi* decreases with a higher amount of rainfall (Fig. 3.9) cannot be explained by previous studies, as this contradicts the explanation of WALKER et al. (2003) which says that humid conditions are preferred by *Haemaphysalis leachi. Haemaphysalis leachi* occurs less in 2008 as in this year the mean number per scat sample is only half of the number of the previous years. A possible interspecific competition between these two tick species needs further investigation.

Species with a low value of FO and PO show a big variation between the years, which is biased towards the low numbers in which they occur. *Amblyomma* spp. could only be found eight times in all three years and only nymphs were discovered. ZIEGER et al. (1998a) and WALKER et al. (2003) state that in Zambia *A. variegatum* only occurs in adult stage from October to February and within this period of time only 44 scats could be collected, and only one (2.3%) during this time (in October 2007) contained nymphs of *Amblyomma* spp..

In 2008 the tick burden was higher than the years before. Whether this was due to the good rainfall in previous years, or to the higher numbers of collected faecal samples, is unclear. In the year 2008 the average burden per scat is 5.4, in 2007 4.6 and in 2006 2.2 ticks. As the wet season 2005 was a very dry one, it is possible that numbers of ticks went down in that year and recovered slowly within subsequent years and the good rainfalls. Bush fires also control tick populations (ZIEGER et al. 1998a, FYUMAGWA et al. 2007), but in Luambe NP the bush fires are not actively managed and they occurred each year at a similar level and in similar regions as the majority were man-made bush fires, so that this should not have influenced the tick populations.

Analyses of monthly changes in tick composition revealed that adult *Rhipicephalus sanguineus* have higher FO and PO values in the beginning of the dry season, as this tick is in its adult stage in summer/wet season. With *Haemaphysalis leachi*, the percentage occurrence of adults rises towards the end of dry season as it completes all stages throughout the year and the less *R. sanguineus* the ratio shows a competitive advantage for *Haemaphysalis leachi.*

Analyses are clearly biased towards dry season as most of the samples (98.2%) were collected between May to October. That is why no clear pattern emerges when comparing rainfall data with monthly tick occurrence in faecal samples. In the months with highest precipitation no data on the ticks were collected.

Further research on the diseases carried by these ticks is necessary. Animals can die due to heavy tick burdens and the diseases transmitted by them, although wildlife is usually not greatly infected by blood parasites. As most of the ticks in these samples are still intact and stored appropriately, it is possible to analyse the viruses carried by them. This could aid in filling the gap in the knowledge of tick-borne diseases for felids in Luangwa Valley, Zambia. It is may also be possible to find out more about the Nematoda species found in the faecal samples by using some faecal matter from the DNA samples, smears can be used to find Nematoda eggs and a DNA analyses carried out for species identification. BJORK et al. (2000) found 7 different Nematoda taxa in 33 faecal samples from lions in Tanzania using these methods.

3.5. Summary Chapter 3

This chapter gives a closer insight into the ectoparasites of Servals, found in scats in Zambia. Besides nematodes and mites, there were four families of the Ixodidae found, of which there were five different tick species. Annual and monthly changes in tick composition, and correlations with rainfall data, were analysed for the samples of Luambe National Park. Zambia-wide 66% of the faecal samples contained any sort of parasites. The most common parasite with a frequency of occurrence of 78% was *Rhipicephalus sanguineus*, the 'Brown Dog Tick'. *Haemaphysalis leachi*, the 'Yellow Dog Tick', was found in 65% of all samples, and mites were found in 60%. Nematoda occur in nearly one fifth of all samples. The other tick species had a minor role, with a frequency each of less than 4%. In Luambe National Park *Rhipicephalus sanguineus* and *Haemaphysalis leachi* were also the most frequent tick species, but the majority were *Haemaphysalis leachi.* All tick species occurred in nearly equal sex ratios, with a small favour to female ticks. The mean number of ticks occurring in one scat sample in all Zambian locations was 13.01 individuals, whereas in LNP the mean number of ticks was slightly higher with 14.7 ticks per scat. In 2008 the burden was higher than the years before and the numbers of *Rhipicephalus sanguineus* increased to a percentage occurrence of 80% and a frequency of occurrence of 96%. Analyses of annual and monthly changes in tick composition revealed no significant correlations, but there was a pattern of adult *Rhipicephalus sanguineus* being more frequent in the beginning of the dry season, while with *Haemaphysalis leachi* the percentage occurrence raised towards the end of the dry season. Further research on the diseases carried by the ticks is needed. All parasites are stored in Ethanol and can be used for further studies on tick transmitted diseases.

4. Potential habitats and distribution of *Leptailurus serval*

This chapter aims to describe the habitat preferences of *Leptailurus serval* in Luambe National Park, as well as its distribution in this region. Results will be compared with the general believe that the Serval is a wetland/savannah species.

4.1. Introduction

The effects of habitat loss, fragmentation, and degradation on carnivore populations and their prey species are largely unknown (CREEL 2001). Many wild cat species are becoming endangered, due to habitat disturbance (NOWELL & JACKSON 1996). Edge effects caused by human activities, such as firewood and charcoal collection, agricultural techniques e.g. 'chitemene', trophy hunting quotas in Game Management Areas and poaching (commercial and subsistence) should be investigated and the impact on wild cat species ecology, populations and behaviour explored. But with lacking knowledge of the ecological needs of respective species, an efficient protection is impossible.

WILSON (1984) and SUNQUIST & SUNQUIST (2002) stated, that the Serval has quite specific habitat requirements, so it may be locally restricted to smaller areas within its broad distribution range; it is not found in areas of rainforest or desert like habitats. The IUCN describes the preferred habitats of the Serval as Subtropical/Tropical Dry Forest, Dry Savannah, Subtropical/Tropical Dry Grassland, Subtropical/Tropical Seasonally Wet/Flooded Grassland, Subtropical/Tropical High Altitude Grassland, Permanent Rivers/Streams/Creeks Wetlands (including waterfalls), and Shrub Dominated Wetlands (source: http://www.iucnredlist.org/ apps/redlist/details/11638/0; 04. 2010). In general Servals are associated with wetlands (SMITHERS 1978, GEERTSEMA 1985, BOWLAND 1990). GEERTSEMA (1981) associated Servals with well-watered habitats like grass savannahs along river reed beds and swamps, in brush and open woodlands and along the edge of forests. VAN AARDE & SKINNER (1986) showed significantly higher usage of riverine habitats than expected. GRIMSHAW et al. (1995) and ANDAMA (2000) even reported Servals on high altitude moorlands and bamboo thickets. ANSELL & DOWSETT (1988) found Servals in Malawi in most types of habitats, including montane grassland, mostly near streams. Servals show a preference for medium to tall grass cover and areas with surrounding swamps; generally speaking for places with a good level of vegetation, cover, water and prey (GEERTSEMA 1985). Cover may be the most important factor in its distribution (SMITHERS 1978, GEERTSEMA 1985). WILSON (1984) notes similar habitat preferences: "…well watered area with tall grass, or in places with good cover of scrub or riverine vegetation." HERMANN et al. (2008) found a recent expansion of Servals in central South Africa, which was facilitated by the increase in man-made habitats, e.g. dams and weirs that promote the growth of reeds and other dense vegetation that support their main prey species. They came to this conclusion because most specimens in their study were collected close to perennial and non-perennial rivers or dams in landscapes that would otherwise be considered unsuitable for Servals.

Only recently ANDERSON (2009) prepared the first small scale habitat map for LNP and the surrounding Game Management Areas (GMAs). This map will help to examine the habitat needs of the Servals in LNP and to compare these to other Serval populations.

ANDERSON (2009) defined eight different habitat classes, besides the category 'Water', for LNP:

1. Thicket (T)

   There are two types, combined in this one class. "The first type consists of dense stands of deciduous bushes and small trees." (ANDERSON 2009; Fig. 4.1). Characteristic tree species are *Schrebera trichoclada* (Wooden Pair Tree) and *Diospyros quiloensis* (Crocodile-bark Jackal-berry). "The second type consists of dense shrubs occurring in open or closed stands. Occasionally tall trees are found within […]. Characteristic tree species are the *Kigelia africana* (Sausage Tree) and *Diospyros quiloensis*. Dominant shrubs include *Combretum obovatum* (Spiny White-leaved Combretum) and a variety of other *Combretum* species." (ANDERSON 2009). The grass layer is sparsely developed in both types.

Figure 4.1: Habitat type „Thicket“ in LNP.

2. Riverine Woodland (RW)

Riverine woodland habitat (Figure 4.2) "forms a narrow, intermittent belt of vegetation along the banks" (ANDERSON 2009) of Luangwa River and its Lagoons and ox-bow lakes. In addition to the tall woodland species, layer of dense shrubs and small trees are found as well. Characteristic tall tree species in this class are *Diospyros mespiliformis* (African Ebony/Jackal-berry), *Kigelia africana, Trichilia emetica* (Natal Mahogany), *Afzelia quanzensis* (Pod Mahogony/Lucky Bean Tree), *Colophospermum mopane* (Mopane) and *Combretum imberbe* (Leadwood) as shrub or tall tree. Smaller tree and shrub species include *Feretia aeruginescens* (Red-Leaved Medlar), *Combretum obovatum* and many other *Combretum* species. The grass layer in this class is sparse.

Figure 4.2: Habitat type „Riverine Woodland" in LNP.

3. Combretum Terminalia Woodland (CTW)

This class consists of "deciduous woodland dominated by *Combretum* and *Terminalia* species and is commonly found in close association with the Thicket class." (ANDERSON 2009). Characteristic trees are *Terminalia sericea* (Silver Terminalia) and various *Combretum* species, such as *C. fragrans (C. adegonium*, Four-leaved Combretum*)*, *C.collinum* subsp. *gazense* (Variable Combretum) and *C. imberbe*. This habitat type has a well developed grass layer with grasses of different heights.

Figure 4.3: Habitat type „Combretum Terminalia Woodland“ in LNP.

4. Acacia Woodland (AW)

This habitat type is represented in the most part by “very characteristic, dense, homogenous stands of *Acacia kirkii* (Flood-plain Acacia).” (ANDERSON 2009). This tree is very dominant and other plants or grasses are rarely found within (Fig. 4.4).

Figure 4.4: Habitat type „Acacia Woodland“ in LNP.

5. Mopane Woodland (MW)

Large areas of LNP are dominated by *Colophospermum mopane* (Mopane) trees, which grow up to 30m in height in a cathedral-like forest. *C. mopane* is the only characteristic tree species, but several other trees and shrubs are occasionally found, including *C. obovatum*, and *Capparis tomentosa* (Woolly Caper-bush). “The grass layer is short and not normally well developed.” (ANDERSON 2009).

Figure 4.5: Habitat type „Mopane Woodland“ in LNP.

6. Mopane Scrub Woodland (MSW)

In this class, *C. mopane* trees only grow a few meters in height and are often underdeveloped and multi-stemmed shrubs. The grass layer is almost non-existent and other plants are not common (Fig. 4.6).

Figure 4.6: Habitat type „Mopane Scrub Woodland“ in LNP.

7. Grassland (G)

The Grassland class is, in general, associated in some way with water. The major component is the floodplain formed by various rivers. “This floodplain covers an extensive area in the centre of LNP and accounts for the majority of the grassland in the park.” (ANDERSON 2009). Tall grassland up to 3 m in height is common, with occasional tree or shrub species within it, including *C. obovatum, K. africana,* and *C. Mopane* and occasionally *Acacia* species.

Figure 4.7: Habitat type „Grassland" in LNP.

8. Aquatic Association Grassland

This vegetation cover class consists of areas of land that are seasonally covered with water (Fig. 4.8). The ox-bow lakes and lagoons associated with the Luangwa River are included in this class. "Many of these areas hold water well into the dry season and, as such, support a range of aquatic association grasses, sedges and herbs." (ANDERSON 2009). Characteristic trees are few, but *C. imberbe* may be found.

Figure 4.8: Habitat type „Aquatic Association Grassland" in LNP.

4.2. Methods

Both, the distribution and the habitat preferences of Servals in Luambe National Park were analyzed using signs of Serval activity, such as sighting, spoor and faeces. All signs were recorded during the three study periods in the years 2006, 2007 and 2008 (see Chapter 1). Sightings were recorded with an observation sheet (see Appendix (Chapter 2)) each time and marked with a GPS device, the same with spoor locations which were recorded with a spoor sheet (see Appendix, average spoor sizes also mentioned in Appendix) and photographed. Scats were georeferenced as well, photographed and collected (see Chapter 2). All signs of activity were registered after incidental findings or during line transect walks.

Line transect sampling has been used since the early 1930's (BURNHAM et al. 1980). Transects are still a common tool to determine occurrence and abundance of animals (THOMAS et al. 2002, GREENWOOD et al. 2006). Line transect sampling requires randomly or systematically distributed line transects to give accurate recording (GREENWOOD et al. 2006). Ideally the lines are straight (THOMAS et al. 2002), as parallel lines avoid overlap (GREENWOOD et al. 2006).

The whole Luambe National Park was walked by foot systematically along line transects and faecal samples were collected, while sightings and spoor were recorded and georeferenced with a GPS device. Transects were completed by me, plus a local armed scout (for security reasons). All transects lines were walked once within 14 days in the dry season, during the months of September to October 2007 and June to July 2008.

4.2.1. Habitat classification in Luambe National Park and its bordering areas

The small scale habitat map of LNP (grid cells 29x29 m) by ANDERSON (2009) was used to overlay with signs of Serval activity, such as sightings, tracks and scats. These tracks and signs were analyzed using ArcMap© Version 9.1 (Environmental Systems Research Institute 2005) to find correlations between habitat and Serval distribution of LNP and its surrounding GMAs.

Habitat preferences were determined using the JOHNSON ranking technique (JOHNSON 1980). Different habitat class are ranked by their percentage availability in the study area on one hand; on the other hand they are ranked by the corresponding Serval's usage. The difference between these two ranks of each habitat class is calculated by subtracting the usage rank from the availability rank. Resulting values of each habitat type are sorted from the highest values to the lowest one, giving an indication of usage from "most preferred" to "least preferred". Both negative and positive values are possible, where positive values show a higher preference and negative values lower preference. The use of ranks avoids absolute statements about avoidance and preferences. JOHNSON (1980) argues that preference values indicate only the relative value of a component in comparison to others.

These habitat preferences by JOHNSON (1980) were calculated using direct correlation of use and availability. The use is defined by the percentage of locations of sightings, droppings and tracks in one habitat type, while the availability is the percentage of a habitat type available in the animal's range. The animal's range is a circle around all data points of this animal, the 'Circle of Available Area'. Here the whole population of LNP is used to represent species in the area. Animals usually do not recognize precise boundaries; hence a circle seems to be an adequate area of the animal's range (WEBER 1987). In addition a buffer of 500 m around this 'Circle of Available Area' was created.

The use *versus* availability approach has the advantage of not needing to make the assumption that some areas are never used by individual animals, this in contrast to presence-absence models (BOYCE et al. 2002, PEARCE & BOYCE 2006, KLAR 2008). The assumption, with this approach, is that observed occurrences are a subsample of available sites, which allows conclusions to be drawn about habitat preferences (MANLY et al. 1993).

Habitat preferences were also analysed with the JACOBS index (JACOBS 1974). This method gives either a negative or a positive value for a habitat preference following the formula:

Jacobs-Index = (p(obs) - p(exp))/(p(obs) + p(exp) - 2p(obs) p(exp)),

'p(obs)' is the frequency of usage (amount of locations/signs in a certain habitat) and 'p(exp)' the total area of this specific habitat represents. Habitat types with less than 5% share of the total study area are not included when using this method. If the usage of a habitat type is similar to its frequency of occurrence, then the index is 0, whereas a higher usage results in a positive result up to an index of +1 and a negative usage to an index of -1.

In addition to JACOBS index and JOHNSON ranks, use *versus* availability was compared using a chi-square test. This is recommended if the data is built on pooled animals (many individuals), as in this study (GARSHELIS 2000). If areas of available habitats are measured from a map rather than estimated by sampling, the chi-square goodness-of-fit test is recommended, rather than the chi-square test for homogeneity (GARSHELIS 2000). The goodness-of-fit test was calculated with SPSS© 13 and measurements were taken from the digital maps with ArcMap© Version 9.1 (Environmental Systems Research Institute 2005).

Annual changes in habitat use and preferences were also tested with SPSS© 13. Graphs are produced with SPSS© 13, Microsoft© Office Excel 2003 and XLSTAT© 2011.1.03.

4.2.2. Distribution in Luambe National Park

In this study transect lines were only walked for collecting presence/absence data, not for density estimation purposes. For this reason LNP was divided into grid cells of 10 km^2 in size. This size was chosen because it is big enough to make the method practical by producing 33 grid cells with a length of 3.3 km each, which is 109 km to walk for one person. On the other hand this grid size is small enough to meet a representative part of LNP by covering areas of all possible habitat classes. Straight transect lines were placed from the western to the eastern boundary of LNP, in the middle of each grid and marked with an X (see Fig. 4.9). Grids were walked if the start position in the west was within LNP, even if the eastern stop position was outside LNP.

In addition to this, samples were also collected when not walking transects. This could be a sighting, a spoor or droppings. This data was handled separately.

All analyses were visualised with ArcMap© Version 9.1 (Environmental Systems Research Institute 2005) and grids were marked with Serval presence or absence.

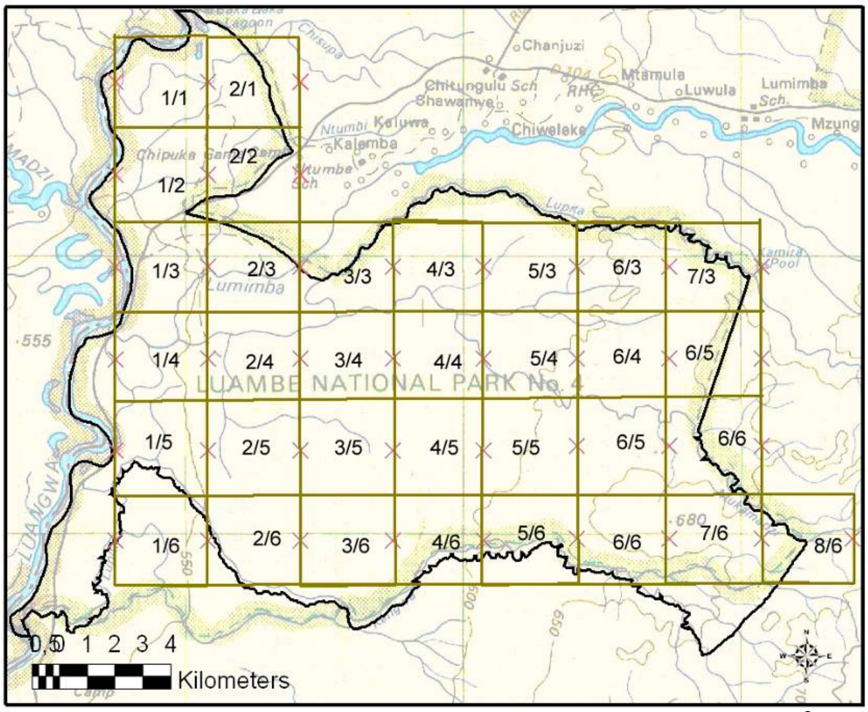


Figure 4.9: LNP divided into 33 grids each 3.3 by 3.3 km (10 km^2).
X = start position/end position of one transect line. Grid numbers in the middle.

4.3. Results

4.3.1. Habitat preferences in Luambe National Park and its bordering areas

Habitat preferences were calculated on the basis of 254 positions within LNP, which included sighting (30), dropping (206) and spoor (18) locations. Figure 4.10 shows LNP and its surrounding GMAs with the vegetation map overlaid with the signs of Serval activity. The main habitat type with Serval sign locations is Grassland (dark green). Table 4.1 shows the values as total numbers of findings and their percentages; with 61.42% of all findings in Grassland habitat, followed by Combretum Terminalia Woodland and Riverine Woodland.

Figure 4.11 shows the same map with the "Circle of Available Area" in violet colour, which has a size of 423 km^2, while the light blue area marks the 230 km^2 counting area for the JACOBS index calculations. In all calculations the habitat type „Water" is excluded, due to the fact that the serval is a land mammal.

Table 4.1: Percentages of composing habitat types in Luambe National Park and the number of Serval signs found.

Habitat type	% for JACOBS index	% for Available Area	% in LNP	% in LNP & GMAs	JOHNSON rank of availability	N samples	% of samples
Mopane Scrub Woodland	7.18	8.48	10.74	10.17	4	3	1.18
Thicket	3.06	5.45	5.57	5.32	5	14	5.51
Riverine Woodland	3.70	3.53	3.28	3.91	6	21	8.27
Combretum Terminalia Woodland	34.60	36.32	36.33	33.62	1	43	16.93
Grassland	22.48	16.59	14.3	11.51	3	156	61.42
Aquatic Association Grassland	1.48	1.42	1.77	2.50	8	5	1.97
Acacia Woodland	1.14	1.44	2.32	1.73	7	3	1.18
Water	0	0.29	0.11	0.96	9	0	0.00
Mopane Woodland	26.36	26.48	25.57	30.18	2	9	3.54
Total area [km²]	**230**	**423**	**331**	**854**			

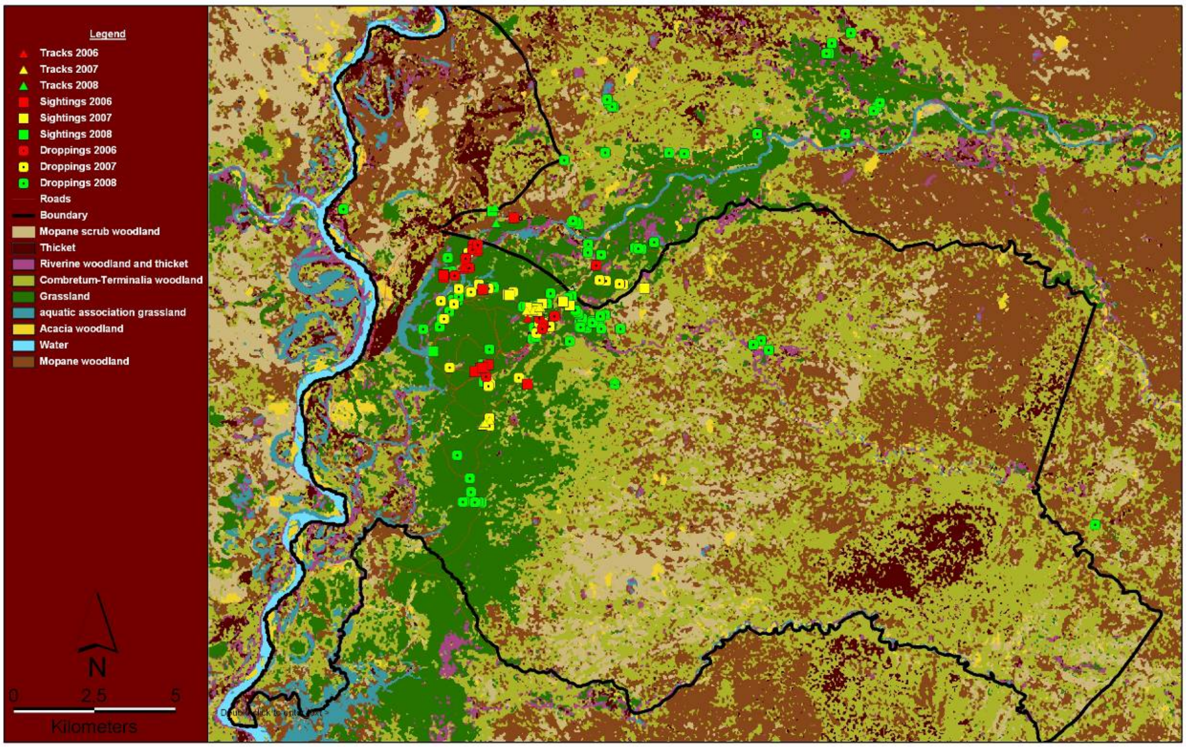


Figure 4.10: Luambe National Park vegetation map with all signs recorded for habitat analyses.

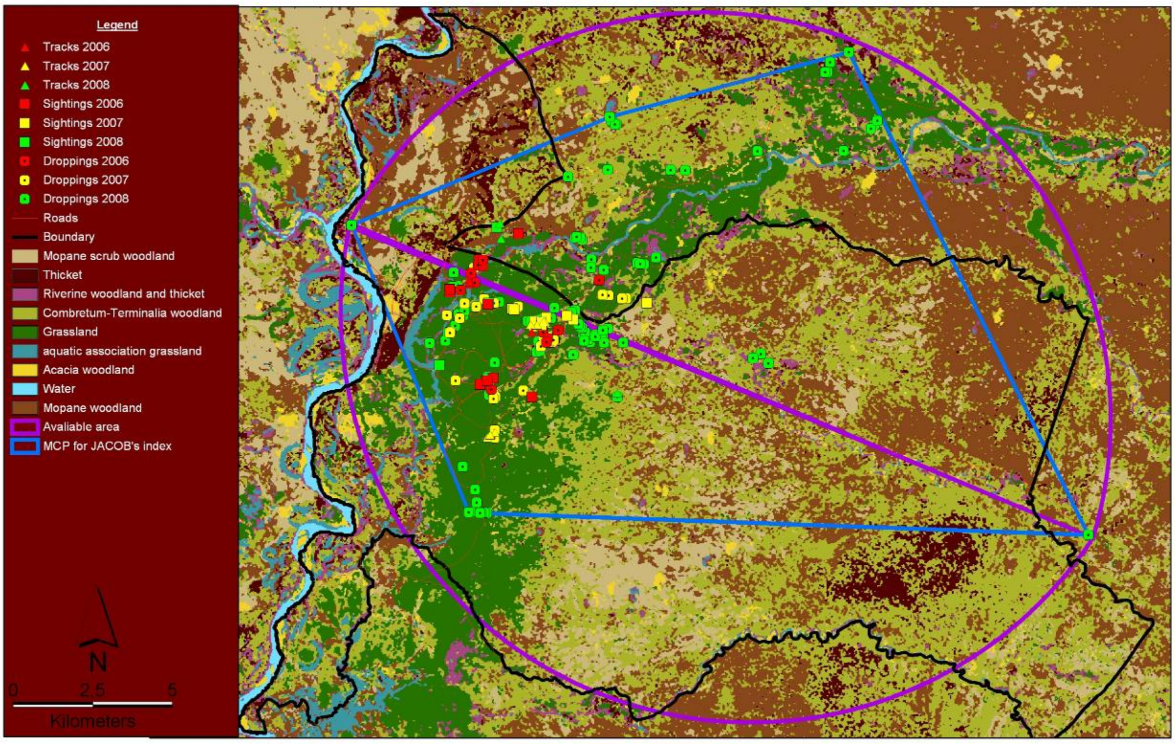


Figure 4.11: 'Circle of Available Area' and JACOBS index Area in LNP.

When the JACOBS index was used to calculate the Servals' habitat preferences, only the habitat type Grassland was categorized as preferred habitat. Due to the fact that all categories with a value of less than 5% are rejected in the JACOBS index, only four out of eight categories where used (see Fig. 4.12). Combretum Terminalia Woodland, Mopane Woodland and Mopane Scrub Woodland show a negative preference/an avoidance following the results of the JACOBS index.

Testing the habitat preferences with the JOHNSON ranks, not only Grassland, but also Riverine Woodland, Aquatic Association Grassland and Thicket are preferred habitat types (Fig. 4.13). Riverine Woodland is actually the highest preferred habitat type, followed by the two Grassland types and the Thicket. In this calculation, the same categories identified as less preferred/avoided with the JACOBS index, are found with the lowest preference values the Acacia Woodland being an addition to them.

All habitat categories showed a significant difference between use and availability (Chi-Square Test, $F_7 = 160.461$; p 0.000). The Chi-Square Test residual values (expected usage - observed usage) were plotted, resulting in the graph shown in Figure 4.14. There, the same four preferred habitat types calculated by the JOHNSON ranks are found, but with Grassland being the most preferred, as with the JACOBS index. Again, the other four categories are least preferred/are avoided, but in different ranking than in the JOHNSON ranks and in the JACOBS index.

Possible annual changes in habitat usage were calculated using the One Way ANOVA test. The test showed no significant differences in the usage of different habitat types ($F_{2,21} < 0.001$, $p = 1.000$; Fig. 4.15). The values of the JOHNSON ranks and the JACOBS index also do not show many differences (Figures 4.16 & 4.17) and the preferences and avoidances are equally every year. One exception is with the habitat type Acacia Woodland, which has a positive value in the JOHNSON ranks in 2007, while in the other years it has a negative or zero value. That means that in 2007 the Servals used the Acacia Woodland slightly more

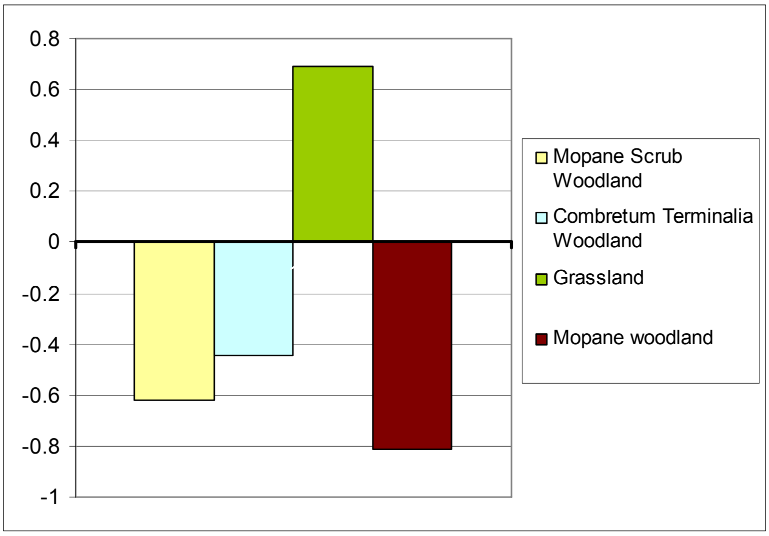


Figure 4.12: Habitat preferences of the Servals in LNP following the JACOBS index.

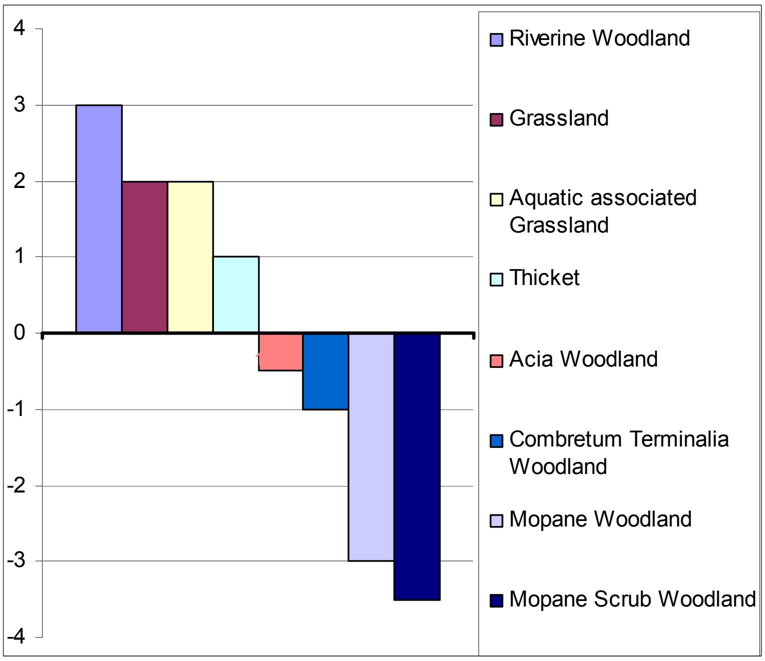


Figure 4.13: Habitat preferences of the Servals in LNP following the JOHNSON ranks.

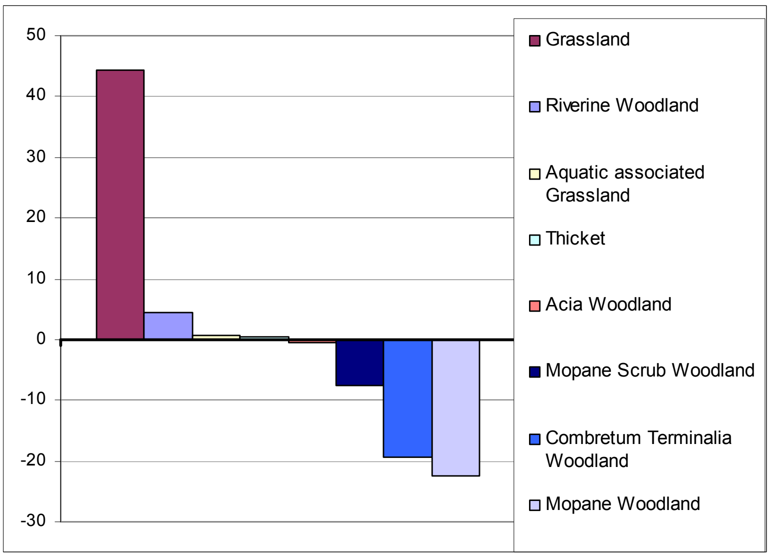


Figure 4.14: Plotted residual values of the Chi Square Test.

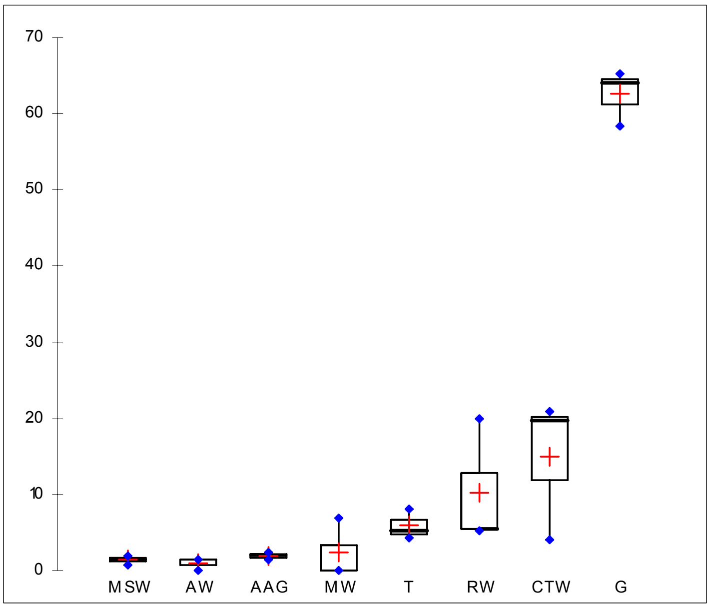
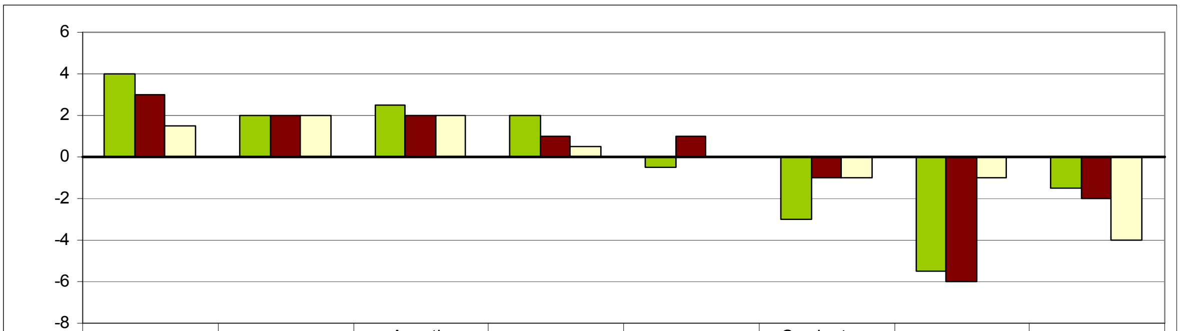
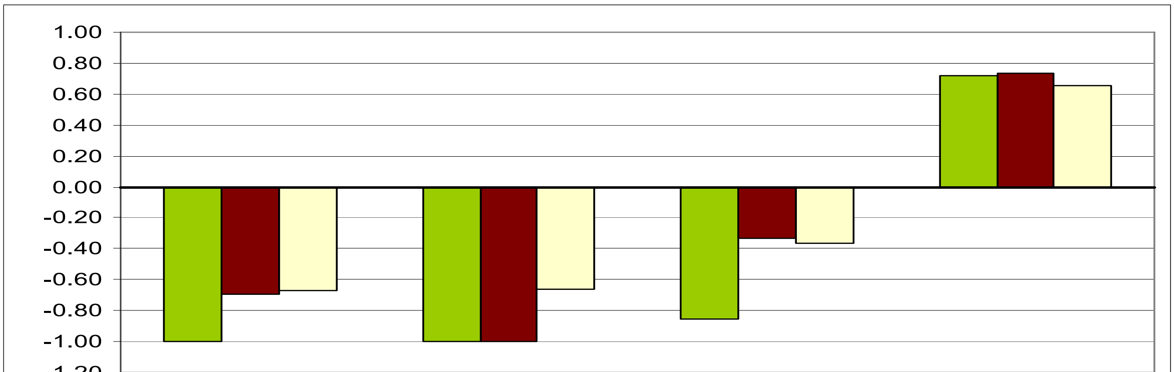


Figure 4.15: Box plot of the mean usage of different habitat types [%] in the study years**.**
MSW = Mopane Scrub Woodland, AW = Acacia Woodland, AAG = Aquatic Association Grassland, MW = Mopane Woodland, T = Thicket, RW = Riverine Woodland, CTW = Combretum Terminalia Woodland, Grassland.



	Riverine Woodland	Grassland	Aquatic associated Grassland	Thicket	Acia Woodland	Combretum Terminalia Woodland	Mopane Woodland	Mopane Scrub Woodland
2006	4	2	2.5	2	-0.5	-3	-5.5	-1.5
2007	3	2	2	1	1	-1	-6	-2
2008	1.5	2	2	0.5	0	-1	-1	-4

Figure 4.16: Habitat preferences of the Servals in LNP following the JOHNSON ranks in 2006, 2007 and 2008.



	Mopane Scrub Woodland	Mopane woodland	Combretum Terminalia Woodland	Grassland
2006	-1.0000	-1.0000	-0.8540	0.7195
2007	-0.6919	-1.0000	-0.3356	0.7327
2008	-0.6682	-0.6606	-0.3665	0.6568

Figure 4.17: Habitat preferences of the Servals in LNP following the JACOBS index in 2006, 2007 and 2008.

4.3.2. Distribution in Luambe National Park

The distribution was calculated on the basis of 170 positions within LNP, which included locations of sightings (26), droppings (129) and spoor (15) (Figure 4.18).

The distribution maps calculated using transect line walks show a presence of Servals in six grids, which make up an area of 60 km^2 (Figure 4.19, light green grids). This covers only 60% of the area used by this cat when random collections were done over 15 months in total (Figure 4.19, dark green grids), where Serval presence was determined in 100 km^2.

The LNP is 331 km^2 in size, which leads to the conclusion, that the Servals inhabit nearly one third (when considering all findings of Serval activities) to one fifth of it (when using transect data). As also shown in Chapter 4.3.1, Servals mainly occur in grasslands and riverine woodlands. Hence, the main distribution is along the central grassland area and its semi permanent riverbeds and associated vegetation (compare signs in Fig. 4.20). No Serval presence could be confirmed in the main grassland area (Grid 2/4) during the two transect line walks (Fig. 4.19).

When all the signs of Serval presence in LNP are taken into consideration to produce a Minimum Convex Polygon (MCP) with ArcMap©, the area of Serval presence is calculated as being 64 km^2 in size (Figure 4.21), which would lead to the conclusion that an area of one fifth of LNP is populated by Servals. With only the signs found on the transect walks an area of 39.7 km² is calculated (Fig. 4.22).

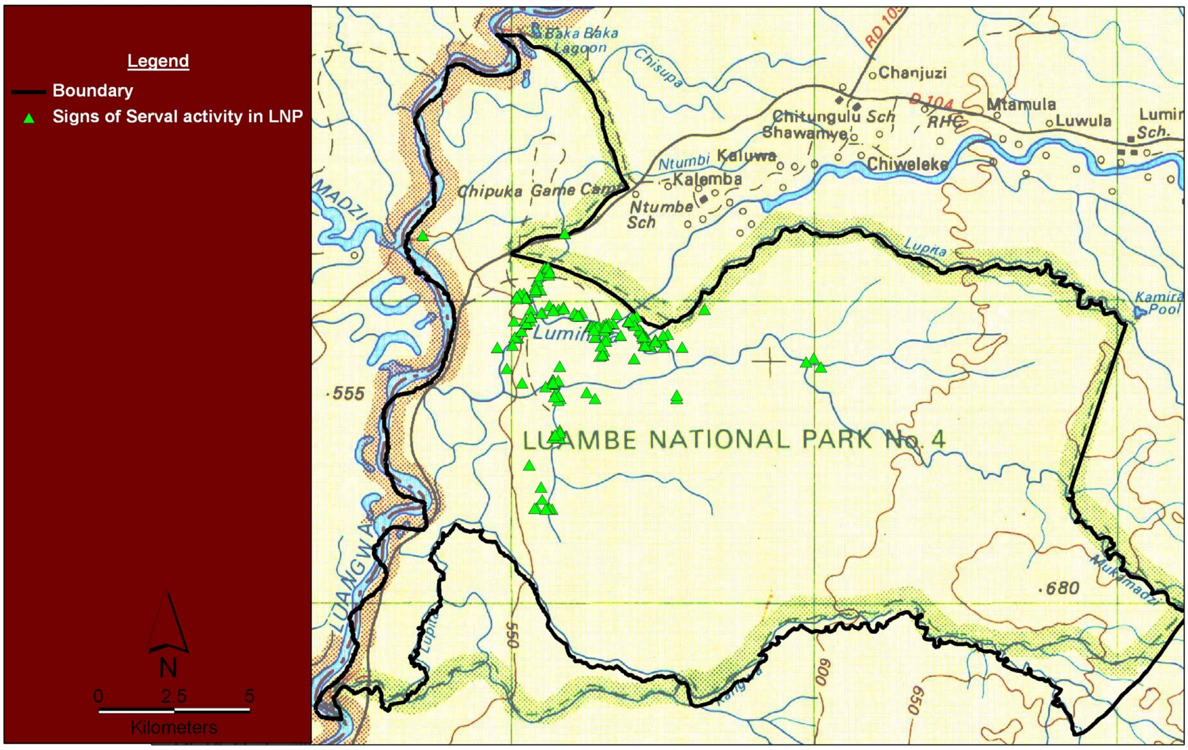


Figure 4.18: Signs of Serval activity in LNP.

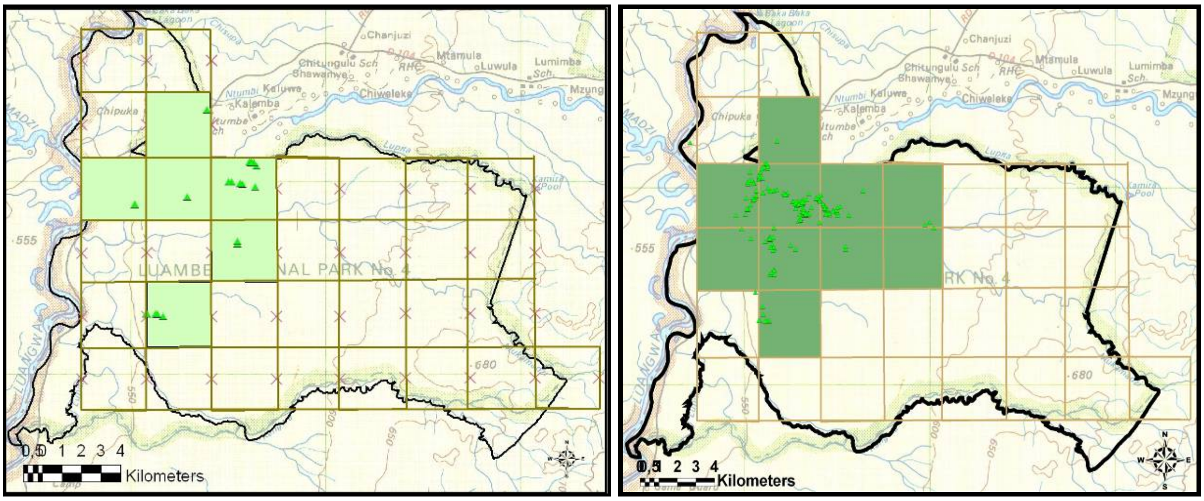


Figure 4.19: Grids of presence determined by transect lines (left) and by random findings (right).

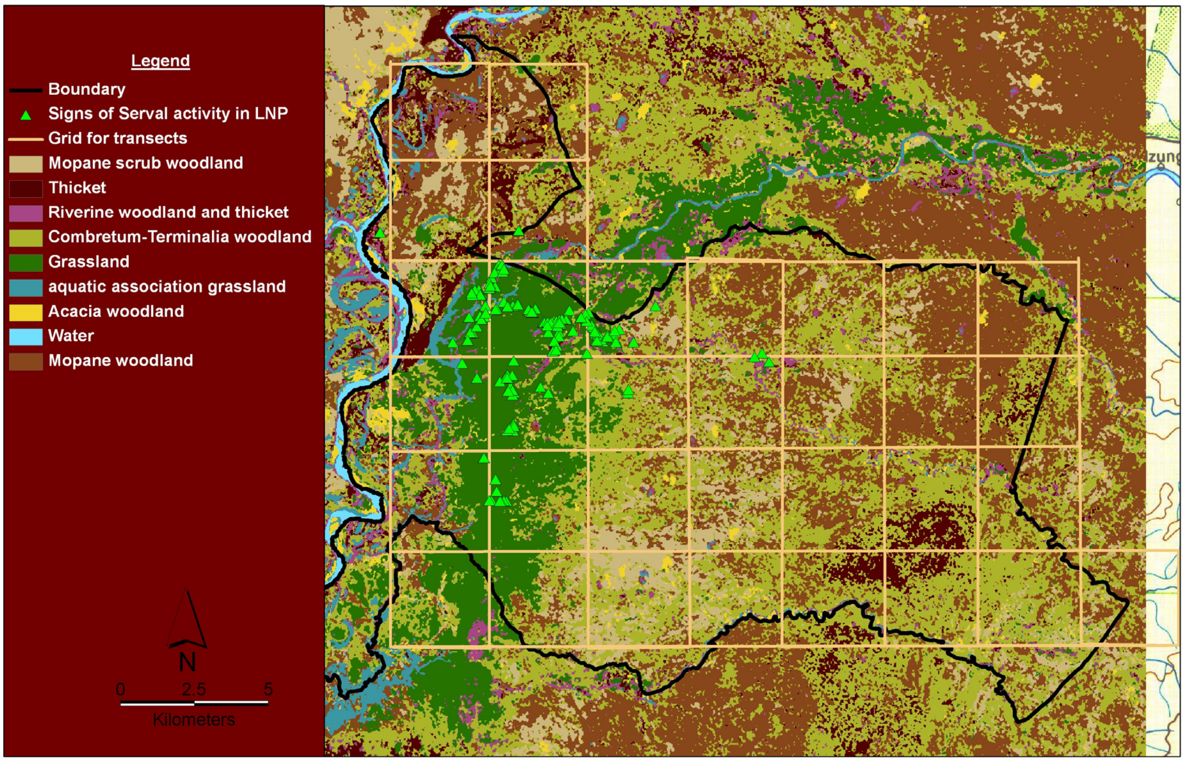


Figure 4.20: Signs of Serval activity with the vegetation map overlay.

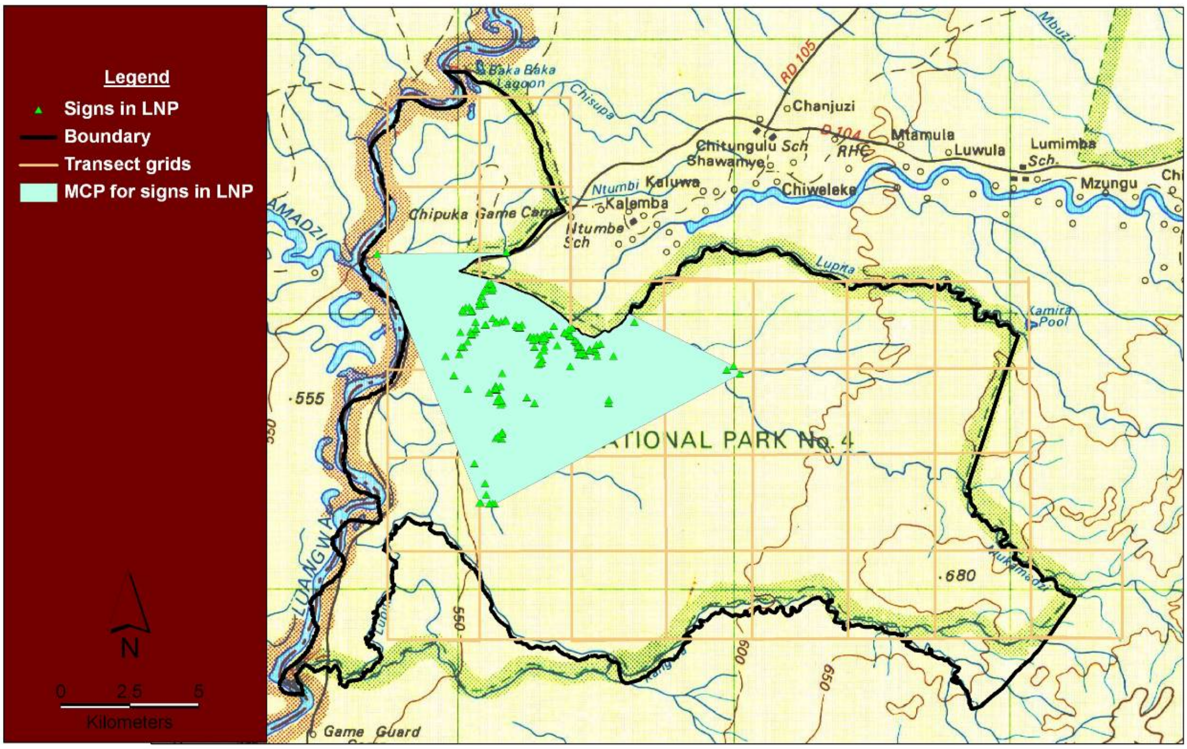


Figure 4.21: Signs of Serval activity and their Minimum Convex Polygon.

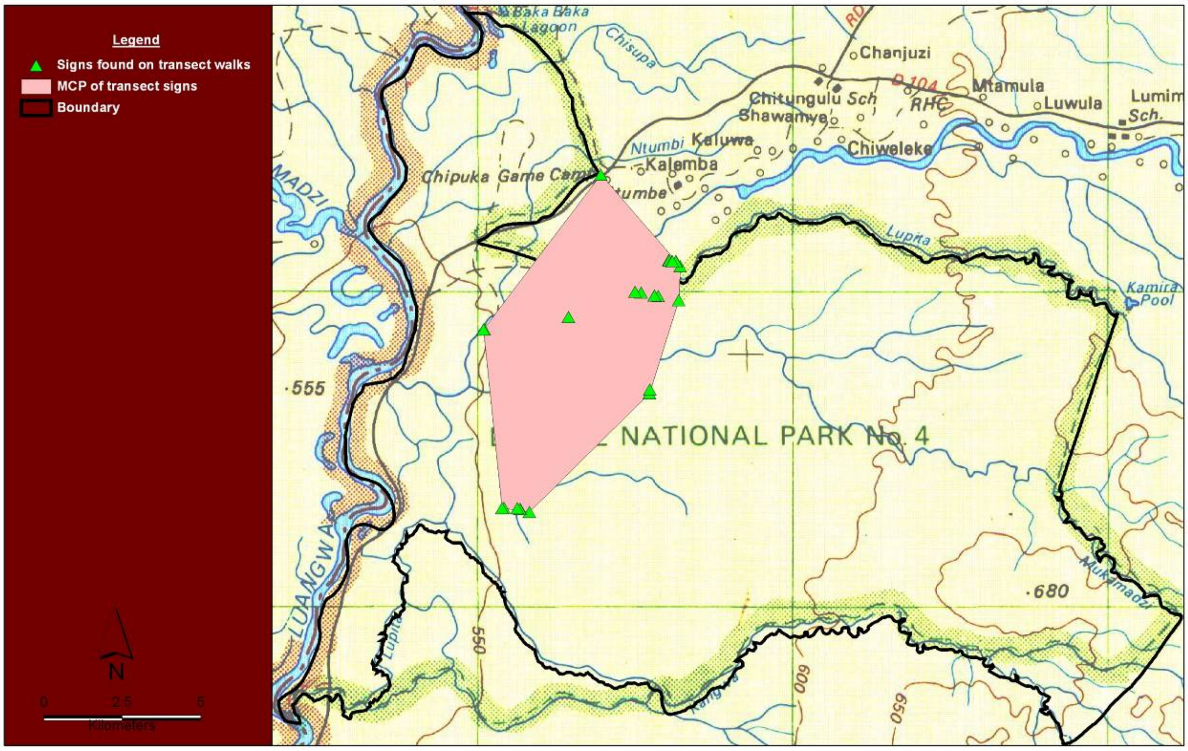


Figure 4.22: Signs of Serval activity found on the transect walks and their Minimum Convex Polygon.

4.4. Discussion

4.4.1. Habitat preferences in Luambe National Park and its bordering areas

As GEERTSEMA (1985) and BOWLAND (1990) mentioned the key to serval conservation is Wetland conservation. For these reasons it is crucial to investigate the Servals' habitat requirements and to create an updated action plan for this species. The Serval can be used as an umbrella species for savannah biotopes, and as an indicator for the heavily endangered humid savannah biotopes. The popularity of this carnivore could help to protect these biotopes. Conversely, protecting the Wetlands will aid in protecting Serval populations.

Counts of scats may poorly represent the habitat use, because defecation rate often varies with food source, and hence the habitat type (COLLINS & URNESS 1981, ANDERSEN et al. 1992). In this study this bias can be ignored, as in Servals the food type is relatively constant every day and the defecation is daily (see Chapter 2). All the habitat classes were sampled nearly equally (with only a slight focus on Grassland).

The Chi Square test clearly showed that the usage of the different categories significantly differs from expectations, which means that the Servals in LNP prefer respectively avoid certain habitats. The most preferred habitat type in this study was difficult to determine. Following the JACOBS index, Grassland is the most preferred habitat class, while Riverine Woodland, Aquatic Association Grassland and Thicket were rejected as categories. Following the JOHNSON ranks, Riverine Woodland is the most preferred habitat, followed by Grassland and Aquatic Association Grassland. Residual values of the Chi Square test showed the category Grassland as being used much more than expected, followed by Riverine Woodland. BOWLAND (1990) determined that Servals frequently lie in patches of woody vegetation, while SMITHERS (1983) and GEERTSEMA (1985) identified mostly long grass as resting spots. In both Grassland and Riverine Woodland the Servals can find areas of long grass and woody vegetation patches. Riverine Woodland is similar to the Thicket habitat type, but as Servals are dependent on water to drink, they may show a preference to the former. Aquatic Association Grassland could show a higher preference than Riverine Woodland, but as this habitat type dries up very quickly, leaving hard, cracked soil behind, it may be used by the Servals only during wet periods. From personal observations Servals also liked sandy reed beds where they hunted on gerbils and other rodents. In this study these reed beds fall under the habitat class Riverine Woodland and Grassland, hence, they are not listed separately.

Combretum Terminalia Woodland, Mopane Woodland, Mopane Scrub Woodland and Acacia Woodland are less preferred/avoided habitat types when using all methods. Hence, this study underlines the statements of reviewed literature about Servals, where this species is associated with grassland/savannah/wetlands/riverine habitats (ANSELL 1978, SMITHERS 1983, GEERTSEMA 1985, VAN AARDE & SKINNER 1986, BOWLAND 1990, NOWELL & JACKSON 1996, HUNTER 2000).

JOHNSON ranks assume that independent data is used (GARSHELIS 2000). As line transects were random and other places were randomly visited, this data can be assumed to be independent. If animals are pooled, as done here, habitat availability may not be independent, as some animals may not have all habitat types represented in their home ranges (GARSHELIS 2000), therefore, the 'Circle of Available Area' might be wrongly placed. To avoid this error JOHNSON (1980) suggested that the habitat of a broader available area should be considered in these studies. This was done by adding a buffer of 500 m around the first calculated 'Circle of Available Area'. JOHNSON (1980) also states that animals can select the area before establishing their home range so that they choose an area covering preferred habitats prior to the analyses by biologists. GARSHELIS (2000) does not completely agree with this conclusion, as some individuals may not have the chance to establish a home range in their preferred area because it is already occupied by competing individuals. In contrast the view of MANLEY et al. (1993) is that JOHNSON's assumption is plausible, because they theorize that erratic and other movements, not directly related to habitat selection, are probably rare in resident individuals and would only introduce a random error in the occurrence subsample. JOHNSON ranks suits data on individuals the best, where comparing the means is possible with the Duncan Waller ad hoc test. The data in this study can be already seen as averaged values on all Servals in LNP, as no classification of the faecal samples was possible, and therefore the JOHNSON ranks have to be analyzed with care and the Duncan Waller ad hoc test was not possible. This is why significant differences between individuals' preferences of the different habitat types could not be identified. Using the JOHNSON ranks, Grassland and Aquatic Association Grassland had the same value, which could indicate that these two habitat types are the only categories which did not differ very much in character.

4.4.2. Distribution in Luambe National Park

Using all findings, the ones from the transect lines and the random ones, a total Minimum Convex Polygon of 64 km^2 with Serval presence was calculated. Contrary, using only the data from transect walks a MCP of 36.7 km^2 could be created. This leads to the conclusion that at least one tenth to one fifth of LNP is inhabited by Servals. If all signs are considered (found within these three years even outside LNP) an MCP of 134 km^2 of Serval presence was calculated (Fig. 4.23).

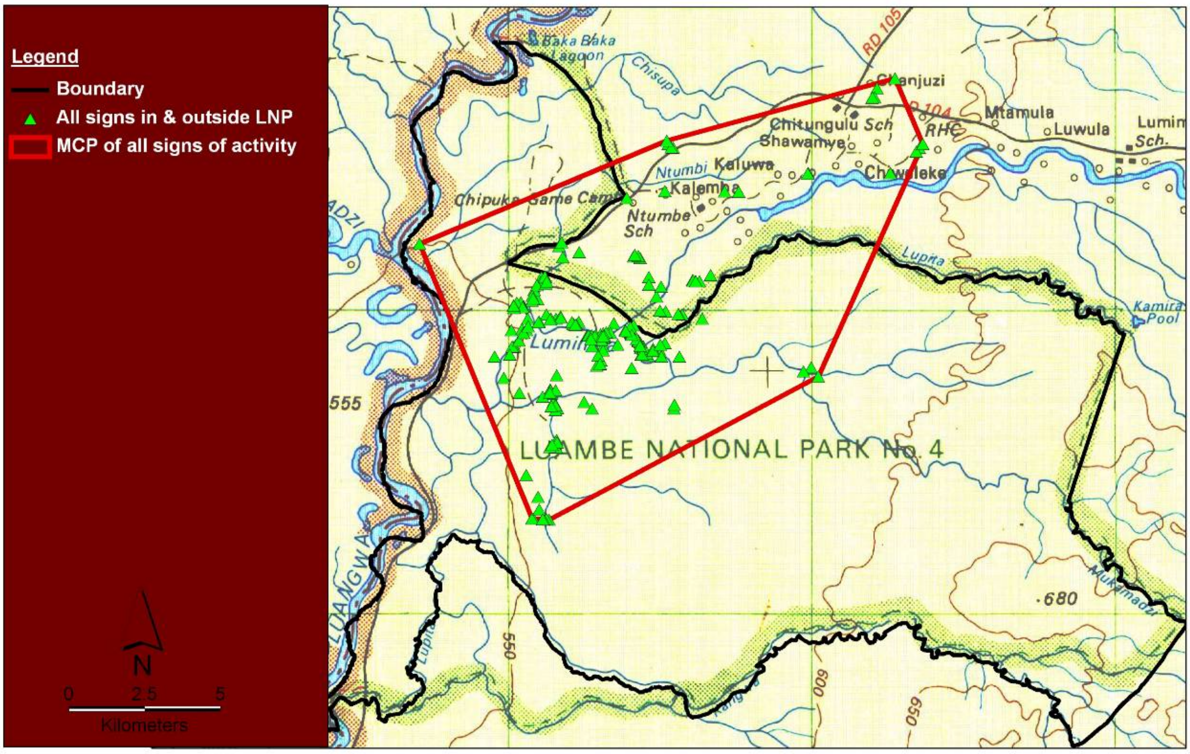


Figure 4.23: Total area of Serval activity (134 km^2) in and around Luambe National Park.

RAY et al. (2005) assume that Serval densities are the highest in savannah woodlands, grasslands and dry forests associated with permanent water, which can be confirmed in this study as all methods have shown the central Grassland area, or even parts of it, as main Serval distribution area.

Relative abundance can be also expressed as an encounter rate (i.e., the number of pugmarks, scrapes or faeces per kilometre walked). However, there have been few studies that attempted to correlate sign density and cat density (AHLBORN AND JACKSON 1988, BEIER & CUNNINGHAM 1996, STANDER 1998, LEWISON et al. 2001, SHARMA & WRIGHT 2005, HOUSER et al. 2009), which indicated that sign predicted about 60% of known visitations with sign density being highest within overlapping ‘core-use areas’. JACKSON et al. (2005) now also integrated a system called *SLIMS*, to calculate relative abundance especially for Snow Leopards. But calculating relative abundance by the encounter rates of pugmarks of Servals in LNP was not feasible as the soil conditions and the high amount of soil cover did not allow an accurate count and therefore no accurate estimation.

The big difference in the presence areas between transect walks and randomly collected samples can be explained through three factors influencing the findings of signs such as tracks and droppings. Firstly: While doing the transect lines, no given paths were followed, but a roughly straight line through the bush. In contrast, random samples were often encountered when following roads/paths/game trails. As MCDONALD (1980) stated, carnivores prefer to walk roads/paths, as they follow their pattern of strategic sent marking spots. SKINNER & SMITHERS (1990) and SMITHERS (1978) describe the Servals' dropping locations being mainly on roads or paths. KOHN et al. (1999) use this theory to estimate coyote population. In this study, 32% of all scat samples were found directly on a dirt road or track in LNP, and nearly 10% more were found on paths or game trails. Secondly: Sampling is even more difficult if there are too many small paths or game trails running through the study area (HENSCHEL & RAY 2003), which was the case in LNP. The game did not need to follow certain paths with vegetation being more open, and the Servals' movements could not be predicted easily and followed for tracks and scats as is possible in dense vegetation with only a few trails running through. Thirdly: Executing transect lines in these habitats often minimized the spotting distances for signs to less than 5 metres on each side due to dense vegetation. This means, an area of approximately 1.1 km^2 (109 km * 0.01 km) was covered each year by transect. Samples found at random occasions had a bigger covered area as daily drives and walks provided enough opportunities for these.

Besides all of these difficulties with the transect line walks, they still resulted in a similar presence area size. Because in the dry season, the discovery probabilities of scats are higher (RAY & SUNQUIST 2001) than in the rainy season, the most accurate results could be expected from these transect walks.

4.5. Summary Chapter 4

Within LNP, habitat preferences and the distribution of Serval were calculated on the basis of 170 positions including those of sightings (26), droppings (129) and spoor (15). Most signs were found in Grassland, Combretum Terminalia Woodland and Riverine Woodland habitats. This chapter showed that the Servals of LNP significantly prefer certain habitat types, while they avoid or show reduced preference for others. They evade all types of Woodlands, apart from Riverine Woodland, which along with Grassland make up the most preferred habitat areas. Preferences/Avoidances were calculated with the JOHNSON ranks, Chi square test and the JACOBS index, with the methods showing similar results. These results are supportive of previous observations that the Serval is a grassland/wetland/savannah species. There were no annual changes in habitat preferences.

Within Luambe National Park, signs of Serval activity (n = 170) were found by transect line walks and by random encounters. Analyses of these signs led to the conclusion that at least 60 km^2 of the 331 km^2 of the Luambe National Park are populated by Servals. This is mainly within the central grassland area and along semi permanent riverbeds, which again confirms the results of the habitat preference analysis.

5. Minimum population size estimation for Luambe National Park

In this chapter, the minimum population size of Servals in Luambe National Park is calculated using capture-recapture models on camera trap photographs. This is the first population estimation of Serval populations; therefore a very important first study on Serval density. Determining Serval densities within protected areas is the first step towards establishing whether a given population exists at levels viable for long-term persistence.

5.1. Introduction

Different techniques are available to estimate minimum population sizes: the pugmark method, scat deposition transects, correlation to prey density or biomass, the camera trap capture-recapture technique and several non-invasive methods of collecting biological samples (CLARK 1972, TABERLET & LUIKART 1999, CARBONE & GITTLEMAN 2002, SILVER et al. 2004, SHARMA et al. 2005, BHAGAVATULA & SINGH 2006, MIOTTO et al. 2007a, MAFFEI & NOSS 2008). The more modern studies more commonly use the camera trap capture-recapture technique and non-invasive methods of collecting scats or hair samples for individual identifications based on genetic analyses (BHAGAVATULA & SINGH 2006, CHAVES et al. 2006, MIOTTO et al. 2007a, NAPOLITANO et al. 2008).

Camera trapping of wildlife has been practiced since the early 20th century (ROWCLIFFE & CARBONE 2008), and in the last 20 years relevant equipment has become easier to handle and more affordable. As a result, more and more studies using this approach are emerging (ROWCLIFFE & CARBONE 2008) for species inventories (e.g. SILVEIRA, JACOMO & DINIZ, 2003), discoveries of new species (e.g. ROVERO et al. 2008), abundance estimation (e.g. Karanth 1995), conservation assessments (e.g. KINNAIRD et al. 2003, LINKIE et al. 2006), and population dynamics (e.g. KARANTH et al. 2006). The last decade has seen a 50% annual growth in the number of published papers that either directly address camera trapping methods or use them as a research tool (ROWCLIFFE & CARBONE 2008).

Camera trap surveys now use standardized methods to estimate population size through capture–recapture statistics, mainly conducted with the Program CAPTURE (OTIS et al. 1978, WHITE et al. 1982, REXSTAD & BURNHAM 1991). The abundance estimate is then divided by the effective trap area of the camera survey (KARANTH & NICHOLS 1998, SILVER et al. 2004, MAFFEI & NOSS 2008, DILLON & KELLY 2008). To obtain an accurate estimate for population density using the population size resulting from calculations using CAPTURE, it is vital to estimate the size of the effective trap area as precisely as possible. In trapping grid studies, it is documented that the area from which animals are captured (effective trap area) is not equal to the area enclosed by the outer traps, because animals are being captured from the surrounding area as well ('edge effect', OTIS et al. 1978). It is therefore typical to add a buffer area to the area enclosed by the traps (OTIS et al. 1978). The buffer radius can be calculated from the mean maximum distance moved (MMDM) of all 'recaptured' animals at two or more camera stations (PARMENTER et al. 2003, TROLLE & KERY 2005, SOISALO & CAVALCANTI 2006, MAFFEI & NOSS 2008) or ½ the mean maximum distance moved (½MMDM) (KARANTH & NICHOLS 1998, SILVER et al. 2004, DILLON & KELLY 2008). The buffer area is placed around the entire camera trapping grid (OTIS et al. 1978, KARANTH 1995) or around each camera station (SILVER et al. 2004, MAFFEI & NOSS 2008).

After KARANTH & NICHOLS (1998) the equation of ½MMDM is:

$W = (\sum d / m) / 2,$

where W is the resulting buffer radius, d the maximum distance moved, and m the number of maximum distances compared. This value is then inserted into the following equation to calculate the population density estimation:

$D = N / A(W),$

where D is the density, N the population size computed by CAPTURE, and $A(W)$ the resulting area sampled, including the buffer.

As most camera studies lack specific information on the target animal's home range size prior to conducting the study, the ½MMDM buffer is used as a proxy for home-range radius (KARANTH & NICHOLS 2002) to ensure the effective trap area is specific to the target species.

"Estimates of absolute abundance depend upon an ability to detect and distinguish individuals from one another, using an unbiased field sampling and analytical technique" (JACKSON et al. 2005). While it is not necessary to photograph every individual of the target species in the study area, every individual present must have an equal chance of being captured (KARANTH & NICHOLS 2002, JACKSON et al. 2005).

Following JACKSON et al. (2005) there are four assumptions to be made before starting a capture-mark-recapture study:

1. During the survey period the population of the target species is demographically and geographically closed. Hence, there are no deaths, births, immigration or emigration.
2. All individuals have the same probability of being captured in each sampling interval.
3. Each individual is permanently marked and uniquely distinguishable from others.
4. All previously captured individuals must be reliable distinguished from unmarked (not captured) individuals.

All assumptions of JACKSON et al. (2005) imply fulfilling various methodological requirements. To accomplish assumption 1, the camera trapping must be conducted in a relatively short time period, 45 to 90 days. Additionally, population closure can be tested with the Program CAPTURE or similar after the survey. Assumption 2 requires survey grids of comparable camera trap density and effort; therefore a grid without any 'holes' is best and most efficiently done by having one (JACKSON et al. 2005), or two to three (KARANTH & NICHOLS 2002, HENSCHEL & RAY 2003) camera traps within each area equivalent to the size of the smallest adult home range of the relevant species. This particular home range size is chosen so as to take into account the most probable capture heterogeneity in capture probability; capture rates may vary with regard to age, sex, social dominance or trap placement. Assumptions 3 and 4 are best addressed by placing two cameras at one station facing opposite each other to cover both sides of the target animal and using rigorous identifying criteria on the permanent marks, such as spots, stripes and rosettes.

ROWCLIFFE et al. (2008) developed a new method to estimate animal abundance without individual recognition. The authors state that under certain conditions (like closed populations, independence of movement of the cameras) in combination with a high sampling effort (20-40 camera placements, deployed until at least 10-20 photographs of the target species are taken), this technique is an accurate method in estimating abundance and density. However, this novel approach was used in an Animal Park, and has not yet been tested in the field; it is still being improved upon and has therefore not been used in this study.

In the last decade, remote camera trapping has been used to study a variety of cat species, such as O'BRIEN et al. (2003) and KARANTH et al. (2006) on Tigers, KELLY (2003) and SILVER et al. (2004) on Jaguars, MAFFEI & NOSS (2008) and DILLON & KELLY (2007) on Ocelots, KELLY et al. (2008) on Pumas, HEILBRUN et al. (2006) and KELLY & HOLUB (2008) on Bobcats, KELLY et al. (2001) on Cheetahs, as well as on the Geoffroy's Cat by CUELLAR et al. (2006). Although camera trapping has become an accepted scientific technique for estimating felid abundance and density, recent studies have shown that reduced spacing between cameras

(DILLON & KELLY 2007), small survey area (MAFFEI & NOSS 2008) and lack of information on true home-range size (SOISALO & CAVALCANTI 2006) can produce an underestimation of the effective survey area, resulting in overestimates of density. Overestimation of density could lead to underestimating the risk faced by threatened and endangered felid species and could hence slow the implementation of appropriate conservation strategies. Therefore, results need to be analysed carefully and cross-checked with other studies or by tested repeatedly.

5.2. Methods

MAFFEI & NOSS (2008) established that the best mean maximum distance moved (MMDM) estimation for the study site is guaranteed if the area covered with camera traps is at least four times the average home range size. Average Serval home range sizes vary between 9.5 to 31 km^2 (GEERTSEMA 1985, BOWLAND 1990), so that the study area had to cover at least 38 to 124 km^2 to fulfill MAFFEI & NOSS's conditions. Altogether 20 automatic digital cameras were placed in potential Serval habitat (Fig. 5.1). After delineating the survey area and producing survey cells (2x2 km), the next step was to visit the grid cells and locate the best spot to place camera traps. The cameras were placed mainly along game trails, at a height of ~60 cm and with clear sight of the target area (without obstructions such as grasses and bushes). Camera traps were mainly set up in habitats most preferred by Servals (see Chapter 4), namely Grassland, Riverine Woodland, and Aquatic Association Grassland habitats. Camera traps were set with a spacing of ~2 km (1.84 km ± 0.14 km) as single stations. On average, one camera trap covered a circular area of 2.67 km^2 (circle is $\Pi r^2 = \Pi * 0.92^2$, see Figure 5.2), implying that there were at least three cameras for every potential home range. The total area surveyed, which was outlined by connecting the outer traps (polygon shaped area; KARANTH & NICHOLS 1998), covered 40.4 km^2 (see Fig. 5.2). All camera stations were unbaited and active 24 hours per day. To validate the assumption of closure the survey was terminated after 75 days. There are no preliminary studies on Serval densities so that there is no expected success rate.

Servals were individually identified by their spot patterns. Comparisons between pictures allowed comparisons of patterns at corresponding body parts. The body parts chosen for comparison were the tail, the shoulders and the hip and legs region (e.g. Fig. 5.3) depending on the picture quality and the angle of the pictures of the animal. To estimate Serval population size and its density in Luambe National Park, the program CAPTURE Version 2 (OTIS et al. 1978, updated by REXSTAD & BURNHAM (1991); http://137.227.242.23/software/capture.shtml; 11. 2010) was used. This program tests the data against several capture-recapture models and suggests the model that best fits the data. The estimate of total abundance based on the number of individuals identified and the capture frequency statistics generates estimates of capture probability and population size.

In general the estimations for an animal abundance *N* follow the equation:

$N = C' / p\alpha$,

where *C*' is the count statistic obtained in the sampled areas, *p* is the estimated detection probability (which varies with the different models used in CAPTURE), and *α* is the proportion of the total area from which the count statistic was taken (KARANTH & NICHOLS 2002).

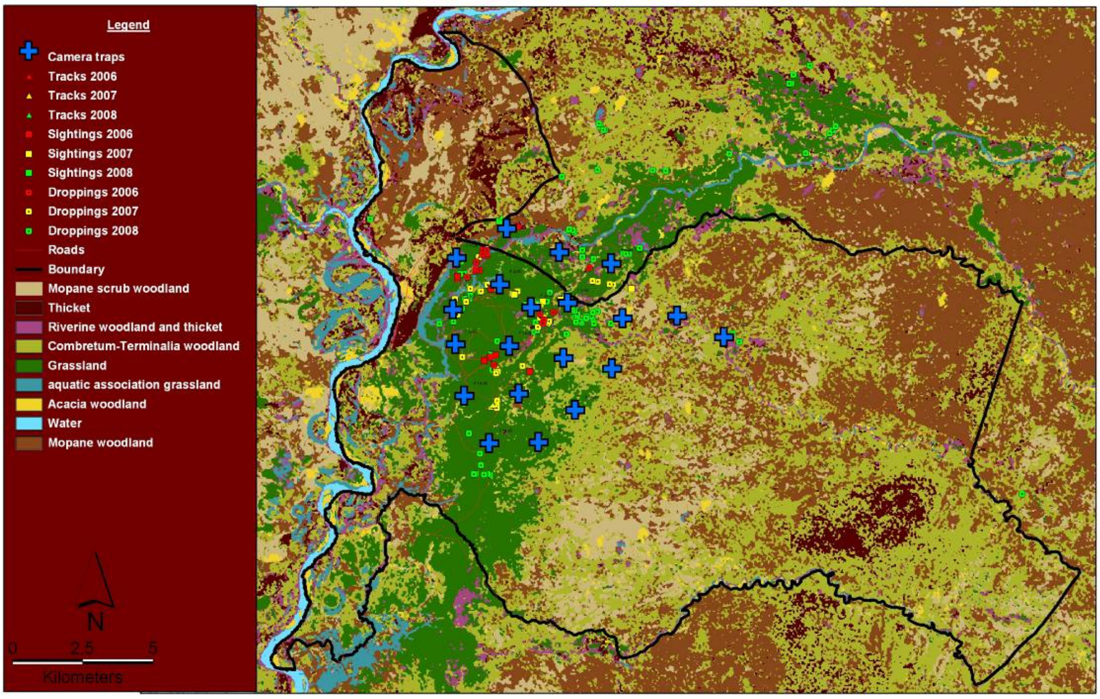


Figure 5.1: 20 camera trap locations in potential Serval habitat, confirmed by tracks and signs in the years 2006-2008.

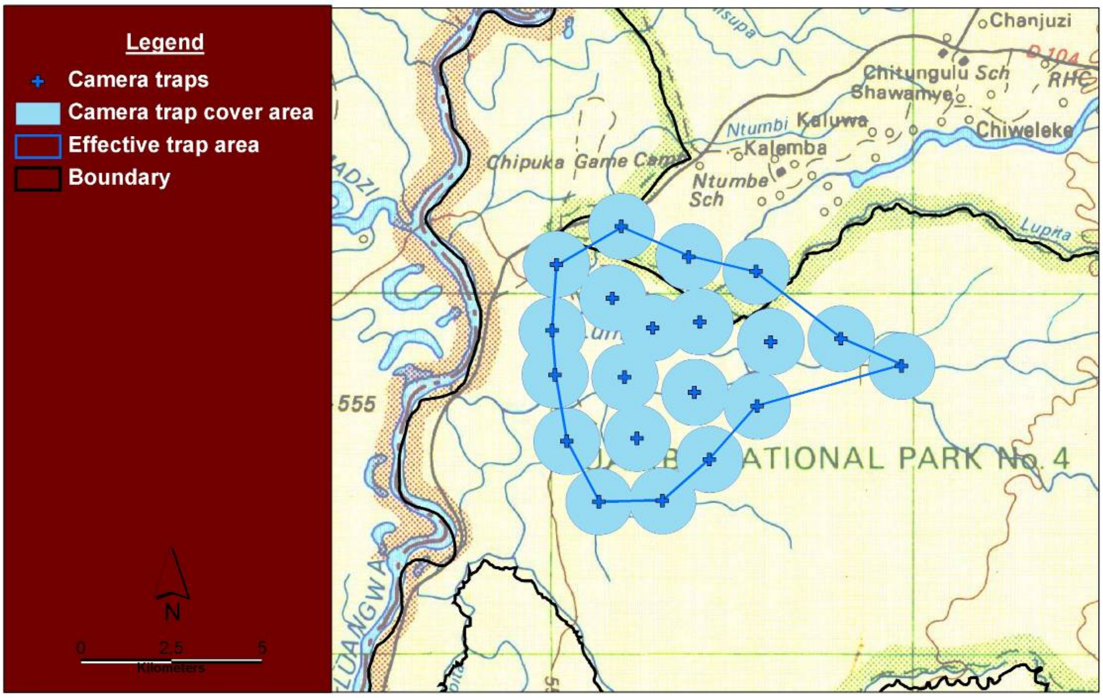


Figure 5.2: Camera trap locations and their circular sampling area of 2.7 km^2 between each station and the polygon shaped area of camera trap setup.

The CAPTURE program offers six different models to estimate population size *N*:

1. The Null Model (M_0) assumes no difference in capture probability between individuals or sampling occasions.
2. The Heterogeneity Model (M_h) tests for differences in capture probabilities between individuals that may result from accessibility to traps, social dominance, or differences in age and sex (WHITE et al. 1982).
   The program CAPTURE offers two estimators for the model M_h; the Jackknife estimator (OTIS et al. 1978) and the Chao estimator (CHAO 1987). The Jackknife estimator increases robustness (JACKSON et al. 2005), while the latter is a less biased estimator if capture probabilities are low (KARANTH 1995).
3. The Schnabel Model (M_t) assumes difference in capture probabilities between different sampling occasions or surveys (i.e., over time).
4. The Trap Response (Behaviour) Model (M_b) allows for differences in capture probabilities between newly caught individuals and subsequent capture probabilities due to different individual behaviour (i.e., trap-shyness).

The program also combines these models to examine the interaction of these effects, using the estimators,

5. M_{bh} (Heterogeneity and Trap Response Model), and
6. M_{tb} (Time and Trap Response Model), all of which require relatively large sample sizes.

CAPTURE gives a value between 0.00 to the least fitting model and 1.00 to the best model, however, OTIS et al. (1978) recommend selecting one with a value > 0.75 and which has acceptable goodness of fit. Following OTIS et al. (1978), if CAPTURE recommends M_0 as best model, you should assume that M_0 is not appropriate for the species, and use the second-best model. The Jackknife estimator under model M_h is known to be statistically robust relative to other available estimators (KARANTH et al. 2004) as long as capture probability is not too low. KARANTH & NICHOLS (2002) recommend M_h as the model of choice. HENSCHEL & RAY (2003) argue that this makes sense for the larger cats like the leopard, given the fact that large cats are territorial animals, with home range size and trap access variable depending on social position and spatial location of the animal on the landscape.

The survey period of 75 days were pooled to 15 occasions (5 days for each occasion), as CAPTURE only calculates abundances with less than 18 occasions. After the survey, the effective trap area was then estimated using the MMDM and the ½MMDM of all Servals photographed at more than one camera station as buffer added around all camera trap stations (after SILVER et al. (2004)) or around the polygon shaped area around all camera traps (KARANTH & NICHOLS 1998). The merged area of the circular buffers provides an estimate of the area sampled i.e. the effective trap area. To estimate Serval density, the population estimate derived from program CAPTURE was divided by three different values of the trap area:

1. Camera trapping ½MMDM buffer.
2. Camera trapping MMDM buffer.
3. Original camera trap area without buffers.

Standard Errors (SE) were calculated following the method by KARANTH & NICHOLS (2000), modified by MAFFEI & NOSS (2008). CAPTURE only generates an error value associated with the population size estimate, it is necessary to generate an error associated with the area (effective survey area) estimate to get a SE for the density estimation. This procedure assumes a circular effective survey area, which is created by adding the buffer to each single camera trap station (SILVER et al. 2004) or to the polygon shaped area around all camera traps (KARANTH & NICHOLS 1998).

The test for closure in the CAPTURE program is known not to be the most reliable test given by the program; as REXSTAD & BURNHAM (1991) state, “the test has poor power and is seldom capable of properly rejecting the null hypothesis of closure”. Therefore, this test was calculated with the Program CLOSURE (www.mesc.usgs.gov/products/software/clostest clostest.asp; 11. 2010) in addition to CAPTURE.

In addition a cross check camera trap survey area was created in the Woodland of LNP. This setup is to support the assumption made by habitat analyses that Serval prefer grasslands and avoid woodlands. With this evidence the ‘edge effect’ of the camera trap setup for the Servals is supposed to be at a minimum scale as there should not be any Serval entering the survey area from “outside” as there is mostly woodland around the grassland area.

Figure 5.3: Example of identification of two separate individuals, based on pelage patterns (red box).

5.3. Results

In 1382 trap days of 24 hours (between end of July until beginning of October), seven Servals were captured, four adult individuals were identified, with three recaptures. Four out of 20 camera trap locations (20%) captured the target species (Fig. 5.4). The four individuals consisted of three adult Servals and another adult female walking with her cub (Fig. 5.5), resulting in a camera trap success of 0.51 Servals per 100 trap days.

Less favourable habitats to Servals (see Chapter 4) were generally not surveyed, but Combretum Terminalia Woodland was covered with 5 camera traps, as some signs of Serval activities (scats and tracks, see Chapter 4) were observed within this habitat. Table 5.1 shows the distribution of camera traps within the available habitats, and the numbers of individuals captured and recaptured in these habitats.

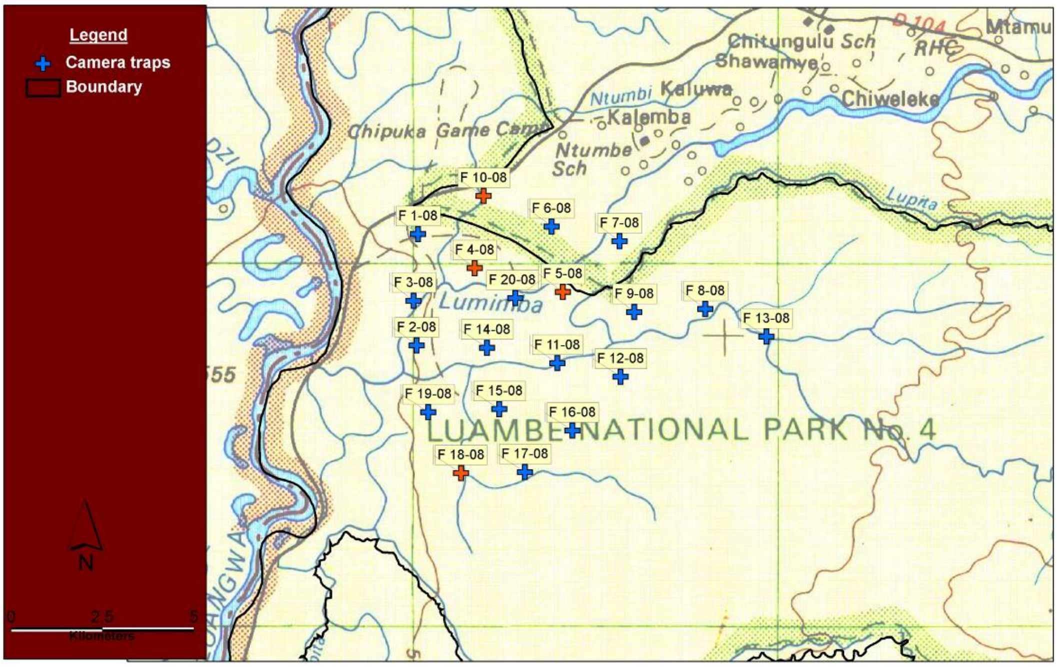


Figure 5.4: Camera trap locations and IDs. Red crosses indicate sites with Serval captures.

Figure 5.5: Female adult Serval (top right), accompanied by young Serval (bottom left).

Table 5.1: Camera trap positions within the different habitats of Luambe National Park and the numbers of Serval individuals captured and recaptured in these habitat types (grey marked habitats = not generally preferred by Servals (Chapter 4)).

Habitat type	N camera trap stations	% camera trap stations	N Servals captured	N Servals recaptured
Mopane scrub Woodland	0	0	0	0
Acia woodland	0	0	0	0
Mopane woodland	0	0	0	0
Thicket	0	0	0	0
Aquatic Association grassland	1	5	0	0
Riverine Woodland	2	10	0	0
Combretum Terminalia Woodland	6	30	1	1
Grassland	11	55	3	2

Other studies with a survey period of 45-90 days proved to have a closed population (KARANTH & NICHOLS 2002, JACKSON 2005, MAFFEI et al. 2005, LARRUCEA et al. 2007, MARNEWICK et al. 2008) and so it can be assumed that the population of Servals remained closed during the 75 days survey period in this study without using the relevant statistical programs, but population closure tests, performed with CLOSURE (STANLEY & BURNHAM 1999) and CAPTURE (OTIS et al. 1978), did indicate that the Serval population of LNP was closed during the trapping period ($p > 0.05$; Tab. 5.2). The null hypothesis is that the population is closed and therefore only a $p < 0.05$ means that the the composition and size of the population does not remain constant for the duration of the study.

Altogether, 70% of the trapping stations were placed on game trails, only 5% on roads, 20% in riverbeds (dry or with small pools), and 5% on an open sandy grass patch. Of the total camera stations only 20% resulted in photo-captures i.e. 80% of the cameras did not contribute any data to the study. Trapping success was not significantly different from that expected from the camera set up locations (Table 5.2; Fisher Test, $p_2 < 0.2817$).

In this study, the Heterogeneity Model M_h was found to be the best fitting model using CAPTURE (Tab. 5.4); the Jackknife and Chao estimator for model M_h was therefore used, which allows each individual to have a different capture probability. The Null Model M_0 and the Heterogeneity and Time Model M_{ht} showed values of above 0.75 with the program CAPTURE (OTIS et al. 1978) (Tab. 5.4). Results of the assumption test in CAPTURE indicated a behavioural response after the initial capture (M_0 vs. M_b), no time variation in capture probabilities (M_0 vs. M_t), and a reasonable fit to the heterogeneity model (M_h goodness-of-fit; Table 5.5). This fit to M_h also supports the findings that M_h is the most suitable model. There was clear evidence of different behavioural responses between newly caught and previously captured individuals (M_b goodness-of-fit; Table 5.5), however the CAPTURE value for the fit of model M_b has only a value of 0.66 and this model was therefore rejected. The sample size was too small to assess M_0 vs. M_h, M_h vs. M_{bh}, and M_t goodness of fit.

Table 5.2: Results of population closure tests, calculated using CLOSURE and CAPTURE.

Closure Test			
CLOSURE: Stanley & Burnham (1999)	$X^2 = 7.05991$	$p = 0.21622$	$df = 5$
CAPTURE: Otis et al. (1978)	$z = 0.00000$	$p = 0.50000$	

Table 5.3: Trap placements and their capture/recapture success with the associated habitat type (CTW=Combretum Terminalia Woodland, G=Grassland, AAG=Aquatic Association Grassland, RW=Riverine Woodland; S= stopgap/edge effect minimiser). The four colourations indicate the four categories of camera location (riverbed, road, no structure and game trail).

Trap ID	Habitat type	Placement	No. of captured animals	Capture success [%]
F 10-08	CTW	dry riverbed	2	28,6
F 18-08	G	dry riverbed	2	28,6
F 2-08	G	dry riverbed	0	0
F 13-08	RW	dry riverbed	0	0
F 14-08	G	road in grassland	0	0
F 6-08	G	sandy open grass patch	0	0
F 1-08	RW	game trail in high grass	0	0
F 4-08	G	game trail in high grass	2	28,6
F 5-08	G	game trail in high grass	1	14,3
F 3-08	AAG	game trail in high grass	0	0
F 20-08	G	game trail in grassland	0	0
F 19-08^s	G	game trail in grassland	0	0
F 15-08^s	G	game trail in grassland patch in CTW	0	0
F 17-08	G	game trail in grassland patch in CTW	0	0
F 7-08	G	game trail in grassland patch in CTW	0	0
F 12-08	CTW	small game trail in Woodland	0	0
F 9-08^s	CTW	small game trail in Woodland	0	0
F 8-08^s	CTW	small game trail in Woodland	0	0
F 11-08^s	CTW	small game trail in Woodland	0	0
F 16-08^s	CTW	small game trail in Woodland	0	0

The capture probability showed much variation between models (Tab. 5.6). While the best fitting model M_h showed a low capture probability of only 0.0933 ($M_{h(Jackknife)}$) and 0.0381 ($M_{h(Chao)}$), the M_0 model showed a slightly higher probability of 0.1077. The estimated population size of adult Servals in LNP was five using $M_{h(Jackknife)}$ and respectively four using $M_{h(Chao)}$ following the best fit model of M_h. The confidence interval of the Chao estimator is narrower than that the Jackknife estimator and because capture probability is small the Chao estimator is used to describe the abundance of Servals in this study. Also the other two models estimated the Serval population at four adult individuals (Tab. 5.6).

The mean maximum distance moved by individual Servals between successive captures was 0 km. All recapture events took place at the same camera trap where the individuals were identified first (F4, F10 & F18, see Fig. 5.6). Therefore no outer buffer strip could be added. Thus, the effective trap area was 40.4 km^2, the size of the polygon around all camera traps and no SE value could be calculated for Serval density as the equation assumes a circular effective trap area. Consequently, the result of abundance estimation was divided by only one value of the effective trap area, as the results of the area of the camera traps plus (½)MMDM buffer and the original camera trap area without buffers are the same. With an abundance of four (SE = 0.5358) individuals the Serval density of LNP is 9.9 (SE = N.A.) individuals per 100 km^2 (excluding cubs). In Chapter 4 an area of 134 km^2 of Serval presence (signs found within the three years study, even outside LNP) was calculated as a Multi-Convex-Polygon. This could lead to indicate a minimum population size of 13.3 Servals in LNP and its neighbouring area (area within the red boundary line; Fig. 5.6). As shown in Figure 5.6, there were different habitat types within the effective trap area with 36.3% of good quality habitat for Serval (preferred habitat mentioned above and in Chapter 4). The total area of Serval presence comprises 30.7% good quality habitat for Servals, which is comparable to the effective trap area of this study (Fig. 5.6).

Table 5.4: Model testing results in CAPTURE.

Model	M_0	M_h	M_b	M_{bh}	M_t	M_{th}
Criteria	0.95	1.00	0.66	0.78	0.00	0.47

Table 5.5: Results of tests of assumptions used by CAPTURE for evaluating the fit of 3 capture–mark–recapture models.

Survey duration	**Total occasions**	**M_0 vs. M_b**	**M_0 vs. M_t**	**M_h goodness-of-fit**	**M_b goodness-of-fit**
75 days (5 d intervals)	15	X^2 = 6.037 *df* = 1 *p* = 0.0140	X^2= 4.267 *df* = 14 *p* = 0.9936	X^2 = 22.217 *df* = 14 *p* = 0.07426	X^2 = 24.408 *df* = 12 *p* = 0.01789

Table 5.6: Results of estimated abundance, standard error, and capture probabilities of Servals sampled in LNP with the three best fitting models.

Heterogeneity model $M_{h\ (Jackknife)}$		**Heterogeneity model $M_{h\ (Chao)}$**		**Null Model M_0**		**Heterogeneity and behaviour model M_{bh}**	
Capture probability	Abundance ± SE (95% CI)	Capture probability	Abundance ± SE (95% CI)	Capture probability	Abundance ± SE (95% CI)	Capture probability	Abundance ± SE (95% CI)
0.0933	5 ± 1.8092 (5-14)	0.0381	4 ± 0.5358 (4-7)	0.1077	4 ± 1.2635 (4-12)	Not computed	4 ± 0.0111 (4-4)

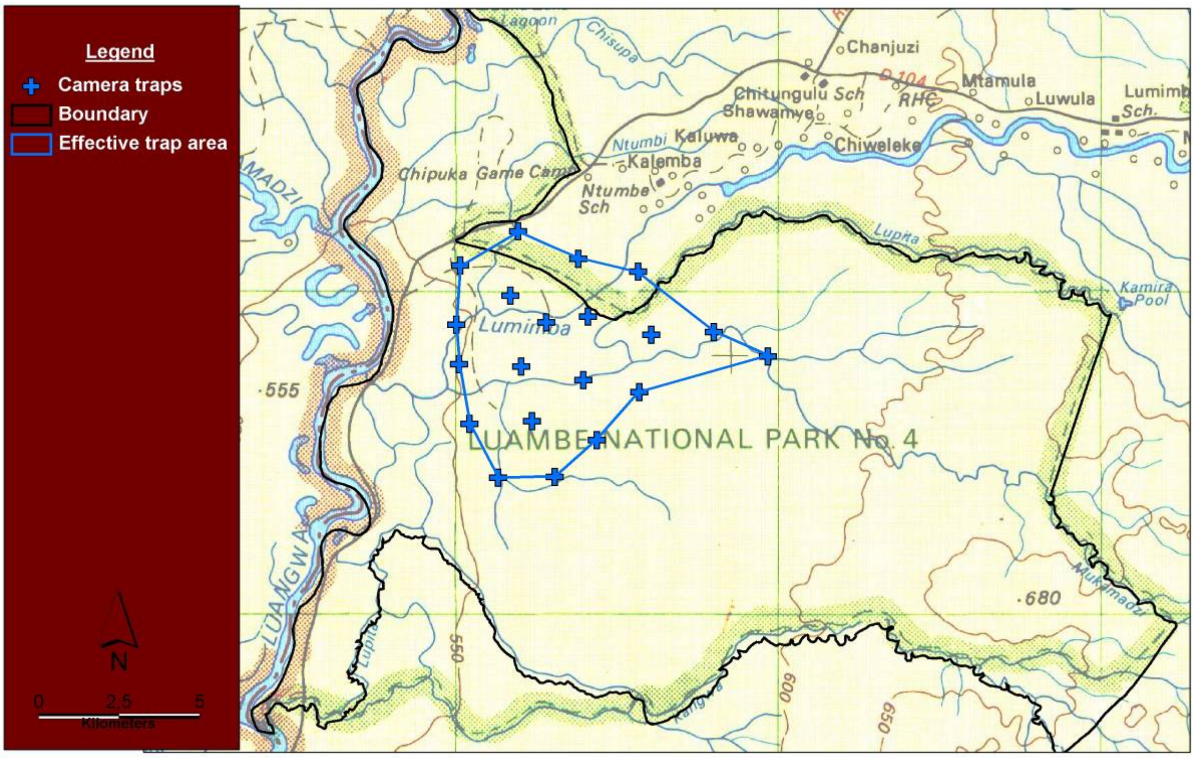


Figure 5.6: Effective trap area 2008 in Luambe National Park (border = blue line).

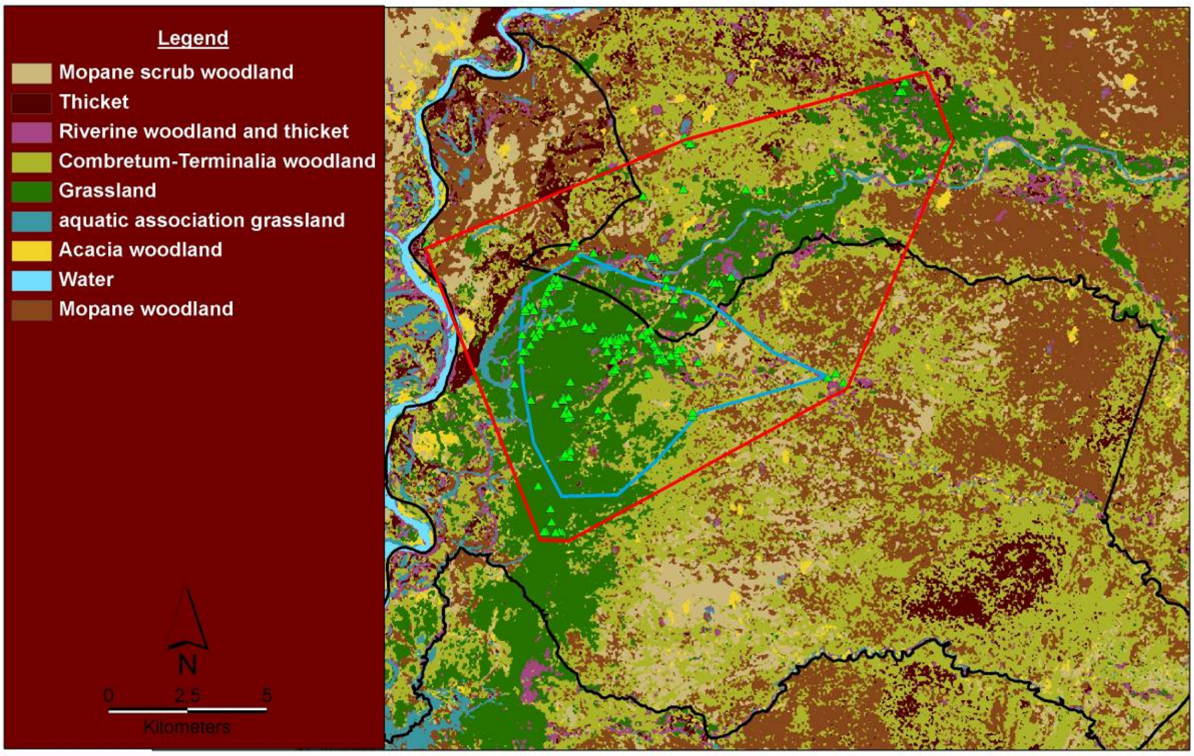


Figure 5.7: Vegetation map of the effective trap area (40.4 km2, blue line) and of the MCP of Serval presence area (134 km^2, red line). Boundary of LNP = black line.; green triangles = Serval activity signs.

The cross check setup did not provide any pictures of a Serval. The setup (see Fig. 5.8) of 19 unbaited camera traps was used for 77 days of 24 hours. The camera traps were placed in the Woodland habitats (58%), Thicket (21%) and Riverine Woodland located directly at the Luangwa River (21%). This proved again that there are no (rarely) any Servals found in Woodland habitats.

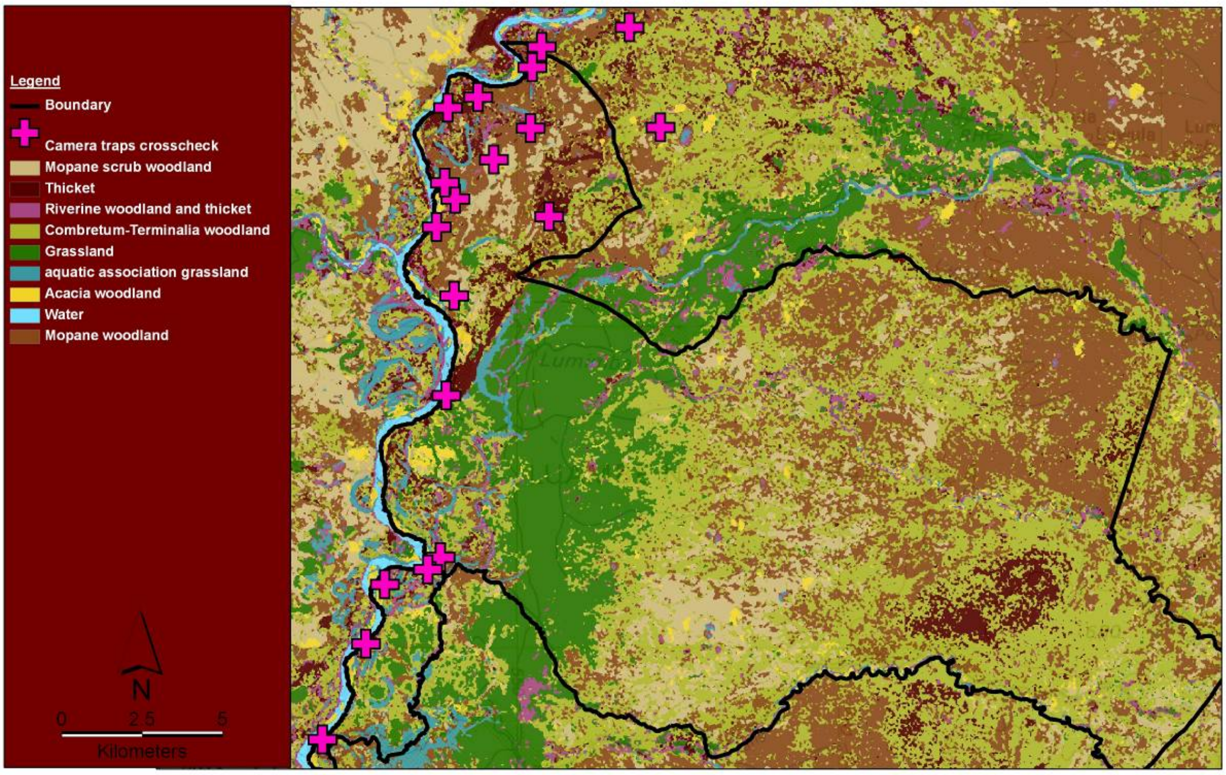


Figure 5.8: Cross check setup of camera traps in Woodland habitat in LNP.

5.4. Discussion

This study provides new information on Serval abundance and density, not only for Zambia but is this the first extensive study on that subject world-wide. Reliable information on abundance of the Serval (*Leptailurus serval*) is more than scarce.

Identification of Servals is possible through their pelage patterns. While MITHTHAPALA et al. (1989) distinguished leopards in Sri Lanka from their whisker spot patterns, body spotting was found easier to use (e.g., BLOMQVIST AND NYSTROM (1980) on snow leopards, KOEHLER (1987) on bobcats, MCDOUGAL (1977) on tigers, HENSCHEL & RAY (2003) on leopards). Also Servals are more easily distinguished from their body spotting and therefore were an ideal target species for identifying individuals. This species fulfils the requirements of JACKSON et al. (2005), that each individual is permanently marked and uniquely distinguishable from others and that all previously captured individuals must be reliable distinguished from 'unmarked' (not captured) individuals. Only adult Servals were identified. The presence of a sub-adult Serval was noted and has to be considered when discussing abundance and density estimates.

Placing of the camera traps proved to be challenging, but it is one of the essential factors in the camera trapping method. Camera density affects the precision of population estimates (LARRUCEA et al. 2007). Higher camera densities result in more captures and recaptures and thus, in more precise density estimates (LARRUCEA et al. 2007). Because different individuals of the same species have different home range sizes and movement patterns, camera trapping should be tailored to the local population (DILLON & KELLY 2008) and the appropriate camera spacing/density and total area size determined using local population statistics. In this study it was only possible to specify areas of usage; sometimes regularly visited places were identified, but no home range size or movement patterns could be measured in advance of the camera trap study. With VHF or GPS telemetry home range sizes and movement patterns can be examined, but in LNP it was not possible to capture Servals in the years 2006 and 2007 to fit them with a transmitter collar, and so no data on the behaviour of the local population was available. Consequently, the study design had to follow common knowledge about Servals as well as study designs of similar sized felines (e.g. Ocelot or Bobcat). Studies on Ocelots were executed with spacing between cameras of 1500 m (one camera in 1.8 km^2) and 2 km (one camera in 3.1 km^2) (DILLON & KELLY 2008, MAFFEI & NOSS 2008). Ocelots showed an average daily distance moved of roughly 2 km, and the smallest home range of an Ocelot is 2 km^2 in size, and thus a spacing of 1500 m guaranteed no holes in the grid; at least one camera trap per home range made it less probable to miss a present Ocelot. In a study on Bobcats, daily distances moved were found to be 1-5 km, and so they placed one camera trap per 1.3 km^2 (HEILBRUN et al. 2006). With average daily distances moved by Servals of 3-4 km (SMITHERS 1978), 2-4 km (GEERTSEMA 1985) and 0.37-6.6 km (VAN AARDE & SKINNER 1986) they are very similar to those of Ocelots and Bobcats. Average home range sizes of Servals vary between 9.5 and 31km^2 (GEERTSEMA 1985, BOWLAND 1990), while the smallest home range examined was, like the Ocelot's, 2.1 km^2 (VAN AARDE & SKINNER 1986). VAN AARDE & SKINNER (1986) followed reintroduced, captive bred Servals for only 2-5 months and found a home range size of 2.1 to 2.7 km^2, whereas the other two studies were more extensive ones showing larger home range sizes. Setting of this study's camera trap area was done following study designs for similar sized felids FROM HEILBRUN et al. (2006), DILLON & KELLY (2008) and MAFFEI & NOSS (2008) so as to get the best possible results. The spacing was approximately 1850 m between cameras (approximately one camera trap every 2.7 km^2), as home range sizes are thought to be slightly larger than the Ocelot's and daily distances moved were similar within all three cat species.

Following MARNEWICK et al. (2008), camera traps should ideally be placed randomly or in a grid format. KARANTH & NICHOLS (1998) stated that it is best to place the traps where there is the highest likelihood of obtaining photographs (e.g. scent stations, roads, "hotspots" that cats in an area regularly visit); this approach has the advantage that relatively few cameras are needed but this kind of selective placement has been proved to influence capture rates of some species, such as Ocelots and Jaguars (TROLLE & KERY 2005; WECKEL et al. 2006). In 2002 KARANTH & NICHOLS reviewed their statement from 1998 and proposed that one should first delineate the survey area to produce survey cells, and then a visit to each survey cell should be made to locate the best spot to place the camera trap. They suggest setting the cameras at locations within the survey cells with the highest chance of getting a picture of the target species. At the same time it may be necessary to place some traps in areas less likely to be visited, to fill potential "holes" in the sampled area. The study by DILLON & KELLY (2008) on Ocelots indicates that this compromise of the two setting approaches (i.e. using a grid system, in which cameras are placed at the best locations with most potential for capturing the target species e.g. along trails or roads where spoor is found) is best. MARNEWICK et al. (2008) proposed investigating suitable camera trapping sites by examining available movement and habitat data in a Geographic Information System (GIS) program to identify good trap locations. In this study, a survey grid (2x2 km squares) was used, followed by an examination of each grid square to choose the best locations to put camera stations. Two camera traps per grid squares were placed at game trails, riverbeds or places with high probabilities of Serval activity. Hence, a compromise between total random and selective placement was reached, to minimize the previous mentioned disadvantages of these approaches. Some of the camera trap stations were placed to fill the gaps between camera locations with more potential for successfully capturing the target species. Some were placed to minimize edge effects; the larger the area, the smaller the possibility of counting animals along the edge of the survey area as "partial residents" (WHITE et al. 1982). These "stopgaps" are mostly the stations placed in Combretum Terminalia Woodland, such as F 9-08, F 11-08 and F 15-08, with F 8-08, F 16-08 and F 19-08 as edge effect minimisers. Consequently, 30% of all camera traps were placed in grid/random placement. In Table 5.6 these locations are marked with an "s". These traps did not contribute any pictures to the study. The other stations (70%) were set selective according to previously known placements of Serval activity and signs. The different camera placements are shown with their capture/recapture success and the associated habitat type (Tab. 5.6).

Studies on Leopards show that the availability of travel routes is a major factor affecting capture probability (HENSCHEL & RAY 2003). If there are many trails of comparable widths available, animals have more choices of convenient routes to go and it becomes increasingly difficult to tell where they will travel and consequently where best to place a camera trap. The opposite is true for sites with few trails. In Luambe National Park, many game trails cut through the vegetation and there were only a few graded roads. During the dry season when more grass disappeared (through burning, grazing or drying out), animals had less need for game trails. Many equally sized game trails in LNP may have been a major factor influencing the capture success of this study. TROLLE & KERY (2005), who worked on medium sized carnivores (Ocelot, Puma), showed that 96% of all their captures took place on roads. This level of capture success on roads could not be tested here, as there were not many roads available to set camera stations. Trapping success was not significantly different from that expected from the camera set up locations. This could be because n is small and in two cases n = 1. Within those placed on game trails, only game trails located in tall grass showed any success rates (Tab. 5.3). This could be because these paths were the easiest route through the tall grass at the time. The other placements showing capture success were located in dry riverbeds, which for animals, could be similar to roads, with comparable width and walking comfort.

In an area with excellent water- and food resources GEERTSEMA (1985) found a density of one Serval per 2.4 km^2. Therefore, the density in her study would have been 41.7 Servals per 100 km^2. BOWLAND (1990) estimated 8 Servals per 100 km^2, in summertime with plentiful food resources, which is closer to the density estimation of 9.9 individuals per 100 km^2 from this study. This estimate sounds plausible, as in 2006 in LNP and surrounding areas 11 Serval observations were made and in 2007 13 sightings were recorded (not including the re-sightings). At present, little data on density estimates are available for other species of smaller African felids. AVENANT & NEL (1998) found a Caracal density of 23 to 47 individuals per 100 km^2, while SLIWA (2004) found 17 Black-footed Cats per 100 km^2; both studies only using their results on radio telemetry in South Africa to come to their conclusions. In contrast, in Turkey only 1.73 Caracals per 100 km^2 were found (GIANNATOS et al. 2006). Caracals are similar in size and therefore comparable to Servals. The numbers found in the two Caracal studies of AVENANT & NEL (1998) and GIANNATOS et al. (2006) show similar number but also high variance, as is the case with the density estimations of the three studies done on Servals (GEERTSEMA 1985, VAN AARDE & SKINNER 1986, and BOWLAND 1990). More studies on the different small African felids may also show different densities within the different populations of the same species as abundance, range size, stability and overlap are affected by habitat quality (e.g. accessibility of food and water, possibility to cover), habitat disturbance (like human disturbance, hunting/poaching, fire or carnivore competitors), sex differences and age differences (GEERTSEMA 1985). The Ngorogoro Crater in Tanzania, GEERTSEMA's Serval study site, is known for its species richness and may provide space, good habitat quality and undisturbed environment for more Servals to utilize than the farmland in Natal, where the study of BOWLAND (1990) was situated. GEERTSEMA (1985) stated that Servals tend to have larger home range sizes in habitats with more disturbance (fires, animal movements), such as in an area outside Gorigor in Tanzania, compared to the home range sizes in the Crater. Luambe National Park is not as well protected as the Ngorogoro Crater, but shows less human impact than the farmland in Natal does. The level of human disturbance may be why the numbers of Serval abundance in LNP might be between those found by these studies. These three studies on Servals took place in different years, seasons and locations, so any comparison is speculative and needs to be investigated further.

If the Serval density in this study reflected that of GEERTSEMA (1985) (one Serval per 2.4 km^2) each camera trap would have photographed at least one Serval, as each station covered an area of approximately 2.7 km^2. Every recapture took place at the same camera trap as the initial identification. If a large percent of animals are captured at only one camera station, maximum distances are not being accurately recorded and the stations may be too far apart (DILLON & KELLY 2008). If all sighting records (own observations, using protocols with drawings and written description, as well as all pictures taken in 2006-2008) are considered, some individuals had been spotted on several occasions (Figure 5.9), so that an average distance moved for some individuals could be estimated after three years of observation. The individuals F10-08 and S06-07 turned out to be the same ones (determined by their pelage pattern) and it was found to cover 2300 m. The individual S6 was seen twice, with 3100 m between the sighting spots. A mother and her young (S03-07 and S04-07) were seen twice with 350 m between sighting locations. S1 was seen three times with a spacing of 250 m altogether. The other four individuals, which were spotted twice, were observed at repeated locations. Hence, Servals of LNP in this study showed an average distance moved of 750 m ± 1150.27 m. Consequently, the density of the camera traps in this study would ideally have been set up closer together (e.g. 750 m). These results strongly suggest that Servals in Luambe National Park must have smaller home range sizes than the previously calculated values of 9.5 km^2 to 31 km^2 (GEERTSEMA 1985, BOWLAND 1990). They reflect better the values of VAN AARDE & SKNINNER (1986) with values of up to 2.7 km^2. Although the study of GEERTSEMA (1985) showed home range sizes of minimum 9.5 km^2, she stated that "[…] in one year an adult female Serval regularly uses about half her total range, while an adult male regularly uses three quarters.", which led to an average home range size of 4.6 km^2 for females and 8.1 km^2 for males (regarding her two study animals). Also GEERTSEMA (1985) calculated that Servals have core areas within their home ranges of 1-2 km^2 in size, which they use ~30% of their time. She observed that their home range sizes also vary with observation period length; in only two month observation time Servals in the Ngorogoro Crater only used an area of 0.3 km^2 (first study period, n = 3) and 4.5 km^2 in size (second study period, n = 6). In contrast, BOWLAND (1990) studied the movement of Servals for 60-100 days and found home range sizes of 15-31 km^2 with core areas of 0.56-0.77 km^2. DILLON & KELLY (2008) stated that Ocelot home range sizes are smaller when food sources are more abundant, whereas GEERTSEMA (1985) found no seasonal changes in distribution and range patterns between dry and wet season in her Serval study. BENSON et al. (2006) stated, that population density should be considered, with reference to energy acquisition and metabolic factors such as food availability and body size. These factors could have been reasons why there appear to be smaller home range sizes for Servals in this study site. The study was conducted over less than three months and in an area with high prey abundance, water resources, and vegetation cover. This capture-recapture study design for LNP resulted in an overestimation of potential home range size. Although a minimum of one camera per home range is acceptable, having up to four cameras per home range is recommended to increase capture success (WHITE et al. 1982), meaning a camera density of one trap per 1km^2 (spacing ~550 m). Another explanation for the low capture success per camera unit could be that in Luambe National Park Servals may not have a large area of overlap in home ranges as GEERTSEMA (1985) found in the Ngorogoro Crater (average of 79% between males and females). However, Figure 5.10 shows groups of Servals, which were observed at the same time at the same place. On two occasions three and four animals respectively were watched together in an area of only 400 m in diameter. Taking all these facts into consideration it is possible that Servals of LNP show small home range sizes of around 2-4 km^2, with a density similar to estimates made by BOWLAND (1990) (0.22 compared to 0.18 Servals per 2.2 km^2), but with a high overlap of home ranges in areas of good habitat quality. This overlap of home ranges and simultaneous use of good quality habitats previously shown in Servals (GEERTSEMA 1976) and other cats (STEFFEN 2003, THIEL 2004, MAFFEI et al. 2004, BENSON et al. 2006, GIANNATOS et al. 2006), although LEYHAUSEN (1979) points out that felids usually avoid direct encounters during their daily routine. If these assumptions apply, the effective trap area size of 40.4 km^2 was then big enough to cover at least four times a home range size, which minimizes the chance of overestimating the density (MAFFEI & NOSS 2008). The number of photo captures and recaptures increases with increasing study duration. Increasing the area sampled results in the capture of more individuals, but not the percentage of recaptures (LARRUCEA et al. 2007). JACKSON et al. (2006) pointed out that capture success might be affected by unknown factors, as in their study, all individual snow leopards were captured within two weeks in one year, while during another year it took two months. Extending the study period up to 90 days (instead of 75 days) would have possibly increased capture success, assuming that the population is still closed within this longer period of time.

Most conducted surveys correlate species density positively with the number of photographs recorded, so that capture frequency may serve as an index of relative abundance (CARBONE et al. 2001). However, capture frequencies do not always translate reliably into species density, even in systematic surveys (JENNELLE, RUNGE & MACKENZIE 2002). For example, MAFFEI et al. (2003) and MAFFEI et al. (2004) showed a discrepancy in the capture frequency and density results calculated with CAPTURE; 81 photographs of eight individual Pumas (*Puma concolor)* and 62 photographs of 18 individual Ocelots lead to Ocelot densities over three times Puma densities. Factors contributing to the breakdown of the relationship between capture frequency and density across sites may be locations for camera placement, availability and condition of roads and trails, weather, season, camera failure, buffer estimation and animal behaviour. In this study, 20% of all camera stations showed any capture success, with only seven captures and recaptures, which still led to a density estimation of 9.9 Servals per 100km^2.

With regard to these estimations of Serval density, it is important to point out the limitations of the program CAPTURE. This software works best with larger populations (like >15-20 individuals of Snow Leopards (JACKSON et al. 2005), or >2-3 Tigers per 100 km^2 (KARANTH & NICHOLS 2002)). Each sampling occasion should be 3-5 days in length for abundance estimations (JACKSON et al. 2005). This study has got a sampling occasion of 5 days and a population of around 10 individuals. JACKSON et al. (2005) state that a capture probability of >0.1 is good, but it is better to have a value >0.3 for >5 occasions for CAPTURE to deliver a plausible abundance estimation. If applied to the data above, the best fitting model M_h would not have been the most appropriate model and model M_0 would have been the model of choice. This would have changed the population size estimation only slightly, from 4 ± 0.5358 to 4 ± 1.2635 Servals in 40.4 km^2. The Trap Response Model (M_b) (the CAPTURE goodness-of-fit test showed a good support for this model) allows for differences in capture probabilities due to behaviour changes in trap responses ('trap-shyness' or 'trap-happiness') (JACKSON et al. 2005). For example, the use of baits may increase capture probabilities by attracting some individuals more than others and make them therefore 'trap-happy', while flashes could scare animals off and making them 'trap-shy'. In this study neither baits nor flashes were used, because of their influences on behaviour. Eliminating behavioural responses to camera traps rules out the use of this model and the lack of behavioural response could have led to its low fit value of 0.66 in CAPTURE, which influenced its exclusion for use in this study.

Density estimations rely on an accurate estimate of the sampling area around the camera traps, which is usually obtained using maximum distances travelled by individuals (MMDM) photographed at two or more different locations. However, even with these buffers, doubts have been raised about whether the usage of ½MMDM or full MMDM, gathered by telemetry, literature or with the camera traps, is accurate enough (MAFFEI & NOSS 2008, DILLON & KELLY 2008). An appropriate study area size also must be chosen (MAFFEI & NOSS 2008, DILLON & KELLY 2008). In this study, no calculation of MMDM was possible. Therefore, a buffer of 0 km (no buffer) was chosen around the camera trap area. MARNEWICK et al. (2008) had a similar result with their study (no movement data and small numbers of captures and recaptures) and did no calculation of density estimates. HENSCHEL & RAY (2003) stated that even if there is no recapture in a study, it is still possible to use certain recapture models to derive a density estimate. Density estimates have to be calculated carefully, especially if capture probability is very low and the confidence limits are very wide. In this case, capture probabilities were low, but confidence intervals were relevant to the best fit model M_h (CI = 4-7). Therefore density estimation is still possible, but subsequent conclusions need to be considered carefully. A repeat of this capture-recapture study is necessary (with narrower spacing, more camera traps or the shift of the cameras in the middle of the study period, and a period of 90 days) to recalculate population size and density with another set of data. Comparisons can give a more accurate estimation for LNP and used to put forward recommendations for further studies and conservation projects for the Serval. Calculating area specific Serval densities is the first step towards determining whether a given population exists at levels viable for long-term persistence. This study found evidence that this population is productive and shows a large enough population to be potential stable and sustainable.

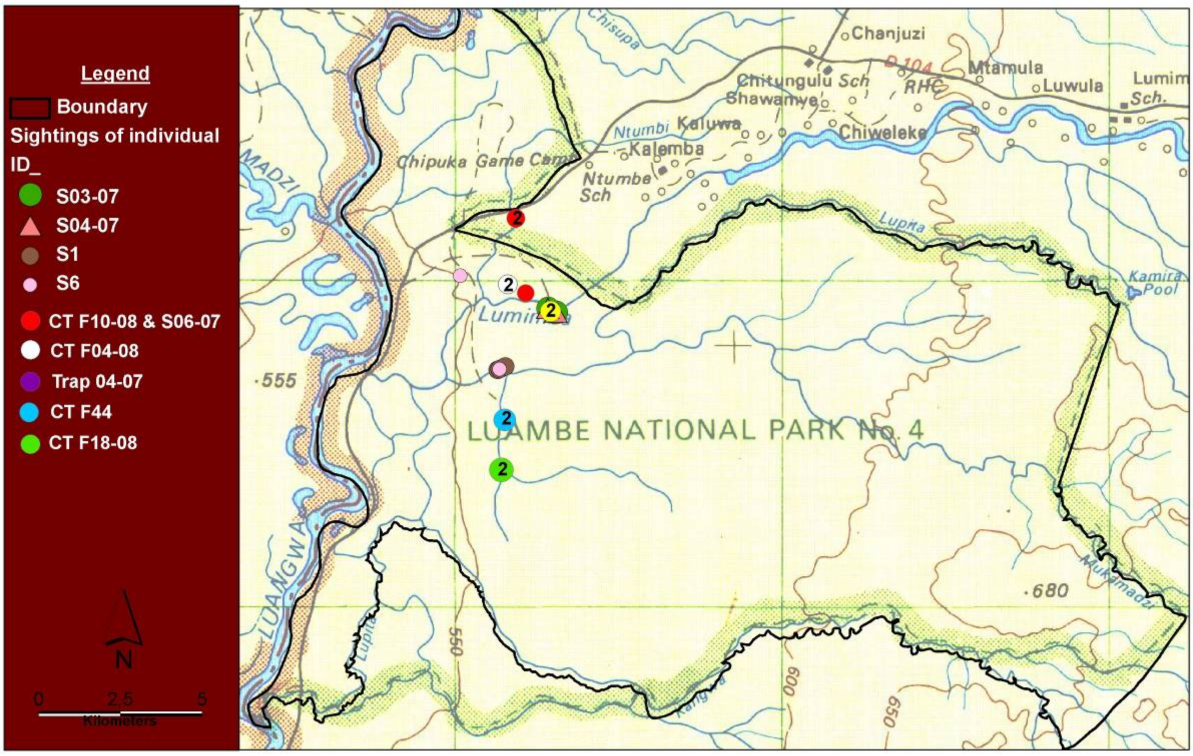


Figure 5.9: Multiple sighting sites of individual Servals in Luambe National Park.
CT = Camera trap (numbers follow the number of locations and the year), S = Serval (numbers follow the number of the sighting and the year), Trap = live trap (see Chapter 6)
② = same individual seen twice at this location.

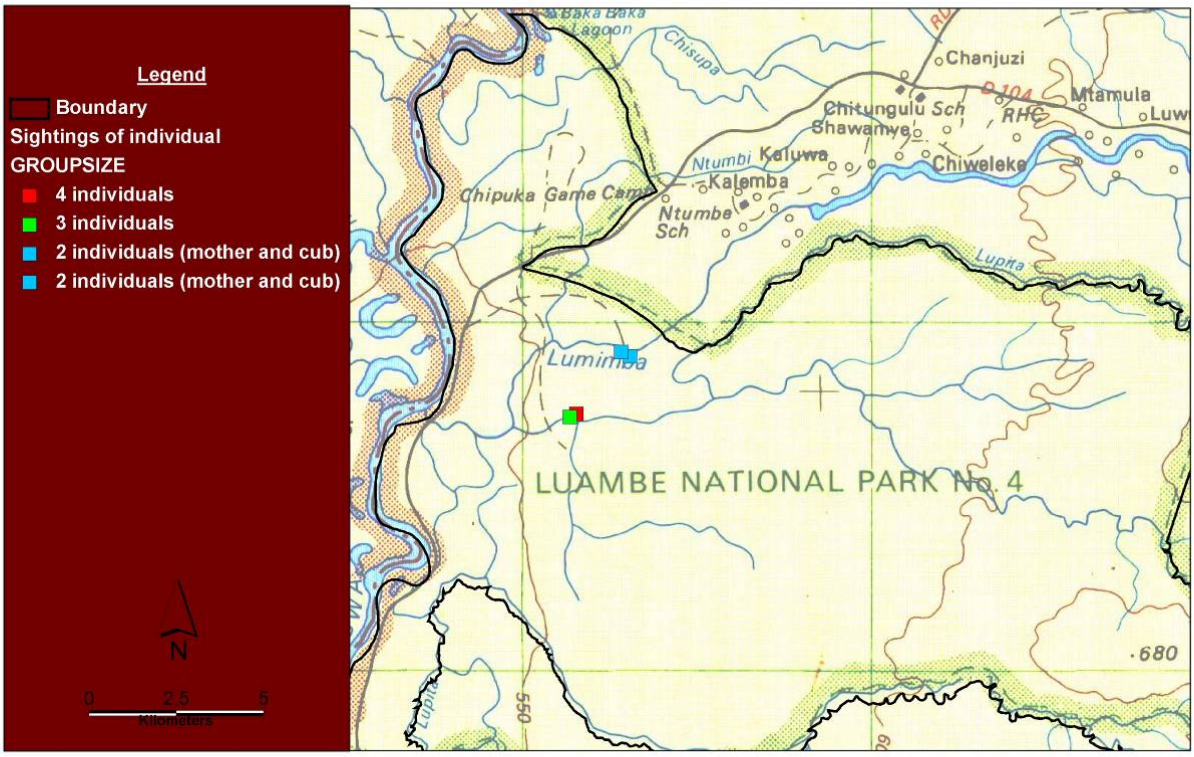


Figure 5.10: Sightings of groups of different sizes of Servals in Luambe National Park.

5.5. Summary Chapter 5

Determining abundance for elusive carnivores, such as the Serval, is difficult, but estimates of abundance are extremely valuable for species conservation. Abundance is a parameter of vital interest to carnivore ecologists, because it affects virtually all other aspects of biology and conservation of the species of interest. This study is the first to attempt to estimate population size of Servals with capture-recapture methods. 20 camera trap stations were set up in 40.4 km^2 of potential Serval habitat in Luambe National Park (LNP), Zambia. The study was carried out between July and October 2008 and all camera traps were set up for 74 consecutive days as single stations, with a spacing of approximately 1850 m, resulting in a trap cover area of 2.7 km^2 per station. Identification of individuals was done using pelage patterns. Seven pictures of Servals were taken, and four adult individuals could be recognized with three recaptures recorded. Abundance was estimated with the software CAPTURE Version 2; test for closed populations was done by the programs CAPTURE Version 2 and CLOSURE. The best fitting model, calculated using the software, was the Heterogeneity Model M_h, followed by the Null Model M_0. The model M_h assumes differences in capture probabilities between individuals that may result from accessibility to traps, social dominance, or differences in age and sex. Minimum population size of Servals in LNP was calculated to be 4 ± 0.5358 adult individuals ($M_{h(Chao)}$) with a confidence interval of 4-7 Servals. Following these abundance estimates, Serval density was 9.9 adult Servals in 100 km^2. Extrapolation of this number onto 134 km^2 of identified Serval habitat in and around LNP lead to a value of 13.3 adult individuals within the study area.

As this study was the first camera trap study on Servals ever undertaken, the design of the effective trap area was not without bias and error. It appears that Servals in LNP showed much smaller home range sizes than other Servals studied in Tanzania and South Africa. Recaptures only took place at the original camera station, where the individual was photographed first. This indicates that the spacing of cameras was too large, as home range size was overestimated. Also the length of the study would need to be extended, as Servals tend to use only parts of their home ranges for a short period of time (e.g. two months) and therefore minimizing the trapping events at different stations by their natural behaviour if camera set up is over too short a time. This Serval population estimation will help to propose guidelines for conservation management and further capture-recapture studies on this less known felid.

6. Distribution models of the Serval in Zambia

One aspect of this chapter is to review the only existing distribution map of Servals in Zambia by ANSELL (1978), as well an investigation on the two types of spot patterns in *Leptailurus serval* occurring in Zambia. These two morphs were described by ANSELL (1978) too, and he claims that they are clearly geographically restricted. To confirm his statement Serval morphs within Zambia will be examined.

Another aspect sketches the Africa-wide distribution of the Serval, determined by a computer based model using maximum entropy (maxent) technique with the software MAXENT.

6.1. Introduction

The Serval is widely distributed throughout Africa south of the Sahara (Fig. 1.4), with a relict population in areas in Senegal (CLEMENT et al. 2007), and reported but not confirmed in the mountainous areas from Morocco and Tunisia (VISSER 1976, SKINNER & SMITHERS 1990, KOWALSKI & RZEBIK-KOWALSKA 1991, CUZIN 2003). Studies on the distribution of Servals in South Africa were conducted intensively (VON RICHTER 1972, RAUTENBACH 1982, VISSER 1976, ROWE-ROWE 1978, SMITHERS 1983, STUART 1985, BURTON & PEARSON 1987) and recently added by HERMANN et al. (2008) with the recovery of the return of the Servals into central South Africa. Other countries rely on data collected decades ago. GADSBY (1991) proofed the Servals occurrence in Nigeria only by the common trade of its furs on local markets. Same evidence is given by MAISEL et al. (2001) for the country Cameroon and by SAYER & GREEN (1984) for Benin. Servals are very rare in Algeria and Guinée Bissau (LIMOGES 1989, KOWALSKA 1991). In the Republic of the Congo, Odzala-Kokoua NP holds the only currently known protected population in the Gabon-Congolian savannah region, which is isolated from the Miombo woodlands south of the Congo River (Phillip HENSCHEL, after http://www.iucnredlist.org/ apps/redlist/details/11638/0; 06. 2010). SMITHERS (1968) described the distribution of Servals in Botswana, as well as western Rhodesia, while SHORTRIDGE (1934) determined their occurrence in Okawango and Caprivi. ANSELL & DOWSETT (1988) found Servals in Malawi to be widely common. In Zambia the most accurate distribution map was provided by ANSELL (1978) (Fig. 6.1). There is a question mark on the map, which is located at the Lower Zambezi National Park region. This region borders Mana Pools where GIBSON (1984) proofed the Serval's distribution on this side of the Zambezi River. ANSELL (1978) describes the distribution as follows: "The species occurs throughout Zambia, including the montane areas and the low-lying valleys [...]. In general it seems common, though seldom seen."

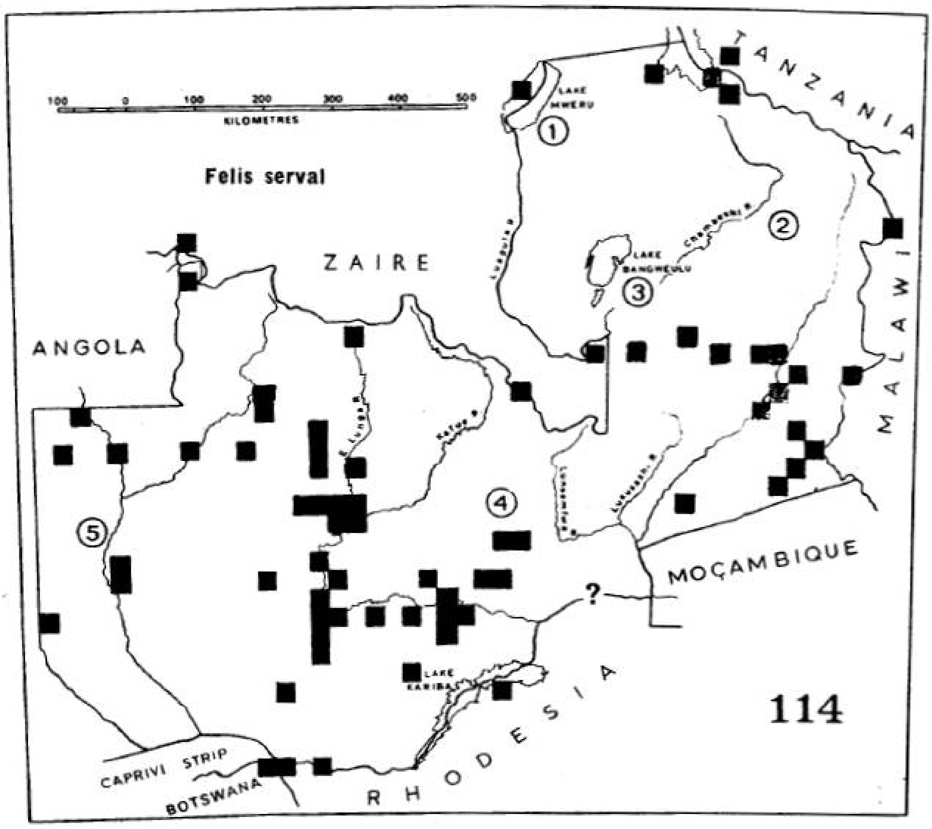


Figure 6.1: Distribution Map of *Leptailurus serval* in Zambia (ANSELL 1978).

Several subspecies of *Leptailurus serval* have been described, but their validity is doubtful. Today there are following 14 subspecies (WOZENCRAFT 1993) or rather 18 subspecies (WILSON & REEDER 2005) accepted but not genetically reviewed (Tab. 6.1).

These subspecies are mostly regionally known and therefore linked to that specific region. In the earlier days of specimen collection the classification underlay pelage colour and pattern (SMITHERS 1978). This led to numerous subspecies. There is a freckled or "servalina" type and a bold black spotted type. The servalina form was originally stated as a separate species *Felis brachyuran* WAGNER, 1841 (POCOCK 1907). In 1917 POCOCK revised his statement from 1907 and counted the small spotted form to the big spotted *Felis serval* SCHREBER, 1776. In 1934 PITMAN (after ROSEVEAR 1979) examined a series of skins and concluded as well that the different spot types have intermediate forms and therefore cannot be two different species. ROSEVEAR (1974) also stated that the extremes are clearly recognisable from each other, with many intermediate forms. Both forms can be found with kittens of the same litter (POCOCK 1917, DOLLINGER 1982). These differences in spot patterns often led to confusion in the taxonomy of this species and are only in some cases correlated with geographic regions (PETERS 1982). ALLEN (1939) listed 17 subspecies, while three of them were of the small spotted form *Felis brachyuran*. WEIGEL (1961) also grouped the subspecies by the size of their spots, while KINGDON (1977) and ROSEVEAR (1974) did not regard that as a relevant taxonomic feature. ELLERMAN et al. (1953) considered the small spotted form as a mutant of the normal *Felis serval*. PETERS (1982) and SMITHERS (1989) stated that spotted cats are known to produce aberrant forms, like the King Cheetah for example. Underlining this statement, there are black Servals known to occur commonly in Aberdare NP in Kenya (MATHEWS & URSCHELER 1993), and from personal observations a spot pattern similar to the King Cheetah, the “King Serval”, is also possible.

SMITHERS (1975) and ANSELL (1978) believed that the small spotted form of *Leptailurus serval* has its distribution in the western parts of Africa, with its south-western distribution boundary located in Zambia. SMITHERS (1971) allocated *Felis brachyura* (Synonym of *Felis brachyuran)* with its alleged subspecies and their synonyms to the synonymy of the various subspecies of *Felis serval*. He included the Zambian form in the nominate race, listing several synonyms, of which only *F. larseni* applied to the most southern form of Servals. He stated that this form is indistinguishable from *Felis brachyuran liposticta* (the servalina form). The holotype of this small spotted form, *Felis servalina larseni* THOMAS, 1913, was found in northern Angola (Annals and Magazine of Natural History (8) 12: 91. Type locality: Near Bembe, northern Angola), while the holotype of the big spotted form was found in South Africa (*Felis serval* SCHREBER, 1776; Säugethiere, 3(16), pl. 108. Type locality: Cape of Good Hope). This could stress the statement of SMITHERS (1975) and ANSELL (1978) of the West African distribution of the small spotted form, but neither a study has been done on that subject nor any genetic research on the correlation of spot patterns and subspecies status has been conducted. ANSELL (1978) noted the following about the different spot types within Zambia: “The small spotted form appears to be limited to the areas adjacent to the Lowland Forest zone, and it is not known south of Zambia. In Zambia it does not occur east of the Muchinga/Zambezi escarpments, and perhaps not in the extreme southern areas [...]. In addition to the two phases there is a good deal of individual variation, and the valid subspecies of *F. serval* (s.l.) are not always clear.”

Table 6.1: Subspecies of Leptailurus serval after Wozencraft (1993) and Wilson & Reeder (2005). Areas marked with a ? means that there is no specific area mentioned for this subspecies.

WOZENCRAFT	WILSON & REEDER	Area	Comment
Leptailurus serval beirae	*Leptailurus serval beirae*	Mozambique	
Leptailurus serval brachyurus	*Leptailurus serval brachyurus*	West Africa, Sahel and Ethiopia	Servaline Cat Synonym: *ogilbyi* (SCHINZ 1844), *servalinus* (OGILBYI 1839)
Leptailurus serval constantinus	*Leptailurus serval constantinus*	Algeria	Endangered Synonym: *algiricus* (J.B. FISCHER 1829)
Leptailurus serval hamiltoni	*Leptailurus serval hamiltoni*	eastern Transvaal	
Leptailurus serval hindei	*Leptailurus serval hindei*	Tanzania, Kenya	
Leptailurus serval kempi	*Leptailurus serval kempi*	Uganda	
Leptailurus serval kivuensis	*Leptailurus serval kivuensis*	Congo and Angola	
Leptailurus serval liposticta	*Leptailurus serval lipostictus*	Northern Angola	Small spotted form
Leptailurus serval lonnberg,	*Leptailurus serval lonnbergi*	South west Angola	Synonym: *niger* (LÖNNBERG 1897)
Leptailurus serval mababiensis	*Leptailurus serval mababiensis*	Northern Botswana	
Leptailurus serval robertsi	*Leptailurus serval robertsi*	Western Transvaal	
Leptailurus serval serval	*Leptailurus serval serval*	Cape Province	Synonym: *capensis* (FORSTER 1781), *galeopardus* (DESMAREST 1820)
Leptailurus serval togoensis	*Leptailurus serval togoensis*	Togo and Benin	
Leptailurus serval ingridi		South Zimbabwe, Botswana, southwest Africa	
	Leptailurus serval ferrarii	? Somaliland	
	Leptailurus serval phillipsi	? Sudan	
	Leptailurus serval faradjius	? Congo	
	Leptailurus serval pococki	? Senegal	Synonym: *senegalensis* (LESSON, 1839)
	Leptailurus serval pantastictus	? Congo	Synonym: *poliotricha* (POCOCK, 1907)

Besides the lack of knowledge on the Serval's subspecies also the status of its Africa-wide population is unclear. Conservation of species requires not only detailed knowledge of their natural history, biology, genetics, and classifications, but also information on the availability of suitable areas where species can survive and reproduce. Large-scale habitat models have been created for some carnivore species using animal location information, remotely sensed data, multivariate statistics, and GIS (CLARK et al. 1993, NIELSEN & WOOLF 2002, LARUE 2007). These models are created by statistically evaluating relationships between species occurrences and landscape or climatic characteristics. Recent developments in species distribution modelling (SDM) have made it possible to apply this to diverse conservation issues, including potential distribution and species range estimates (GAUBERT et al. 2006, GUISAN et al. 2006, PAPES & GAUBERT 2007), and effects of habitat disturbance on species distributions (RHODES et al. 2006). In recent years, the number of studies applying species distribution models has increased (GUISAN & ZIMMERMANN 2000, GUISAN & THUILLER 2005, RÖDDER & LÖTTERS 2010). These models are used for a variety of applications such as assessments of possible climate change impacts (ARAÚJO et al. 2004, THUILLER et al. 2004, RÖDDER & SCHULTE 2010), regions of potential invasive species establishment (BOMFORD et al. 2009, PETERSON & VIEGLAIS 2001, RÖDDER et al. 2008, RÖDDER & LÖTTERS 2010), reserve selection (ARAÚJO et al. 2004), spatial epidemiology (PETERSON 2007, RÖDDER et al. 2008, RÖDDER et al. 2009) or species delimitation related to taxonomy or historical biogeography (BROWN & TWOMEY 2009, LÖTTERS et al. 2010, RÖDDER et al. 2010). SDMs try to characterize the niche of a species and project it into geographic space including regions from which it is unknown. This can be conducted via correlative models, which can be developed using geo-referenced species records and environmental information stored in grid-based geographic information system (GIS) layers (JESCHKE & STRAYER 2008, RÖDDER & LÖTTERS 2010). The SDM characterizes the target species' niche by comparing environmental conditions at presence records with the environment at localities where the species is absent. As reliable absence records in the majority of species are rare (GU & SWIHART 2004), pseudo-absence data or background data reflecting the available climate space can be used (JESCHKE & STRAYER 2008, PHILLIPS et al. 2006). These correlative models identify statistically significant relationships between a species presence at a given locality and the locality's features of the environment, which are subsequently used to determine probability values or an index of 'relative habitat suitability' to all grid cells covering the study area (GUISAN & ZIMMERMANN 2000, GUISAN & THUILLER 2005, JESCHKE & STRAYER 2008, RÖDDER & LÖTTERS 2010).

The 'suitable habitat' for each species can be defined as the set of environmental conditions (abiotic factors) under which a species is able to maintain viable populations without immigration (GRINNELL 1917, after PAPES & GAUBERT 2007). These new SDM methods apply specifically to presence-only records, which remain the major source of occurrence data (PHILLIPS et al. 2006). This data is available through recent field studies or through networking of museum collections.

There are several different software products to construct an SDM. MAXENT (PHILLIPS et al. 2006), being one of these, is a maximum entropy-based machine-learning method used for making predictions when incomplete data are available. "MAXENT estimates the probability distribution for a species' occurrence that is most spread out given the constraints derived from the available data." (PHILLIPS et al. 2004, PHILLIPS et al. 2006). These constraints are educed from environmental conditions at species presence records and require that the expected value of an environmental variable or its function must be within a confidence interval derived from its empirical mean (PHILLIPS et al. 2006). Such approaches rely on the assumption that climatic tolerances of species are the primary determinants of their current distributions and at the same time that climatic niches are conservative, at least within evolutionarily relatively short time frames such as some hundreds to thousands of years (WIENS & GRAHAM 2005). The goal is to predict which areas within the region satisfy the requirements of the species' ecological niche, and thus form part of the species' potential distribution (PHILLIPS et al. 2004). The idea of MAXENT is to estimate the target species' distribution by finding the distribution of maximum entropy (i.e., that is closest to uniform).

6.2. Methods

6.2.1. Distribution model of morphs/subspecies in Zambia

The chosen collection sites in this study (Fig. 6.2) are marked by ANSELL (1978) as Serval distribution area, so that a review on ANSELL's distribution map and also on his assumption on the distribution of the two morphs/subspecies in Zambia is feasible. If possible, pictures of Servals were taken at the visited sites in addition to a note on the presence or absence of Servals. Data of current findings and pictures of Servals, recently compiled by lodge employees and researchers within Zambia, as well as pictures of skins from museum collections were used to complete the data for a revised distribution map. The acquisition of museum skins was difficult, as the only large collection of Serval skins from Zambia got lost in Zimbabwe. The other small collection could be examined in the Livingstone Museum in Zambia itself.

Figure 6.3 shows confirmed occurrences and the south-western distribution boundary of the small spotted form of the Zambian Serval after ANSELL (1978). All results of the analyses were projected onto ANSELL's map of the subspecies/morphs to verify it with more recent findings.

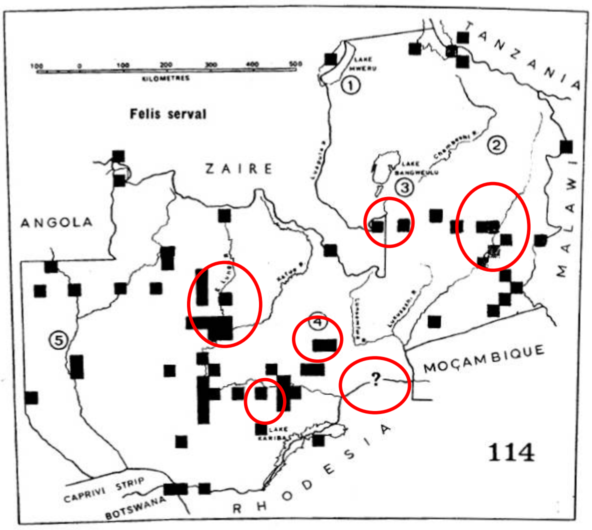


Figure 6.2: Chosen collection sites (red circles) for this study in reference to the distribution map by ANSELL (1978).

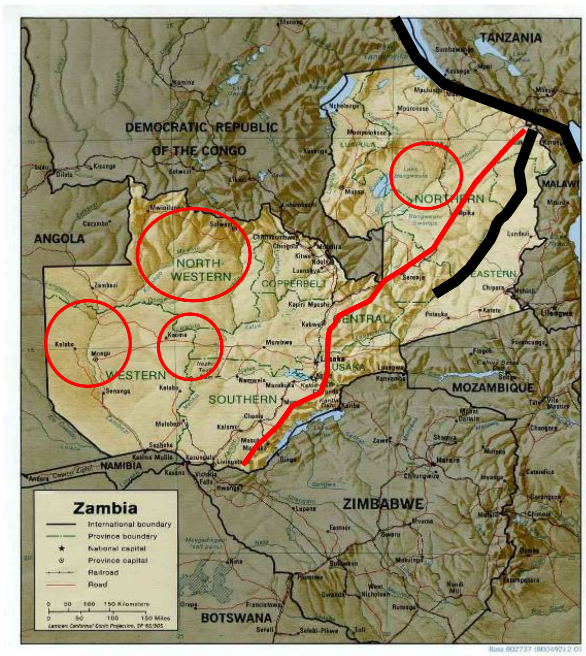


Figure 6.3: Map of Zambia with the distribution range of the small spotted form of *Leptailurus serval*, after ANSELL 1978.
Black line = Great Rift Valley;
Red Line = South-western border of the distribution;
Red circles = assured locations of occurrence.
Distribution model of *L. serval* in Zambia

Presence data for Servals within Africa was acquired through own data collection (342 species records), added by 53 records of the Global Biodiversity Information Facility database (www.gbif.org) and 119 records from literature. All species records are not older than from 1950. Georeferencing, if necessary, was conducted with Google Earth (Google; www.googleearth.com). To avoid autocorrelation a cluster analysis was performed with XLSTAT (http://www.xlstat.com/de/home/; 05. 2009) and out of these 514 data points 101 locations of Serval presence were used in the MAXENT model. All data were checked in the DIVA-GIS software for bias and errors. Duplicate presence records per grid cell were removed by the MAXENT program prior to model development. The latest desktop version (MAXENT 3.3.3e; www.cs.princeton.edu/~schapire/maxent; 01. 2011) was used. The settings were set to create response curves, to use random seed, to do Bootstrap, not to extrapolate, but do clamping. Seventy percent of the data points were randomly selected as training points, while the remaining 30% of the records were test points, used for model validation. The MAXENT model output was set to logistic, which returns an estimated probability of presence ranging between 0 (no probability of species presence) to 1 (species is certain to be present). In order to determine, which variables contribute most to the model, the MAXENT program was set to calculate Jackknife tests of variable importance. This procedure produces three different types of models: (1) models created with one variable at a time excluded and all other variables included, (2) models created with only one variable included, and (3) a model created with all variables. Variables that contribute to the model at most are those that decrease the training gain when removed from the model and show gain when the model is developed with only one variable. At the same time the maximum number of background points was set to 10,000 and 50 replicated runs were performed. All other parameters stayed at default settings.

To summarize environmental variation, 19 'bioclimatic' variables based on the global climate data sets developed by HIJMANS et al. (2005) were used (Tab. 6.2; http://www.worldclim.org/bioclim.htm; 05. 2009). Bioclimatic variables have been proven to be useful for many large scale SDM approaches (BUSBY 1991). These GIS data sets characterize global climates from 1950-2000 using average monthly weather station data and are available at different spatial resolutions, with the 30 arc-seconds (~1 km^2) and the 5 arc-minutes (~85.7 km^2) chosen for this study. The two models were created with only a subset of the 19 variables, because the inclusion of too many variables in SDMs can cause over-fitting problems (BEAUMONT et al. 2005, HEIKKINEN et al. 2006). Therefore, the first step was to rank all variables in their importance for the target species. The second step is to analyse the chosen variables for auto-correlation. This step was conducted with ENMTools (WARREN et al. 2008, WARREN et al. 2010). All 19 variables and their correlation to each other were determined (see Table 6.1 in Appendix) and all resulting r-values were squared. If any $r^2 > 0.75$ was found, only one of the two variables could be chosen, to avoid pairs of high correlation. This method of variable choice let to the following seven variables for the Serval distribution modelling: BIO1, BIO4, BIO6, BIO9, BIO12, BIO15 and BIO18.

Table 6.2: BioClim variables and their definition. (green marked = used for this model)

BIO1	= Annual Mean Temperature
BIO2	= Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3	= Isothermality (P2/P7) (* 100)
BIO4	= Temperature Seasonality (standard deviation *100)
BIO5	= Max Temperature of Warmest Month
BIO6	= Min Temperature of Coldest Month
BIO7	= Temperature Annual Range (P5-P6)
BIO8	= Mean Temperature of Wettest Quarter
BIO9	= Mean Temperature of Driest Quarter
BIO10	= Mean Temperature of Warmest Quarter
BIO11	= Mean Temperature of Coldest Quarter
BIO12	= Annual Precipitation
BIO13	= Precipitation of Wettest Month
BIO14	= Precipitation of Driest Month
BIO15	= Precipitation Seasonality (Coefficient of Variation)
BIO16	= Precipitation of Wettest Quarter
BIO17	= Precipitation of Driest Quarter
BIO18	= Precipitation of Warmest Quarter
BIO19	= Precipitation of Coldest Quarter

For each run, MAXENT provides a variety of possible thresholds to convert continuously scaled logistic output maps into reasonable presence/absence maps. MAXENT tests the model performance by calculating the Area Under the Curve (AUC), referring to the Receiver Operating Characteristic (ROC) curve (HANLEY & MCNEIL 1982). In ROCs, the sensitivity values, the true-positive fraction against 1-specificity and the false-positive fraction for all available probability thresholds are calculated (FIELDING & BELL 1997). This method is recommended for ecological applications because it is nonparametric (PEARCE & FERRIER 2000). MAXENT also provides this calculation of the AUC for all training points. Values of AUC range from 0.5, which means that this model is random, to 1.0 for models, which give a perfect prediction. SWETS (1988) described AUC values >0.9 as a ‘very good’ model fit, values >0.8 are considered ‘good’ and values >0.7 still show ‘useful’ discrimination ability.

The MAXENT models can be evaluated using both threshold-dependent and threshold-independent methods (LIU et al. 2005). The area under the curve (AUC) of the receiver operating characteristic (ROC) analysis is a threshold-independent method of evaluating model quality (PHILLIPS et al. 2006). This technique computes the total area under the curve created by plotting sensitivity against the fractional predicted area for the species, corrected for the predicted range. The threshold-dependent measure used is the minimum training presence in which the probabilities are converted to binomial values with 0 being absent and 1 being present (PHILLIPS et al. 2006). Using this method, all pixels with a probability of presence equal to or greater than that of the training point with the lowest probability of presence are classified as present and all pixels with a lower probability of presence are classified as absent. In this study the value for the lowest 10 percentile training presence was applied instead of the minimum training presence, as it is more widely used in SDM applications (LIU et al. 2005). Hence, the mean 10 percentile training presence value of the model is used to reclass all values equal or greater than its mean value as presence and values below as absence data.

The resulted cumulative probability distribution raster maps with pixel values of 0 - 1 were imported into DIVA-GIS Version 7.3 (HIJMANS et al. 2001) as raster files. The output map was overlaid with land cover data, eco-region maps, areas of wilderness and protected areas. Land cover data was obtained from the Global Land Cover 2000 database (http://bioval.jrc.ec.europa.eu/products/glc2000/products.php; 12. 2010). This is a global land cover classification of 96 land cover classes (27 classes for Africa) at a resolution of 1 km^2. Eco-region maps were obtained at http://www.worldwildlife.org/science/data/item6373.html (accessed 12. 2010) and the World database on protected areas was provided by the IUCN and UNEP-WCMC (IUCN and UNEP-WCMC 2010), The World Database on Protected Areas (WDPA): Annual Release [On-line]. Cambridge, UK: UNEP-WCMC), available at: www.protectedplanet.org; 30.12.2010. The wilderness areas were created by MCCLOSKEY & SPALDING (1989) and show areas bigger than 400,000 ha in size, which do not show any human impact such as road, settlements, airports and other constructs and are at least 6 km away from such improvements and areas of agricultural development and logging. This map is for free as well and to download on the United Nations Environment Program – UNEP Geo Data Portal (http://geodata.grid.unep.ch; 12. 2010).

Graphs are produced with XLSTAT© 2011.1.03.

6.3. Results

6.3.1. Distribution model of morphs/subspecies in Zambia

All study sites were confirmed positive for Serval occurrence. While Lower Zambezi was marked by ANSELL (1978) with a question mark now data can be added on this National Park (Fig. 6.4).

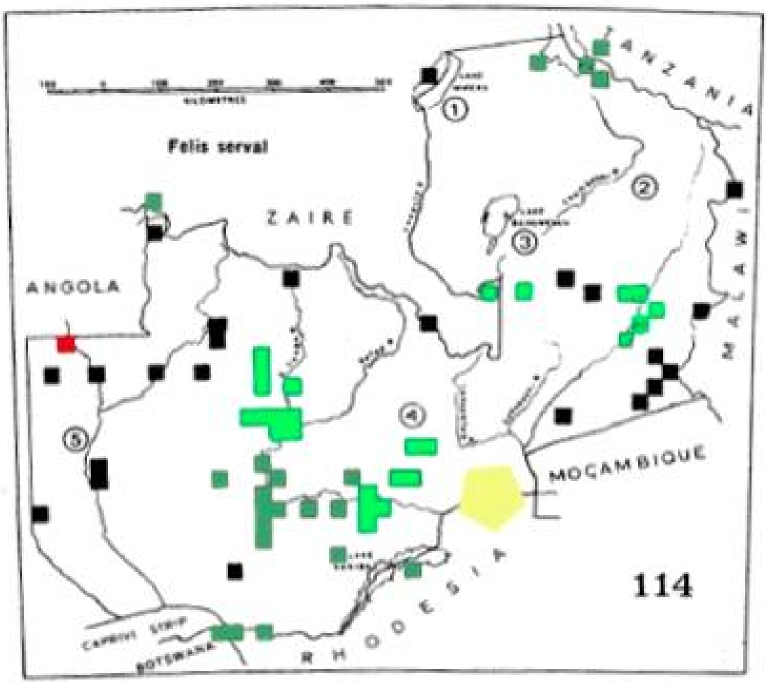


Figure 6.4: Map of Zambia after ANSELL (1978) reviewed and added by recent findings.
Black squares: original data, unconfirmed;
Green squares: confirmed data (light green by C. Thiel, dark green by personal communications);
Red squares: absence data (by personal communications);
Yellow polygon: newly confirmed area by C. Thiel

Serval pictures and skins were combined with Ansell's spot pattern map (Fig. 6.5). In this figure all acquired pictures are shown, together with an 'out-group' of pictures of a Congolese Serval which shows very small spot patterns and therefore definitely belong to the servalina form. Also in the collection of the Livingstone Museum in Zambia was a skin of a servalina Serval, but this skin did not have any description or locality and consequently is shown here only as an example of the extreme morph possible in Zambia. During this study no morph like this could be found. The lilac arrows show some kind of intermediate forms, but mostly big spotted cats (blue arrows) could be recorded. No intermediate form was observed beyond the south-western boundary ANSELL proclaimed. Hence, it is not given that ANSELL misinterpreted the distribution range of the servalina morph. Further investigations are needed as this morph seems to be rare in Zambia.

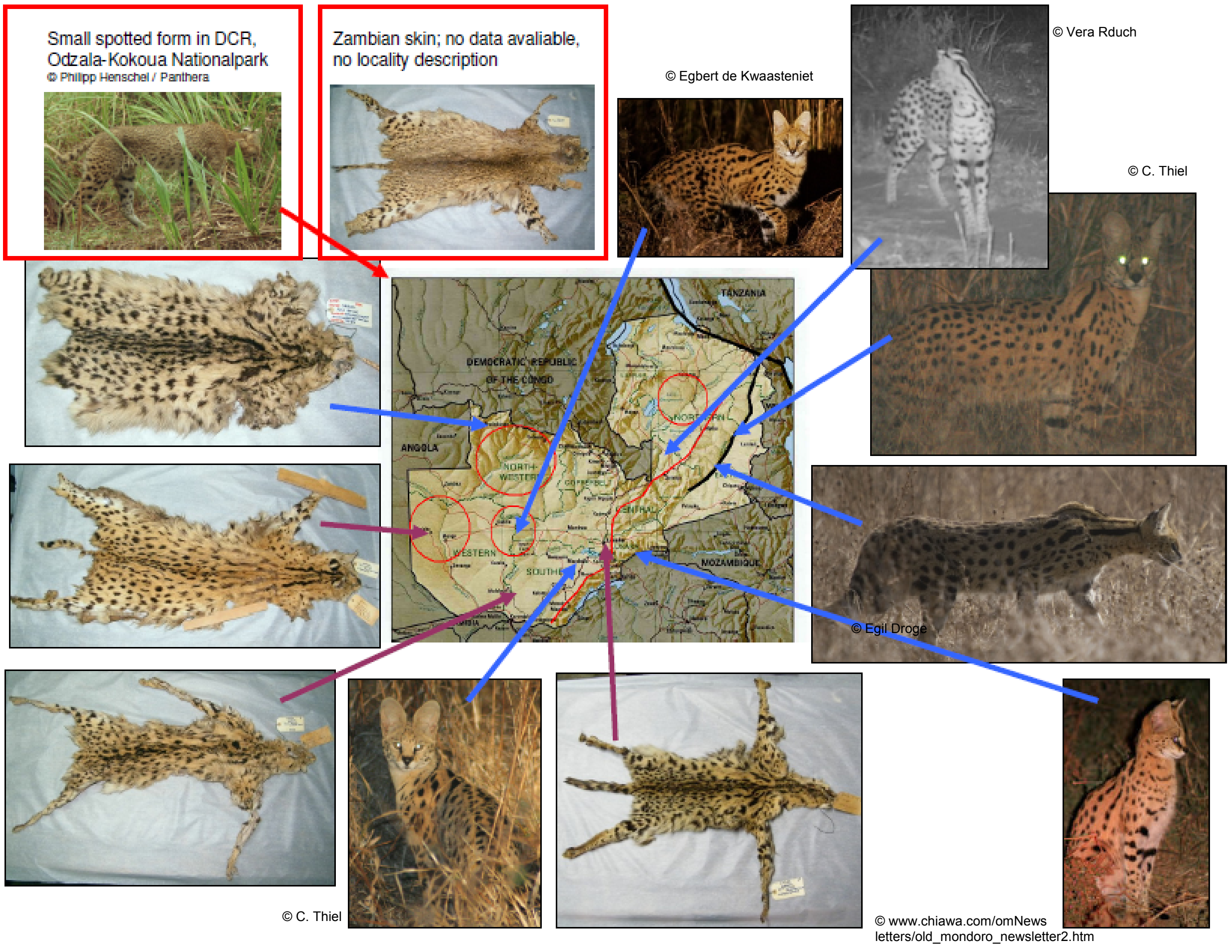


Figure 6.5: Map of pelage spot pattern found in Zambia.
Blue arrows = big spotted form; Red arrows = small spotted form; Lilac arrows = intermediate form.
(Photos of skins by Clare Mateke, Livingstone Museum, Zambia)

6.3.2. Distribution model of *L. serval* in Zambia

The model with the chosen variables and the 30 arc-second resolution received 'good' AUC values (training AUC = 0.8618 ± 0.017) using 30 % random test points out of each data set for testing (test AUC = 0.8106 ± 0.034) (Fig. 6.6). The mean 10 percentile training presence logistic threshold value was 0.308 (SD = 0.038).

The model with the chosen variables and the 5 arc-minutes resolution received 'good' AUC values (training AUC = 0.8632, SD = 0.015) using 30 % random test points out of each data set for testing (test AUC = 0.8227 ± 0.03) (Fig. 6.6). The mean 10 percentile training presence logistic threshold value was 0.302 (SD = 0.047).

The contribution of the seven BioClim variables is shown in Figure 6.7. It is obvious that BIO12 is the most important variable, followed by BIO18 and BIO9.

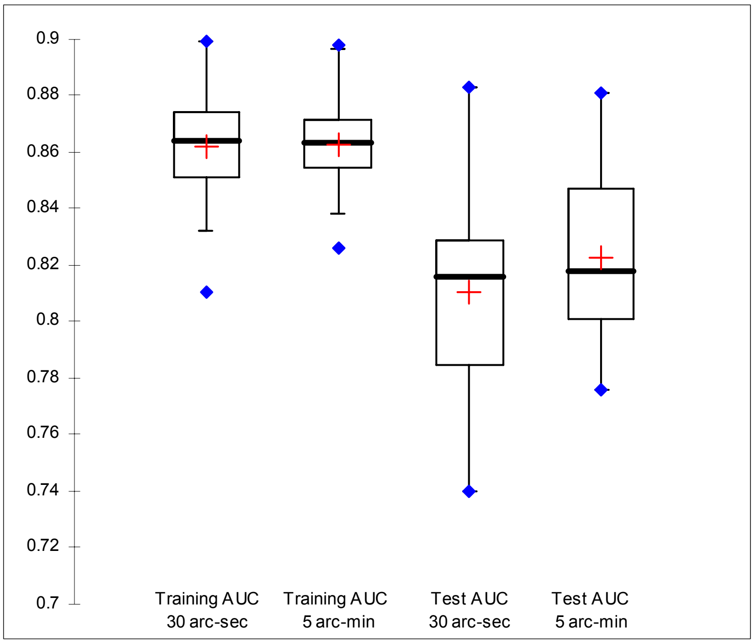


Figure 6.6: Box plot of AUC values.

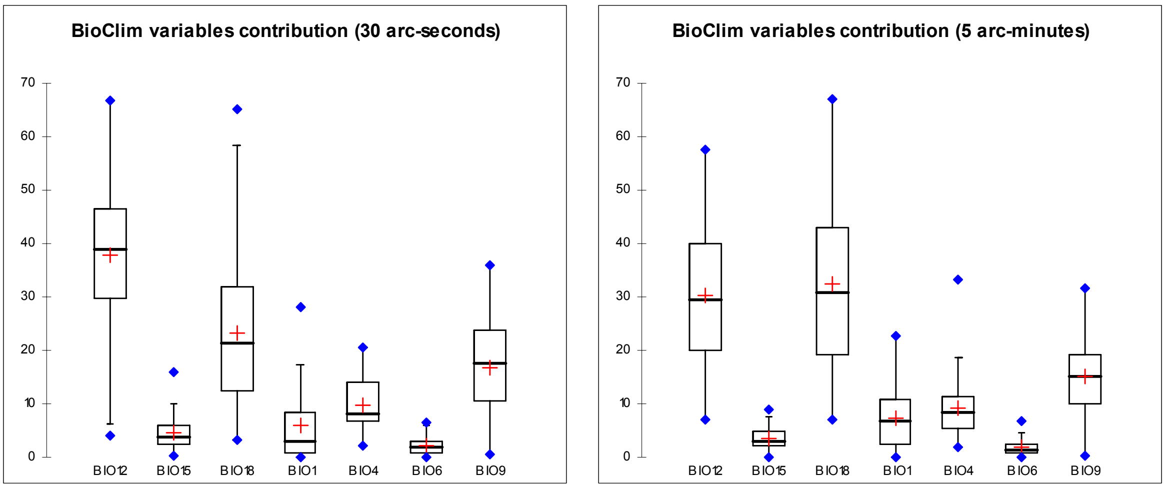


Figure 6.7: The contribution box plot of the BioClim variables for both models.

Figures 6.8 & 6.9 show the potential distribution of the Serval resulting from these two MAXENT models, modified with DIVA-GIS and overlaid with the Serval presence data points used in the model. Values below the average 10 percentile training presence threshold are areas of absence. Both predictions show very similar patterns, but in the 5 arc-minutes resolution the presence area Africa-wide is much bigger than with the finer resolution. Areas of high probability (> 0.7) are similar but the extend of low probability areas diverges tremendously after the presence/absence threshold was applied. The areas of the highest MAXENT fit (> 0.7) are in both models the southern and south-eastern coast line of South Africa (Western Cap, Eastern Cape, KwaZulu-Natal), the former Transvaal provinces in South Africa (Gauteng, Mpumalanga, and Limpopo), Lesotho, the Eastern Highlands of Zimbabwe, the northern part of Rwanda and the bordering southern part of Uganda, the northern mountainous boundary of Tanzania and from there following the East African Rift Valley, through Kenya and Ethiopia and to its northern end, up to the Gulf of Aden and the Red Sea. In the 5 arc-minutes resolution model also an area close to the western Angolan coast is of high probability. Additionally the southern tip of the Yemen and parts of the Moroccan coast is calculated to have good MAXENT fits for Serval presence.

MAXENT cannot highlight potential distribution barriers for the target species, so that African islands are also taken into calculations, but the Serval cannot get past the barrier of a sea and therefore all islands were left out in the subsequent figures.

More detailed analyses were conducted only with the 30 arc-seconds model as for a land mammal, such as the Serval, a grid of 5 arc-minutes comprises too many microhabitats to be inhabited by this species (a home range size is much smaller than this grid size) and therefore produces biases right from the beginning. If the MAXENT map of higher resolution is overlaid with information on the eco-regions it is obvious that some biomes are more suitable for Servals than others. Areas of higher probability are mostly areas of the biome 'Montane Grasslands & Shrublands', 'Tropical & Subtropical Grasslands, Savannas & Shrublands', and also of the biome 'Tropical & Subtropical Moist Broadleaf Forests' if bordering the preceding. One exception in both models is the southern coast of South Africa and the Moroccan Coast, where the biome is 'Mediterranean Forests, Woodlands & Scrub'. The distribution along the East African Rift Valley from Tanzania to the Red Sea is interrupted by the 'Masai xeric grass- and scrublands', which are too dry for Servals. Figure 6.10 shows the model's results modified with these biomes. Several biomes were excluded (grey areas) as not suitable for Servals and some were included as suitable (see Tab. 6.3). Most of the excluded areas overlap with areas of low probability for Serval presence, but some excluded biomes cut through areas of even high MAXENT fit. This is the case for example in Kenya and Ethiopia where the biome 'Tropical & Subtropical Moist Broadleaf

Forests' is less likely to inhabit Serval populations. Also big lakes, such as the Lake Victoria and Tanganyika, are marked as not suitable biomes.

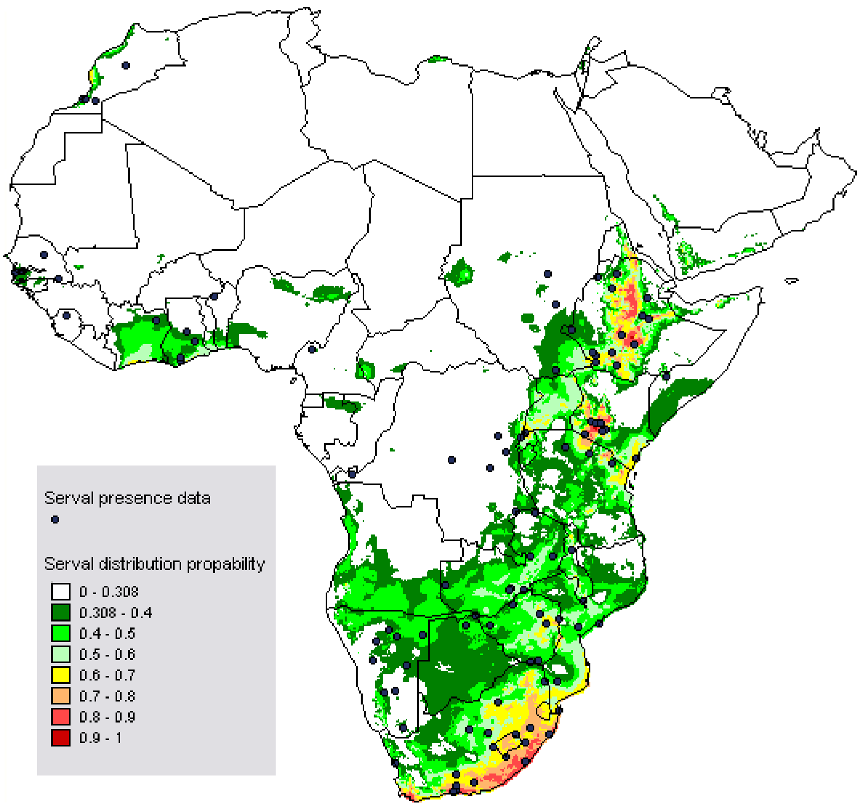


Figure 6.8: Potential distribution of *Leptailurus serval* in 30 arc-seconds resolution.

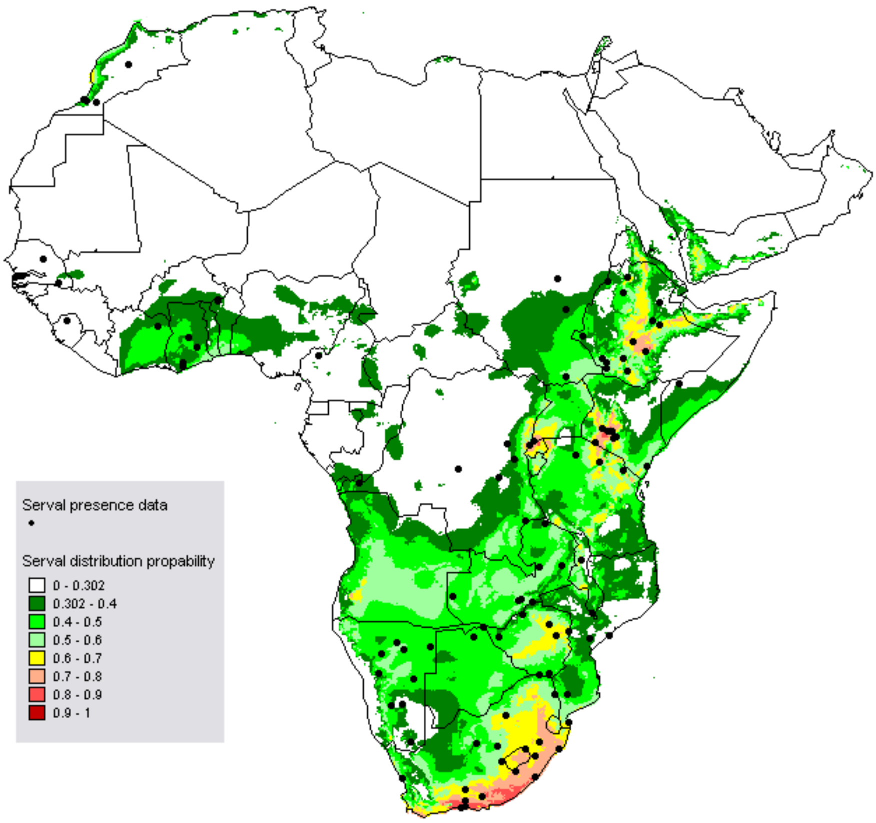


Figure 6.9: Potential distribution of *Leptailurus serval* in 5 arc-minutes resolution.

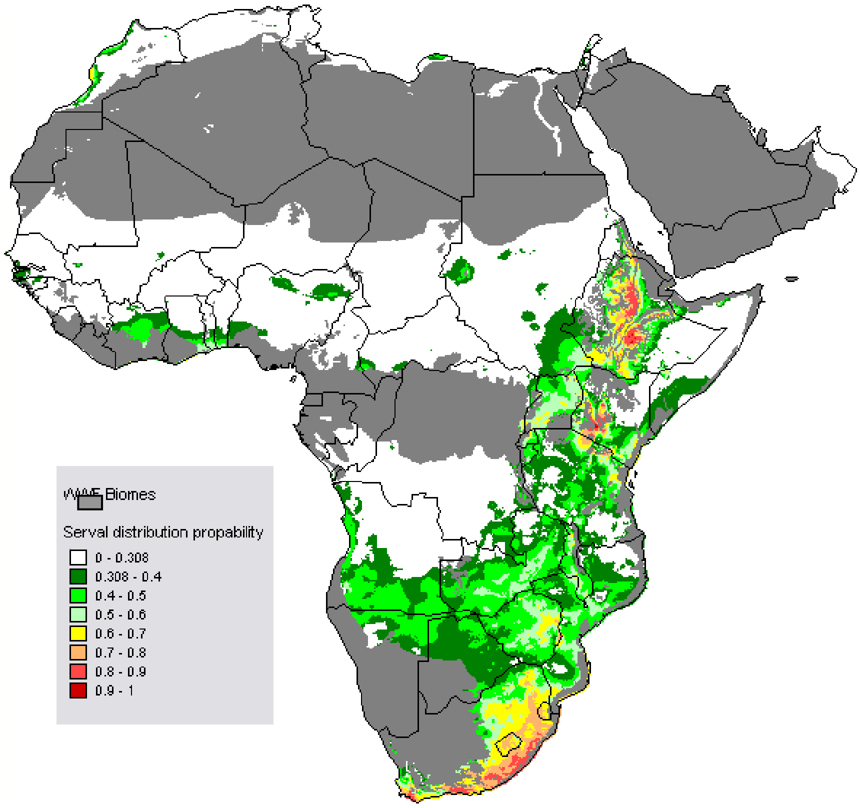


Figure 6.10: Map of potential distribution areas of *Leptailurus serval* overlaid with the excluded WWF biomes.

Table 6.3: WWF biome table. X = not included, √ = included.

WWF Biomes	included
Tropical & Subtropical Moist Broadleaf Forests	x
Tropical & Subtropical Dry Broadleaf Forests	x
Tropical & Subtropical Coniferous Forests	x
Temperate Broadleaf & Mixed Forests	x
Temperate Conifer Forests	x
Boreal Forests/Taiga	x
Tropical & Subtropical Grasslands, Savannas & Shrublands	√
Temperate Grasslands, Savannas & Shrublands	√
Flooded Grasslands & Savannas	√
Montane Grasslands & Shrublands	√
Tundra	x
Mediterranean Forests, Woodlands & Scrub	√
Deserts & Xeric Shrublands	x
Mangroves	x

The same can be done with land cover classes in a 30 arc-seconds resolution projected onto the potential distribution map. With this index also the human influence is taken into consideration, as e.g. cities and cropland are separate classes which are not accounted for within the WWF biomes. Table 6.4 shows all land cover classes and their inclusion or respectively their exclusion. Figure 6.11 illustrates the results, with grey areas being excluded land cover classes. Again, most excluded classes already were outside the most probable Serval presence areas, and big water bodies such as lakes were taken out. But areas of high MAXENT fit show high overlays by excluded land cover classes, too. Especially the Ethiopian region of high probability and the South African coastline are excluded mostly due to the land cover classes ‘Cities’, ‘Croplands (>50%)’ and ‘Closed […] forest’ classes.

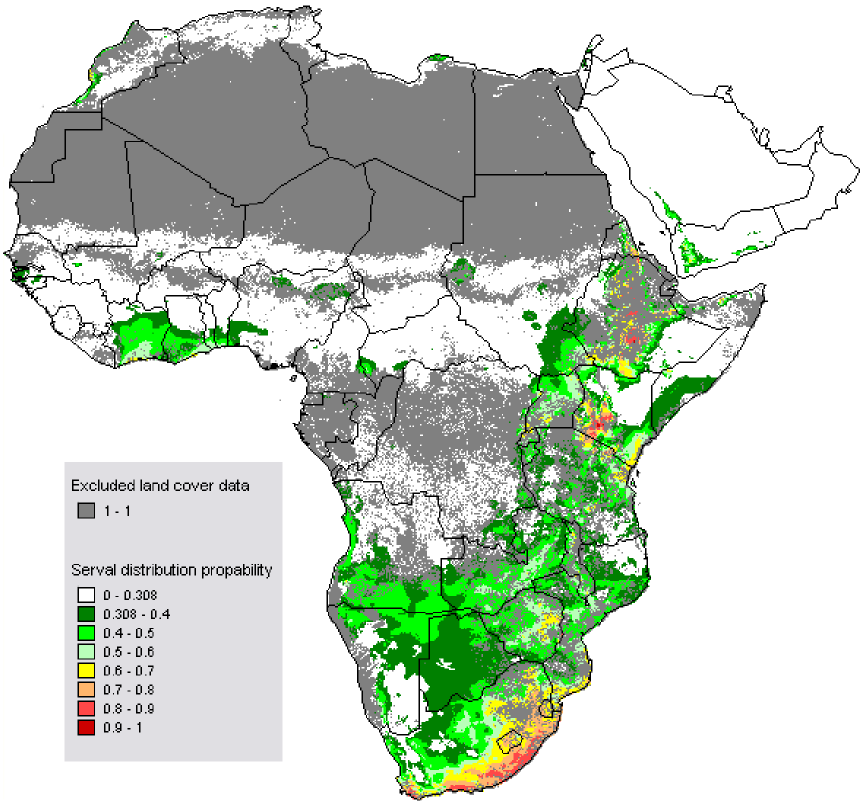


Figure 6.11: Map of potential distribution areas of *Leptailurus serval* overlaid with the excluded land cover classes.

Table 6.4: Land cover classes table. X = not included, √ = included.

Land cover classes	included	Land cover classes	included
Closed evergreen lowland forest	x	Open grassland	√
Degraded evergreen lowland forest	x	Sparse grassland	√
Submontane forest (900 -1500 m)	x	Swamp bushland and grassland	√
Montane forest (>1500 m)	x	Croplands with open woody vegetation	√
Swamp forest	x	Croplands (>50%)	x
Mangrove	x	Irrigated croplands	x
Mosaic Forest / Croplands	√	Tree crops	x
Mosaic Forest / Savannah	√	Sandy desert and dunes	x
Closed deciduous forest	x	Stony desert	x
Deciduous woodland	√	Bare rock	x
Deciduous shrubland with sparse trees	√	Salt hardpans	x
Open deciduous shrubland	√	Waterbodies	x
Closed grassland	√	Cities	x
Open grassland with sparse shrubs	√		

Taking a closer look at the areas of high probability together with all Africa-wide wilderness areas it becomes clear that nearly no high probability area lies within one of these wilderness zones; and also the lower values do not show high overlap with wilderness areas (Fig. 6.12). Figure 6.13 illustrates the model combined with areas with critical or endangered conservation status. This “conservation status represents an estimate of the ability of an eco-region to maintain viable species populations, to sustain ecological processes, and to be responsive to short- and long-term environmental changes." (OLSON & DINERSTEIN 2002). Conservation status assessments of the Global 200 eco-regions were based on landscape or aquascape-level criteria, such as total habitat loss, the degree of fragmentation, water quality, and estimates of future threat. In combination with the Serval distribution model it shows that most of the highly probable areas for Serval presence are also the most endangered areas Africa-wide.

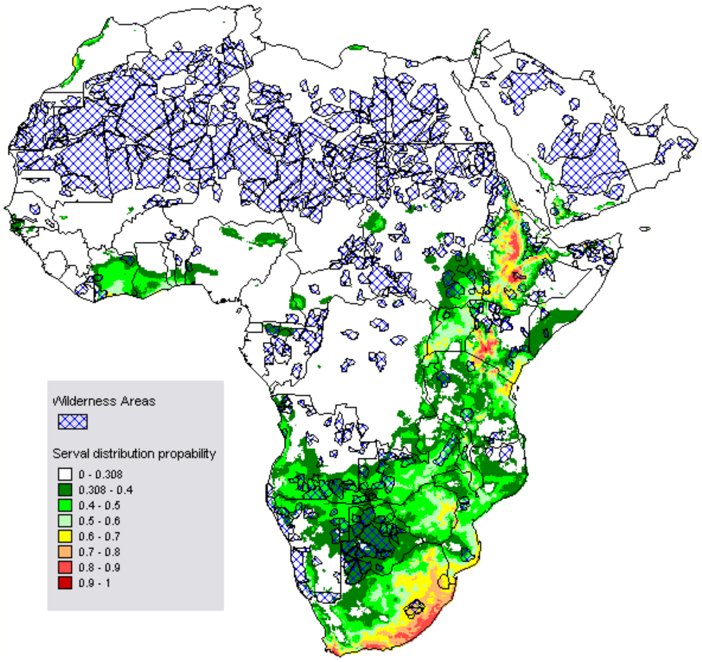


Figure 6.12: Map of potential distribution areas of *Leptailurus serval* overlaid with all Africa-wide wilderness areas.

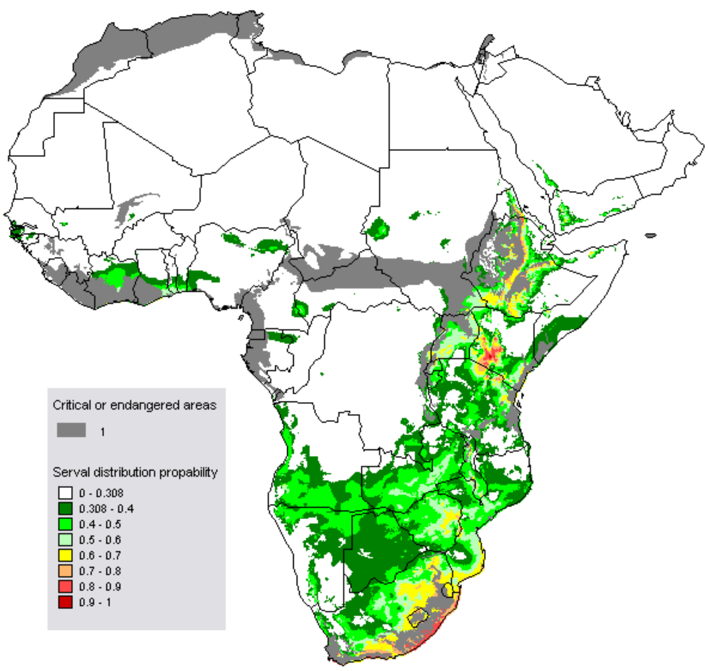


Figure 6.13: Map of potential distribution areas of *Leptailurus serval* overlaid with Africa-wide areas with critical or endangered conservation status.

6.4. Discussion

6.4.1. Distribution model of morphs/subspecies in Zambia

The different morphs of the Servals' spot patterns can be found in Zambia. With this study ANSELL's distribution map compiled in 1978 could not be verified but also not rejected. Spot patterns of intermediate size could be found in regions where he postulated to be distribution areas of the small spotted form, but not in areas where only the big spotted morph is prevailing. It would be necessary to do a more extensive pelage study on the Servals throughout Africa, ideally combined with genetic analyses. This could lead to a better understanding of the differences between the Servals' subspecies and possible morphs. Subspecies are often geographically isolated and clearly recognizable different from each other (genetically, in their morphology or behaviour), while morphs are not. This knowledge would surely alter the existing nomenclature of *Leptailurus serval* and is definitely overdue.

6.4.2. Distribution model of *L. serval* in Zambia

MAXENT and other programs on SDMs rely on presence data. Presence-only records extracted from museum collections have several potential errors that may affect the accuracy of SDMs (PAPES & GAUBERT 2007). First, it often remains impossible to consider areas lacking records as true areas of absence data (ANDERSON et al. 2003). Second, temporal correspondence between occurrence data and environmental variables like current land cover classifications is often poor (GAUBERT et al. 2006). Third, records may be geographically biased because of uneven sampling effort (PHILLIPS et al. 2006). But in this study the presence data only partially relied on these sources. At the same time presence data older than from 1950 were discarded. These precautions minimized the possible bias.

SDM applications rely on the assumption that the range of the target species is in equilibrium with environmental variables and that its fundamental niche is conservative in space and time (ARAÚJO & PEARSON 2005, PEARMAN et al. 2008). Although the use of SDMs has been underlying many improvements, the theoretical background and the validity of underlying biological assumptions is still not well understood (RÖDDER & LÖTTERS 2010). It became clear that the predictive ability of SDMs can be robust within the area for which the models have been fitted, but their transferability into other areas or in time may weaken this robustness (e.g. ARÚJO & RAHBEK 2006; BEAUMONT et al. 2009; FITZPATRICK et al. 2007). Therefore it is important to consider these models as what they are – only models. They cannot give a guarantee that the study species really is present everywhere the model predicts environment to be suitable, and on the other hand is absent where the models predicts its absence. A powerful software like MAXENT has been proven to be a reliable tool (ELITH et al. 2006, ORTEGA-HUERTA & PETERSON 2008), which can help conservationists planning management efforts for the well-being of the target species, but a researcher still needs to go out in the field to confirm the model's findings.

There are different possible reasons why the model might predict inadequately for any location: a species might be more adaptable to different abiotic factors than assumed, geographic barriers prevent dispersal, microbiotic changes within a bigger area, availability of food and water resources, or even other interacting species. PETERSON et al. (2007) and RANDIN et al. (2006) stated that the model transferability may be affected by different species compositions between areas due to possible niche property altering. For the Serval as model species this would mean the presence and abundance of Lions, Leopards, Caracal, Jackal, African Wildcat and other carnivores (predators or food competitors) would influence their occurrence and abundance. But in Luambe National Park, where there is a viable population of at least 13 Servals (see Chapter 5), there are plenty of predators and food competitors. The same circumstances can be found in most of Zambia where the Serval also seems to be common. Although in Zambia Servals are occasionally killed by Leopards, this seems not to have a critical influence on the Servals' distribution (Fig. 6.14). To asses the interspecific influence on the Serval's abundance one need a more detailed study.

Figure 6.14: A Leopard with its Serval kill in Lower Zambezi National Park, Zambia.
Source: http://www.chiawa.com/omnewsletters/old_mondoro_newsletter-jan06.htm; 06.2009.

"Areas of predicted presence will typically be larger than the species' realized distribution and few species occupy all areas that satisfy their niche requirements." (PHILLIPS et al. 2006). Another reason of inaccurate prediction may be the land cover at the specific areas. Climate variables only allow making inferences about naturally growing flora, but they don't give any indication on the actual land cover condition, whether it is in its prime condition or altered by any kind, e.g. human modification of the environment. Therefore, some studies include land cover into their models to create a species' present-day distribution, e.g. for conservation purposes, to exclude highly altered habitats (ANDERSON & MARTÍNEZ-MEYER 2004). Another method is to exclude land cover classes after the modelling by altering the raw data by retaining only areas where the species were predicted present and the adequate land cover types are found. This approach turned out to be the more useful and reliable way to leave out unsuitable habitats (THUILLER et al. 2004, PAPES & GAUBERT 2007).

Recent studies have indicated that the grid size used can have an effect on the output of these species distribution models. The standard 50x50 km grid size can select up to 2.89 times more area than when modelled with a 1x1 km grid for the same species. This can result in the misidentification of the actual status of this species and its possible distribution area. This is why two different resolutions were chosen to be used in this study, which supports this statement of bigger presence areas coming with bigger resolution. But even a 1x1 km grid can be too big for mountainous region as many levels of elevation and their corresponding fauna and flora can occur within an area of 1 km². Therefore, very steep rising mountainous regions as being part of the Servals distribution area need to be considered carefully. Servals range up into alpine grasslands (ANSELL & DOWSETT 1988), up to 3,200 m in Ethiopia (YALDEN et al. 1980) and 3,800 m in Kenya (YORK 1973), but are not likely to occur in even higher regions.

The MAXENT predictions were overlapped with current land use and location of protected areas to estimate the distribution area and with that the conservation status of the target species. The predictions show that Servals are more likely to occur south of the Saharan region, with only small possible areas of presence in Morocco and Yemen. Ethiopia, Kenya, Tanzania, Uganda, Rwanda, Zimbabwe and South Africa are the countries with the highest MAXENT predictions. In the countries crossed by the East African Rift Valley the high presence probabilities follow this rift, only interrupted by the Masai xeric grass- and scrublands ecosystem. But regions of high presence likelihood are in general not protected and are already declared as endangered areas. If overlaid with current land cover it becomes obvious that these endangered areas are mostly cropland and cities. In addition some areas are closed forests or other habitats which can be ruled out to be good Serval habitat (see Chapter 4) and therefore have to be subtracted from the original prediction as well. Altogether the potential Serval distribution area is shrinking the more factors are taken into consideration (Fig. 6.15 & 6.16). The most accepted distribution map of *Leptailurus serval* by the IUCN (http://www.iucnredlist.org/apps/redlist/details/11638/0; 12. 2010) differs from this thesis' predictions, sometimes it extents the areas of presence by far and sometimes even shows new areas of distribution, but in general fits the proposed area (Fig. 6.17 & 6.18). Especially the region of central Africa shows contradictory results in distribution patterns; the

MAXENT model rules out the presence of the Serval while the IUCN proclaims its presence in all regions of central Africa. The MAXENT model relies on presence data and there was no species record for the central African region. If this is due to lacking collection sites and chances or because there is and was no local population of Servals has to be proven.

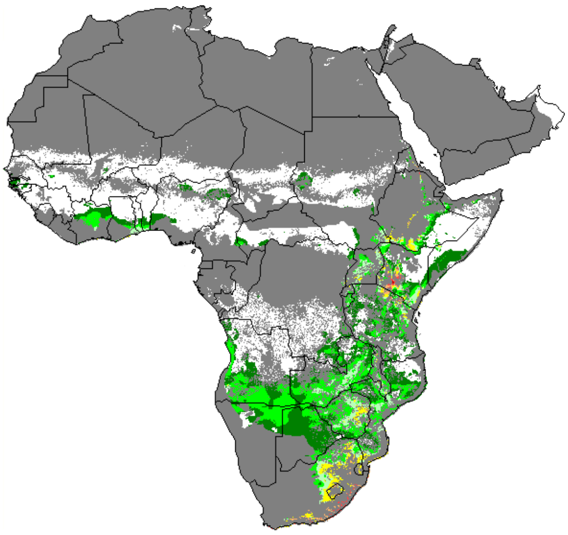


Figure 6.15: MAXENT prediction with 30 arc-seconds resolution overlaid with all excluded areas.

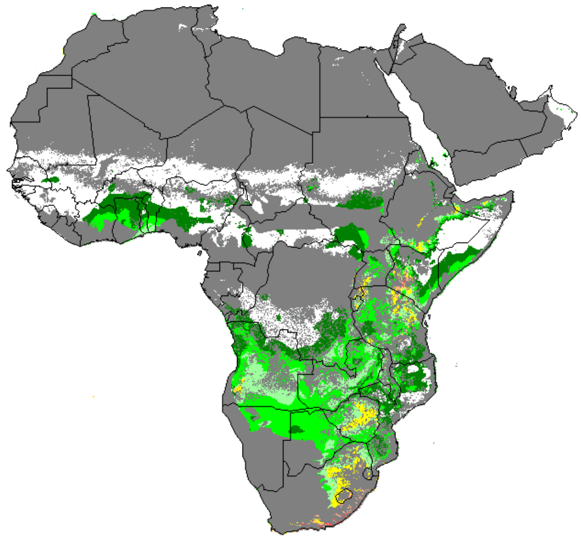


Figure 6.16: MAXENT prediction with 5 arc-minutes resolution overlaid with all excluded areas.

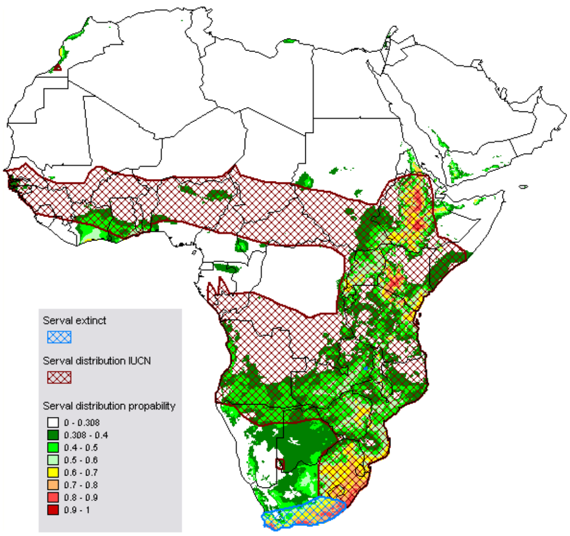


Figure 6.17: MAXENT prediction with 30 arc-seconds resolution overlaid with most recent distribution map by the IUCN.

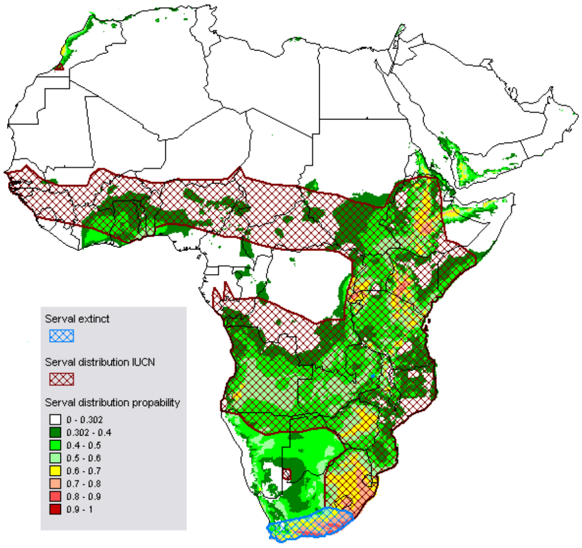


Figure 6.18: MAXENT prediction with 5 arc-minutes resolution overlaid with most recent distribution map by the IUCN

There is no clear international consensus on the Serval's population status. On one hand the Serval is thought to be widespread, relatively abundant and of least concern (IUCN, http://www.iucnredlist.org/apps/redlist/details/11638/0; 12. 2010), on the other hand it is thought to be widespread, but not abundant and in some countries even considered rare (IUCN-Cat Specialist Group, http://www.catsg.org/catsgportal/cat-website/20_cat-website/home/index_en.htm; 12. 2010). Even with a calculation of one population's minimum size (see Chapter 5) it is not possible to make a statement on the Africa-wide abundance of Servals without risking huge biases. Extrapolation of numbers sampled in one area to a broader area may not be valid, especially if terrain, habitat, prey abundance or human influences differ (ROWCLIFFE 2008). In the last century, Servals have been extinct from the extreme south of their range and the unique North African population is now probably extinct and will not be able to recolonize as it is considered to be an isolated lineage from Sub-Saharan Servals for around 7,000 years. Contrary, in West Africa, where the deforestation is producing Serval-friendly grasslands, numbers may be on the rise. However, Servals are mostly endangered by habitat loss, like the loss of wetlands, and by increased vulnerability to human hunting, particularly given traditional medicine's huge market for feline body parts and the permanent use of skins for ceremonial clothing. But all the consequences for this beautiful cat stay speculative as long as there is no true ground check on this felid which has been treated with 'least concern'.

6.5. Summary Chapter 6

One aspect of this chapter was to review the only existing distribution map of Servals in Zambia by ANSELL (1978), as well an investigation on the two types of spot patterns in *Leptailurus serval* occurring in Zambia. Most places of occurrence ANSELL marked could be confirmed, some were rejected and the big gap around the Zimbabwean border could be filled with proof of presence. On the other hand no clear pattern on the distribution of the two different pelage markings could be found in Zambia.

Secondly, an Africa-wide species distribution model (SDM) for the Serval was created with the software MAXENT. This model based on 101 presence data points, which were used together with seven BioClim variables (BIO1, BIO4, BIO6, BIO9, BIO12, BIO15 and BIO18) in two different resolutions (30 arc-seconds and 5 arc-minutes). The MAXENT model revealed good results (training and test AUCs > 0.81) and showed possible distribution areas mostly south of the Sahara, with hotspots in the highlands of Ethiopia, in Kenya, Tanzania, Uganda, Rwanda, the eastern highlands of Zimbabwe and at the South African coast line. The output map was overlaid and modified with land cover data, eco-region maps, areas of wilderness and areas of critical or endangered conservation status. Altogether, the potential Serval distribution area is shrinking the more factors are taken into consideration, especially the areas of high MAXENT fit are endangered and unsuitably influenced to provide good and stable Serval habitat. With this first Serval distribution model it becomes clear that there is a need to learn more about the Serval's distribution and the impacts of habitat loss and changes on its population. The Serval is rated as 'least concern' but maybe this status needs a revision.

In theory, there is no difference between theory and practice.
But, in practice, there is.
- Jan L. A. van de Snepscheut

7. Review of other methods

This chapter discusses other, not successful methods which were used in the years 2006-2008 on Servals. They include the baiting of Servals to attract them in front of camera traps and into live traps. These trials were undertaken to capture Servals and equip them with collars for radio-tracking. This failed on the Servals in Luambe National Park (LNP). Nonetheless, the fact that Servals seem to show only little response to olfactory baiting is an important detail for researchers for further Serval studies.

In the past, several olfactory experiments with different felids were carried out, *in-situ* and *ex-situ* (DIEFENBACH 1994, MCDANIEL 2000, WEAVER 2005, BREMNER-HARRISON 2006, SCHMIDT 2006, ZIELINSKI 2006, MESTEMACHER et al. 2007). Members of the cat family seem to favour strong smelling lures like valerian (root & oil), catnip (leaves & oil & brew), curry, different essential oils, and beaver (*Castor fiber*) castoreum (DIEFENBACH 1994, MCDANIEL 2000, WEAVER 2005, BREMNER-HARRISON 2006, SCHMIDT 2006, ZIELINSKI 2006, MESTEMACHER et al. 2007), but no acid like smells (e.g. vinegar, citrus fruit), or onion or even the oil of the garden plant Common Rue (Herb of Grace) (MORRIS 2005).

Servals were trapped in two studies, while the one study caught captive-bred Servals from an enclosure in the De Wildt Research Centre, South Africa (VAN AARDE & SKINNER 1986), only the study by BOWLAND (1990) baited wild Servals successfully into the traps. BOWLAND camouflaged the traps with vegetation and baited with dead chicken and a sound lure, only added twice by a live caged chicken in the back of the trap.

7.1. Baiting Servals

7.1.1. Baiting experiment in ZOOM Erlebniswelt Gelsenkirchen

At the ZOOM Erlebniswelt Gelsenkirchen three Servals, two females (mother and her young adult offspring) and a male (father of the young female), were tested for their reactions to olfactory lures twice a week. The experiment was set up in their regular enclosure, where all reactions could be observed and recorded (Fig. 7.1). Each day of the experiment two different smells and a cross check smell were applied. Therefore, brushes made out of wood and natural fibre were screwed to three different locations within the enclosure, one brush without any smell and the other two with smells. All three brushes were placed at positions as far away from each other as possible, in a height of 30-50 cm (Fig. 7.2).

All results were noted. The behaviour at the different lures (i.e. sniffing, rubbing), the sex, and the duration of the encounter with the lure was recorded. At the same time the date, time, weather, condition of the animals and the possible disruptive influence was also written down (see Appendix – Chapter 7). Within one month (5 experiments) the following smells were tested: essential oils (myrtle, cypress, thyme, and anise), commercial fish-sauce, catnip (spray and leaves), curry paste, valerian root, and beaver castoreum.

There was a clear tendency for the male being more interested into olfactory baits than the females. The male showed the clearest reaction towards two essential oils: myrtle and cypress. Being exposed to these smells, the male sniffed for over 120 seconds, followed by biting into the brushes and rubbing himself with the brushes (Fig. 7.3). The females showed only little interest in some baits; they only sniffed for up to 30 seconds when the essential oils myrtle, thyme, and castoreum was offered to them.

But there were several big disruptive influences from the male towards the females. The old female was pregnant again and therefore the male seemed more interested in her smell, following her everywhere she went. This went so far that the Zoo management had to separate the male from the pregnant female. When the daughter was let in the enclosure together with her father the male needed to subdue her before he could go on with his routine and show more interest for the smells. The young Serval never showed any interest as she was too stressed in the enclosure together with her father.

It was expected that these Servals would be interested in new structures within their territory as they were captive ones and maybe bored. In contrast, none of the Servals showed any reaction of a longer duration than 400 seconds. And after the first exposure to the brushes on the first day, they showed even less interest. The only exception was with the essential oil myrtle. This could point to a small willingness of Serval to react to smells at all.

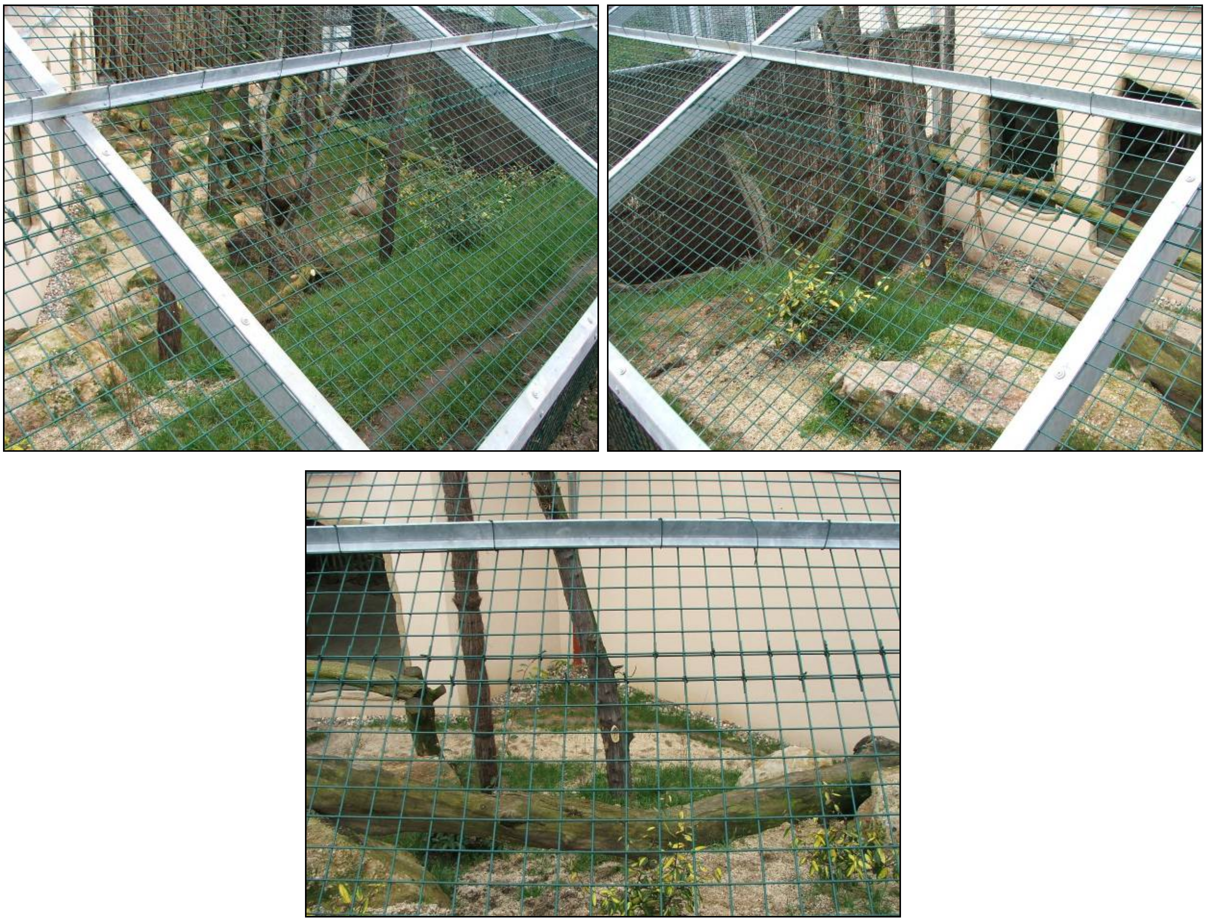


Figure 7.1: Enclosure with all three brushes (one in each picture), seen from observation point.

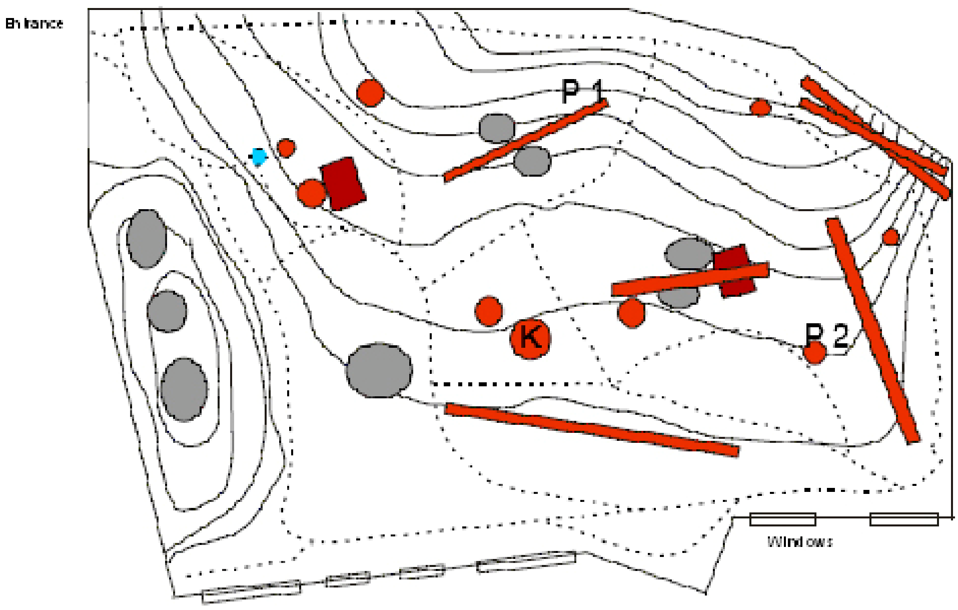


Figure 7.2: Drawing of the Serval enclosure from above. P1 & P2 = olfactory baits, K = cross check, grey = rocks, brown = wooden structures (trees, logs, boxes), ··· = walking paths.

Figure 7.3: Male Serval sniffing at brush soaked with essential oil.

7.1.2. Baiting in Luambe National Park

In the years 2006 and 2007 different baits were tested on Servals in LNP. These baits were olfactory and/or auditory and/or visual (Tab. 7.1). All baits were placed in confirmed (visually by sightings, spoor or scats) Serval habitat. Baits were placed at lure sticks, at trees or in traps (reed or wooden). Lure sticks were made out of wooden poles with a height of up to 1 m. Around each wooden pole a track plate and/or a camera trap was set to confirm the species' presence (Fig. 7.4). Track plates were made out of sand, originated from dry riverbeds near by to minimize foreign smells. The smells were applied onto a piece of carpet, which was nailed to the pole, while extra nails or wire was attached as hair catchers to collect hair samples from individuals showing rubbing behaviour (Fig. 7.5). Smells were applied with Vaseline (for long term effect) and without (LAMPE et al. 2006, MESTEMACHER et al. 2007). Baits with only visual aspects, such as the chicken feathers, were placed in or at trees (Fig. 7.6). Visual baits were also combined with olfactory ones by hanging feathers or foil into the tree or bush above a trap. Trap design and success will be discussed in 7.2.

Table 7.1: Different baits used in the years 2006 and 2007 in Luambe National Park and their attracted animals.

Bait	Olfactory	Auditory	Visual	Applied to	Duration (days)	Attracted animals
Valerian oil	x			Lure stick	5	
	x			Lure stick	4	Small-spotted Genet (*Genetta genetta*) Lion (*Panthera leo*)
	x			Lure stick	4	**Serval (*Leptailurus serval*)**
Catnip (dried leaves)				Lure stick		
Catnip (brew)	x			Lure stick	4	Small-spotted Genet (*Genetta genetta*) African Civet (*Civettictis civetta*)
	x			Lure stick	5	
Catnip (brew) & Vaseline	X			Lure stick	5	**Serval (*Leptailurus serval*)**
	X			Lure stick	7	
Castoreum from male beavers (*Castor fiber*)	x			Lure stick	3	
	x			Lure stick	5	**Serval (*Leptailurus serval*)**
Castoreum from male beavers & Vaseline	x			Lure stick	4	Hyaena (*Crocuta crocuta*) Elephant (*Loxodonta africana*)
Castoreum from female beavers (*Castor fiber*)	x			Lure stick	4	**Serval (*Leptailurus serval*)** Leopard (*Panthera pardus*) African Civet (*Civettictis civetta*)
Cat food (dry)	x			Wooden trap	6	
Cypress essential oil	x			Wooden trap	8	
Catnip (brew) & Myrtle essential oil	x			Wooden trap	7	
Anise essential oil	x			Lure stick	4	
Curry (paste)	x			Lure stick	4	
Live chicken (adult)	x	x	x	Reed trap	3	
	x	x	x	Reed trap	2	
	x	x	x	Reed trap	9	
	x	x	x	Reed trap	6	
	x	x	x	Wooden trap	3	African Civet (*Civettictis civetta*)
	x	x	x	Reed trap	4	
	x	x	x	Reed trap	3	
Live chicken (chickling)	x	x	x	Wooden trap	2	
Dead Chicken	x		x	Reed trap	3	**Serval (*Leptailurus serval*)**
	x		x	Reed trap	5	
Live mice	x	x	x	Wooden trap	2	
Chicken feathers (from freshly killed chickens)	x		x	Tree	4	Small-spotted Genet (*Genetta genetta*) Vervet Monkey/ Yellow Baboon

Baiting, olfactory, auditory and visual, did show only little success in Luambe National Park similar to the results in the ZOOM Erlebniswelt Gelsenkirchen. Out of 125 days of baiting at only five occasions a Serval was attracted to these baits (Tab. 7.1). This could be mainly proven by tracks in the track plates (Fig. 7.4) and once by a camera trap (Fig. 7.7). Successful baits were valerian, catnip (& Vaseline for long term use), castoreum from male and female beavers (*Castor fiber*) and a dead chicken. But none of these baits always attracted a Serval, as some trial periods with the same bait went without a Serval attracted by it (Tab. 7.1). This could mean that Servals only visit these places by chance, if they are close by passing through their home range. Unlike European Wildcats, which can be easily attracted with valerian root even from kilometres away (PIECHOCKI 1990, THIEL 2004, HÖTZEL et al. 2007), Servals do not to show strong reactions to olfactory baits. No rubbing behaviour could be recorded as Serval hair was not found at the lure sticks.

Recommendations for further baiting trials would be to combine smells with each other and combine them with more auditory or visual baits, first in an enclosure with one Serval only, as Servals usually are solitary cats, then in the field.

Figure 7.4: Lure stick in sandy riverbed.
Camera trap in the back. In the front: track of a Serval being measured.

Figure 7.5: Lure stick with carpet soaked full of olfactory bait, applied with mosquito wire to pull hair of rubbing individuals.

Figure 7.6: Visual & olfactory bait (fresh chicken feathers) in tree with a camera trap in the back.

Figure 7.7: Serval checking on olfactory bait (dead chicken) in trap.

7.2. Trapping with live traps

In 2006 and 2007 traps were placed within a period of three months, usually 4 at a time. Traps were made out of wood (Fig. 7.8), with a door release in the rear of the trap tied to a footboard. Baits were placed inside the trap at the far end (Fig. 7.8) or outside the trap, behind the mosquito wire at the rear end and easy to see but not reachable (Fig. 7.9). Other traps were made out of reed and palm leaves by the villagers of Chitungulu village, bordering LNP (Fig. 7.10). This kind of trap is traditionally made and also used by the locals to catch Servals, Genets, Civets, African Wildcats or all other possible poultry raiders coming into the villages. Hence, these traps had been proven to work on Servals. The design is similar to a fish trap, but bigger and with a separate entrance to a separate back part for the bait (usually a live chicken). The pointy, cut ends of the reed prevent the turning around and crawling back of the trapped animal.

Traps were set for 24 hours, camouflaged with surrounding vegetation and baited. Altogether the traps were set for 62 days with no capture success at all. Only once a Serval came close enough towards one of the reed traps to be captured by a camera trap (Fig. 7.7). Therefore, trapping Servals in LNP was impossible.

Later, in the year 2007 a veterinary was asked to dart a Serval from the car to immobilize it for collaring. After habituating the Servals to the car for approximately two months, in six nights (approx. 20 hours) four Servals could be found and approached but not darted by the veterinary.

To catch Servals in traps maybe the same technique used by BOWLAND (1990) needs to be reviewed for future projects. It is also possible that the traps were too dark and therefore hindered the Serval to go in. A metal-grid-like trap should be used as well with next trials (like BOWLAND in 1990). Also, the reed traps were sometimes cracked open and the bait (mostly the chickens) was taken by a predator without entering the trap. That is why reed traps were enforced with mash wire after a while. Also, a longer period than six nights for darting should be applied. The best would be to habituate the local Serval population to the car for a longer period of time before starting the darting period.

Figure 7.8: Wooden trap.
Bait (live mouse) inside the BioBox, camera trap in the front.

Figure 7.9: Wooden trap with bait (live chicken) outside the trap.

Figure 7.10: Reed trap made by locals. Top left: view inside. Down left: Enhanced trap with wire. In the left compartment there is a live chicken. Right: Trap camouflaged in the reed.

Of all God's creatures, there is only one that cannot be made slave of the lash.
That one is the cat.
If man could be crossed with the cat it would improve the man,
but it would deteriorate the cat.
- Mark Twain

8. General Synthesis

The Serval, being a medium sized and elusive living cat, is neither well known to non scientists nor to biologists. Lions, Leopards, Tigers, and Cheetahs are the best known members of the Felidae and all attention is directed to their conservation; they are so-called ‘flagship’-species. But they are only four out of 36 cat species. The effects of habitat loss, fragmentation, and degradation on carnivore populations and their prey species are still only partially known. Many species of wild felids are becoming endangered due to habitat disturbance. *Leptailurus serval* is one of these potential felids as it inhabits wetlands and humid savannahs, which are already endangered habitats. Increased interest in such carnivores could help to protect these biotopes and consequently the species.

To protect and conserve a species we need to know about their needs and the threats to their populations. The Serval’s official status is of ‘least concern’, but there is not much knowledge on this felid to prove this status. This thesis aims to create a new foundation on information about *Leptailurus serval*. This knowledge can help to create a new understanding and it can build up a new awareness for this species.

From theory to practice

There are several methods and procedures implemented in felid studies, which needed to be revised for a Serval study. The methods chosen for this study needed to be feasible; they had to fit the budget, the available man-power, and the time limits. Hence, the tools of choice became transect walks, faecal sample collections and analyses, olfactory baiting, camera trapping and modelling of a species distribution map. The latter was additionally modified based on the knowledge gathered from this study.

During the transect line walks faecal samples, spoors and sightings were collected and recorded. In addition the same signs of presence were collected and noted when encountered by chance. Together with scat analyses and the determination of prey items down to the lowest taxa possible, this data revealed answers to questions like distribution patterns within LNP (Chapter 4), habitat use (Chapter 4), parasite burden (Chapter 3), and prey spectrum (Chapter 2). This method has proven to be feasible and very cost-effective, while providing a high amount of data for multiple analyses. Through guard hair analyses the origin of the faecal samples could be determined in ~80% to verify the findings, so that scat analyses turned out to be a reliable and efficient tool as well.

After creating an overview map on the Servals' distribution within LNP, certain areas could be ruled out to provide any data on Servals (Chapter 4). Consequently, it was possible to set up camera traps in a Serval specific calculated grid to estimate the minimum population size of LNP (Chapter 5). Camera trapping has many pitfalls, especially if no data on home range sizes is available from previous studies. As neither home range size data on Zambian Servals nor camera trapping studies on Servals were available, the implementation of this method was difficult. On the other hand, a capture-recapture analysis with camera traps proved to be a reliable method to estimate population sizes. And even though there were flaws in this study the results were still plausible and provided a solid first Serval population estimation. Camera trapping is easy to set up, time effective and provides additional data on sympatric living animals (e.g. competitors, prey species). But the cameras are expensive and as they are needed in high amounts the researchers using them need to balance between financial limits and effectiveness of the camera trap set up.

Species distribution models became a commonly used technique in the last decade for conservationists. They rely on presence records of the target species. The models present results on the calculation of the probability of occurrence of the target species in a specifically defined area, based on climatic variables. The assumption that the climatic variables can fully describe the fundamental niche of a species is most important. But as this assumption holds potential biases, the resulting map of the model can be altered afterwards with species-specific information. Hence, in this study land cover classes unsuitable for Servals were cut out of the Africa-wide potential distribution areas, as well as less preferred or endangered habitats (Chapter 6). This thesis provides the first potential distribution map for *Leptailurus serval*.

Some methods have not been successful when used on Servals. Olfactory baiting and setting of box traps were the two methods which needed to be constantly adjusted and still failed after two years of trials and errors (Chapter 7). Some cat species are known to react strongly to olfactory baits, e.g. European Wildcats to valerian root. But Servals turned out to basically ignore this and other lures. Also they did not enter any of the provided traps, whether they were out of wood and closed or out of reed and therefore more open. The method for catching Servals needs future adjustments and more testing.

The outcome

Three years of 'on the ground' studies, followed by extensive analyses of gathered information led to confirmation and amendment on known details about Servals, as well as to new and exciting conclusions:

1) The most studied fact on Servals found in literature was their diet. Dietary analyses from scats, through observations and stomach analyses were done and also this thesis supported these studies' findings, that the *Leptailurus serval* is a rodent hunter (Chapter 2). But besides that, they also prey extensively on birds, on reptiles, and on arthropods. In Luambe National Park 216 scats, and 121 samples from the other eight locations were proved to be Serval scats and used for further analyses. The minimum sample size for accurate estimations of diet composition was reached in Luambe National Park, but not at the other eight locations. Dietary composition was expressed as 'frequency of occurrence' (FO) - the percentage of scats in which a particular item was found, and as 'percentage occurrence' (PO) - the number of times a prey item was found, expressed as a percentage of all items recorded and additional information was provided by calculating biomass consumed using the prey categories 'small mammals' and 'birds'. Regarding the FO in Luambe National Park, the Servals' diet includes 89% small mammals (mostly rodents), 25% birds, 15% reptiles and 22% arthropods. At the other eight locations, on average Servals preyed on small mammals (FO=74%), birds (FO=55%), arthropods (FO=31%), reptiles (FO=18%) and also once on an amphibian (FO=0.83%).This cat is not as much of a specialist as previous studies suggested, but its diet breadth, calculated in this study, of 0.5 indicates a more opportunistic lifestyle.
2) Parasites of Servals were never analysed up to now. Faecal samples were searched for parasites and the findings were identified up to species level if possible (Chapter 3). Besides nematodes and mites, there were four families of the Ixodidae found, of which there were five different tick species altogether. Zambia-wide 66% of the faecal samples contained some sort of parasites, with *Rhipicephalus sanguineus* and *Haemaphysalis leachi*, both so-called 'Dog Ticks', to be the most common ticks of *Leptailurus serval*. The mean number of ticks occurring in one scat sample in all Zambian locations was 13.01 individuals. Analyses of annual and monthly changes in tick composition and rainfall data in LNP revealed no significant correlations, but there was a pattern of adult *Rhipicephalus sanguineus* being more frequent in the beginning of the dry season, while with *Haemaphysalis leachi* the percentage occurrence raised towards the end of the dry season.
3) Furthermore, analyses of habitat preferences revealed a new, more detailed picture of the Serval's habitat usage. Servals are associated with grasslands and wetlands, but here they also showed preferences for thickets and riverine woodland (Chapter 4). This cat needs water resources near by and some kind of cover, whether it is grass or thickets/bushes. Closed forests with little ground cover are less preferred or even avoided habitats. Preferences/Avoidances were calculated with the JOHNSON

ranks, Chi square test and the JACOBS index, with all methods showing similar results.

4) Within Luambe National Park, signs of Serval activity were found by transect line walks and by random encounters (Chapter 4). Analyses of these signs led to the conclusion that at least 60 km^2 of the 331 km^2 of the Luambe National Park are populated by Servals.
5) 20 camera trap stations were set up in 40.4 km^2 of potential Serval habitat in Luambe National Park for 74 consecutive days to provide data for minimum population size estimations (Chapter 5). In this area, composed of 30% potentially preferred habitat, a density of 0,099 Servals per 1 km^2 could be determined, resulting in a minimum population size of 13,3 Servals within 134 km² of proved Serval presence area. This study provides the first density estimation based on the capture-recapture technique with the usage of camera traps.
6) Also the first Africa-wide species distribution model for the Serval was created with the software MAXENT (Chapter 6). The MAXENT model revealed good results and showed possible distribution areas mostly south of the Sahara, with hotspots in the highlands of Ethiopia, in Kenya, Tanzania, Uganda, Rwanda, the eastern highlands of Zimbabwe and at the South African coast line. On the basis of the newly gained knowledge on preferred and less preferred habitats the output map was overlaid and modified with land cover data, eco-region maps, areas of wilderness and areas of critical or endangered conservation status. If all these factors are taken into consideration the potential Serval distribution area decreases. Especially the areas of high probability are endangered and unsuitably influenced to provide good and stable Serval habitat.
7) Zambia-wide distribution, determined by ANSELL (1978), was reviewed and most of the areas were confirmed (Chapter 6). The occurrence and distribution of the two proclaimed different morphs in spot size and patterns of Servals (ANSELL 1978) occurring in Zambia were assessed. ANSELL's statement on the south-eastern boundary of the distribution of a small spotted morph could neither be proven nor rejected.

Future perspectives

After these years of studying the Servals of Zambia this thesis provides new fundamental knowledge about the Serval.

But there is much more to find out! This PhD thesis raised questions on home range sizes, genetics, distribution, diseases and interspecific relationships of *Leptailurus serval*. In detail, the following urgent issues need to be researched on:

1) An examination of available literature and this study pointed out that a review on the Serval's subspecies and its morphs supported by genetic and morphological properties is overdue. Therefore, to conduct an extensive study a collection of more faecal samples of Serval populations from all over Africa is necessary. Additionally, genetical analyses on mitochondrial D-loop (hypervariable region I) and cytochrome b sequences could lead to a biogeographic review on the Serval's natural history. A hypothesis of an upcoming study could be that the Luangwa Valley, as part of the East African Rift Valley, forms a migration corridor for the South African populations of the Serval. The Great Rift Valley has previously been implicated as a barrier to the dispersal of other cat species, like the Lion (BARNETT et al. 2006). Also, the projection of ANSELL's (1978) proclaimed distribution boundary of the two morphologically described forms onto a map of Zambia is correlated with the Great Rift Valley. Consequently, another hypothesis could be that the morphs occurring in the Luangwa Valley are possible subspecies, one being closely related or genetically the same to those in Kenya and Tanzania (east of the rift valley), while the other morph could be genetically more similar to Servals in Angola and Congo (west African distribution range, west of the rift valley).
2) Of almost all faecal samples collected in Luambe National Park DNA samples were stored and deep-frozen for further genetic analyses. Individual identification is possible with the help of microsatellites. To ensure that no siblings will be handled as one single individual the sex of each sample's origin could be determined with sequences of the zinc-finger region of the x and y-chromosomes (*Zfx* and *Zfy)*. Assigning scat samples to single individuals will lead to another estimation of a minimum population size of Luambe National Park, which number could then be compared with the data of the camera trap study to validate this method. This study provided the first estimation on population size. Another cross-check to evaluate the method and its results would help to conduct more studies on this matter.
3) The Serval distribution model created with MAXENT offers a new chance to evaluate the population status of the Serval Africa-wide. But therefore, confirmation of the reliability of the model needs to be established by direct observations at the predicted locations. If the model would prove to be dependable the status of highly probable Serval habitat needs to be assessed for possible threats and influences. With that a new status report can be conducted to update the old existing status report. Together with more minimum population size studies an estimation of the Africa-wide number of Servals could be possible.
4) The behavioural data gained in this study give a new insight into Serval ecology. But these data should be completed by other behavioural studies. Determination of home range sizes and social behaviour in a more detailed way would be desirable. Trapping

trials would need to be conducted to successfully equip Servals with telemetry transmitters. With these, more information on behavioural aspects would be available, such as on home range sizes, home range overlap, intraspecific and interspecific interactions, activity patterns and emigration/ immigration behaviour. This knowledge could be implemented into future management and conservation plans.

5) Diseases, transmitted by viruses and bacteria, carried by the retrieved ticks of these scat analyses, need to be identified. All tick samples are stored in 99% Ethanol and could be genetically examined. Ticks are known to be hosts of multiple diseases affecting wild populations, sometimes even to a substantial degree. Therefore, subsequent analyses on the threat to local Serval populations need to be conducted to complete the evaluation of the current population status.

I urge every felid enthusiast to look into the stunning species *Leptailurus serval* and its behaviour and needs as well as the threats it is being exposed to. Instead of focusing conservation only on the already endangered or on the “sexy” species it is my wish to encourage conservationists to intensify efforts to ensure the long term conservation of the biological treasure of this world. We need to put all our efforts into research on whole biotopes and their including fauna and flora, so that also small species like the Serval are recognized in their value and meaning to the specific habitat.

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Appendix

Chapter 2 – Diet analyses

Observation sheet:

Observation

Date: Area: Observer:

.... °C ... / 8 Wind strength .... Wind direction............ ☾ ● ☽ ○

Weather:

Individual:							
Mark	Time	Active +/-	Coordinates		♀ / ♂	Age	Distance to water

Biotop	Synchronously with

Comment:

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Table App 2.1: Data for comparison of prey composition between LNP and Zambia-wide samples.

	FO	PO
LNP	76.98	23.02
LNP	89.89	10.11
LNP	27.76	72.24
LNP	47.7	52.3
LNP	13.83	86.17
LNP	49.96	50.04
Zambia-wide	76.98	23.02
Zambia-wide	89.89	10.11
Zambia-wide	27.76	72.24
Zambia-wide	47.7	52.3
Zambia-wide	13.83	86.17
Zambia-wide	49.96	50.04
Zambia-wide	73.2	26.8

Table App 2.2: T-Test FO LNP and Zambia-wide scat sample prey composition.

Group Statistics

	Years	N	Mean	Std. Deviation	Std. Error Mean
FO	FO LNP	6	51,0218	28,70845	11,72018
	FO Zambia	7	54,1904	27,51536	10,39983

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
FO	Equal variances assumed	,004	,950	-,203	11	,843	-3,16864	15,61335	-37,53339	31,19610
	Equal variances not assumed			-,202	10,532	,844	-3,16864	15,66904	-37,84376	31,50648

Table App 2.3: T-Test PO LNP and Zambia-wide scat sample prey composition.

Group Statistics

	Years	N	Mean	Std. Deviation	Std. Error Mean
PO	PO LNP	6	48,9782	28,70845	11,72018
	PO Zambia	7	45,8096	27,51536	10,39983

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PO	Equal variances assumed	,004	,950	,203	11	,843	3,16864	15,61335	-31,19610	37,53339
	Equal variances not assumed			,202	10,532	,844	3,16864	15,66904	-31,50648	37,84376

Chapter 3 – Parasite identification

Table App 3.1: Mean frequency of occurrence of all ectoparasites found in scat samples in LNP (N=183) and their standard deviation (SD).

Species	No. of scats	Mean of FO of the years 2006-2008 (N=183)	SD of FO of the years 2006-2008
Amblyomma spp.	8	5,36	3,62
Haemaphysalis leachi	131	70,15	1,52
Hyalomma truncatum	3	2,40	2,17
Rhipicephalus sanguineus	145	72,78	13,07
Rhipicephalus simus	1	0,32	0,46
Mites	127	66,87	6,64
Nematoda	38	20,13	5,39

Table App 3.2: Mean frequency of occurrence and the percentage occurrence of ticks in LNP samples containing ticks in the years 2006-2008 (N=174) and their standard deviation (SD).

Species	Mean of FO within all tick samples in the years 2006-2008 (N=174)	SD of FO within all tick samples	Mean of PO of the years 2006-2008	SD of PO of the years 2006-2008
Amblyomma spp.	5,83	4,04	0,54	0,36
Haemaphysalis leachi	75,23	3,41	51,06	21,45
Hyalomma truncatum	2,53	2,29	0,26	0,29
Rhipicephalus sanguineus	77,83	15,81	48,12	21,88
Rhipicephalus simus	0,34	0,59	0,02	0,03

Table App 3.3: Mean sex ratio of all ticks found in LNP in all faecal samples with ticks in the years 2006 2007 & 2008.

Species 2006	% of male ticks	% of female ticks	% of nymphs	% of fed ticks
Amblyomma spp.	0,00	0,00	100,00	0,00
Haemaphysalis leachi	46,53	50,50	0,00	2,97
Hyalomma truncatum	0,00	100,00	0,00	0,00
Rhipicephalus sanguineus	36,17	59,57	0,00	4,26
Species 2007	**% of male ticks**	**% of female ticks**	**% of nymphs**	**% of fed ticks**
Amblyomma spp.	0,00	0,00	100,00	0,00
Haemaphysalis leachi	48,02	47,32	1,17	3,50
Rhipicephalus sanguineus	45,54	52,68	0,00	1,79
Species 2008	**% of male ticks**	**% of female ticks**	**% of nymphs**	**% of fed ticks**
Amblyomma spp.	0,00	0,00	100,00	0,00
Haemaphysalis leachi	44,69	48,77	1,63	4,90
Hyalomma truncatum	50,00	50,00	0,00	0,00
Rhipicephalus sanguineus	46,92	51,86	0,21	1,00
Rhipicephalus simus	0,00	100,00	0,00	0,00

Chapter 4 – Distribution and habitat analyses

Spoor sheet:

SIGNS

Date: **Area:** Observer:

Biotop: **Time:**

Age of sign:

Kind of Sign [Track (T); Faeces (F); Urin (U); kin (S); Hair(H)]:__________

Faeces:
Archived as Sample No. ________ Picture No.______

Urin:
Archived as Sample No. ________ Picture No.______

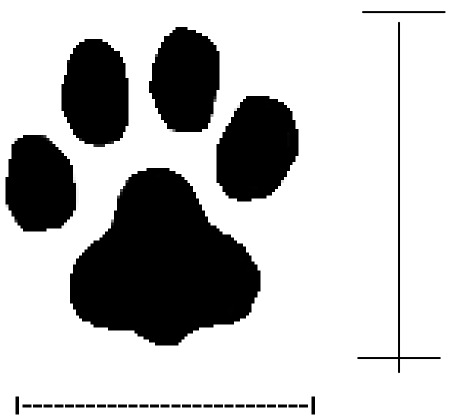
Skin:
Archived as Sample No. ________ Picture No.______

Hair:
Archived as Sample No. ________ Picture No.______

Tracks:

Kind of Tracks [Single (S); in line (L); random (R)]:_________

Archived as Picture No.________



.... mm

.... mm

Comment:

Ø .....…..... mm Main pad ……….. mm Sex: ♀ ♂

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Measurements of all spoors:

Sizes of [mm]	width	length	diameter	main pad	stride length
Track 1	57	49	43	32	
Track 2	52	48	53	29	150
Track 3	56	54	56		
Track 4	58	53	58		
Track 5	46	53	49		240
Track 6	44	50	58	28	
Track 7	49	50	51	29	280
Track 8	47	49	48		180
Track 9	46	44			
Track 10	52	52	53		280
Track 11	48	42	47		
Track 12	45	45	45		
Track 13	54	49		32	
Track 14	38	40	40		
Track 15			50		
Track 16	45	46	47		
Track 17	45	44	44		
Track 18	50	50	51		280
Track 19	42	45	42		
Track 20			50		
Track 21	47	47			280
Track 22	48	44			300
Track 23	48	50	52		270
Track 24	46	48			260
Track 25	50	46	50		230
Track 26	45	50	45		280
Average	**48.25**	**47.83**	**49.14**	**30.00**	**252.50**

Picture of a Serval spoor:

Chapter 6 – Distribution modelling

Table 6.1: Correlation analyses with ENM Tools (WARREN et al. 2008, WARREN et al. 2010). All r- values were squared and r² > 0.75 were marked in red to avoid pairs of high correlation, the variables chosen for the model are marked green.

SPECIES	BIO19	BIO1	BIO2	BIO3	BIO4	BIO5	BIO6	BIO7	BIO8	BIO9	BIO10	BIO11	BIO12	BIO13	BIO14	BIO15	BIO16	BIO17	BIO18
BIO19		0.0026	0.1543	0.1498	0.1232	0.0498	0.1299	0.1682	0.0032	0.0189	0.0314	0.0680	0.3772	0.2846	0.1778	0.0854	0.2997	0.2100	0.0679
BIO1			0.0006	0.0516	0.0702	0.3386	0.5561	0.0421	0.5990	0.1884	0.4997	0.6727	0.0003	0.0100	0.0011	0.1306	0.0042	0.0008	0.0042
BIO2				0.1605	0.2606	0.2909	0.3058	0.5633	0.0037	0.0202	0.1086	0.1076	0.3152	0.2109	0.1730	0.1511	0.2125	0.2156	0.2418
BIO3					0.8566	0.2934	0.5059	0.7597	0.1210	0.0463	0.2190	0.4836	0.5410	0.4453	0.2690	0.0518	0.4306	0.3212	0.4425
BIO4						0.3399	0.5924	0.8860	0.1515	0.0585	0.2373	0.5863	0.5453	0.5481	0.1391	0.0294	0.5323	0.1745	0.4222
BIO5							0.0027	0.4299	0.0876	0.2983	0.9203	0.0024	0.3309	0.2344	0.1386	0.1911	0.2549	0.1642	0.3937
BIO6								0.6212	0.3818	0.0606	0.0157	0.9148	0.2706	0.2768	0.0986	0.0000	0.2474	0.1257	0.1506
BIO7									0.0811	0.0226	0.2466	0.4797	0.5592	0.4846	0.2179	0.0725	0.4723	0.2681	0.4626
BIO8										0.0111	0.1483	0.5294	0.0038	0.0170	0.0002	0.1711	0.0111	0.0002	0.0144
BIO9											0.3749	0.0292	0.0152	0.0160	0.0022	0.0020	0.0207	0.0013	0.0905
BIO10												0.0353	0.2557	0.1860	0.0853	0.1727	0.2083	0.1011	0.2954
BIO11													0.2084	0.2638	0.0404	0.0144	0.2340	0.0539	0.1108
BIO12														0.8551	0.3347	0.1643	0.8858	0.4036	0.6703
BIO13															0.1236	0.0586	0.9816	0.1583	0.5432
BIO14																0.1557	0.1365	0.9677	0.2895
BIO15																	0.0738	0.1841	0.1213
BIO16																		0.1717	0.5679
BIO17																			0.3351
BIO18																			

Chapter 7 – Review of other methods

Observation sheet for olfactory bait trials:

Date: **Weather:**

Beginning: **End:**

Olfactory lures for today:

Lure	Behaviour			Sex		Time	Duration	Comment
	Sniffing	Rubbing	Detailed description	♂	♀			