Sokoine University of Agriculture

MSc Dissertation

Diversity of Rodents and Shrews in Tanzania and Prevalence of Their Parasites: A Case Study of Zaraninge Coastal Forest and Gongo Village

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May 2024

DIVERSITY OF RODENTS AND SHREWS IN TANZANIA AND PREVALENCE OF THEIR PARASITES: A CASE STUDY OF ZARANINGE COASTAL FOREST AND GONGO VILLAGE

Dissertation Submitted to Sokoine University of Agriculture in Partial Fulfilment of the Requirements for the Degree of Master of Science in Wildlife Management and Conservation

By

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May 2024

EXTENDED ABSTRACT

Rodents are important in the ecology of mammals because they serve as predators, prey, pests, and grazers. Their composition, community structure, population density, and habitat utilization are linked to environmental variables like resource availability and biological interactions. In Zaraninge Coastal Forest, several studies on rodents and shrews were undertaken before and after it the Coastal Forest was incorporated to the Saadani National Park (SANAPA). However, these studies focused on distribution and diversity of specific species of mammals in the Coastal Forest. The studies reported that human encroachment in the Coastal forest as one of threats affecting the forest. Nonetheless, information on the diversity of rodents and shrews and their parasites after annexing the forest to the National park to enhance its protection was not availed. Thus, there is a knowledge gap on the parasites of rodents and shrews, given that the rodents and shrews are reservoirs of parasites that can be potential agents of transmitting diseases to human beings. So, it was crucial to investigate the diversity of rodents and shrews, but also investigate the parasites hosted in rodents and shrews that can transmit zoonotic diseases to human beings. The findings from the study aimed to provide information on the diversity of rodents and shrews, but also information of their parasites of health importance as most outbreaks of rodent-borne diseases in humans are commonly related to socio-economic deficiencies. The study was carried out from May to October 2021. The removal method using two types of traps –Sherman and Havahart was used to collect rodents and shrews. For ectoparasites, fur of the captured individuals were combed to dislodge ectoparasites, and for hemoparasites, blood samples were collected from a supra orbital vein and blood was smeared on glass slide to make smears. In analysis the Paleontological Statistics (PAST) Program version (3.22) and Microsoft Excel (2007) were used to analyze the data, which determined the diversity and relative abundance of rodents and shrews. The prevalence of parasites in the captured individuals was also investigated using the prevalence formula in the study. The Chi-square test was employed to investigate the link between the ectoparasites infestation and the individuals' sexes. About 203 individuals were caught in this study, where 197 individuals were rodents (*Mastomys natalensis, Gramomys dolichurus, Gerbilliscus leucogaster, Lemniscomys rosalia, Cricetomys* spp, *Beamys hindei, Graphiurus murinus and Xerus rutilus*) and 7 individuals were the non-rodentia (*Crocidura hirta, Petrodromus tetradactylus and Galago* spp. The study findings revealed that the rodents' diversity value was higher in the Coastal Forest, than in the Gongo Fallow Lands. The diversity of rodents in Zaraninge Coastal Forest obtained was 1.49 and that of Gongo Fallow Land was 0.22, yet, there were no any statistically difference on the diversity of the two sites. Meanwhile, the shrew diversity appeared to be similar on both sites (0.6931). The trap success (abundances) for rodents ranged from 4.60% to 0.03%, while for the shrews ranged from 0.08% to 0.05%. The infestation of ectoparasites to rodents and shrews, was higher (92.2%) in the fallow lands of Gongo Village than in the Coastal forest which had 7.8%. However, the infection rate of hemoparasites to rodents and shrews was also higher (95.1%) in the fallow lands than in the Coastal forest (4.9%). There was no significant association of the parasites infection and infestation to the sexes of the individuals caught. Yet, the count of the ectoparasites was higher on the female rodents and shrews (1035) than that of the male rodents and shrews (1026). In this study, the ectoparasites obtained were the *Echinolaelaps echidninus*, *Boophilus* spp, *Xenopyslla brasiliensis* and *Polyplax stephensi*. *E. echidninus* had higher prevalence of 942.6% on rodents particularly on *Mastomys natalensis* while the lower prevalence was seen in *P. stephensi*. In shrews, *Boophilus* spp had the highest prevalence of 233.3% than other ectoparasites. On the account of hemoparasites, *Plasmodium* sp had higher prevalence of 59.8% while *Bacillus* sp had lower prevalence of 0.5%.Therefore, these findings raises a concern on the public health of the nearby community, livestock and the wildlife since their interaction is inevitable. The parasites found in this study are of zoonotic importance, hence it’s important to put emphasis on the hygiene of the people and the environment so as to avoid any eruption of the zoonotic diseases in the community. The findings on diversity provide the information on the importance of the conservation on habitats in order to preserve species. However, higher captures on fallow lands alerts the community on developing pests control strategies to protect their farms and houses from been invaded by rodents. Further studies on rodents and shrews of peri-domestic and domestic areas, reports on zoonotic diseases that maybe found in the nearby community, development of strategies to prevent rodents as destructive pest in farms are recommended so as to get more detailed information on the rodents and shrews in these areas.

Keyword: Rodents, shrews, parasites, diversity, abundance, Zaraninge Coastal Forest

IKISIRI KUU

Panya ni muhimu katika ikolojia ya mamalia kwa sababu wanatumika kama chanzo cha chakula, chakula cha wanyama wengine, hula wadudu na huaribu mazao na pia hubeba vimelea ambazo husambaza magonjwa mbalimbali kwa binadamu. Makundi yao, muundo wa jamii yao, uwiani wa idadi na matumizi ya makazi yao yanahusiana na vipengele vya mazingira kama upatikanaji wa rasilimali na mwingiliano wa kibaolojia. Utafiti huu ulijikita katika kutambua wingi, muundo wao na utofauti wa panya, lakini pia ueneaji wa vimelea vinavyopatikana nje ya mwili na kwenye damu ya panya katika Msitu wa Pwani wa Zaraninge na Ardhi ya konde ya kijiji cha Konde. Utafiti huu ulifanyika katika maeneo mawili ambapo moja ni eneo la kijiji cha Gongo lililokaribu na msitu na eneo la pili ni Msitu wa Zaraninge. Njia ya kutowarudisha katika jamii yao baada ya utafiti ilitumika kukamata panya. Jumla ya aina 10 za panya zilikamatwa. Aina hizo ilihusisha *Mastomys natalensis*, *Beamys hindei*, *Grammomys dolichurus, Graphiurus murius, Lemniscomys rosalia, Cricetomys* spp*, Xerus rutilus, Gerbilliscus leucogaster, Crocidura hirta* na *Petrodromus tetradactylus*. M. natalensis na B. hindei waliopatikana kwa wingi katika tafiti hii. Jumla ya aina nne za vimelea vinavyopatikana nje ya mwili wa panya zilipatikana. Hii ilihusisha *Echinolaelaps echidninus* (90.2%)*, Xenopyslla brasiliensis* (6.7%), *Boophilus* spp (3.01%) *na Polyplax stephensi* (0.04 %)*.* Kwa upande wa vimelea wa Kwenye damu aina mbili zilipatikana, hii ilihusisha *Schizonts of Plasmodium* spp na *Bacillus* spp*.* Asilimia ya panya 87 walikutwa na vimelea vya nje ya mwili Wakati asilimia 60.3 ya sampuli za damu zilikutwa na vimelea vya damu.. Aina moja ya panya: *Mastomys natalensis* (N =84.77%) ilithibitika kuwa na ueneaji mkubwa wa vimelea vinavyopatikana nje ya mwili wa panya kuliko panya wegine wote, kwa upande wa aina ya viemelea wa nje ya mwili: aina mbili *Xenopsylla brasiliensis* na *Echinolaelaps echidininus* walionekana kwa wingi katika spishi mbalimbali kuliko vimelea wengine wa nje. Katika upande wa vimelea wa damu Schizonts of Plasmodium spp walionekana kwa wingi kuliko bacillus spp. Ukiangalia katika utofauti na familia za panya Msitu wa Pwani wa Zaraninge ulionesha utofauti mkubwa (*Diversity t-test =7.64, df= 28, p=0.0001*) wakati ardhi ya konde ya Gongo ilionesha utofauti mdogo japo panya wengi walishikwa katika eneo hilii, hili ni kwasabau usumbufu na uvamizi katika maeneo ya ardhi ya konde ya kijiji cha Gongo ulikua mkubwa na hivyo maeneo ambayo yangekuwa salama kwa spishi nyingi za panya hayakuwepo lakini wingi ni kwasababu ya mashamba mapya ambayo yalikua yameanzishwa kwa mbele ya maeneo haya.

Kutokana na ukweli kwamba miongoni mwa aina zote nne na mbili za vimelea zilizopatikana, katika tafiti hii kuthibitika kuwa na uwezo wa kusambaza magonjwa mbalimbali ikiwepo Tauni, homa ya virusi, chanzo cha upungufu wa damu, Malaria mbili kutoka kwa panya kwenda binadamu, uwepo wa umakini pamoja na mkakati wa kuepuka ukaribu na vimelea hivi ni muhimu ili kulinda afya za jamii ya Gongo iliyokaribu na msitu huu wa Zaranige na taarifa ya tofauti na muundo wa panya hawa kuwa faida kwa wataalamu wa mazingira na uhifadhi.

Maneno muhimu: Panya, Vimelea, Uwingi, Ueneaji, Msitu wa Zaraninge

DECLARATION

I, IRENE ROMANUS MKUDE, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been nor being concurrently submitted in any other institution.

________________________ ___________________

Irene Romanus Mkude Date

(MSc. Candidate)

The above declaration confirmed by

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Prof. Abdul A. S. Katakweba Date

(Supervisor)

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Dr. Sayuni B. Mariki Date

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ACKNOWLEDGEMENT

First and foremost, I would like to express my heartfelt gratitude to God for his constant direction and protection.

I am grateful to my supervisors at Sokoine University of Agriculture (SUA), Prof. Abdul Katakweba (Institute of Pest Management) and Dr. Sayuni Mariki (Department of Wildlife Management), for their presence, assistance, advice, and constructive criticism in moulding this work to its current form.

Dr. Nsajigwa Mbije (Department of Wildlife Management), Prof. Rhodes Makundi, and Prof. Apia Massawe (Institute of Pest Management) are also thanked for their excellent advice and support.

I also like to thank the Africa Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development (ACE-IRPM & BTD), from the Institute of Pest Management for supporting this project and providing me with the opportunity to further my studies

I'd also like to thank my parents, Mr. and Mrs. Romanus Mkude, as well as my siblings Michael, Joshua, Sarah, David, and Rebecca, for their unwavering love, support, and prayers, which enabled me to get this far.

Finally, many thanks to Mr. Muhamphi and Mr. Omary from IPM-SUA for their invaluable assistance throughout data collection in the field and laboratory work.

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LIST OF ABBREVIATIONS

ACE-IRPM & BTD	Africa Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development
Chi^{2} -	Chi-square
df	Degree of freedom
Ecto & hemo	ectoparasites and hemoparasites
IPM	Institute of Pest Management
PAST	Paleontological statistics
SANAPA	Saadani National Park
Spp	Species
SUA	Sokoine University of Agriculture
TANAPA	Tanzania National Parks

STRUCTURE OF THE DISSERTATION

This dissertation is divided into four chapters. CHAPTER ONE provides background information on the classification of rodents and shrews, habitat and behavior, diversity of rodents and shrews in forests and fallow lands/villages, ectoparasites and hemoparasites of rodents and shrews in forests and fallow lands/ villages, problem statement and justification, research objectives, and a list of manuscripts. CHAPTER TWO (Manuscript ONE) focuses on the diversity of rodents and shrews in Tanzania's Saadani National Park's Zaraninge Coastal Forest and Gongo fallow land. CHAPTER THREE (Manuscript TWO) focuses on the prevalence of rodent and shrew parasites in the Zaraninge Coastal Forest and Gongo fallow lands. CHAPTER FOUR includes an overview, conclusion, and recommendations.

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background

Background information on rodents and shrews

Rodents are small mammals distinguished by continuous gnawing and the constant growth of their long incisor teeth, whereas shrews are tiny insectivorous mammals distinguished by sharp-like teeth, a very small body, and being generally smaller than a mouse (Katakweba, 2018). Both are members of the Kingdom Animalia, Phylum Chordata, and Class Mammalia, but rodents are classified as Rodentia and shrews as Soricomorpha (Kingdon, 1997).

The term “habitat” in this work is defined as a location or place with distinct abiotic and biotic factors where animals stay and get food, shelter, or mates (Riha and Prchalová, 2022). According to Michael and Janice (2021), animal behavior is how animals move in their environment, how they interact socially, how they learn about their environment, and how an animal may achieve cognitive understanding of its environment, whereas abundance is the relative representation of a species in a specific ecosystem, which is measured as the number of individuals found per sample (Preston, 1948).Rodents and shrews are the most successful group of mammals in terms of exploiting a diverse range of habitats, as they are found in large numbers on all continents except Antarctica (Sharma, 2013). In Africa, there are four major rodent divisions: gundi and porcupine (Hystricomorphs), squirrel (Sciuromorphs), anomalures (Anomaluromorphs), and rats (Myomorphs) (Kingdon, 2015). Rodents and shrews have successfully exploited a wide range of habitats and environments around the world due to their high reproductive potential (Makundi *et al.,* 2003). These include forest and shrubs, as well as agricultural areas (Mulungu *et al.,* 2013; Claveria *et al.* 2005).Despite the fact that rodents and shrews are successful species with a diverse range of habitats, their diversity is heavily influenced by factors such as habitat loss, food resource depletion, encroachment, and logging (Kiwia, 2006). The abundance of rodents and shrews is an important factor because it reveals more about the rodents and shrews in an ecosystem, in term of dominance, favourable habitats or the pull of certain favourable resources for some species. Seasonal variations, disturbance in the vegetation cover, and habitat characteristics can all have an impact on the abundance of rodents and shrews (Meserve *et al.,* 2011; Malcom and Ray, 2020; Karasov-Olson and Kelt, 2020). The seasonal variations can lead to high or low abundance, as when the rainfall is adequate, there will be more resources that help to increase their reproduction, but minor changes in habitat or vegetation cover can lead to fluctuations in rodent and shrew abundance.

Diversity of rodents and shrews

Species diversity is the number of different species present in an ecosystem and relative abundance of each of those species (Xu *et al.,* 2020). The diversity of small mammals in modern Africa appeared to have been impacted mostly by the diverse ecosystems that cover the majority of Africa (Monadjem *et al.,* 2018). Rodents are the most diverse and abundant mammals in Africa, with a wide range of ecology, morphology, physiology, behavior, and life history strategies (Nedbal *et al.,* 1996).

Various studies on the diversity of rodents and shrews in forests, agricultural regions or fallow lands, and settlements or communities have been undertaken around the world (e.g. Mulungu *et al.,* 2008; Lema and Magige, 2018; Assefa and Chelmala, 2019). According to the study by Mulungu *et al.,* 2008 show that there was higher diversity of rodents in the disturbed forest than in the community areas. Another study conducted by Lema and Magige (2018) on the influence of agricultural operations on the diversity of rodents in the North Pare Mountains found that agricultural regions had more diversity than forest areas. The authors hypothesized that the variety was associated with the availability of favorable food resources in the agricultural lands. Assefa and Chelmala (2019) reported that the diversity was higher on both forest and agricultural land on different seasons of the year. During the rainy season diversity was higher in the forest while in the agricultural lands was associated with favourable food resources.

Ectoparasites in rodents and shrews

Rodents and shrews are major reservoirs and hosts for numerous animal parasites, including ectoparasites and hemoparasites. Ectoparasites are parasites that live in the skin or outgrowths of their host's skin; some are host specific, while others parasitize a wide spectrum of hosts (Dada, 2016). Mesostigmata (Mites), Prostigmata (Chiggers), Acarina (Ticks), Phthiraptera (Louse), and Siphonaptera (Fleas) are the five major groups of ectoparasites found on rodents' bodies (Paramasvaran, 2009).

The term “Prevalence” is defined as proportion of host individuals infected with a particular parasite and it is always expressed as a percentage (Ebert, 2005). According to Paramasvaran *et al.* (2009) study on the prevalence of ectoparasites of public health concern in forest regions, agricultural lands, and the community, revealed that the prevalence of ectoparasites in the community areas was higher than in the forest and agricultural lands. The authors also stated that the greater number of ectoparasites found posed the greatest harm to the community's public health. Other studies on ectoparasite prevalence in forest and community areas include that of Ishak *et al.* (2018), who found that prevalence was higher in the forest than in the community. The authors speculated that persons visiting the recreation forest would come into touch with ectoparasites, posing a risk to public health. Another study, conducted by Obiegala *et al.* (2021), found a higher incidence of ectoparasites in the community than in the forest region, as well as probable diseases such as Murine typhus fever and leptospirosis that might be introduced to the population by mice carrying these ectoparasites. As a result of these findings, we can conclude that awareness of ectoparasites can help to reduce the spread of rodent-borne diseases in the population.

Hemoparasites in rodents and shrews

Babesia sp., *Theileria* sp., *Bacilli* sp., and *Trypanosome* sp. are blood parasites that spend the most of their lives in the circulatory system of vertebrates (Batter *et al.,* 2002; Katakweba *et al.,* 2012). According to Thanee *et al.* (2009) study on the prevalence of blood parasites in diverse habitats such as forest and recreational areas, revealed the higher infection of blood parasites in the forest areas. The author also discussed the diseases induced by the blood parasites infection seen in their study. Katakweba *et al.* (2012) conducted a study on zoonotic diseases in three nations, collecting blood samples from rodents and shrews in domestic and peridomestic regions. The study focused on hemoparasites and bacteria, specifically leptospires and Yersinia pestis. The multiple hemoparasites and bacteria were detected in those blood samples, demonstrating that rodents and shrews are reservoirs of zoonotic-infectious organisms.

Various studies, however, indicate that hemoparasites identified in rodents and shrews receive less attention (Katakweba, 2018). Thus, understanding hemoparasites and their frequency is important to the community in order to control and prevent diseases carried by rodents and shrews.

So, the study is of importance to the nearby community in terms of protecting themselves from transmission zoonotic diseases but also help in developing strategies to control pests that could be troublesome to their agriculture activities. To SANAPA, the information helps in focusing on how to conserve and protecting multiple species of rodents and shrews but also the parasites information is to alert of diseases that can rise among wildlife animals due to transmission of parasites among wild animals.

1.2 Problem Statement and Justification

Several researches have been carried out to explain the diversity of rodent species in relation to vegetation (e.g.Mulungu *et al.,* 2008). For example, Sangiwa and Magige (2019) focused on species diversity in connection to the effects of roads in Northern Serengeti, whereas Magige (2013) investigated the diversity of rodent species in relation to the altitudinal gradient in Serengeti National Park. Furthermore, numerous studies on ectoparasites on rodents in relation to plague outbreaks have been undertaken in various places such as Karatu, Mbulu, and the Usambara Mountains (Laudisoit *et al.*, 2007: Makundi *et al.*, 2008). Other researches, such as Katakweba *et al.* (2013) and Katakweba (2018), focused on hemoparasites and how they act as disease agents. Dada (2016), for example, researched ectoparasites and hemoparasites on domestic rodents in the Akure region of Nigeria. In the Zaraninge Coastal Forest, studies on small mammals have been undertaken with an emphasis on the ecology and distribution of a specific species, the smaller pouched rat (Beamys hindei) (Sabuni *et al.,* 2015) as well as species composition and diversity (Kiwia, 2006). Some of these studies were carried out prior to Zaraninge Coastal Forest being annexed to Saadani National Park. The studies reported on how the diversity of mammals including small mammals has been affected by the people encroachment activities. The information on the diversity of rodents and shrews in the forest in relation to the adjacent fallow lands after protection was enhanced is not readily available. Furthermore, there is a knowledge gap on the parasites harbored by rodents and shrews that could raise a risk of transmission of zoonotic diseases to the human community.

So, it was critical to investigate on the diversity of the rodents and shrews and the ectoparasites and hemoparasites hosted in rodents and shrews that could transmit diseases like plague, hanta infections, rodent typhus, and helminthasis (as hymenolepiasis, schistosomiasis, and lung worm) to the human community because some of these small mammals harbor disease parasites (Singleton *et* *al.*, 2003). The findings of the study aimed to add to the body of knowledge on the diversity of rodents and shrews in the Zaraninge Coastal Forest and the adjacent fallow lands. Before the forest was annexed to Saadani National Park, it was heavily impacted by human encroachment, which had impact on the diversity of wildlife including rodents and shrews. Also the findings are to provide information on parasites on rodents and shrews, as most outbreaks of rodent-borne diseases in human communities are usually associated with socioeconomic inadequacies such as poor hygiene, poverty, and overcrowding, because there is relatively little awareness that rodents can transmit diseases (Katakweba *et al.,* 2013).

1.3 Objectives

1.3.1Main objective

Assessment of the diversity of rodents and shrews and prevalence of their parasites in Zaraninge Coastal Forest and Gongo Village in Tanzania

1.3.2 Specific objective

The specific objectives were to:

i. To determine the diversity of rodents and shrews in Zaraninge Coastal Forest and Gongo Village
ii. To determine the prevalence of hemoparasites and ectoparasites in rodents and shrews of public health importance.
iii. To compare the association between parasite infestation and sexes of rodent and shrews.

1.3.3 Hypotheses

H_0: The conservation status of the study sites has no significant effect on diversity of rodents and shrews

H_1: The conservation status of the study sites has a significant effect on diversity of rodents and shrews

H_0: There is no significant difference between prevalence of parasites on rodents and shrews in Zaraninge Coastal Forest and Gongo fallow lands.

H_1: There is a significant difference between prevalence of parasites on rodents and shrews in Zaraninge Coastal Forest and Gongo fallow lands.

H_0: There is no significant association between parasites infestation and sexes with rodent and shrews

H_1: There is a significant association between parasites infestation and sexes with rodent and shrews

1.3.4 List of manuscripts

This dissertation is based on two manuscripts titled;

i. Diversity of rodents and shrews in Zaraninge Coastal Forest and Gongo fallow lands.
ii. Prevalence of parasites from rodents and shrews in Zaraninge Coastal Forest and Gongo fallow lands

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CHAPTER TWO

Paper One

2.0. Diversity of Rodents and Shrews in Zaraninge Coastal Forest and Gongo Fallow Lands

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Status: Submitted to Integrative Zoology

Abstract

Diversity and trap success (abundance) of rodents and shrews between two sites were assessed. Rodents and shrews were sampled using two types of traps; Sherman and Havahart traps. A total of 203 individuals were caught, 185 from fallow lands and 18 from the Coastal Forest. Where 8 species (*Gerbilliscus leucogaster, Xerus rutilus, Lemniscomys rosalia, Mastomys natalensis, Beamys hindei, Graphiurus murinus, Grammomys dolichurus, and Cricetomys spp.)* were the rodents, two species (Crocidura hirta, *Petrodromus tetradactylus*) were shrews. Using Mann-Whitney test, the diversity of rodents between Zaraninge Coastal Forest *(H'= 1.49)* and Gongo Fallow Lands *(H'= 0.22)* did not differ significantly. The shrew diversity in this study was similar in both locations (0.6931).The Sorensen Coefficient (CCs) value of 0.67 indicates a low similarity in the species inhabiting the two study sites. Comparison of the Shannon diversity index value of between two sites was computed by the Hutcheson diversity test, which showed higher diversity value in Zaraninge Coastal Forest (t = 7.64, df =28, p =0.0001). The findings of higher diversity value in the Coastal Forest could be linked to the habitat heterogeneity. The higher capture on fallow lands could be due to the closer proximity of food resources from the current farms used by the community. These findings serve as an alert to the community to set strategies to control rodents from raiding their crops as they are crops pests. We recommended having more long term studies on rodents and shrews, to assess their abundance, diversity and their impacts to the peridomestic and domestic areas in Gongo village.

Keywords: *small mammals, Coastal forests, Gongo village*

Introduction

Coastal forests are habitats which are mostly fragmented, with various forest patches that vary in size, shape and structure (Burgess *et al*., 2000). These forests are isolated to each other and have a vegetation matrix between the forest being a mixture of farmland, woodland and thickest. Most of these forests patches have been affected with various climatic conditions and anthropogenic activities, however, they are considered to be habitats of greater importance in conservation of some endemic and near endemic species (Rodgers, 2000).

Zaraninge Forest is one of the coastal forests in Tanzania that supports a number of resident mammal species both large and small, including four species of antelopes, four species of primates, a few rodents and two species of elephant shrews, shrews and small carnivores (Clarke and Dickinson, 1995; Sabuni *et al*., 2015). Despite supporting a number of animals, the forest has also been surrounded by human settlements in its southern, northern and western parts, which has led to various disturbances due to multiple human activities.

The rodents and shrews composition, abundance and diversity in an area, provide more information on the quality or health of the environment and those parameters can be used in monitoring the degradation of the environment (Bowland and Perring, 1994). Rodents and shrews are also greater contributors to the biodiversity ecosystem chain. They feed on variety of foods such as plant material, insects, and worms but they are also preyed upon by small carnivores, birds of prey, and snakes (Delany, 1971). Yet, due to their habitat and cover requirements, the rodents and shrews tend to be affected by the overuse of the habitats by other species like domestic animals and larger mammals (Mulungu *et al.,* 2008).

Most rodents and shrews are not specific to some habitats, which helps them to survive in multiple habitats worldwide (Amori & Luiselli, 2011). In general, rodents and shrews are very adaptive since they tend to transpire in all continents worldwide except for Antarctica (Meserve *et al.,* 2011). Despite their ability to adopt most environments and habitats, the rodents and shrews are also sensitive to most environmental disturbance such as expansion of lands for settlements, farming etc., thus affecting their abundance and diversity (Webala *et al.,* 2006; Meserve *et al.,* 2011).

Most studies conducted on rodents and shrews in Zaraninge Coastal Forest focused more on the ecology and distribution of a specific mammal species. Some of these studies were conducted before the Coastal Forest was annexed to the Saadani National Park (Kiwia, 2006; sabuni, 2015). Despite these studies, information on the diversity of the rodents and shrews of the Coastal Forest and the adjacent fallow lands is limited. The findings of diversity of rodents and shrews at various habitats will assist in their protection and monitoring.

So, this study aims to examine (a) the composition of the rodents and shrews in Zaraninge Coastal Forest and adjacent fallow lands of Gongo Village; (b) the abundance of the rodents and shrews between the two sites. We hypothesized that diversity of rodents and shrews in the forest is higher than in the fallow land.

Study Area and Methods

Study area

The study was conducted in Zaraninge, a dry evergreen coastal forest along the eastern coast of Tanzania. The forest is situated at 6°04′–6°13′S and 38°35′–38°42′E, 15 km inland from the Indian Ocean on the South West of Saadani National Park (SANAPA). The rainfall pattern of the area is bimodal, receiving short rains between October and December and long rains between March and June. The mean annual rainfall ranges between 900 and 1 400 mm (Clarke, 2000). The temperature is typical of equatorial coastal forest regions of East Africa, with an annual maximum temperature of 29.7°C and a minimum of 21.9°C (Sabuni *et al.,* 2015).

The Gongo Village is located on the Southwest of the Saadani National Park, in which the village lies within Zaraninge Coastal Forest. The village was established in 2009. The population of the people is 2000, mostly are the "Wadoe" tribe. The people in this village are engaged in farming, mostly pineapple. The Kikwati Wildlife Corridor that connects to Wami Mbiki passes through the village (Anna and Smargada, 2019).

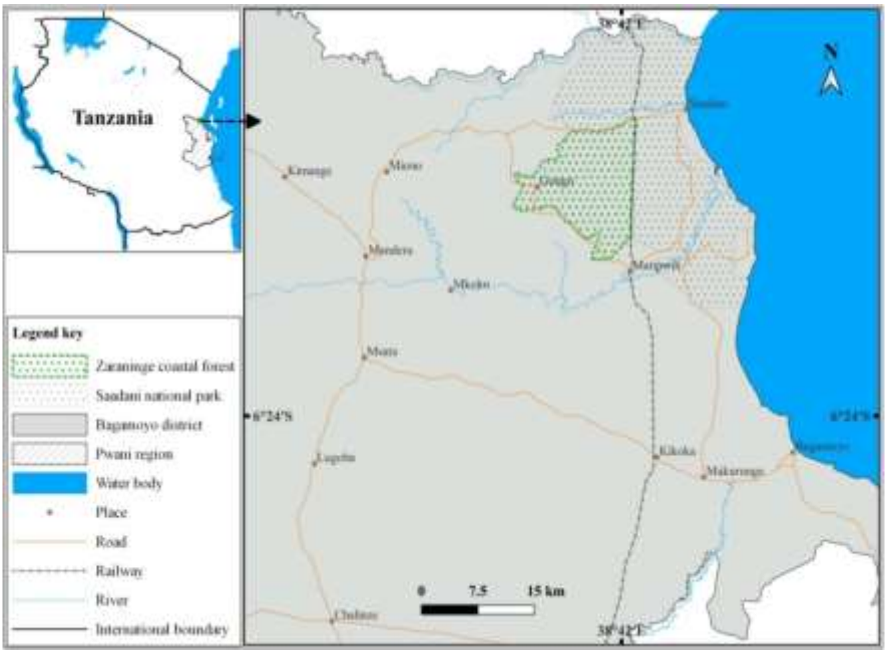

Figure 2.1: Map showing the location of Zaraninge Coastal Forest and Gongo Village in Tanzania (Irene, 2022).

Rodent and shrew trapping

Rodents and shrews were trapped between May and October of 2021 in the Zaraninge forest and the Gongo fallow lands using the removal method. Two grids of 10 × 10 m and their replications were established, two transects were situated in the forest and the other two on the fallow lands. Each transects had 10 parallel lines which are 10 m apart and 10 trapping stations per line. The space from one trapping station to another was 10 m apart making a total of 100 trapping stations per grid. One Sherman trap was set at each trapping station while 5 Havahart traps were set randomly at each grid to enhance capturing large rodents that cannot enter in Sherman traps e.g. the giant rat (Cricetomys spp). All Sherman traps were baited with peanut butter mixed with maize bran and fried coconut, while Havaharts were baited with fresh maize cobs, ripe bananas, and tomatoes. All traps were set for three consecutive nights in every month.

Animal processing

A cotton bag was used to remove the captured animals from the traps and then their morphological characteristics such as age, sex, weight, tail length, ear length, and hind foot length were recorded to aid in the identification of the rodents and shrews. Also, their reproductive statuses were recorded. After that the rodents and shrews were killed in the process using the Halothene thus, removing them completely from the population (Close *et al.,* 1997).

Data analysis

Trapping success

Trap success is usually expressed as the number of animals caught per total trap nights× 100. It was used to determine the relative abundance of the caught species (Stanley *et al*. 1996, Barnett *et al*. 2002). Trap success was calculated using the formula: TS = Tc / Tn × 100. Where Tc = to the total number of rodents and shrews species captured, while Tn = total number of a product of the number of traps used and trapping effort (trapping effort =number of days of trapping or effective trapping nights). A trap in use for a 24-hour period from sunrise to sunrise is referred to as a trap night.

Coefficient of Community similarity

Sorensen Coefficient (CCs) was used to determine the similarity of rodents and shrews species between the Zaraninge Coastal Forest and Fallow lands of Gongo Village based on binary (present-absent) data (Magige & Senzota, 2006; Wolda, 1981). The coefficient was calculated as follows

$$CCs = \frac{2c}{s1 + s2}$$

Where *s1* and *s2* = the number of species encountered in the study site 1and 2respectively, and *c* = the number of species common to both study sites (Alila, 2020). The value of *CCs* ranges from 0 (when all species found in the two habitats are not similar) to 1.0 (when all species found in both habitats are similar).

Diversity

The Paleontological Statistics Program software (PAST) of version 3.22 was used to estimate the richness of the species but also compute diversity using the Shannon- winner diversity index (Shannon & wiener 1948). The formula used to compute the diversity of the two sites was

$$H^{'} = -\sum_{i=1}^{s} pi, lnpi.$$

Where H′ is the diversity index and *pi* is the proportion of species *i* in the total number of animals captured. The comparison of the diversity index value between two sites was also computed in using the diversity package in the (PAST) software by using Hutcheson diversity t- test. The Hutcheson diversity t – test is the special test based on comparing diversity using the Shannon diversity indices computed using logarithm base. It is also applied to the data that can be normally or not normally distributed and the test can be done on one side or two sides (Hutcheson 1970).

Results

Family composition

Muridae, Nesomyidae, Gliridae, Soricidae, Sciuridae, Macroscelididae were the families of rodents and shrews found in this study. The Muridae family had four species, while the Nesomyidae, Sciuridae, and Macroscelididae families each had two, and the Gliridae, Soricidae families each had one. Table 2.1 lists the species caught as well as those observed but not caught.

Table 2.1: Rodents and shrews caught and observed in Zaraninge Coastal Forest and Gongo fallow lands

Family	Common name	Species
Muridae	Multimammate rat	*Mastomys natalensis (A. smith 1834)*
	Common thicket rat	*Grammomys dolichurus (Smuts 1832)*
	Bushveld gerbil	*Gerbilliscus leucogaster (*Peters 1852)
	Single-striped grass mice	*Lemniscomys rosalia (Thomas 1904)*
Nesomyidae	African giant pouched rat	*Cricetomys* spp (Waterhouse 1840)
	Lesser pouched rat	*Beamys hindei(Thomas 1909)*
Gliridae	African common dormouse	*Graphiurus murinus (*Desmarest 1822)
Sciuridae	Unstriped Ground Squirrel	*Xerus rutilus(*Cretzschmar 1828)
	Red bush squirrel	*Paraxerus palliates (*Peters 1852) +
Soricidae	Shrew	*Crocidura hirta(*Peters 1852)
Macroscelididae	Four toed elephant Shrew	*Petrodromus tetradactylus(*Peters 1846)
	Black-and-rufous-elephant Shrew	*Rhynchocyon petersi(*Bocage 1880) +

Key: **+** =mammals spotted but not caught.

Species composition

A total of 203 individuals of rodents and shrews belonging to 10 species and 6 families were captured (185 on fallow lands and 18 in the Coastal Forest). *Gerbilliscus leucogaster, Xerus rutilus*, and *Lemniscomys rosalia* were discovered in Gongo fallow fields, whereas *Cricetomys* spp. and *Graphiurus murinus* were discovered in the Zaraninge Coastal Forest. *Beamys hindei, Mastomys natalensis, Crocidura hirta, Grammomys dolichurus*, and *Petrodromus tetradactylus* were discovered in both habitats as shown in Table 2.2.

Trapping success (trapping success)

The relative abundance was expressed as trapping success, and the relative abundance of rodents and shrews ranged 4.6 % to 0.03 % with *Mastomys natalensis* been the dominant in the fallow lands and *Beamys hindei* dominant in the Costal Forest, as shown in the parentheses figures (Table 2.2).

Table 2.2: The trapping success of rodent and shrew species between Zaraninge Coastal Forest and Gongo fallow lands

SITES		**Fallow lands**		**Zaraninge**		
Rodent species	**Number of animals**	**Trap nights**	**Trap success (%)**	**Number of animals**	**Trap nights**	**Trap success (%)**
Mastomys natalensis	174	3780	4.60	1	3780	0.03
Beamys hindei	2	3780	0.05	5	3780	0.13
Grammomys dolichurus	2	3780	0.05	4	3780	0.11
Graphiurus murinus	0	3780	0.00	4	3780	0.11
Cricetomys spp	0	3780	0.00	2	3780	0.05
Lemniscomys rosalia	1	3780	0.03	0	3780	0.00
Xerus rutilus	1	3780	0.03	0	3780	0.00
Gerbilliscus leucogaster	1	3780	0.03	0	3780	0.00
Total	**181**			**16**		
Shrew species						
Crocidura hirta	2	3780	0.05	3	3780	0.08
Petrodromus tetradactylus	2	3780	0.05	3	3780	0.08
Total	**4**			**6**		

Coefficient community similarities

The 8 species of rodents and shrews encountered in Gongo fallow land areas and 7 species of rodents and shrews found in Zaraninge Coastal Forest, only 5 species were common to both Gongo fallow land areas and Zaraninge Coastal Forest which resulted into a Sorensen Coefficient (CCs) value of 0.67, indicating a low similarity of the species inhabiting the two study sites.

Diversity of the rodents and shrews

As indicated in Table 2.3, the diversity of rodents and shrews was evaluated between Zaraninge Coastal Forest and Gongo fallow land areas. Six species of rodents were found in fallow land areas and five species were found in the Coastal Forest; the diversity showed no significant statistical difference (U=30.5, P= 0.9, n1=n2=8). Table 2.4 shows that two species of shrews were observed in each environment (Zaraninge Coastal Forest and Gongo Fallow Lands) and their diversity showed similarity between the two sites. The comparison of Shannon diversity indices of rodents in both site revealed a significant difference (Diversity t-test =7.64, df= 28, p=0.0001), with the Coastal Forest showing higher diversity index value than the fallow fields, as shown in Figure 2.

Table 2.3: Diversity of rodents in Zaraninge Coastal Forest and Gongo fallow lands

	Gongo fallow lands	**Zaraninge CR**
Species richness	6	5
Individuals	181	16
Trapping success	4.8%	0.4%
Shannon_H	0.2236	1.49
Evenness	0.2084	0.8873

Table 2.4: Diversity of Shrews in Zaraninge Coastal Forest and Gongo fallow lands

	Gongo fallow lands	Zaraninge CR
Species richness	2	2
Individuals	4	2
Trapping success	0.1%	0.1%
Shannon_H	0.6931	0.6931
Evenness	1	1

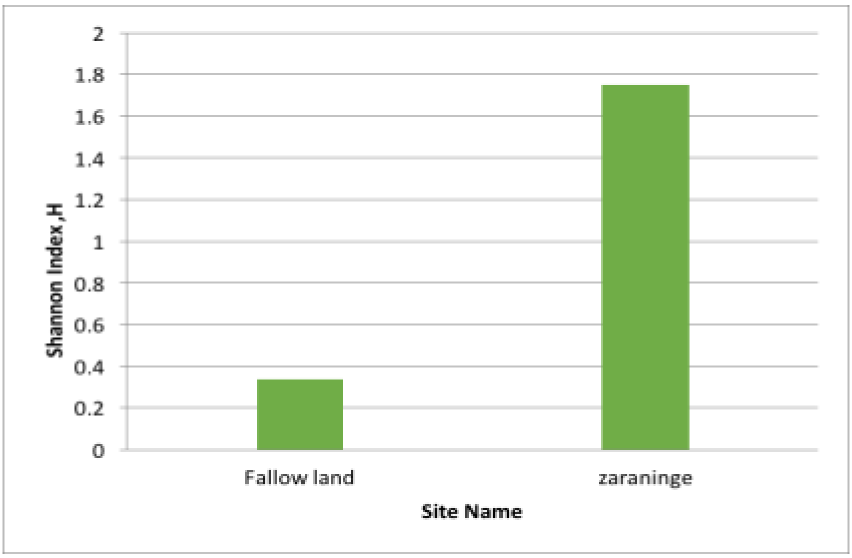

Figure 2.2: The diversity comparisons using the Shannon diversity indices of rodents in Zaraninge Coastal Forest and Gongo fallow lands

DISCUSSION

The most abundant species in the two habitats evaluated in this study were *Mastomys natalensis*, *Beamys Hindei, Grammomys dolichurus*, and *Graphiurus murinus. Mastomys natalensis* was more abundant and capable of living in both habitats. However, it was more dominant in fallow fields. This could be due to the presence of agricultural areas surrounding these fallow lands, thus enhancing food availability, as documented by previous research (Leirs, 1992, 1995; Leirs *et al.,* 1993; Makundi *et al.,* 1999; Mlyashimbi *et al.,* 2018). Because of their specific herbivorous/grainvorous nature (Mulungu *et al.,* 2014), *M. natalensis* are also known as crop pests, which explains why they are more abundant and dominant in fallow land than in forest settings. Other species with higher abundance included *Beamys hindei*, which was more dominant in the forest than in the fallow lands. This species prefer more forest habitats than inland places, where they emerge rarely and in low numbers due to forest habitat degradation. This observation is reinforced by other researches (FitzGibbon *et al.,* 1995; Sabuni *et al.,* 2015), which reveal that *B.hindei* is more common in coastal forests and scarce in inland locations. *Graphiurus murinus* was only found in the forest because they are forest specialists, but also because of their feeding habits (Lema and Magige, 2018); they also favor high canopy cover areas and rely on timber corridors for locomotion (Kingdon, 1997). *Grammomys dolichurus* was found in both fallow lands and forest habitats because they like both dry and moist forest areas as well as anthropogenic environments such as fallow lands and arable fields (Schoeman *et al.,* 2016). They also possess climbing features such as a large digit on the rear foot and a long tail for balance, which supports their survival in the Coastal Forest (Happold, 2013). Other species, on the other hand, were taken in low numbers, which could be owing to a variety of factors, as discussed below.

Gerbilliscus leucogaster was discovered in fallow fields near a pineapple farm, as this species prefer habitats that are near cultivated areas (Skimmer & Chimimba, 2005). Only one individual was captured in the study, which could be attributed to their solitary behavior (Rymer *et al.,* 2021). The study was also conducted during the dry season, when this species prefer to store more of their food in burrows and restrict their mobility far from their burrows due to heat; and the fact that they have more to feed inside their burrows (Prater, 1980).

Cricetomys spp. occurred in pairs of female and male, as evidenced by Skinner and Chimimba (2005). The study revealed that the species have solitary behavior and pairs stay together in a same burrow due to breeding. As a result, this could explain why they were caught as a couple in this study. However, the catch of this species was similarly minimal, which could be attributed to the limited number of Havahart traps employed as well as the season when the data was collected. Similar to *G. leucogaster*, this species save most of their food in their burrows during the dry season to maintain themselves (Knight, 1986). They also acquire other habitats and can adapt, but if the places have an increase in foreign invasive flora that does not favor their habitat appropriateness, they will relocate to other areas (MacFayden *et al.*, 2016).

Lemniscomys rosalia acquires diverse habitat ranges, including cultivated regions, but the unifying feature to these habitats is tall grassland areas (Rautenbach *et al.,* 2014). Taylor (1998) and Skinner and Chimimba (2005) both reported that *L. rosalia* inhabits tall grasses around agricultural fields and fallow lands, and the *L. rosalia* was detected in the fallow land areas in tall grasses covering around the fallow lands in our study. It also had low capture in this study, which could be due to the random burning of fallow lands areas to chase away many farm invaders, as also reported in the study by Monadjem and Perrin (1997), that the *L. rosalia* prefers habitats with tall grassland areas, but if these areas are burned, they leave until the tall grass grows again.

According to Kingdon, *Xerus rutilus* was discovered on fallow lands in this study (1974). As a result, because this species is a generalist eater, it was expected to be found in fallow lands. They have also been labeled as crop pests, particularly in maize, ground nuts, yam, and cassava (Doist and Dandelot, 1970), but capture of this species was low in this study, which could be attributed to their solitariness behavior, which causes them to be alone in specific areas, as well as their habit of creating a larger range of territory, not allowing interference from other species (Coe, 1972). As a result, the single individual caught alone may have established its region away from other species.

The diversity of rodents in Zaraninge Coastal Forest (1.49) and that of the Gongo fallow land areas (0.22) were not significant different. Thus, could be because Zaraninge Coastal Forest is still facing some encroachment activities which were seen even during the study and the Gongo fallow land areas faced mostly disturbances from anthropogenic activities as, it is reported that any change in the habitat can influence the diversity of the area (Malcom and Ray, 2020). In this study, there was no any difference in shrew diversity between Zaraninge Coastal Forest and Gongo fallow land areas. This could be due to the fact that the data was gathered while the shrews had comparable niche opportunities to utilize the quality and quantity of important supplies (Mulungu *et al.,* 2008). Furthermore, the breeding and reproductive seasons could have influenced the diversity, resulting in no change in shrew diversity across the two habitats (Kapala, 2021).

However, the comparison of the diversity index value of the two habitats showed significant higher diversity index value in Zaraninge Coastal Forest than in the Gongo fallow land areas, which could have been due to the forest being in its final transition stage causing certain species to travel between the two habitats in search of resources (Alila, 2020). It is also argued that the larger diversity index value of rodent and shrews in the forest may be related to habitat variability due to the presence of various resources, such as sufficient food variety and shelter (Cramer and Willig, 2002; Yihune and Bekele, 2012). It can also be attributed by the dense vegetation cover, habitat variability, and ground materials which are present in Zaraninge Coastal Forest but not in Gongo fallow land areas. Furthermore, it could also be due to the provision of macro and microhabitats, forest environments are known to sustain the life of many species of rodents and shrews (Byrom *et al.,* 2014).

CONCLUSION

The diversity of rodents and shrews was compared between the Zaraninge Coastal Forest and the Gongo fallow areas in this study. The Coastal Forest had a significant diversity index value of rodents and shrews than the Gongo fallow land areas. This could be due to the forest heterogeneity and resources that favored rodents and shrews, but it could also be due to the enhanced insitu-protection. For the Gongo fallow land areas, the low diversity index value, could be due to unplanned and random fires used by villagers to chase destructive animals from their farms, causing damage to the health status of the land but also disturbance to the rodents and shrews in terms of favourable habitat, protection from their predators etc.

In this study, the total abundance of rodents was higher on the fallow land areas. These findings showed greater impact to the community, since the rodents are known as pests that tend to raid farms and destroy most crops. Some of the rodents tend to even raid the crops storage and destroy the stored crops. Apart from crops raiding the rodents and shrews presence in an area shows the health quality of the environment, this can be a good impact to conservationists as they could use the results in monitoring the biodiversity and assessing the health quality of the environment. Through these findings, the conservationists can also be able to focus of specific species that can disappear due to threats or absence of favorable habitat parameters that support their existence and develop conservational strategies that will protect and guide these specie species from extinction. The Zaraninge Coastal Forest was induced with a protection status, yet captures were lower than on fallow land areas. This is concluded by the availability of abundant food resources of the established farms seen near the fallow land areas of the Gongo village.

We, recommend more studies on rodents and shrews of the peri-domestic and domestic areas, so that to gain information on their composition, abundances, diversity and even the threats that the community faces due to their presence. Long-term studies should be conducted to cover more areas but also gain more detailed information on population, diversity, and abundance, as well as the effects of habitats on the survival of rodents and shrews in the studied areas.

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CHAPTER THREE

Paper Two

3.0 Prevalence of Parasites of Rodents and Shrews in Zaraninge Coastal Forest and Gongo Fallow Lands

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Status: In process to be submitted

Abstract

Rodents and shrews are key reservoirs and hosts of parasites that spread zoonotic disease all over the world. The aim of this study was to determine the prevalence of parasites in the Zaraninge Coastal Forest and Gongo fallow land areas as there is greater risk of zoonotic disease transmission due to inevitable movements of rodent and shrews to both sites. The body brush technique was employed to gather ectoparasites from the rodents and shrews. The ectoparasites that fell were stored in 70% alcohol, and then were processed for identification. A capillary tube was inserted to the supra orbital vein of the individuals' eye to collect blood samples where, thin and thick smears were produced from the collected blood, and the smears were examined under a microscope for hemoparasites. The data was evaluated by comparing abundance using Mann-Whitney test, prevalence was computed by (N) = N1/N2*100/1 formula, where N is the percentage prevalence, N1 is the number of infected hosts, and N2 is the total number of hosts screened for parasites. The Chi-square test was performed to determined significant relationship between sexes, hemoparasites infections, and ectoparasites infestations. The ectoparasites obtained in this study were *Echinolaelaps echidninus* (90.2%), *Xenopsylla brasiliensis* (6.7%), *Boophilus* spp (3.0%), and *P.stephensi* (0.04%). The hemoparasites obtained were the Schizonts of *Plasmodium* sp. (99.2%) and *Bacillus* sp. (0.8%). In terms of ectoparasite prevalence in rodents, *Mastomys natalensis* had the highest prevalence of 84.8%, while *Crocidura* had prevalence of 33.3%. In terms of prevalence of ectoparasites the *Echinolaelaps echidninus* accounted for 942.6% been the highest and the least been the *P. stephensi* accounting for 0.51%. The prevalence of hemoparasites was higher in schizonts of *Plasmodium* sp accounting for 60.9%, with *Mastomys natalensis* being the most infected specie while *Bacillus* sp accounted for 33.4%. There was no statistically significant difference in the abundance of the ectoparasites, but also between hemoparasite infection, ectoparasite infestation and the sexes of the individuals. Prevalence of parasites was found to be higher in several species in this investigation, and the majority of them were parasite of zoonotic importance. These result, has health implications to the nearest community. Even though there is little information on diseases caused by parasites in the study sites, more research and effective prevention strategies are needed to avoid zoonoses from erupting.

Keywords: *Ectoparasites, hemoparasites, small mammals*

Introduction

Small mammals, despite being important animals that have a greater contribution to the ecosystem, they are also important sources of infections for viral, rickettsial, and bacterial pathogens that cause diseases in humans (Thanee *et al.*, 2009). The diseases that are transmitted to humans include plague, typhus, spotted fever and Hantavirus. All these diseases are transmitted by arthropod vectors which infest small mammals such as rodents as they act as their reservoirs. Rodents and shrews are key reservoirs for the development and adult stages of these arthropod (ectoparasite) vectors (Obiegala *et al.,* 2021).

The ectoparasites are parasites that reside on the outer parts of their host, with some been host specific and some appearing at multiple hosts. The ectoparasites recovered from rodents have been classified into five main groups, which are Mesostigmata (Mites), Prostigmata (Chiggers), Acarina (Ticks), Phthiraptera (Louse) and Siphonaptera (Fleas) (Paramasvaran *et al.*, 2009).These ectoparasites may also be related to habitat selection by the host, and as a result, any changes in the habitat, composition and community of the rodents and shrews, the ectoparasites also adopts to the changes caused by its host. Therefore, the ectoparasites may encounter different hosts during the changes, enhancing the ectoparasites to gain new different host that exist near their nest microhabitat or other areas (Gettinger and Ernest, 1995). The presence of a certain ectoparasite species on more than one host species may be related to the behavior, intra and interspecific relationships of the hosts and with the microhabitats utilized by the host (Barker, 1994).

Apart from being reservoirs of ectoparasites that disseminate pathogens causing diseases to humans, rodents and shrews are also sources of zoonotic hemoparasite infections that spread globally (Korbawiak *et al.,* 2005). Hemoparasites are blood parasites that spend practically their entire lives in the vascular structure of vertebrates and mammals; examples include *Babesia*, *Theileria*, *Borrelia*, *Trypanosomes*, *Bacilli*, and *Plasmodium* (Silayo, 1992; Gratz, 1997 and Battersby *et al.,* 2002).

Many rodent-borne diseases in humans have been related to these pathogens, including plague, leptospirosis, leishmaniasis, and hemorrhagic fevers (Machang'u 1992, Kilonzo *et al.,* 2005, Laudisoit *et al.,* 2009). Some hemoparasitic pathogens have been more helpful in investigating different models of human diseases, whereas others pose a greater risk of spreading zoonotic diseases (Katakweba, 2018). As a result, it is more important to investigate hemoparasites in order to avert threats to the public health of many communities ranging from humans to animals.

Many researchers have been undertaken globally on the parasites (ectoparasites and hemoparasites) of rodents and shrews in diverse settings (e.g., Paramasvaran *et al.,* 2009; Katakweba 2018; Obiegala *et al.,* 2021). Despite these studies, there is a knowledge gap on the parasites harbored by rodents and shrews that could raise a risk of transmission of zoonotic diseases to the human community. The study findings are to provide information of various zoonotic parasites but also assist in formulating strategies that helps in combating the zoonotic diseases transmission in their community.

Thus, the purpose of this study is to investigate the abundance, composition, and prevalence of the parasites of rodents and shrews for the sake of public health concern in the Zaraninge Coastal Forest and its surrounding Gongo fallow land areas. Also there was testing to see, if there is any significant relation between the ectoparasites infestation, hemoparasites infection and the sexes of the individuals.

Study Area and Methods

Study site

This study was conducted in Zaraninge, a dry evergreen coastal forest alongside the eastern coast of Tanzania as shown in Figure 1.

The forest is located at 6°04′–6°13′S and 38°35′–38°42′E, 15 km inland from the Indian Ocean on the South West of Saadani National Park (SANAPA). The precipitation model of the area is bimodal, receiving little rains between October and December and extensive rains between March and June, the mean yearly rainfall ranges between 900 and 1400 mm (Clarke, 2000). The temperature is typical of equatorial coastal forest regions of East Africa, with a yearly utmost temperature of 29.7°C and the least of 21.9°C (Sabuni *et al.,* 2015).

Gongo Village is situated on the Southwest of the Saadani National Park and it was established in 2009. It has a population of about 2000 people and the main occupants are Wadoe tribe. The main economic activity for the majority of people is pineapple farming. The village is a home to the Kikwati wildlife corridor, which connects to Wami mbiki and the village lies within the Zaraninge Coastal Forest (Anna and Smargada, 2019).

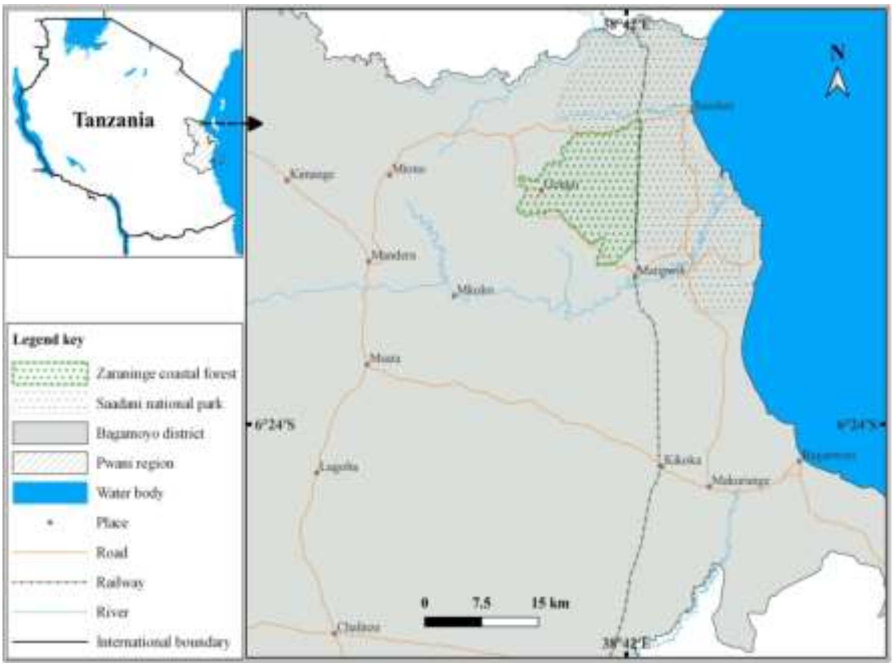

Figure 3.1: Map showing the location of Zaraninge Coastal Forest and Gongo Village in Tanzania (Irene, 2022).

Trapping

Trapping of rodents and shrews was conducted from May and October of 2021 in the forest and the Gongo fallow lands, using the removal method. Two grids of 10 × 10 m and their replications were made; two grids were located in the forest and the other two on the fallow lands. Each grid had 10 corresponding columns which were 10 m apart and had 10 trapping stations per column. The space from one trapping station to another was 10 m apart making a total of 100 trapping stations per grid. One Sherman trap was set at each trapping station while the 5 Havahart traps were set by chance at every grid. All traps were set for 3uninterrupted nights in every month. The Sherman traps were baited with Peanut butter mixed with maize bran and fried coconut. Havaharts were baited with green maize, ripe bananas, avocado and tomatoes.

Ectoparasite collection

The captured rodents and shrews were anesthetized by inhalation using Halothene soaked in cotton wool. Then their fur was combed to remove or dislodge the ectoparasites from their bodies into the enamel tray. The brushing of ectoparasites was more focused on the areas of the axilla, groin, tail base, genitalia and anus, behind the ears and under the chin. From the enamel tray, fallen ectoparasites were removed and preserved into well labeled tubes containing ethanol 70% by using camel brush, then the ectoparasite collected from the field were taken to the Institute of Pest Management (IPM) of Sokoine University of Agriculture (SUA) laboratory for processing and identification.

Identification of Ectoparasites

Fleas were boiled in 10% KOH (Potassium hydroxide) for 10 minutes, after that they were transferred into acidified water and then they were rinsed in distilled water. Later they were put in 50% ethanol for 1 hour and then replaced into 70% ethanol for another 1 hour and replaced again into 95% of ethanol for 1 hour. After that they were placed into absolute ethanol for another hour and after they were placed in Clove oil for overnight for clearing them, then mounting was done by DPX solution and examined under compound microscope (Bahmanyar and Cavanaugh, 1976).

For the mites and ticks, they were heated into the KOH (potassium hydroxide), then after a curved slide was prepared and a drop of Hoyer’s medium was placed at the centre of the slide. Mites and ticks were singularly placed into the drop of Hoyer’s medium in each slide; the orientation was either dorsoventrally or laterally then a cover slip was placed on top of it. The slides were then placed into the oven at 45-50 degrees for 24 hours, then the slides were removed from the oven and more Hoyer’s medium was added and left for the slides to cool and then they were placed under microscope for identification (Krantz, 1971).

Hemoparasites sample collection

The captured rodents and shrew were drawn blood from the supraorbital veins using glass capillaries, after drawing the blood, thick blood smears were prepared using one drop of whole blood on the centre of microscope slide and allowed to air dry, thin blood smear were also prepared using a small drop of blood placed near one end of a microscopic slide and allowed to air dry. Then the blood smears were transferred to the IPM laboratory from the field, in the laboratory they were fixed with methanol for 3 minutes then left to dry. After drying the blood smears were stained by 10% of Giemsa stain, then washed with running water tap and then allowed to dry (Katakweba *et al.,* 2013).

Identification of Hemoparasites

The stained slides were added a drop of oil help magnification and clear sight and then they were placed under the microscope (100 magnifications) for identification. The hemoparasites were identified using the structures and information on parasitized red blood cells (WHO, 1991).

Data analysis

Composition and abundances

The composition of ectoparasites and hemoparasites was acquired in a list and the abundances of parasites across the habitats were computed using the formula; (A= Tp/Tn* 100)

Where Tp= total number of an individual specie, Tn = total number of ectoparasites or blood samples with hemoparasites infections. Then a Mann-Whitney test was used to test the significance difference of the abundances of the ectoparasites in between two sites.

Prevalence of parasites

The estimation of prevalence of parasites on rodents and shrews was tested and expressed in percentage using the prevalence formula (N) = N1/N2*100/1 (Okeke *et al.* 2013), where N is percentage prevalence, N1= number of hosts infected, N2= total number of host examined for parasites (ectoparasites and hemoparasites). The prevalence was estimated between the species of rodents and shrews but also species of ectoparasites and hemoparasites.

The rate of ectoparasites infestation or hemoparasites infection to the rodents and shrews mostly depends on intra and interspecific behavior between parasites and their host. Therefore, Chi- square test was used to compute the significant relationship between ectoparasites infestation, hemoparasites infection and the sex variation of individuals.

Results

Abundances of the ectoparasites

The 203 rodents and shrews yielded a total of 2058 ectoparasites. The ectoparasites recovered from rodents and shrews belonged to four major groups: mites, ticks, fleas, and lice, but the species discovered were *Echinolaelaps echidninus (mites), Xenopsylla brasiliensis (fleas), Boophilus* spp *(ticks), and Polyplax stephensi (lice) as shown* in Table 3.1. Since the same method was used in obtaining the ectoparasites, the abundance of the ectoparasites were then compared between the two sites using the Mann-Whitney test. The Zaraninge Coastal forest and Gongo fallow lands showed no statistically significant difference (U=8, P=0.8, n1&n2=4) in the individual abundances of the ectoparasites.

Table 3.1: Abundance of ectoparasites in Zaraninge Coastal Forest and Gongo fallow lands

Ectoparasites	**Gongo Fallow lands**	**Zaraninge CR**	**Total (%)**
Mites (*Echinolaelaps echidninus*)	1848	9	1857 (90.2%)
Ticks (*Boophilus* spp)	47	15	62(3.01%)
Fleas (*Xenopsylla brasiliensis*)	3	135	138(6.7%)
Lice (*Polyplax stephensi*)	0	1	1(0.04%)
Total	1898	160	2058

Composition of hemoparasites

A total of 123 rodents and shrews blood samples were discovered to be contaminated with hemoparasites. These blood samples had the infections of schizonts of *Plasmodium* spp. and *Bacillus* spp. The blood samples obtained from the rodents and shrews of the fallow land areas showed higher infection of hemoparasites than the blood samples obtained from rodents and shrews of Zaraninge Coastal Forest. The blood samples of rodents and shrews from the fallow land revealed were infected by two species of blood parasites, whereas the blood samples from the rodents and shrews of Zaraninge Coastal Forest were infected with only one blood parasite, as shown in Table 3.2.

Table 3.2: Composition of the hemoparasites related to habitat sites

Hemoparasites	Gongo Fallow lands	Zaraninge CR	Total (%)
Schizonts of Plasmodium Spp	116	6	122(99.2%)
Bacillus Spp	1	0	1(0.8%)
Total	117	6	123

Key: (%) = the percentages of blood samples infected by hemoparasites

Prevalence of the ectoparasites in rodents and shrews

Only 177 out of 203 individuals were discovered to be infested with ectoparasites, with rodents and shrews infested with at least one to three species of ectoparasites*. Mastomys natalensis* and *Cricetomys* spp were discovered to be infested with mites, fleas, and ticks, whereas *Beamys hindei, Graphiurus murinus* and *Crocidura hirta* were found to be infested with two species of ectoparasites and the remainder with one. Prevalence was calculated for each rodent and shrew species, as well as each ectoparasite species as shown in table 3.5. *Mastomys natalensis* had a higher prevalence of mites and ticks than other species on rodents (Table 3.3), while in shrews the *C. hirta* had a higher prevalence of fleas and *P. tetradactylus* had a higher prevalence of ticks (Table 3.4).

Table 3.3: Prevalence of ectoparasites with respect to rodent species

Rodents species	No. of rodents captured	No. of infected & prevalence (%)
Beamys hindei	7	2(1.02)
Cricetomys spp	2	2(1.02)
Grammomys dolichurus	6	1(0.51)
Graphiurus murinus	4	1(0.51)
Lemniscomys rosalia	1	1(0.51)
Mastomys natalensis	175	167(84.77)
Xerus rutilus	1	0(0)
Gerbilliscus leucogaster	1	0(0)
Total	**197**	**174(88.3)**

Table 3.4: Prevalence of ectoparasites with respect to shrew species

Shrew species	No. of rodents captured	No. of infected & prevalence (%)
Crocidura hirta	3	2(33.3)
Petrodromus tetradactylus	3	1(16.7)
Total	**6**	**3(50)**

Table 3.5: Prevalence of ectoparasites related to rodents and shrews

Rodent species	Number of mites & prevalence	Number of ticks & prevalence	Number of fleas & prevalence	Number of lice & prevalence
Beamys hindei	6(3.04)	0(0)	0(0)	1(0.51)
Cricetomys spp	4(2.03)	2(1.02)	135(68.5)	0(0)
Grammomys dolichurus	6(3.04)	0(0)	0(0)	0(0)
Graphiurus murinus	2(1.02)	1(0.51)	0(0)	0(0)
Lemniscomys rosalia	40(20.3)	0(0)	0(0)	0(0)
Mastomys natalensis	1799(913.2)	45(22.8)	1(0.51)	0(0)
Total	1857(942.6)	48(24.3)	136(69.0)	1(0.51)
Shrew species	**Number of mites & prevalence**	**Number of ticks & prevalence**	**Number of fleas & prevalence**	**Number of lice & prevalence**
Crocidura hirta	0(0)	2(33.3)	2(33.3)	0(0)
Petrodromus tetradactylus	0(0)	12(200)	0(0)	0(0)
Total	0(0)	14(233.3)	2(33.3)	0(0)

Prevalence of the hemoparasites of rodents and shrews

The prevalence was calculated for each rodent and shrew species, as well as each hemoparasite species. *Mastomys natalensis* was found infected by both *Bacillus* spp and schizonts of *Plasmodium* spp in rodents and shrews, but showed a greater infection rate in schizonts of *Plasmodium* spp. Table 3.6 shows that the prevalence of hemoparasites infection in both species of shrews was similar, many blood samples of different species were found to have schizonts of *Plasmodium* spp infection, and only one blood sample of *Mastomys natalensis* had *Bacillus* spp. infection, as shown in Table 3.7.

Table 3.6: Prevalence with respect to rodent and shrew species

Rodent species	No of infected blood samples & Prevalence (%)
Beamys hindei	6(3.05)
Grammomys dolichurus	1(0.51)
Lemniscomys rosalia	1(0.51)
Mastomys natalensis	111(56.3)
Cricetomys spp	0(0)
Xerus rutilus	1(0.51)
Gerbilliscus leucogaster	1(0.51)
Graphiurus murinus	0(00
Total	**121(61.4)**
Shrew species	**No of infected blood samples & Prevalence (%)**
Crocidura hirta	1(16.7)
Petrodromus tetradactylus	1(16.7)
Total	**2(33.4)**

Table 3.7: Prevalence of Hemoparasites related to rodents and shrews

Rodent species	Prevalence of schizonts of *Plasmodium* spp (%)	Prevalence of *Bacillus* spp (%)
Beamys hindei	6(3.05)	0(0)
Grammomys dolichurus	1(0.51)	0(0)
Lemniscomys rosalia	1(0.51)	0(0)
Mastomys natalensis	110(55.8)	1(0.51)
Cricetomys spp	0(0)	0(0)
Xerus rutilus	1(0.51)	0(0)
Gerbilliscus leucogaster	1(0.51)	0(0)
Graphiurus murinus	0(0)	0(0)
Total	**120(60.9)**	**1(0.51)**
Shrew species	**Prevalence of schizonts of Plasmodium spp (%)**	**Prevalence of Bacillus spp (%)**
Crocidura hirta	1(16.7)	0(0)
Petrodromus tetradactylus	1(16.7)	0(0)
Total	**2(33.4)**	**0(0)**

The relationship between the infestation and sex of rodents and shrews

There were 89 males and 88 females of rodents and shrews infested with ectoparasites, and there was a difference in the number of ectoparasites infesting them, with the males having 1026 and the females having 1035. There was no statistical difference between the infestation rate and the sexes of the individuals (X^2=0.85347, df =1, p = 0.3556). Even though the blood samples indicated a higher incidence of Schizonts of Plasmodium spp than Bacillus spp, there was no any significant relationship in infection rate between the sexes (X^2=0.43122, df =1, p = 0.51139).

Discussion

The ectoparasites recorded in this study included mites, ticks, fleas, and lice, which were also found in investigations of ectoparasite prevalence in other nations (Paramasvaran *et al.*, 2009; Rahdar *et al.*, 2015; Dada, 2016). However, Thanee *et al.,* (2009), De Jesus Santos *et al.,* (2018), and Obiegala *et al.,* (2021) reported on the prevalence of ectoparasites and recorded on mites, ticks, and fleas, with the exception of lice. *Echinolaelaps echidninus* (mites), *Xenopsylla brasiliensis* (fleas), *Boophilus* spp (ticks), and *Polyplax stephensi* (lice) were the ectoparasites identified in this study. The species *E. echidninus* was more abundant, as in Thanee *et al.* (2016) study, whereas *P. stephensi* was the least abundant, as in Dada's study (2016).

The infestation rate was higher in the Gongo fallow lands than in the Zaraninge Coastal Forest, which could be attributed to the plant matrix and disturbance in the locations, as well as the habitat generalist hosts' increased tolerance for degraded habitats (De Jesus Santos *et al.,* 2018). The Laelapidae mites had the most infestation among the four species of ectoparasites detected in this study, as reported by Nieri-Bastos *et al.* (2004), Reis *et al.* (2008) and De Jesus Santos *et al.* (2018).

During this study, *M. natalensis* had a greater parasite prevalence, accounting for 913.2% of total mites (*E. echidninus*), 22.8% of total ticks (*Boophilus* spp), and 0.51% of total fleas (*X. brasiliensis*). *Cricetomys* spp. had the highest prevalence of ectoparasites in fleas, accounting for 68.5% of total fleas; other rodent species (*B. hindei* and *G. murinus*) were found to be afflicted by only two parasites, while *L. rosalia* had only one parasite (mites).*C. hirta* showed the highest prevalence in shrews species, accounting for 33.3% of total ticks and fleas, whereas *P. tetradactylus* was found to be mostly infested with ticks. Blood parasites found in the blood samples of rodents and shrews included Schizonts of *Plasmodium* spp. and *Bacillus* spp. Schizonts are the mature stages of *Plasmodium* spp. which were identified by observing their extracellular and Pleomorphic forms but also the absence of white food vacuoles and multiple infected blood cells. The maximum prevalence was reported in *M. natalensis* blood samples, where most blood samples of the *M. natalensis* had Schizonts of *Plasmodium* spp infection whereas only one blood sample had *Bacillus* spp. infection. The other individuals were determined to be infected with only one blood parasite, the Schizonts of *Plasmodium* spp.

The findings of blood parasites in this study are similar to the findings of the study by Katakweba *et al.* (2018), the authors reported about the higher prevalence of *Plasmodium* spp infection in the form of schizonts in both *R. rattus* and *M. natalensis* while the least prevalence was of *Bacillus* sp, but during this study the higher prevalence of Schizonts of *Plasmodium* spp was observed in different species of rodents *(M. natalensis* and *B. hindei*).

However, Makokha *et al.* (2011) found a low prevalence of *Plasmodium* spp. infections in *P. jacksoni* at 6.8% and *M. natalensis* at 3.7%, respectively. Another study by Katakweba *et al.* (2013), found a low prevalence of *Plasmodium* spp infection and a larger prevalence of *Bacillus* sp infection, with 0.3% and 3.6%, respectively. However, Alias *et al.* (2013) discovered a greater prevalence of

Plasmodium sp infection in the *R. rattus diardii* species in their study, which was the first study to identify *Plasmodium* sp infection in Malaysian household areas.

Other studies that reported on Plasmodium sp infection include Ramarkrishan and Prakash (1950) and Kreier *et al.* (1972). Kreier et al., (1972) reported on the relationship between erythrocyte morphology and *Plasmodium* sp parasitication while Ramarkrishan and Prakash (1950) identified the species of the Plasmodium and the morphological characteristics of the *P.berghei* and its infections on *R.norvegius* and *R. rattus,* unlike this study.

The findings on low prevalence of *Bacillus* spp cannot be concluded, as the study was conducted for a short period of time, so the results may alter if a longer term study is conducted.

On the findings of overall prevalence of parasites, the ectoparasites showed higher prevalence of *E. echidninus* as it was largely detected on rodent species of M. *natalensis* and *L. rosalia* which were captured in the Gongo Village fallow land areas. Because *E. echidninus* is a potential vector of pathogens such as *Coxiella burnetii* and *Leptospira interrogan* (Mawanda *et al.* , 2020), as well as parasites that spread the *lethal Hepatozoon murius* and *Junin virus*, hence the public health of the community may be jeopardized as all these pathogens can transmit zoonotic diseases to humans (Baak-Baak *et al.,* 2016).

Other ectoparasites are the fleas (*X. brasiliensis*) which were found to have infested both shrews and rodents in this study, just as in other studies by Bahmanyar and Cavanaugh (1976); WHO (1976); Paramasvaran *et al.* (2009); Zimba *et al.* (2011). They reported that the presence of fleas in an area gives us important information that helps in supervising the areas for any signs of plague transmission. The flea species detected in this investigation was *X. brasiliensis*, which is widely regarded as an excellent vector of the plague, similar to *X. cheopis*, as reported in the work by Laudisoit *et al.* (2007). The ectoparasite of *X. brasiliensis* just like *X. cheopis* is likely capable of transmitting the bacteria of *Y. pestis*. It is suggested that the bacteria multiplies itself in their host at a high level, ensuring that the infected host blood has a high concentration of these bacteria before it perishes from the community, so the possibility of plague transmission to the community is not at lower level because interactions between rodents and humans are unavoidable (Amatre *et al.,* 2009).

Apart from fleas and mites, this study found ticks (*Boophilus* spp) in rodents and shrews. The ticks (*Boophilus* spp) were mostly found in *M. natalensis*, with little observation in other species, but these findings are concerning because these rodents have more interactions with peridomestic areas, which involve people and other animals. As a result, this interaction demonstrates how much the health of people and animals (domestic and wild) is at stake, because ticks infested in these rodents are disease vectors that are detrimental to humans and animals around. Ticks are a potential vector for *Rickettsia rickettsia*, which causes fever, but ticks can also carry *Babesia* spp. and *Theileria* spp., which cause significant harm to the health of a community and cattle exposed to these diseases (Balakrishnan *et al.,* 2019).

The ectoparasites that was least observed in this study was the *P. stephensi*, as it was observed in only one rodent specie. This can also be seen in the study by Dada (2016) as he reported on the least observation of the *Polyplax* spp. The *P.stephensi* was found on *B.hindei*; however, Khosravani (2018) and Rahdar *et al.* (2015) reported *P.stephensi* on *Gerbilliscus leucogaster*. Other studies have identified *Polyplax* spp as a threat to public health because they are not only a source of anemia due to their blood sucking characteristics, but they are also vectors that transmit *Rickettsia* spp and the virus of *Mexican typhus*. However, most of these studies focused on the public health of other louse species, particularly *P.spinulosa* (Kaneko, 1959; Baker, 1999).

The occurrence of *Plasmodium* spp infection in this study is especially concerning because rodents prefer to contact with the nearby community, but also because the fallow lands are nearby, which creates further concerns because the vector can assist transmit the parasite from the rodent to the people. As is well known, *Plasmodium* causes Malaria illness, and it has been observed in many places throughout the world that malaria illness in people produces significant death and morbidity rates, thus it has a greater impact on public health (Katakweba, 2018). However, some *Plasmodium* species, such as *P.falciparum*, can induce kidney failure, convulsions, mental confusion, coma, and even death if not detected and treated promptly (Alias *et al.,* 2013).

The current study also examined the significant relationship between ectoparasite infestations and individual sex of rodents and shrews. However, there was no any significant relationship between the infestation and the sexes of the subjects, much as Paramasvaran *et al.* (2009) found no difference between the sexes and the ectoparasite infestation. Despite the fact that there was no any significant relation in sex and ectoparasite infestation, the quantity of ectoparasites infesting females was found to be higher than that of males. This finding is supported by the study of Mohd-Taib *et al.* (2021), who reported a higher number of ectoparasite infestations on female rodents and shrews and suggested that this is because ectoparasites tend to lay their eggs in their host nests, thus captivating the female rodents and shrews that mostly stay in their nests for a long time, leading to females harboring more ectoparasites than males(Gorrell and Schulte,2008).However, other studies by Kowalski *et al.* (2015) and Ishak *et al.* (2018) reported that males (Apodemus agrarius and Myodes glarelous) had a higher infestation than females. Also, the study by Bantihun and Bekele (2015) supported males having a higher number of ectoparasites because they have larger home ranges but also have more movements than females, making them more susceptible to ectoparasites. The study also examined the hemoparasites infection rates between rodents and shrews based on their gender. The findings show that females had greater infection rates than males (52.8% and 47.2%) correspondingly. However, Alias *et al.* (2013) found that males had greater infection than females, with 61.4% and 57.1%, respectively, and also found similarity of Plasmodium spp infection on both sexes, whereas our study found no resemblance at all. The current study also looked at the significant relationship between the sexes and blood parasite infection of the rodents and shrews; however, there was no any significant relation between the hemoparasites infection and the sexes of the individuals.

Conclusion

The ectoparasites infested almost 87% of the rodents and shrews obtained in the Zaraninge Coastal Forest and Gongo fallow lands, whereas the hemoparasites infection was around 60.3%. The parasites (ectoparasites and hemoparasites) observed in this study were of zoonotic importance, as they are possible pathogens of various zoonotic diseases which can be transmitted to people, domestic and wildlife animals. The rodent parasitic diseases are highly erupted in areas where the community's environment and personal hygiene standards are not well maintained. As a result, it is critical to focus on more studies and the development of effective programs to prevent the transmission of parasitic diseases from rodents to the community, its domestic animals, their peri-domestic areas, and even areas that support more of the cycles and growth of these parasites. The appearance of the fleas in this study suggests that there is a risk to eruption of plague in the areas. This information shows that there is a need to conduct a long- term studies get more detailed information on parasites of fleas in order to prevent the eruption of the plague in the area but also to get more information of other parasites not identified or observed during this study. The increased prevalence of Plasmodium sp infection raises concerns, as malaria disease cannot be taken lightly, as it has been documented to pose greater threats to the community worldwide.

This study was conducted in a short period of time due to some limited factors, so it provides preliminary information on the parasites (ectoparasites and hemoparasites) and the possibility of diseases that may spread to the community through these parasites. This is information is important as there is little baseline information on parasite-caused diseases in the Gongo Village. I believe that there should be additional studies that focus on a broader coverage of the locations over a longer period of time and even across seasons in order to learn more about the parasites, rodents, and shrews in the area. Since the forest area is annexed to the Park, the Park Management should intensify protection to prevent human encroachment within the protected forest area. Further, conservation education should be provided to the nearby community concerning the parasites of zoonotic importance and their reservoirs (rodents and shrews). So, that the community can be able to prevent themselves and their domestic animals from infection and gain knowledge on what to do when one is infected by zoonotic diseases. Apart from the community, the health sector and community leaders should work together, in reminding and educating the community on how to handle their environment, and health in order to avoid greater risk of transmission of zoonotic diseases in the near future as the movements of rodents and shrews towards the community is inevitable.

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CHAPTER FOUR

4.0 GENERAL DISCUSSION CONLCUSION AND RECOMMENDATIONS

4.1General discussion

In summary, the study was able to report on the composition and diversity of rodents and shrews in the Zaraninge Coastal Forest and Gongo fallow land area in Tanzania. The information acquired will be of increased value in many sectors such as conservation, education and so on. We were able to record eight rodent species (*M.natalensis, B.hindei, G.dolichurus, G.murinus, G. leucogaster, L. rosalia, X. rutilus*, and *Cricetomys* spp.) and three non-rodentia species in the study (*C. hirta, P. tetradactylus* and *Galago* spp).

Since the fallow lands in this study were near present agricultural fields, the larger number of rodents and shrews in the fallow lands validates many studies conducted on different places attesting to higher populations of rodents and shrews in fallow lands and agricultural lands. As a result, earning a higher number was due to the availability of resources, but also to ideal habitats that favor certain of the species present in farm or fallow areas (Skinner and Chimimba, 2005; Lema and Magige, 2018; Mlyashimbi *et al.,* 2018).

M. natalensis was found to be more abundant than other species, although it was also found to be abundant in fallow lands, whilst other species were caught in low numbers. The studies can back up these findings (Christensen, 1996; Mulungu *et al.,* 2015; Mlyashimbi *et al.,* 2020). While *B. hindei* was found to be more abundant in the forest than in the fallow lands, this finding supports studies by FitzGibbon *et al.* (1995) and Sabuni *et al.,*(2015) that reported the *B. hindei* to be a species that prefers the forest habitat over other habitats where it can be found infrequently and in small numbers. In another study, the findings on other species were low, which was attributed to their behaviors, habitat preferences, and the season of the study, which did not favor them being caught at greater frequency.

The study conducted a composition and diversity comparison of rodents and shrews, and the results of the composition provided us seven families, with the family Muridae having the highest composition of species, which might be similar to the studies (Kiwia, 2006; Alila, 2020). In terms of rodent diversity index value, the forest provided higher diversity index than the fallow lands, despite the fact that the fallow lands had more catches. This was supported by other studies that reported on factors of the forest having heterogeneity, ground materials, and food varieties that provide macro and microhabitats that can be lacking in the fallow lands (Byrom *et al.,* 2014).

The parasites of rodents and shrews in Zaraninge Coastal Forest and Gongo fallow land areas in Tanzania, were studied in this study. This data serves as a baseline information, but it is also useful in economic, rodent control, disease control, and public health monitoring.

The study was able to detect the ectoparasites that have been reported by other studies in different nations, such as mites, fleas, ticks, and lice (Paramasvaran *et al.,* 2009; Dada, 2016; Thanee *et al.,* 2018; Anna *et al.,* 2021).The data revealed that mites were more prevalent, particularly *Mastomys natalensis* (Nieri- Bastos *et al.*, 2004), but that some ectoparasites were more concerning for public health, such as *Xenopyslla brasiliensis*, which is reported to be capable of causing plague outbreaks like *X. cheopis*(Laudisoit *et al.*, 2007). However, other ectoparasites should not be overlooked because they are all carriers for other infections.

The study also looked at the hemoparasites found in blood samples taken from rodents and shrews at the study site. The findings revealed the presence of Schizonts of *Plasmodium* sp and *Bacillus* sp, with the *Plasmodium* sp being more abundant and prevalent, as evidenced by another study by Katakweba *et al.,* (2018), who found the Plasmodium sp to be more abundant in their study but also reported the Bacillus sp to be in low numbers, just as in this study.

The increased Plasmodium sp infection elevates the risk of malaria, which appears to be a cause of many deaths and morbidities worldwide. Because there was little information about the diseases that could have attacked the Gongo Village due to the presence of these parasites, this finding raises attention on the public health of the community in these studied areas because ignorance can lead to damaging the health of the people, and because there was little information about the diseases that could have attacked the Gongo Village due to the presence of these parasites, this finding gives out the alert to more findings about parasites in the studied areas, particularly the malaria illness.

4.2 Conclusion

The current findings provide early information on rodent and shrew parasites in the Zaraninge Coastal Forest and the neighboring fallow areas of Gongo Village. As a result, the transmission of zoonotic diseases between rodents, humans, and wild animals is unavoidable due to present agricultural areas that serve as a source of food and a habitat of interaction between humans, wildlife, and rodents. Aside from parasites, the current study found diversity of rodents and shrews in the Coastal Forest and nearby fallow fields. A comparison of diversity was made, and the forest showed greater diversity index value than the fallow lands.

The diversity index value of the fallow lands could have been higher due to the closer proximity to the current agricultural lands, but the challenges facing the area was random burning and low wire traps kept in the areas to trap any intruder to the farms, which could have pushed the rodents and shrews away from the fallow land areas. Despite laying a large number of traps, the forest had less captures.

This could be due to other animals disturbing the traps and attacking the trapped individuals, allowing them to easily escape and be killed in the process. As a result, the capture in the forest seems to have been influenced by the above mentioned factors; nevertheless, there could have been additional unknown factors contributing to the lower catches in the forest.

4.3 Challenges

The random burning during trapping times, some of which were conducted in trapping zones, was one of the obstacles encountered in this study. As a result, we often had to collect more empty traps than rodents and shrews in traps. Another problem was trap theft, as after setting the traps, some people would come and remove the traps from the trapping station, and these traps were later discovered at their residences or waste holes. As a result of these difficulties, there were few rodents and shrews captured during the investigation.

Another difficulty was disturbances from wild creatures that broke the traps in order to obtain the trapped rodents or shrews inside, making it simple for the captive individual to escape. There was also shifting of the traps by wild animals from the trapping stations to their burrows, stepping of the traps by wild animals passing by the line stations, causing damage to the traps, and attacks from wild animals on the captured rodents and shrews, which resulted in the death of the captured individuals, particularly the large rodents and shrews, some of which were barely alive due to attacks and teeth marks found on their bodies from other wild animals.

4.4 Recommendations

Based on the findings of the study and conclusions, the following recommendations can be made: establishment of more long-term studies (1-3 years) to learn more about the parasites (ectoparasites and hemoparasites) and the rodents and shrews on these examined sites. To begin, long-term investigations should focus on broader coverage of the areas to obtain more detailed information about other species that may not have been caught during this study, but larger coverage may also help us uncover more parasite species hosted by rodents and shrews.

Second, studies on rodents and shrews in peridomestic and domestic regions to learn about the composition, diversity, and infestation of rodents and shrews in the village, as residents have complained about rodents infiltrating their homes and stores where they store produced crops.

Third, studies to report the zoonotic diseases that could be present in the community, because there hasn't been any report showing the possible diseases that have attacked the community that could be related to the parasites carried by the rodents that roam around the community, which can help narrow the information on the viruses, bacteria, and other zoonotic pathogens that could have affected the Gongo community. As a result, it is critical to pay attention to these parasites in order to avoid health consequences and to concentrate on pest control measures in order to avoid being infected by pathogens carried by rodent parasites.

Fourth, it is critical to consider establishing effective methods of preventing the spread of rodent-borne diseases to the community and expanding participatory education to villages so that they can learn how to prevent disease outbreaks in their community. On the part of the Zaraninge Coastal Forest, it can also help conservationists understand how to prevent pathogenic disease outbreaks, but it should also have stricter laws and follow-up measures that might target people who still enter the Coastal Forest illegally to perform encroachment activities, which leads to the destruction of rodent and shrew habitats Education provision could be utilized to teach students about the value of rodents in their ecosystem as well as the importance of the forest to the species that live there.

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APPENDICES

Appendix 1: Raw data, number of rodent species captured, ectoparasites present in each rodent specie and variables measured.

Species	Label	Site	Trap	Weight	Sex	Sex cond.	HB	Tail	Hind F	Ear L	*Mites*	*Ticks*	*Fleas*	*Lice*
M. natalensis	1	Farm	3H	46	Female	**PSN**	124	104	21.3	16.3	5	0	0	0
B.hindei	2	Farm	3F	38	Male	**SV**	105	90	22.7	18.0	6	0	0	0
M. natalensis	3	Farm	7D	112	Female	**PSY**	130	110	22.9	17.4	8	0	0	0
B.hindei	4	Farm	10F	74	Female	**CSN**	110	84	20.2	16.8	0	0	0	0
M. natalensis	5	Farm	3B	68	Male	**SV**	32	104	20.5	16.7	27	0	0	0
M. natalensis	6	Farm	3C	81	Female	**PSY**	134	103	24.1	20.2	5	0	0	0
M. natalensis	7	Farm	1D	53	Female	**PSN**	134	105	22.9	17.6	4	0	0	0
M. natalensis	8	Farm	1C	32	Female	**CSN**	100	97	21.4	19.1	9	0	0	0
M. natalensis	9	Farm	7F	63	Female	**PSY**	140	70	24.6	18.3	23	0	0	0
M. natalensis	10	Farm	2C	66	Female	**PSY**	125	110	23.7	17.9	3	0	0	0
M. natalensis	11	Farm	4F	34	Male	**SV**	120	98	22.5	19.2	18	0	0	0
M. natalensis	12	Farm	9B	60	Male	**SV**	140	110	24.1	17.3	55	3	0	0
M. natalensis	13	Farm	9A	58	Female	**PSY**	134	94	24.3	17.6	11	0	0	0
M. natalensis	14	Farm	9C	94	Male	**SV**	135	104	24.3	15.2	10	0	0	0
M. natalensis	15	Farm	2I	49	Female	**PSN**	136	106	24.0	21.7	8	1	0	0
M. natalensis	16	Farm	8J	52	Female	**PSN**	141	115	22.9	18.5	17	0	0	0

M. natalensis	17	Farm	6C	40	Female	**CSN**	130	100	24.4	17.8	0	0	0	0
M. natalensis	18	Farm	2B	44	Male	**SV**	120	104	24.4	18.9	7	0	0	0
M. natalensis	19	Farm	2K	42	Female	**CSN**	126	102	23.2	18.6	44	0	0	0
B.hindei	20	Forest	3C	40	Male	**SV**	138	107	23.0	20.2	0	0	0	1
B.hindei	21	Forest	3D	13	Male	**SV**	122	120	19.5	13.8	0	0	0	0
M. natalensis	22	Farm	5F	42	Male	**SV**	110	100	19.8	16.0	17	0	0	0
M. natalensis	23	Farm	5G	53	Male	**SV**	115	104	23.8	16.4	12	0	0	0
M. natalensis	24	Farm	3J	70	Female	**PSY**	121	94	23.9	19.8	23	0	0	0
M. natalensis	25	Farm	3D	50	Male	**SV**	124	97	24.2	16.1	0	0	0	0
M. natalensis	26	Farm	4G	53	Male	**SV**	120	115	22.5	18.3	11	0	0	0
M. natalensis	27	Farm	4F	68	Male	**SV**	134	104	23.7	19.2	15	0	0	0
M. natalensis	28	Farm	6G	29	Female	**CSN**	100	84	21.7	18.2	27	0	0	0
M. natalensis	29	Farm	8J	72	Male	**SV**	140	107	23.2	19.7	7	0	0	0
M. natalensis	30	Farm	9A	63	Female	**PSN**	140	105	24.5	18.7	40	0	0	0
M. natalensis	31	Farm	9I	28	Male	**SV**	104	90	22.4	18.0	5	0	0	0
M. natalensis	32	Farm	9B	58	Female	**PSY**	110	95	21.6	15.6	21	0	0	0
M. natalensis	33	Farm	9C	66	Male	**SV**	140	100	25.4	20.7	35	0	0	0
M. natalensis	34	Farm	1C	32	Male	**SV**	114	67	21.7	19.2	23	0	0	0
M. natalensis	35	Farm	4F	85	Female	**PSY**	110	90	21.8	19.6	4	1	0	0
M. natalensis	36	Farm	2F	55	Male	**SV**	121	110	24.1	17.1	27	1	0	0
M. natalensis	37	Farm	6F	59	Female	**PSY**	130	115	23.2	20.9	8	1	0	0
M. natalensis	38	Farm	2J	65	Male	**SV**	141	110	25.1	20.2	27	1	0	0

M. natalensis	39	Farm	7B	67	Male	**SV**	134	115	24.4	21.3	38	0	0	0
M. natalensis	40	Farm	6J	56	Male	**SV**	134	122	23.5	20.4	23	2	0	0
M. natalensis	41	Farm	1F	34	Female	**CSN**	116	102	23.7	15.8	23	0	0	0
M. natalensis	42	Farm	2G	46	Female	**PSN**	122	111	22.0	18.5	6	0	0	0
M. natalensis	43	Farm	2J	62	Female	**PSY**	130	120	21.6	17.9	28	0	0	0
M. natalensis	44	Farm	9C	22	Female	**CSN**	97	86	20.9	13.4	7	0	0	0
M. natalensis	45	Farm	9I	41	Female	**PSN**	107	100	20.9	17.5	16	0	0	0
M. natalensis	46	Farm	3J	62	Female	**PSY**	130	106	22.6	17.1	9	0	0	0
M. natalensis	47	Forest	8G	21	Female	**CSN**	98	80	20.3	15.7	3	0	0	0
M. natalensis	48	Farm	1F	24	Female	**CSN**	102	90	22.0	14.8	0	0	0	0
M. natalensis	49	Farm	3I	21	Female	**CSN**	104	85	24.4	18.7	2	1	0	0
M. natalensis	50	Farm	9C	31	Female	**PSN**	105	95	21.6	19.5	5	1	0	0
G. murinus	51	Forest	8A	25	Male	**AN**	106	80	17.9	15.6	0	0	0	0
C. hirta	52	Forest	3E	10	Female	**CSN**	67	66	15.5	8.1	0	0	0	0
M. natalensis	53	Farm	9C	70	Male	**SV**	145	135	24.5	21.4	2	3	0	0
M. natalensis	54	Farm	9J	27	Male	**AN**	100	90	21.6	15.8	12	0	0	0
M. natalensis	55	Farm	1F	54	Male	**SV**	120	125	24.7	19.2	12	0	0	0
M. natalensis	56	Farm	6D	42	Male	**SV**	119	85	22.9	18.3	4	3	0	0
B.hindei	57	Forest	6C	76	Male	**SV**	140	130	19.8	14.7	0	0	0	0
M. natalensis	58	Farm	5A	25	Female	**CSN**	130	117	21.0	17.4	9	0	0	0
M. natalensis	59	Farm	5I	22	Male	**AN**	120	116	19.2	14.6	12	0	0	0
M. natalensis	60	Farm	4E	22	Female	**CSN**	120	110	22.0	18.1	10	0	0	0

M. natalensis	61	Farm	5B	18	Male	**AN**	100	89	19.0	13.1	0	0	0	0
M. natalensis	62	Farm	4F	38	Male	**SV**	150	115	21.0	13.1	16	1	0	0
M. natalensis	63	Farm	7C	34	Male	**SV**	152	122	21.3	15.4	30	2	0	0
M. natalensis	64	Farm	6C	24	Female	**CSN**	126	115	20.3	14.6	0	0	0	0
M. natalensis	65	Farm	2H	25	Male	**AN**	122	105	21.0	15.3	6	0	0	0
M. natalensis	66	Farm	2B	34	Male	**SV**	150	138	22.3	18.5	5	1	0	0
M. natalensis	67	Farm	4I	20	Female	**CSN**	105	97	20.2	14.3	7	1	0	0
M. natalensis	68	Farm	2I	24	Male	**AN**	110	100	19.1	15.2	5	0	0	0
M. natalensis	69	Farm	2A	25	Female	**CSN**	120	119	21.1	18.2	3	0	0	0
M. natalensis	70	Farm	2C	24	Female	**CSN**	122	110	20.1	16.7	16	0	0	0
M. natalensis	71	Farm	1C	28	Male	**SV**	128	115	22.3	16.1	10	0	0	0
M. natalensis	72	Farm	4C	24	Female	**CSN**	122	118	20.1	15.6	11	0	0	0
M. natalensis	73	Farm	1A	30	Female	**CSN**	141	130	20.0	18.3	23	0	0	0
M. natalensis	74	Farm	3A	22	Female	**CSN**	115	112	20.1	15.3	9	0	0	0
M. natalensis	75	Farm	1G	24	Female	**CSN**	120	110	19.3	15.2	25	0	0	0
M. natalensis	76	Farm	3G	23	Male	**AN**	123	112	21.3	15.2	14	0	0	0
M. natalensis	77	Farm	8H	18	Female	**CSN**	93	90	18.3	14.2	0	0	0	0
M. natalensis	78	Farm	10H	22	Female	**CSN**	114	110	20.3	16.2	3	0	0	0
M. natalensis	79	Farm	9A	12	Female	**CSN**	90	82	17.1	12.3	4	0	0	0
M. natalensis	80	Farm	8G	26	Male	**SV**	124	103	21.2	16.7	5	0	0	0
M. natalensis	81	Farm	1D	27	Female	**CSN**	141	120	21	17.2	7	2	0	0
M. natalensis	82	Farm	7I	19	Female	**CSN**	98	90	18.2	13.1	2	0	0	0

M. natalensis	83	Farm	6C	20	Male	**AN**	94	90	20.2	16.3	4	0	0	0
M. natalensis	84	Farm	7F	18	Male	**AN**	100	94	20.1	17.2	6	0	0	0
M. natalensis	85	Farm	1C	27	Male	**SV**	121	118	22.3	16.7	6	0	0	0
M. natalensis	86	Farm	1A	16	Female	**CSN**	80	75	16	12.3	0	0	0	0
M. natalensis	87	Farm	4G	18	Female	**CSN**	92	88	20.1	17.3	2	1	0	0
M. natalensis	88	Farm	2A	17	Male	**AN**	86	82	19.2	17.3	2	0	0	0
M. natalensis	89	Farm	2I	24	Male	**SV**	115	104	21.2	17.3	5	0	0	0
M. natalensis	90	Farm	10I	26	Female	**CSN**	130	129	21	17.2	10	0	0	0
M. natalensis	91	Farm	3F	19	Female	**CSN**	90	88	18.1	13.4	2	0	0	0
M. natalensis	92	Farm	3G	17	Female	**CSN**	92	86	19.1	17.3	1	0	0	0
M. natalensis	93	Farm	3E	24	Female	**CSN**	130	115	22.3	17.4	19	0	0	0
M. natalensis	94	Farm	1J	32	Male	**SV**	133	130	22.3	14.7	11	0	0	0
M. natalensis	95	Farm	2G	18	Female	**CSN**	94	90	20.1	12.3	1	0	0	0
M. natalensis	96	Farm	4F	26	Male	**SV**	135	110	21.3	18.4	15	0	0	0
M. natalensis	97	Farm	2I	27	Male	**SV**	126	120	22.1	16.3	3	0	0	0
M. natalensis	98	Farm	3F	22	Male	**SV**	120	98	19.1	15.6	14	0	0	0
M. natalensis	99	Farm	3C	16	Male	**AN**	75	78	16.1	13.2	1	0	0	0
M. natalensis	100	Farm	10H	21	Female	**CSN**	110	104	21.2	15.6	7	0	0	0
M. natalensis	101	Farm	10A	29	Male	**SV**	135	121	21.6	19.3	30	0	0	0
M. natalensis	102	Farm	7J	26	Female	**CSN**	120	114	20	19.1	43	0	0	0
M. natalensis	103	Farm	7C	24	Female	**CSN**	120	114	19	13.2	14	1	0	0
M. natalensis	104	Farm	3J	27	Male	**SV**	128	120	21.2	13.6	4	0	0	0

M. natalensis	105	Farm	1C	24	Male	**SV**	110	98	20.1	13.2	7	8	0	0
M. natalensis	106	Farm	3C	23	Male	**SV**	120	115	21.3	19.4	8	0	0	0
M. natalensis	107	Farm	2D	19	Female	**CSN**	105	100	20.3	18.2	3	0	0	0
M. natalensis	108	Farm	10C	23	Female	**CSN**	108	98	19.3	16.7	8	0	0	0
M. natalensis	109	Farm	7F	27	Female	**CSN**	128	119	21.3	17.4	39	0	0	0
M. natalensis	110	Farm	4G	19	Male	**AN**	90	88	19.1	15.4	2	0	0	0
M. natalensis	111	Farm	4F	29	Female	**CSN**	130	124	21.1	17.4	16	1	0	0
M. natalensis	112	Farm	1G	34	Male	**AN**	85	83	19	15	15	0	0	0
M. natalensis	113	Farm	5H	33	Male	**SV**	110	100	21	19.0	4	0	0	0
M. natalensis	114	Farm	5B	29	Male	**AN**	105	95	22.3	17	3	0	0	0
M. natalensis	115	Farm	7I	43	Male	**SV**	130	121	22	19.3	11	0	0	0
G. dolichurus	116	Forest	4C	39	Male	**SV**	114	155	22.3	18.9	0	0	0	0
G. murinus	117	Forest	6D	18	Male	**AN**	90	79	20.3	10.8	2	1	0	0
G. dolichurus	118	Forest	6B	34	Female	**PSN**	100	165	21.2	17.3	0	0	0	0
B.hindei	119	Forest	4D	49	Female	**CSN**	126	106	20.3	16.2	0	0	0	0
G. dolichurus	120	Farm	7A	31	Female	**CSN**	105	106	22.3	18.2	6	0	0	0
X. rutilus	121	Farm	6E	106	Male	**SV**	165	115	34.3	12.4	0	0	0	0
B.hindei	122	Forest	8E	52	Female	**CSN**	140	120	22.3	20.4	0	0	0	0
G. dolichurus	123	Forest	3C	20	Female	**CSN**	90	145	20.3	17.2	0	0	0	0
M. natalensis	124	Farm	8E	23	Male	**AN**	90	85	20.3	15.3	6	0	0	0
M. natalensis	125	Farm	4J	19	Female	**CSN**	90	87	20.2	16.3	5	2	0	0
M. natalensis	126	Farm	7F	18	Female	**CSN**	90	78	19.3	17.4	9	0	0	0

M. natalensis	127	Farm	7C	25	Male	**SV**	104	96	21.3	18.2	9	0	0	0
M. natalensis	128	Farm	2G	23	Male	**AN**	110	96	22.1	18.3	4	2	0	0
M. natalensis	129	Farm	2J	30	Male	**SV**	120	100	22.3	15.0	15	0	0	0
M. natalensis	130	Farm	4F	27	Male	**SV**	110	96	20.3	19.0	13	0	0	0
M. natalensis	131	Farm	1D	18	Male	**AN**	95	86	20.3	17.0	4	0	0	0
M. natalensis	132	Farm	1C	26	Female	**CSN**	90	87	21.0	17.3	14	0	0	0
M. natalensis	133	Farm	1G	23	Male	**AN**	97	95	19.0	17.8	3	0	0	0
M. natalensis	134	Farm	7H	28	Female	**CSN**	85	80	20.0	17.3	3	0	0	0
M. natalensis	135	Farm	7G	24	Male	**AN**	94	90	20.3	17.8	1	1	0	0
M. natalensis	136	Farm	9B	27	Female	**CSN**	100	96	20	14.3	9	0	0	0
M. natalensis	137	Farm	3F	30	Female	**CSN**	80	87	20	19.3	6	0	0	0
M. natalensis	138	Farm	3H	36	Male	**SV**	110	104	20.2	19.3	6	0	0	0
M. natalensis	139	Farm	3B	34	Male	**SV**	120	115	21.0	19.3	10	0	0	0
M. natalensis	140	Farm	3E	25	Male	**SV**	100	95	21.3	17.2	11	0	0	0
G. dolichurus	141	Forest	1C	29	Male	**AN**	100	150	20.3	13.4	0	0	0	0
G. murinus	142	Forest	1B	19	Female	**CSN**	90	55	19.3	12.1	0	0	0	0
G. murinus	143	Forest	4B	21	Female	**CSN**	92	85	17.3	14.2	0	0	0	0
M. natalensis	144	Farm	1D	23	Female	**CSN**	92	90	20	15.3	2	0	0	0
M. natalensis	145	Farm	9I	28	Male	**AN**	100	98	21.2	17.3	5	0	0	0
M. natalensis	146	Farm	7F	51	Male	**SV**	121	115	21.0	17.8	14	0	0	0
M. natalensis	147	Farm	1H	24	Female	**CSN**	89	90	21.3	17.0	10	0	0	0
M. natalensis	148	Farm	10C	42	Male	**SV**	115	121	21.0	17.3	8	0	0	0

M. natalensis	149	Farm	4G	34	Male	**AN**	100	95	20.0	17.3	6	0	0	0
M. natalensis	150	Farm	6F	17	Female	**CSN**	95	80	18.0	15.3	1	0	0	0
M. natalensis	151	Farm	2H	34	Male	**SV**	115	100	20.3	17.2	8	1	0	0
M. natalensis	152	Farm	10A	27	Male	**AN**	100	99	20.2	19.5	4	0	0	0
M. natalensis	153	Farm	10J	35	Male	**SV**	117	103	21.3	18.1	5	0	0	0
M. natalensis	154	Farm	7G	34	Male	**SV**	110	95	21.3	17.2	2	0	0	0
M. natalensis	155	Farm	5G	24	Female	**CSN**	95	90	18.0	16.1	5	0	0	0
M. natalensis	156	Farm	3G	42	Male	**SV**	120	115	22.4	20.3	27	0	0	0
G. dolichurus	157	Farm	4C	43	Female	**PSY**	115	152	23.1	15.3	0	0	0	0
M. natalensis	158	Farm	4F	30	Female	**CSN**	100	103	22.3	17.2	3	0	0	0
L. rosalia	159	Farm	2J	55	Male	**SV**	124	130	27.1	15.2	40	0	0	0
P. tetradactylus	160	Farm	10A	177	Male	**AN**	200	154	52.1	31.3	0	0	0	0
Cricetomys spp	161	Forest	2D	1039	Female	**CSN**	226	304	63.1	42.3	0	1	90	0
M. natalensis	162	Farm	2J	23	Male	**AN**	102	95	21.1	16.3	9	0	0	0
M. natalensis	163	Farm	7I	18	Female	**CSN**	96	85	19.1	17.3	6	0	0	0
M. natalensis	164	Farm	1F	20	Female	**CSN**	89	98	22	18.9	5	0	0	0
M. natalensis	165	Farm	5I	30	Female	**CSN**	104	90	19.1	17.8	2	0	0	0
M. natalensis	166	Farm	10J	28	Male	**AN**	100	97	20.1	18.3	3	0	0	0
M. natalensis	167	Farm	8A	34	Male	**SV**	110	117	21.2	18.3	9	0	0	0
Galago spp	168	Forest	2G	90	Male	**SV**	141	176	25	33.2	0	0	0	0
P. tetradactylus	169	Forest	4 Hav	75	Female	**CSN**	160	165	56	32.3	0	12	0	0

P. tetradactylus	170	Farm	10 Hav	95	Female	**CSN**	205	155	55.3	30.1	0	0	0	0
M. natalensis	171	Farm	4J	33	Male	**SV**	125	100	21.0	19.1	12	0	0	0
M. natalensis	172	Farm	8H	22	Male	**SV**	114	104	21. 1	18.3	3	0	0	0
M. natalensis	173	Farm	2J	22	Female	**CSN**	94	93	20.1	16.3	5	1	0	0
M. natalensis	174	Farm	10B	23	Female	**CSN**	110	107	21.3	18.3	7	0	0	0
M. natalensis	175	Farm	3B	18	Female	**CSN**	105	98	21.4	16.5	4	0	0	0
Cricetomys spp	176	Forest	8Hav	1300	Male	**SV**	400	390	75	49.1	4	1	45	0
M. natalensis	177	Farm	7F	22	Female	**CSN**	100	86	18.1	16.3	3	0	0	0
M. natalensis	178	Farm	7G	38	Female	**CSN**	110	100	20.1	18.3	7	0	0	0
M. natalensis	179	Farm	7B	29	Female	**CSN**	100	105	19.1	17.4	17	1	0	0
M. natalensis	180	Farm	9F	21	Female	**CSN**	90	94	20.3	17.1	9	0	0	0
M. natalensis	181	Farm	6B	54	Male	**SV**	115	104	19.0	16.2	19	0	0	0
M. natalensis	182	Farm	6G	65	Female	**PSY**	130	119	22.1	19.3	10	0	0	0
M. natalensis	183	Farm	7I	75	Female	**PSY**	136	109	20.1	18.2	27	0	0	0
M. natalensis	184	Farm	10D	55	Female	**CSN**	102	100	20.1	16.3	9	0	1	0
M. natalensis	185	Farm	10J	75	Female	**PSY**	121	106	22.3	18.2	11	0	0	0
M. natalensis	186	Farm	8E	55	Male	**AN**	105	94	20.1	15.2	1	0	0	0
M. natalensis	187	Farm	10I	65	Male	**SV**	114	105	22.1	18.3	4	0	0	0
M. natalensis	188	Farm	9B	60	Male	**SV**	100	105	22.3	18.1	10	0	0	0
M. natalensis	189	Farm	8C	55	Female	**CSN**	90	85	20.4	18.1	4	0	0	0
M. natalensis	190	Farm	3H	60	Male	**SV**	116	104	21.4	18.2	3	0	0	0

C. hirta	191	Farm	5D	15	Male	**AN**	94	45	12.1	9	0	2	0	0
M. natalensis	192	Farm	5B	30	Female	**CSN**	105	90	18.1	17.2	7	0	0	0
M. natalensis	193	Farm	8E	38	Female	**CSN**	100	81	20.1	16.3	1	0	0	0
M. natalensis	194	Farm	7J	40	Male	**AN**	90	88	18.1	16.3	0	0	0	0
M. natalensis	195	Farm	5C	45	Female	**CSN**	110	93	20	18.1	11	0	0	0
M. natalensis	196	Farm	8B	54	Male	**AN**	102	84	20	15.4	2	0	0	0
M. natalensis	197	Farm	1E	52	Male	**SV**	115	110	21.4	19.3	4	0	0	0
M. natalensis	198	Farm	3C	50	Male	**SV**	124	117	22.1	18.2	9	0	0	0
M. natalensis	199	Farm	7D	55	Female	**CSN**	126	115	22.3	20.1	8	0	0	0
M. natalensis	200	Farm	9G	36	Female	**CSN**	105	84	20.1	16.4	4	0	0	0
M. natalensis	201	Farm	6G	55	Female	**PSN**	124	112	20.4	18.1	24	1	0	0
C. hirta	202	Farm	4C	12	Male	**SV**	100	46	15.1	5	0	0	2	0
M. natalensis	203	Farm	3B	49	Female	**CSN**	96	90	21.4	17.3	8	0	0	0
G. leucogaster	204	Farm	9D	87	Female	**CSN**	167	158	35.1	24.2	0	0	0	0
		TOTAL									**1857**	**62**	**138**	**1**