THE DIET OF THE BLACK MONGOOSE (*GALERELLA NIGRATA)* (CARNIVORA: HERPESTIDAE) IN NORTH-WEST (HOBATERE CONCESSION) AND NORTH-CENTRAL (ERONGO CONSERVANCY), NAMIBIA.

MASTER OF SCIENCE

BY

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ABSTRACT

The black mongoose (*Galerella nigrata*) (Carnivora: Herpestidae) is a diurnal predator that favours rocky habitats. It is endemic to southwest Africa. Due to its elusive behaviour, the ecology of black mongoose has not been studied and only little ecological information is documented about this species. The general objective of this study was to determine the diet of the black mongoose from Erongo, north central and Hobatere in north-west Namibia through faecal analysis. Seventy one and 76 scats of black mongoose were collected from Hobatere and Erongo, respectively. Scats were broken up and washed through a 1mm mesh sieve. Prey remains were examined using a Vicker dissecting microscope. Based on faecal analysis, insecta was the principal food item in the diet of black mongoose (91.5% at Hobatere and 78.9% at Erongo). This study, therefore, suggests that the black mongoose is predominantly insectivorous but, also fed on small mammals, reptiles and birds. The results of the present study further revealed that the diet of the black mongoose varied between the two study sites. A chi square test revealed a highly significant difference in the percentage occurrence of the main prey categories occurred in the diet of the black mongoose at Hobatere and Erongo; $\chi_9^2 = 323.00$, $P = 0.000$; $n = 10$. Factors such as the dissimilarity in the composition of plants, the difference in prey composition at the study sites may have contributed to the variation in the diet. Orthoptera was the most prevalent prey while Isoptera was the least.

Key words: Black mongoose, diet, faecal analysis, prey,frequency of occurence, Insecta, Namibia.

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This thesis is dedicated to the most adorable and diligent mother, Meme Paskalia K. Negumbo, who has loved, encouraged and catered for all my financial needs during the 6 years I have been at the University of Namibia.

DECLARATIONS

I, Dietlinde N. Nakwaya, hereby declare that this thesis is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

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CHAPTER 1
GENERAL INTRODUCTION

1.1 Introduction

1.1.1 The importance and feeding aspects of carnivores

Carnivores are an important part of functioning ecosystems and through predation have an effect on all aspects of the ecosystem mainly on the diversion and transfer of what they do not need for their own energy requirement to scavengers, detritivores and microorganism (Smithers, 1983). The knowledge of the diet of carnivores within an ecosystem is crucial to understand their spectrum of prey and how they compete for food with other carnivores.

In Namibia, for example, farmers perceive carnivores as a threat to their game and livestock and for this reason, large carnivores such as spotted hyena (*Crocuta crocuta*), wild dog (*Lycaon pictus*), lion (*Panthera leo*) and cheetah (*Acinonyx jubatus*) have been removed from the farms during the last decade without appropriate assessment of their diet (Marker *et. al.,* 1996). This forms part of the human-wildlife conflicts. The need for the knowledge of feeding ecology of carnivores therefore cannot be overemphasized.

Carnivores tend to have different diets as a result of associated disparity in factors such as home range size, presence and absence of territoriality and sociality (Mills, 1991). For example, the distribution of food of the European badgers (*Meles meles*) is suggested as the main factor affecting the size of territories and the number of animals living within a territory (Kruuk and Parish, 1981).

In addition, there are large differences in the range of prey species which carnivores feed on. Some carnivores such as cheetah, take a wide variety of prey species from insects to animals their own size (Marker *et al.,* 1996). Carnivores such as the bat-eared fox (*Otocyon megalotis*) are more specialized and feed mainly on insects (Stuart *et al*., 2003), while others such as the small Indian mongoose (*Herpestes auropunctatus*) are omnivorous feeding on a wide variety of prey such as insects, fruits and small vertebrates (Cavallini and Serafini, 1995). In addition, carnivores differ in their feeding niches and geographic distribution, with more adaptable species being less dependent on particular habitats and using wider geographical ranges than less adaptable carnivores (Sillero-Zubiri and Gotteli, 1992).

Information on the feeding ecology of carnivores also contributes substantially to the understanding of their behavioral ecology (Breuer, 2005). For example, species of mongoose such as the slender mongoose (*Galerella sanguinea*) feed on a small-sized meal that includes insects and small vertebrates. This contributes to its solitary behaviors (Rood and Wozencraft, 1984). However, the vulnerability of small-sized mongoose to predation by bird of prey may encourage communal living (Hinton, 1967).

Other aspects of feeding ecology such as prey availability and distribution can influence the activity patterns as well as spatial and temporal distribution of the species (Breuer, 2005). For example, spotted hyenas (*Crocuta crocuta*) are known to roam over vast distances in search for food (Sillero-Zubiri and Gotteli, 1992). More importantly, knowledge of the feeding ecology of carnivores helps in documenting the impact on prey species and inter-specific competition.

Although previous studies have investigated the interrelations between various aspects of life history of several groups of carnivores emphasizing on feeding ecology (Henschel and Skinner, 1990; Breuer, 2005) similar studies have been difficult for small carnivores such as mongooses (Cavallini and Serafini, 1995). This is because some mongooses such as the slender mongoose are solitary, small and difficult to follow in order to observe their food habits. Nocturnal species such as the bushy-tailed mongoose (*Bdeogale crassicauda*) are difficult to study (Smithers, 1983). Hence, indirect methods are employed to study the feeding ecology of such carnivores.

Previously, the diets of mongooses such as the yellow mongoose (*Cynictis penicillata*), the selous' mongoose (*Paracynictis selousi*) and the bushy-tailed mongoose have been studied through the analysis of their stomach content (Smither, 1983). The process of stomach content analysis is a destructive method as it involves sacrificing an animal to inspect diet from the gut content.

Although this analysis provides apparent type of prey that the animals feed on, it is not an appropriate method especially with the least studied or data-deficient animals such as the black mongoose because one might sacrifice the last few surviving individuals of the species. The diet of mongooses such as the small Indian mongoose (Cavallini and Serafini, 1995) and the yellow mongoose (Avenant and Nel, 1992) have been studied through faecal analysis.

Faecal analysis involves the collection and examination of an animal's faeces in order to recover undigested remains (Ciucci *et* al., 1996). The recovered remains of the prey are identified to determine the diet of the animal. Faecal analysis can also be a useful method in determining the distribution and abundance of animals (Arim and Naya, 2003; Trites and Joy, 2004; Cossíos and Angers, 2006). This method is particularly relevant for monitoring elusive and secretive carnivores for which faeces are often the only available materials. It assumes that solid remains of the prey eaten pass into faeces in the same proportion as they were consumed and their relative occurrence in the diet will not be critically biased (Trites and Joy, 2004).

Faecal analysis not only provides useful information about the diet of the carnivore but can also be used as an indirect method to provide an indication of animal and plant diversity in a given area. In a study to examine diet of foxes, scat analysis was considered as an appropriate method because it provided a good indication of the mammalian species preyed upon in a given area particularly during the colder months (Brunner *et al.*, 1976).

Termites such as *Hodotermes* species were reported as the principal food that occurred in the diet of the bat-eared fox throughout the year while avoiding *Trinervirtermes,* the equally abundant species (Stuart *et al*., 2003).
A similar technique to faecal analysis, pellet analysis has been, suggested as a useful tool for monitoring small mammal communities (Agnelli and De Marinis, 1992).

While faeces or scats are the terms used to define the excreta of mammals (carnivores), pellets in this study refer to oval-shaped matter regurgitated from the mouth of the owls. According to Agnelli and De Marinis (1992), pellet analysis is more efficient than faecal analysis because it provides useful information regarding the type of prey occurring in the area and is used a tool to monitor populations of small mammal (Agnelli and De Marinis, 1992). During the study on the feeding ecology of the fox (*Vulpes vulpes*) (50 scats) and the barn owl (*Tyto alba)* (100 pellets) at Villa Demidoff Park (about 12 km N of Florence, Italy), faecal and pellet analyses were compared on the basis of time, working effort and output (Agnelli and De Marinis, 1992).

The study revealed that pellet analysis required 39 hours (Collection time: 9hours, laboratory analysis time: 30 hours). Faecal analysis however needed 73 working hours (collection time: 26 hours and laboratory analysis time: 47 hours). In addition, faecal analysis only provided useful information during the first 3 weeks of the study after analysing 22 of the 50 scats. In the following weeks, no other taxonomic group was recognised in the scats (Agnelli and De Marinis, 1992).

This possibly happened because the bat-eared fox fed on similar prey and the identified prey remains were the same as those identified in previous weeks. While pellet analysis has been appropriate in studying small mammal fauna, faecal analysis has also been used to infer habitat use, range size and relative abundance and behaviour of wild populations (Trites and Joy, 2004). The information derived from faecal analysis is relevant to both conservation and biodiversity management of the species and their habitats. Faecal analysis has also been commonly used in studying the diet of large carnivores such as wolves, lions and spotted hyenas and the wild dog (Ciucci *et al.,* 2004; Webbon, 2002; Breuer, 2002).

This is because faecal analysis allows continuous determination of diet choice and has been used in many different habitats to determine the feeding ecology of carnivore species without disturbing or being in physical contact with the animals (Breuer, 2005). Consequently, the present study was initiated as part of an investigation of the ecology of the previously unstudied and ‘data-deficient’ black mongoose (*Galerella nigrata*) in Namibia. The aim of this study was to examine the diet of the black mongoose from Erongo and Hobatere through faecal analysis.

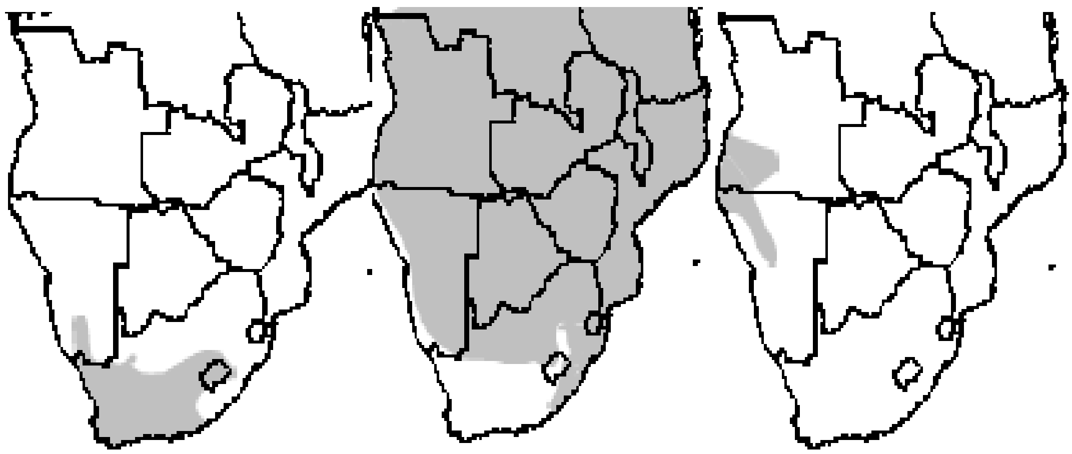
1.2 Problem statement and justification

Mongooses were formerly classified within the family Viverridae (Estes, 1990). However, mongooses have characteristic and distinguishing morphological and behavioural features which are different from those of viverrids and have been allocated to the family Herpestidae (Estes, 1990). Despite this, viverrids have seemingly been understudied given the patchy and incomplete data at our disposal (Rood and Wozencraft, 1984). There is therefore a need to enhance ecological study of Herpestids of which the black mongoose forms part.

Since its taxonomic revision in 1987, the black mongoose has not been studied and lacks ecological, geographical and phylogenetic information (Watson and Dipennar, 1987). According to Taylor (1975), most *Galerella* subspecies are subject to the pressures of habitat destruction and data-deficiency and it is likely that some of its subspecies and close relatives are also threatened with extinction. A lack of data is probably the most serious conservation issue currently facing the black mongoose and chances are high that this species is endangered or threatened.

Similar to other mammals in Namibia which are now under review, the conservation status of the black mongoose has not been determined. According to Griffin (1998), the interim status of little data bestows a high level of protection until the species is evaluated and placed in a conservation category. It is therefore vital that intensive and reliable information on the ecology of the black mongoose is made available to confirm its conservation status and ensure the development and implementation of management strategies to protect the black mongoose and its habitat. In addition, the black mongoose is endemic to southwest Africa (Rathbun *et al.*, 2003). Endemic species are a unique biological heritage and Namibia has a special responsibility to conserve them as an essential part of its biodiversity . Hence, the importance of documenting information that will contribute to the conservation of the black mongoose cannot be overemphasized.

The *Galerella flavescens* has been argued as similar to *Galerella nigrata* (Skinner and Chimimba, 2005). Figure 1 shows the distribution of *Galerella flavescens* in southern Africa, it is therefore necessary to study and find out the distribution of the *Galerella nigrata*.



Galerella pulverulenta *Galerella sanguinea* *Galerella flavescens*

Figure 1.2: The distribution maps of the 3 close relatives (*Galerella* species) of the black mongoose in Southern Africa.
(Adopted from: http://www.gisbau.uniroma1.it/data/amd/amd317/amd317.pdf)

According to Griffin (1998), only 14% of Namibia is designated as formal conservation area. The western escarpment and adjacent mountainous plateaus in central and southern Namibia have adequate protection. However, the northern part where many endemic vertebrates are concentrated remains unprotected (Griffin, 1998). Currently, areas where black mongooses are found (Erongo, Ruacana, Hobatere and Spitzkoppe) are only protected by conservancies, private nature reserves and game farms. Given that the area where black mongooses are found coincides with areas of high endemism in the northern area, these unique habitats can receive more conservation status by using the black mongoose as a flagship species to encourage interest and protection of those areas.

In addition, yellow mongooses are believed to be reservoir hosts of rabies between outbreaks (Tislerics, 2000). Black mongooses could potentially be reservoir hosts of rabies in their habitat. Because rabies is a health concern to humans and other animals, research on the black mongoose is important.

In Namibia for example, domestic dogs can possibly acquire rabies from the black mongoose. This can cause a health hazard to people in the community especially in Erongo and Hobatere where black mongoose is found. According to Cavallini and Serafini (1995), the high level of predation on rodents by mongooses reduces their populations and is beneficial to humans particularly with regard to invasive species. For example, the small Indian mongooses were introduced in Jamaica in 1872 to control rats in sugar cane plantations (Dennis and Macdonald, 1999).

Mongooses have been the target of studies worldwide because they are a concern in wildlife management as local people complain that mongooses harm and eat wild fowls and chicken (Cavallini and Serafini, 1995). However, according to a study conducted on the diet of the small Indian mongoose on an Adriatic island, birds were the least preferred prey (Cavallini and Serafini, 1995). It is therefore relevant to study and determine the diet of the black mongoose. In order to determine the diet of the black mongoose, faecal analysis was used in this study. Faecal analysis is ideal because it does not require physical contact and disturbance of the animal (Arim and Naya, 2003). Diet analysis studies may also generate data that may be used to estimate the home range and habitat utilization.

Ultimately, the black mongoose is a valuable asset to eco-tourism in the country. Tourism is a growing industry in southern Africa and carnivores are arguably a great attraction to Namibia (Stander, 1990). The present study will contribute to the ecology, diet in particular, of the black mongoose that in turn will guide long-term conservation of the species.

1.3 Objectives

1.3.1 General objectives

To this end, the general objective of the study was to determine the diet of the black mongoose.

1.3.2 Specific objectives

The more specific objectives in the present study include:

(a) To determine the diet of the black mongoose through faecal analysis.

(b) To compare the diet of the black mongoose between two selected locations.

(c) To determine the most prevalent prey in the diet of the black mongoose.

1.4 Research questions

The following research questions were investigated in the present study:

(a) What do the black mongooses feed on?

(b) Is there a difference in the diet of the black mongooses that live in different habitats?

(c) What is the most prevalent prey item in the diet of the black mongoose?

1.5 Research hypotheses.

(a) The diet of the black mongoose will constitute small mammals such as rodents, insects and fruits because these are the most common prey in the diet of other mongoose *(Galerella)* species (Cavallini and Serafini, 1995).

(b) The diet of the black mongoose in the 2 selected areas will differ and reflect different prey items available in the habitat because of different factors such as topography, altitude, rainfall and predation that affect prey availability and distribution in the study area.

(c) Insects will be the most prevalent prey in the diet of the black mongoose because it has been the most abundant species in the diet of other Herpestids such as the yellow mongoose and the small Indian mongoose (Avenant and Nel, 1992; Cavallini and Serafini, 1995).

CHAPTER 2

LITERATURE REVIEW

2.1 The feeding ecology of carnivores

The foraging and feeding ecology of carnivores is an essential element to understanding the contribution that they make towards shaping the structure and function of terrestrial ecosystems (Hayward *et al*., 2006). Much of the foraging ecology of carnivores is influenced by their degree of sociality (Sillero-Zubiri and Gotteli, 1992). Large carnivores randomly kill and consume large ungulates for survival through cooperative hunting while some small carnivores hunt singly (Hayward *et al*., 2006). For example, a pack of wolves defend their territory against other wolves and do not allow them to share their prey (Stahler *et al*., 2006) while the slender mongoose which is solitary strivse to capture a prey and does not share its prey with others (Rood and Wozencraft, 1984).

Some carnivores such as wolves select their prey on the basis of species, age, and sex while foraging (Stahler *et al*., 2006). For example, African wild dogs (*Lycaon pictus*) and wolves (*Canis lupus*), hunt in packs and are able to kill very large prey such as moose (*Alces alces*) (Breuer, 2002; (Stahler *et al*., 2006). Although most large carnivores prefer medium-sized animals such as antelopes, they occasionally hunt small prey such as hares, lizards and also eat eggs (Creel and Creel, 1995a).

Unlike large carnivores, small solitary carnivores, hunt singly and feed on small vertebrates and insects (Smithers, 1983). It has also been reported that areas with high vegetation density do not have an influence on hunting success as carnivores often use surprise attacks in these habitats (Creel and Creel, 1995a).

There are several methods that have been used to study the feeding ecology of carnivores. These include field observations and the examination of stomach content (Hiscocks and Perrin, 1987; Smithers, 1983). With field observations, an animal is followed and their activity and feeding behaviour is recorded. Field observations are done using binoculars and telescopes and behaviours are often recorded using the scan sampling method (Su and Lee, 2001). The examination of stomach content involves sacrificing the carnivore and examining its gut content under a microscope (Smithers, 1983). Another method used in studying the diet of carnivores is faecal analysis and the method is described below.

2.2 Faecal analysis

Faecal analysis has become an important method in the study of the feeding ecology of carnivores. The method involves collection of scats (faeces) which are soaked in water, broken up and prey remains are examined under a microscope (described in Chapter 3). The diet of free-ranging cheetah (*Acinonyx jubatus*) has been assessed using faecal analysis (Wachter *et. al*., 2006) from two study sites of the Cheetah Research Project in central Namibia run by the Leibniz-Institute for Zoo and Wildlife

Research, Berlin (Wachter *et. al*., 2006). Wachter and others collected 67 faecal samples mainly from trees that cheetah use to scent-mark. Hairs found in the faeces were macroscopically divided into different types according to length, colour, thickness and shape. Hair imprints were made using a 0.1 x 1 x 2 cm celluloid plate. Twenty two faecal samples contained hairs from both prey and carnivore species, 44 faeces contained hairs of prey species only. Eighteen of the 22 faeces with carnivore hairs contained cheetah hairs that were most likely ingested during grooming.

The remaining four scats contained leopard hair and were excluded from the analyses. Without correction factors, hartebeest (*Alcelaphus buselaphus*) and springbok (*Antidorcas marsupialis*) were the most represented prey species in the diet of the cheetah. In contrast, when correction factors were applied, spring hares (*Pedetes capensis*) comprised the highest proportion (0.43), followed by duikers (*Sylvicapra grimmina*) (0.17). Livestock (goats), kudu, hartebeest, warthog comprised the least proportions (Wachter *et. al*., 2006).

In the 44 scats that consisted of only hair from prey species, two additional prey species, oryx (*Oryx gazelle*) and grey climbing mouse (*Dendromus melanotis*) were identified (Wachter *et al*., 2006). These results were similar to those of a study that determined the diet of the cheetah based on faecal samples by Marker *et. al*., (2003). In their study, the main prey of cheetah was also a small mammalian species, the scrub hare (*Lepus saxatilis*), with a proportion of 0.41 while livestock comprised only a small proportion (0.04) of their diet (Marker *et. al*., 2003).

Another study was carried out by Sillero-Zubiri and Gotteli (1992) on the feeding ecology of spotted hyaenas (*Crocuta crocuta*). Three hundred and thirty two scats and 138 regurgitations were collected in the dense forest of Aberdare National Park, Kenya. Faecal analysis was used to determine the diet. Bush buck, suni and buffalo were the most important food items, accounting for 59% of food occurrence in the samples (Sillero-Zubiri and Gotteli, 1992).

Faecal analysis has also been used to determine the diet choice of large carnivores (Arim and Naya, 2003). A study by Breuer (2005) in Cameroon indicates that although faecal analysis does not determine if prey was killed or scavenged, it often identifies small prey species, which are underestimated in studies using kill samples or which are overlooked by direct observations. Faecal analysis has thus been described as a good method to reveal the diet choice of large carnivores especially in large protected areas where direct observations are rare.

In a total of 280 carnivore faecal samples, 388 mammalian prey items were found and identified (Breuer, 2005). The analysis revealed that the diet of the three large carnivores (wild dog, lions and spotted hyenas) overlaps considerably. Remains of large and medium sized antelopes had the highest percentage frequency of occurrence, with buffon's kob being by far the most common prey. According to this study, large carnivores seem to consume most abundant prey species and no domestic livestock remains were found in their faeces (Breuer, 2005).

Breuer (2002) collected 119 faecal samples to determine diet choice of lions in Faro National Park and its adjoining hunting areas in Cameroon. One hundred and seventy two prey items were found in the scats. Fourteen mammal species were identified in the faeces and an average of 1.4 prey items was found in each sample, with a maximum of three species within a faecal sample.

Buffon's kob appeared in 61 samples, and was the most common prey (35.3%). Bushbuck (9.2%), waterbuck (7.5%), porcupine (7.5%), red river hog (6.9%), olive baboon (6.9%), roan antelope (6.9%), oribi (6.4%) and Grimm's duiker (5.2%) also formed part of the diet. Rare prey species included the reedbuck (2.9%), warthog (2.3%) and Guereza colobus (12%). The buffalo (0.6%) and the African civet (0.6%) were found in only one sample. Although large carnivores were reported having killed livestock, no domestic animal was found in the faeces of the lion (Breuer, 2002).

Food habits of the Formosan rock macaques, the only non-human primate native to Jentse Taiwan, were studied using faecal analysis and direct field observation from October 1991 to September 1992 (Su and Lee, 2001). In this study, ten faecal samples were collected each month, and macaques were recorded to have eaten 51 plant species and insects of ≥5 Orders. The frequency of occurrence of fruits, plant material, flowers and animal matter in macaque faeces were 96 %, 98%, 3% and 83.2 %, respectively (Su and Lee, 2001). Macaques spent more time feeding on fruits than other plant parts and insects. They spent more time feeding on fruits and insects during summer and survived on leaves and stems during the cold season.

Seasonal variation and composition of macaque's diet was documented from faecal analysis (Su and Lee, 2001). Another study on actual feeding and diet was carried out on the black-backed jackal (*Canis mesomelas)* in the Namib Desert coast (Hiscocks and Perrin, 1987). Fourty seven scats were analyzed and indicated that the Cape fur seal (*Arctocephalus pusillus)* was the main food item (86%) in the diet of the black-backed jackal (Hiscocks and Perrin, 1987). The jackals were not observed attacking seals but dead and dying seals were frequently washed up to the beach providing constant food supply for the jackals. Birds (12%) were the second most eaten species and were dominated by Cape cormorant (*Phalacrocorax capensis)* (Hiscocks and Perrin, 1987).

The remaining food of the black-backed jackal consisted of marine bivalves, insects and plant material. One hundred and two observations were made of the jackals scavenging. The study concluded that the black-backed jackal is an opportunistic scavenger and that competition for food plays an insignificant role in its feeding ecology (Hiscocks and Perrin, 1987).

In another field report by Stuart *et. al*., (2003), the diet of the bat-eared fox was determined using scat analysis on the western escarpment, South Africa. Bat-eared foxes do not use latrines but defecate when they come out of their roosts. Four hundred and fifty scats were collected from May 1994 to January 1995 and analyzed using scat analysis to determine seasonality in food consumption. Faecal analysis revealed the presence of insect, arachnids, plant parts and mammalian hair in the diet of the bat-eared fox Stuart *et. al*., (2003).

Isoptera (termites, *Hodotermes species*) had the highest occurrence, followed by Coleoptera (beetles). The study concluded that, the bat-eared fox is one of many carnivores that rely on insects for the greater part of its diet (Stuart *et. al*., 2003).
In addition, faecal analysis has also been used to determine the diet of aquatic carnivores. The diet of Cape clawless otters (*Aonyx capensis)* was assessed at two sites along the Bloukrans River, Western Cape, South Africa using faecal analysis (Parker *et. al.,* 2005). Out of 78 spraints analyzed, the study found that crabs (*Potamonautes perlatus*) made up (50%) of the diet (Parker *et. al*., 2005), frogs (*Xenopus* and *Rana spp*) (11.4%) were the second most important component, while fish (*Micropteris salmonides*) (<14%) were of least importance (Parker *et. al*., 2005).

The European otter (*Lutra lutra*) on the other hand, feeds opportunistically on a wide range of prey, but mainly on fish (Kingston *et. al.*, 1999). Its diet on the north–east coast of Irishmore, Ireland was investigated by analyses of monthly collected droppings. The diet comprised of 70% by weight of rockling and wrasse in almost equal quantities. The study also found that otters only fed on fishes classified as frequent to rare on the Irishmore coast (Kingston *et. al.*, 1999).

In addition, faecal analysis is a valuable additional tool to the conventional techniques used in mammal surveys and it can provide useful information on the diet of carnivores (Brunner *et. al.*, 1976). Its main advantages are that field collection is rapid and the scats can be stored and processed at a convenient time, the costs are low and there is no effect on wildlife.

Faecal analysis has also been found to be capable of identifying small prey species which are underestimated in studies using kill samples or are even overseen by direct observations (Breuer, 2005). For example, a small carnivore less than 2 kilo grams was found in the faeces of a wild dog in Cameroon (Breuer, 2002).

In comparison, pellet analysis requires expertise, much time and can disturb the biocenosis (Agnelli and De Marinis, 1992). The main constraint in using faecal analysis is that it can give only limited information on the ecology of the prey species (Brunner *et al.*, 1976; Agnelli and De marinis, 1992). A common problem encountered in the identification of the faecal content of mammalian carnivores is that more obvious characteristics of prey's remains such as colour, size and shape are lost in the process of mastication and digestion. Hence, it is often difficult to identify prey items in faeces to species level (Day, 1966).

Faecal analysis is much easier in large carnivores because a lot of species can be identified macroscopically by prey items such as hoofs, fingers and nails (Breuer, 2002). That is unlike the bones and hair of vertebrate and legs, wings and carapace of insects found in the faeces of small carnivores. Faecal analysis does not provide information on the age and the sex of the prey. This minimizes the accurate estimation of the biomass of prey (Breuer, 2005). If a carnivore feeds on prey with soft parts, the prey is completely digested and its parts will not appear in faeces. This may result in a gross under-estimation of an important component of the diet (Jones *et al.*, 2003).

Conversely, any hard-bodied prey such as plant structural parts eaten are poorly digested in the gut of the carnivores and their contribution can be easily over-estimated from their proportion in the scats (Jones *et al*., 2003). Dickmann and Huag (1998) concluded that faecal analysis can be a relatively reliable method for determining the diet of generalist insectivores that eat hard bodied prey.

Finally faecal analysis has been used in combination with genetic analysis such as PCR amplification (Deagle *et. al*., 2005). In 2005, Deagle and others carried out a study to investigate the capacity of genetic techniques to recover prey DNA from scats of the captive Steller sea lion (*Eumetopias jubatus*).The study indicated that the DNA method can obtain more accurate taxonomic identification of prey remains in scats and is helpful in recovering soft-bodied prey (Deagle *et. al*., 2005). The DNA based methods are more powerful; however the cost of undertaking them can be a constraint.

2.3 The general biology of mongooses

Mongooses are African small- to medium-sized carnivores. They belong to Family Herpestidae, together with one genus that is widespread in Asia and southern Europe (Smithers, 1983; Myers, 2000). The Family Herpestidae is divided into two subfamilies, the Herpestinae and the Galidiinae. The Herpestinae is a group of small carnivores with body mass that range from 1kg to 5kg, and have a body length ranging from 23cm to 75cm (Lioncrusher and Postanowicz, 2007).

Herpestids tend to have small heads, pointed snouts, and short, rounded ears that are not pointed as those of viverrids (Myers, 2000). Members of the Galidiinae, a subfamily found only in Madagascar are included on the Red List of Threatened Species by the World Conservation Union (IUCN) (Myers, 2000). Five mongoose species are considered vulnerable (*Salanoia concolor, Galidictis fasciata, Fossa fossana, Mungotictis decemlineata, Galidia elegans*) facing a high risk of extinction while two are endangered *(Eupleres goudoti, Cryptoprocta ferox)* with a very high risk of extinction (Myers, 2000).

The Herpestidae are primarily terrestrial and have a tapered head, long tail, and short feet (Smithers, 1983). Species such as the black mongoose (*Galerella nigrata*) and the slender mongoose are solitary and diurnal. Mongooses have been introduced to many areas of the world in order to control rodents and snakes (Cavallini and Serafini, 1995; Myers, 2000).

Unfortunately, mongooses have become a worse problem than the animals they were introduced to control. Mongooses are ground-dwelling and subsist on a range of invertebrates such as insects and also on rodents and snakes and are well-known for attacking even the largest and most poisonous snakes (Skinner, 1990). Species such as the meerkat (*Suricata suricata)* and the small Indian mongoose however include seeds and fruits in their diet (Cavallini and Serafini, 1995).

Mongooses are opportunistic in their diet and can easily adapt to changed conditions or resource by enlarging their home range, intensifying activity or by diversifying their diet (Dennis and Macdonald, 1999). The Herpestids specifically, has 38-40 teeth with a pair of long canines for fast-grabbing especially when hunting small vertebrates (Smithers, 1983). Because of the differences in the structure and number of teeth, as well as hunting techniques, the diet of mongoose is diversified and is difficult to classify. The small Indian mongoose has variably been classified as a generalist and as an insectivorous and or a vertebrate feeder (Cavallini and Serafini, 1995). However, according to Roy (2006), the small Indian mongoose has been classified as an opportunistic, omnivorous carnivore.

2.4 The general biology of the black mongoose (*Galerella nigrata*)

The black mongoose was originally collected from Ruacana area of Namibia, which is on the Kunene River that forms border with Angola (Rathbun and Cowley, 2008). The species was first described by Thomas in 1928 and was identified as a separate species from the Kaokoveld and was named *Myonax nigratus*, a melanistic variant of the Cape grey mongoose (*Herpestes pulverulenta*) (Watson and Dipennar, 1987).

Subsequently, the species was classified as *Galerella flavescens* from south western Angola (Watson and Dipennar, 1987). Subs equally, the black mongoose was treated as a subspecies of the slender mongoose until in 1987 when Watson and Dipennar (1987) and Taylor (1993) confirmed the specific distinction of *Galerella nigrata* as an independent species (Watson and Dipennar, 1987).

Crawfrod-Carbral (1989b) and Mills and Bester (2005) considered *G. nigrata* as a conspecific of *G. flavescens* of which they referred to as Kaokoland slender mongoose (Skinner and Chimimba, 2005). The present study consider that the mongoose studied is referable to the black (*nigrata)* and not to the chestnut-colured *(flavescens).*This is based on the morphological studies by Watson and Dipennar (1987) and the morphology and habitat description given by Rathbun and Cowley (2008).

There is no rigorous taxonomic study of the two forms *nigrata* and *flavescens* that supports conspecific status and recent publications that support the conspecific status has not provided any information about the habitat, habits or and food of *G. flavescens* (Rathbun and Cowley, 2008). Also based on Crawford-Carbral (1996), the locations of *G flavescens* specimens in that study indicate that this mongoose is not as closely associated with habitats dominated by granite boulders as *G. nigrata*. The present study therefore surmises there is no much evidence to refer *G nigrata as G flavescens*.

Galerella nigrata is dark-reddish brown, sometimes with a stripe down its back and tail. The species is distributed in a long thin band from the region of the Kunene River south through the Kunene region to the Spitzkoppe and Erongo Mountains in north-central Namibia (Rathbun and Cowley, 2008). Early observations indicated that the black mongoose is diurnal, mostly solitary and favours habitats dominated by large rock boulders (Cowley and Cunningham, 2003; Rathbun and Cowley, 2008).

The black mongoose roams an area of up to 200 hectare in size which is rather large for an animal with an average body length of 68 cm, half of which is a bushy tail (Cowley and Cunningham, 2003) and an average body mass of nearly one kg (Rathbun *et. al*., 2003). According to Cowley and Cunningham (2003), there is considerable home range overlap amongst the males. Individuals were found to spend the majority of their time amongst granite boulders and highly vegetated dongas, and the least amount of time in open grass and veld plains. Black mongooses were also noted to mark their dens with concentrated urine and on few occasions with faeces (Cowley and Cunningham, 2003).

For years, black mongoose remained unstudied and the little ecological information known about the black mongoose ((Cowley and Cunningham, 2003; Rathbun and Cowley, 2008). Due to its elusive nature, and small size, the black mongoose is difficult to observe continuously for a long period of time in order to determine its feeding habits. The diet of black mongoose is largely unknown and hence the need for studies on its feeding ecology.

2.5 The diet of the Cape grey mongoose (*Herpestes pulverulenta*)

The main prey of the Cape grey mongoose are the small to middle-sized rodents when available (Cavallini, 1992). In the West Coast National Park, South Africa *Otomys unisulcatus* (average body mass = 124 g) and *Rhabdomys pumilio* (average body mass = 45 g) constitute over 90% of their diet by volume (Cavallini, 1992). Predation of a young porcupine (*Hystrix africaeaustralis*) was also recorded.

In the same area, insects (especially Coleoptera) were the secondary food resource. The Cape grey mongoose removes a small proportion (probably <10%) of the total rodent propulation (Cavallini, 1992). In other studies, small mammals appeared less frequently in the diet of the Cape grey mongoose. The relative frequency of occurrence ranged from 15% to 30%, whereas arthropods formed more than 50% of their diet (Cavallini and Nel, 1990a). The Cape grey mongoose also scavenges on road-kills and human garbage (Cavallini and Nel, 1990a).

Although basically a solitary animal, males show some sociality (Cavallini and Nel, 1990b). The usual feeding technique consists of moving quickly from bush to bush or other potential feeding site. The Cape grey mongoose sniffs often when in search of food, but it may rely on sight to a large extent (Cavallini, 1992). Although it is the least active species than other mongoose such as the yellow mongoose and the meerkat, the Cape grey mongoose scratches the soil in search of subterranean prey items, although less actively so than other mongooses (Cavallini, 1992).

2.6 The diet of the slender Mongoose (*Galerella sanguinea*)

The slender mongoose is primarily a predator of small vertebrates but also feeds, to some extent, on some insects (Taylor, 1975). Observations were made 20 meters from the 12 to 16 August 1973 on two males and a female that visited a giraffe (*Giraffa camelopardalis*) carcass 17 kilometres east and 10.5 kilometres north of Kibwezi in southern Kenya (Vaughan, 1976).

The slender mongooses were observed to forage primarily from mid-morning until late afternoon. With noses to the ground, the mongooses explored the soil around the carcass. They chose feeding sites beneath the edge of the carcass where they exposed pupae by digging. Pupae were eaten rapidly but the mongooses often fed continuously for over an hour. On one occasion, a male fed continuously from 1300 until 1430, and remained near the carcass and fed repeatedly until 1800.

The mongooses stopped visiting the carcass after five days when the number of maggots decreased (Vaughan, 1976). The slender mongoose foraged solitarily, although at times, two males foraged at the carcass simultaneously, they were always at least two meters apart (Hinton, 1967). According to Rood and Wozencraft (1984), slender mongooses are predators of small vertebrates such as mice, rats and lizards. From the five scat samples collected during the study by Rood and Wozencraft (1984), scats of slender mongoose contained mostly hair and not insects that dominate the scat content of other mongoose species such as banded mongoose and dwarf mongoose.

2.7 The diet of the yellow mongoose (*Cynictis penicillata*)

A comparative faecal analysis of the diet of the yellow mongoose was conducted in the Postberg Nature reserve, West Coast National Park and in the Karoo, Beaufort west, South Africa (Avenant and Nel, 1992). Insects were the most prevalent prey in both study areas. However, rodents and reptiles were the most eaten prey at the coast while birds were found in more than 10% of the scats from both study sites (Avenant and Nel, 1992). Variations in dietary patterns were noted in the prey availability at the coastal site. Overall, other prey appeared in small quantities at both sites, hence indicating the opportunistic feeding behavior of the yellow mongoose (Avenant and Nel, 1992).

2.8 The diet of small Indian mongoose (*Herpestes auropunctatus*)

The small Indian mongoose is a predator of ground-nesting birds, small mammals and reptiles. Many snakes and iguanas are at risk from this mongoose. The small Indian mongoose is a vector of rabies, and causes economic loss to game species and the poultry industry (Roy, 2006). It also threatens endemic species on tropical cane growing islands and has caused the population extinction of many endemic vertebrates. This species has been identified to be among 100 of the "World's Worst" invaders (Roy, 2006). Small Indian mongooses forage during the day, except in close contact with humans, when it may become nocturnal.

Studies have concurred that the small Indian mongooses is an opportunistic, omnivorous-carnivore that feeds principally on rodents, birds (and their eggs) and insects (Cavallini and Serafini, 1995). However, fruits dominate the winter diet of an introduced population on the Adriatic Island (Cavallini and Serafini, 1995). The winter diet of the small Indian mongoose in 1992 -1993 was dominated by vertebrates (46% by volume), mostly murine rodents, plant matter (43%) and mainly fruits (Cavallini and Serafini, 1995). The diet was analyzed through faecal analysis.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study sites

3.1.1 Hobatere (northern Namibia)

Scats of the black mongoose were collected around Hobatere Lodge, in the Hobatere concession 19°19'02"S; 14° 28'10.8" E, (Figure 3.1). Hobatere concession is 2 km north-west of Etosha National Park and 80 km north of Kamanjab, northern Namibia. Hobatere is positioned in the mopane savanna, mountainous Kaokoveld in the North West escarpment zone (McGinley, 2008).

The concession is made up of roughly hewn rocky outcrops, rolling granite hills, and kopjes interspersed with open valleys, plains and watercourses. The area covered during faecal collection was 0.7 hectares. Hobatere was less vegetated and comprised of numerous flat rocks and big boulders which were closer to each other. A relatively small area was surveyed in Hobatere than in Erongo because boulders in Hobatere were closer to each other. In addition, same latrine sites were checked after 4 to 5 days because faeces were not frequently found at new rock boulders.

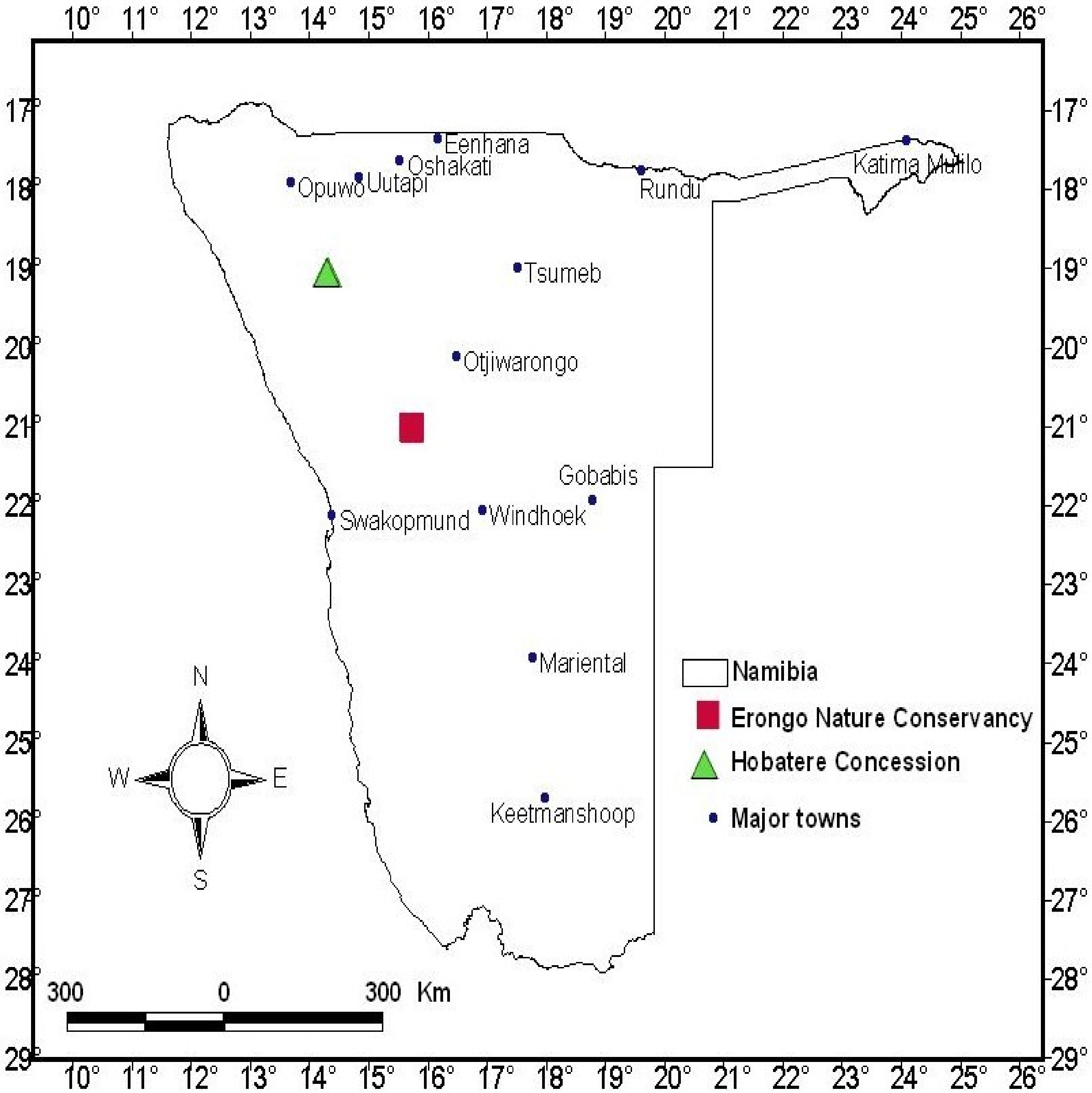


Figure 3.1: Map of Namibia showing the location of the Erongo Nature Conservancy, and Hobatere Concession in the central and north-west part of Namibia, respectively.

3.1.2. The background of Hobatere

The Hobatere Concession is 258 km^2 and is located in the Khoadi //Hoas Conservancy on the north-western border of Etosha National Park on the banks of the small Otjovasandu River. The #Khoadi //Hoas (meaning elephant corner) Conservancy has an area of 32 000 hectares and was the first conservancy to be registered in Namibia in 1998 (http://www.travelnews.com.na). Hobatere was created in 1985 by the former Damaraland Representative Authority (DRA) from a combination of five farms next to Etosha National Park that were expropriated in the 1970s as part of the Odendaal Commission's establishment of Damaraland (GRN-NET, 2004). The DRA created Hobatere as a tourism attraction and it was leased out as a concession for hunting and tourism (GRN-NET, 2004).

The Hobatere concession was approved by the Namibian cabinet to be proclaimed as a national park in 2004 (GRN-NET, 2004). The Ministry of Environment and Tourism was tasked to initiate an intensive and consultative management and development planning process for this national park aimed at creating opportunities for generating benefits from tourism to the state and the people of the region. Hobatere is not inhabited by people and does not hold any significant agricultural potential (GRN-NET, 2004). The best form of future management of the concession is to elevate its legal status to that of a national park to enable the regulation of tourism, longer-term planning and management, and the expansion of development opportunities (MET, 2004).

3.1.3 The climate of Hobatere

Hobatere has three distinct seasons: hot and wet (January to April); cool and dry (May to August); and hot and dry (September to December) (McGinley, 2007). Hobatere typically receives late summer rainfall between January and April, with February having the mean maximum rainfall of 110 mm and is positioned within the 200-250 mm annual average rainfall area (Barnard, 1998). There is great variation between years, with the driest years having the least predictable rainfall.

The area has low humidity and is not exposed to the cooling effect of the Benguela Current, resulting in extreme temperatures (McGinley, 2007). The mean maximum monthly temperature is 33°C in summer and 28°C in winter. The mean minimum temperature for summer is 17°C and 7°C in winter (Ebedes, 1976). Peak temperatures, higher than 40°C, are frequent in the hot season and 0°C is the lowest temperature recorded (Berry, 1972). High velocity winds are common during late winter (Le Roux *et. al*., 1988). The soil type is lithosols. Rainfall is usually unpredictable and patchy in both study areas. However, in 2008, they received more than average rainfall turning them into green vegetated locales (Meteorological Service of Namibia, 2008).

3.1.4. The fauna and flora of Hobatere

Hobatere encompasses free-roaming animals, such as the cheetah (*Acinonyx jubatus*), the leopard (*Panthera pardus*), the eland (*Taurotragus oryx*), the Hartmann's zebra (*Equus zebra hartmannae*) and the giraffe (*Giraffa camelopardalis*). The area also holds wildlife populations of high national and international conservation importance such as black rhinoceros (*Diceros bicornis*), desert elephants (*Loxodonta africana)*, lions (*Panthera leo*) and many other plant and animal species of which some are endemic to the area (McGinley, 2008).

The area has the potential for the restoration of the black-faced impala, an endemic species of great conservation concern. The Hobatere area has a distinct vegetation type comprising *Colophospermum mopane*, *Combretum apiculatum* and *Terminalia prunioides* which occurs in both tree and shrub form. The grasses that occur in the study area are mainly annuals such as *Stipagrostis hirtigluma, Schmidtia kalahariensis* and *Eragrostis superb* (Barnard, 1998).

3.1.5 Erongo (central Namibia)

Scats of the black mongoose were collected in the area of the Erongo Wilderness Lodge of the Erongo Mountain Nature Conservancy, 10 km west of Omaruru, central Namibia (Figure 3.1). The site is located at 21°27'19.8"S; 15°52'35.6"E in the western central escarpment and inselbergs of the Nama Karoo biome and semi desert - savanna transition of Namibia (Barnard *et al*., 1998). Erongo is comprised of round shaped granite domes and large boulders and is more sheltered than Hobatere. The total area covered during the period of collecting scats was only 1.3 hectares because of a large number of scats found in Erongo.

3.1.6 The background of Erongo

The Erongo Wilderness Lodge is located amid granite formations on the outskirts of an ancient volcano; the Erongo Mountains. The granite massif, which forms part of the Erongo Mountains, was created by the collapse of a gigantic volcano more than 100 million years ago and the subsequent erosion, which exposed the volcanic rock granite (McGinley, 2008). The Erongo Wilderness Lodge joined other 30 private landowners to form Erongo Mountain Nature Conservancy, a natural treasure of over 200 000 ha in extent (McGinley, 2008). The Erongo Mountain Nature Conservancy incorporates the Erongo Mountains and the western escarpment. It encompasses one of the most environmentally diverse areas in Namibia including cultural artifacts such as rock-paintings and engravings, and prehistoric settlements.

Erongo is bordered by the Namib Desert to the west and the mixed-woodland savannah to the east (McGinley, 2008). The Conservancy was created to preserve the rich cultural heritage in the form of rock-paintings and engravings that are found throughout Erongo such as at the Paula's Cave Rock Art site, to conserve and protect the biodiversity and to re-introduce species that formally inhabited the area such as the black-faced impala and the black rhino (McGinley, 2008).

3.1.7. The climate of Erongo

The study area has an annual rainfall of 100 – 150 mm per year (Barnard, 1998). Rainfall is highly seasonal, peaking between December and March. The climate is typically harsh, and both seasonal and daily temperatures fluctuate considerably. There is a temperature variation of 25°C between day and night. Mean maximum temperatures in mid-summer exceed 30°C, whereas mean minimum mid-winter temperatures are below freezing (Palmer and Hoffman, 1997). The land form of Erongo is a result of the surface erosion of the degraded escarpment made of shallow, weakly-developed lime-rich soils (Watkeys, 1999).

3.1.8 The fauna and flora of Erongo

The Erongo Mountains form a rare confluence of ecosystems that give rise to remarkable biodiversity, including a vast array of plant, reptile, mammal and bird species that are endemic or near-endemic to Namibia. Species include the Angolan dwarf python (*Python anchietae*), white-tailed shrike (*Lanioturdus torquatus*), Hartlaub's francolin (*Francolinus hartlaubi*), Ruppell's parrot (*Poicephalus rueppellii*), Damara rockrunner (*Chaetops pycnopygius*) and Hartmann's zebra (*Equus zebra hartmannae*).Extremely rare species such as the peregrine falcon and the booted eagle also inhabit the Erongo Mountains conservancy. The striking black eagle can also be observed breeding in many parts of the mountains (McGinley, 2008). Erongo is comprised of *Combretum apiculatum, Terminalia prunioides, Acacia erioloba and Acacia erubescens* as well as *Grewia flava and Grewia flavescens.*

3.1.9 Human influence on the study areas

<u>Human population</u>

Rock paintings in Erongo mountain nature conservancy, shows signs of long and intensive human habitation of the area (McGinley, 2008). These areas were long used by bushmen and the san people who were nomadic. The activities of the ethnic groups including the settled Nama people concentrated in areas with water courses where they ambush the animals for hunting (Wardell-Johnson, 2000). The study areas are also under continuous migration of people in search for employment opportunities and as the lodges expand, the population also increases. For example, the black mongooses were normally observed at rocks close to the lodge, and are no longer there most likely because of the number of people and domestic dogs in the vicinity of the lodge (P. Tylvas, pers. comm. 2008).

Agriculture and farming

Loss of habitat and habitat-fragmentation is the single most important cause of loss of biodiversity, and has an enormous influence on desertification (Wardell-Johnson, 2000). Agriculture in villages close to Hobatere contributes to this process as large areas of land are cleared for cultivation. The use of pesticides in agricultural field has affected the wildlife in areas close to Hobatere. Birds that fly to nearby fields are contaminated and when carnivores feed on them are likely to be affected (Wardell-Johnson, 2000). Livestock such as cattle in open communal areas around the study sites also destroy the vegetation-cover through overgrazing that often leads to habitat degradation and erosion (Wardell-Johnson, 2000).

Bush fires

Bush fires are also an important factor damaging biodiversity in the study areas. Most fires in African savannas result from human activities (Caspary, 1999). The effects of bushfires on vegetation and animal distribution are positive for herbivores such as antelope species by promoting the sprouting of grasses which are an important source of nutrients (Caspary, 1999). However, bush fires have negative influence on small mammals and insects which are prey for mongooses (Cavallini, 1992).

3.2 Vegetation assessment of the study areas

The vegetation assessment was conducted during the faecal collection period in the two study sites. The vegetation assessment was conducted at five stations in the surrounding of rocks and sites where the black mongoose scats were found. These 5 stations were positioned between 450 m and 600 m from each other depending on the location of the next rock boulders where scats were found in order to cover the study area. Plants were categorised as trees and shrubs whereby trees were single or multi-stemmed woody plants with a height $\geq$ 3.0 m and shrubs were single or multi-stemmed woody plants with a height of $\leq$ 3.0 m (Walker, 1976).

A nested plot was designed covering a 20m x20m quadrat for trees, 10m x10m for shrubs and 1m x1m quadrat for grass cover at each station (Barbour *et al*., 1987). The number of trees and shrubs in each quadrat were counted and identified using the trees of southern Africa (Palgrave, 1977). Grass cover was visually estimated as percentage ground cover (Walker, 1976).The number of quadrats for plant life form (trees, shrubs and grass cover) were five.

3.3 Faecal analysis

Scats of mongoose were collected in March 2008 at Hobatere and June 2008 at Erongo. A scat is a technical term referring to faeces of an animal. In this study, a scat refers to a single, whole faecal pellet of the black mongoose. The black mongoose scats were distinguished from other scats that occurred at the same location such as those of porcupine, rock dassies and plaited lizards by size and shape.

Porcupine faeces are round and about 20 - 30mm long. They contain barks of plants and other plant material whilst faeces of plaited lizards are almost the same size as those of a young black mongoose with a length of 20 - 40 mm but have a white substance on the end pointed part. Faeces of rock dassies are round and contain grass and are between 5 mm and 10 mm in length.

Scats of the black mongoose are cylindrical, sausage shaped, pointed at one end and between 30 mm and 60 mm long. They have a musty odour that can be detected at about 2 m to 3 m from the latrine sites. The black mongoose scats contain long thick dark hairs that are ingested during grooming. These hairs were not included in the analysis. During field work, a sample of black mongoose hair was collected from the tail and body of a female black mongoose which was trapped at Hobatere. The collected hairs were then used to visually compare with hairs found in the scats.

Scats were individually stored in paper bags and information such as location, date and time of collection were recorded using a geographical positioning system. Scats were individually soaked in water for about 30-40 minutes to soften them. They were broken up and washed through a 1mm mesh sieve. Prey remains were spread out in a petri dish and examined using an Olympus(CX21FSI) compound light microscope (x10 magnification), a Vicker (AC240V) dissecting microscope (x3 magnification), and a hand-held magnifying glass.

Prey items were categorised to main prey categories namely Insecta (insects), Arachnida (solifugae and scorpions), Mammalia (small mammals), Aves (birds), Reptilia (lizards and snakes), and others (fully digested prey, difficult to identify). The categories were adopted from Cavallini (1995). The mammalia were identified to genus and where possible to species level using hair cuticular scale patterns (Keogh, 1985). Insecta were identified to Order and the rest of the prey remains were identified to the above mentioned categories.

Each prey category identified was converted into relative volume between 0 and 100% by spreading prey remains evenly over a petri dish. A grid was placed underneath the petri dish and the number of squares (1cm) on a grid covered by the prey remain were counted and recorded (Jones, 1990).

The number of squares counted for an individual prey category in each scat was divided by the total number of squares for all the prey categories in that one scat and multiplied by 100 to obtain the percentage volume for a particular prey category in all the scats analysed (Jones, 1990). The percentage volume of similar prey was summed to obtain the percentage volume of prey category in the diet of the black mongoose.

3.4 Field collection of invertebrates.

Invertebrates were collected at Erongo and Hobatere using wet pitfall traps (Topping and Sunderland, 1992). Collection of invertebrates was done to ground-truth the type of species that occur in the area and also to help in the identification of invertebrate remains found in the scats. The study area was mapped as a circle and four stations chosen around the area. The fifth station was located in the middle of the mapped study area. The stations were selected in such a way that they were located in the surrounding of rock boulders where scats of black mongoose where found.

A 90 m transect with 9 pitfall traps was set at each station and each transect was set at spacing between 450 m to 600 m away from each other depending on the location of the next rock boulders where scats were found. Pitfall traps were set 10 m apart and were left for 24 hours before first inspection. Pitfall traps were inspected and reset once a day for three consecutive days.

Trapped invertebrates were preserved in 70% alcohol. Invertebrates were identified using the Picker *et al*. (2002); Skaife, (1979); Leeming (2003) and also using the preserved insect archive of the National Museum of Namibia. Other small invertebrates were identified with the help of the Curator of the National Museum of Namibia. Vertebrates such as lizards and toads that were trapped in the pitfall traps were identified and allowed back into the wild.

3.5 Techniques for studying the cuticular hair imprints of small mammals.

With ordinary microscopy, cuticular scales cannot be observed on the hair of small mammals (Keogh, 1985). However, by using imprints, the scale patterns are revealed and easily studied. Cuticular scales are made by placing the hair on gelatine, and later removing it, leaving the imprint of only that part of the hair which came into contact with the gelatine (Keogh, 1985).

3.5.1 Preparation of cuticular hair scale patterns

Cuticular hair scale patterns are a cast of markings left by a hair of small mammals when laid on a media such as gelatine solution. The cuticular hair scale patterns are unique to every species of small mammals and were therefore used to identify hairs of small mammals found in the scats of the black mongoose. Hairs of 16 rodent species from Namibia were collected from the specimens at Humboldt University Natural Museum, Berlin, Germany in January 2008. The rodent specimens used were collected between 2000 and 2003 and identified for the BIOTA project (P. Gierre, pers. comm. 2008).

Cuticular hair scale patterns were prepared using guard hairs taken from the back of a small mammal to ensure clear scale patterns which were used as a reference collection in this study. Cuticular hair scale patterns of hairs were also prepared in Windhoek, Namibia from the hairs of small mammals found in the scats of the black mongoose that were collected from Erongo and Hobatere. The cuticular hair scale patterns of small mammals from Berlin and those from scats collected at Hobatere and Erongo were prepared using the same method which as described below.

Hairs of small mammals were cleaned in absolute alcohol, washed in distilled water for approximately three minutes and dried between two white plain paper layers. Finely granulated gelatine was added to cold distilled water until the solution was saturated. Ten per cent by volume: of red dye (Eosin) was added and the container was heated in a water bath at boiling point.

Clean slides were thinly coated with this gelatine solution and the hair was laid in the film. Gelatine was allowed to harden for about 30 minutes and the hair was peeled off, leaving behind a cast of scales or imprints which were then ready for microscopic analysis. Three slides were prepared for each hair and the slide with the most visible imprints was used to identify small mammals to species or genus.

Magnified pictures of the species cuticular scale patterns were prepared using a Lattar 4.0 compound microscope (x 10) and cell imaging software for life science microscopy at the Leibniz-Institute for Zoo and Wildlife Research (IZW) in Berlin. Imprints prepared from the hairs of small mammals found in the scats were identified to their respective genus and species by using keys and magnified photographs of Keogh (1985) and also comparing with the reference hair imprints prepared at IZW, Berlin in January 2008.

Table 3.1: Species of small mammals from Namibia from which hair imprints were prepared from specimens of small mammal from the Humboldt University natural Museum.

Scientific names	**Common names**
Aethomys chrysophilus	Redveld rat
Aethomys namaquensis	Namaqua rock mouse
Crocidura hirta	Lesser red musk shrew
Desmodillus auricularis	Short-tailed gerbil
Elephantulus intufi	Bushveld elephant shrew
Gerbillurus paeba	Hairy-footed gerbil
Gerbillurus vallinus	Bush-tailed hairy-footed gerbil
Mastomys sp	Multimammate mouse
Mus indutus	Desert pygmy mouse
Mus minutoides	Pygmy mouse
Rhabdomys pumilio	Striped grass mouse
Saccostomus campestris	Pouched mouse
Steatomys pratensis	Fat mouse
Tatera brantsii	Highveld gerbil
Tatera leucogaster	Bushveld gerbil
Thallomys nigricauda	Black-tailed tree rat

3.6 Diet analysis

A statistical software package, Statistical Package for the Social Science 14.0 (SPSS) (Breuer, 2005) was used to analyse data of the diet of the black mongoose obtained from the two study areas. Dietary data recorded in the form of the recovered food remains was expressed in the following parameters (Breuer, 2005): percentage absolute occurrence was the number of scats (*n*) in which a prey category (*c*) occurred (*nc*) divided by the total number of scats examined multiplied by 100, and percentage relative frequency of occurrence was *nc* divided by $\sum nc$ for all prey categories x100.

Percentage occurrence was used to express the differences in the diet between the two study sites; Hobatere and Erongo using the Chi Square (Martin and Bateson, 1993). Data of invertebrates and vegetation at Erongo and Hobatere was grouped and illustrated using the Average Linkage Hierachical Cluster Analysis (HCA) (Krebs, 1989). The Jaccard Coefficient of Similarity (Krebs, 1989) was used to calculate the similarity of invertebrates and type of plants recorded at Erongo and Hobatere, respectively.

CHAPTER 4

RESULTS

4.1 Vegetation assessment

Ten species of plants in different life forms were recorded at Erongo and Hobatere, study sites. A list of these plant species is given in Table 4.1 and is arranged as plants at Hobatere, Erongo and those found at both sites.

Table 4.1: The vegetation assessment of the two study sites: Hobatere and Erongo. The green shaded boxes show plant species at Hobatere, the yellow boxes shows plants species at Erongo and the orange boxes indicate plant species found at both sites. The blank boxes indicate the absence of plant species from a study site.

Scientific name	Common name	Erongo		Hobatere	
		Life form	Abundance	Life form	Abundance
Boscia albitrunca	Shepherd's tree			shrub	2
Combretum imberbe	Leadwood			tree	2
Colophospermum mopane	Mopane			shrub tree	6 20
Acacia nebrownii	Water thorn	shrub tree	8 8		
Grewia flavescens	Rough-leaved raisin bush	shrub	3		
Dichrostachys cinerea	Sickle bush	shrub tree	14 8		
Grewia flava	Velvet raisin bush	shrub	3	shrub	6
Acacia erubescens	Yellow bark acacia	shrub tree	10 2	shrub	2
Terminalia prunioides	Purple-pod terminalia	shrub tree	2 4	tree	3
Combretum apiculatum	Kudu bush	shrub tree	13 1	shrub tree	15 6

Erongo and Hobatere study sites share four similar plant species, and each site has three different plant species (Figure 4.1). Data on the composition of plant species were grouped into three clusters and is showing the similarity of plant species in physical space (Figure 4.1). At about 50% similarity, plant species were divided into two main clusters revealing the homogeneity between plant species recorded at either Hobatere and or Erongo. At 65%, three clusters were formed, differentiating plant species into three clusters (Figure 4.1).

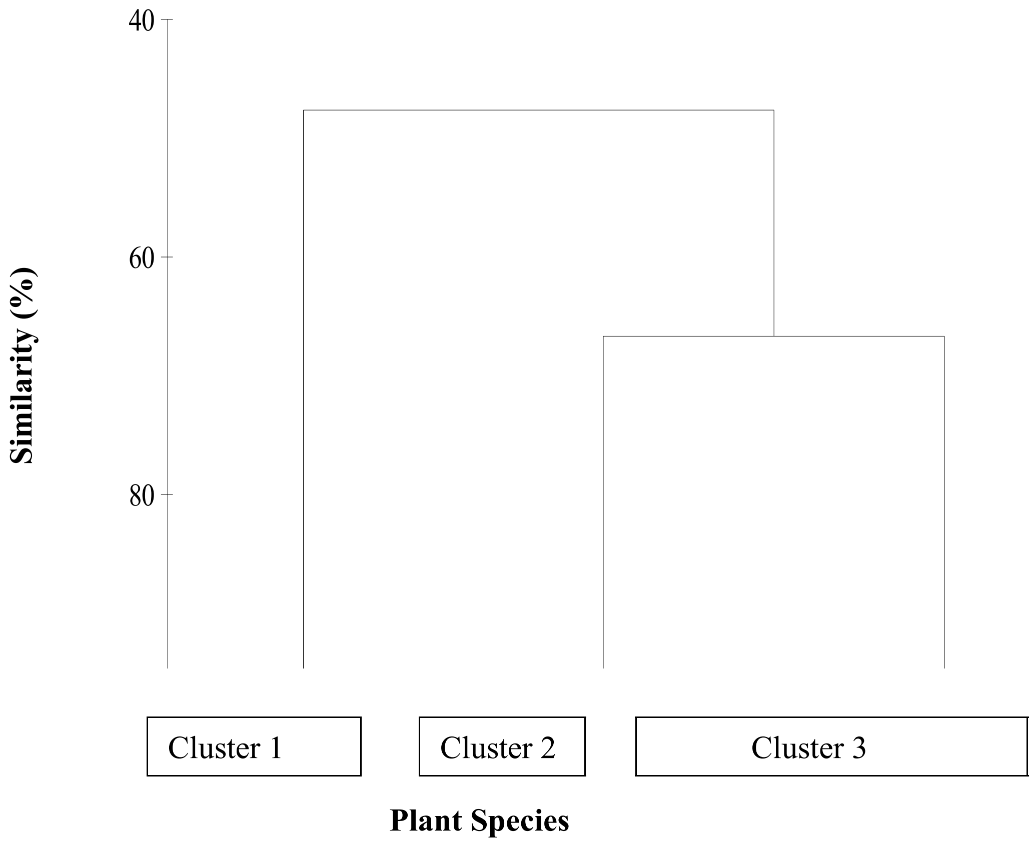


Figure 4.1: A dendrogram adopted from the Average Linkage Hierarchical Cluster Analysis (Krebs, 1989) showing the classification of plant species recorded in a nested plot at Erongo and Hobatere in 2008, with regard to percentage similarity. The total number of plants recorded was 134; Hobatere = 68 and Erongo = 66. The letters on the dedrogram represent the first letter of the genus and species name of the plant species as indicated in Table 4.1. The two *Grawia* species, GFL: *G. flavescens*.

Cluster 1 represents the three plant species (*Boscia albitrunca, Combretum imberbe,* and *Colophospermum mopane*) found only at Hobatere. Hobatere was more open and less vegetated than Erongo. *Colophospermum mopane* and *Combretum apiculatum* were the most dominant plant species at Hobatere (Figure 4.1). The average grass cover at Hobatere was 75% and comprised of gravel loam soil which is good for the growth of grasses. Cluster 2 represents two plant species (*Acacia nebrownii* and *Grawia flavescens*) found only at Erongo. Erongo had an average grass cover of 65% and it has a gravel sandy soil where *Dichrostachys cinerea* and *Combretum apiculatum* predominate.

Cluster 3 contains most of the recorded plant species and represents plant species that were common to both study sites. Plant species found at both Erongo and Hobatere, were *Grawia flava, Acacia erubescens, Terminalia prunioides, Dichrostachys cinerea* and *Combretum apiculatum* (Figure 4.1). Overall, there was a low similarity between plant species found at Erongo and Hobatere (Jaccard Coefficient similarity $S_j = 0.4$).

4.2 The diet of the black mongoose determined from faecal analysis

The results of the faecal analysis are illustrated in two ways. Prey occurring in the diet was presented according to how often they were found in the total number of scats analysed. The occurrence data is presented as percentage occurrence in Table 4.2. The contribution of the prey found in the scats is presented as percentage volume. The two parameters; percentage occurrence and percentage volume are incorporated to illustrate the diet of black mongoose. Seventy one scats (faeces) were collected from Hobatere and 76 scats were collected from Erongo.

Scats were mainly found on isolated boulders, often under or beside the rock boulder, which were least surrounded by vegetation. Scats of the black mongoose and their urine have a distinct musty odour that perhaps allows them to locate their territory. The musty odour can be smelled at about two to three meters from the latrine site. Scats were occasionally found at the same location three to four days after previous collection. In Hobatere, for example, where scats were difficult to find, known latrine sites were repeatedly checked after a number of days and scats and urine marks were found on the rocks after three to four days.

4.2.1 Percentage occurrence of different prey in the diet of the black mongoose

The diet of black mongoose at Erongo and Hobatere are represented in Table 4.2. The main prey occurring in the diet of the black mongoose was Arthropoda, Vertebrata and Plantae. From scat analysis, it was evident that the diet of the black mongoose at Hobatere and Erongo varied, but was dominated by insects (Hobatere: 91.5%; Erongo 78.9%) and small mammals (15.5%; 32.9%) (Table 4.2). Other main prey at were arachnida (32.4%; 15.8%) and fruits (14.1%; 18.4%).

A chi-square test revealed that there was a highly statistically significant difference between the percentage occurrence of prey categories occurring in the scats of black mongoose at Hobatere and Erongo ($\chi_9^2 = 323.00$, $P < 0.05$, $n = 10$). Hobatere had an overall higher percentage occurrence of prey categories with the main prey categories summing up to about 188.7% occurrence and 170.9% occurrence at Erongo (Table 4.2).

Amongst the Order of insects in the diet of the black mongoose, Coleoptera was the most abundant prey at Hobatere occuring in 59.2% of the scats of the black mongoose, followed by Lepidoptera (50.7%), and Orthoptera (39.4%) (Table 4.2). On the other hand, Orthoptera (46.1%), Coleoptera (27.6%), and Lepidoptera (25%) were the most frequent insect prey at Erongo (Table 4.2).

Table 4.2: The dietary composition of black mongoose (*Galerella nigrata*) at Erongo(central) and Hobatere (north west Namibia) as determined by faecal analysis. A total of 147 scats were collected: Hobatere = 71 and Erongo = 78. Data represent the number of scats in which a food category occured (nc), the percentage absolute occurence (% Occ.)* and percentage relative frequency of occurence (%Freq)* of prey items. Data in the columns may exceed 100% because more than one prey item may be present in each of the analysed scat. Prey category ‘‘other’’ represents prey that were fully digested and could not be identified to any taxon.

	Hobatere			Erongo		
Food item	**(nc)**	**%Occ.**	**%Freq**	**(nc)**	**%Occ.**	**%Freq.**
Arthropoda	93	130.9	56.3	72	94.7	44.2
Insecta	65	91.5	39.4	60	78.9	36.8
Orthoptera	28	39.4	17.0	35	46.1	21.5
Coleoptera	42	59.2	25.5	21	27.6	12.9
Lepidoptera	36	50.7	21.8	19	25.0	11.7
Isoptera	2	2.8	1.2	1	1.3	0.6
Hymenoptera	30	42.3	18.2	11	14.5	6.7
Diptera	0	0.0	0.0	4	5.3	2.5
Hemiptera	4	5.6	2.4	1	1.3	0.6
Odonata	2	2.8	1.2	0	0.0	0.0
Mecoptera	1	1.4	0.6	0	0.0	0.0
Diplopoda	1	1.4	0.6	0	0.0	0.0
Arachnida	23	32.4	13.9	12	15.8	7.4
Acarina	4	5.6	2.4	0	0.0	0.0
Vertebrata	25	35.2	15.2	42	55.2	25.7
Mammalia	11	15.5	6.7	25	32.9	15.3
Mastomys sp	2	2.8	0.8	0	0.0	0.0
Aethomys Sp.	4	5.6	1.6	2	2.0	0.9
Dendromus melanotis	2	2.8	0.8	2	2.0	0.9
Desmodillus auricularis	1	1.4	0.4	0	0.0	0.0
Gerbillurus paeba	2	2.8	0.8	6	7.9	3.7
Gerbillurus vallinus	0	0.0	0.0	2	2.6	1.2
Tatera leucogaster	0	0.0	0.0	3	3.9	1.8
Otomys sp.	1	1.4	0.4	1	1.3	0.6
Mystromys sp.	0	0.0	0.0	2	2.6	1.2
Thallomys sp.	0	0.0	0.0	1	1.3	0.6
Crocidura hirta	0	0.0	0.0	1	1.3	0.6
Reptilia	10	14.1	6.1	9	11.8	5.5
Aves	4	5.6	2.4	8	10.5	4.9
Plantae	16	22.6	9.7	16	21	9.8
Fruits	10	14.1	6.1	14	18.4	8.6
Twigs &leaves	6	8.5	3.6	2	2.6	1.2
Other	32	45.1	19.4	27	35.5	16.6

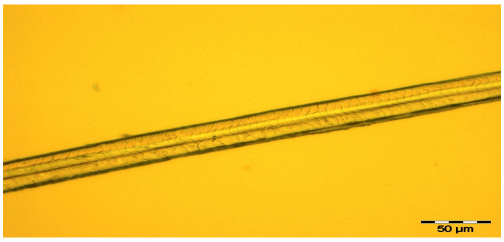
* % Occ. = *nc* / *n* x 100 and % Freq. = *nc* / ∑*nc* for all prey categories x100.

Hymenoptera also formed part of the diet of the black mongoose and recorded 42.3% and 14.5% at Hobatere and Erongo, respectively (Table 4.2). Isoptera was the least frequent Order in the diet of the black mongoose. It occurred in the scats from both study sites, contributing 2.8% and 1.3% of the insects occurring at Hobatere and Erongo (Table 4.2).

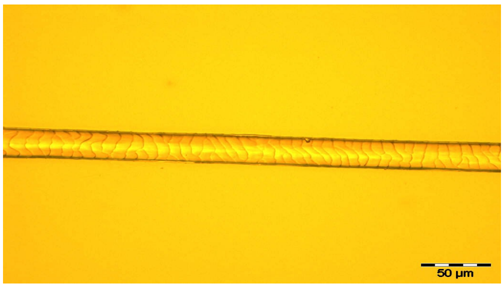
Vertebrates made up 35.2% and 55.2% of the diet of the black mongoose at Erongo and Hobatere, respectively (Table 4.2). The most frequent vertebrate remains in the diet of the balck mongoosewere from small mammals and were represented by 11 species, of which five occurred at Erongo and six at Hobatere. Four small mammal species were represented at both study sites in the scats of the black mongoose (Table 4.2).

Species found at both sites included *Aethomys sp*, *Dendromus melanotis, Gerbillurus paeba* and *Otomys sp.* Of the five species of small mammals utilized as prey at Erongo, *Gerbillurus paeba* dominated the diet (7.9%) followed by *Tatera leucogaster* (3.9%), *Gerbillurus vallinus* (2.6%) and *Mystromys sp* (2.6%) (Table 4.2.1). The remaining four small mammalian species contributed less than 2% of occurrence (Table 4.2). Some of the imprints of the small mammals found in the diet of the black mongoose are shown below (Figure 4.2.1).

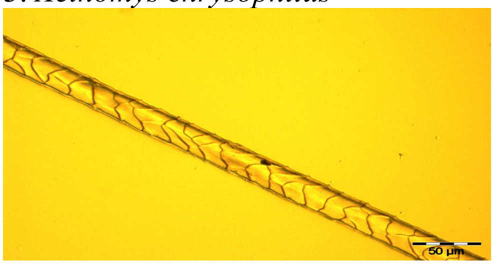
1. *Crocidura hirta*



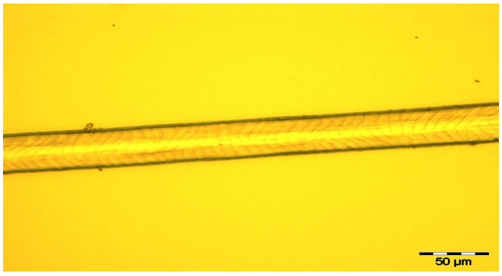
2. *Desmodillus auricularis*



3. *Aethomys chrysophilus*



4. *Gerbillurus vallinus*



5. *Gerbillurus paeba*

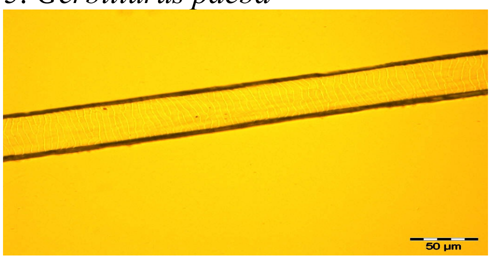


Figure 4.2.1: Illustrations of some of the hair imprints of some small mammals found in the diet of the black mongoose (with the name of the species on the top left).

At Hobatere, *Aethomys sp* had the highest percentage occurrence (5.6%), followed by *Gerbillurus paeba* (2.8%) and *Mastomys sp* (2.8%) (Table 4.2). A chi square test revealed that there was a statistically significant difference between the percentage occurrence of small mammal species occurring in the diet of the black mongoose at Hobatere and Erongo: χ_{10}^2 Value = 31.00, $P < 0.05$, $n = 11$. Arachnida (scorpions, spiders and solifugae) had an occurrence of 32.4% at Hobatere and 15.8% at Erongo.

In addition, Aves (birds) and Reptilia (reptiles) were also present in the diet of the black mongoose at both study sites (Table 4.2). Ground-nesting birds bred during March 2008 and newly hatched birds in nests were seen around the study area especially in Hobatere.

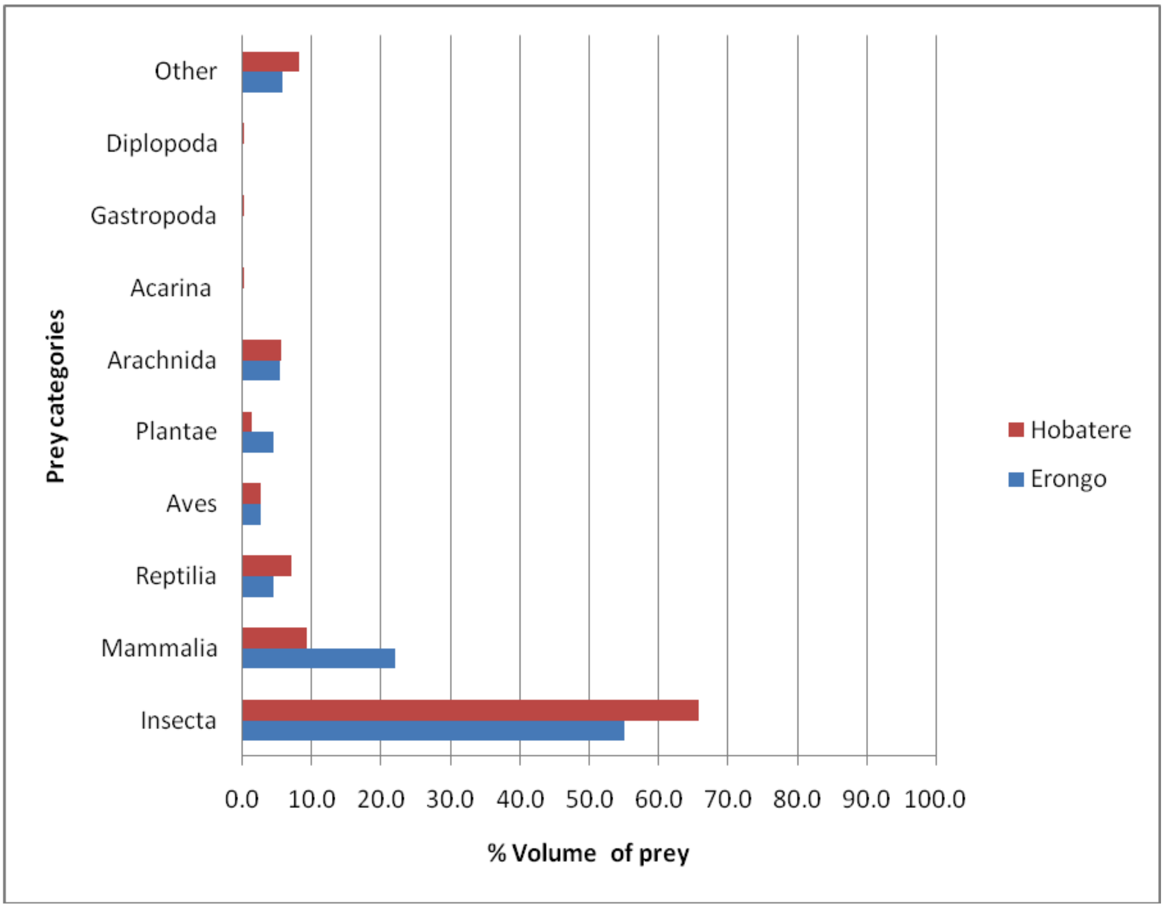
Bird remains from scats collected at Hobatere were represented by bones and skulls but not feathers, showing that the black mongoose likely fed on newly hatched birds. Feathers of bush-prefering birds such as sparrows were found in the scats collected from Erongo. One scat collected from Erongo contained the remains of eggs. It was difficult to identify whether the egg remains belonged to birds or reptiles. These remains were however, categorised as Aves because only birds remains were found in that scat.

Plantae (fruits, twigs and leaves) had a percentage occurrence of 22.6 % at Hobatere and 21% at Erongo (Table 4.2). Fruits (14.1% at Hobatere and 18.4% at Erongo) constituted seeds of raisin bush berries (*Grawia* species) and seeds of *Eragrostis* species. Twigs and leaves (8.5% at Hobatere and 2.6% at Erongo) comprised of pieces of *Eragrostis* species and leaves of *Acacia* species.

Other prey present in the diet of the black mongoose included Diplopoda (millipedes and centipedes) and Gastropoda (winkles). Each prey type occured in one scat and had an occurence of 1.4% (Table 4.2). Acarina (ticks) were also present in the diet and occured in four scats with a percentage occurrence of 5.6% (Table 4.2). These three types of prey (Diplopoda, Gastropoda and Acarina) were the least abundant in the scats and only occured at Hobatere.

4.2.2 Percentage volume of different prey in the diet of the black mongoose

Figure 4.2.2 show the percentage volumes of the prey categories found in the scats of the black mongoose at Erongo and Hobatere study sites.



	Insecta	Mammalia	Reptilia	Aves	Fruits	Arachnida	Acarina	Gastropoda	Diplopoda	Other
Erongo	3924.6	1572.2	321.6	192.8	317.7	378.4	0	0	0	410.7
Hobatere	4304.7	605.5	464	177	89.7	363.3	12	3	1	530.9

Figure 4.2.2: The percentage volume of the main prey categories identified from 76 and 71 scats analysed from Erongo and Hobatere, respectively. The insert shows the calculated percentage (%) volume of each prey category.

Insecta contributed the highest percentage volume at (Hobatere: 65.7% and Erongo: 55.1%) followed by small mammals (Hobatere: 9.2% and Erongo: 22.1%) and reptiles (Hobatere: 7.1% and Erongo: 4.5%) (Figure 4.2.2). Birds contributed 2.7% by volume to the diet of the black mongoose at both Erongo and Hobatere (Figure 4.2.2).

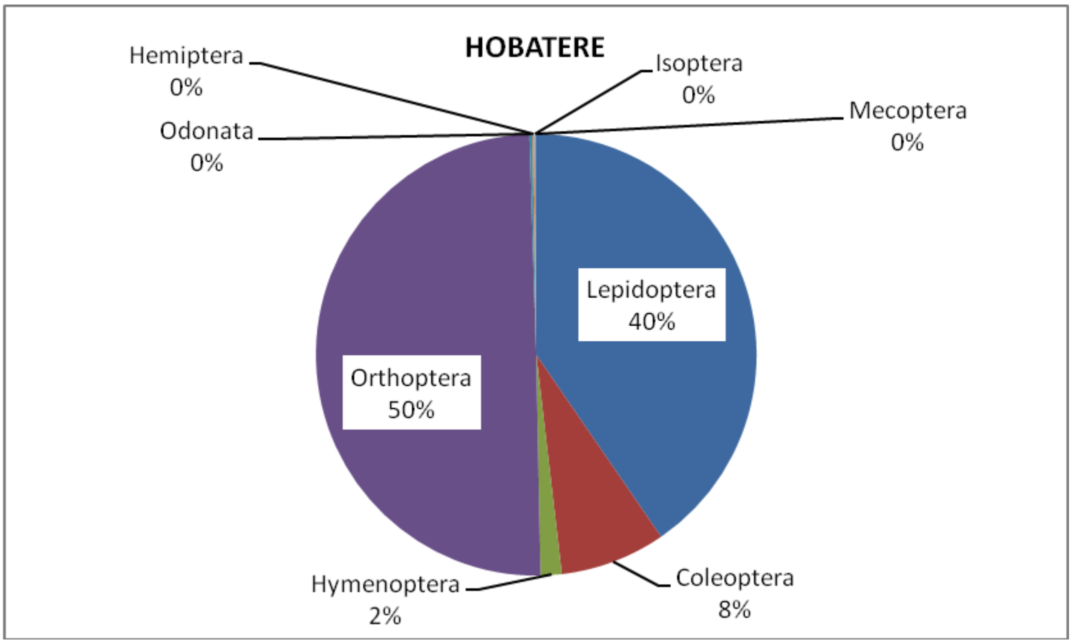
Arachnida (scorpions, spiders and solifugae) appered in equal almost volume contributing 5.3% and 5.5% by volume to the diet of the black mongoose at Erongo and Hobatere, respectively (Figure 4.2.2). Plantae contributed 4.5% by volume at Erongo which was about three times higher than its contribution at Hobatere (1.4%) (Figure 4.2.2).

The percentage volume of reptile remains in the diet of the black mongoose was higher at Hobatere (7.1%) than at Erongo (4.5%) (Figure 4.2.2). Acarina contributed the least percentage volume (0.2%) at Hobatere (Figure 4.2.2). No amphibian remains were found in the scats of the black mongoose at both study sites, although 93 toads (*Bufo sp*) were caught in pitfall traps at Hobatere.

4.3 Composition and diversity of invertebrates at Erongo and Hobatere determined from faecal analysis

Amongst the invertebrate Orders in the diet of the black mongoose, Orthoptera was the most preyed insect Order with percentage volume of 50% at Hobatere and 84% at Erongo (Figure 4.3). Although it only appeared in 3% of the trapped invertebrates at Hobatere, Orthoptera (armoured crickets and grasshoppers) appeared in the diet of the black mongoose throughout the study and was utilised more in June at Erongo when almost all other insect Orders decreased (Figure 4.3).

Lepidoptera (worms) was the second-most prevalent invertebrate in the diet at Erongo, making up 9% of the invertebrates in the diet of the black mongoose (Figure 4.3). Most remains of Lepidoptera at Erongo appeared as rough brown matter (pupae segments) that possibly belonged to caterpillars and worms that already developed into pupae during scat collection at Erongo in June. At Hobatere, Lepidoptera made up 40% of the invertebrates in the diet of black mongoose and was dominated by mopane worms (*Gonimbrasia belina*).


HOBATERE
Hemiptera
0%
Isoptera
0%
Mecoptera
0%
Odonata
0%
Lepidoptera
40%
Orthoptera
50%
Hymenoptera
2%
Coleoptera
8%

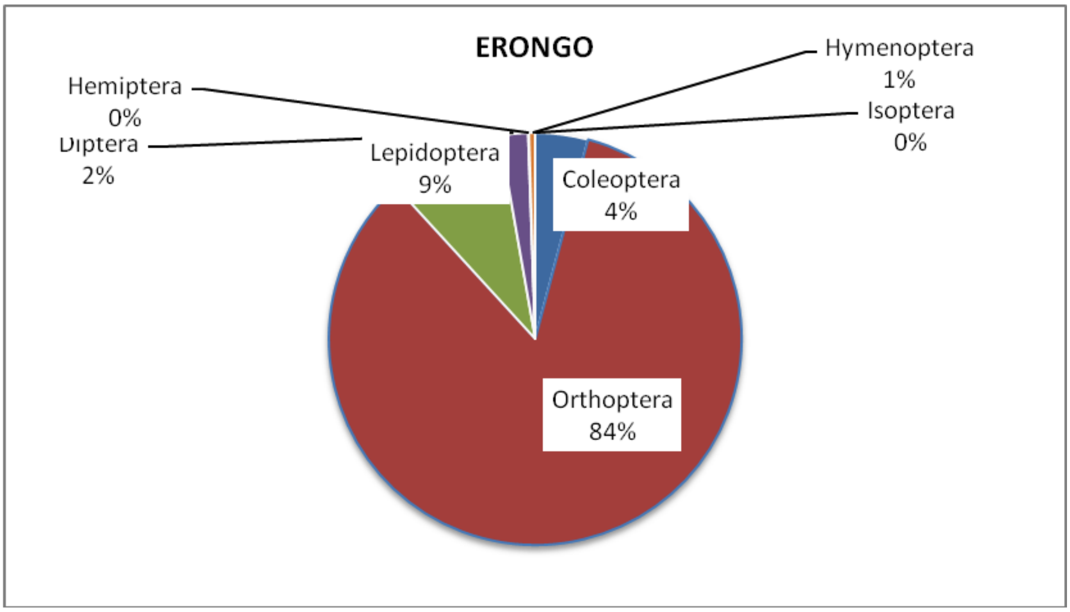

ERONGO
Hymenoptera
1%
Hemiptera
0%
Isoptera
0%
Diptera
2%
Lepidoptera
9%
Coleoptera
4%
Orthoptera
84%

Figure 4.3: Proportional percentage of Orders of the Class Insecta found in the diet of the black mongoose at Hobatere and Erongo in 2008 as determined from faecal analysis.

Coleoptera (beetles) was the most occuring insect Order in the diet of black mongoose at both study sites. It occured in 59.2% and 27.6% of the scats analysed from Hobatere and Erongo, respectively (Table 4.2). However, due to the smaller size of beetles, Coleoptera contributed only 4% and 8% by volume to the diet of the black mongoose at Erongo and Hobatere, respectively (Figure 4.3).

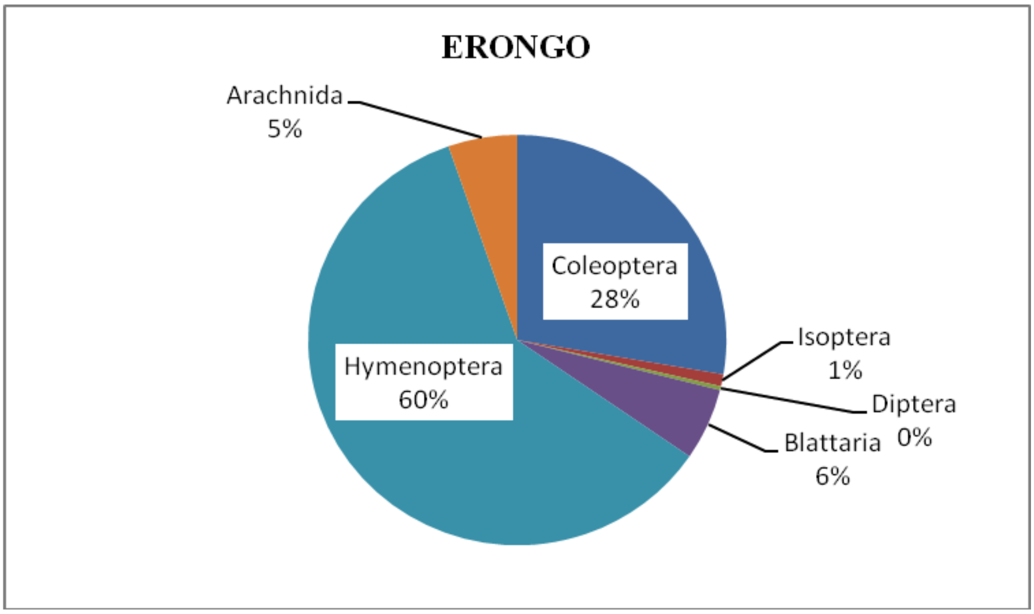
Hymenoptera (ants) were also represented in the diet of the black mongoose (Figure 4.3). Most ants found in the scats were not digested. Other insect Orders such as Isoptera (termites) and Hemiptera (unidentified small bugs) were also present in the diet of the black mongoose and also appeared whole. Hymenoptera, Hemiptera and Isoptera were small and only covered a few squares on a grid which was used to calculate the percentage volume. Therefore, they contributed the least volume to the diet of the black mongoose at both study sites. Hymenoptera contributed 1% by volume at Erongo and 2% at Hobatere, while Isoptera and Hemiptera were recorded in a very small number (Figure 4.3).

Among other food items of lesser occurence, Odonata (dragon flies) and Mecoptera (Caddies flies) were identified only in scats from Hobatere. They occured in very small numbers and contributed adiminutive percent to the percentage volume of the diet of the black mongoose (Figure 4.3). A Chi- Square test revealed that there was a statistically significant difference in the proportion of Orders of insects occurring in the diet of the black mongoose at Hobatere and Erongo: $\chi_8^2 = 183.72$; $P < 0.05$; $n = 9$.

4.4 Composition and diversity of invertebrates determined from wet pitfall traps at Erongo and Hobatere

Wet pitfall traps showed that Hymenopterans (ants and wasps) were the most-trapped invertebrates and contributed the largest percentage at Erongo (60%) and Hobatere (35%), respectively (Figure 4.4). Coleoptera (beetles and weevils) was represented by the Families Scarabaeidae (dung beetles - *Gymnoplerus sp*), Carabidae (ground beetles - *thermophilum sp*), Curculionidae (weevils), and Tenebrionidae (tok tokkie beetles - *Renatiella sp*).

Coleoptera were the second-most commonly trapped invertebrates and constituted 28% of the insect Orders caught in the pitfall traps at Erongo and 26% at Hobatere (Figure 4.4). At Erongo, Coleoptera was represented by Histeridae (S*tenocara sp*) and was dominated by Tenebrionidae (*Zophosis sp*) while at Hobatere the trapped invertebrates were dominated by Tenebrionidae (*Stenocara sp*) (Figure 4.4).


ERONGO
Arachnida
5%
Coleoptera
28%
Isoptera
1%
Diptera
0%
Blattaria
6%
Hymenoptera
60%

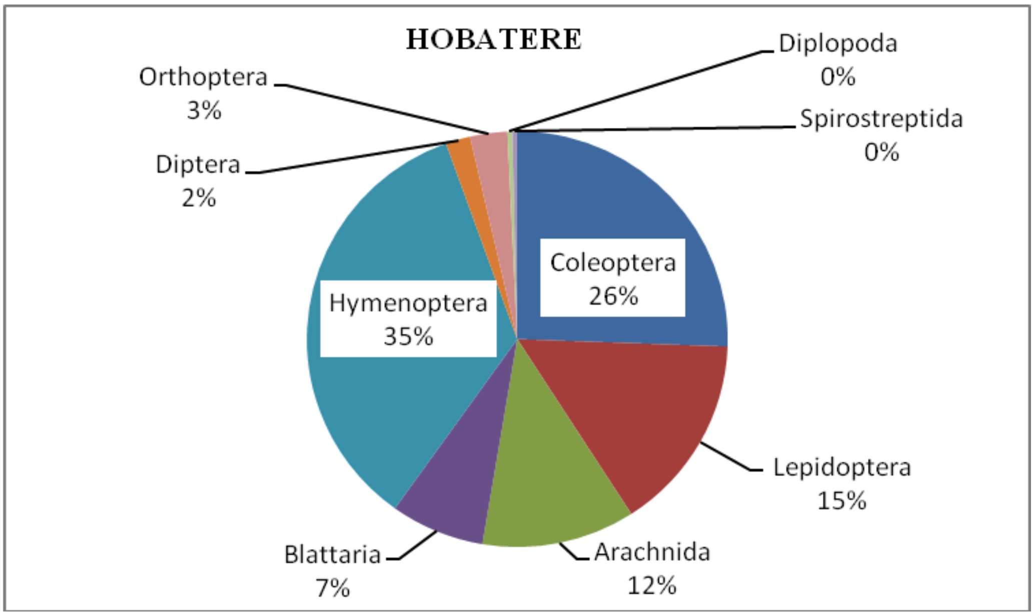

HOBATERE
Diplopoda
0%
Orthoptera
3%
Spirostreptida
0%
Diptera
2%
Coleoptera
26%
Hymenoptera
35%
Lepidoptera
15%
Blattaria
7%
Arachnida
12%

Figure 4.4: Proportional percentage of Orders of Insecta collected from pitfall traps set at Hobatere and Erongo in 2008. The total number of invertebrates collected was 318 at Erongo and 530 at Hobatere.

Blattaria was represented by cockroaches mainly the Blaberidae (*Aptera sp*) at both study sites. Blattaria was the third-most trapped species at Erongo making up 6% of the trapped invertebrates (Figure 4.4). It was however, the third-least trapped insect species at Hobatere contributing only 7%.

Diptera was represented by Family Muscidae (*Musca sp)* and Isoptera was represented by Hodotermitidae (*Hodotermes sp*). Diptera and Isoptera were the least trapped invertebrates at the two study sites. Diptera was represented by 2% of insect at Hobatere while Isoptera contributed 1% at Erongo (Figure 4.4). Arachnida was represented Heteropodidae (solifugae) at both study sites and by Lycosidae (spiders), Buthidae (*Parabunthus brelimanus*) and Scorpionidae (*Opistophthalmus wahlbergi*) at Hobatere (Table 4.4). The percentage of Arachnida caught in pitfall traps was therefore higher at Hobatere (12%) than at Erongo (5%) (Figure 4.4). Two centipede (*Scolopendra morsitans*) and one millipede species (*Archispirostrepus gigas*) were trapped only at Hobatere.

Orthoptera (grasshoppers and crickets) and Lepidoptera (moths and butterflies) were trapped at Hobatere. Orthoptera (4%) was represented by Gryllotalpidae (mole crickets and grasshopper), while Lepidoptera (14%) was the third-highest trapped invertebrates, and was dominated by Nymphalidae (mopane worms and butterflies) (Figure 4.4).

Invertebrates that were collected from pitfall traps were grouped according to the study site where they were found. Figure 4.5 below shows an Average Linkage Hierarchical Cluster Analysis dedrogram of invertebrates collected from pitfall traps at Erongo and Hobatere.

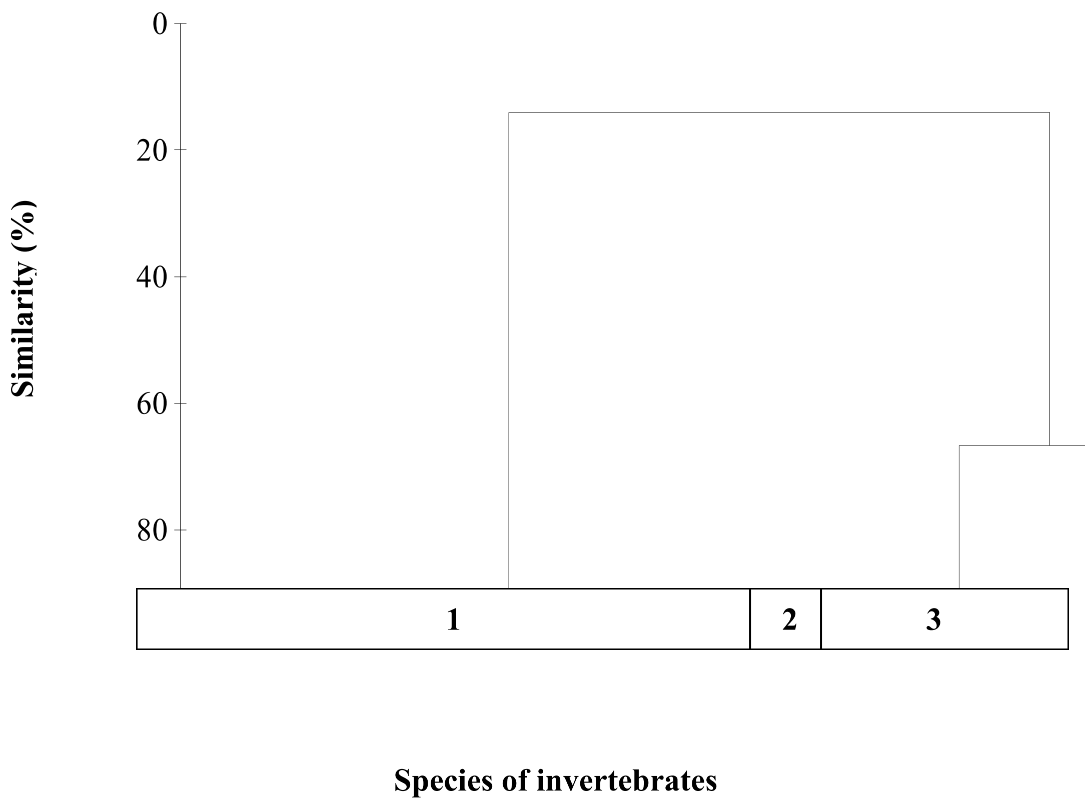


Figure 4.5:The Average Linkage Hierachical Cluster Analysis(ALHCA) dedrogram showing the composition of invertebrates collected from pitfall traps in Erongo (409) and Hobatere (527) in 2008. The clusters are indicated by numbers 1, 2 and 3and were generated using presence and absence data of invertebrates at Hobatere and Erongo. The letter code on the X-axis of the dedrogram represents the scientific names of the invertebrates trapped at Hobatere and Erongo in 2008 (Figure 4.5).The full names of the invertebrates are shown in Appendix 5 and 6.

There was a slight similarity in the invertebrates species trapped at Hobatere and Erongo (Figure 4.5). This can be observed at ~15% similarity- only two clusters were formed indicating invertebrates species that were trapped at either Erongo or Hobatere. There are three clusters at 70% similarity. Cluster 1 represents invertebrates which were trapped at Hobatere only (Figure 4.5). Cluster 2 represents invertebrates which were trapped at both sites. The species include *Mylabris sp* (Coleoptera), *Stenocara sp* (Coleoptera), *Aptera sp*. (Blattaria) and ants (Formicidae *sp* (Hymenoptera). Cluster 3 represents the invertebrates from Erongo.

Amongst the invertebrates trapped at the two sites, Lepidoptera (40%), Orthoptera (50%), Coleoptera (8%) and Hymenoptera (2%) were represented in the diet of the black mongoose at Hobatere whereas Orthoptera (84%), Lepidoptera (9%), Coleoptera (4%), Diptera (2%) and Hymenoptera (1%) were represented in the diet at Erongo (Figure 4.3).

The Jaccard coefficient of similarity (S_j) revealed that there was a low similarity between the Orders of invertebrates that were trapped in wet pitfall traps and those that occurred in the diet of the black mongoose at the two study sites (Erongo: S_j = 0.44; Hobatere: S_j = 0.30).

A number of vertebrates were also recovered in the pitfall traps at Hobatere. Two species of lizards*, Mabuya capensis and Cordylus cordylus* and 93 *Bufo* species were the second commonly trapped species at Hobatere.

CHAPTER 5

DISCUSSION

Knowledge of the diet of any species is fundamental to understanding its biology and role in the ecosystem (Woolnough and Carthew, 1996). The diet of carnivores are characterized by a high content of water, protein, vitamins, minerals, a variable fat content, and a low level of carbohydrates (Jones *et al*., 2003). The present study investigated the dietary composition of the black mongoose with particular attention given to the type of prey that occurred in the diet of this species at the two study sites, Erongo and Hobatere. The study also determined the most prevalent prey item in the diet of the black mongoose.

5.1. The diet of the black mongoose

The present study revealed that the diet of the black mongoose (*Galerella nigrata*) comprised mainly of insects and small vertebrates such as small mammals, reptiles and birds at Erongo and Hobatere (Table 4.2). The percentage occurrence of prey categories presented in the scats at the two study sites was significantly different ($\chi_9^2 = 323.00$, $P < 0.05$, $n = 10$). Hence, the diet of the black mongoose at Hobatere differed markedly from that at Erongo. A low similarity was detected between the plant composition at Erongo and Hobatere, $S_j = 0.4$).
The low similarity in the plant composition may suggest the dissimilarity in the types of invertebrate and vertebrate present in an area and in turn it has an effect on food availability and abundance of prey at Hobatere and Erongo. Therefore, contributing to the variation in the diet composition of the black mongoose at the two study sites.
The fact that scats at Hobatere were collected in March and at in June Erongo possibly also contributed to the difference in the diet of the black mongoose.

Insects from different Orders were the principal food items in the diet of the black mongoose and had by far the highest percentage occurrence of 91.5% at Hobatere and 78.9% at Erongo (Table 4.2). It is possible that the percentage occurrence of insects at Erongo was low because the scats were collected in June when insect diversity is at its lowest.

The black mongoose is diurnal and forage for insects which are a plentiful food source in the southern climes they inhabit (Cowley and Cunnigham, 2003). The fact that insects can be found in large numbers even in small microhabitats such as dug piles or an ant nest and are easy to catch was possibly the reason why they were dominant in the diet of the black mongoose (Dennis and Macdonald, 1999). While they were the dominant prey at both study sites, insects were not represented in the same volume.

A highly statistically significant difference was detected between the occurrence of invertebrates in the diet of the black mongoose at Hobatere and Erongo: χ_8^2 = 183.72; P <0.05; n = 9, (Figure 4.3). Amongst the Orders of insects that were present, Coleoptera, Lepidoptera, Hymenoptera, and Orthoptera were the most prevalent Orders in the diet of the black mongoose at Hobatere. However, Orthoptera, Coleoptera, Lepidoptera, and Hymenoptera were the most prevalent Orders in the diet of the black mongoose at Erongo. Coleoptera was represented with a percentage occurrence of 59.2% and 27.6% at Hobatere and Erongo, respectively, while Orthoptera had an occurrence of 39.4% and 46.1% at Hobatere and Erongo, respectively (Table 4.2).

Although, Coleoptera were present with the highest percentage of the analyzed scats than Orthoptera, they contributed less to the percentage volume because of their small size. Prey of smaller size such as beetles are easily digested and only smaller pieces were found in the scats. This make up a small percentage volume of 8% at Hobatere and 4% at Erongo. Armoured corn crickets (Orthoptera) due to their large size contributed a large proportion to the diet of the black mongoose. Hence, Orthoptera was the most prevalent invertebrate and prey in the diet of the black mongoose at both Erongo and Hobatere on the basis of volume. Although, Orthoptera were not trapped in pitfall traps large numbers of armoured corn crickets were observed during scat collection at both study sites. This contributed to the high occurrence in the diet of the black mongoose.

Similar to other mongooses, the black mongoose has a preference for Coleoptera and Orthoptera. Previous studies, based on stomach content reported that insects were also the main prey in the diet of mongooses such as the selous mongoose, the banded mongoose, the slender mongoose, the small grey mongoose (Smithers, 1983), and the yellow mongoose (Avenant and Nel, 1992). The study revealed that Coleoptera and Orthoptera were the second and third-most prevalent insect Orders after Isoptera in the diet of the yellow mongoose with a percentage occurrence of 26% and 14%, respectively (Table 4.2) (Avenant and Nel, 1992).

In the present study, Isoptera was the least presented prey in the diet of the black mongoose with a percentage occurrence of 2.8% at Hobatere and 1.3% at Erongo (Table 4.2). Isoptera was represented by harvester termites (*Hodotermes sp*) which were busy on the dry grass and woods in the study area. Harvester termites are usually at diversity peak during winter and this may have contributed to the occurrence of termites in the diet of the black mongoose at Erongo. Isoptera, particularly, *Hodotermes sp* has also been reported to occur frequently in the diet of a bat-eared fox (*Otocyon megalotis*) (Stuart *et. al*., 2003)

The high occurrence of Lepidoptera in the diet of the black mongoose at Hobatere was due to a high number of mopane worms in the area. Mopane trees and shrubs were the most dominant vegetation at Hobatere. The mopanes provided food and shelter for mopane worms, making these worms to be the most-trapped invertebrates at Hobatere.

Due to its dominance, mopane worms were the second-most prevalent prey in the diet of the black mongoose at Hobatere and contributed the second-largest percentage of 40% by volume. At Erongo, the black mongoose also fed on Lepidoptera. Lepidoptera occurred in small numbers in the diet of the black mongoose and none were trapped or observed at Erongo. During the study period at Erongo, most worms such as mopane worms had already metamorphosed into pupae which are not easily found by the black mongoose for consumption. Hymenoptera (ants) were the most-trapped invertebrates at Erongo (60%) and Hobatere (35%) (Figure 4.4). Although it was dominant in the pitfall traps, the Hymenoptera contributed the least to the percentage volume of the diet of black mongoose because their small size.

The low similarity detected between data of invertebrates found in the scats and those recovered from pitfall-trapping reveal that, the black mongoose forages far away from where they drops its scats. Since trapping was only undertaken at areas closer to rocks where scats were found, invertebrates eaten from other areas were poorly represented in the pitfall traps. The low similarity may imply that the black mongoose is selective, hence prefer certain prey and roam large areas in search of such.

Small mammals, reptiles, and birds were the vertebrates in the diet of the black mongoose (Figure 4.2.2). Small mammals were the secondary food resource for the black mongoose with 22.1% and 9.2% by volume at Erongo and Hobatere, respectively (Figure 4.2.2). According to Griffin (1998), high rainfall in 1970 influenced species such as *Tatera leucogaster* to invade the central Namib for distances of up to 50 km from the base of the escarpment. The bushveld gerbil however, moved back after periods of poor rainfall years.

The high rainfall experienced at Erongo and Hobatere in 2007 and 2008 (S.Tromp and P.Tylvas, pers. Comm.) possibly increased the population of several small mammals in the two study sites. The high rainfall also contributes to the growth of grass and increases the food sources as well as shelter for small mammals. This study therefore needs to be repeated in years with different amounts of rainfall in order to assess the effect of rainfall on the diet of the black mongoose.

The widely distributed hairy-footed gerbil (*Gerbillurus paeba*) (Perrin and Boyer, 2000) was the most abundant small mammal species in the diet of the black mongoose at Erongo with a 7.9% occurrence and was second abundant at Hobatere with a 2.8% occurrence (Table 4.2). The hairy-footed gerbil is associated with arid climates of the south western Africa and is assumed to favour open edge microhabitats for foraging, hence making it easy for the black mongoose to catch them (Perrin and Boyer, 2000).

Aethomys sp was the most commonly eaten small mammal species at Hobatere with an occurrence of 5.6% (Table 4.2). *Aethomys sp* is widely distributed throughout Namibia and favours rocky koppies and outcrops (Smithers, 1983). This may have contributed to its availability at Erongo and Hobatere. Both *Gerbillurus paeba* and *Aethomys sp* are nocturnal (Smithers, 1983). Another nocturnal species represented in the diet of the black mongoose was the grey climbing mouse (*Dedromus melanotis*). The grey climbing mouse was the most occurring small mammal species at Hobatere (Table 4.2).

This species makes their nests between grass stems where the black mongoose can easily search for them (Smithers, 1983). The results of the present study show that the black mongoose, a diurnal predator, fed on nocturnal small mammal species. According to Rood and Wozencraft (1984), the slender mongoose, a close relative of the black mongoose forages until sunset (18h00). The black mongooses may have the same habit of foraging until dusk as the slender mongoose, hence had an opportunity to capture nocturnal small mammals.

In addition, small mammals could return to nests later at dusk hence can be captured by the diurnal foraging black mongoose. The contribution of small mammals to the diet of the black mongoose may also reflect the ability of the black mongoose to catch them. Others studies have also indicated the occurrence of small mammals in the diet of other mongoose species such as the slender mongoose (Taylor, 1975), the cape grey mongoose (Cavallini, 1992), and the small Indian mongoose (Cavallini and Serafini, 1995).

According to Begon *et al.* (1996), carnivores tend to feed on prey items that require fairly short handling times than prey that require long handling and search times in order to acquire a diet with high average energy profitability. Like other carnivores, perhaps the black mongoose fed on few small mammal species to avoid long search times required to catch small mammals as opposed to other prey such as insects.

It is also possible that there were few small mammals at the two study sites, therefore decreasing the chances of the black mongoose to find and catch them.

Reptiles ranked second among other vertebrates after small mammals in the diet of the black mongoose (Table 4.2). It occurred at a prevalence of 14.1% at Hobatere and 11.8% at Erongo (Table 4.2). Reptiles contributed a percentage volume of 7.1% at Hobatere and 4.5% at Erongo (Figure 4.2.2). The occurrence of reptiles in the diet of the black mongoose corresponds with results of the sample of stomach contents of the yellow mongoose and the selous mongoose from the Western Cape Province, South Africa where reptiles ranked second among the vertebrate prey (Smithers, 1983).

The black mongoose also fed on birds (Table 4.2). Numerous nests of ground-nesting birds (with eggs and sometimes chicks) were observed during scat collection at

Hobatere. Only skulls and bones of birds were found in the scats of the black mongoose collected at Hobatere, and no feathers were found in the scats. It seems that the black mongoose at Hobatere fed on the newly hatched, featherless birds. Feathers of birds were however, found in scats of the black mongoose collected at Erongo.

This was closely associated with the time when the Orders of invertebrates trapped in pitfall traps decreased (Appendix 6). Only six Orders of invertebrates were trapped at Erongo compared to three additional Orders at Hobatere (Figure 4.4).

Birds contributed large volumes at Erongo than at Hobatere because feathers which were found at Erongo have a large surface area compared to bones at Hobatere, hence contributing the largest volume to the diet of the black mongoose. Since the scats of the black mongoose were collected at different times of the year, the presence of bird feathers in scats from Erongo and no feathers at Hobatere may reveal the effect of seasonality on the diet of the black mongoose.

Toads (93) were the second most trapped vertebrates at Hobatere. However, none were found in the scats of the black mongoose. The black mongooses seem not to have selected the toads suggesting that black mongoose might have a low preference of frogs. Other *Galerella sp* such as the slender mongoose and the Cape grey mongoose have included amphibians in their diet, however with a small percentage occurrence of 4% and 2%, respectively (Smithers, 1983). In addition, the white-tailed mongoose (*Ichneumia albicauda*), a species associated with savanna woodland in well-watered areas such as the Okavango delta, was reported to have frogs as the second-most common prey in their diet (Smithers, 1983).

Plantae (fruits, leaves) occurred with a prevalence of 22.6% at Hobatere and 21% at Erongo in the diet of the black mongoose (Table 4.2). Plantae contributed 4.5% and 1.4% of the percentage volume to the diet of black mongoose at Erongo and Hobatere, respectively (Figure 4.2.2). A high percentage volume of seeds occurred in the diet of the black mongoose at Hobatere while leaves and grasses were presented in the diet of black mongoose at Erongo. The high occurence of plant material in the diet of the black mongoose probably explains the high occurrence of insects in the diet of black mongoose. Most of the plant materials were probably ingested fortuitously with insects and perhaps cannot be considered as an important part of the diet of the black mongoose.

A study on the diet of the yellow mongoose, also sugested that plant material found in the diet of the yellow mongoose were incidentally ingested when feeding on insects. The yellow mongoose occasionaly also fed on leaves of succulent plants for its water content (Smithers, 1983). The black mongoose also included centipedes (Diplopoda; 1.4%), ticks (Acarina; 5.6%) and winkles (Gastropoda; 1.4%) in their diet at Hobatere (Table 4.2). According to Smithers (1983), centipedes are palatable to small carnivores and this may explain why centipedes formed part of the diet of the black mongoose.

The combination of prey items occurring in the diet of the black mongoose as determined through faecal analysis shows that the black mongoose feeds on a variety of prey. It feeds on the easily accessed prey such as beetles and corns crickets and at the same time includes the most energetically profitable prey such as small mammals and reptiles (Figure 4.2.2) (Dennis and Macdonald, 1999). It is also possible that the black mongoose has a preference for small-sized prey such as insects.

According to Woolnough and Carthew (1996), small prey items represent the most energy efficient prey option because they are easily captured, subdued and consumed than larger prey. The optimal foraging theory (Begon *et. al.,* 1996) also implies that smaller prey items are more appropriate than larger prey because the cost of eating a larger prey energetically outweighs the energy return.

Smithers (1983) and Avenant and Nel (1992) described the yellow mongoose as an insectivorous animal that feeds predominantly on insects and rodents, small birds, and reptiles. In a study undertaken in the Postberg Nature Reserve, South Africa, the diet of the yellow mongoose comprised of insects (90%), rodents (40.8%), aves (12.8%), reptiles, arachnida, mollusca and plants (Avenant and Nel, 1992). The present study, therefore, suggests, in accordance with Smithers (1983) and Avenant and Nel (1992), that the black mongoose is classified as an insectivorous. Ultimately, predation on rodents and insects such as grasshoppers by the black mongoose is beneficial to humans especially in agricultural plantations because they reduce the population of these destructive pests.

5.2 Techniques used in diet analysis

The diet of carnivores has been examined using different methods such as the examination of stomach content,faecal analysis and PCR amplification (Deagle *et al*., 2005). The examination of stomach content is done by sacrificing an animal and removing its guts. This method has been used in the past and is not currently recommended due to strict measures on the protection and conservation of carnivores (Creel, 2001). PCR amplification is the new method used to recover prey DNA from scats of carnivores (Deagle *et. al*., 2005). A study by Deagle and others (2005) indicated that the PCR method can obtain more accurate taxonomic identification of prey remains in scats and is helpful in recovering soft-bodied prey (Deagle *et. al*., 2005). The DNA-based method is more powerful; however the cost of undertaking it can be a constraint to researchers.

The present study used faecal analysis to determine the diet of the black mongoose. Faecal analysis is cheap and is a widely used technique in carnivore feeding studies (Hiscocks and Bowland, 1989). It is an appropriate method for determining the diet of secretive and solitary species such as the black mongoose whose scats are the most easily accessible materials. Faecal analysis has also been used to determine the diet of large carnivores in larger parks where monitoring is less possible (Arim and Naya, 2003; Breaur, 2005).

Faecal analysis is a non-invasive method that involves morphological identification of undigested remains of prey (Jones *et al*., 2003). It is however, a less direct method as compared to methods such as the examination of stomach contents because of the substantial modification of ingested material that occurs during the passage through the alimentary canal. Differential digestibility and passage rates of various ingesta through the gut of carnivores limit the accuracy of data derived from faecal analysis. In addition, faecal analysis allows low taxonomic resolution of prey, at best only up to the family level (Hiscocks and Bowland, 1989).

The present study did not experience difficulties with the identification of scats in the field because the scats of the black mongoose scats contained their own long, thick, dark hairs which were probably ingested during grooming. A sample of scats of the black mongoose which were found in several traps used for trapping the black mongoose was also used to recognize the scats found in the field. Hairs of small mammals were identified based on form, colour and structural patterns formed by cuticular scales.

Keogh (1985) described the scale patterns of hairs of small mammals as coronal (single scale across width of hair), chevron (waved pattern scales), mosaic (regular/

irregular pattern with a number of scales), pectinate (Comb like patterns) and petal (patterns of a diamond shape). The identification of hair is a labour-intensive because similar species or individuals may have different scale patterns on different hair-types (Day, 1966) and even vary on the shaft of one single hair (Keogh, 1985).
For example the grey climbing mouse has fluff- type of hair with one scale across the width of the hair and therefore has a coronal scale pattern. The short-tailed gerbil has medium-short length hair with one or two waved pattern scales covering the width of the hair making it chevron. However, the base of the short-tailed gerbil is covered by a single coronal scales and failure in examining the whole hair shaft can result in not identifying the species correctly.

At times, only twisted under-hairs were present in the scats and or only a few small mammal hairs were available in the scats. This makes it difficult to prepare a clear imprint hence, resulting in not correctly identifying the prey. In the present study, more than two imprints were made from the twisted hairs to increase the possibility of getting a clear imprint and correctly identifying small mammals to species. However, when it was difficult to identify small mammals to specific level they were identified to the genus level.

Differential passage rates of prey through the gut is one of the factors that confound the analysis of scats (Hiscocks and Bowland, 1989). Differential digestibility of prey types can result in the underestimation of an important component in the diet. For instance, if the black mongoose fed on a soft bodied prey such as maggots, its parts are completely digested and do not appear in the scats, therefore resulting in an underestimation of the occurrence and importance of maggots in the diet.

On the other hand, prey with robust parts which can readily survive digestion are likely to be over-represented in the scats. For instance, bones, teeth, and hairs of small mammals and scales of reptiles are hardly digestible. Their presence in the diet of the black mongoose is therefore, likely to be over-estimated. Hairs of an individual small mammal can be present in more than one scat collected at different times and from different locations.

For example, in a feeding trial conducted on four servals (*Felis serval*) and two black-backed jackals (*Canis mesomelas*), small mammal hairs occurred in two to four scats after ingestion (Bowland and Bowland, 1991). In such cases where small mammals were eaten, their percentage estimate to the relative frequency of occurrence in the diet can be over-estimated.

Several parameters such as percentage weight and percentage relative frequency of occurrence and percentage absolute frequency of occurrence have been used to illustrate the diet of carnivores (Breaur, 2005). The present study used percentage absolute frequency of occurrence to explain the presence and the difference in the prey remains found in the scats of the black mongoose at Erongo and Hobatere.

Percentage absolute frequency of occurrence is the number of scats (n) in which a prey category (c) occurred (nc) divided by the total number of scats examined multiplied by 100. This parameter gives a reasonable reflection of the proportions of the different dietary components (Hiscocks and Bowland, 1989).

Percentage absolute frequency of occurrence designates prey consumption without regard to other prey occurring in the diet, temporal availability of prey, selectivity and / or ease of capture of individual prey. According to Arim and Naya (2003), frequency of occurrence has been suggested as an adequate index that is not largely affected by environmental biases and is less affected by degradation of remains.

Pitfall traps were used to determine the types of invertebrates in the two study areas. Pitfall-trapping is a common method used in studying surface-active invertebrates because it is cheap and requires less effort (Topping and Sunderland, 1992). Considering that pitfall-trapping mainly targets ground-dwelling invertebrates, trapping was not as efficient in capturing all types of invertebrates which were present in the diet of the black mongoose. It was however, helpful because invertebrates that were trapped were useful in the identification of the remains found in the scats of the black mongoose at Erongo and Hobatere.

5.3 Threats to the black mongoose

Like other mammals, the black mongoose is threatened by habitat destruction, poor land management through over-stocking, and loss of grass species diversity, consequently reducing shelter and availability of prey for the species (Griffins, 1998). The black mongoose is secretive and is most likely to be affected by human population growth. For example, at Erongo the black mongooses were commonly seen around the Erongo Wilderness Lodge in 2006 and 2007 but were hardly seen in 2008 (P.Tylvas, pers. comm.). It is possible that they are disturbed by people and their activities.

Observations suggest that the black mongoose favours rocky habitats with a protective cover of vegetation made up of grass and bushes and trees such as *Colophospermum mopane*, *Combretum apiculatum* and *Terminalia prunioides* hence, the destruction of those plants should be avoided.

CONCLUSIONS

The use of faecal analysis to study the diet has provided an insight into the diet of the black mongoose. Though, with low taxonomic resolution of dietary components, faecal analysis provided a means to carry out an independent dietary analysis of the elusive black mongoose. The diet of the black mongoose was determined from 76 and 71 scats collected from Erongo and Hobatere, respectively.

The study revealed that insects were the principal prey in the diet of black mongoose at Erongo and Hobatere, followed by vertebrates such as small mammals, reptiles and birds. The results of the study therefore, suggest that, the black mongoose is largely insectivorous and predominantly feeds on insects. However, small vertebrates also form an important component of the diet of the black mongoose.

The present study also reveals that, there was a difference in the diet of the black mongoose at the two study sites. The difference was mainly a result of the variation in the percentage occurrence between the main prey categories present in the diet of the black mongoose at Erongo and Hobatere. A highly statistically significant difference was also detected in the percentage occurrence of invertebrates and small mammal species that were present in the diet of the black mongoose at the two study sites.

The low similarity in the composition of plant species at Erongo and Hobatere may have contributed to the variation in the diet of black mongoose at the two study sites. In addition, the difference between periods of collecting scats may also have contributed to the difference in the diet of the black mongoose at Erongo and Hobatere. Finally, Orthoptera (armoured crickets) was the most prevalent prey by volume in the diet of black mongoose at both study sites whereas Isoptera was the least presented prey.

RECOMMENDATIONS

- Faecal analysis was an appropriate method for this study because it provided an insight into the diet of the black mongoose. However, other methods such as PCR amplification of DNA of prey in the scats are recommended in order to detect soft bodied prey that is affected by biases associated with differential digestion and passage rates through the alimentary canal and to improve the taxonomic resolution of prey remains found in the diet of the black mongoose.
- This study was the first attempt to determine the diet of the black mongoose. It therefore needs to be repeated in order to validate the results of the present study. The diet is only one of aspects of the life history of the black mongoose and it is also recommended that there should be a Namibian-led research initiative for the black mongoose.
- The results of the present study revealed that there was a low similarity between the invertebrates found in the scats and those from pitfall traps. In case the dissimilarity was a result of poor sampling (when trapping was done only at areas where scats were found), it is recommended that adequate sampling of invertebrates and also small mammals be carried out on a larger area and for longer period to assess seasonal variation in the diet of the black mongoose.

More sampling is also essential in order to assess prey availability and prey selectivity with reference to the feeding habits of the black mongoose.

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APPENDICES

Appendix 1: GPS coordinates indicating locations where scats of the black mongoose collected at Erongo mountain conservancy, central Namibia, in 2008.

ERONGO	
S21°27'44.6" E15°53'10.7"	S 21°27'40.9" E 15°52'22.8"
S21°28'02.8" E15°53'06.8"	S 21°27'19.2" E 15°52'33.1"
S21°28'00.5" E15°53'18.7"	S21°27'40.9" E1552'22.8"
S21°28'00.5" E15°53'18.7"	S 21°27'33.5" E 15°53'00.5"
S21°27'34.2" E15°15'00.5"	S 21°27'33.7" E 15°53'01.0"
S21°27'34.2" E15°15'00.5"	S 21°27'33.7" E 15°53'01.1"
S21°27'34.2" E15°15'00.5"	S 21°27'39.9" E 15°53'22.1"
S21°27'55.8" E15°53'29.4"	S 21°27'41.5" E 15°52'19.1"
S21°28'09.7" E15°53'17.2"	S21°27.40.9" E 15°52'22.8"
S21°27'25.1" E15°52'41.1"	S 21°27'16.8" E 15°52'38.2"
S21°27'25.1" E15°52'41.1"	S 21°27'16.8" E 15°52'38.2"
S21°27'25.1" E15°52'41.1"	S21°27.40.9" E 15°52'22.8"
S21°27'34.3" E15°53'17.6"	S 21°27'40.9" E 15°52'22.8"
S21°27'38.0" E15°52'23.3"	S 21°27'34.1" E 15°52'59.5"
S21°27'40.9" E15°52'22.5"	S 21°27'40.9" E 15°52'22.8"
S21°27'40.4" E15°52'24.8"	S21°27'16.6" E15°52'58.1"
S21°27'40.4" E15°52'24.8"	S21°27'16.6" E15°52'58.1"
S21°27'16.7" E15°52'38.2"	S21°27'16.8" E15°52'38.7"
S21°27'16.7" E15°52'38.2"	S21°27'34.2" E15°53'00.5"
S21°27'18.6" E15°52'42.0"	S21°27'19.8" E15°52'35.4"
S21°27'19.8" E15°52'35.6"	S21°27'40.9" E15°52'22.8"
S21°27'25.8" E15°52'37.4"	S21°28'03.4" E15°53'22.7"
S21°27'25.1" E15°52'41.1"	S21°27'38.3" E15°52'53.3"
S21°27'47.0" E15°52'39.7"	S21°27'19.2" E15°52'33.1"
S21°27'19.8" E15°52'35.5"	S21°27'19.2" E15°52'33.1"
S21°27'19.8" E15°52'35.5"	S21°27;18.2" E15°52'36.6"
S21°27'19.8" E15°52'35.5"	S21°27'18.2" E15°52'36.6"
S21°27'19.8" E15°52'35.5"	S21°27'53.6" E15°53'25.3"
S21°27'34.4" E15°53'00.5"	S21°27'18.2" E15°52'36.6"
S21°27'24.7" E15°52'44.6"	S21°27'19.8" E15°52'35.4"
S 21°27'56.0" E 15°53'29.3"	S 21°27'34.6" E 15°53'00.4"
S 21°27'34.2" E 15°52'59.3"	S 21°27'41.5" E 15°52'19.1"
S 21°28'03.4" E 15°53'22.7"	S 21°27'41.5" E 15°52'19.1"
S 21°28'02.7" E 15°53'22.5"	S 21°27'19.2" E 15°52'33.1"
S 21°27'33.5" E 15°53'00.5"	S 21°27'56.0" E 15°53'29.3"
S 21°27'33.5" E 15°53'00.5"	S 21°27'40.5" E 15°53'18.6"

S 21°27'33.5" E 15°53'00.5"	S 21°28'02.2" E 15°53'22.5"
S 21°27'40.9" E 15°52'22.8"	S 21°27'33.5" E 15°53'00.5"
S 21°27'40.9" E 15°52'22.8"	S 21°27'33.7" E 15°53'01.0"
S 21°27'19.2" E 15°52'33.1"	S 21°27'33.7" E 15°53'01.1"
S21°27'40.9" E1552'22.8"	S 21°27'39.9" E 15°53'22.1"

Appendix 2: GPS coordinates indicating locations where scats of the black mongoose collected at Hobatere, north-west Namibia in 2008.

HOBATERE	
S19°18'59.0" E14°28'13.5"	S19°19'01.1" E14°27'45"
S19°18'50.3" E14°28'18.4"	S19°19'22.9 "E14°28'07.6"
S19°19'10.8" E14°27'46.0"	S19°19'31.5" E14°28'21.9"
S19°19'10.8" E14°27'46.0"	S19°19'10.9" E14°27'46.3"
S19°19'06.4" E14°28'06.1"	S19°19'00.7" E14°27'57.1"
S19°19'09.0" E14°27'39.7"	S19°19'00.7" E14°27'57.1"
S19°19'09.0" E14°27'39.7"	S19°19'00.7" E14°27'57.1"
S19°19'09.0" E14°27'39.7"	S19°19'00.7" E14°27'57.1"
S19°19'09.8" E14°2752.9"	S19°19'00.7" E14°27'57.1"
S19°19'13.1" E14°2741.9"	S19°18'49.8" E14°27'55.4"
S19°19'14.2" E14°28'18.4"	S19°18'49.8" E14°27'55.4"
S19°19'14.2" E14°28'18.4"	S19°19'34.5" E14°28'19.2"
S19°19'14.2" E14°28'18.4"	S19°19'20.1" E14°28'19.2"
S19°19'16.9" E14°28'16.5"	S19°19'20.1" E14°28'19.2"
S19°19'16.9" E14°28'16.5"	S19°19'22.9" E14°28'07.6"
S19°19'16.9" E14°28'16.5"	S19°19'23.2" E14°28'07.6"
S19°19'16.9" E14°28'16.5"	33k0443910-7864423
S19°19'16.9" E14°28'16.5"	S19°19'34.4" E14°28'19.3"
S19°19'16.9" E14°28'16.5"	33k0443515-7864157
S19°18'57.8" E14°27'55.3"	S19°19'19.8" E14°28'28.5"
S19°19'19.8" E14°28'28.3"	S19°19'14.4" E14°28'18.6"
S19°19'19.8" E14°28'28.3"	S19°19'17.0" E14°28'16.4"
S19°19'19.8" E14°28'28.3"	S19°19'19.0" E14°28'10.3"
S19°19'19.8" E14°28'28.3"	S19°19'11.9" E14°28'31.9"
S19°19'02.2" E14°27'23.1"	S19°19'11.9" E14°28'31.9"
S19°19'07.6" E14°27'23.6"	S19°19'11.9" E14°28'31.9"
S19°19'07.6" E14°27'23.6"	S19°19'11.9"E14°28'31.9"
S19°18'56.2" E14°27'44.3"	S19°19'11.9" E14°28'31.9"
S19°18'56.2" E14°27'44.3"	S19°19'11.9" E14°28'31.9"
S19°19'01.1" E14°27'45.0"	S19°18'56.1" E14°27'44.3"
S19°19'01.1" E14°27'45.0"	S19°18'56.1" E14°27'44.3"
S19°19'01.1" E14°27'45.0"	S19°19'01.1" E14°27'45"
S19°19'00.8" E14°27'57.1"	S19°19'22.9 "E14°28'07.6"
S19°19'00.0" E14°27'55.1"	S19°19'31.5" E14°28'21.9"
S19°19'10.9" E14°27'47.0"	S19°19'10.9" E14°27'46.3"
S19°19'10.9" E14°27'47.0"	S19°19'00.7" E14°27'57.1"
S19°19'10.9" E14°27'47.0"	S19°19'00.7" E14°27'57.1"

S19°19'11.9" E14°28'31.9"	S19°19'00.7" E14°27'57.1"
S19°19'10.9" E14°27'47.0"	S19°19'00.7" E14°27'57.1"
S19°19'00.7" E14°27'57.1"	S19°18'49.8" E14°27'55.4"
S19°19'00.7" E14°27'57.1"	S19°18'49.8" E14°27'55.4"
S19°19'34.5" E14°28'19.2"	S19°19'23.2" E14°28'07.6"
S19°19'20.1" E14°28'19.2"	33k0443910-7864423
S19°19'20.1" E14°28'19.2"	S19°19'34.4" E14°28'19.3"
S19°19'22.9" E14°28'07.6"	33k0443515-7864157

Appendix 3: Percentage volume of prey found in scats collected at Erongo, central Namibia.

Scat No.	Other	Insecta	Vertebrata	Plantae	Solifugae
36	7%	7% Coleoptera			
		46% Orthoptera			
		1.7% Orthoptera			39%
3	39%	31% Lepidoptera			
		31% Orthoptera			
5	9%	91% Diptera			
41			100% Rodentia		
45	57%	43% Coleptera			
19	5%	45% Diptera		1%	
		46% Lepidoptera			
		3% Orthoptera			
52	8%	8% Hemiptera			
		1% Hymenoptera			
		82% Lepidoptera			
34	8%	8% Coleoptera			
		84% Lepidoptera			
67		50% Lepidoptera			
	12%	38% Lepidoptera			
54		51% Lepidoptera		49%	
39		2% Coleoptera	90% Rodentia	8%	
61	6%	16% Coleoptera			
		79% Lepidoptera			
63	6%	1% Coleoptera	22% Rodentia	70%	
24	11%	29% Coleoptera			
		61% Lepidoptera			
10		95% Lepidoptera	5% Rodentia		
35		54% Lepidoptera	46% Rodentia		
38		81% Coleoptera		19%	
31	2.00%	98% Lepidoptera			
32	1%	12% Coleptera			
		87% Lepidoptera			
59		12% Coleptera			
		86% Lepidoptera			
		1% Hymenoptera			
46	5%	78% Lepidoptera		10%	

		5% Coleptera			2%
29		84% Lepidoptera	16% Rodentia		
17	5%	22% Coleoptera			
		73% Diptera			
18		100% Diptera			
62	11%	26% Coleoptera			
		63% Lepidoptera			
47	19%	57% Lepidoptera		24%	
36	7%	7% Coleoptera			
		46% Orthoptera			
		1.7% Orthoptera			39%
3	39%	31% Lepidoptera			
		31% Orthoptera			
5	9%	91% Diptera			
41			100% Rodentia		
45	57%	43% Coleptera			
19	5%	45% Diptera		1%	
		46% Lepidoptera			
		3% Orthoptera			
52	8%	8% Hemiptera			
		1% Hymenoptera			
		82% Lepidoptera			
34	8%	8% Coleoptera			
		84% Lepidoptera			
67		50% Lepidoptera			
	12%	38% Lepidoptera			
54		51% Lepidoptera		49%	
39		2% Coleoptera	90% Rodentia	8%	
61	6%	16% Coleoptera			
		79% Lepidoptera			
63	6%	1% Coleoptera	22% Rodentia	70%	
24	11%	29% Coleoptera			
		61% Lepidoptera			
10		95% Lepidoptera	5% Rodentia		
35		54% Lepidoptera	46% Rodentia		
38		81% Coleoptera		19%	
31	2.00%	98% Lepidoptera			
32	1%	12% Coleptera			
		87% Lepidoptera			
59		12% Coleptera			
		86% Lepidoptera			
		1% Hymenoptera			
46	5%	78% Lepidoptera		10%	
		5% Coleptera			2%
29		84% Lepidoptera	16% Rodentia		
17	5%	22% Coleoptera			
		73% Diptera			

18		100% Diptera	
62	11%	26% Coleoptera 63% Lepidoptera	
47	19%	57% Lepidoptera	24%

Appendix 4: Percentage volumes of prey found in scats collected at Hobatere, north-west Namibia.

Scat no	**other**	**insecta**	**vertebrata**	**solifuga e**	**Plantae**
9	17%	Lepidoptera 11.4% Coleopteran 71.4%			
21		Coleoptera 95%			5%
39	25%	Coleptera 59%		12%	4%
17		Coleoptera 88%	Rodentia 2.9%	8.80%	
48		Coleoptera 94%		4%	2%
64		Coleptera 11%	Rodentia 89%		
71	49.30%	Hymenoptera 1.45% Lepidoptera 36.2%	Rodentia 8.6%	4.50%	
41		Orthoptera% 75 Hymenoptera 12.5% Lepidoptera 12.5%			
24	20.50%	Lepidoptera 51.3% Orthoptera 25.6% Hymenoptera 2.6%			
52	3.60%	Odonata 16% Hemiptera 7.2% Coleoptera 72%			0.72%
10	11.30%	Coleoptera 17.3% Lepidoptera 60.8% Orthoptera 10.4%			
68	8.60%	Orthoptera 42.9% Coleoptera 42.9% Hymenoptera 5.7%			
40	13.30%	Hymenoptera 8% Coleptera 28% Lepidoptera 50.6%			
37			Rodentia 100%		
13	14%	Orthoptera 62% Hymenoptera 24%			
50			Rodentia 100%		

38	25%	Odonata 12.5%			
		Orthoptera 62.5%			
57	25%	Lepidoptera 60%			
		Hymenoptera 15%			
14		Coleoptera 93%			
		Orthoptera 7%			
43	18.80%	Coleoptera 18.75%			
		Lepidoptera 50%			
		Orthoptera 12.5%			
62	20%	Orthoptera 40%			
		Lepidoptera 40%			
5		Coleptera 99%			1%
49	20%	Hymenoptera 9%			
		Lapidoptera 22%			
		Hemiptera 9%			
51		Coleptera 12%	Rodentia60%	22%	
		Hymenoptera 5%			
56		Orthoptera 7%	Reptlia 76%		
		Orthoptera 13%			
		Hymenoptera 3%			
30		Hymenoptera 1%	Aves 99%		
29			Rodentia 100%		
28			Rodentia 100%		
47	13.50%	Coleoptera 46%		41%	
26	13%	Coleoptre 7%	Reptlia 53%	20%	
		Hemiptera 7%			
		Hymenoptera 0.7%			
18		Lepidoptera 74%			
		Coleopteran 7%			
		Orthoptera 19%			
27	13%	Orthoptera 9%			1%
		Coleopteran 7%			
		Hymnoptera 5%			
		Lepidoptera 65%			
59		Orthoptera 9%	Reptilia 89%		
		Hymnoptera 2%			
22		Coleptera 17%			2%
		Orthoptera 20%			
		Lepidoptera 61 %			
33		Coleopteran 59%		18%	
		Hymenoptera 6%			
		Isopteran 6%			
		Orthoptera 12%			

35		Hymenoptera 1% Orthoptera 5% Coleptera 9% Lepidoptera 82%		2%	
46		Hymenoptera 1% Mecoptera 2% Hemiptera 2% Coleopteran 12% Lepidoptera 82%			
34	5%	Orthoptera 31% Lepidoptera 45%		19%	
58	9%	Orthoptera 6% Lepidoptera 74%		11%	
31	13%	Hymenoptera 2% Coleoptera 5% Orthoptera 14% Lepidoptera 67%			
1		Hymenoptera 1% Millipede 1% Odonata 14% Coleopteran 55%			3%
55		Lepidoptera 10% Coleoptera 55%	Reptlia 10%	15%	10%
36	10%	Tick 2% Hymenoptera 5% Orthoptera 7% Lepidoptera 12% Coleoptera 20%		39%	5%
4		Coleoptera 5% Lepidoptera 74%		21%	
11		Lepidoptera 9% Coleoptra 91%			
7		Coleoptera 8%	Reptilia 92%		
23		Hymenoptera 67%			33%
20		Coleoptera 18% Lepidoptera 76%	Mammals 3%	3%	
54	20%	Coleoptera 13% Isoptera 20% Hymenoptera 20%	Aves 20%	7%	3%
67	4%	Hymenoptera 7% Coleoptera 22% Orthoptera 19% Lepidoptera 22%	Reptlia 19%	7%	
69	15%	Hymenoptera 8% Coleoptera 15% Lepidoptera 62%			
19		Lepidoptera 46%		54%	

63	66%	Coleoptera 11%			
		Orthoptera 23%			
70	11%	Hymenoptera 11%	Rodentia11%	17%	11%
		Coleoptera 28%			
6	17%	Orthoptera 13%			
		Lepidoptera 70%			
61	10%	Hymenoptera 15%	Rodentia31%	23%	5%
		Coleoptera 15%			
45	4%	Hymenoptera 2%	Reptlia 90%	4%	
44		Hymenoptera 14%		2%	
		Coleoptera 84%			
42	13%	Ticks 2%		9%	
		Lepidoptera 76%			
25		Tick 8%			
		Hymenoptera 25%			
		Lepidoptera 67%			
3	5%	Coleoptera 9%	Aves 55%		
		Lepidoptera 32%			
32		Hymenoptera 2%			
		Orthoptera 16 %			
		Lepidoptera 82%			
60	3 % (snail)	Orthoptera 11%	Aves 3%		
		Lepidoptera 11%			
16	11 % (stone)	Ticks 2%			
		Coleoptera 2%			
		Lepidoptera 85%			
12	1%	Lepidoptera 26%			4%
		Coleoptera 67%			
53	3%	Coleptera 6%	Reptlia 33%		
		Hymenoptera 17%			
		Orthoptera 42%			
8	3%	Orthoptera 16%	Reptlia 2%		
		Lepidoptera 79%			

Appendix 5: Families of invertebrates collected from pitfall traps at Erongo and at Hobatere. The shaded blocks indicate the families which were present at Erongo, Hobatere and / or both localities.

Order	**Family**	**Hobatere**	**Erongo**
Coleoptera	Apterogynidae		■
	Curculionidae		■
	Histeridae		■
	Tenebrionidae	■	■
	Scarabaeidae	■	■
	Bruprestidae		■
	Bostrichidae	■	■
	Meloidae		■
	Carabidae	■	■
Isoptera	Hodotermitidae		■
Diptera	Hariatidae		■
	Muscidae	■	
Blattaria	Blaberidae		■
	Blattodea	■	
	Blaterridae	■	
Hymenoptera	Formicidae	■	■
	Spheciclae		■
	Chalcidae		■
	Apidae	■	
	Sphecidae	■	
	Pteromalidae	■	
Lepidoptera	Nymphalidae Saturniidae	■	
	Noctuoidea	■	
	Sphingidae	■	
Araneae	Lyocosidae	■	
	Heteropodidae	■	■
Scorpiones	Buthidae	■	
	Scorpionidae	■	

Orthoptera	Acridoidea		
	Gryllidae		
Spirostreptidae	Spirostreptidae		
Diplopoda	Bradyporidae		
Scolopedrida	Scolopendridae		

Appendix 6: Invertebrates collected (and their numbers) from pitfall traps during scat collection at Erongo, central Namibia in 2008.

Order	**Species name**	**No:**
Coleoptera	*Apterogynidae* Sp	1
	Curculionidae Sp	1
	Hister Sp	2
	Stips dohrni	8
	Renatiella Sp	4
	Rutelinae Sp	1
	Acmaeodera Sp	2
	Eparopsis Sp	3
	Alleculidae Sp	2
	Mylablis Sp	2
	Stenocara Sp	8
	Zophosis punlticollis	21
	Zophosis hologenosis	33
Isoptera	*Hodotermes* Sp	3
Diptera	*Hariatidae*	1
	Heteropodidae Sp	17
Blattaria	*Aptera* Sp	18
Hymenoptera	*Formicidae*	185
	Spheciclae Sp	2
	Chalcididae Sp	4

Appendix 7: Invertebrates collected (and their numbers) from pitfall traps during scat collection at Hobatere, north-west Namibia in 2008.

Order	**Species name**	**No**
Lepidoptera	*Gonibrasia belina*	66
	Phalantha Sp	3
	Trichoplusia Sp	2
	Acraea species.	1
	Cynithia Sp	2
Coleoptera	*Mylabris oculata*	26
	Eurychora Sp	3
	Stenocara Sp	45
	Caminara Sp	16
	Alogenius Sp	14
	Khepher Sp	7
	Graphipterus Sp	2
	Garreta Sp	2
	Astyuls Sp	5
	Apate Sp	8
	Thermophilum Sp	7
	Diuches Sp	2
Hymenoptera	*Formicidae (small)*	166
	Meliponula Sp	7
	Delta Sp	1
	Pachycondyla Sp	4
	Sphex Sp	4
Archinida	*Apalystos* Sp	26
	Pteromalus Sp	1
	Spodoptera Sp	2
	Lyocosidae Sp	8
	Heteropodidae Sp	23
	Parabunthus brelimanus	3
	Opistophthalmus wahlbergii	2
Blattaria	*Blepharodera* Sp	4
	Ctenolepisma Sp	2

	Aptera Sp	30
Diptera	*Musca* Sp	9
	Acanthoproctus Sp	1
	Supella Sp	2
Orthoptera	*Conistica* Sp	4
	Schizodatylidae Sp	3
	Spirostreptus Sp	2
	Brachytrupes Sp	8
Diplopoda	*Scolopendra* Sp	**2**