ASSESSMENT OF SPECIES RICHNESS AND RELATIVE ABUNDANCE OF SMALL CARNIVORES IN NATURAL FOREST AND SHRUB THICKETS AT THE UNIVERSITY OF DODOMA

By

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Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Biodiversity Conservation of the University of Dodoma.

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CERTIFICATION

The undersigned certify that she has read and hereby recommend for acceptance by the University of Dodoma dissertation entitled ***Assessment of species richness and relative abundance of small carnivores in natural forest and shrub thickets at the University of Dodoma*** in fulfillment of the requirements for the degree of masters of science in biodiversity conservation of the University of Dodoma.

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DECLARATION AND COPYRIGHT

I, **Baraka David Mwiyoha**, declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

Signature………………………………..

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DEDICATION

This work is dedicated to Faith and Ebenezer.

My patient has been to see great good things happening. Time limits all of us. As a conservationist and a scientist you will encounter challenges pertaining resources use among living organisms. The paradigm for conservation for the present and the future needs much more than prioritizing some few species.

ABSTRACTS

Urbanization developments results in the loss and fragmentation of habitat, which can significantly alter animal communities. Wildlife species occupying higher trophic levels, such as mammalian carnivores may be especially affected by habitat alteration and concomitant losses of cover and prey. Tanzania has high carnivore diversity, 35 species or more, but relatively little is known about carnivore communities outside protected areas or the effects of urbanization on carnivore communities. I used remote cameras equipped with active infrared sensors to document carnivore species presence in the University of Dodoma area and to identify natural or anthropogenic factors associated with high carnivore species richness. I sampled 50 different sites during 2012–2013 and each camera was set for 5 consecutive sampling nights. I used Poisson regression to develop predictive models using carnivore species richness as the dependent variable. Among the shrub cover, distances to forest edges, buildings, roads and rock outcrops. I analyzed 9*a priori* models based on combinations of 6 different habitat variables and used Akaike's information criterion (AICc) to examine the evidence for competing models. I detected 10 species of Carnivora, about 29% of the current Tanzania`s Carnivore species. Carnivore species richness per camera site varied from 0 to 4 species. Only one species of large carnivore, the striped hyena, was documented.

Species activity patterns varied significantly; genets species were entirely documented at nights. The same was for bushy-tailed mongoose and white-tailed mongoose, on the other hand, slender mongoose and dwarf mongoose dominated the day time. Thus competition among carnivore species community in these UDOM habitats can be high as a result variation in active time.

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LIST OF ABBREVIATIONS

ASR	All Mammalian species richness
CSR	Carnivora species richness
EWT	Endagered Wildlife Trust
GPS	Global positioning System
Ha	Hectare
IUCN	International Union for Conservation of Nature
mm	millimeter
SSC	Species Survival Commission
TAWIRI	Tanzania Wildlife Research Institute
UDOM	The University of Dodoma
URT	United republic of Tanzania
USGS	United States Geological Durvey

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Mammals of the order Carnivora demonstrate tremendous variability in morphology, behaviour, and life history (Ewer, 1973; Gittleman, 1989). Although, the carnivores all share a flesh-eating ancestry, modern carnivores demonstrate a variety of adaptations for diets that might consist mostly of meat in some species to largely vegetarian in others (Ewer, 1973; Gittleman, 1989). The ecology and social organization of small carnivores also exhibits much interspecific and intraspecific variability, depending on resource distribution (De Luca and Mpunga, 2005; Gittleman, 1989; Jennings and Veron, 2009). Mammalian carnivores are among the most ecologically sensitive to the effects of fragmentation because they tend to occupy the higher trophic levels of ecological food chains, occur at relatively low densities, need larger areas of contiguous habitat to meet ecological requirements, and are often persecuted by humans (Woodruffe and Ginsberg**,** 1998). The removal of carnivore species from food chains can result in top-down effects such as trophic cascades and changes in community structure (Eisenberg, 1989; Primack, 2010). Thus, species richness of this ecological guild is often considered an indicator of the overall health of an ecological community.

Little is known about the distribution, behaviour and dynamics of most small carnivore populations, especially in the tropics (Schaller, 1996). The diversity, distribution and abundance of these mammals greatly depend on food availability, (Caro, 2002); diseases and anthropogenic impacts (habitat alteration and exploitation) also limit their populations and may result in extirpation of larger carnivores. In mainland Tanzania about 28 species of small carnivores are known to inhabit wilderness areas across a diversity of habitat types. These include cats, canids, mongooses, mustelids, viverrids and genets (TAWIRI, 2009; Pettorelli *et al*., 2010). Most small carnivores are not considered threatened species under IUCN Red List of species, although this may owe largely to deficiencies in monitoring because smaller species typically receive less attention. Outside protected areas, human disturbance bring significantly impacts to populations of many carnivore species, resulting in local extinction due to habitat alteration, prey unavailability, and altered competitive interactions, all stemming from rapid human population growth. Reduced prey densities from increased human populations have caused shy, secretive and less adaptable species of small carnivores to move to places where interaction with human is minimal (Gaubert *et al*., 2006).

In the recent past, the area around The University of Dodoma (UDOM) was known to have a variety of small to medium-sized carnivores (Loveridge, 1926); spotted hyenas have been sighted in the area, and occasionally leopards. However, rapid expansion of Dodoma city and the change of climate has degraded the natural habitats for most large to medium-sized carnivores, hence their disappearance from the area. Certain biological characteristics make species more vulnerable to extinction, including large body size, complex social behavior, low population density, specialized niche requirements, and high trophic position (Primack, 2010). On the other hand, some small carnivores might be more adaptable to human presence (Gittleman, 1989) and might even thrive in habitats occupied by humans.

New infrastructure, roads and buildings have brought much change to natural habitat during the rapid expansion of UDOM, notably a reduction of area and quality of suitable habitat for carnivores. Unregulated exploitation of fuel wood from regenerating forest, burning of shrubs and young trees, and clearing of natural forests around the UDOM boundaries for corn fields progressively degrades remaining habitat. Small carnivores may be adaptable enough to tolerate and thrive in such landscapes features of UDOM that promote their continued existence. The question is for how long these low to medium shrub cover and rocky outcrops may sustain a diversity of viable populations of small carnivores.

1.2 Statement of the problem

For effective conservation, rational and critical mitigation based on reliable, adequate and practicable information is needed. In the past, both naturalists and the public have focused mostly on the ecology of large charismatic carnivores, possibly because of their ability to portray strength, agility and intelligence (Gittleman, 1989); little is known about the distribution and ecological requirements of small carnivores, in particular small tropical carnivores. In Tanzania, most information on carnivores comes from protected areas (Caro, 2002; De Luca and Mpunga, 2005; TAWIRI, 2009; Tanzania carnivores, 2013). Very little is known about the presence/absence, population status and ecology of small carnivores in unprotected areas. On the other hand, several projects based in Tanzania under TAWIRI such as Tanzania mammals atlas project and Tanzania carnivore conservation project are working all across the country to accumulate information on distribution and ecology as well foster the conservation plans of endangered species.

A systematic survey of carnivores in unprotected areas in Dodoma has not yet been conducted. Conservation and preservation of carnivore diversity should begin with an inventory of existing species and the identification of potential factors associated with their distribution. Lack of adequate information however, make conservation processes difficult. This initial work done can be then expanded to identify ecological requirements of different species and address specific questions on carnivore population and community ecology. Such knowledge is critical for assessing the adaptability of different carnivore species to human disturbance, elucidating their ecological roles in human altered landscapes, and developing management strategies for carnivore conservation.

1.3 Objectives

1.3.1 General objectives

The study done was carried out based on general objective to assess the species richness and relative abundance of carnivores on the campus of the UDOM and identify ecological factors associated with carnivore species richness, or the presence of particular carnivore species.

1.3.2 Specific objectives

The study was carried out based on the three specific objectives. These were

i. To characterize the carnivore community on the UDOM campus and assess carnivore species richness and relative abundance.

ii. To identify important ecological factors (natural and anthropogenic) associated with carnivore species richness.

iii. To assess activity patterns of different small carnivore species.

1.4 Study hypotheses

The research has done have four hypotheses that were tested. These hypothesis were based on null assumption that

i. The carnivore community will consist mostly of small, generalist species adapted to dry communities.

ii. Carnivore species richness will be positively associated with distance to habitat edges and rock outcrops, and with the degree of shrub cover.

iii. Carnivore species richness will decrease with proximity to human infrastructure (roads and buildings).

iv. The variation in active time of different carnivore species will determine their coexistence.

1.5 Significance of the study

Tanzania supports one of the world's most diverse assemblages of species in the Order Carnivora (Gus *et al.*, 2001; De Luca and Mpunga, 2005) and is considered a hotspot of biodiversity (Clarke, 2001), particularly to variety of carnivore species. TAWIRI has initiated a nationwide effort to map carnivore diversity and distributions across Tanzania (TAWIRI, 2009). This carnivore survey results and inventory will serve as a benchmark against which future carnivore surveys in Dodoma that can be compared as baseline information on the ecology and composition of carnivore communities in a human-dominated landscape in central Tanzania. The UDOM natural habitat is presenting a national and public with opportunity for its natural resource heritage of which potentials values for learning, leisure, and study trips and for further field research purposes can be accessible in the future. Furthermore, study done aimed to provide the UDOM administration with baseline information for planning, setting territories and prohibiting uncontrolled public activities around the University area, Planning and initiating scientific studies and research, to serve as a role model for other areas with similar condition on conservation of biodiversity and to initiate conservation plans that will promote and enhance field training for students. National wide this research project results support TAWIRI's goal to mark the carnivore distribution throughout the country and provide valuable information on the current diversity and composition of carnivore assemblages in unprotected areas particularly in Dodoma.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of key Terms

2.1.1 Carnivores

Carnivores are known as animals that derive their energy and nutrients requirements from diet consisting of both animal tissues and non-animal food (Ewer, 1973; Gittleman, 1989; Raia, 2004). These are rare, cryptic animals that play key role in ecosystems such to prey on many other herbivore species. (Gittleman, 2000; Ray, 2000; Mudappa, 2002). They have evolved morphological and behavioral adaptations to their mode of life including slender, good senses for hunting secretive and camouflages coat color (Gittleman, 1989). Carnivores are the top predators in many ecosystems. They include lions (*Panthera leo*), Leopard (*Panthera pardus)* and cheetah (*Acinonyx jubatus).*

2.1.2 Habitats

Habitats are defined as large areas within which territorial, reproductive and resource areas so called home ranges for an animal are found (Belcher and Darrant, 2004; Nelson *et al*., 2007), Nelson *et al*., (2007) describe habitat as an area where an animal spends much of its time. A habitat has been stated also as an environment where different species interacts among themselves and their food resources (Polis *et al*., 1989), for denning and shelter (Rathbun and Cowley, 2008),for reproduction, protection and hunting (Blaum *et al*., 2007b). Also, Gittleman and Harvey (1982) revealed a habitat as an area of typical characteristics within a large geographical range. Therefore, a habitat can be summed as geographical area where a carnivore species is reproductively and metabolically active, defend its territorial boarder and is able to obtain food and shelter. Within habitats there are variables such as shrub cover, rock outcrops, which can be used as predictors of carnivore species richness.

2.1.3 Mesopredator/mesocarnivore

Mesopredator/mesocarnivores are small mammals of the order Carnivora that weigh below 15kg and are normal abundant than large carnivore (Roemer *et al.,* 2009). In absence of large carnivores the mesocarnivores play an important role as top predators (Lloyd, 2007; Roemer *et al.,* 2009; Ordernona *et al*., 2010). Their feeds range from flesh of animals and insects to plant such as fruits (Loveridge, 1926; Gittleman, 1989; Raia, 2004). Thus, mesocarnivores includes genets, mongoose, some weasels and skunks apart from lions, leopards, tigers, sea otters, panda and ursus. The UDOM habitat was hypothetically thought to consist of mesocarnivores and small carnivores because of absence of large prey for large carnivore also presence of fragmented habitat that could not be preferred by large carnivore

2.1.4 Non-invasive

Many techniques or methods have been deployed to study carnivore ecology in different areas (De Luca and Mpunga, 2005; TAWIRI, 2009). Non invasive techniques do not harm the animal under study also do not destruct environmental habitats. These techniques include spoor count, scat analysis, camera trapping, snow track survey and vision search (Gompper *et al.,* 2006; TAWIRI, 2009; Ordernona *et al*., 2010; Jennings, 2011).

2.1.5 Remote camera

Remote cameras are an effective tools that photograph an animal once has been detected using either infrared sensor or when an active beam of light is broken by the passing animal (De Luca and Mpunga, 2005; TAWIRI, 2009; Ratnayeke and van Manen, 2012).The research done used an active remote cameras (Trailmaster^{TM} 1500) that consist of a transmitter unit, a receiver and an automatic 35mm camera. Active remote cameras are effective tools for photographing secretive, cryptic and difficult to capture animals (Mudappa *et al*., 2002; Stevens *et al*., 2004; De Luca and Mpunga, 2005; Gompper *et al*., 2006; TAWIRI, 2009; Pettorelli *et al*., 2010; Reed, 2011). The use of active remote camera in this study was as necessary to reveal the presence of nocturnal, diurnal and crepuscular species of small carnivore in the area.

2.1.6 Urban

An urban area is defined as area of continuous development with high labor market of 500,000 human populations or more (Demographia, 2013), Tibaijuka (2010) revealed as an area where lives large population of people. The United States Geological Survey (USGS), (1999) referred as an area that was once forests, farmlands (natural lands) and then transformed into human settlements. Thus urban area is a continuous area characterized with development projects such as manufacturing industries and factories, adequate social services such as education health and entertainments. Dodoma urban recently, is experiencing large growth in development projects such educational institutions. These include UDOM, St. Johns University of Dodoma, colleges and schools. Dodoma town is a centre for political and national meetings (parliaments), economic forums, business routes to nearby countries; thus have influenced massive movements to Dodoma than the past five to ten years. The current increasing population needs labor market in return it attracts more urban migrations

2.2 Empirical Literature Review

2.2.1 Order Carnivora

The Order Carnivora includes 16 families, 128 genera and 281 species. The family includes Nandiniidae, Felidae, Prionodontidae, Viverridae, Hyaenidae, Herpestidae, Eupleridae, Canidae, Ursidae, Otariidae, Odobenidae, Phocidae, Ailuridae, Procyonidae, Mephitidae and Mustelidae (Wilson and Mittermeier, 2009). Of these; the largest family is Mustelidae comprising the weasels, badgers, otters, and polecats (Wilson and Mittermeier, 2009). All Carnivora families, except Ailuridae, Procyonidae and Ursidae currently may occur in Africa. The Order Carnivora comprises mammals that originally evolved as predators during the mid Cretaceous (Savage, 1977), but whose adaptation to a variety of environments and lifestyles has resulted in diversification into different lineages (Ewer, 1973; Gittleman, 1989). Small carnivores represent over half of all species in the order Carnivora and include 150 species in 9 families (Ailuridae, Eupleridae, Herpestidae, Mephitidae, Mustelidae, Nandiniidae, Prionodontidae, Procyonidae and Viverridae (Schipper *et al.*, 2008) Currently 25 of the 34 species of mongoose are found in Africa and only 9 species in Asia (Gilchrist *et al*., 2009). On the other hand, 34 species of civets, genets and oyans are found in Asia and Africa while only 9 species are found in Europe (Jennings and Veron, 2009). Most terrestrial species of carnivore are nocturnal, solitary (Loveridge, 1926) and live in dense habitats in which less than

15% of all Carnivora solitary species can aggregate during some non-breeding seasons (Gittleman, 1989). Furthermore, modern carnivore lineages exhibit much variability in diet, morphology, behaviour, and social organization depending on geography and resource distribution (Messeri, 1983; Gittleman, 1989; Schaller, 1996). Carnivores have adapted to several habitats ranging from deserts to aquatic environments. Some species, like the giant panda (*Ailuropoda melanoleuca*) or spectacled bear (*Tremarctos ornatus*) have diets relying almost exclusively on plant matter, whereas others are omnivorous, and feed on both animal and plant matter (Loveridge, 1926; Raia, 2004). Similar omnivory has been observed among civets and genets (Gittleman, 1989).

2.2.2 Ecological significance of carnivores

Large carnivores often play important keystone roles in ecosystems through trophic stability of many ecosystems (Gros *et al*., 1996; Gittleman, 2000; Ray, 2000; Mangas *et al.*, 2008; Prugh *et al.*, 2009; Primack, 2010). Large carnivore species are often prioritized in conservation because of their sensitivity to habitat loss, charisma, and ecological importance. Because large carnivores need large areas to sustain viable populations, small carnivores, including many other species tend to be conserved by default because their habitat requirements are contained within the home ranges of large carnivores (Primack, 2010). Thus, large carnivores can serve as umbrella species for most small and medium sized carnivores (Ratnayeke and van Manen, 2012). Large carnivores are sensitive indicators of ecosystem change; Changes that disrupt their populations also result in changes in their ecosystem. The changes may be beneficial to some species and may also be harmful to other species. Large carnivores regulate large prey populations; increased populations of some herbivores species may overgraze their food source (Norrdahl and Korpimaki, 1995; Prugh *et al.*, 2009), thereby out competing other species or reducing the carrying capacity of the habitat. Ability of top carnivore to suppress other lower carnivore species and herbivore species has been observed in many ecosystems. For instance Prugh *et al.*, (2009) in North America observed that the wolves as top carnivore were able to control the populations of Elk (*Cervus Canadensis*) that in their absence the vegetation along river banks re-grow and thus more beavers (*Castor Canadensis*) population was recovered. Large carnivores also need large areas as home ranges (Blaum *et al*., 2007; Long *et al*., 2007).

Large carnivore populations worldwide have declined, thus, cognitive home ranges for carnivores to survive on their environment have been jeopardized (Powell, 2012; Spencer, 2012). Factors for decreasing in large carnivores includes increasing human activities in areas inhabited by carnivores; Clearing large areas for agriculture, settlements and logging. Lack of enough prey species also is contributing to large carnivore disappearance. Declines in the numbers of large (top) carnivores worldwide have accompanied increased numbers of mesopredators as a result of an ongoing human persecution of large (top) carnivores (Beckmann and Berger, 2003; Lloyd, 2007; Prugh *et al*., 2009). Humans have competed with large carnivore for prey species as well increased wildlife habitats loss, and in predator control programs (Lloyd, 2007) to reduce wildlife-domestic livestock kills (Prugh *et al.*, 2009).Follow with reasons for the decline (both extrinsic and intrinsic) this have led to increases of mesocarnivore, that are less sensitive to the loss of habitat (Beckmann and Berger, 2003).and more adaptable in absence of large carnivores. Many of the land use changes such as fragmentations, that have been bad for large carnivores, may have benefitted mesopredators. Thus, there was a rapid increase in density and distribution of mesopredator populations while top carnivore populations were decreasing, on the other hand, this may have been caused by increase of populations of prey species that were once preyed on by large carnivores. The rise of mesopredator is evident in fragmented habitats (Prugh *et al*., 2009) still there is little information just to rely solely on decrease of large carnivore species.

The rise of mesopredators has benefitted the ecosystem in some cases, for instance mesocarnivores have become the top predator that fairly so far stabilized the ecosystem (Gompper, 2002). Gompper (2002) revealed that coyotes have maintained stable community despite extirpation of previously known top predators puma and wolves in Europe and North America. As beneficial mesocarnivores in some ecosystems however, in others has led to outbreak of diseases (Prugh *et al.*, 2009). As populations of mesopredators increase, direct transmission of parasites to humans and domesticated carnivores also increase (Lindenfors *et al.*, 2007), such as viruses that cause canine distemper and rabies, has found among humans and dogs in areas inhabited by coyotes in North America (Gompper, 2002). The same has been reported to domesticated dogs surrounding nationals parks in Tanzania (Cleaveland *et al.*, 2007) Transmission of diseases always occur due to fecal contamination of water and food sources, exposure to vector and animal transport, mostly to animals with large home range areas (Lindenfors *et al*., 2007) and large wildlife populations that are confined within a small home range. Studies on impacts of mesocarnivores in many areas have not yet conducted thoroughly, thus this explain the little information on the ecological and adaptation of mesocarnivore in new areas around the globe.

2.2.3 Small carnivores and mesocarnivores (medium sized-carnivores)

Morphologically, most carnivores are small mammals (Gittleman, 1989) with slender bodies, long faces, long tapering tails, and body weights ranging between 25g least weasel (*Mustela nivalis)* to about 28kg sea otters (*Enhydra lutris*) Gilchrist *et al.*, 2009;). However, some medium sized canids can reach about 16kg (Geffen, 1996). Most small carnivores are terrestrial except for a few species such as otters. Hunting in terrestrial vast environment requires good senses for hearing and vision; some small carnivores have a layer of reflective cells in the retina (*tapetum lucidum*) an adaptation to nocturnal life. Apart from nocturnal, diurnal and crepuscular adaptation also camouflaging to environmental habitats is common. The variation in coat color and patterns depend largely on the habitat the species has evolved in, thus the coat patterns may play role in social interaction (Gittleman, 1989; Jennings and Veron, 2009).

Studies on medium to small carnivores have been carried out in many areas across the globe using capture and telemetry, or non-invasive techniques such as genetic analysis of feces, track-plates, remote cameras and surveys using den, midden, scat and spoor (Kelly *et al*., 2008; TAWIRI, 2009). The use of remote cameras is one technique among many other non invasive techniques such as scat analysis, spoor count that have been used in many studies to document species presence and absence, relative abundance, and habitat use (Karanth, 1995; Wemmer *et al*., 1996; Karanth and Nichols, 1998; Kelly *et al*., 2008; TAWIRI, 2009).

Most studies on habitat relationships of small carnivores have been conducted in Europe and North America (Gompper, 2002; Ordenona *et al*., 2010). A study using remote cameras in coastal southern Califonia revealed that coyote, (*Canis latrans)* and raccon (*Procyon lotor)* were abundant closer to urban or human settlement than bobcat (*Lynx rufus)* and gray fox (*Urocyon cinereoargenteus*) (Ordenona *et al*., 2010). Despites coyote and raccon abundance, domestic dogs and Virginia opossums (*Didelphis virginiana)* revealed no relationship in relation to urban areas (Ordenona *et al.,* 2010). Another research study in Belarus showed that two species European mink (*Mustela lutreola*) and polecat (*Mustela putorius*) co-occurred with their hybrid within the same overlapping home range of maximum 5.1 km^2, and were also observed to have the same feeding habits (Sidorovich, 2001). Thus, it is evident that closely related species of small carnivores may have fairly similar ranges and ecological niches. Some species of small carnivores may demonstrate marked preferences for certain types of habitat; Blaum *et al.,* (2007) showed that yellow mongoose, bat-eared foxes and small spotted genets were abundant in areas with low shrub cover (between 10-18%), thus, adapted to open grasslands where densities of insects and small mammal prey are usually greater. However, in the same study, African wildcats, striped polecats, Cape foxes and suricates were found in a range of habitats from low shrub cover to dense vegetation cover. Thus vegetations are significant for small carnivores survival (Blaum *et al.*, 2007). Carnivore studies in wetland have been very useful for instance, using camera traps the occurrence of small carnivore species such the otter civet (*Cyogale bennettii*), short-tailed mongoose (*Herpestes brachyurus*) and collared mongoose (*Herpestes semitorquatus*) was documented in wetland areas in commercial plantations in Malaysia (Wilting *et al*., 2010). Many studies describing habitats and feeding have also been conducted in many places despites the fact that small carnivore feeds always do vary. De marinis (2001) showed that badgers prey on small food items, that are much less than their body weight ranging from fruits and insects depending on prey availability and seasonal changes of habitats on open and wooded habitats. Small carnivores favor scrublands and moderate covered shrub for prey hunts, yet it has not been observed that densely shrub areas are not as diverse in prey species as less densely shrubs (Mangas, *et al*., 2008). Changes in habitats characteristics as well result in prey species populations. Thus, the variation in prey species population justify the distribution of small carnivore species among a range of habitats (Crooks, 2002)

Understanding species ecology is the crucial step for conservation planning and management at all levels. Conservation of coyote (*Canis latrans*) in northern eastern North America has revealed that successes have been achieved through extensive and ongoing research studies (Gompper, 2002). Cardillo, *et al*., (2008b) revealed that species extinctions may be highly associated to human pressure, changes in natural geographical areas. Some species need large area to survive, others require a continuous habitat, however, the currently rapid human increase that is largely associated with habitat changes such as environment clearance for industries, farming and settlements pose challenges to future of many species. Thus a clear understanding of the currently carnivore species ecology and the dynamic of human interferences are the key to the survive of the future species; unless, these factors are studied thoroughly in various insightful researches and the information appropriately used in conservation then species extinction is doomed to happen so fast.

2.2.4 Carnivore studies in Tanzania

Tanzania has 35 species of carnivores (Table 2.0) and 28 species are classified as small carnivores (Table 2.1); Until recently, very little research on carnivore distributions, abundance, habitats and behavior has been carried out (Pettorelli, *et al*., 2009).

Table 2.0. Current Tanzania Carnivora species believed to be found across the country§

Family	Common name	Scientific name
Canidae	Side striped jackal	*Canis adustus*
	Golden jackal	*Canis aureus*
	Black backed jackal	*Canis mesomelas*
	Wild dog	*Lycaon pictus*
	Bat eared fox[†]	*Otocyon megalotis*
Mustelidae	African clawless otter	*Aonyx capensi*
	Spotted necked otter	*Lutra maculicolis*
	Zorilla	*Ictonyx Striatus*
	Honey badger	*Mellivora capensis*
	Striped weasel	*Poecilogale albinucha*
Viverridae	African civet	*Viverra civetta*
	Common genet	*Genetta genetta*
	Servaline genet	*Genetta servalina*
	Large spotted genet	*Genetta maculate*
	Miombo genet	*Genetta angolensis*
Herpestidae	Marsh mongoose	*Atilax paludinosus*
	Bushy tailed mongoose	*Bdeogale crassicauda*
	Dwarf mongoose	*Helogale parvula*
	Egyptian mongoose	*Herpestes ichneum*
	Slender mongoose	*Herpestes sanguineus*
	White tailed mongoose	*Ichneumia albicauda*
	Banded mongoose	*Mungos mungo*
	Mellers mongoose	*Rhynchogale melleri*
Hyaenidae	Spotted hyaena	*Crocuta crocuta*
	Striped hyaena	*Hyaena hyaena*
	Aardwolf	*Proteles cristatus*
Felidae	Cheetah	*Acinonyx jubatus*
	Caracal	*Felis caracal*
	Serval	*Felis serval*
	Wild cat	*Felis sylvestris*
	Lion	*Panthera leo*
	Leopard	*Panthera pardus*

[§] Tanzania small carnivore organization (2013)
[†]Species classified as small carnivores (TAWIRI 2009).

Table 2.1. TAWIRI'S list of small carnivore species currently found in Tanzania.‡

Family	Common Name	Scientific name
Felidae	Serval	*Leptailurus serval*
	Caracal	*Caracal caracal*
	African wildcat	*Felis silvestris*
Mustelidae	Cap clawless otter	*Aonyx capensis*
	Sppoted-necked otter	*Hydrictis maculicollis*
	Honey badger	*Mellivora capensis*
	Striped weasel	*Peocilogale albinucha*
	Zorilla	*Ictonyx striatus*
Canidae	Bat-eared fox	*Otocyon megalotis*
	Black-backed jackal	*Canis mesomelas*
	Golden jackal	*Canis aureus*
	Side-striped jackal	*Canis adustus*
Viverridae	Common genet	*Genetta genetta*
	Large-spotted genet	*Genetta maculate*
	Servaline genet	*Genetta servalina*
	African civet	*Viverra civettina*
	Two-spotted palm civet	*Nandinia binotata*
Herpestidae	Bushy-tailed mongoose	*Bdeogale crassicauda*
	Egyptian mongoose	*Herpestes ichneumon*
	Banded mongoose	*Mungos mungo*
	Dwarf mongoose	*Helogale parvula*
	Marsh mongoose	*Atilax paludinosus*
	Meller`s mongoose	*Rhyncholgale melleri*
	Slender mongoose	*Galerella sanguine*
	Sokoke-dog mongoose	*Bdeogale omnivore*
	Jackson mongoose	*Bdeogale jacksoni*
	White tailed mongoose	*Ichneumia albicauda*

‡ Source: TAWIRI (2009)

Most of these studies were conducted in national parks, and most of the parks are in the northern part of Tanzania. Carnivore research demands much time and resources, and data is not easily obtainable. Also lack of funds from government, private and international donors has resulted in few studies, especially in developing countries where carnivore diversity and conservation issues are greatest. The lack of information on carnivore distributions, ecology and population status has inhibited the development of conservation action plans mostly for small carnivores (De Luca and Mpunga, 2005).

Large carnivores of Tanzania, previously roamed freely in the wild when human population size was relatively low (Loveridge, 1926). Currently ecosystems have changed significantly. Human encroachments to protected areas are becoming an alarming issue in poor communities surrounding national parks, game reserves and forest management areas where most large carnivore and their native prey are now confined. Human-carnivore conflicts, especially raiding of domestic livestock, have resulted from overgrown demand for natural resources. There are reports of large carnivore, lions (*panthera leo*) attacks on humans and livestock in villages around protected areas in Tanzania (Shemweta and Kideghesho, 2000; Ikanda, 2010; Nyahongo, 2010). It was reported that between 1985-1988 about 48 people were killed by lions in Kijima village Tunduru around Selous game reserve and within a period of one year at Songorwa and Tunduru 12 and 29 people were killed respectively (Skuja, 2000). Ikanda (2010) reported that between 1987-2008 more than 600 people were killed by lions in Tanzania. Sometimes these conflicts are difficult to resolve and may lead to misunderstandings among conservationists and local communities surrounding protected areas because conserving animals may means restricting humans to access some resources.

Recent studies on the diversity and distribution of small carnivores in Tanzania have revealed remarkable diversity, especially in the Eastern Arc Mountains. A carnivore assessment of Udzungwa National park (De Luca and Mpunga, 2005) revealed 26 carnivore species including four small carnivores documented for the first time in Tanzania. Bushy-tailed mongooses previously thought to be rare in Tanzania were abundant in national parks (Pettorelli *et al.*, 2009; De Luca and Mpunga, 2005). However, low carnivore populations in most areas might be due to extensive degradation of habitats mostly as result of clearing areas for agriculture. Although small carnivores species may be still much more abundant in open areas however, large carnivores are likely to be extirpated, on the other hand, ecological factors influencing the presence and diversity of small carnivores still needs to be explored(Caro ,2001; Caro, 2002).

2.2.5 Carnivore status and conservation in Tanzania

Historically, In Tanzania the processes of conservation started since the pre-colonial era during which spiritual affiliation to particular species were common in some societies, human population density was still low and did not have large impacts on carnivore populations. The introduction of laws and acts between 1885 to 1961 by both German and British in Tanganyika colony (Tanzania mainland) served mainly to restrict local people from excessive and uncontrolled wildlife killing (Kideghesho, 2010); that could have been caused by the rapid increase in human populations. The conservation model introduced by colonialists led to the creation of national parks where strict laws and enforcement of power was a feature of those governments. The current Tanzanian government inherited the colonial system of conservation; today in Tanzania, carnivore diversity is higher in protected areas, namely national parks.

National parks are the most studied areas, with game reserves and forest reserves a close second (Kingdon, 1997; De Luca and Mpunga, 2005). Kideghesho, 2010; Pettorelli *et al*., 2010). However, very little information on carnivore populations comes from protected and unprotected areas usually the least. Today, the higher diversity in protected areas is because national parks, game reserves and wildlife management areas attract significant funds from tourism, private contributors, charity organizations and governments. These funds foster habitat protection and laws enforcement against exploitation of wildlife, thus, this is the most significant contributor to small carnivores protection because poachers are not interested in harvesting them.

In Tanzania conservation priorities for small carnivores focus on 18s of its 28 species. These species are the caracal, serval, wildcat, spotted-necked otter, African clawless otter, striped weasel, golden jackal, side-striped jackal, black-backed jackal, bat-eared fox, African civet, two spotted palm civet, servaline genet, miombo genet, Meller's mongoose, marsh mongoose, sokoke dog mongoose and Jackson's mongoose (TAWIRI, 2009).

Major challenges to biodiversity and conservation in Tanzania and sub-Saharan Africa are ongoing increased human exploitation of resources on environments and global environment change (climate change). Also food availability still determines presence of many species in various habitats (Caro, 2002). There are several challenges that have presented great unprecedentedly rapid biodiversity extinction (Petorelli *et al*., 2010). Carnivore populations suffer from habitat loss, degradation due to logging and farming, also encroachment and fragmentation (Rovero and De Luca, 2007), road kills, retaliatory killing when carnivores prey on domestic animals, depletion of their prey base (De Luca and Mpunga, 2005; Ray, 2005), inadequate management and disease (TAWIRI, 2009). However, most small carnivore species are not considered threatened (De Luca and Mpunga, 2005; IUCN Red List, 2008; TAWIRI, 2009)

The information gap on the distribution and ecology of all small carnivores in Tanzania is still large (TAWIRI, 2009). Knowledge about carnivore communities in landscapes greatly altered by humans will provide insights regarding the relative sensitivity of species to human presence and help to identify those species in greater need of conservation attention. Therefore, there is a need, to prioritize current resources and efforts to assess the distribution and ecology of small carnivores in both protected areas and unprotected areas of Tanzania.

2.2.6 Effects of habitat loss/degradation on carnivore populations

Carnivores in general are sensitive to alteration of their habitat (Blaum *et al*., 2007; Long *et al*., 2007), particularly species that are habitat specialists or that have a narrow range of species they feed on are seriously affected to changes in habitats (Rathbun, 2008). On habitat species specialist for instance, large Indian civet (*Viverra zibetha*) and crab-eating mongoose (*Herpestes urva*) have adapted to broad habitat ranges that they occur on high elevated and evergreen forests while large-spotted civet (*Viverra megaspila*); malay civet (*Viverra tangalunga*) and short tailed mongoose (*Herpestes branchyurus*) occur in lowlands and evergreen forests. On the other hand, small Indian civet (*Viverricula indica*) and Javan mongoose (*Herpestes javanicus*) occur at lower elevated habitats in Southeast Asia (Jennings, *et al*. 2011).

Major challenges to carnivore conservation are habitat degradation and clearance due to human activities (IUCN Red List 2007). In the tropical rainforest of the Western Ghats of India carnivore habitats had been fragmented due to tea, coffee and teak plantations started between 1860 and 1950 (Kumar, 2002). This type of commercial agriculture has the same impact as uncontrolled fires and wild fires (Mangas, 2008) where large extents of habitat are removed within a short period leaving little cover or food for carnivores. In Tanzania, farming along wildlife corridors and encroachment to protected areas can have a negative impact on small carnivore populations (Pettorelli *et al.*, 2010), including loss of species (Stanley, *et al*. 1998), spread of diseases to human and domestic livestock and sometime human mortality from carnivore attacks (Skuja, 2000). In the process of urban development, more carnivore habitats are lost and fragmented leaving insufficient areas to maintain viable populations of native species in the future.

The current study has been conducted in an ongoing constructional developmental activities area. The current full operating colleges were established before 2007 and the ongoing constructions of news college buildings and roads, water pipes and sewage facilities may present challenges to remaining habitats, thus threatening the existence of most small carnivore species in the area. These ongoing activities have lead to natural habitat loss, degradation and fragmentation of shrubs and small forests habitat that was once contiguity at UDOM. There is no doubt that sooner or later most species of small carnivore will be locally extirpated unless urgent and effective conservation plans are implemented.

The primary role of this study was to assess presence of small carnivores; other purpose was to gain an understanding of the ecological variables important for small carnivore survival. Thus, knowledge gain will foster administrative officials to plan strategically management and conservation priorities for small carnivores in UDOM habitats will be facilitated.

2.2.7 Use of remote cameras in carnivore studies

Many species of carnivore occur at low densities, and are nocturnal and secretive (Mudappa, 2002; Gompper *et al*., 2006). Also, many carnivore species are solitary. These characteristics pose challenges for gathering information on their behavior and ecology (Gittleman, 1989). Remote cameras have been an effective method for studying secretive and shy mammals with minimal negative effects on wildlife habitat and animal behaviour (De Luca and Mpunga, 2005; Long *et al*., 2007; Kelly *et al*., 2008). Remote cameras have been used to determine species presence/absence, occupancy, and habitat use of carnivores (Ordenana *et al.*, 2010; Jennings and Veron, 2011). Sometimes use of camera trapping alone may not be an effective method in surveying some canids such as coyote (*Canis latrans*) in forest where information on ecology, distribution and abundance is needed, for instance in New York forests; a combination of non-invasive methods such as genetic analysis of feces, track-plates and snow track surveys yielded more information that guided for conservation plans (Gompper *et al*., 2006). However, remote camera techniques has proved to be an effective non-invasive technique to assess species richness, relative abundance and distribution of carnivore species in various vegetative areas (Pettorelli *et al*., 2009), carnivore occurrence and pattern of occurrence than hair trap, track stations, and scat counts (Reed, 2011). Hair traps, trap stations and scat counts are not useful to tell species activity patterns, thus do not give information on species-habitat use. Remote camera traps may be as effective without use of lure or baits (Wilting *et al*., 2010). These usually provide information on the residence animals, so the probability of capturing individual species in its natural habitats that help to understanding the species natural adapted environment.

An advantage of most remote camera systems is their ability to document the date and time a species is photographed. Schmidt (2008) used remote cameras to document the time and date a certain carnivore species was photographed and developed activity charts for each species. Measuring carnivore activity patterns provide information on energy budgets, and seasonal and sexual differences in activity patterns (Chen *et al*., 2009). Factors that influence activity patterns include environmental changes in temperature and day length, food availability, human disturbance, predator-prey interactions and avoidance of competition (Zielinski, 1988; Schmidt, 2008; Chen *et al*., 2009). Adequate and accurate information on carnivore activity patterns can behave important management implications, especially in situations where human carnivore conflict occurs. For example, Chauhan (2006) reported that in areas where human densities were high, sloth bears were predominantly active at night; thus informing people to restrict movement at night could reduce the frequency of attacks by sloth bears. Based on available data of carnivore activity patterns; hence, these information will help in conservation and management of small carnivores, effective planning and priority decision making. These data will also promote positive considerations to conservation strategies in open and non protected areas often with large human population surrounded by small carnivore community highly rich in carnivore species. Activity data for several co-occurring carnivore species may reveal important mechanisms for avoiding competition within a small geographical area, especially if distinct differences in activity patterns among closely related species were observed.

The focus of this research was to assess the diversity and habitat relationships of small carnivores in the 6000ha area of the campus of the University of Dodoma. Furthermore, I attempted to compare the relative importance of natural and anthropogenic habitat variables to small carnivore diversity. These included variation in vegetation density (shrub) cover, distance to buildings and roads, rock outcrops and forest edges. Furthermore, activity patterns of species were determined in relation to the other to identify potential ways by which closely related species reduce competitive interactions co-existing.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the study area

Dodoma region is the capital city of Tanzania and it covers an area of 41,310 km^2, which is about 5% of the Tanzania mainland, lies at 4^o to 7^o S and 35^o – 37^o E. Dodoma has 2,083,588 inhabitants (URT, 2012). University of Dodoma is located about seven kilometers south of Dodoma, Tanzania's political capital. The Dodoma region is situated on a plateau at an average elevation of 1000m. It covers area of 6000ha (UDOM, 2007) of plateau small hills dominated by natural vegetation of savannah with thicket type or bush, which is widespread throughout the area with *Acacia-Commiphora* and *Dichrostachys* woodland in various stages of regeneration. Species of *Commiphora* and *Acacia* (*A.tortilis, A. nilotica, A. senegal*) dominate the community (URT, 2012). Google image of 2012 of the study area (Appendix 1).

The Dodoma area is semi-arid to arid with an average 600mm rainfall per annum. Dodoma Region has a savanna type of climate, which is characterized by a long dry season with persistent desiccating winds and low humidity that lasts from late April up to early December, and a short single wet season during the remaining months. Apart from the rainfall being relatively low, it is rather unpredictable in frequency and amount. Unreliable rainfall creates an unpredictable environment for native flora and fauna as well as serious constraints for the livelihood of people that depend on subsistence farming, which is the traditional source of income for most of the human population. Generally the average maximum and minimum temperatures are 31^oC and 18^oC respectively. However, temperature is always high during the day during any time of the year. This climate favors production of both drought-tolerant livestock and crops; the major crops that are grown include sorghum, millets, cassava, maize, paddy, beans, and oil-seeds (groundnuts, sunflower and castor) and grapes.

Seasonally wet areas with impeded drainage support grasses and sometimes a mixture of grasses mixed with woody plants. And regeneration of bushes, herbs and grasses form a type of induced vegetation. Most of the hill ranges, steep slopes and protected forest reserves are covered with large woody plants, which form good watershed protective covers. However in some areas the natural plant vegetation has been altered by anthropogenic factors such as crop production, livestock keeping and cutting trees for charcoal and firewood. Dodoma has a small number of wildlife diversity as compared to the northern part of Tanzania; it consist small animals that are able to survive well in dry and less vegetated area with inadequate or unpredictable water availability. The current changing climate may have significant impacts on the fauna of the area, which may favor small generalist species of Carnivora that can adapt to human presence and that progressively fragmented habitats.

Being the third region in Tanzania with the largest number of cattle, goat and sheep, Dodoma is vulnerable to habitat loss and desertification as livestock populations grow and demand larger areas for grazing and water. Thus, alteration in the habitat is likely to negatively affect populations of all native carnivores, and result in the extirpation of some species.

3.2 Materials and Methods

Objective 1. To characterize the carnivore community on the UDOM campus and assess carnivore species richness and relative abundance.

Species richness and relative abundance of carnivores at UDOM was assessed using remote-camera stations (Trailmaster®, Lenexa, Kansas) (Kucera and Barrett, 1993; Ratnayeke and van Manen, 2012). All mammalian species richness (ASR) and all carnivore species richness (CSR) were obtained by identifying the number of different individual species captured at each site using the remote cameras. Remote cameras triggered by active infrared sensors, have proved effective for studying species that are secretive and difficult to capture (Karanth, 1995; Wemmer *et al.*, 1996; Karanth and Nichols, 1998; Kelly *et al.*, 2008; TAWIRI, 2009). Also the cameras are programmable and produce high quality photographs (Pettorelli *et al.*, 2010).

The Trailmaster 1500® consists of an infrared trail monitor (transmitter, a receiver) and a camera that is triggered when the infrared beam is broken, for example when an animal passes the trail monitor. (Kucera and Barrett, 1993; TAWIRI, 2009; Ratnayeke and van Manen, 2012). The transmitter and receiver are constructed to be mounted on vertical structures such as tree trunks. Because few trees occurred in the study area, wooden stands were used to support the transmitter and receiver on smooth land surfaces. A four-foot iron stand and elastic rubber was used to support the receiver and transmitter on rough and rocky surfaces. The beam was positioned about 5-10cm above the surface to capture different sizes of target animals and to ensure that the smallest possible carnivores (dwarf mongoose) could intercept it. The distance between the transmitter and receiver was set at a distance depending on the location, nature and type of the site; in small river beds for instance the trail monitors were set on either edge of the river bank, while in shrub thickets vegetation was cleared so to prevent obstructions between the receiver and transmitter. The distance between receiver and transmitter was usually between 2-3 m to ensure that photos could be easily and clearly identified. Camera units were programmed and tested prior to placement in the field. I programmed all cameras using a 1-minute delay between pictures. I placed sensors to maximize detection of small and medium-sized carnivores by positioning the infrared beam at a height of 10–15 cm above ground level across animal trails (Ratnayeke and van Manen, 2012). Camera systems recorded an event when the infrared beam was intercepted for > 0.15 seconds.

Before camera placing in the field, a thorough survey of the area was conducted by walking through the targeted areas. Cameras were strategically placed in stream beds, gullies and existing animal trails to maximize the probability of capturing different species of carnivores, and at the same time minimize the risk of theft. Thus cameras were not placed on trails that received heavy human use. I attempted to balance sampling probability of every carnivore species as best as possible by sampling across several habitat types (forest patch interiors, edges, hill tops and stream gulleys).

Sampling design was based on Wemmer *et al.*, (1996), but adjusted for small carnivores: cameras were spaced at distances of approximately 300m apart and operated for a fixed period of 5 nights. Because the study area and amount of available habitat were relatively small, all available patches of habitat were systematically sampled. The cameras were operated for 24 hours to ensure that nocturnal, diurnal and crepuscular species were documented. Sampling was conducted from April to September 2012 and from April to May 2013.

Data analysis

Photographs of carnivores were identified to species using descriptions and photos from the literature (De Luca and Mpunga, 2005; Gaubert *et al*., 2005; Gilchrist *et al*., 2009; Jennings and Veron, 2009; Lariviere and Jennings, 2009; Wilson and Mittermeier, 2009); (TAWIRI, 2009) and internet sources. Species richness was calculated for each camera site by enumerating the total number of carnivore species detected at that site. Absolute abundance of species is difficult to measure using remote cameras because individuals cannot be distinguished most of the time. However, the number of detections of a species at a camera site can be used as a measure of relative abundance because abundant species are more likely to be detected by camera, assuming that camera placement is not biased toward any particular species. Relative abundance was calculated as the number of nights that a carnivore species was detected at a camera site. Because cameras were operated for 5 nights, relative abundances of any carnivore species ranged from 0 to a maximum of 5. The Simpson Reciprocal Index (1/D); Krebs (1989) was calculated for the total area. The Simpson Reciprocal Index was calculated from the formula below.

$$1/D = 1/ \sum P_i^2$$

P_i is the fractional (relative) abundance of the i^{th} species at a camera site, and

$\sum P_i^2$ is the sum of the fractional abundances of all species at a camera site.

Objective 2. To identify important environmental factors (natural and anthropogenic) associated with carnivore species richness.

All sampled sites were located using a Garmin Etrex Global Positioning System (GPS). I also obtained measurements of the following habitat variables: elevation, horizontal cover, and distance to the nearest rock outcrop, building, forest/thicket edge and blacktop (tarmac) road. Elevational gradients are frequently associated with species diversity or the presence/absence of individual species (e.g., Clark *et al*., 1993; Gibson *et al*., 2004; Ratnayeke *et al*., 2007). Roads or buildings are the most common types of human infrastructure and serve as an index of human activity/disturbance (Ratnayeke *et al.,* 2007; Selas *et al*., 2009). Habitat loss and fragmentation increases species' proximity to forest/thicket edges and can result in population declines and extirpation of edge-sensitive species or improved conditions for species that benefit from edge habitats (Crook, 2002), and rock outcrops are often associated with potential prey such as hyrax and rodents (EWT, 2012; Baker, 2013).

Elevation at camera sites was obtained by entering the coordinates of camera sites into Google Earth. Distances to the nearest rock outcrop were measured directly in the field using the GPS. Horizontal cover at camera sites was measured following Sahlén *et al.,* (2011). A white cylinder of 60cm height 10cm diameter was used to measure horizontal visibility at each camera site on the 5th (last) day of sampling. Subsequent to removing the camera unit, the cylinder was placed between camera receiver and transmitter. The cylinder height was selected to meet the height of the largest possible carnivore and was painted white to enhance visibility in the field. Using a compass and GPS, I then measured the minimum distance from which the cylinder was at least 95% invisible. Four such measurements of horizontal cover were taken at each site starting with a randomly selected azimuth and each subsequent measurement taken at 90^0 from the previous one. The average of the 4 measurements thus served as an inverse measure of horizontal cover; that is, the larger the mean, the less horizontal cover at the camera site. Although horizontal cover chiefly represented vegetation cover in our study area, at several sites, horizontal cover was a function of both topography (for example rock outcrops or the banks of stream gullies blocked camera visibility) and vegetation.

I ground-truthed a satellite image of the study area on Google Earth by using a GPS to record coordinates of recognizable landmarks, namely road intersections. All (N=8) landmarks lined up precisely with the same locations on the Google Earth satellite image of the study area. Distances to buildings, black top roads and forest edges were measured by entering the coordinates of camera sites into a 2012 satellite image in Google Earth and using the ruler function to measure ground distance in meters from each camera site to the nearest building, black top road, or forest/thicket edge.

Data Analysis

I used Poisson regression (Sahlén *et al.,* 2011, Ratnayeke and van Manen 2012) to evaluate the effect of one or more habitat variables (independent variables) on carnivore species richness, the dependent variable. I analyzed 9 *a priori* models based on combinations of the 6 different habitat variables and used Akaike's information criterion adjusted for small sample sizes (AIC_c: Hurvich and Tsai, 1989; Burnham and Anderson, 2002) to examine the evidence for competing models. Because there were few candidate models and few variables appeared more than once in any of the models, I did not average models, but based inference on models with the lowest AIC_c. Overdispersion is a common problem that violates Poisson regression assumptions. Overdispersion arises when there is more variability than predicted by the Poisson distribution. I compared each model's residual deviance to the Chi-square distribution on the stated degrees of freedom to test for overdispersion (Gibson *et al*., 2004). I used R (version 2.14.1; R Development Core Team 2007) statistical software to perform the Poisson regressions.

Objective 3. To assess activity patterns of small carnivore species.

Remote camera units were set for a one-minute delay between successive photographs, and also documented the time and date when a certain carnivore species was photographed. This information was used to develop activity charts for each species. I divided each 24-hour cycle into 8 time slots, each having a 3-hour interval. The number of times a species was photographed within each time interval was recorded and used as an index of activity. Thus, all carnivore photos were used.

Data Analysis

For each species, I plotted the number of observations against each time slot to examine its range of activity, identify peaks in activity, and examine the extent of interspecific overlap in periods of activity. I tested the activeness of individual species by correlating the number of observations (individual photographs) within each time slot to obtain the peak hours. Time slots with high number of photographs were considered to be the highest peak hours for that species. Thus, species activeness was a measure of highest peak within the eight time slot in 24-hours. Peak hours for different carnivore species were determined and then compared.

3.3 Validity and reliability of the results

The use of remote camera in carnivore studies has significantly increased the carnivore species inventory in many areas across the global and Tanzania in particular. In this study research active remote camera units were placed in areas more or less reached by human, that is areas with little human infrastructure and activities such as heavily used human tail, roads, buildings and farm edges (strategic placement of cameras within study sites). This aimed to avoid loss of camera units; My personal experience, cameras or any other valuable things placed in widely open areas have been stolen or sometime destroyed in many areas surrounding local communities. However in such doing might have some bias to trap carnivore species closely associated to those human structures. During the research data collection one camera unit holdings and rubber accessories were stolen, also other trap units for small carnivore were stolen. The area recently is on constructions of different colleges, thus, a lot of workers movement and activities and disturbing noises sometimes are heard; this might have biased few sites that were surveyed close to those areas at time of constructions. To avoid a lot of disturbances, cameras were placed during time of no or little interferences; each camera was regularly visited after two day during the operation time. Cameras were re-placed in sites of disturbances or interferences to make sure data obtained were not interrupted or biased. All photographs obtained were easily identified by guidance references and help from colleagues at the University of Dodoma except for few genets' photos that were not easily distinguished because of the darkness on photographs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter provides the results obtained from the analyzed study data followed by a discussion that interprets the results in context of the specific objectives of this study and the relevant broader issues in the carnivore literature

4.1 Results

4.1.1 Characteristics, species richness, and relative abundance of the carnivore community at UDOM

A total of fifty sites were sampled during the dry season: 40 sites were sampled from May to September 2012, and 10 more sites from April to May 2013 (Figure 4.0). A total of 187 photos of carnivores were obtained during 250 trap nights. Nine species of small carnivore were observed and one large carnivore, the striped hyena (*Hyaena hyaena*) was also recorded (Table 4.0). This list is probably comprehensive of the total number of carnivore species resident in UDOM habitats; cumulative species richness increased rapidly to 9 species with the first 12 sites, increased to 10 species at the 30th site (when the first striped hyena was photographed), and did not change thereafter even though 19 additional sites were sampled no (Figure 4.1).

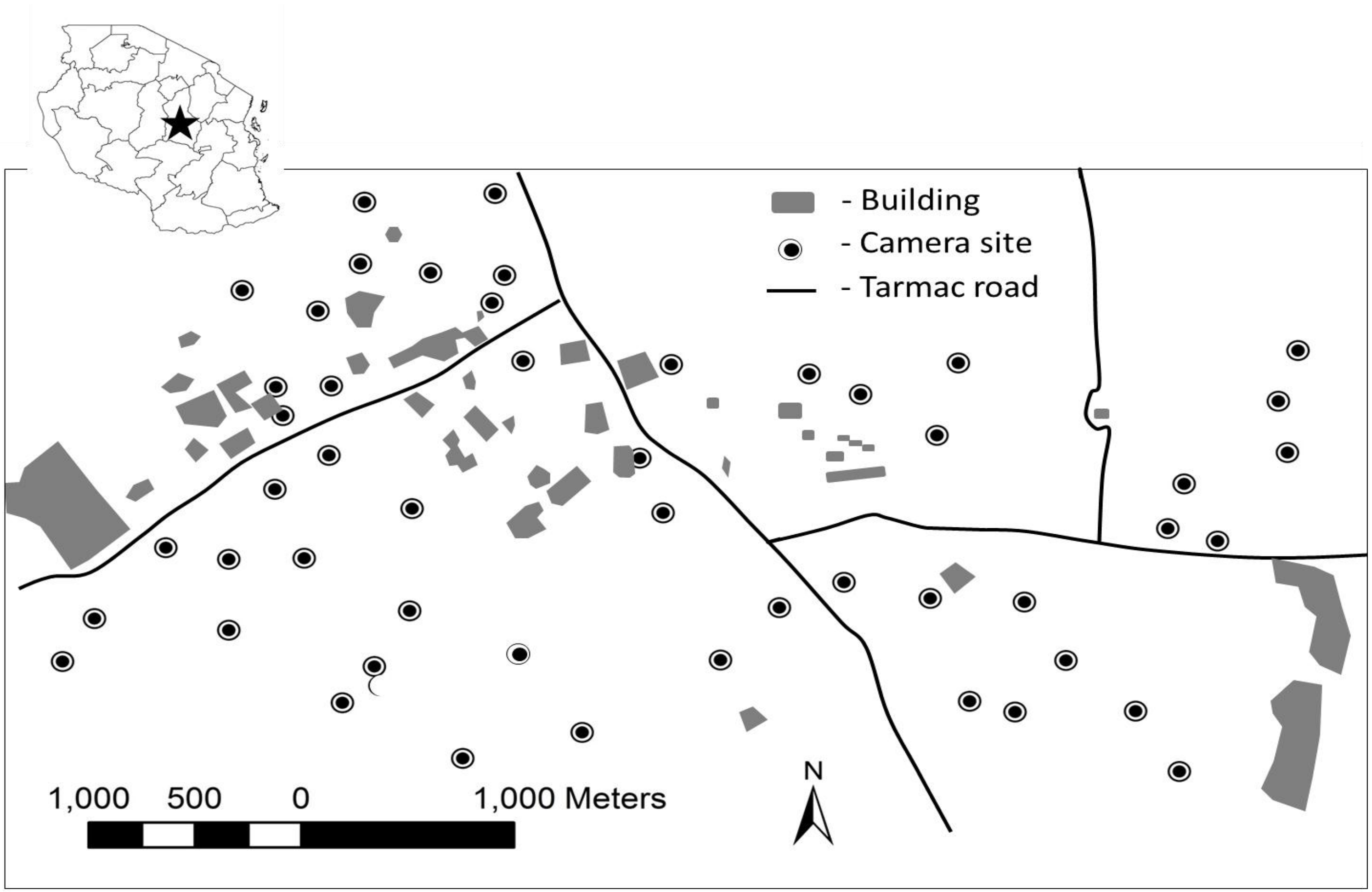

Figure. 4.0 Study sites with camera sites at UDOM, 2012-2013

Table 4.0. Carnivore species list photographed with Trailmaster active infrared cameras at 50 sites on The University of Dodoma campus.

No.	Family	Common name	Scientific name
1	Herpestidae	Bushy tailed mongoose	*Bdeogale crassicauda*
2	Herpestidae	Slender mongoose	*Galerella sanguinea*
3	Viverridae	Common genet	*Genetta genetta*
4	Viverridae	Large spotted genet	*Genetta maculata*
5	Herpestidae	Dwarf mongoose	*Helogale parvula*
6	Herpestidae	White tailed mongoose	*Ichneumia albicauda*
7	Mustelidae	Zorilla	*Ictonyx striatus*
8	Herpestidae	Banded mongoose	*Mungos mungo*
9	Hyaenidae	Striped hyaena	*Hyaena hyaena*
10	Canidae	African wildcat	*Felis silvestris*

Source: Researcher, April 2012-April 2013.

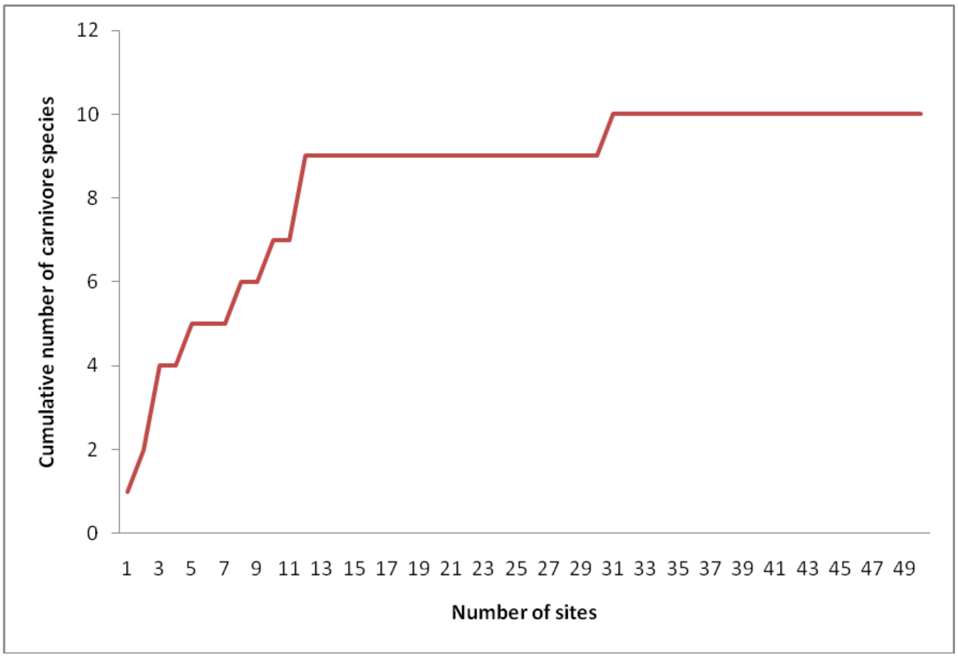

Figure. 4.1 Cumulative numbers of new species against the cumulative number of remote camera sites at The University of Dodoma, April 2012-April 2013.

Among slender mongooses photographs there was variation in coat color; few individuals species were dark brown to almost black in colour (Figure 4.2).

Figure 4.2. Variation in coat colour among slender mongooses photographed at UDOM, 2012-2013. Source: Researcher.

Mean carnivore species richness per remote camera site was 1.46 (N=50 sites, range = 0-5, SD= 0.97). The overall Simpson Reciprocal Index (1/D) across all 50 sites was 1.43. A maximum of four carnivore species at a single camera site was observed at only two sites. Other mammalian species frequently photographed were the rock Hyrax, some rodents and Elephant shrews. The mean number of mammalian species per site was 2.26 (N=50, range = 0-6, SD= 1.35).

The most frequently documented species were the genets reflecting their high relative abundance (Figure 4.3). Because genets could not always be identified to species, I combined observations for common genets and large spotted genets. The total photographs for the genets were 70 and 60% were common genets and 14.3% were large spotted genets, where the rest were not easily identified. Some photographs of Carnivora species documented at UDOM area (Appendix 2).

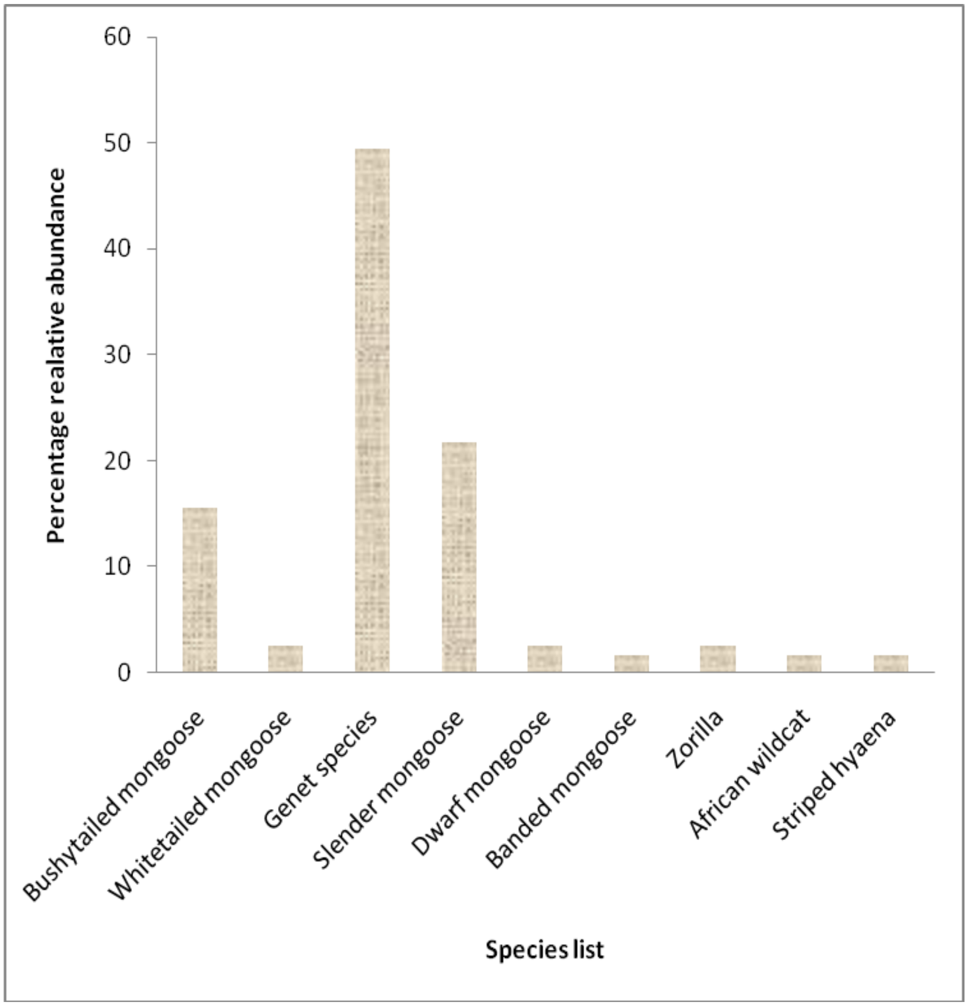

Figure .4.3 Relative abundance (number of camera nights a species was detected) of different Carnivora species expressed as a percentage, University of Dodoma, April 2012-April 2013.

4.1.2 Ecological factors (natural and anthropogenic) associated with carnivore species richness or the relative abundance of individual carnivore species.

The best Poisson regression models for the influence of habitat variables indicated that proximity to buildings and roads were the likeliest predictors of carnivore species richness (Table 4.1). Models 1 and 2 had a ΔAIC_c of less than 2 suggesting that they had equivalent support. Parameter estimates indicated that the closer a remote camera site to a building, or to a road, the greater likelihood of detecting a larger variety of carnivore species (Table 4.5) variable (a). However, for a sample size of 50 camera sites, significance levels were marginal (p = 0.03 to 0.04).

Sample sizes for genets (common genets and large-spotted genet), slender mongoose and bushy-tailed mongoose were reasonably large (species presence at $\geq$10 sites), thus I tested the influence of habitat variables on the relative abundance (number of nights the species was detected at a remote camera site) of these four species only. Differentiating between common genets and large spotted genets was not possible for several photos; thus, I treated them as a single species. Three models provided the best support for data on genets (Table 4.2), with the variables distance to forest edges, distance to buildings, and elevation included in these models. Parameter estimates indicated that genets were most likely to use low lying areas (negative parameter estimate for elevation) closer to buildings and edges of forests/thickets (Table 4.5) variable (b). However, the relationship to elevation was insignificant at the alpha = 0.05 level.

For the slender mongoose species the model that provided best predictions were three with the variables distance to roads, elevation and distance to forest edge (Table 4.3). This indicates that slender mongoose species were likely to use roads edges and low lying area (negative parameter estimates for elevation) Table 4.5 variable (c). Also, they most likely use forest interiors than closer to forest edges. The bushy-tailed mongooses found closer to forest edges and buildings (Table 4.4). However, they most likely use high elevated areas (Positive parameter estimates for elevation) Table 4.5 variable (d).

Table 4.1. Poisson regression model selection results to assess habitat variables associated with high carnivore species richness at University of Dodoma, Tanzania, 2012–2013.

Model	AIC_c [a]	ΔAIC_c [b]	AIC_c weight	*df* [c]
Carnivore Species Richness				
Distance to building	138.17	0.00	0.45	2
Distance to road	139.14	0.96	0.28	2
Distance to forest edge	141.01	2.84	0.11	3
Distance to forest edge ,distance to rock	143.16	4.99	0.04	3
Distance to forest edge, elevation	143.22	5.05	0.04	3
Distance to rock	143.30	5.13	0.04	2
Shrub cover	143.54	5.37	0.03	2
Distance to rock, shrub cover	145.55	7.37	0.01	3
Elevation, shrub cover	145.64	7.46	0.01	3

[a]Akaike's information criterion adjusted for small *n*.

[b]Difference in AIC_c compared with lowest AIC_c model.

[c]Number of model parameters.

Table.4.2. Poisson regression model selection results to assess habitat variables associated with the relative abundance (number of camera nights detected) of common genets and large-spotted genets at University of Dodoma, Tanzania, 2012–2013.

Model	AIC_c [a]	ΔAIC_c [b]	AIC_c weight	*df* [c]
Genets Relative Abundance				
Distance to forest edge, elevation	154.43	0.00	0.44	3
distance to building	156.03	1.60	0.20	2
Distance to forest edge	156.17	1.74	0.19	2
distance to forest edge ,distance to rock	157.41	2.97	0.10	3
Distance to road	159.85	5.41	0.03	2
Elevations, shrub cover	160.72	6.28	0.02	3
distance to rock	161.59	7.15	0.01	2
distance to rock, shrub cover	163.44	9.01	0.01	3
Shrub cover	163.61	9.18	0.01	2

[a]Akaike's information criterion adjusted for small *n*.

[b]Difference in AIC_c compared with lowest AIC_c model.

[c]Number of model parameters.

Table.4.3. Poisson regression model selection results to assess habitat variables associated with the relative abundance (number of camera nights detected) of slender mongoose at University of Dodoma, Tanzania, 2012–2013.

Model	AIC_c [a]	ΔAIC_c [b]	AIC_c weight	*df*
Slender mongoose Relative Abundance				
Distance to road	103.71	0.00	0.53	2
Elevation	105.44	1.73	0.22	2
Elevations, shrub cover	106.94	3.23	0.11	3
Distance to forest edge, elevation	107.65	3.94	0.07	3
distance to building	109.22	5.50	0.03	2
Shrub cover	110.86	7.15	0.02	2
distance to rock	111.76	8.05	0.01	2
Distance to forest edge	111.96	8.25	0.01	2
distance to rock, shrub cover	113.11	9.40	0.01	3
distance to forest edge ,distance to rock	113.93	10.22	0.00	3

[a]Akaike's information criterion adjusted for small *n*.

[b]Difference in AIC_c compared with lowest AIC_c model.

[c]Number of model parameters.

Table 4.4. Poisson regression model selection results to assess habitat variables associated with the relative abundance (number of camera nights detected) of bushy tailed mongoose at University of Dodoma, Tanzania, 2012–2013.

Model	AIC_c [a]	ΔAIC_c [b]	AIC_c weight	*df* [c]
Bushy-tailed mongoose RelativeAbundance				
Distance to forest edge, elevation	78.57	0.00	0.36	3
Distance to building	79.81	1.24	0.19	2
Distance to forest edge	79.93	1.36	0.18	2
Distance to forest edge ,distance to rock	82.06	3.49	0.06	3
Elevation, shrub cover	83.00	4.44	0.04	2
Shrub cover	83.14	4.57	0.04	3
Distance to road	83.95	5.38	0.02	2
Distance to rock	84.06	5.49	0.02	2
Distance to rock, shrub cover	85.24	6.67	0.01	3

[a]Akaike's information criterion adjusted for small *n*.

[b]Difference in AIC_c compared with lowest AIC_c model.

[c]Number of model parameters.

Table 4.5. Parameter estimates of Poisson regression models relating habitat variables to a) carnivore species richness, b) the relative abundance of slender mongoose, c) the relative abundance of genets, and d) the relative abundance of bushy-tailed mongoose.

Variable	Parameter estimate	Standard error	z value	P
a) Carnivore species richness				
Intercept	0.8192	0.2155	3.801	0.0001
Distance to building	-0.0012	0.0005	-2.228	0.0259
Distance to road	-0.0009	0.0004	-2.012	0.0442
b) Relative abundance of genets				
Intercept	8.1067	4.1527	1.952	0.0509
Distance to forest edge	-0.0028	0.0012	-2.315	0.0127
Elevation	-0.0059	0.0033	-1.814	0.0697
Distance to building	-0.0017	0.0006	-2.565	0.0103
c) Relative abundance of slender mongoose				
Intercept	0.1466	0.3361	0.436	0.6627
Distance to road	-0.0025	0.0010	-2.495	0.0126
Elevation	-0.0125	0.0060	-2.087	0.0368
Distance to forest edge	0.0003	0.0014	0.244	0.8076
d) Relative abundance of bushy-tailed mongoose				
Intercept	-9.7792	4.5280	-2.160	0.0308
Distance to forest edge	-0.0058	0.0028	-2.001	0.0454
Elevation	0.0073	0.0035	2.072	0.0382
Distance to building	-0.0002	0.0013	-1.850	0.0642

4.1.3 Assessment of activity patterns of small carnivore species at university of Dodoma habitats.

The dates and times at which carnivore species were detected by remote camera were summarized by dividing each 24-hour cycle into eight time slots and recording the number of times the species was photographed per time slots. The results were presented in percentage of number of individual species photographs obtained within each slot for 24 hrs cycle for all 50 sites (Figure 4.4).

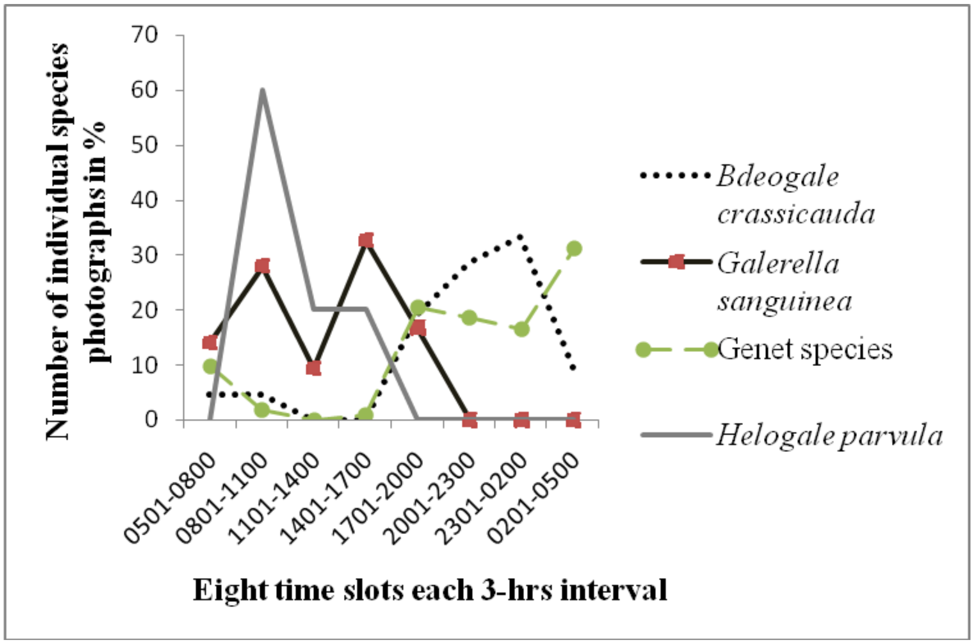

Figure 4.4 Variation in peaks of activity among five small carnivore species at University of Dodoma 2012-2013. Source: Researcher.

Bushy tailed mongooses and white tailed mongooses were recorded at nights; genet species were mostly recorded at night but in a few cases they were observed early in the morning. Slender mongooses were frequently recorded during the day with activity peaks between 0800 – 1100 hrs and 1400-1700 hrs, although data were limited for banded mongooses and dwarf mongooses, these species were documented by cameras only during daylight hours, and mostly before noon (Table 4.6).

Table 4.6. Carnivore species activity patterns in 8 time slots within 24-hrs cycle for 50 sites shown in percentage of number of photographs during 2012-2013 study at UDOM.

Species	Time of occurrence at camera site in %							
	0501-0800	0801-1100	1101-1400	1401-1700	1701-2000	2001-2300	2301-0200	0201-0500
Bdeogale crassicauda	4.76	4.76	0	0	19.05	28.57	33.33	9.52
Galerella sanguinea	13.95	27.91	9.3	32.56	16.28	0	0	0
Genet species	9.8	1.96	0	0.98	20.59	18.63	16.67	31.37
Helogale parvula	0	60	20	20	0	0	0	0
Ichneumia albicauda	0	0	0	0	0	100	0	0
Ictonyx striatus	0	0	0	0	0	100	0	0
Mungos mungo	0	100	0	0	0	0	0	0
Hyaena hyaena	0	50	0	0	0	50	0	0
Felis silvestris	50	0	50	0	0	0	0	0

Source: Researcher.

Although sample sizes for dwarf mongoose were small (N = 5), activity is displayed to provide a comparison with the strongly diurnal slender mongoose (*Galerella sanguinea*).

4.2 Discussion

4.2.1 Carnivore species richness and relative abundances.

The carnivore community in this study was dominated by small Carnivora species; only one large carnivore, the striped hyaena (*Hyaena hyaena)*, was recorded on two occasions, suggesting that individuals may not be residential, but commute on occasion to UDOM areas. Four species such as the common genet (*Genetta genetta*), large spotted genet (*Genetta maculata*), slender mongoose (*Galerella sanguinea*) and bushy-tailed mongoose (*Bdeogale crassicauda*) were frequently documented, reflecting greater relative abundances. Thus these species are likely to tolerate or even benefit from human presence (human commensals). It is possible that most of the Carnivora species that have been documented in this study are attracted to food waste in urban areas, or to rodent or other prey populations that thrive in human settlements.

Species coat colour variation was observed among the slender mongoose; Photos of African wildcat (*Felis silvetris*) in this study may actually be domestic cats with the coat colour and pattern resembling F. *sylvetris*; the species may be difficult to identify in the field particularly because coat colour and general appearance to domestic cats are similar and hybridization with domestic cats is common, (TAWIRI, 2009). The African wildcat tends to have more pale tawny brown in its coat, faint stripes and spots, and longer legs than domestic cats, suggesting that the photos we attributed to *F. sylvestris* are correctly identified. I could not clearly distinguish common genets from rusty spotted genets in about 30 percent of the genets photographs trapped. Generally, the common genet is distinguishable from the large spotted genet by the presence of a distinct black dorsal crest, dark brown spots, and white rings and black mark on the white tipped tail, black mark on back of hind limbs; however, confusion between the two species of genet is likely common to happen in identifying unclear photographs (TAWIRI 2009).

In the past 6-7 years the University of Dodoma area has undergone much change in terms of reduction of natural habitats due to roads and buildings constructions. According to island biogeography model, species richness may decrease (species extinction rate increase) as an area of large habitat shrinks in size or is broken up into smaller patches through fragmentation (Primack 2010). Small carnivore populations may be highly affected by habitat destruction and fragmentation; however, this may not be true as some species could adapt very well and survive longer beyond extinctions predictions. This study has documented only about 29% of all Carnivora species currently present in Tanzania which is about 50% less than Udzungwa mountains national park (De Luca and Mpunga, 2005).

4.2.2 Ecological influences on small carnivore species richness and relative abundances

Overall carnivore species richness was greater closest to buildings and roads. On the other hand rock out crops and shrub cover has shown low correlation and seem as not good predictors of carnivore species richness in this study. Measures of carnivore species richness at any one camera site were likely influenced by the most abundant species in the area (genets, slender mongoose and bushy tailed mongoose). These four species are likely adapted to human altered habitats and possibly thrive by foraging on dead (animal kills) along roads, garbage from buildings and greater rodent or insect prey (e.g., insects attracted to lights) around students hostels, staffs residences and offices. Moreover, carnivores can forage on garbage around buildings, heavily used human trails and along roads. Furthermore, buildings and roadsides are sources of gray water that are a critical resource for animals during the extended dry season in Dodoma.

Different studies have shown that vegetation, forest areas and mountain areas are strong predictors of carnivore species richness because of shelter, high probability of prey availability, safe environment for denning and raising new ones. (De Luca and Mpunga, 2005; Nelson *et al*., 2007; Pettorelli *et al*., 2009; Wilting *et al*., 2010). Small carnivores have been adaptable to medium shrub cover; *Blaum et al.*, (2007b) described shrub cover between 10%-18% to be most suitable for small carnivore species. On the other hand, some studies in North America have shown that small carnivores (e.g. coyotes) are found closer to human settlements (Gompper, 2002; Ordenona *et al*., 2010).

However, there is still a large information gap, because few studies have been carried out in urban areas where human development activities are many and operating at full scale.

Lack of strong habitat predictors for the listed small Carnivora species indicate that, UDOM study area carnivore community consists of habitat generalists that seem to benefit from human presence. For the four species, the common genets, large spotted genet, slender mongoose and bushy-tailed mongoose seem to be slightly habitats specialist. Genets and bushy tailed mongoose are likely found in slightly elevated forest edges habitats while slender mongoose are more adapted to building in slightly elevated areas. Thus, their species richness and relative abundance is much higher than the rest because they have adapted better to these UDOM habitats. On the other hand, fire burning during farm preparation in dry seasons and charcoal making activities (few poor people around UDOM community depend on charcoal sell to run their families) local hunting of prey species around UDOM nearby communities mighty has reduced the carnivore and prey species to interior and peripheral areas; thus these activities can justify fewer carnivore species in those areas than closer to buildings where such actives are not common.

Although there was no habitat variable that was a strong predictor of the small carnivore species richness in this study, there are still other unmeasured variables that could explain species richness better. These include variation in food availability in wet and dry seasons, vegetation (trees or shrubs) diversity and canopy cover (Fitzherbert *et al*., 2007), prey distribution and availability and percentage of vegetation cover (Crooks, 2002). Also, the influence of regenerating shrub and forest may be strong predictors of current carnivore species richness in UDOM habitats.

4.2.3 Co-existence of small carnivore species within University of Dodoma habitats

Dwarf mongoose (*Helogale parvula*) and slender mongoose (*Galerella sanguinea*) were observed to be active during the day peak with hours between 0801-1100 and 1401-1700 respectively. However, bushy-tailed mongoose and genet species were mostly active during night with peak hours between 2301-0200 and 0201-0500 respectively. The peak hours indicate crucial time for the individual species to access food, mates and for reproduction and social company for social species of mongooses.

Mongooses are diurnal (Blaum *et al.*, 2007b; Gilchrist *et al*., 2010), genets on the other hand are nocturnal (Jennings and Veron, 2009). Diurnal species have great visual ability than nocturnal species, thus can compete with the rest of species (Gilchrist *et al*., 2010). Mongooses can feed on a range of food items than genets and other small carnivore species; therefore, difference in active time for hunting and food searching is necessary to reduce competition for species that have the same habitats. Thus, there may be differences in diet for species with similar activity or they may not be competing for food and other resources; as a result little resources partitioning may be evident.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research was the first to document the presence of ten Carnivora species currently found at these UDOM fragmenting habitats since the commencing of the university. Most abundant species were the genets, slender mongoose and bushy-tailed mongoose. Carnivore species richness was greatest near building, roads and forest edge than to rock outcrops. Common genets (*Genetta genetta)* were much abundant 60% than the large spotted genets (*Genetta maculata*) 14% thus; *G. genetta* may be more adapted to human dominated habitats than the later.

Carnivora species richness in this study is much lower than documented for national parks and protected areas in Tanzania (include references); this may be a consequence of habitat loss, degradation and fragmentation that isolates populations and results in the extirpation of species that cannot adapt to fragmented landscapes and the accompanying human disturbance. This study has identified small carnivore species that have been able to adjust to human altered environments, or may benefit from the presence of human populations.

Species coexistence in the UDOM study area indicates small carnivore species may reduce interspecific competition through variation in activity patterns. However, inability to separate genet species and small data sets for many species limits inference. The genets, bushy-tailed mongoose and white tailed mongoose have shown to be nocturnal while other have been actively during the day still occasionally have been documented at nights.

Conservation concerns for most of small carnivore species photographed in this study are currently reported as not threatened or of least concern. Again being at these states may facilitate fast extinction in local-urbanizing areas where conservation management is not much enforced as in protected areas. Therefore, conservation priorities in national parks alone while neglecting unprotected areas including human dominated environments will facilitate rapid extirpation of valuable species that still inhabit those areas. A new conservation paradigm may serve a better future for wildlife animals.

5.2 Recommendations

Documenting only species present, relative abundance and species co-existence does not provide solutions to future challenges, thus this need to be addressed in future researches. Such challenges for instance include type of interactions existing, food and habitat selection among species, and continuing habitat loss and fragmentation due to constructions. Human populations are increasing within Dodoma and the UDOM area. Thus, future research should determine the nature of the small carnivore species co-existence at the University of Dodoma natural habitats. Future researches needs to determine information on resource availability and partitioning among individual species, ecological factors relating to existing species, and individual species home ranges.

The community awareness of conservation particularly of small Carnivora species and their habitats are still doubtful. Local communities still use UDOM areas to fetch firewood and charcoal; these activities degrade habitats as well as threaten wild animals that still persist within the environment. Community based education programs should be initiated that will integrate both the UDOM community and surrounding communities on conservation.

5.3 Areas for further research

More areas need to be addressed in future research to fill the information gap on these small carnivore populations at UDOM habitats. Future research should focus on the following

I. To determine carnivore space and resource use

II. To determine type, nature and extent of interspecific and intraspecific competition of small carnivore communities at UDOM.

III. To examine the nature of association of small carnivores with human dominated habitats or settlements.

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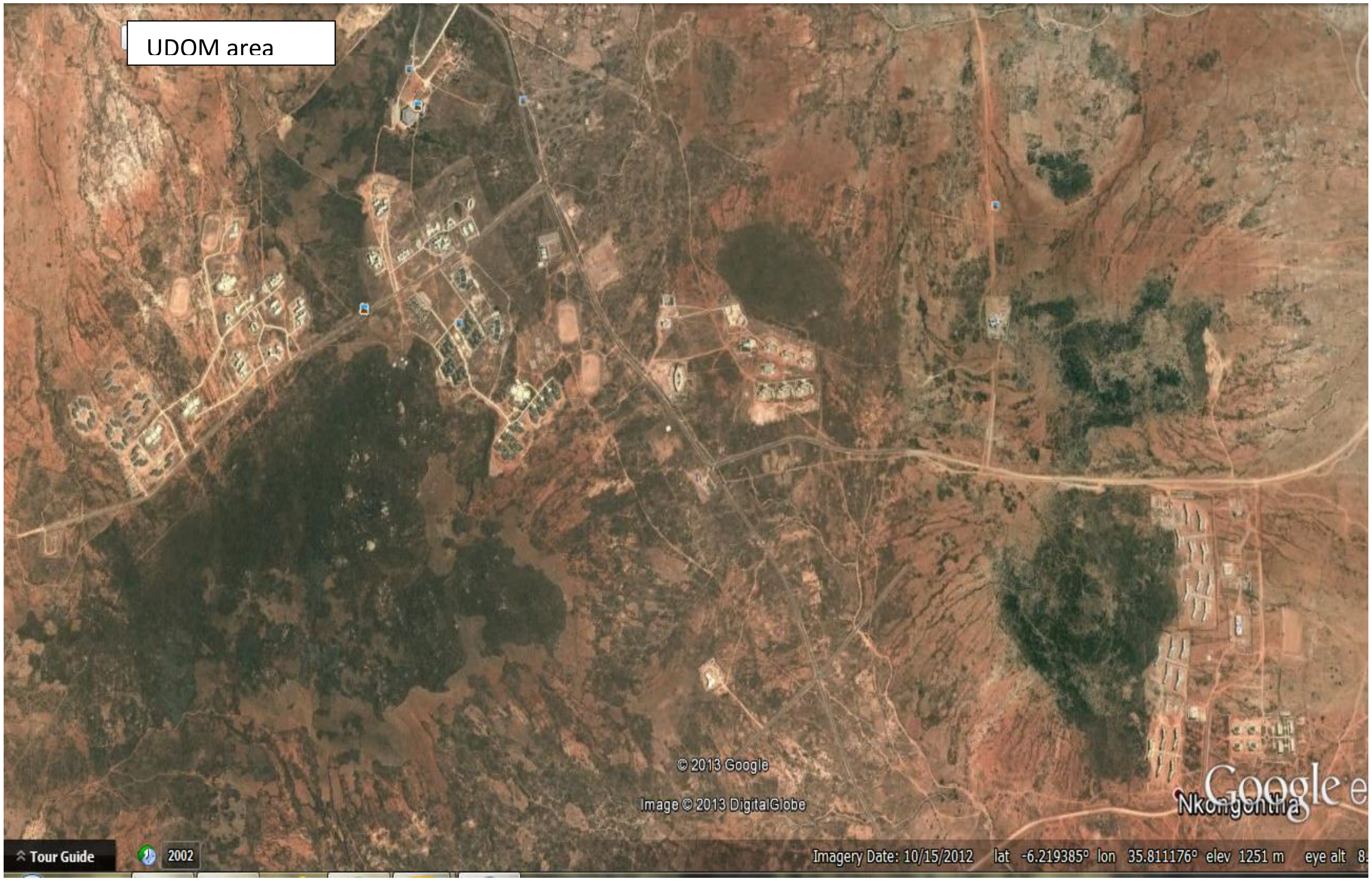
APPENDIX 1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APPENDIX 2

Carnivores photographs trapped at UDOM 2012-2013.

Genetta maculata***: Picture by Mwiyoha, B.D. 2013***

Genetta genetta: Picture by Mwiyoha, BD. 2013

Mungos mungo: Picture by Mwiyoha, B.D. 2013

Bdeogale crassicauda: Picture by Mwiyoha, B.D. 2013

APPENDIX 2

Carnivores photographs trapped at UDOM 2012-2013.

Helogale parvula*: **Picture by Mwiyoha, B.D. 2013***

Galerella sanguinea*: **Picture by Mwiyoha, B.D. 2013***

Ichneumia albicauda*: **Picture by Mwiyoha, B.D. 2013***

Ictonyx striatus: Picture by Mwiyoha, B.D. 2013

APPENDIX 2

Carnivores photographs trapped at UDOM 2012-2013

Felis sylvestris: Picture by Mwiyoha, B.D. 2013

Hyaena hyaena: Picture by Mwiyoha, B.D. 2013