ABUNDANCE AND SPECIES RICHNESS OF SMALL TO MEDIUM-SIZED MAMMALS ALONG A GRADIENT OF HUMAN DISTURBANCE AT MAU FOREST COMPLEX, KENYA

BY

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SEPTEMBER, 2023

DECLARATION

Declaration by the Candidate

I declare this thesis is my original work and has not been submitted for any academic award in any institution, and shall not be reproduced in part or full or any format without prior written permission from the author and the University of Eldoret.

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DEDICATION

To my late mother, Rose Opar, and my late father, Joab Opar, who departed too soon, sooner than I would have expected, I dedicate this work.

To my Siblings, Grace, Millicent, Richard, and Felix, for their support, encouragement, and occasionally unrelenting trouble, to them, I dedicate this work

ABSTRACT

Anthropogenic influence on biodiversity results from the burgeoning human population and the associated human agricultural and infrastructural needs. The Mau Forest Complex (MFC) is a biodiversity hotspot, however, species are predicted to be declining at unprecedented rates due to the loss of habitats. Using camera traps, this study investigated the abundance and species richness of non-volant small to medium-sized mammals (including small carnivores) along a gradient of human disturbance of three treatments (adjacent farmlands – AFs, secondary forest – SFs, and primary forest – PFs) at the Transmara and Maasai Mau forest blocks of the MFC. Mammals were recorded at 181 camera-trap locations from 246 camera deployments and 5,509 sampling days. From 302,997 images, 47,345 were of wildlife species. A total of 53 species belonging to 8 mammal orders were recorded, with 20 species belonging to the order Carnivora representing seven families. Additionally, 15 species of the order Artiodactyla, 1 species of Lagomorpha, 1 species of Hyracoidea, 1 species of Proboscidea, 9 species of Rodentia, 7 species of Primates and 1 species of Tubulidentata were recorded. While Alpha diversity, as measured by Shannon's entropy, was not significantly different between Transmara and Maasai Mau forest blocks ($P > 0.05$), it differed significantly among treatments, with AFs showing lower diversity than both PFs and SFs, and the former having significantly higher diversity than the latter at both forest blocks. Beta diversity differed significantly between primary and secondary forests (df = 1, $P < 0.05$), primary forests and adjacent farmlands, and adjacent farmlands and secondary forests, and this trend was the same for the two forest blocks. In terms of occupancy of small carnivores, overall occupancy (mean ψ) was highest in PFs and least in AFs. At the individual species level, Jackson's mongoose (*Bdeogale jacksoni*), a known forest specialist, had the highest occupancy in PFs and the least in AFs. Detection rates for various functional groups were similar across treatments for Afrotherians, Carnivora, and small rodents but differed significantly for large rodents, primates, and ungulates. This study demonstrates the adverse negative influence of anthropogenic disturbance on the persistence of a range of small to medium-sized mammalian communities at the Mau Forest Complex, with different species and functional groups responding differently to human land-use practices. Particularly important is that the less-disturbed primary forests supported more habitat specialists or forest-dependent mammals and should be preserved to support overall and forest specialist species richness.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AI	Artificial Intelligence
AIC	Akaike’s Information Criterion
AF	Adjacent farmlands
GIS	Geographic Information System
GPS	Global Positioning System
IDH	Intermediate Disturbance Hypothesis
IUCN	International Union for Conservation of Nature
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
MFC	Mau Forest Complex
PF	Primary Forests
SF	Secondary Forests
WI	Wildlife Insight
WRTI	Wildlife Research and Training Institute

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A mission of this magnitude would have been more daunting than it was if my friends Brian Otiego and Alphonse Onyango had not have volunteered countlessly and relentlessly to take me to the field. I would be careless to assume it was ordinary to spend several nights camping inside the Mau Forest and the fears associated with it to be normal. I cannot forget the continuous working days inside the forest, the heavy KWS bags “44” on our backs, the rugged and hilly terrains we traversed, and the occasional misunderstandings when other research team members claimed we were overdoing research. The day we ran “quicker than Usain Bolt” evading the Transmara elephants. This team is the best research team I’ve ever worked with, I am forever grateful for their support.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Biodiversity loss is one of the most critical current environmental problems, threatening valuable ecosystem services and human well-being (Ceballos *et al.,* 2010; Barnosky *et al.,* 2011; Mace *et al.,* 2012). Globally, rapid habitat loss due to human-induced factors is a major driver behind the current unprecedented loss or decline of many species (Schipper *et al.*, 2008, Crooks *et al.*, 2011).

In Kenya, the human population has been increasing rapidly (KNBS 2010), prompting people to settle closer to, or within, protected areas and forests, and consequently creating challenges for conserving these ecosystems and associated biological resources through agricultural expansion, human settlements, selective logging, and infrastructure development. Such activities hamper conservation efforts while escalating the reduction of critical, yet under-valued biodiversity and ecosystem services. This has led to extreme declines in wildlife numbers across the country (Ogutu *et al*., 2011).

Kenya is a megadiverse country with >400 known mammals (Musila *et al.,* 2019), representing approximately one-third of the 1,116 mammal species recorded in Africa (Butynski *et al.,* 2013; Kingdon *et al.,* 2013). However, for many mammal groups, especially small to medium-sized mammals, systematic surveys to understand their distribution, abundance, and ecological roles are rudimentary, hampering the implementation of appropriate management and conservation strategies. The imminent anthropogenic threats posed to biodiversity in Kenya paired with the exceptionally high number of mammal species, many of which are yet to be described, (Fisher *et al.,* 2018) highlight the need for urgent scientific attention if vulnerable ecosystems like the MFC are to be understood before they are all but lost. However, the fieldwork necessary for data collection to appropriately direct conservation is often limited by the time and availability of observers. Camera traps are a solution that enables continuous sampling in difficult-to-access areas, increasingly being used to study wildlife behaviour, and conduct estimations of populations and richness of elusive, rare, and nocturnal species (Long *et al.,* 2008; Tobler *et al.,* 2008; O'Connell *et al.,* 2011; Rovero *et al.,* 2013; Rovero *et al.,* 2014). The increasing number of systematic camera-trapping surveys that generate spatial data (e.g., Wells *et al*., 2004, Belden *et al*., 2007, Cheyne *et al.,* 2010a, Mathai *et al*., 2010, Wilting *et al*., 2010, Brodie and Giordano 2011, Matsubayashi *et al*., 2011), opportunistic sightings (Boonratana and Sharma 1997, Bennett 2014), and targeted samples (Colón 2002, Nakashima *et al.,* 2013) have begun to narrow information gaps for the management and conservation of rare but threatened biodiversity, especially in difficult terrains.

The Mau Forest Complex (MFC) is Kenya's largest closed-canopy forest ecosystem and the single most important water catchment in the Rift Valley and western Kenya. The forest consists of multiple forest blocks (Fig. 1) and provides several critical ecological services nationally and regionally in East Africa, which include; reducing soil erosion, reducing soil siltation, water purification, water storage, river flow regulation, mitigation of floods, groundwater recharge, climate regulation, and biodiversity conservation, among others. Apart from the Ogiek (a minority group of indigenous forest dwellers), the MFC also supports the livelihoods of millions of local communities through tourism, agriculture, and energy.

The MFC is an essential component of the Mara-Serengeti ecosystem that supports countless wildlife species, most rivers forming the Mara River originate from the MFC, and the river supports countless species and livelihoods. Yet, the forest has been and continues to be degraded through irregular and ill-planned human settlements arising from forest excisions and human encroachment (Mutugi and Kiiru, 2015). The resultant effects are uncontrolled and illegal forest resource extraction, forest clearance, land transformation, and conversion to farms. Whilst concerted efforts are geared towards restoring this important ecosystem to curb the alarming rates of destruction, knowledge based on scientific research such as the abundance, species richness and status of extant native flora and fauna remains limited for the MFC. Moreover, the difficulty of conducting research in the MFC cannot be gainsaid, the difficult terrain, acquisition of access rights since different sections are under different management, and hostile wildlife species among other challenges are hampering wildlife surveys in the forest.

Using camera traps, this study investigated extant small and medium-sized mammal species along a gradient of human disturbance at the MFC, an extremely fragmented closed-canopy forest ecosystem in Kenya. Human disturbance here refers to the conversion of natural habitat to human use, which includes livestock grazing, crop farming, illegal tree falling for timber and cedar posts harvesting, and illegal charcoal burning, among other human-induced disturbances. This study fulfils many vital gaps in the knowledge of the abundance and species richness of small to medium-sized mammals at the MFC, Kenya.

1.2 Why the study was carried out at the Mau Forest Complex (MFC)

Globally, only 12.2% of land is under nominal protection (Chape *et al.,* 2005), out of which 5.8% is strictly protected (Jenkins and Joppa, 2009). Therefore, chunks of land and natural habitats remain undesignated under formal governmental and/or alternative management regimes. Protection of these lands for biodiversity may vary, making such places vulnerable to destruction depending on the decisions and priorities of the individuals and organizations responsible for conserving them. Most attention is given to the affected habitats, with the species using the habitat getting little or no conservation attention. Therefore, this study focused on determining the contribution of different treatments resulting from degrees of human-induced habitat alteration, namely, secondary forest, primary forest, and adjacent farmlands, on the abundance and species richness of small to medium size mammals.

Protected areas can be useful reservoirs of biodiversity (Watson *et al.*, 2014), especially the pristine, undisturbed natural forests found in some sections of the Mau Forest Complex, hence maintaining essential ecosystem processes and services for a myriad of species (Watson *et al.*, 2014), preventing the destruction of ecological communities (Laurance *et al.*, 2012) and reducing risks to species extinction (Karanth *et al.*, 2010). With >400 known mammal species in Kenya, comprehensive biodiversity surveys using current cutting-edge scientific techniques within and around protected areas could potentially yield additional undocumented species, information on extant species (such as the taxonomic status of small mammals), and clarify their ranges in Kenya and the region.

Anthropogenic modification of the Earth's ecosystems is responsible for unprecedented declines and extinction of species (Dirzo *et al.*, 2014). Therefore, the basis of this research conducted at the Mau Forest complex (MFC) was precipitated by the unprecedented habitat modification and land-use changes as a result of human activities affecting resident species (Swart, 2016). Specifically, the region has seen increases in human population demands such as land for subsistence agriculture and settlement, among others. This activity alone could affect habitat availability for many species, although data on individual species' responses to land conversion are lacking for the MFC. Furthermore, human encroachment into wetlands has resulted in extensive deforestation of the catchment, wetland destruction, and habitat fragmentation. The implications of these types of habitat alterations are unknown for small to medium-sized mammals, including the carnivores in the MFC.

The effects of these anthropogenic modifications are slowly taking a toll, as is anecdotally evident from the declining numbers of resident species such as the African Golden Cat at the MFC, alterations to rivers, including reduced discharges during periods of low flows and pollution from point and non-point sources further supports lasting impacts of human disturbance on the MFC (Kenya Forests Working Group [KFWG], 2001; Baldyga *et al.*, 2007).

Understanding and predicting how species respond to threatening processes and conservation actions depends on information on species' ecological traits (Hayward *et* *al.,* 2006), and habitat use (Blouin-Demers and Weatherhead, 2001). Therefore, a study aimed at estimating the diversity (abundance and species richness) of small to medium-sized mammals amidst anthropogenic disturbance in primary forests, secondary forests, and adjacent farmlands was conducted at the Mau Forest Complex. The resulting information forms the scientific basis for management actions for conserving small to medium-sized mammals at the MFC.

1.3 Statement of the Problem

Due to human activities that lead to habitat loss, degradation, and fragmentation of natural habitats such as forests, many wildlife species are declining at unprecedented rates. Habitat destruction and degradation have led to the alteration of natural ecosystems, which is the current leading threat to global biodiversity (Schipper *et al.,* 2008). Among the species that are likely to face such threats are the small to medium-sized mammals of the Mau Forest Complex (MFC) since the forest is highly encroached, degraded, and fragmented. Notwithstanding the emerging importance of decentralization as an approach to forest management in the developing world (Agarwal and Gupta, 2005), there is insufficient information about the biodiversity value of such lands, including the small and medium-sized mammals that persist in the MFC. The decline of some species can be slowed through conservation measures such as habitat preservation *in situ*. Still, such measures require data on extant species and their biology, status, and biogeography. Such data is anecdotal at best or absent altogether for the MFC.

Africa's small carnivores are poorly known (Do Linh San *et al*., 2013). This is thought to be a result of more attention being given to relatively larger carnivores (Brooke et al. 2014; Do Linh San *et al.* 2022). However, such small carnivores may be of great importance to the ecosystem, through the balancing of herbivore populations, seed dispersal, controlling agricultural pests, and augmenting the overall diversity of mammals (Do Linh San *et al.* 2022). Despite their importance, small carnivores and other small and medium-sized mammals have received little conservation attention and remain among the least-known groups of higher vertebrates at the Mau Forest Complex. Further, there is a dearth of information on the impacts of the ongoing forest destruction at the MFC on small carnivores and other small to medium-sized mammals. Threats to carnivores (larger and smaller ones) vary among species and populations but largely revolve around habitat loss and human encroachment on their habitats and protected areas (Riggio *et al.,* 2013; Ripple *et al.,* 2014; Watson *et al.,* 2015). With the rising human population, the growing demand for food, human settlement, and assorted needs has led and continues, to contribute to the conversion and alteration of most forest land to other land uses, including farmlands (Mutugi and Kiiru, 2015). Conservation of biodiversity in increasingly human-dominated landscapes requires specific knowledge of extant species and their potential ecological responses to modified habitats. In the face of human pressures, the Mau Forest Complex is predicted to support a high diversity of small to medium-sized mammals but little is known of the extant species and how they may be affected by continuing human impacts on the forests.

1.4 Significance of the Study

In Kenya, inordinate research efforts and funding are channelled towards the charismatic megafauna, including large carnivores such as lions, leopards, and cheetahs, this trend is consistent in Africa as well according to Lindsey *et al.*, (2017). Moreover, according to Costello *et al.,* (2013), and Donaldson *et al.,* (2017) the knowledge gaps in megafauna ecology are relatively thin cracks compared with the chasms of knowledge that exist for the vast majority of species. Yet small and medium-sized mammals, including small carnivores, may play distinct and important ecological roles in ecosystems (Waser 1980, Do Linh San *et al.* 2022, Marneweck *et al.* 2022).

Given the current species extinction rates (Dirzo *et al.*, 2014), evidence-based policies to conserve at-risk species are urgently needed. Information on extant species in a given area is therefore vital for informing conservation actions, allowing scientists to evaluate how individuals and populations respond to habitat loss, climate change, and other threats. This study documented the abundance and species richness of small to medium-sized mammals along a gradient of human disturbance in the Mau Forest Complex (MFC), Kenya. This information is necessary as a scientific basis for underpinning conservation actions for small carnivores (mesocarnivores), other small to medium-sized mammals, and other fauna, and their imperilled forest habitat at the MFC.

1.5 Objectives and Hypotheses

1.5.1 Main Objective

To determine the abundance and species richness of small to medium-sized mammals along a gradient of human disturbance at the Mau Forest complex.

1.5.2 Specific objectives and Hypotheses

i) To determine the impacts of anthropogenic disturbance on the abundance and species richness of small to medium-sized mammals at the Mau Forest Complex, Kenya

Null Hypothesis (H_o): No differences exist in alpha or beta diversity of small to medium-sized mammals across different levels of anthropogenic disturbance at the Mau Forest Complex.

Alternative Hypothesis 1 (H_{A1}): Alpha diversity differs in response to anthropogenic disturbance at the Mau Forest Complex, with the secondary forest predicted to have the highest species diversity due to the intermediate disturbance hypothesis (Connell, 1978; Wilkinson 1999)

Alternative Hypothesis 2 (H_{A2}): Beta diversity differs across levels of anthropogenic disturbance, with particular treatments differing in their overall mammal community composition due to the loss of forest-dependent species as forest cover decreases.

Alternative Hypothesis 3(H_{A3}): Alpha and beta diversities differ between Maasai Mau and Transmara forest blocks due to differential management practices, community use, and histories of these two isolated forest patches.

ii) To determine the impacts of anthropogenic disturbance on the occupancy and relative abundance of small carnivores at the Mau Forest Complex.

Null Hypothesis (H_o): No significant differences exist in the relative abundance or occupancy of small carnivores across the anthropogenic disturbance gradient at the Mau Forest Complex.

Alternative Hypothesis 1 (H_{B1}): Significant differences are reflected in the relative abundance of small carnivores across the anthropogenic disturbance gradient at the Mau Forest Complex, with forest-dependent species demonstrating higher relative abundance in the primary forest than in either secondary forests or cultivated areas.

Alternative Hypothesis 2 (H_{B2}): Detection probabilities and occupancy estimates differ across the disturbance gradient due to small carnivores' preferences for various habitat types.

iii) To examine how pre-defined mammalian functional groups respond differently to anthropogenic disturbance across the three treatments: primary forest, secondary forest, and cultivated habitats.

Null Hypothesis (H_o): Functional groups do not show significant differences in detection rates (count/day) across the three treatments.

Alternative Hypothesis (H_{C1}): Functional groups exhibit different detection rates across the three treatments, with groups dominated by forest-dwelling species (e.g., primates and ungulates) maintaining higher detection rates in more forested habitats.

CHAPTER TWO

LITERATURE REVIEW

2.1 Classification of Mammals according to size

Mammals range in body size, from African pygmy mice (*Mus minutoides*) weighing 3 grams to the blue whale (*Balaenoptera musculus*) weighing up to 160,000 kilograms (Hashim and Mahgoub, 2008). They are classified according to their body size as small, medium, and large-sized mammals.

However, different orders of mammals can also be classified differently as either small, medium, or large mammals. While a study by Francis and Barrett (2008) used body size as a parameter to categorize mammals as medium (between 2-15 kilograms) and large-sized mammals (weighing more than 15 kilograms) other works of literature use varied sizes to give different definitions with variances. For example, according to Do Linh San *et al*., 2022 small carnivores are defined as members of the mammalian Order Carnivora with a body mass < 21.5 kg. Differently, Order Artiodactayla, family Bovidae, consists of species ranging in size from the 3-kilogram (kg) royal antelope to the 1200-kg gaur, hence are different categorizations.

2.2 Geographical distribution of small and medium-sized mammals

Small and medium-sized mammals are widely distributed because they are highly adaptive animals (Scott *et al.,* 1987). However, small mammals and some large mammals are rarely observed, with limited information available on their range distribution and diversity in East Africa (Kingdon *et al.,* 1977 vols. I-IIID). This can be attributed to their cryptic, concealed, and non-charismatic nature (Oguge, 2004).

Moreover, there exists a clear-cut distribution of small and medium-sized mammals across the world. Some species of these categories of mammals, for instance, tree shrews (*Tupaia glis),* are endemic to some areas of South-East Asia. On the other hand, most insectivores and rodents occur almost everywhere except Antarctica (Small Mammal Specialist Group, n.d).

2.3 Diversity of small and medium-sized mammals

The diversity of small and medium-sized mammals depends on habitat composition (Glennon and Porter, 2007). Habitats with more diverse flora and ground cover support higher diversity than habitats with lower floral diversity and ground cover (Mulungu *et al.*, 2008). Legese *et al.*, (2019) suggest that the rate at which small and medium-sized mammals decline may be less evident but equal to or even greater than those of large mammals.

A study by Schipper *et al.*, (2008) shows that small mammals comprise nearly two-thirds of the global mammalian diversity. Kenya hosts a high diversity of small and medium-sized mammals (Musila *et al.* 2019). According to Patterson and Webala (2012), there are more than 108 species of bats alone, occurring in Kenya. Despite this high diversity of small mammals, they remain little studied and have hence received notably little attention in conservation (Amori and Gippoliti, 2003). Moreover, due to Kenya's unique and endemic species, it has been recognized by IUCN's small mammal specialist groups as a key target for studying and conserving rodents and insectivores (Soricomorpha) in Africa (Amori *et al.,* 2012).

2.4 Ecological significance of small and medium-sized mammals

Both small- and medium-sized mammals play a significant role in the ecosystems, often functioning as indicator species (Scott *et al.,* 1987). Furthermore, small mammals act as the main producers of biomass compared to other vertebrates of their size (Ryszkowski, 1975). They also form the fundamental food chain for small and medium-sized carnivores and birds of prey such as raptors and owls.

In addition, small and medium size mammals play a critical role as they are responsible for a certain degree of dispersal of plant species through their behaviour of not chewing all that they consume (Scott *et al.*,1979). They also have selective feeding, spreading of seeds, and concentration of nutrients using latrines which play a critical role in plant species dispersal and green matter decomposition (Grant and French, 1980). Moreover, small mammals promote ventilation and bioturbation of soil and drainage after rainfall.

2.5 Anthropogenic Influence on Small and Medium-sized Mammals' Conservation

The prevalent modification of the climate, landscape, and environment alongside the advent of anthropogenic global warming has brought humans to the fore as a formidable force of nature. The aquatic and terrestrial environment of the East African region is sensitive to a variety of global, regional, and local stresses (Odada *et al.,* 2020). There is growing concern over increasing pressure from climate change (Hulme *et al.,* 2001) along with anthropogenic disturbance, such as habitat change (Sinclair, 2008) in the East African ecosystem.

Habitat disturbance can contribute to changes in population density and community structure of small and medium-sized mammals, irrespective of whether it is human or animal-driven. The rise of human activities altering the world landscape since ancient times continues at an alarming rate. These activities greatly affect species distribution patterns and diversity in the East African ecosystem (Sinclair, 2008).

As the human population grows, agricultural and infrastructural development rapidly increases. This amounts to a lot of pressure on the environment, adversely affecting biodiversity to the level of extirpation of local species (Marzluff *et al.,* 2001). Loss of suitable habitat is a major challenge to biodiversity conservation at large. Its adversative impact ranges from limited species dispersal (With and Crist, 1995), altering species interaction (Tayler and Merriam, 1995), reducing species breeding success (Kurki *et al.,* 2000), erosion of genetic diversity (Gibbs, 2001), reduced population growth rate (Donovan and Flather, 2002), increased predation rate (Hartley and Hunter, 1998), negative influence on the species richness (Findlay and Houlahan, 1997) and limited range of distribution and abundance of organisms in the ecosystem (Gibbs, 1998).

Biodiversity conservation experiences its greatest impediment from the lack of fundamental ecological data from urban and rural green space facets (Hong *et al.,* 2005). The relationship between landscape dynamics (e.g., land use intensification or abandonment) and biodiversity highlights the importance of planning tailored landscape management actions to achieve specific conservation goals (Odada *et al.,* 2020).

2.6 Critiques on Small Carnivore Census Techniques

Over the years, carnivore census techniques have been typically invasive. This has always proven intensive and impractical for studies targeting large study areas (Gompper *et al.,* 2006). The invasive techniques may also not be appropriate due to cost and logistical challenges. In addition, there is a low potential of capturing the targeted species. At the same time, invasive survey techniques pose risks of disease transmission between researchers and the targeted species. This, therefore, prompted the development of non-invasive census techniques (Zielinski and Kucera 1995). Of the developed non-invasive survey techniques, the common ones are; camera traps, covered track plates, scent stations, snow tracking, and scat surveys (Gompper *et al.,* 2006).

Non-invasive techniques have been explored occasionally to collect data to determine relative species abundance and distribution (Carbone *et al.,* 2001, 2002). Moreover, carnivore survey techniques have been frequently reviewed (Zielinski and Kucera 1995), while some have been compared and criticized in various case scenarios (Harrison *et al.,* 2002). Therefore, understanding the efficiency of survey techniques is critical for deciding on the survey method and the right study design.

Different survey techniques have been used with various study objectives. For example, snow tracking or DNA-enhanced scat surveys have been used for sampling to estimate relative abundance (Prugh *et al.*, 2005). However, Livingston *et al.*, (2005) report that some data collected using non-invasive survey techniques to monitor and quantify population size are sometimes unclear because identifying an animal may prove difficult. Additionally, detecting tracks and signs that are not obvious may not be perfect and thus compromise the study’s result.

2.7 The Use of Camera Traps for the Study of Forest Mammals (Nocturnal, Elusive, and Discrete)

Globally, camera traps (trail cameras) have been and continue to be used in ecological research for the detection of rare species, estimation of population sizes, species richness, occupancy determination of mammal communities, and habitat use in a wide range of habitats. Trail cameras are key tools in ecological studies and are increasingly used to understand entire wildlife communities. Camera traps have been used to record diverse fauna to monitor terrestrial mammals, that is, small and medium-sized mammals across the globe in a wide range of habitats, from snow leopards in the Himalayas (Jackson *et al.*, 2006) and bobcats in northern California (Larrucea *et al.,* 2007) to a wealth of studies in the humid tropics (Rovero & De Luca, 2007; Tobler *et al.,* 2008).

Camera trapping is often used to capture images of medium to large-sized terrestrial mammals and birds. Still, most recently, they have been used for arboreal mammals as more robust cameras are being developed daily (Oliveira-Santos *et al.,* 2008). Camera traps yield visual information in the form of short videos or still images. Depending on the desire of the researcher, the images or the short videos are always captured from a fixed position.

Most forest mammals are elusive, while some are nocturnal, hence the reliance on indirect evidence of their presence, such as tracks, scats, burrows, and other tell-tale evidence. Whilst such evidence can be useful, deployment of remotely-triggered camera traps gives more dependable and reliable evidence of the animal presence and, with appropriate study design and analysis, provides an array of opportunities to investigate their ecology (Sollmann *et al.,* 2013).

Camera trapping is an excellent tool for identification and a non-invasive tool for identifying and monitoring cryptic wildlife species (Yasuda, 2004; Rowcliffe *et al.*, 2008; Caravaggi *et al.*, 2017; Hofmeester *et al.*, 2019; Silveira *et al.*, 2003; Weingarth *et al.*, 2013). The camera trapping approach has already provided invaluable insights into global mammal community patterns (Ahumada *et al.*, 2011).

Remote camera trapping makes it possible to detect and monitor elusive wildlife, particularly carnivores, without their physical capture and handling, which would otherwise need more experts and a bigger team with risks of the spread of zoonotic diseases. Within the African large carnivore guild, the majority of publications that employ camera trapping skew towards larger carnivores, especially African leopards *Panthera pardus* (Du Preez *et al.*, 2014; Braczkowski *et al.*, 2016). The employment of trail camera technology also has great potential to increase the spatial and temporal scales across which we can collect data on elusive species (Kelly & Holub 2008).

In Kenya, little is known about the elusive, nocturnal, and discrete fauna of forests, especially the Mau Forest Complex, which is imperilled by anthropogenic activities. Trail cameras have proven to be a very versatile tool in bridging the knowledge gaps of the species, as mentioned earlier. To increase the capture rate or the detection probability of mammals, attractants (edible baits or inedible lures) are placed at camera stations for some species (Cove *et al.*, 2014; Kilshaw *et al.*, 2015; Gerber *et al.*, 2012).

2.8 Distribution, Population, and Conservation status of the small carnivores

Globally, there is little knowledge of small carnivores due to their cryptic and nocturnal nature. The Americas represent about 26% of the extant small carnivores worldwide (Shipper 2009). For example, in South America, the Patagonian Weasel (*Lyncodon patagonicus*) and the Colombian Weasel (*Mustela felipei*) are among the rarest small carnivores of the South American continent due to the scarcity of records (Ramírez-Chaves *et al.*, 2012, Formoso *et al.*, 2016, Ramírez-Chaves and Torres-Martínez 2016).

In Asia, species such as Otter Civet (*Cynogale bennettii*) and Malabar Civet (*Viverria civettina*) are also considered among the rarest carnivores. This, on many occasions, undermines the appropriate conservation planning for such species in the world or these regions (Cheyne *et al.*, 2010b, Ross *et al.*, 2015).

African small carnivores represent about 34% of extant small carnivores worldwide. However, they are poorly known (Do Linh San *et al.*, 2013), with species such as Pousargues's Mongoose (*Dologale dybowski*) being listed among the least-known African small carnivore (Stuart & Stuart 2013, Do Linh San *et al.*, 2013).

Because of their primary activity during the day, size, and economic value like tourism, many large African mammals have been subjected to considerable fundamental studies, especially the big five (Kingdon *et al.*, 2013). Hence, they have received more conservation attention than the smaller ones (Brooke *et al.*, 2014).

Among the species that have received more attention are the large African carnivores — the major ones from researchers and conservation organizations. Large carnivores are important in regulating land and aquatic ecosystems (Estes *et al.*, 2011) through their sequential interactions across the different trophic levels (Steneck, 2005, Terborgh and Estes, 2010).

Because of the underlying large carnivore's impacts, small carnivores, although more species-rich and generally more common, are mistakenly thought to have a lower impact at the ecosystem level (Roemer *et al.,* 2009). Small carnivores are important ecosystem regulators since they assist in the structuring of invertebrates and small mammals (Virgós *et al.,* 1999). It is also worth noting that their effects are far-fetched to even contribute to the higher trophic levels.

Some small carnivores are important in seed dispersal hence contributing to plant gene flow or ecology (Jordano *et al.*, 2007, Nakashima and Sukor 2009, Mudappa *et al.,* 2010). In Africa, more attention has been paid to the yellow mongoose (*Cynictis penicillata*), Meerkat *(Suricata suricatta)*, banded mongoose (*Mungos mungo*), and common dwarf mongoose (*Helogale parvula*) than other small carnivores (Do Linh San & Ferguson, unpublished). The conservation status of all mammals worldwide was assessed for the 2008 IUCN Red List of Threatened Species (Schipper *et al.,* 2008a), and results were summarised for small carnivores globally (Schipper *et al.,* 2008a).

2.9 Factors Influencing the Abundance, Distribution, and Diversity of Small Carnivores

Ecological processes are one of the prominent and stand-out factors that affect the distribution and abundance of mammals, specifically carnivores. Literature supports that, ecological processes, such as predation, competition, and food limitation, may limit species (Sinclair *et al.,* 2003). This research has provided the foundation for wildlife management and conservation programs in Africa for several decades.

Ecological aspects such as resource partitioning explain the coexistence of some sympatric carnivore communities and activity patterns, representing important variables in the dynamics of carnivore communities (Brown and Peinke, 2007). All these provide important information for considerations for conservation planning (Hwang and Garshelis. 2007).

Human activities and modification of natural wildlife habitats are one of the greatest threats to the global diversity of flora and Fauna. Widespread changes in human land use have fragmented landscapes and expanded the interface between people, carnivores, and ungulates (Ogutu *et al.,* 2011, Western *et al.,* 2009). For instance, forest fires, continuing human disturbances, such as deforestation, and changes in land use are alarming and have caused global warming. Specifically, burning has serious negative impacts on forest cover (Fuller *et al.,* 2004), tree mortality (Siegert *et al.,* 2001), and wildlife conservation (Singleton *et al.*, 2004).

Other than habitat loss through human interference, hunting is equivalently a large threat to small carnivore populations (Petrozzi *et al.*, 2016; Onuegbu *et al.*, 2020). Perceived declines in the abundance of several carnivore species are likely to be related to hunting pressure, which is perceived to be a major threat to wildlife (Aiyadurai *et al.*, 2010; Velho *et al.*, 2012).

Topographic factors are likely to influence species abundance, distribution, and species richness either positively or negatively coupled with other factors. Topography is considered a key influencing factor driving spatial variation of precipitation, temperature, and soil fertility, which may, in turn, determine forest floral and faunal diversity, functioning, and structure (Jucker *et al.,* 2018).

Topographies influence and form important ecoregions for biodiversity conservation due to their outstanding and unique biogeographical and evolutionary characteristics. For instance, the predominantly montane ecosystem holds high endemism across numerous taxa and supports several species.

Edaphic factors and vegetation cover contribute to the distribution and abundance of diverse species ranging from vertebrates to invertebrates. Over time carnivores' have evolved other feeding guilds, for example, some carnivores are frugivores, piscivores, and insectivores, while some are omnivores. Therefore, edaphic factors affecting either of these species are likely directly or indirectly affecting carnivores. Edaphic factors may be equally, if not more significant than plant attributes in explaining ant diversity patterns since most ant species nest in the soil (Boulton *et al.*, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Ethics Statement

Data collection used remotely set camera traps and, therefore, did not involve direct contact or interaction with the targeted mammalian community in the study area. Fieldwork was conducted under access and research permits from the relevant authorities: the National Commission for Science, Technology, and Innovation (NACOSTI Licence No: NACOSTI/P/20/4694), the Kenya Wildlife Service (KWS/BRP/5001) and the Kenya Forest Service (REF: NO. RESEA/1/KFS/VOL.IV (6) (see Appendices 2, 3, and 4).

3.2 Study Area

3.2.1 Location

The Mau Forest Complex (MFC) is the only remaining near-continuous block of mountain forest in the East African region. The forest lies across the equator between 00 1’ 0” N and 00 55’ 0” and between the latitude of 35^0 15’ 0” and 36^0 15’ 0” E in Kenya's Rift Valley. The MFC is the biggest surviving closed canopy forest block in East Africa (Jebiwott *et al*., 2021), covering an area of over 400,000 ha. Forest fragmentation due to anthropogenic activities is rampant in the MFC and negatively affects habitat connectivity and microhabitats for extant species. The MFC comprises 23 forest blocks located in the counties of Narok, Bomet, Kericho, Nandi, Uasin Gishu, Elgeyo Marakwet, Baringo, and Nakuru, of which 22 are designated as forest reserves (Fig. 1).

The MFC is classified as a montane forest below 2,300m transitioning to bamboo (*Arundinaria alpina*) thickets interspersed with forest and grassland or tundra as the altitude increases. It extends further to the montane sclerophyllous forest next to the escarpment crest (Mau Forest complex, Kenya–Key Biodiversity Areas.org, 2022).

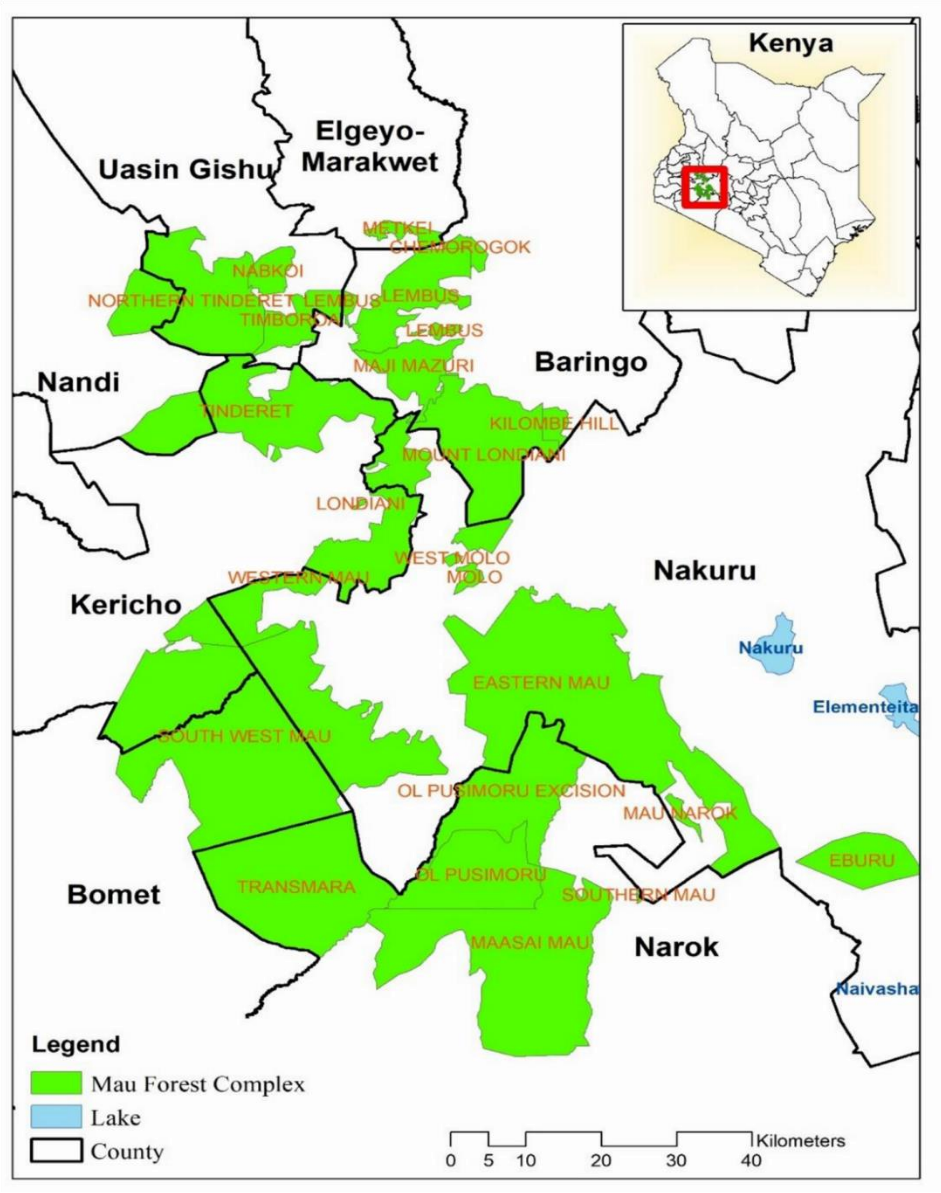


Figure 1. Map showing the spatial location of forest blocks at the MFC, including Maasai Mau and Transmara forest blocks, where this study was conducted. (Mwiu *et al*., 2021).

3.2.2 Climate

The MFC consists of moist forest vegetation types on the leeward side of Lake Victoria at altitudes between 2100 and 3300 metres above sea level, with annual precipitation above 1500 millimetres. On the leeward banks of Lake Victoria, dry forest vegetation occurs between 1800 and 2900 metres above sea level, where annual precipitation varies from 700 to 1,350 millimetres (Mutugi and Kiiru, 2015).

3.2.3 Flora and Fauna

Although little is known about the MFC, it is a sanctuary for biodiversity with a wide and unique variety of flora and fauna. Some of these unique species are endangered such as the Mountain Bongo (*Tragelaphus eurycerus isaaci*), and the African Elephants *(Loxodonta africana)* (Mutugi and Kiiru 2015). According to Key Biodiversity Areas.org (2022), the lower montane forest with *Aningeria adolfi-friedericii* and *Strombosia scheffleri* trees is in the best condition in the southwestern MFC area. However, *Tabernaemontana stapfiana*, *Syzygium guineense*, and *Neoboutonia macrocalyx* are the dominant tree species in the over-logged regions of the MFC. Even though *Olea capensis*, *Prunus africana*, *Albizia gummifera*, and *Podocarpus latifolius* create pockets of undisturbed forest regions, major portions of the high *Juniperus–Podocarpus–Olea* Forest have been severely encroached upon and removed (Key Biodiversity Areas.org, 2022).

3.2.4 Land Use Activities

In 2001, approximately 35,000 ha of forest land was lost to forest excisions for human settlement which led to massive changes in land use and land cover of the MFC (East Mau - revised - Kenya water towers agency, 2020). Out of the excised land, about

18% is under crop farming and livestock production while human settlement takes approximately 3% (East Mau - revised - Kenya Water Towers Agency, 2020). Indigenous tribes, such as the Ogiek, who have lived in the forest sustainably and rely solely on it for their subsistence, ascribe religious and cultural significance to the species variety. In addition, the complex supports wood-based enterprises and commerce with several local people whose lives rely on forest resources (Nabutola, 2010; Langat *et al*., 2016). Nonetheless, the assorted human activities have resulted in massive deforestation, habitat degradation, elimination of wetland habitats in fertile upstream regions, and land fragmentation (Omondi & Musula, 2011).

3.3 Sampling Strategy

3.3. 1 Camera Surveys

In this study, trail camera traps (Browning Trail Cameras, Strike Force HD Pro X/Model BTC-5HDF, and Strike Force HD Pro/Model BTC-5HDP) were used to record mammals including small carnivores (mesocarnivores, < 21.5 kg), as camera traps represent an efficient, cost-effective, and easily replicable tool to study and monitor ground-dwelling terrestrial animals (O'connell and Bailey, 2011; Rovero *et al.,* 2013).

For the combined Maasai Mau and Transmara forest blocks, a total of 144 camera traps were deployed. Camera trap locations were determined by creating a 1x1 km grid across the study area and selecting centroids from these grid cells using QGIS (Fig. 2). BaseCamp software vs. 4.6.2 (Garmin Ltd., USA) and a handheld GPS receiver (eTrex® 20x and GPSMAP® 60CSx) were used to locate camera trapping points in the centre of each grid cell. All cameras were placed within a 200-m radius of the grid centroid. Camera trap site placement was guided by identified wildlife trails and along riparian areas. This resulted in a spatial separation of approximately 1 km between each camera trap.

Each forest block (Maasai Mau and Transmara) consisted of three treatments (adjacent farmlands, secondary forest, and primary forest). Primary forest is one which has undergone little human disturbance. Such disturbances could be human-instigated or as a result of stochastic events. Contiguous to the primary and adjacent farmlands, secondary forest is the region of transition between mature forests and ones that have re-grown after human-induced disturbances such as forest logging or clearing for agriculture. However, some sections of secondary forest have lasted long enough such that disturbance effects are no longer/least evident while disturbance is evident in some other sections. Such shreds of evidence included cut tree stumps, charcoal kilns, and abandoned timber posts, among others. Adjacent farmlands were areas within the community lands, typically at the periphery of the MFC.

Twenty-four camera traps were deployed for 21 days for each treatment, resulting in a total of 72 camera trap locations per forest block. Traps were run in a rotation within a single forest block until each camera location was run for 21 days. Thirty-six camera traps were run simultaneously across the three treatments, 12 camera traps per treatment, for a 21-day period. After these 21 days, the 12 cameras per treatment were rotated within treatment grids such that all 24 camera locations for each grid were covered during 42 days. Cameras were randomly placed (the cameras were only placed randomly at a radius of 200 metres depending on where the trees were found) at a specified pre-set GPS coordinate and attached to a robust tree at a height ranging from 15 to 25 cm as recommended by Zungu *et al*., (2020).

Camera traps were set to take a burst of 3 photographs with a 1-second delay between bursts. Thus, detections were defined as independent photos separated by 60 seconds. Camera trap mode was set as -Trail and Capture delay was set at 1 second, picture size 12M, Multishot STD-3shot, Smart IR-on, Night Exp-Long range, Motion test-ok, and Info strip-on. This was intended to enable the recognition of photographic records. As a result of the above settings, during daylight (high light levels in the daytime only), images were in natural colour (RGB), while at low light levels in the daytime and night, pictures were taken using infrared flash (Appendix 7).

Following Coronel-Arellano *et al.,* (2018), and to ensure as many mammal detections as possible, bananas, chicken, and peanut butter oat balls were used as bait. The bait was placed 1.5 m from the camera on day 1 of each setup but never refreshed. The vegetation cover in front of each camera was cleared within the view range to allow for maximum camera sensor optimal range and also to avoid blank shots (Zungu *et al*., 2020).

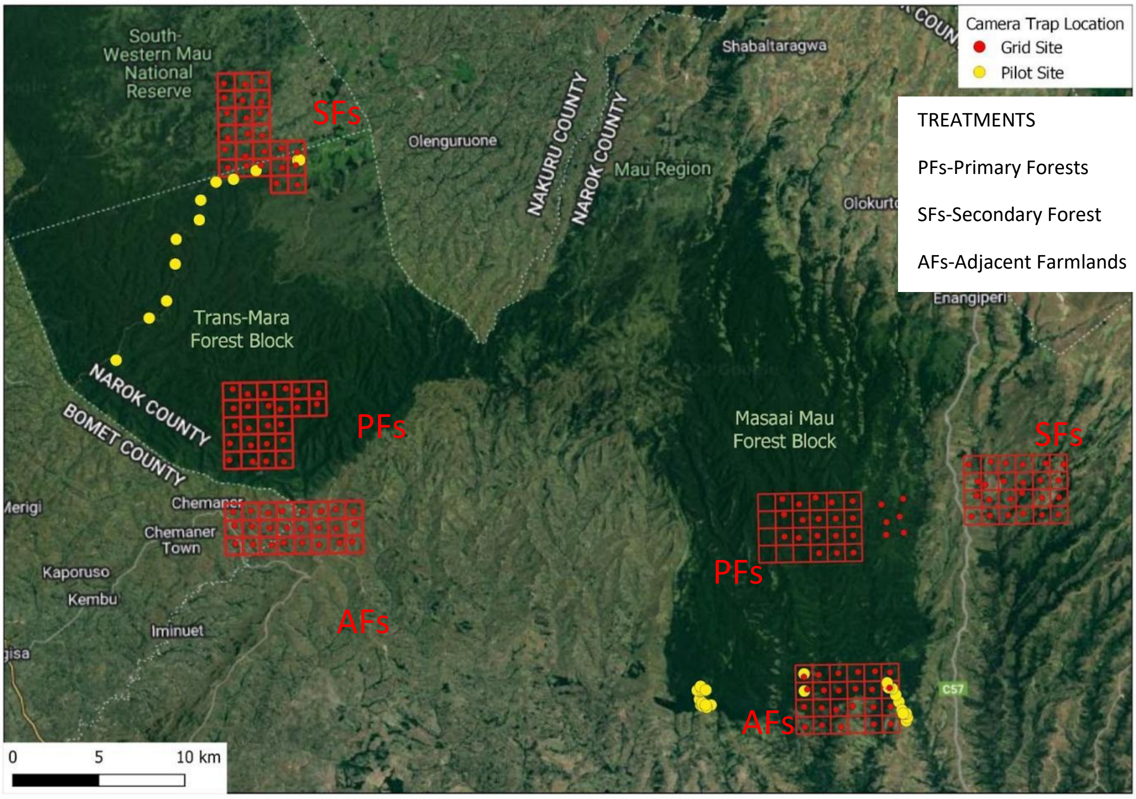


Figure 2. **Map showing the location of sampling grids (red dots) and pilot locations (yellow dots) for the Transmara and Maasai Mau forest blocks**

3.3.2 Pilot Camera Trap Surveys

Prior to implementing systematic, grid-based sampling, both forest blocks were surveyed haphazardly during a pilot period. A total of 102 pilot locations were surveyed, this included 19 sampling locations in the Maasai Mau and 18 locations in the Transmara before the implementation of the grid system.

3.4 Data Presentation and Analyses

3.4.1 Data Management and Species Identification

All camera trap images were uploaded to the online Wildlife Insights (WI) platform for curation and identification. WI is an initiative developed by Conservation

International in partnership with the Wildlife Conservation Society, World Wildlife Fund, Zoological Society of London, The Smithsonian Institution, North Carolina Museum of Natural Sciences, Yale University, and Google (Ahumada *et al.,* 2019). WI was used as an interface tool to support the processing, visualizing, and analysing of the systematic camera trap data. The data model was evaluated using the camera trap survey performed from March 2019 - October 2021 for wildlife detection at the MFC. Camera traps were spaced 1 km apart in two forest blocks and three treatments per forest block.

The metadata (e.g., project ID, deployment ID, place name, longitude, latitude, start date, end date, event name, bait description, feature type methodology, camera ID, camera functioning, height, other sensor orientation, recorded by, plot treatment, etc.) were formatted, and together with uploaded images as per the camera deployment were formatted into Wildlife Insights (WI) after creating accounts for the project (Table 1).

Images were uploaded, stored, and later reviewed by experts, led by Dr. Adam Ferguson of Negaunee Integrative Research Center, Field Museum of Natural History, Chicago, IL, USA, using the Wildlife Insights (WI) platform. WI was chosen because it provided advanced processing capabilities that helped to accelerate image review individually or concurrently (e.g., multiple image selection and image editing).

Comparison of the images' actual identity against the predictions derived from Artificial Intelligence (AI) models associated with Wildlife Insights was drawn and edited where necessary. Camera deployments were used, e.g., TMPB06, and set the burst at 15 seconds; additional identifications to each photo burst were also included, for instance, if more than one animal of the same or different species was present in the image and added other identifying information (e.g., sex, age, or any other remark noteworthy under the comments section).

The resulting output was a CSV file that captured data related to cameras and a summary of species in the dataset (Fig. 4). The resultant CSV was used for further analysis of the results. All analyses were carried out using the R Statistical Program (v4.1.0, (R Core Team 2021)).

3.4.2 Alpha Diversity

The effective number of all mammal species was measured in a community using a combination of Hill numbers (Chao *et al.,* 2014), which allows simultaneous accounting of differences in richness (total number of unique species) and evenness (relative abundance), and rarefaction curves to account for biases associated with sampling efforts, and the exponential of Shannon's entropy. Historically, Hill numbers have been used to quantify the species diversity of a congregation because they represent an intuitive and statistically rigorous alternative to other diversity indices (Chao *et al*., 2014). Since rarefaction curves compare species richness, the alpha diversity (Shannon entropy) was run to compare the three treatments (adjacent farmlands, secondary forest, and primary forest) and the two forest blocks (Maasai Mau and Transmara). Using the iNEXT package (Hsieh *et al.,* 2022) in the R program, rarefaction curves were constructed for each treatment and forest block that accounted for imbalanced sampling to assess asymptotic alpha diversity.

3.4.3 Beta Diversity

To assess statistical differences in beta diversity or compositional similarity or dissimilarity between communities, Jaccard distances (Aziz *et al.,* 2010) were calculated among the presence of community data for each forest type and block along principal component (PCA) axes. A permutational-based analysis of variance (PERMANOVA) via the Adonis routine in the vegan package (Oksanen *et al.*, 2017) in program R was used to test significance levels.

3.4.4 Small Carnivore Abundance and Occupancy

To assess relative abundance, the percentage of overall detections of each small carnivore species in each treatment was descriptively assessed. To assess the occupancy of small carnivores, a single-season occupancy modelling framework of MacKenzie *et al.,* (2006) was used, and estimated detection probability (p), defined as the probability of detecting an occurring species at a camera site, and occupancy (ψ), defined as the probability that a given camera site is occupied, for each species that had at least 30 detections. A model was constructed using the unmarked package in Program R and allowed p to remain constant over occasions (intercept-only) and allowed ψ to vary with treatment. Akaike's Information Criterion (AIC) was used to verify that our model performed better than an intercept-only model for ψ. The model was used to estimate ψ and associated 95% confidence intervals for $\leq$30 detections alone.

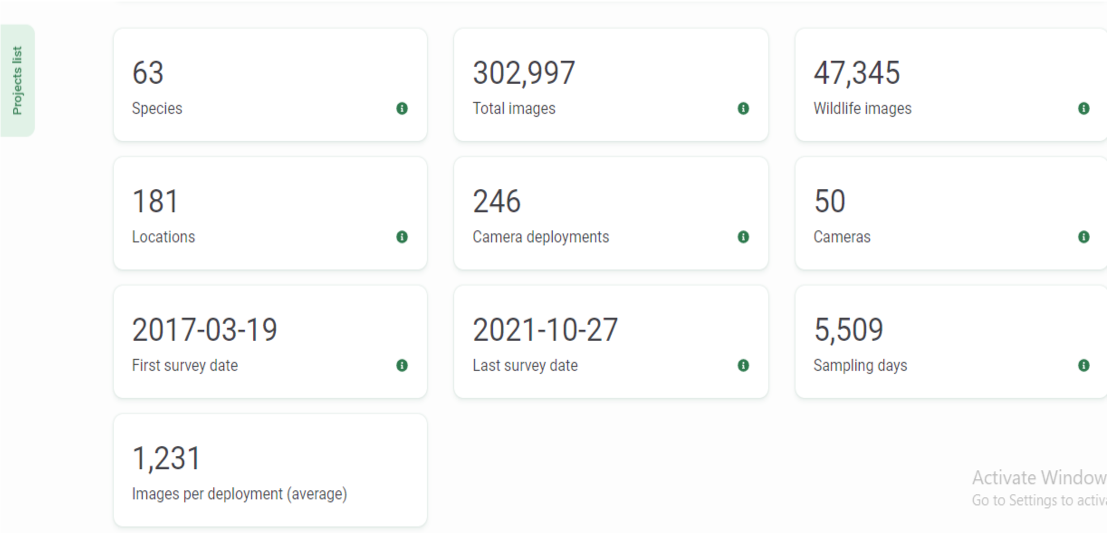
3.4.5 Functional Group Detection Rates

To understand how different groups of ecologically similar or phylogenetically related mammals were responding to treatments, wild mammal species were grouped into six functional groups (Afrotheria, carnivores, large rodents, small rodents, primates, and ungulates). Afrotherian mammals included the ecologically distinct but phylogenetically related species, including the Southern Tree Hyrax (*Dendrohyrax arboreus)*, African Elephant (*Loxodonta africana*), and the Aardvark (*Orycteropus afer*). Carnivores included 18 of 20 species of the Order Carnivora detected during the study (Table 2). Large rodents included the African Pouched Rat (*Cricetomys ansorgei*), Red-legged Sun Squirrel (*Heliosciurus rufobrachium*), African Crested Porcupine (*Hystrix africaeaustralis*), and the African Crested or Manned Rat (*Lophiomys imhausi*). Small rodents included three genera that could be readily identified from photographs (e.g., *Graphiurus*, *Lemniscomys*, and *Lophuromys*). Primates included six monkey species and ungulates included 12 species of hoofed mammals (Order Artiodactyla) detected during the study (Appendix 5). Using these groupings, detection rates (count/day) were calculated for each functional group at each camera site, then averaged (with associated standard error) within each treatment, considering groups in which standard errors did not overlap to be statistically different.

CHAPTER FOUR

RESULTS

From 181-camera-trap locations (144 grid-based locations + 102 pilot locations) with 246 camera deployments and 5,509 sampling days, a total of 302,997 images were captured (Fig. 3). Out of the 302,997 images, 47,345 images (15.6%) were of wildlife species. A total of 52 non-human, mammalian species were recorded from 72 camera traps over 100 sampling nights. Of the 52 species, 3 (leopard (*Panthera pardus*), elephant (*Loxodonta africana*), buffalo (*Syncerus caffer)*) had too few detections and were thus excluded from further analyses. Primary forest recorded the highest detections (*n* = 952), followed by secondary forest (*n* =584) and adjacent farmlands (*n* = 272). From the detections, 9 orders were documented, 20 species of Carnivora from 7 taxonomic families (2 Canidae, 5 Felidae, 5 Herpestidae, 3 Mustelidae, 3 Viverridae, 1 Hyaenidae, and 1 Nandinidae), 15 species of Artiodactyla from two taxonomic families (12 species of family Bovidae, 3 species of family Suidae), 1 species of the order Lagomorpha, 9 species of order Rodentia, 7 species of order Primates and 1 species each of the orders Hyracoidea, Perissodactyla, Proboscidea, and Tubulidentata. In general, the Maasai Mau forest block (*n* = 1036) had the highest detections compared to the Transmara forest block (*n* = 772) (Table 1). However, in terms of treatments, detection rates in both forest blocks followed a similar pattern.



63
Species

302,997
Total images

47,345
Wildlife images

181
Locations

246
Camera deployments

50
Cameras

2017-03-19
First survey date

2021-10-27
Last survey date

5,509
Sampling days

1,231
Images per deployment (average)

Figure 3. Sampling details from Wildlife Insight (WI)

Table 2. Detection rates of different mammals at Mau Forest Complex, March 2019 and September – October 2021

			Maasai Mau Forest Block			Transmara Forest Block			
Order	**Family**	**Species**	**Primary**	**Secondary**	**Cultivated**	**Primary**	**Secondary**	**Cultivated**	**T**
Artiodactyla	Bovidae	*Cephalophus* sp.	7	5	0	3	0	0	
		Yellow-backed Duiker (*Cephalophus silvicultor*)	6	11	0	18	0	0	
		Weyns's Duiker (*Cephalophus weynsi*)	44	68	0	16	0	0	1
		Waterbuck (*Kobus ellipsiprymnus*)	9	1	0	0	0	0	
		Kirk's Dik-dik *(Madoqua kirkii)*	0	13	9	0	0	0	
		Blue Duiker *(Philantomba monticola)*	62	41	0	66	12	0	1
		Common Duiker (*Sylvicapra grimmia*)	0	1	3	0	15	0	
		Bongo (*Tragelaphus eurycerus*)	2	0	0	0	0	0	
		Bushbuck (*Tragelaphus scriptus*)	84	22	0	25	9	0	1
	Suidae	Giant Forest Hog (*Hylochoerus*	3	0	0	9	0	0	

		meinertzhageni)						
		Bushpig (*Potamochoerus larvatus*)	6	1	0	1	1	0
Carnivora	Canidae	*Canis* sp.	0	0	0	0	0	2
		Side-striped Jackal (*Canis adustus*)	0	0	4	0	0	3
		Caracal (*Caracal* sp.)	0	1	0	0	0	0
		Caracal (*Caracal caracal*)	0	3	0	0	0	0
		Domestic Cat (*Felis catus*)	0	0	2	0	0	22
		African Wild Cat (*Felis silvestris lybica*)	0	0	1	0	0	0
		Felis sp.	0	0	0	0	0	3
		Serval (*Leptailurus serval*)	0	2	1	3	2	3
	Herpestidae	Marsh Mongoose (*Atilax paludinosus*)	0	0	0	6	4	0
		Jackson’s Mongoose (*Bdeogale jacksoni*)	32	36	2	21	1	0
		Egyptian Mongoose (*Herpestes ichneumon*)	3	0	2	7	1	1
		Common Slender Mongoose (*Herpestes sanguineus*)	13	9	0	1	1	0
		Herpestes sp.	8	1	16	0	0	0

		White-tailed Mongoose (*Ichneumia albicauda*)	0	2	4	0	0	20
	Hyaenidae	Spotted Hyena (*Crocuta crocuta*)	0	0	0	1	2	0
	Mustelidae	Zorilla (*Ictonyx striatus*)	12	20	1	3	0	0
		Honey Badger/Ratel (*Mellivora capensis*)	4	0	0	3	1	0
	Nandinidae	African Palm Civet (*Nandinia binotata*)	0	0	0	2	0	3
	Viverridae	African Civet (*Civettictis civetta*)	0	8	1	0	1	1
		Large-spotted Genet (*Genetta maculata*)	60	92	44	5	13	28
		Servaline Genet (*Genetta servalina*)	0	0	0	59	0	0
		Genetta sp.	7	5	3	2	5	1
Hyracoidea	Procavidae	Southern Tree Hyrax (*Dendrohyrax arboreus*)	11	6	7	25	3	0
Lagomorpha	Leporidae	*Lepus* sp.	0	15	6	0	0	12
Primates	Cercopithecidae	Red-tailed Monkey (*Cercopithecus ascanius*)	1	0	0	12	5	0
		Blue Monkey *(Cercopithecus mitis)*	115	34	6	56	25	0
		Cercopithecus sp.	1	6	0	12	10	0

		Guereza *(Colobus guereza)*	0	3	0	8	1	0
		Olive Baboon *(Papio anubis)*	0	5	5	1	0	0
Rodentia	Gliridae	*Graphiurus* sp.	0	5	0	0	2	0
	Hystricidae	Cape Porcupine *(Hystrix africaeaustralis)*	0	3	0	0	16	2
	Muridae	*Lemniscomys* sp.	0	0	0	1	0	1
		Crested Rat *(Lophiomys imhausi)*	3	1	0	5	0	0
		Lophuromys sp.	0	0	0	2	2	0
	Nesomyidae	Gambian Rat *(Cricetomys gambianus)*	0	2	1	84	22	52
	Sciuridae	Red-legged Sun Squirrel *(Heliosciurus rufobrachium)*	0	1	0	1	0	0
	Thryonomyidae	*Thryonomys* sp.	0	1	0	0	6	0
***Proboscidea**	Elephantidae	African Elephant *(Loxodonta Africana)*	0	0	6	1	0	0
***Carnivora**	Felidae	Leopard (*Panthera pardus*)	1	0	0	0	0	0
***Artiodactyl**	Bovidae	African Buffalo *(Syncerus caffer)*	0	2	0	0	0	0

a									
***Tubulidentata**	Orycteropidae	Aardvark *(Orycteropus afer)*	0	9	0	0	0	0	
***Primates**	Hominidae	Human Resident (*Homo sapiens*)	7	67	225	54	68	137	5
	Galagidae	Thick-tailed Greater Galago (*Otolemur crassicaudatus*)	0	13	0	0	0	0	
		Total detections	**493**	**424**	**118**	**458**	**160**	**154**	**1**
		Species richness (*S*)	**22**	**32**	**19**	**30**	**24**	**15**	

4.1 Alpha Diversity

Although not statistically significant, the mean alpha diversity of small to medium-sized mammals, as measured by Shannon's entropy, was lower in cultivated than in both secondary and primary forests. Similarly, the primary forest recorded significantly higher diversity than the secondary forest (Fig. 4). However, for the two forest blocks (Transmara and Maasai Mau), the alpha diversity of small to medium-sized mammals did not differ significantly (Fig. 5).

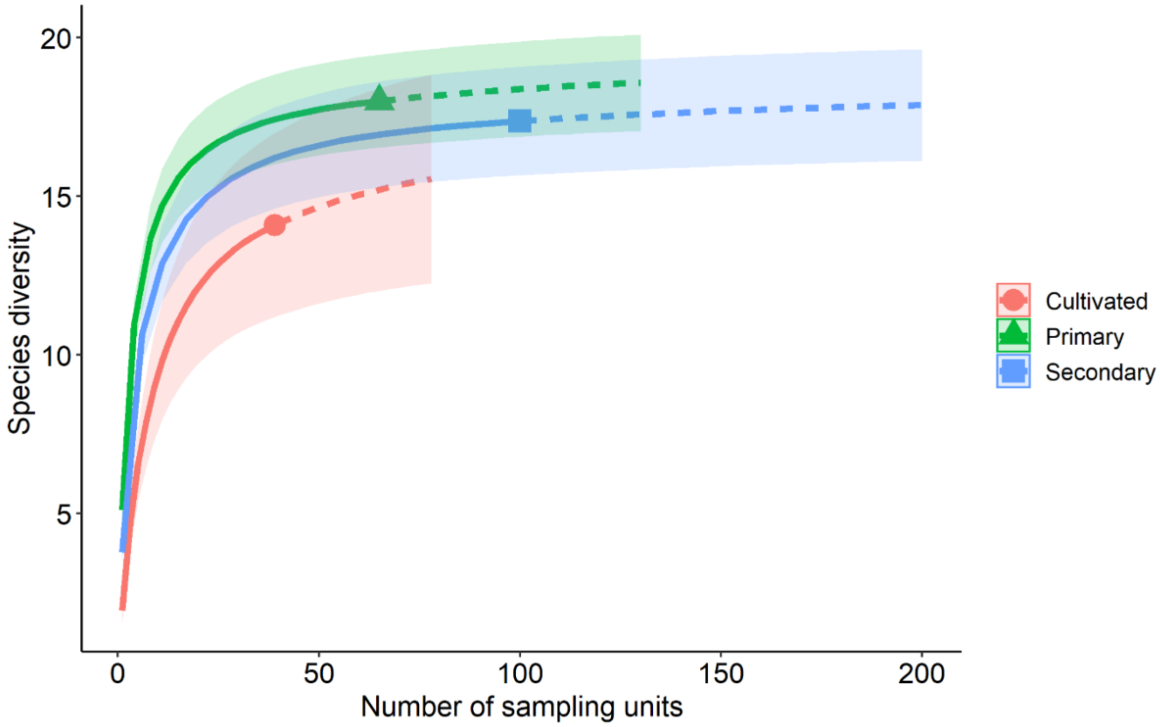


Figure 4. Alpha diversity, as shown by the exponential of Shannon's entropy, for small to medium-sized mammal species between adjacent farmlands, primary forests, and secondary forests

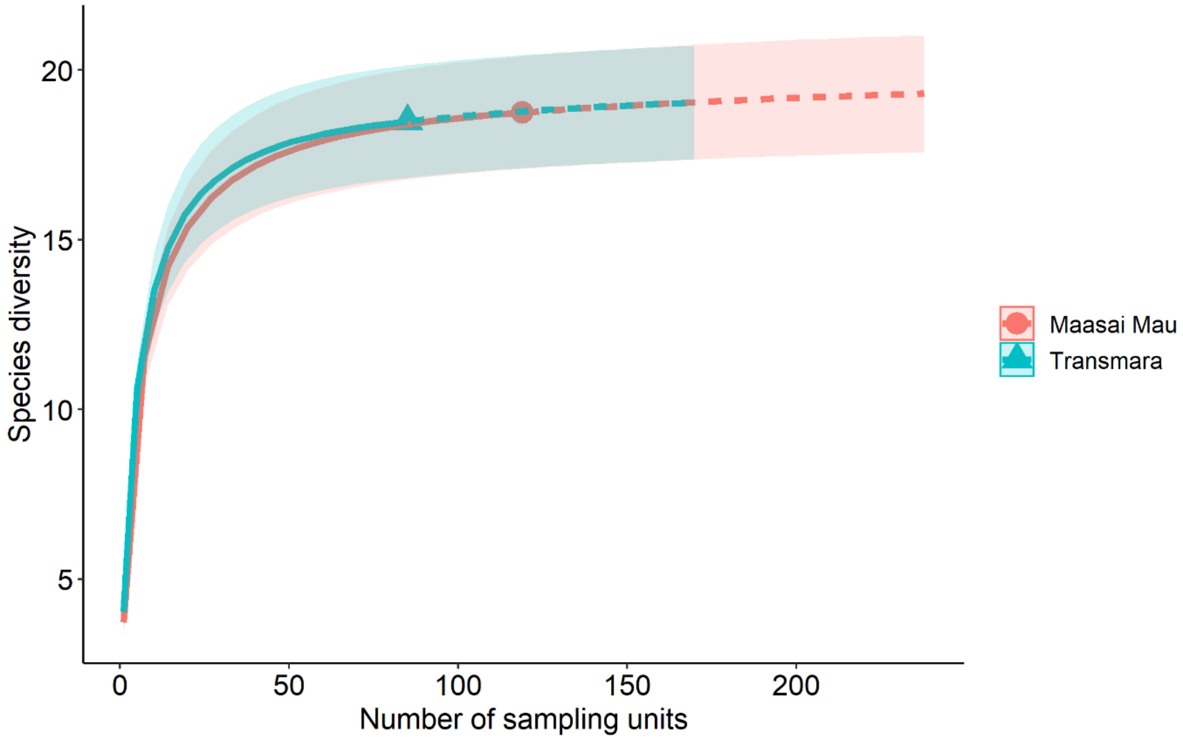


Figure 5. Alpha diversity, as shown by the exponential of Shannon's entropy, for small to medium-sized mammal species between Maasai Mau and Transmara forest blocks

4.2 Beta Diversity

The community composition of mammals differed relatively between primary and secondary forests (*F* = 4.27, df = 1, p = 0.001), primary forest and adjacent farmlands (*F* = 6.99, df = 1, p = 0.001), cultivated and secondary (*F* = 4.65, df = 1, p = 0.001), and forest blocks (*F* = 6.20, df = 1, p = 0.001). Differences were especially apparent when comparing cultivated to both primary and secondary forests (Fig. 6).

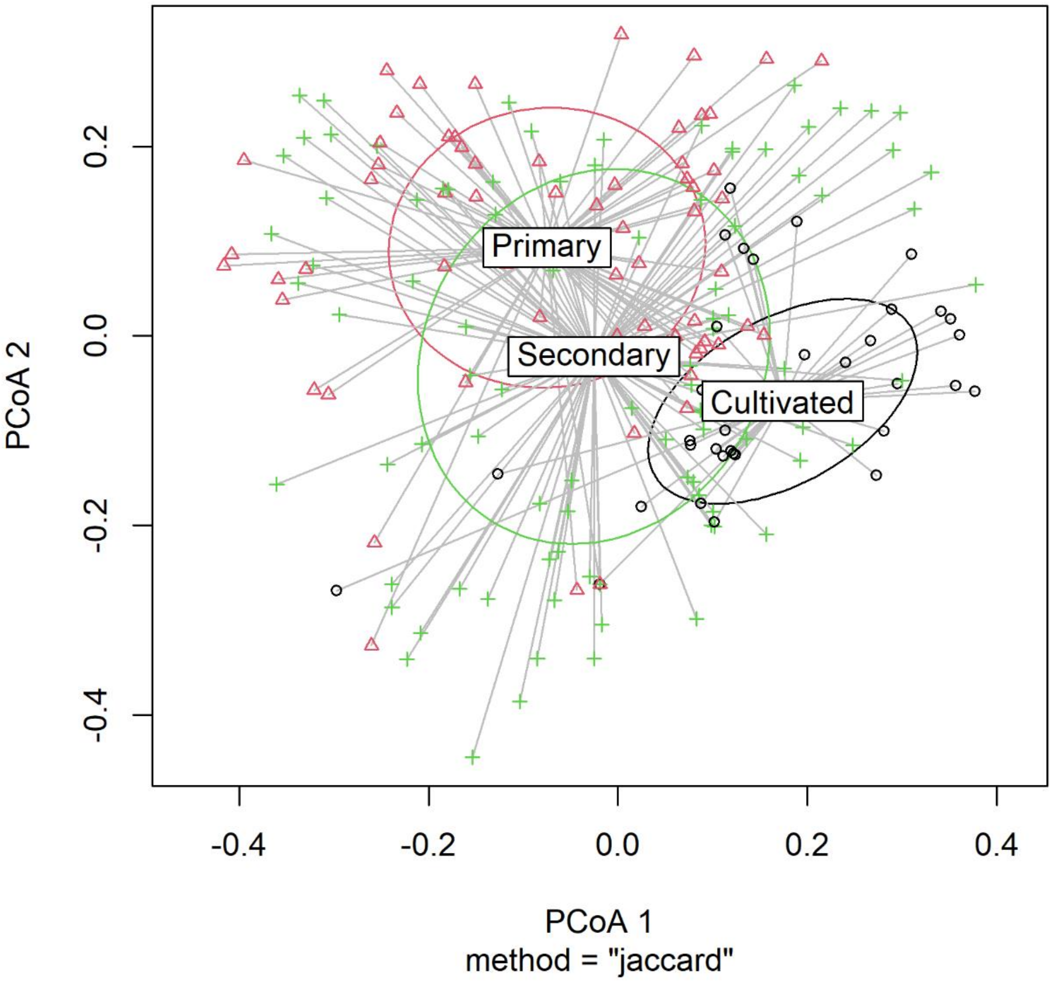


Figure 6. Differences in mammal community composition between cultivated, primary, and secondary forests as assessed by Jaccard distances and principal components analysis

4.3 Small Carnivore Abundance and Occupancy

The overall number of detections of small carnivores varied among species (Fig. 7) and treatments (Fig. 8). Large spotted genets (*Genetta maculata*) had the highest number of detections (*n* = 344), followed by Jackson's mongoose (*Bdeogale jacksoni*; *n* = 158), and servaline genet (*Genetta servalina*; *n* = 123). The African wild cat

(*Felis silvestris*) had the fewest detections with a single individual reported from farmland site deployment ID: MMCC24_2021-01-26. However, given the similarity of these wild cats with their domestic counterparts and their ability to hybridize, these results should be interpreted with caution.

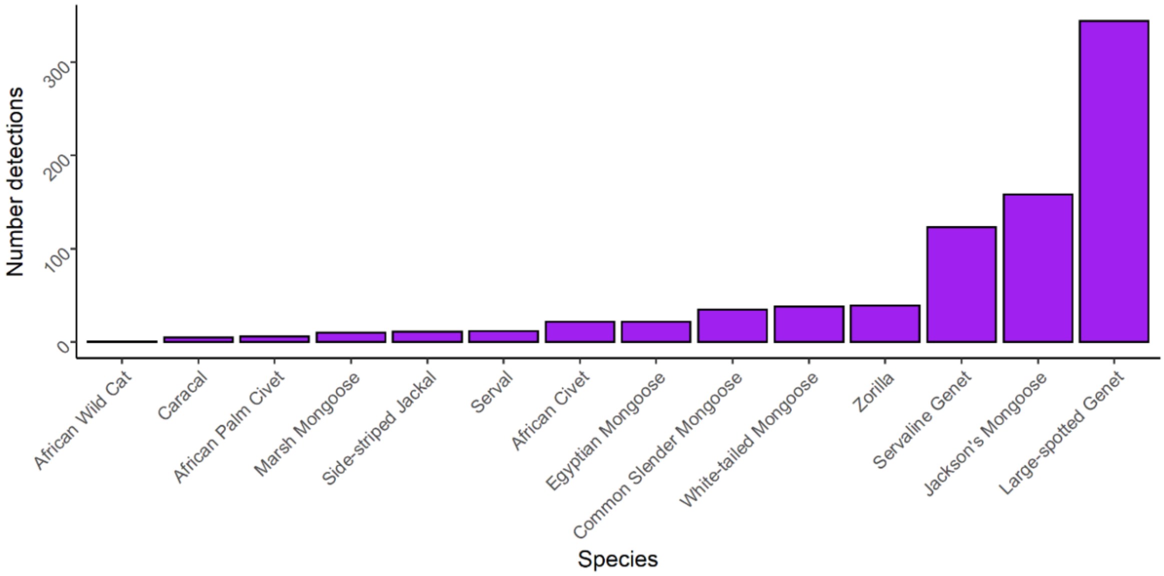


Figure 7. The number of detections captured of each of the 14 species of small carnivora over 246 camera trap locations

Four species of small carnivores each were detected in only a single treatment, with African Wild Cat (*Felis silvestris*) in cultivated farmland at Maasai Mau, caracal (*Caracal caracal*) in secondary forest at Maasai Mau, Side-striped Jackal (*Canis adustus*) in cultivated farmland at Transmara, and Servaline Genet (*Genetta servalina*) in the primary forest at Transmara (Fig. 8).

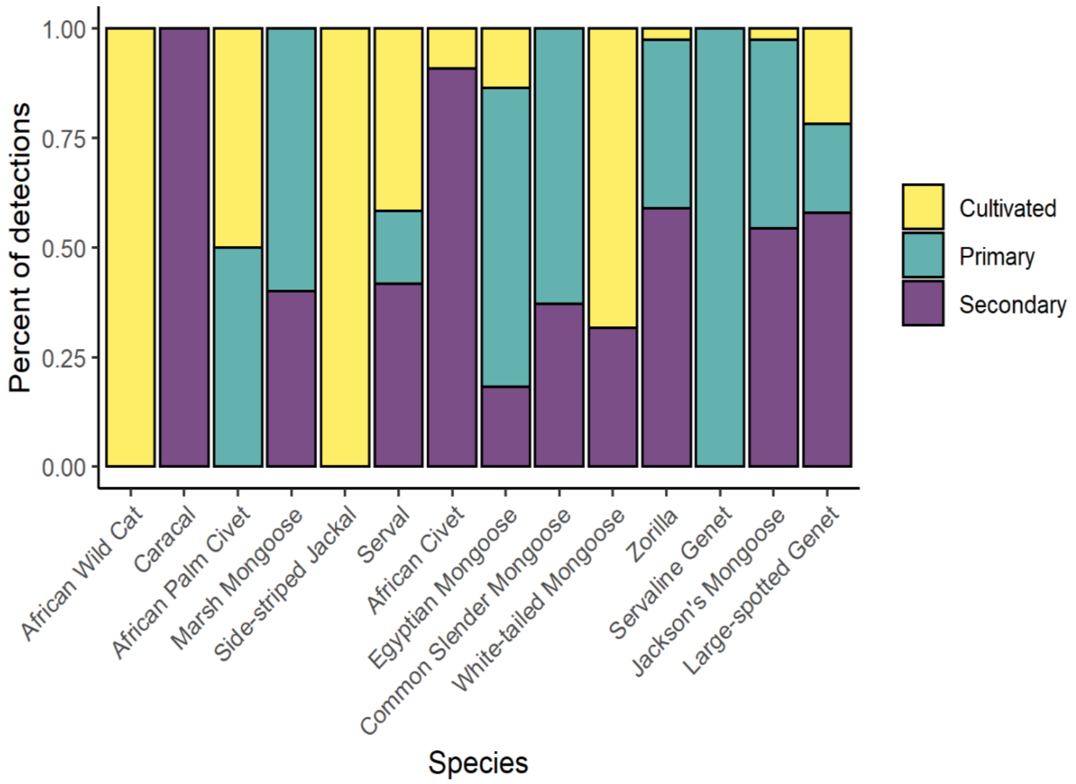


Figure 8. The percentage of total detections of the 14 small carnivore species located in adjacent farmlands, or primary or secondary forests

Some species, such as Slender Mongoose (*Herpestes sanguineus*), Servaline Genet, and White-tailed Mongoose (*Ichneumia albicauda*), had no detections in one or more treatments. Thus, occupancy probabilities associated with those habitats for such species could not be estimated. Focusing on six small to medium-sized carnivores with at least 30 detections, occupancy probabilities were estimated for each species in each treatment (Fig. 9). The Large-spotted Genet had significantly higher occupancy (mean ψ = 0.56, 95%CI=0.44 - 0.68) in secondary forests when compared to primary (mean ψ = 0.26, 95%CI=0.16 – 0.39) and cultivated (mean ψ = 0.32, 95%CI=0.21 – 0.46).

The Jackson’s mongoose, a known forest specialist, had higher occupancy in both primary (mean ψ = 0.32, 95%CI=0.21 – 0.46) and secondary (mean ψ = 0.28, 95%CI=0.20-0.40) forests when compared to farmlands (mean ψ = 0.04, 95%CI=0.01 – 0.14).

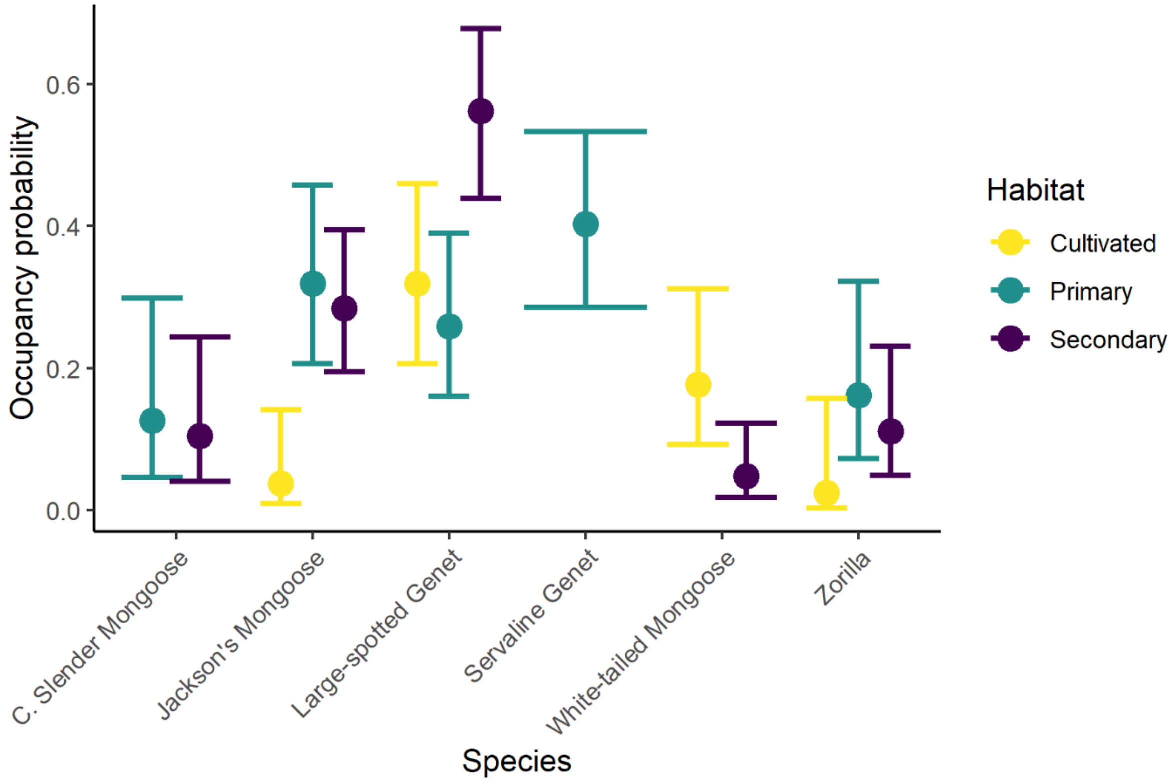


Figure 9. The probability of occupancy for 6 small carnivore species in adjacent farmlands, and in primary and secondary forests, respectively (Points are means and bars are at 95% confidence intervals)

4.4 Functional Group Detection Rates

Detection rates for various functional groups were similar across treatments for Afrotherians, Carnivora, and small rodents (Fig. 10), but differed significantly for large rodents, primates, and ungulates (Fig. 10). Both primates and ungulates had higher detection rates in primary and secondary forests than in the farmlands. Large rodents had the highest detection rates in primary forests, but their detection rates did not differ between farmlands and secondary forests. Each functional group includes 3-24 species (Appendix 5).

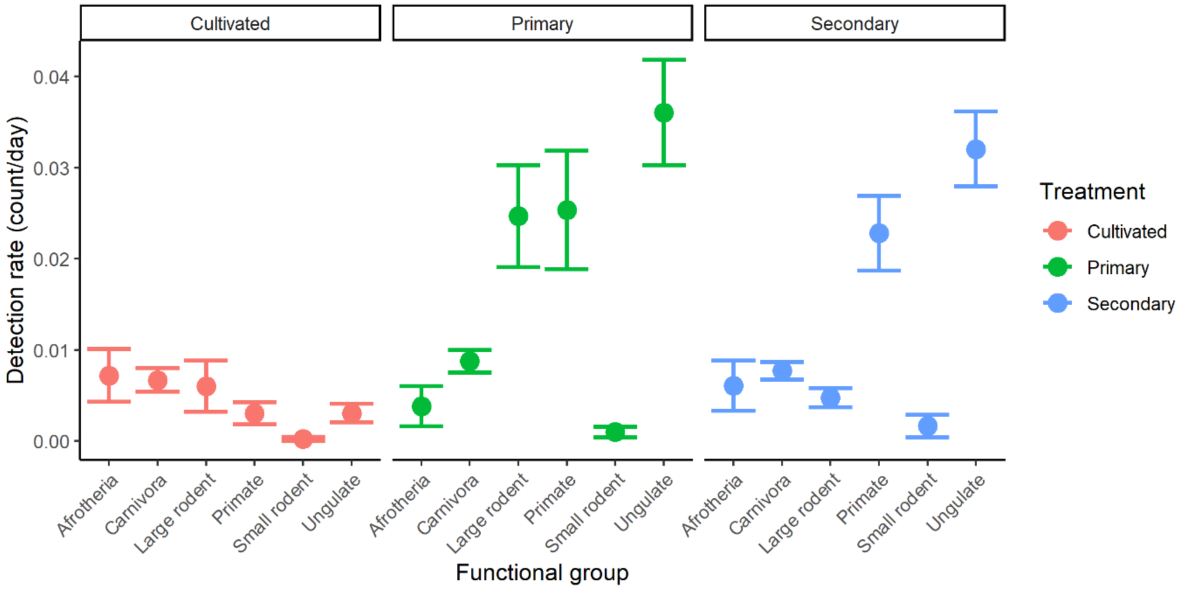


Figure 10. Detection rate (count/day) of six functional groups of small to medium-sized mammals in adjacent farmlands, and in primary and secondary forests (Points represent mean detection rates and bars 95% confidence intervals)

CHAPTER FIVE

DISCUSSION

This is the first study of species-specific and assemblage-wide responses of small to medium-sized mammals, including small carnivores, to forest degradation and fragmentation in Kenya. Human disturbance negatively affected the abundance and species richness of small to medium-sized mammals, in agreement with similar studies elsewhere (Xingyuan *et al.,* 2015, Sponchiado *et al.*, 2012). Human activities can cause variation in microhabitats thereby influencing population parameters such as the presence and abundance of different species in a particular habitat. In general, the primary forest supported the highest relative abundance and species richness, including the richness of forest specialist species, compared to the more disturbed secondary forests and adjacent farmlands, which were inhabited more by generalist species.

5.1 Impacts of Anthropogenic Disturbance on Small to medium-sized mammal communities at the MFC

5.1.1. Alpha Diversity

The results from the camera trapping survey of small to medium-sized mammals within the treatments and forest blocks used Hill numbers, also known as the effective number of species. This study on diversity patterns attempts to unravel how small to medium-sized mammals respond to different degrees of human disturbance. Despite not showing statistical significance, alpha diversity/Shannon’s entropy appeared to differ among the three treatments, with primary forests being more diverse than both secondary forests and adjacent farmlands. This can be attributed to forest-dependent species/specialists' preference for undisturbed/pristine habitats. This, however, while consistent with many studies that demonstrate primary forests as richer in species than disturbed secondary forests and other modified habitats (Barlow *et al*., 2007), conflicts with the intermediate disturbance hypothesis (IDH), which predicts local species diversity to be maximal at an intermediate level of disturbance (Connell, 1978; Wilkinson 1999, Moi *et al.*, 2020). The rejection of the IDH by this study is consistent with other empirical studies only rarely finding higher species diversity at intermediate levels of disturbance (Fox 2013). That higher diversity was found in more pristine habitats instead of those at intermediate levels of disturbance is likely because some mammal species are disturbance intolerant as was explained by Webala *et al.*, (2019). For instance, the Mountain Bongo (*Tragelaphus euryceros isaaci)*) and some carnivores such as the Jackson’s Mongoose were only or primarily detected in primary forests in this study because they are sensitive to disturbance and fragmentation of their natural habitats through anthropogenic activities (Ginsberg 2001, Woodroffe 2001). This might explain why primary forests had slightly, and significantly, higher diversity than secondary forests and adjacent farmlands, respectively.

High species diversity in the primary forests could also be due to some species thriving in the pristine or relatively less disturbed environment (Ferreira and Van Aarde, 2000). Dietary preference may also explain differences in community composition in primary forests. Alterations of the prey base or plant community may cause dietary shifts, favouring some consumers over others. With such shifts, the generalist species prefer secondary forests with intermediate disturbances and also the less-disturbed primary forests. In this study, specialist species preferred the less-disturbed sections of the MFC, and together with some generalist species, allowed the primary forests to exhibit the highest diversity of small to medium-sized mammals compared to other (more disturbed) habitats.

In terms of forest blocks, alpha diversity was not significantly different between Maasai Mau and Transmara forest blocks. This could be attributed to the similarity in the modes of human disturbances (such as encroachment, illegal logging, charcoal burning, wildlife snaring, and uncontrolled grazing) following similar patterns despite the two forest blocks being far apart.

5.1.2 Beta Diversity

Species composition is one key component of species diversity (Li *et al.,* 2017). Comparing the community composition of small to medium-sized mammals in this study indicated a significant difference in beta diversity. There was a relatively different combination of species in the primary forest than in both secondary forests and adjacent farmlands, with the latter recording lower beta diversity than secondary forests. This was indicated by a gradually increasing trend associated with an increase in the frequency of anthropogenic activities across treatments, with the primary forests and adjacent farmlands being the least and most disturbed, respectively. These findings are consistent with Flynn *et al*., (2009) and Horváth *et al*., (2009) who reported that the intensification of agricultural activities was associated with a significant decrease in species richness. The difference in beta diversity from adjacent farmlands to secondary forests and from secondary to primary forests may be attributed to the different intensities of anthropogenic impacts at the three respective habitats with human influence being higher in the adjacent farmlands compared to primary forest in the two ecoregions.

5.2 Impacts of Anthropogenic Disturbance on the Abundance and Occupancy Levels of Small to medium-sized Carnivores

5.2.1 Occupancy modelling

The Jackson's Mongoose (*Bdeogale jacksoni*) is a known forest specialist and had the overall highest occupancy in primary forests compared to secondary forests and farmlands across Maasai Mau and Transmara forest blocks. Kingdon (1997) suggested that the presence of remains of two rodent genera *Dasymus* and *Otomys* in the stomach of the Jackson's Mongoose indicates that it frequently hunts in the thick herbaceous growth. In this study, the Jackson's Mongoose had the highest occupancy in the primary forest (mean $\psi = 0.32$, 95%CI=0.21 – 0.46) and least in the cultivated sites (mean $\psi = 0.04$, 95%CI=0.01 – 0.14). Its preference for forested habitats explains the variation in occupancy across the three treatments from primary to secondary forests and farmlands.

Little is known about the range of Jackson's Mongoose, especially in Kenya. This species has been confirmed in the Aberdare and Mt Kenya forests and is also likely to occur at Mt Elgon National Park (Van Rompaey and Kingdon, 2013). These factors call for the conservation of the Mau Forest Complex since habitat destruction poses a serious threat to this rare and specialist species. According to Van Rompaey and Kingdon (2013), the apparent dependence of Jackson's Mongoose on forest habitat is its main threat since the ongoing forest loss is shrinking its range.

Similar to patterns observed in the forest-dwelling Jackson's mongoose, *Servaline genets* were only recorded in the primary forest. However, their detection in only one of the three treatments limited the ability to compare *Servaline genets*' occupancy. In comparison, the results contradict other studies on the detection of *Servaline genets* where, Gaubert *et al.,* (2015) for instance, reported this species to be present in primary and secondary lowlands.

The Large-spotted Genet (*Genetta maculata*), on the other hand, had significantly higher occupancy in secondary forests compared to primary forests and farmlands. This species occurs in the rainforest and generally prefers open corridors and secondary growth with sufficient hiding places (Angelici and Gaubert 2013), so it was unsurprising that its occupancy levels were highest in secondary forests at MFC.

5.3 Responses of functional groups of small to medium-sized mammals to anthropogenic disturbance across treatments

Rapid anthropogenic modification of forest habitats has led to unprecedented rates of population loss and defaunation in terrestrial vertebrates (Newbold *et al*., 2015). This study examined the response of targeted functional groups of small to medium-sized mammal species to different treatments along a gradient of anthropogenic disturbance. Under this context, similar detection rates were observed for small rodents, Afrotherians, and carnivores across the three treatments. However, the detection rates differed for large rodents, primates, and ungulates. Large rodents had a higher detection rate in the primary forests but had lower detection rates in both adjacent farmlands and secondary forests, this was most likely driven by the two most frequently documented species, *Cricetomys ansorgei* and *Lophiomys imhausi*. On the other hand, ungulates and primates had higher detection rates in primary forests than in secondary forests and adjacent farmlands.

Typically, undisturbed or less disturbed forests exhibit complexity in vertical stratification (Kricher, 2011). On the contrary, human-induced disturbance can alter diverse and heterogeneous natural forests to become homogeneous and simple ecosystems (Sans, 2007; Sarmiento-Garce´s and Hernández, 2021). This is the case even in low-intensity anthropogenic impacts such as controlled logging (Kricher, 2011; Edwards *et al*., 2012). This may explain the higher detection rates of both primates and ungulates in the primary forest compared to both secondary forests and farmlands in this study. The primary forest offers resources such as tall trees for primate foraging and shelter, and ground cover for ungulate foraging. These results conform to a global meta-analysis of the effects of human disturbance on tropical forests, which reported relatively mild changes in mammal assemblages between selectively logged and unlogged forests (Gibson *et al*., 2011).

This study, however, showed that some functional groups are unaffected or may even benefit from habitat disturbance. This was observed in Afrotherians, some carnivores, and some small rodents and large ones that recorded similar detection rates across the three treatments. For instance, the Gambian Rat (*Cricetomys gambianus*), a large rodent is habitat-generalist and thus were unaffected by human disturbance at the Mau Forest Complex. The study is consistent with Ajayi (1977) who found that *C. gambianus* is found in a wide variety of habitats including abandoned farms, degraded deciduous forests, zoological garden complex, and forest plantations thus indicating that this species is a habitat generalist. Conversely, this study demonstrated that specialist species such as the Jackson’s Mongoose use mainly the less-disturbed primary forests and may be highly vulnerable to human disturbance. Such species, including many medium-sized mammals (Dirzo et al., 2014; Cardillo et al., 2005), primates, and large rodents were either absent or their detections were extremely low in the highly disturbed secondary forests and farmlands.

One noteworthy caveat of this study is that detection rates depend on the census technique and habitat structure, especially for arboreal species (Johns and Skorupa, 1987). The use of camera traps in surveys of secretive mammals may be biased against arboreal species since cameras are typically placed low to the ground, possibly underestimating the relative abundance of such species and masking responses to tropical forest disturbance (Whitworth *et al.*, 2019). Thus, using additional and complementary methods, such as unique or targeted sampling/capture methods such as placing camera traps in trees for arboreal surveys coupled with traditional capture, eDNA, or other specialized survey methods useful for detecting rare or habitat specialists. Accessing mammal fauna in forested habitats may demonstrate more contrasting data between disturbed habitats and less undisturbed forests (Mendez-Oliveira *et al.*, 2017).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In summary, small to medium-sized mammal species responded differently to anthropogenic disturbance across treatments at the Mau Forest Complex (MFC). Some species are known to be disturbance intolerant while others are disturbance tolerant. Indeed, the Mountain Bongo (*Tragelaphus euryceros isaaci)*), and the Servaline Genet (*Genetta servalina*) were only detected in the less-disturbed primary forests in this study because they are sensitive to disturbance and fragmentation of their natural habitats.

Similarly, the abundance and occupancy of small to medium-sized carnivores reflected their preference for certain habitats over others. Human influence appears to be an important factor in the choice of habitat for some species, with the Large-spotted Genet (*Genetta maculata*), a species known to prefer open corridors and secondary growth being recorded at their highest numbers in secondary forests and lowest in the farmlands. Contrarily, the use of camera traps alone amounts to a biased detection rate against arboreal species. In essence, this may underestimate negative responses to tropical forest disturbance (Whitworth *et al*., 2019).

Importantly, this study clearly demonstrates the positive effects of protection as indicated by primary forests having higher species abundance, and disturbance-intolerant species such as the mountain bongo. These are mostly attributable to differences in land use between protected and unprotected sites (adjacent farmlands). This study is consistent with the findings of Gray *et al.*, (2016) that protected areas are widely essential for biodiversity conservation hence reinforcing their global importance.

6.1 Recommendations

Hitherto, financial and personnel resources were limited to gathering systematic data across all the MFC forest blocks. With the findings of this study providing a baseline for systematic studies on small to medium-sized mammals at the MFC, there is need for medium and long-term studies to understand better the persistent long-term effects of human activities on small- to medium-sized mammals and other fauna at the MFC. Given that some sections of the MFC may still be less disturbed, accessing these areas and employing modern scientific cutting-edge research techniques, including complementary survey techniques alongside camera traps, could yield more data on different extant mammalian species. An adequate assessment of mammal assemblage responses to tropical forest habitat modification should also consider arboreal species, which tend to be highly vulnerable to forest canopy destruction but severely under-sampled by camera trapping.

Mau Forest Complex consists of 23 forest blocks and while this study only focused on Maasai Mau and Transmara, there is a dearth of knowledge on the biodiversity value of these remaining forest blocks. Future studies should focus more on these sections to assist in policy and management plan formulation for the entire Mau Forest Complex.

During data collection, active trails of donkeys, freshly harvested cedar posts, and other forms of human disturbance were prevalent in many parts of the secondary forest. Despite taking bold steps in evicting people from the MFC, strict law enforcement needs to be sustained to halt or minimize human activities for the conservation of the magnificent forest habitats and its biodiversity at the Mau Forest Complex.

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APPENDICES

Appendix I. Species recorded from camera traps

Artiodactyla (Hoofed Mammals)

Bovidae (Cows, sheep, antelope)

Bos taurus (Domestic cow)

Cephalophus weynsi (Weyns's duiker)

Cephalophus silvicultor (Yellow-backed duiker)

Domestic sheep

Domestic goat

Kobus ellipsiprymnus (Waterbuck)

Madoqua kirkii (Kirk's dikdik)

Philantomba monticola (Blue duiker)

Sylvicapra grimmia (Common bush duiker)

Tragelaphus scripta (Bushbuck)

Tragelaphus euryceros (Bongo)

Suidae (pigs)

Potamochoerus larvatus (Bushpig)

Hylochoerus meinertzhageni (Giant Forest hog)

Domestic pig

Carnivora

Canidae (dogs)

Canis adustus (Side-striped jackal)

Canis familiaris (Domestic dog)

Felidae (cats)

Caracal caracal (Caracal)

Felis catus (Domestic cat)

Felis silvestris (African wildcat)

Leptailurus serval (Serval)

Panthera pardus (Leopard)

Herpestidae (mongooses)

Atilax paludinosus (Marsh mongoose)

Bdeogale jacksoni (Jackson’s mongoose)

Herpestes sanguineus (Slender mongoose)

Herpestes ichneumon (Egyptian mongoose)

Ichneumia albicauda (White-tailed mongoose)

Hyaenidae

Crocuta crocuta (Spotted hyena)

Mustelidae (honey badger, otters)

Aonyx capensis (Cape clawless otter)

Ictonyx striatus (Zorilla)

Mellivora capensis (Honey badger, ratel)

Nandinidae (Palm civet)

Nandinia binotata (African palm civet)

Viverridae (civets and genets)

Civettictis civetta (African civet)

Genetta maculata (Large-spotted genet)

Genetta servalina (Servaline genet)

Hyracoidea (Hyraxes)

Dendrohyrax arboreus (Tree hyrax)

Lagomorpha (Hares)

Lepus sp.

Rodentia

Cricetomys ansorgei (Southern pouched rat)

Hystrix africaeaustralis (African crested porcupine)

Lophiomys imhausi (African crested rat)

Lemniscomys sp. (Zebra mouse)

Praomys sp. (Forest rat)

Graphiurus sp. (Doormouse)

Paraxerus ochraceus (Ochre bush squirrel)

Heliosciurus rufobrachium (Red-legged sun squirrel)

Thryonomys sp. (Cane rat)

Primates

Cercopithecus ascanius (Red-tailed monkey)

Cercopithecus mitis (Blue monkey)

Cercopithecus neglectus (De Brazza’s Monkey)

Chlorocebus pygerythrus (Vervet monkey)

Otolemur crassicaudata (Greater lesser-eared bush baby)

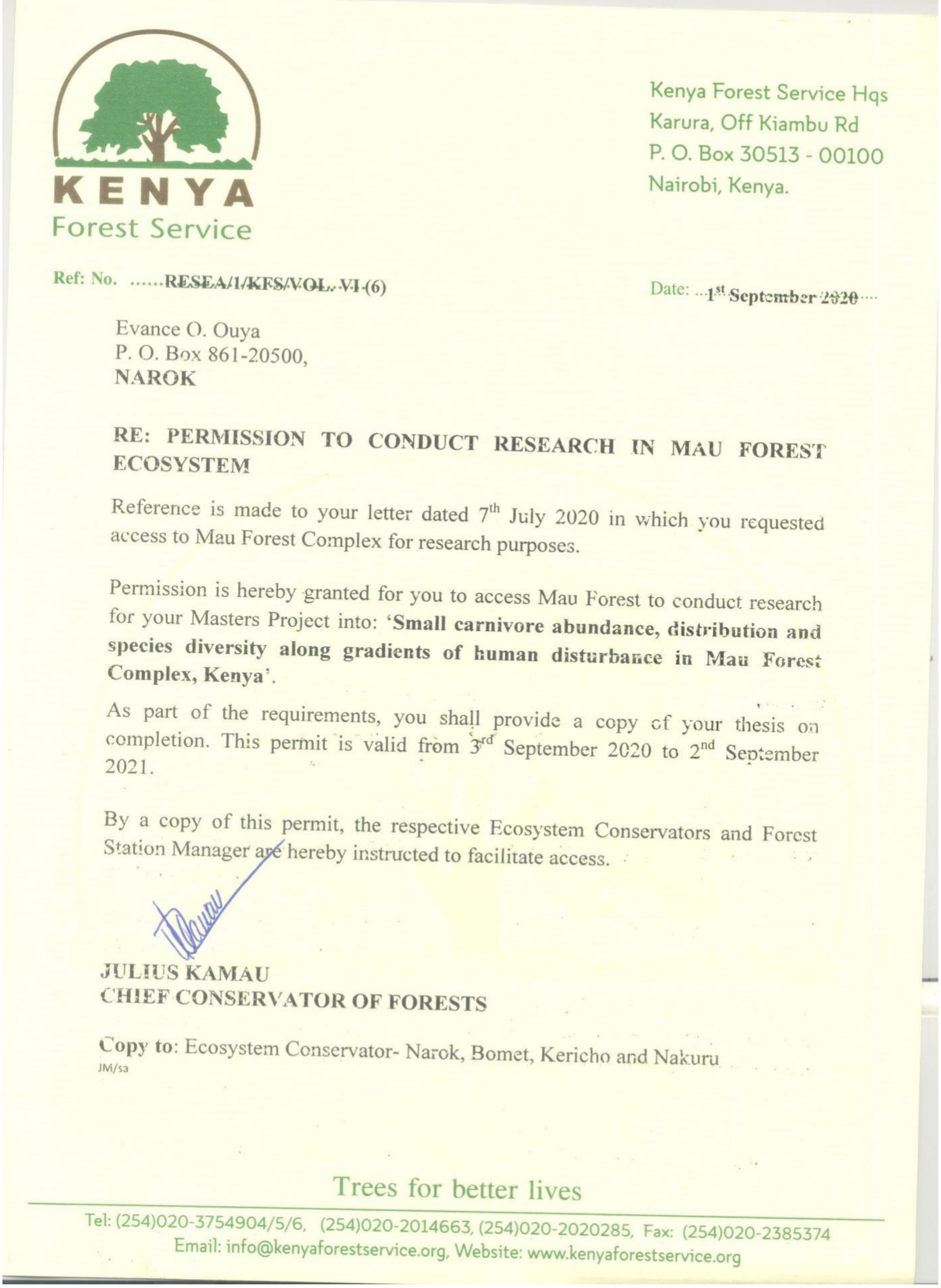
Papio anubis (Olive baboon)

Colobus guerza (Guerza colobus)

Tubulidentata (Aardvark)

Orycteropus afer (Aardvark)

Appendix II: KFS Permit



KENYA
Forest Service

Kenya Forest Service Hqs
Karura, Off Kiambu Rd
P. O. Box 30513 - 00100
Nairobi, Kenya.

Ref: No. ……RESEA/1/KFS/VOL. VI (6)

Date: …1st September 2020…

Evance O. Ouya
P. O. Box 861-20500,
NAROK

RE: PERMISSION TO CONDUCT RESEARCH IN MAU FOREST ECOSYSTEM

Reference is made to your letter dated 7th July 2020 in which you requested access to Mau Forest Complex for research purposes.

Permission is hereby granted for you to access Mau Forest to conduct research for your Masters Project into: '**Small carnivore abundance, distribution and species diversity along gradients of human disturbance in Mau Forest Complex, Kenya**'.

As part of the requirements, you shall provide a copy of your thesis on completion. This permit is valid from 3rd September 2020 to 2nd September 2021.

By a copy of this permit, the respective Ecosystem Conservators and Forest Station Manager are hereby instructed to facilitate access.

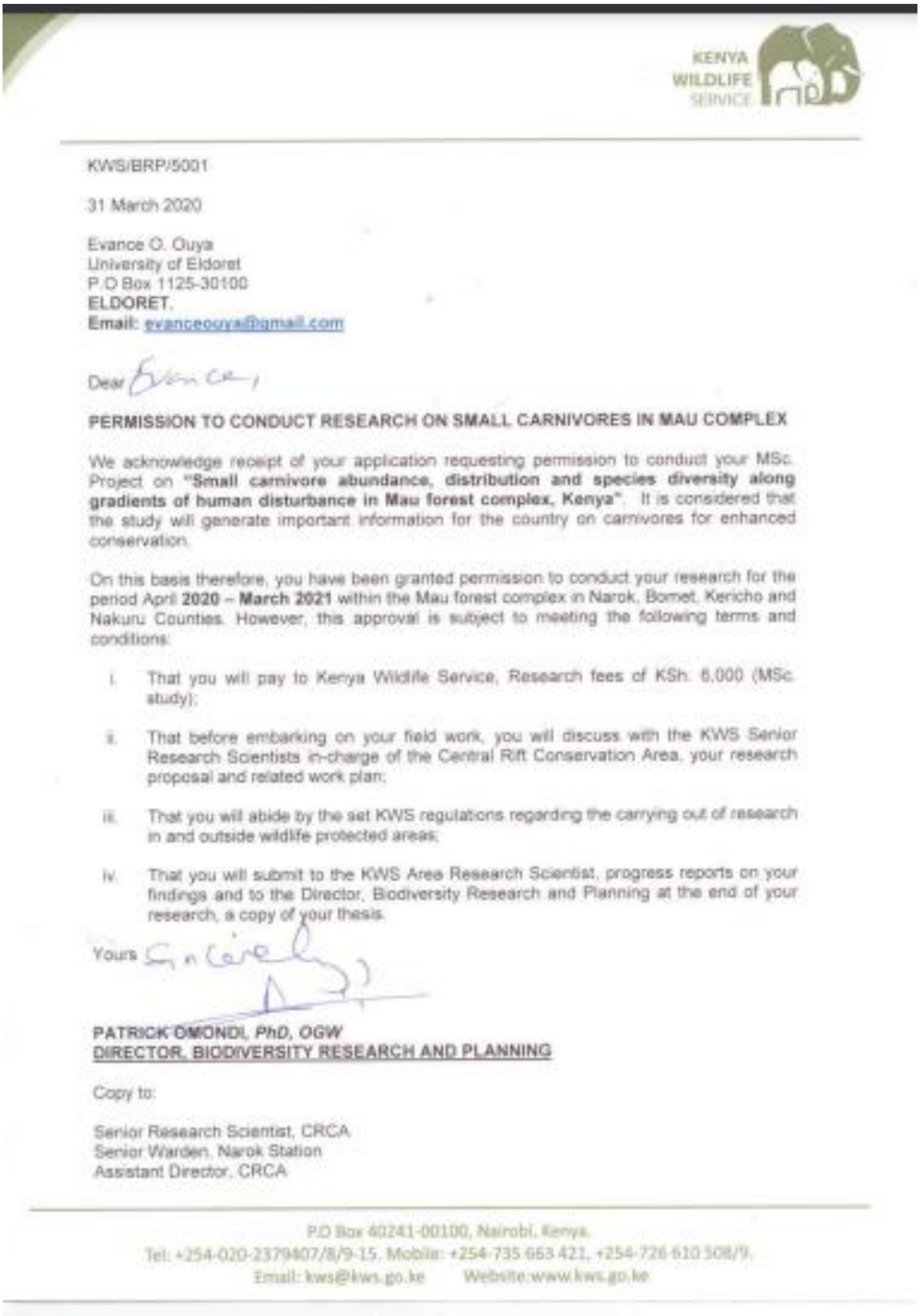
JULIUS KAMAU
CHIEF CONSERVATOR OF FORESTS

Copy to: Ecosystem Conservator- Narok, Bomet, Kericho and Nakuru
JM/sa

Trees for better lives

Tel: (254)020-3754904/5/6, (254)020-2014663, (254)020-2020285, Fax: (254)020-2385374
Email: info@kenyaforestservice.org, Website: www.kenyaforestservice.org

Appendix III: KWS Permit



KENYA
WILDLIFE
SERVICE

KWS/BRP/5001

31 March 2020

Evance O. Ouya
University of Eldoret
P.O Box 1125-30100
ELDORET.
Email: evanceouya@gmail.com

Dear Evance,

PERMISSION TO CONDUCT RESEARCH ON SMALL CARNIVORES IN MAU COMPLEX

We acknowledge receipt of your application requesting permission to conduct your MSc. Project on **"Small carnivore abundance, distribution and species diversity along gradients of human disturbance in Mau forest complex, Kenya"**. It is considered that the study will generate important information for the country on carnivores for enhanced conservation.

On this basis therefore, you have been granted permission to conduct your research for the period April **2020 – March 2021** within the Mau forest complex in Narok, Bomet, Kericho and Nakuru Counties. However, this approval is subject to meeting the following terms and conditions:

i. That you will pay to Kenya Wildlife Service, Research fees of KSh. 6,000 (MSc. study);

ii. That before embarking on your field work, you will discuss with the KWS Senior Research Scientists in-charge of the Central Rift Conservation Area, your research proposal and related work plan;

iii. That you will abide by the set KWS regulations regarding the carrying out of research in and outside wildlife protected areas;

iv. That you will submit to the KWS Area Research Scientist, progress reports on your findings and to the Director, Biodiversity Research and Planning at the end of your research, a copy of your thesis.

Yours Sincerely,

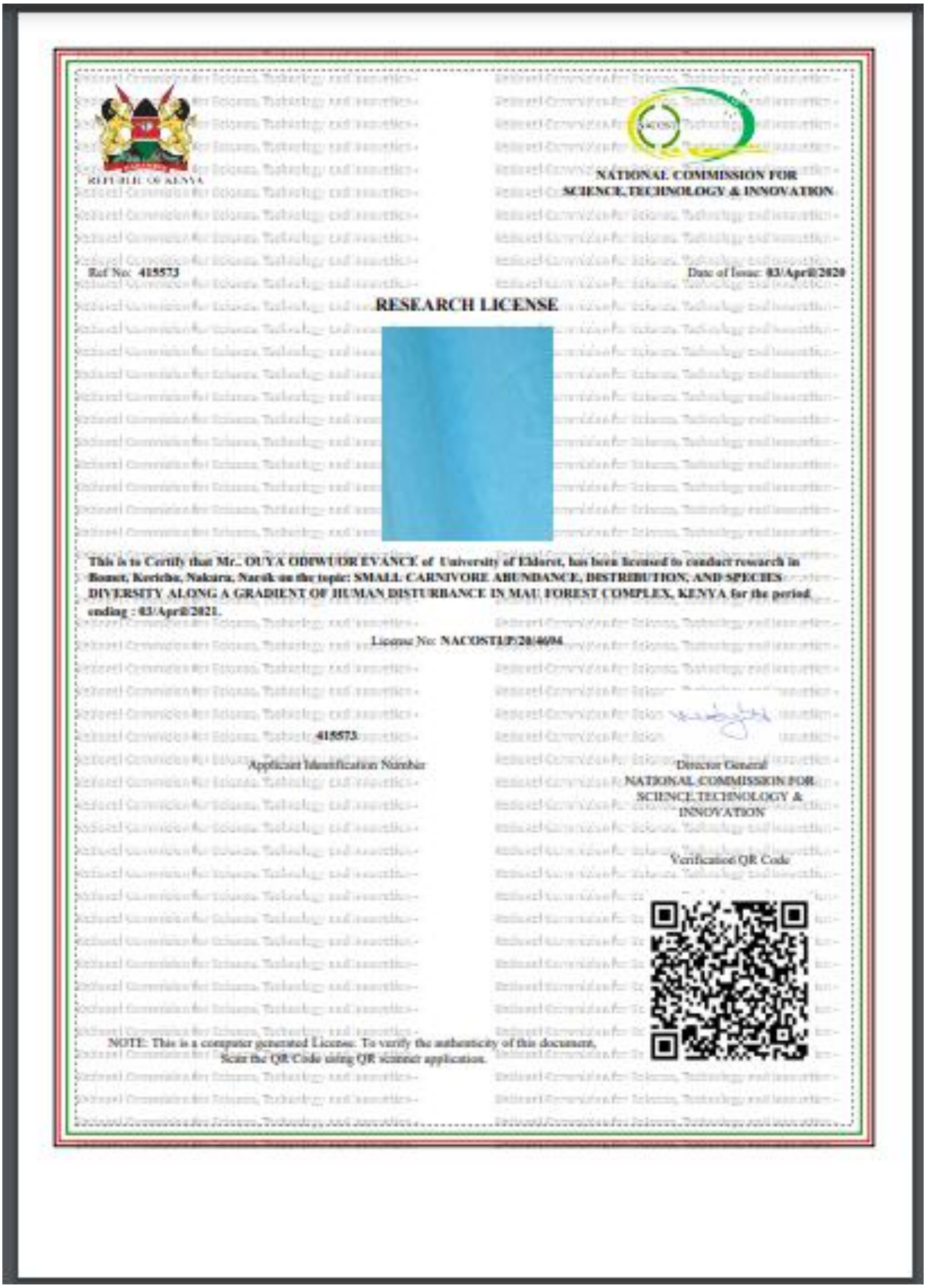
PATRICK OMONDI, *PhD, OGW*
DIRECTOR, BIODIVERSITY RESEARCH AND PLANNING

Copy to:

Senior Research Scientist, CRCA
Senior Warden, Narok Station
Assistant Director, CRCA

P.O Box 40241-00100, Nairobi, Kenya.
Tel: +254-020-2379407/8/9-15, Mobile: +254-735 663 421, +254-726 610 508/9.
Email: kws@kws.go.ke Website: www.kws.go.ke

Appendix IV: NACOSTI Permit



REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: **415573**

Date of Issue: **03/April/2020**

RESEARCH LICENSE

This is to Certify that Mr.. OUYA ODIWUOR EVANCE of University of Eldoret, has been licensed to conduct research in Bomet, Kericho, Nakuru, Narok on the topic: SMALL CARNIVORE ABUNDANCE, DISTRIBUTION, AND SPECIES DIVERSITY ALONG A GRADIENT OF HUMAN DISTURBANCE IN MAU FOREST COMPLEX, KENYA for the period ending : 03/April/2021.

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Appendix V: List of mammals photographed during the pilot and thesis project from Mau Forest, Kenya.

							Maasai Mau			Transmara		
Order	Family	Species	Images	Detections*	Pilot	Thesis	Primary	Secondary	Cultivated	Primary	Secondary	Cultivated
Artiodactyla	Bovidae	*Bos taurus*	23593	2084	X	X	x	x	X	x	x	x
Artiodactyla	Bovidae	*Capra aegagrus hircus*	3959	1302	X	X		x	X			x
Artiodactyla	Bovidae	*Cephalophus* sp.	55	15		X	x	x		x		
Artiodactyla	Bovidae	*Cephalophus silvicultor*	584	37		X	x	x		x		
Artiodactyla	Bovidae	*Cephalophus*	3779	494	X	X	x	x	X	x		

la		*weynsi*										
Artiodactyla	Bovidae	*Kobus ellipsiprymnus*	413	10		X	x	x				
Artiodactyla	Bovidae	*Madoqua kirkii*	695	96	X	X		x	X			
Artiodactyla	Bovidae	*Ovis aries*	4137	1210	X	X		x	X		x	x
Artiodactyla	Bovidae	*Philantomba monticola*	5343	703	X	X	x	x	X	x	x	
Artiodactyla	Bovidae	*Sylvicapra grimmia*	208	23	X	X		x	X		x	
Artiodactyla	Bovidae	*Syncerus caffer*	12	2	X			x				

Artiodactyla	Bovidae	*Tragelaphus eurycerus*	6	2		X	x					
Artiodactyla	Bovidae	*Tragelaphus scriptus*	5171	258	X	X	x	x		x	x	
Artiodactyla	Suidae	*Hylochoerus meinertzhageni*	208	12		X	x			x		
Artiodactyla	Suidae	*Potamochoerus larvatus*	509	14	x	X	x	x		x	x	
Carnivora	Canidae	*Canis* sp.	26	3	X	X						x
Carnivora	Canidae	*Canis adustus*	146	11	X	X			X			x
Carnivora	Canidae	*Canis familiaris*	5720	1110	X	X	x	x	X	x	x	x
Carnivora	Felidae	*Caracal* sp.	2	1		X		x				
Carnivora	Felidae	*Caracal caracal*	12	4	X	X		x				

Carnivora	Felidae	*Felis catus*	174	32	X	X		x	X			x
Carnivora	Felidae	*Felis silvestris lybica*	16	1		X			X			
Carnivora	Felidae	*Felis* sp.	6	3		X						x
Carnivora	Felidae	*Leptailurus serval*	46	12	X	X		x	X	x	x	x
Carnivora	Felidae	*Panthera pardus*	21	1		X	x					
Carnivora	Herpestidae	*Atilax paludinosus*	92	10		X				x	x	
Carnivora	Herpestidae	*Bdeogale jacksoni*	1741	156	X	X	x	x	X	x	x	
Carnivora	Herpestidae	*Herpestes ichneumon*	127	20	X	X	x		X	x	x	x

Carnivora	Herpestidae	*Herpestes sanguineus*	157	35	X	X	x	x		x	x	
Carnivora	Herpestidae	*Herpestes* sp.	121	25		X	x	x	X			
Carnivora	Herpestidae	*Ichneumia albicauda*	116	37	X	X		x	X			x
Carnivora	Hyaenidae	*Crocuta crocuta*	40	5	X	X				x	x	
Carnivora	Mustelidae	*Aonyx capensis*	3	1	X					x		
Carnivora	Mustelidae	*Ictonyx striatus*	339	39	X	X	x	x	X	x		
Carnivora	Mustelidae	*Mellivora capensis*	79	10	X	X	x	x		x	x	
Carnivora	Nandinidae	*Nandinia binotata*	107	6	X	X				x		x
Carnivora	Viverridae	*Civettictis civetta*	135	22	X	X		x	X		x	x

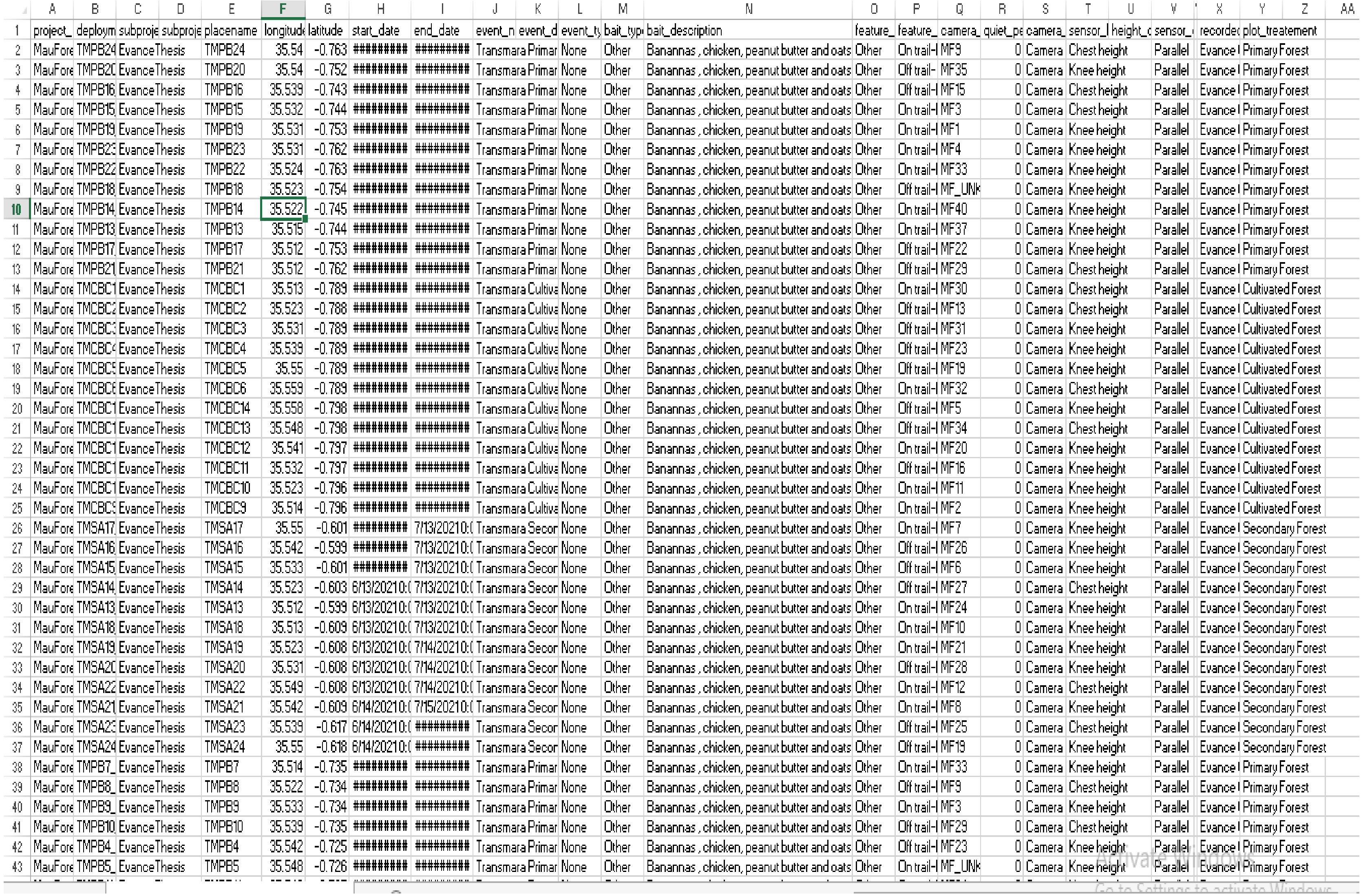
Carnivora	Viverridae	*Genetta maculata*	2478	343	X	X	x	x	X	x	x	x
Carnivora	Viverridae	*Genetta servalina*	953	123	X	X				x		
Carnivora	Viverridae	*Genetta* sp.	85	26	X	X	x	x	X	x	x	x
Hyracoidea	Procavidae	*Dendrohyrax arboreus*	294	54	X	X	x	x	X	x	x	
Lagomorpha	Leporidae	*Lepus* sp.	238	83	X	X		x	X			x
Perissodactyla	Equidae	*Equus asinus*	4379	421	X	X		x	X			x
Primates	Cercopithecidae	*Cercopithecus ascanius*	70	27	X	X	x	x		x	x	
Primates	Cercopithecidae	*Cercopithecus mitis*	2413	420	X	X	x	x	X	x	x	x

Primates	Cercopithecidae	*Cercopithecus* sp.	159	15	X	X	x	x		x	x	
Primates	Cercopithecidae	*Colobus guereza*	44	13	X	X		x		x	x	
Primates	Cercopithecidae	*Papio Anubis*	100	27	X	X		x	X	x		
Primates	Galagidae	*Otolemur crassicaudatus*	337	13	X			x				
Primates	Hominidae	*Homo sapiens*	47620	3484	X	X	x	x	X	x	x	x
Proboscidea	Elephantidae	*Loxodonta Africana*	93	6	X	X			X	x		
Rodentia	Gliridae	*Graphiurus sp.*	6	7	X	X		x			x	

Rodentia	Hystricidae	*Hystrix africaeaustralis*	415	24	X	X		x			x	x
Rodentia	Muridae	*Lemniscomys* sp.	2	2	X	X				x		x
Rodentia	Muridae	*Lophiomys imhausi*	24	9		X	x	x		x		
Rodentia	Muridae	*Lophuromys* sp.	4	4	X	X				x	x	
Rodentia	Nesomyidae	*Cricetomys ansorgei*	2014	380	X	X		x	X	x	x	x
Rodentia	Sciuridae	*Heliosciurus rufobrachium*	54	14	X	X		x		x		
Rodentia	Thryonomyidae	*Thryonomys* sp.	28	7		X		x			x	
Tubulidentata	Orycteropidae	*Orycteropus afer*	46	9	X			x				

*Detections are defined as independent photos separated by 60 seconds

Appendix VI. Deployments showing Camera protocol that was filled into the WI



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X	Y	Z	AA
1	project_	deploym	subproje	subproje	placename	longitude	latitude	start_date	end_date	event_n	event_d	event_ty	bait_typ	bait_description	feature_	feature_	camera_	quiet_pe	camera_	sensor_l	height_c	sensor_	recordec	plot_treatement		
2	MauFore	TMPB24	EvanceThesis		TMPB24	35.54	-0.763	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF9	0	Camera	Chest height		Parallel	Evance	Primary Forest		
3	MauFore	TMPB20	EvanceThesis		TMPB20	35.54	-0.752	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF35	0	Camera	Knee height		Parallel	Evance	Primary Forest		
4	MauFore	TMPB16	EvanceThesis		TMPB16	35.539	-0.743	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF15	0	Camera	Chest height		Parallel	Evance	Primary Forest		
5	MauFore	TMPB15	EvanceThesis		TMPB15	35.532	-0.744	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF3	0	Camera	Chest height		Parallel	Evance	Primary Forest		
6	MauFore	TMPB19	EvanceThesis		TMPB19	35.531	-0.753	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF1	0	Camera	Knee height		Parallel	Evance	Primary Forest		
7	MauFore	TMPB23	EvanceThesis		TMPB23	35.531	-0.762	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF4	0	Camera	Knee height		Parallel	Evance	Primary Forest		
8	MauFore	TMPB22	EvanceThesis		TMPB22	35.524	-0.763	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF33	0	Camera	Knee height		Parallel	Evance	Primary Forest		
9	MauFore	TMPB18	EvanceThesis		TMPB18	35.523	-0.754	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF_UNK	0	Camera	Knee height		Parallel	Evance	Primary Forest		
10	MauFore	TMPB14	EvanceThesis		TMPB14	35.522	-0.745	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF40	0	Camera	Knee height		Parallel	Evance	Primary Forest		
11	MauFore	TMPB13	EvanceThesis		TMPB13	35.515	-0.744	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF37	0	Camera	Knee height		Parallel	Evance	Primary Forest		
12	MauFore	TMPB17	EvanceThesis		TMPB17	35.512	-0.753	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF22	0	Camera	Knee height		Parallel	Evance	Primary Forest		
13	MauFore	TMPB21	EvanceThesis		TMPB21	35.512	-0.762	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF29	0	Camera	Chest height		Parallel	Evance	Primary Forest		
14	MauFore	TMCBC1	EvanceThesis		TMCBC1	35.513	-0.789	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF30	0	Camera	Chest height		Parallel	Evance	Cultivated Forest		
15	MauFore	TMCBC2	EvanceThesis		TMCBC2	35.523	-0.788	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF13	0	Camera	Chest height		Parallel	Evance	Cultivated Forest		
16	MauFore	TMCBC3	EvanceThesis		TMCBC3	35.531	-0.789	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF31	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
17	MauFore	TMCBC4	EvanceThesis		TMCBC4	35.539	-0.789	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF23	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
18	MauFore	TMCBC5	EvanceThesis		TMCBC5	35.55	-0.789	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF19	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
19	MauFore	TMCBC6	EvanceThesis		TMCBC6	35.559	-0.789	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF32	0	Camera	Chest height		Parallel	Evance	Cultivated Forest		
20	MauFore	TMCBC1	EvanceThesis		TMCBC14	35.558	-0.798	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF5	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
21	MauFore	TMCBC1	EvanceThesis		TMCBC13	35.548	-0.798	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF34	0	Camera	Chest height		Parallel	Evance	Cultivated Forest		
22	MauFore	TMCBC1	EvanceThesis		TMCBC12	35.541	-0.797	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF20	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
23	MauFore	TMCBC1	EvanceThesis		TMCBC11	35.532	-0.797	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF16	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
24	MauFore	TMCBC1	EvanceThesis		TMCBC10	35.523	-0.796	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF11	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
25	MauFore	TMCBC9	EvanceThesis		TMCBC9	35.514	-0.796	#########	#########	Transmara	Cultiva	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF2	0	Camera	Knee height		Parallel	Evance	Cultivated Forest		
26	MauFore	TMSA17	EvanceThesis		TMSA17	35.55	-0.601	#########	7/13/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF7	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
27	MauFore	TMSA16	EvanceThesis		TMSA16	35.542	-0.599	#########	7/13/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF26	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
28	MauFore	TMSA15	EvanceThesis		TMSA15	35.533	-0.601	#########	7/13/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF6	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
29	MauFore	TMSA14	EvanceThesis		TMSA14	35.523	-0.603	6/13/20210:	7/13/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF27	0	Camera	Chest height		Parallel	Evance	Secondary Forest		
30	MauFore	TMSA13	EvanceThesis		TMSA13	35.512	-0.599	6/13/20210:	7/13/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF24	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
31	MauFore	TMSA18	EvanceThesis		TMSA18	35.513	-0.609	6/13/20210:	7/13/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF10	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
32	MauFore	TMSA19	EvanceThesis		TMSA19	35.523	-0.608	6/13/20210:	7/14/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF21	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
33	MauFore	TMSA20	EvanceThesis		TMSA20	35.531	-0.608	6/13/20210:	7/14/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF28	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
34	MauFore	TMSA22	EvanceThesis		TMSA22	35.549	-0.608	6/13/20210:	7/14/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF12	0	Camera	Chest height		Parallel	Evance	Secondary Forest		
35	MauFore	TMSA21	EvanceThesis		TMSA21	35.542	-0.609	6/14/20210:	7/15/20210:	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF8	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
36	MauFore	TMSA23	EvanceThesis		TMSA23	35.539	-0.617	6/14/20210:	#########	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF25	0	Camera	Chest height		Parallel	Evance	Secondary Forest		
37	MauFore	TMSA24	EvanceThesis		TMSA24	35.55	-0.618	6/14/20210:	#########	Transmara	Secor	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF19	0	Camera	Knee height		Parallel	Evance	Secondary Forest		
38	MauFore	TMPB7_	EvanceThesis		TMPB7	35.514	-0.735	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF33	0	Camera	Knee height		Parallel	Evance	Primary Forest		
39	MauFore	TMPB8_	EvanceThesis		TMPB8	35.522	-0.734	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF9	0	Camera	Chest height		Parallel	Evance	Primary Forest		
40	MauFore	TMPB9_	EvanceThesis		TMPB9	35.533	-0.734	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF3	0	Camera	Knee height		Parallel	Evance	Primary Forest		
41	MauFore	TMPB10	EvanceThesis		TMPB10	35.539	-0.735	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF29	0	Camera	Chest height		Parallel	Evance	Primary Forest		
42	MauFore	TMPB4_	EvanceThesis		TMPB4	35.542	-0.725	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	Off trail-	MF23	0	Camera	Knee height		Parallel	Evance	Primary Forest		
43	MauFore	TMPB5_	EvanceThesis		TMPB5	35.548	-0.726	#########	#########	Transmara	Primar	None	Other	Banannas , chicken, peanut butter and oats	Other	On trail-	MF_UNK	0	Camera	Knee height		Parallel	Evance	Primary Forest		

Appendix VII: Carnivores of Mau Forest Captured by camera traps during the survey

1. Atilax paludinosus (Marsh Mongoose) Herpestidea

2. Bdeogale jacksoni (Jackson’s Mongoose) Herpestidea

3. Herpestes sanguineus (Slender Mongoose) Herpestidea

4. Herpestes ichneumon (Egyptian Mongoose) Herpestidea

5. Ichneumia albicauda (White-tailed Mongoose) Herpestidea

6. Leptailurus serval (Serval) Felidae

7. Caracal caracal (Caracal) Felidae

8. Panthera pardus (Leopard) Felidae

9. Felis silvestris (African wildcat) Felidae

10. Canis adustus (Side-striped Jackal)

Canidae

11. Crocuta crocuta (Spotted Hyena)

Hyaenidae

12. Ictonyx striatus (Zorilla)

Mustelidae

13. Mellivora capensis (Honey Badger/Ratel)

Mustelidae

14. Nandinia binotata(African Palm Civet)

Nandinidae

15. Civettictis civetta (African Civet)

Viverridae

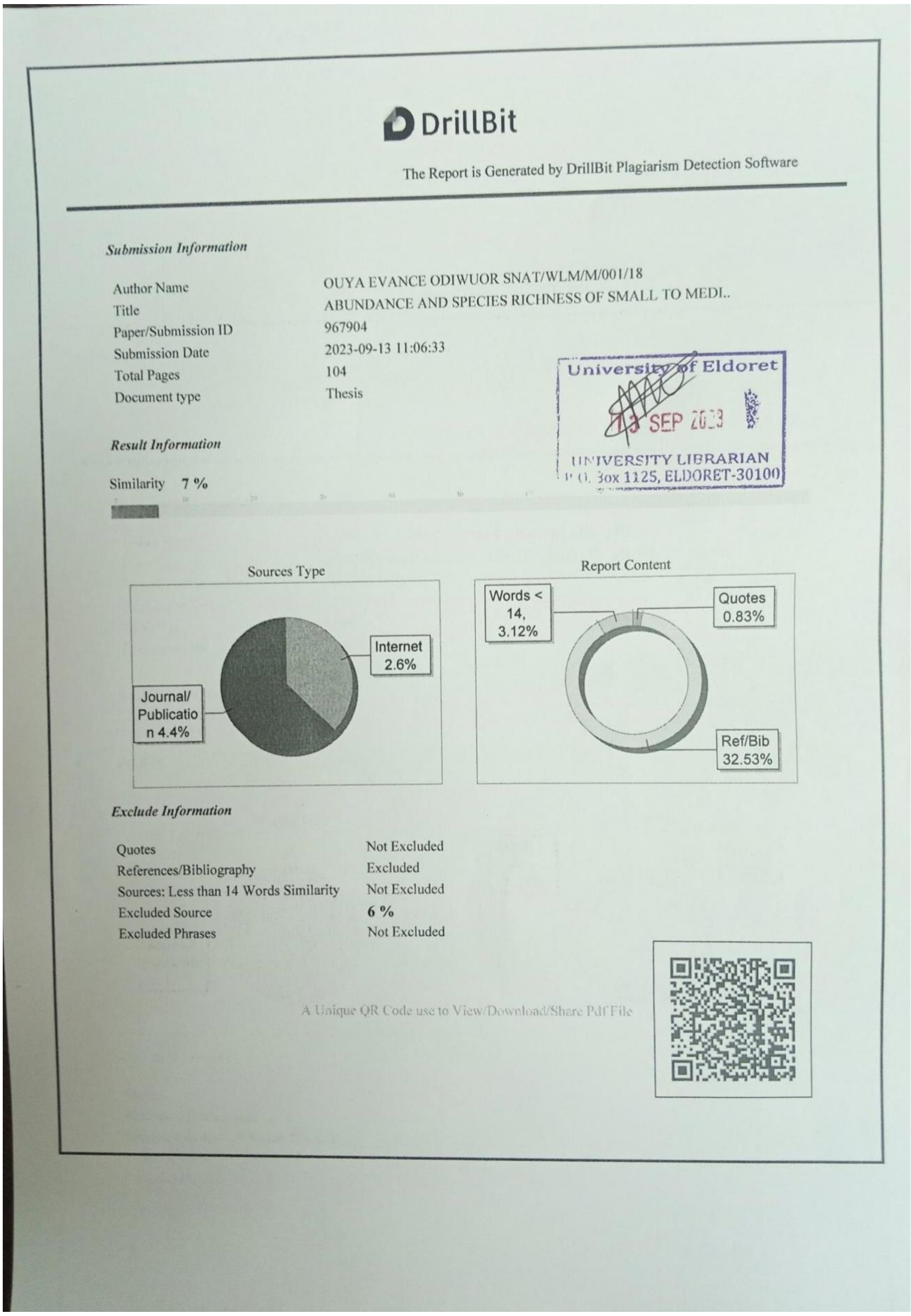
16. Genetta maculata (Large-spotted Genet)

Viverridae

17. Genetta servalina (Servaline Genet)

Viverridae

Appendix VIII: Similarity Report



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